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December 1, 1992

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Enclosed is a copy(ies) of the technical report  
for the USRA/Goddard Visiting Scientist Program  
for the period April 1, 1992 through June 30,  
1992

If you have any questions, please don't hesitate  
to contact us.

Sincerely,



Frank J. Kerr  
Program Director

(NASA-TM-108588) GODDARD VISITING  
SCIENTIST PROGRAM FOR THE SPACE AND  
EARTH SCIENCES DIRECTORATE  
Technical Report, 1 Apr. - 30 Jun.  
1992 (USRA) 318 p

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Contract No. NAS5-30442  
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Subject: Enclosed is the technical report for the period  
April 1, 1992 through June 30, 1992.

Goddard Visiting Scientist Program  
for the Space and Earth Sciences Directorate  
Contract No. NAS5-30442

Technical Report  
for April 1, 1992 through June 30, 1992

Program Director: Dr. Frank Kerr

Submitted to:

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P.14

Brief Summary of Task Activities under Contract NAS5-30442  
During the Period April 1, 1992 through June 30, 1992.

(Individual Project Reports are attached on the indicated pages).  
Summary notation and actual reports are sequentially listed by Task  
Assignment number.

**SPACE SCIENCE**

**Task #:**

5010 F. Verter summarized her work on Interstellar clouds in the solar neighborhood, Interstellar clouds in external galaxies, and the Shadowing of the X-ray background. p. 1

660-001 P. Sreekumar summarizes his accomplishments in working with the EGRET project team, and his responsibility to finalize the diffuse gamma ray model for the galactic plane (GALDIF).  
p. 2-3

J. Steinacker has installed his environment on the SUN-cluster and gave a review of his scientific activities regarding acceleration in solar flares. p. 4-7

660-003 T. Turner has concentrated on Position Sensitive Proportional Counter (PSPC) calibration issues. p. 8-23

660-004 A. Smale summarizes his activities in working on the BBXRT data and the FITS format for community release. p. 24-29

660-005 E. Christian updates his research activity on the following projects: ALICE (A Large Isotopic Composition Experiment); ASTROMAG (a superconductor magnet facility); IMAX (Isotope Matter-Antimatter eXperiment); and MASS (a balloon experiment for detecting electrons, positrons and anti-protons).  
p. 30-31

660-006 L. Jalota describes his research activities relating to ASTRO-D X-ray telescopes, Mirror Development and BBXRT data analysis. p. 32-33

Y. Soong highlights the making of the Astro-D mirrors in terms of mirror fabrication, calibration, and ground performance verification. p. 34-35

660-016 E. Schlegel has made substantial progress in research on the x-ray spectrum of X Per. p. 36-42

660-017 D. Bhattacharya provides a description of his activities relating to the analysis of HEAO 3 all-sky data. p. 43-44



- 660-018 J. Mitchell discusses the successful flights of the balloon-borne cosmic ray experiments. p. 45-53
- 660-020 A. Rots discusses his research on the Proto-typing Astronomical Software in *Khoros*. p. 54-59
- 660-023 L. Angelini describes her activities on the conversion of the X-ray imaging program XIMAGE from VMS to UNIX. p. 60-62
- P. Barrett highlights each of the following activities; 1). Cataclysmic Variables and Single White Dwarfs, 2). Photopolarimetry of Pre-Main Sequence Stars. p. 63-68
- 660-024 C. Day's work has centered on the analysis of X-ray data from various sorts of astronomical objects - X-ray binaries, active galactic nuclei and clusters of galaxies. p. 69-72
- K. Ebisawa joined LHEA in April 1992 after finishing the Ph-D study at ISAS in Japan. He has been studying the low mass X-ray binaries and black hole candidates using the Ginga data, and working on development of the Astro-D calibration and data analysis system. p. 73-78
- K. Mukai gives a general account of his work relating to Astro-D matters. p.79-80
- 660-025 G. Reichert reports on the following activities: 1). Ultraviolet, Optical, and X-ray Observations of LINER galaxies, 2). Coordinated, multi-wavelength monitoring of active galactic nuclei (AGN). p. 81-86
- 660-026 M. Loewenstein discusses his research for the X-ray branch of LHEA primarily focussed on X-ray observations of hot plasma in two classes of astronomical objects. p. 87-90
- 660-027 I. George has been collaborating on a recently published paper on the X-ray bright BL Lac object HO414+009. p. 91-96
- 660-028 W. Pence discusses his research activities which include FITSIO, CDROMS, FITS 'Selector' Software Development and Conversion of Archival Data to FITS format. p. 97-99
- 660-029 S. Drake highlights his accomplishments and progress with ROSAT, Einstein IPC and SSS Database. p. 100-105
- 660-030 L. Whitlock is working on HEASARC data from the all-sky monitors aboard Vela 5B, Ariel 5, and the GRO BATSE experiment. p. 106-108
- 660-031 K. Black continues his work on developing flight electronics, and flight software for the MOXE experiment

and its interface to the Spectrum-X-Gamma spacecraft and ground station. p. 109

- 660-032 W. Zhang efforts this quarter went into the following areas, XTE/PCA, ROSAT A03 Proposal, and the CYGNUS Air Shower Experiment. p. 110-113
- 660-035 B. Dingus reports on her work with the high energy gamma ray group which has been divided between detector development for the Advanced Gamma-Ray Telescope Experiment (AGATE) and Energetic Gamma-Ray Experiment Telescope (EGRET) data analysis. p. 114-118
- 660-038 M. Corcoran continues his activities on the Analysis of IUE spectra of 1700-37 HD 153919, the ROSAT X-ray Observations of V444 Cyg, BBXRT observations of hot stars, and others. p. 119-121
- 660-040 H. Awaki has been working on the Astro-D Mirror Project. p. 122
- 660-041 G. Pike highlights his research activities on the X-ray and ultraviolet spectra of Active Galactic Nuclei (AGN). p. 123-125
- 660-042 R. Nemiroff has been investigating the visual distortion effects of a neutron star and black hole due to the strong gravity. p. 126-128
- 660-043 W. Chen describes his activity relating to black hole mass in X-ray Nova Muscae, and Jets and pair-production in the Galactic Center source. p. 129-143
- 660-044 H. Seifert has been working on various aspects of the instrument development for the Transient Gamma-Ray Spectrometer (TGRS). p. 144
- 660-046 J. Lochner is working on HEASARC data from the all-sky monitors aboard Vela 5B, Ariel 5, and the GRO BATSE experiment. p. 145-148
- 680-007 I. Hubeny describes his work with new observations of hot stars taken by the Hubble Space Telescope. p. 149-150
- 680-021 G. Hinshaw continues his research to the data analysis for the DMR experiment on COBE. p. 151-163
- A. Kogut's major effort has been on the analysis of full-sky maps from the Differential Microwave Radiometers (DMR) experiment aboard the Cosmic Background Explorer (COBE). p. 164-170
- A. Banday has been providing support for the COBE space project. p. 171

A. Banday has been providing support for the COBE space project. p. 171

680-022 D. Falconer reviews the progress of his dissertation by analyzing the SERTS 3 and 4 data set under the guidance of J. Davila. p. 172-173

680-028 D. Cottingham reviews the completed analysis of the 19 GHz sky map data and on the development software to support COBE data analysis. p. 174-177

680-029 T. Namioka updates the work on the development of a new grating design method for the Lyman/FUSE mission. p. 178-180

690-001 S. Ghosh continues his study of the applications using both incompressible and compressible 2-D magnetohydrodynamic (MHD) simulations. p. 181-182

690-010 C. Farrugia continues his research on interplanetary clouds. He also mentions a paper that was submitted to the Journal of Geophysics Research. p. 183-184

690-011 M. Teague is serving as the Solar Terrestrial Energy Program (STEP) Coordinator. His role as coordinator is to provide a variety of coordination services to the U.S. and international STEP scientific communities. p. 185-186

V. Papitashvili has been working with Dr. M. Teague as a co-editor of the STEP International Newsletter. p. 187

690-012 T. Morgan reviews his observations on the emission from Mercury and the origin of the Na exosphere of the Moon. p. 188

690-013 T. Huang's scientific work includes a new collaborative version of the paper: "Neptune's Magnetosphere in the OTD Magnetic Field Frame". p. 189-193

690-014 S. Hoban continues to work in the area of infrared spectroscopy of cometary parent molecules. She also reviews proposals and carries on her continuing programmatic work. p. 194

E. Roettger has been working on the possibility of detecting a set of cometary parent molecules with low and medium-resolution instruments. p. 195

690-015 M. Goodman has learned enough about the graphics language PV-WAVE to write software to view satellite key parameters. p. 196

690-018 H. Laakso joined USRA in April 1992, and has begun the following research activities: 1) double probe theory, 2) cometary plasma physics, 3) magnetospheric physics. p. 197

## **EARTH SCIENCE**

### **Task #:**

900-001 Y. Shimabukuro has been in the Biospheric Sciences Branch working with GIMMS (Global Inventory Mapping and Monitoring) Group. The Biospheric Sciences Branch is concerned with terrestrial ecosystem and atmosphere interactions, patterns and processes occurring at several spatial and temporal scales. p. 198-199

900-002 J. Dozier highlights his accomplishments in his final year as Project Scientist for the Earth Observing System (EOS). p. 200-206

910-002 This task sponsors visitors and lecturers. No reports were received for this quarter.

910-003 S. Moorthi highlights his significant improvement of the computer code in the development of the Semi-Lagrangian (SLSI) GCM. His efforts during this quarter focused on improving the efficiency of the adiabatic versions of the model code. p. 207-212

910-007 C. Sui reports on his continuing involvement in the joint TRMM project and the TOGA-COARE project. p. 213

V. Mehta reviews the analysis of the global hydrologic cycle (GHC) and its variability using observational and model data. p. 214-216

910-008 L. Peng is continuing the investigation of the relationships between tropical-extratropical interactions. p. 217-218

910-009 J. Rosenfield continues her research into the radiative effects of polar stratospheric clouds (PSCs). p. 219-220

910-015 K. Pickering updates his four major research areas: (1) Simulating the effects of deep convective events on free tropospheric ozone production, (2) Simulating the effects of deep convective events during STEP on upper tropospheric ozone production, (3) NASA/GTE/TRACE-A Experiment, (4) Pre-TRACE-A Ozone/Fires Trajectory Analysis. p. 221-222

- 910-030 This task supports short-term visiting scientists for the purpose of collaboration on research involving clouds, radiation and climate. No reports were received for this quarter.
- 910-032 L. Lait's effort this quarter continues in the planning and support of the second Airborne Arctic Stratospheric Expedition II (AASE II). p. 223
- 910-036 S. Bloom reviews the development of an improved methodology for simulating observation errors for use in OSSE (Observing System Simulation Experiments) studies involving LAWS data.  
p. 224-226
- 910-037 R. Higgins and others have completed the development of the adiabatic version of a global multilevel atmospheric model using a vector semi-Lagrangian finite difference scheme.  
p. 227-232
- 910-038 M. Fox-Rabinovitz updates his activities with the testing of the GLA GCM with three new convection schemes, and the testing of the diabatic dynamical initialization (DDI). p. 233-237
- 910-041 M. Fiorino informs us of the objective of the AMIP which is to determine whether GCM's can simulate observed atmospheric interseasonal climatic events. p. 238-242
- 910-046 J. Gleason has been primarily involved in the development and implementation of a correction algorithm for the correction of the Numbus-7 SBUV ozone data. p. 243
- 910-047 A. Mehta has completed development of an algorithm for calculating terrestrial Outgoing Longwave Radiation (OLR). The algorithm is being implemented with the HIRS/MSU retrieval algorithm developed by Dr. J. Susskind's group.  
p. 244-248
- J. Joiner has been involved in the development and implementation of an algorithm to retrieve climate parameters using AIRS/AMSU. p. 249-250
- 910-049 G. Huffman has been involved in research on global estimates of precipitation using passive microwave data recorded by satellite sensors in conjunction with other data sources.  
p. 251
- 910-050 C. Park updates activities with Low-Frequency Waves in the Atmosphere, GLA GCM Diagnostic and Seasonal Predictability of Regional Climate. p. 252-253

- 910-052 H. Chun is working on the long-lasting large amplitude mesoscale wave events. p. 254-255
- 910-055 J. Scala has been involved in research investigating the transport dynamics associated with squall-type mesoscale convective systems. p. 256-257
- 910-056 T. Mitchell describes his research activities in working on the documentation and interpretation of historical records of summertime surface temperature and precipitation for the U.S.  
p. 258-259
- 920-002 R. Myneni reports on several areas of research; 1). Synergistic use of optical and microwave data in agrometeorological applications, 2). Atmospheric effects in the remote sensing of surface albedo and radiation absorption by vegetation canopies, and 3). Atmospheric effects and spectral vegetation indices. p. 260-266
- 920-004 G. Bluth reports on his involvement in completing the inventory of TOMS data for publication. p. 267-271
- 920-007 H. Guertler updates a supplement to the Database for the Gravity-field evaluation of Mars. p. 272
- 920-010 A. Nelson reports on his activities relating to the BOREAS (BOReal Ecosystem-Atmosphere Study) project. p. 273-275
- 930-002 M. Manohar reports on the Vector Quantization (VQ) based Image Compression on Massively Parallel Systems. p. 276
- 930-008 M. Satake has been engaged in the development of TRMM Science Data and Information System (TSDIS) and radar rainfall measurements. p. 277-281
- 930-015 K. Olson has been focusing his research on the development of a gravitational N-body code to study the dynamics of galaxy-galaxy interactions. p. 282-283
- A. Deane describes his research activities relating to the turbulence, MHD, magnetoconvection, computational fluid dynamics and parallel supercomputing. p. 284-285
- 970-002 T. Iguchi has been assigned the task of conducting airborne radar measurements of rainfall and to analyze the data.  
p. 286

970-006 This task supports short-term visitors who come in various guises to collaborate with the Goddard research community.

C. Chen has concentrated his research on the numerical simulations of gravity currents in neutral and stratified shear flows. p. 287-291

970-017 V. Karyampudi has been performing GEMPAK analyses on the observational case study of the 13-14 April 1986 severe weather case. p. 292

970-020 B. Ferrier reviews the importance of his efforts in developing a double-moment four-class (4ICE) microphysical parameterization for simulating convective storms in different large-scale environments. p. 293-300

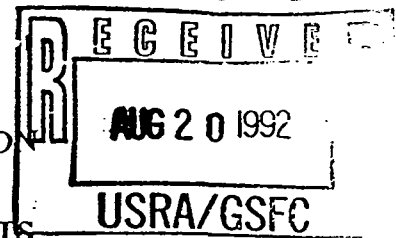
970-021 J. Baik has investigated the formation and intensification mechanisms of cold-frontal rainbands using the two dimensional hydrostatic, primitive-equation model with the explicit water-ice phase microphysics (MASS2D). p. 301

970-022 N. Chauhan reviews the microwave models that are being developed to study the backscatter signatures from vegetation. p. 302-304

970-027 A. Kowalski's primary research activity has been concerned with the development and algorithms and corresponding programs for high performance numerical modeling of coupled ocean-atmosphere circulation. p. 305-307

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: FRANCES VERTER Task Number: 5010

General Description of Your Research Activities: (Include a Paragraph on each Activity).

There is no clear distinction between my "programmatic" and "independent" research activity. The projects in my original proposal for a Long-term Space Astrophysics Research Grant have evolved with time, a normal scientific process, and now tend to blur with the projects conceived independently of that proposal. All work conducted during the past year is summarized below.

**Interstellar clouds in the solar neighborhood**

- (1) Work is still in progress on the main paper (Verter, Magnani, Rickard, & Dwek) which will describe the results of applying the Dwek grain model to the IRAS emission of cirrus clouds. The main scientific conclusion of this project is that stochastic thermal emission cannot explain the 12  $\mu\text{m}$  fluxes of cirrus; an additional contribution to the 12  $\mu\text{m}$  band from line emission is needed.
- (2) Verter and Rickard will soon submit a paper which describes the photometric accuracy of IRAS image products for the study of faint extended sources.
- (3) Rickard and Verter are also studying the photometric accuracy of image destriping in the Fourier domain. Caroline Coberly is a summer student at NRL who is processing images for use in this project.
- (4) Chiar, Kutner, Verter, and Leous have submitted a paper to ApJ which describes a CO(2-1) survey of the Milky Way Scutum Arm. Our survey at 1' resolution supports the recent conclusions of the COBE FIRAS instrument at 7° resolution: most of the emitting material in the Galactic molecular ring is cool, only 5 - 7 K.

**Interstellar clouds in external galaxies**

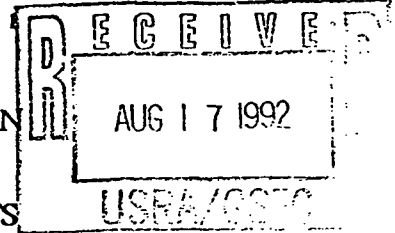
- (1) This year Verter produced the paper, "Effect of Malmquist Bias on Correlation Studies with the IRAS Data Base", now in press. This work derives the first correction for Malmquist Bias in linear regressions to appear in the astronomical literature. It also demonstrates that previous interpretations of the IR luminosities of galaxies were often based on faulty statistics.
- (2) Verter has continued her collaboration with Leisawitz on the appearance of large bubbles created by star formation in external galaxies. Michele Thornley is a USRA summer student who is gathering data and writing computer code for this model. Work is still in progress, but we hope to use our model to solve for the relative fractions of compact and blister HII regions in external galaxies.
- (3) Kutner and Verter had an observing run at the NRAO 12m telescope in Dec. 1991, for our collaboration with Berkhuijsen and Beck. We completed observations for a study of the relationship between magnetic fields and molecular clouds in a spiral arm of the M31 galaxy.

**Shadowing of the X-ray background**

- (1 - N) For this project Verter is collaborating with a large team of X-ray astronomers (in alphabetical order, Bloch, Jahoda, Lockman, McCammon, Mebold, Sanders, Schmitt, Snowden and Verter; principle investigators are Sanders and Snowden). So far, we have used ROSAT pointed observations in the M-band (0.4 - 0.9 keV) to detect X-ray shadows towards the high latitude molecular clouds MBM 12, 18, 33, 36, and possibly MBM 16 and 102, but not MBM 20. More observations either have been taken but are not yet reduced, or are scheduled. A paper is in preparation (Snowden *et al.*) on MBM 12. The ultimate goal of the search for X-ray shadows is to elucidate the size and distribution of the local bubble of hot gas that surrounds the Sun and produces the soft X-ray background.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
 GODDARD VISITING SCIENTIST PROGRAM  
 EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
 (for the year ending 9/30/92)



Employee Name: PARAMESWARAN SREEKUMAR Task Number: NASS-30442

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Since October 1991, a significant part of the time was devoted to the reduction of data from the Energetic Gamma Ray Experiment Telescope (EGRET) aboard the CGRO satellite. On a routine basis, my responsibilities included assisting Dr. David Thompson with reviewing spark chamber events of concern that a team of 8 data analysts have difficulties with; creating and maintaining the nearly final gamma ray database (summary database) on the IBM and Sun machines; creating the corresponding exposure files and carrying out a quick analysis of the data to look for new or expected bright gamma ray sources.

Another aspect involved my continuing responsibility to finalize the diffuse gamma ray model. The diffuse background for the galactic plane (GALDIF) was merged with the high latitude model (ISODIF) to create a single all sky FITS file for use with the EGRET analysis programs. An existing program (ADDMAP) was modified (DIFFUSE) to provide subsets of the all-sky map in galactic or celestial coordinates at any bin size > 0.5 deg. Currently, I am using the model to examine the goodness of fit with the EGRET data. Also under study is possible performance changes of the EGRET instrument using regions of overlapping observations.

My interest in the Magellanic Clouds led us to examine the LMC at high energy gamma rays. For the first time we have detected an external normal galaxy in gamma rays with the observed emission consistent with the prediction reported a year ago (Fichtel et al. 1991). A paper has been submitted to Ap.J Letters containing the results on the LMC observations.

On a support level, I have also been involved with studying the time variability of 3C279, fine positioning and identification of point sources, carrying out deep analysis to detect weak sources within the field of view for a couple of EGRET observations, determining upper limits from the globular cluster 47 Tuc, determining zenith angle cutoffs to exclude earth albedo gamma rays, creating and assisting graphics program development in IDL to image our skymaps, etc

Fichtel, C.E., Özel, M., Stone, R., & Sreekumar, P. 1991, ApJ, 374, 134

## PUBLICATIONS IN REFEREED JOURNALS

"Cosmic Ray Distribution and the Dynamic Balance in the Large Magellanic Cloud", Fichtel, C. E., Özel, M. E., Stone, R. G., and Sreekumar, P., 1991, *AJ.*, 374, 134-141

"Cosmic Rays in the Small Magellanic Cloud", Sreekumar P., and Fichtel, C. E., 1991, *AA*, 251, 447-453

"Detection of High Energy Gamma Radiation from Quasar 3C 279 by the EGRET Telescope on the Compton Gamma Ray Observatory," Hartman, R. C., Bertsch, D. L., Fichtel, C. E., Hunter, S. D., Kanbach, G., Kniffen, D. A., Kwok, P. W., Lin, Y. C., Mattox, J. R., Mayer-Hasselwander, H. A., Michelson, P. F., von Montigny, C., Nel, H. I., Nolan, P. L., Pinkau, K., Rothermel, H., Schneid, E., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *ApJ Letters*, 385, L1

"EGRET Detection of High Energy Gamma Rays from the Gamma-Ray Burst of 3 May 1991," Schneid, E. J., Bertsch, D. L., Fichtel, C. E., Hartman, R. C., Hunter, S. D., Kanbach, G., Kniffen, D. A., Kwok, P. W., Lin, Y. C., Mattox, J. R., Mayer-Hasselwander, H. A., Michelson, P. F., von Montigny, C., Nolan, P. L., Pinkau, K., Rothermel, H., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *AA* 255, L13-L16

"Pulsed High-energy Gamma-radiation from Geminga (1E 0630+178)", Bertsch, D. L., Brazier, K. T. S., Fichtel, C. E., Hartman, R. C., Hunter, S. D., Kanbach, G., Kniffen, D. A., Kwok, P. W., Lin, Y. C., Mattox, J. R., Mayer-Hasselwander, H. A., v. Montigny, C., Michelson, P. F., Nolan, P. L., Pinkau, K., Rothermel, H., Schneid, E. J., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *Nature*, Vol. 357, p. 306

"Detection of a long-duration Solar Gamma-Ray Flare on June 11, 1991 with EGRET on COMPTON-GRO," Kanbach, G., Bertsch, D. L., Fichtel, C. E., Hartman, R. C., Hunter, S. D., Kniffen, D. A., Kwok, P. W., Lin, Y. C., Mattox, J. R., Mayer-Hasselwander, H. A., Michelson, P. F., Nolan, P. L., Pinkau, K., Rothermel, H., Schneid, E. J., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *A&A* (in Press)

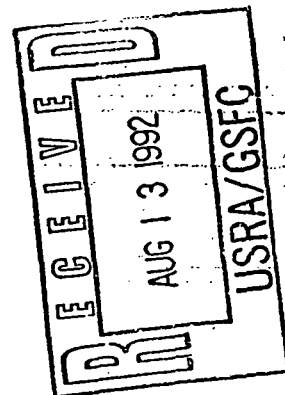
"Overview of the First Results from EGRET," Fichtel, C. E., Bertsch, D. L., Hartman, R. C., Hunter, S. D., Kanbach, G., Kniffen, D. A., Kwok, P. W., Lin, Y. C., Mattox, J. R., Mayer-Hasselwander, H. A., Michelson, P. F., von Montigny, C., Nolan, P. L., Pinkau, K., Rothermel, H., Schneid, E. J., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *A&A*, (In Press).

"EGRET Observations of 3C273," von Montigny, C., Bertsch, D. L., Fichtel, C. E., Hartman, R. C., Hunter, S. D., Kanbach, G., Kniffen, D. A., Kwok, P. W., Lin, Y. C., Mattox, J. R., Mayer-Hasselwander, H. A., Michelson, P. F., Nolan, P. L., Pinkau, K., Rothermel, H., Schneid, E., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *A&A*, (In Press)

"Search for Periodic Gamma-Ray Emission from Cygnus X-3 by the EGRET Telescope on the Compton Gamma Ray Observatory," Michelson, P. F., Bertsch, D. L., Chiang, J., Fichtel, C. E., Hartman, R. C., Hunter, S. D., Kanbach, G., Kniffen, D. A., Kwok, P. W., Lin, Y.-C., Mattox, J. R., Mayer-Hasselwander, H. A., von Montigny, C., Nolan, P. L., Pinkau, K., Rothermel, H., Schneid, E., Sommer, M., Sreekumar, P., and Thompson, D. J., 1992, *A&A*, (In Press)

# Summary of Accomplishments

Dr. Jürgen Steinacker



After my arrival at 1 May 91 I installed my environment on the SUN-cluster and gave a review talk of my scientific activities regarding acceleration in solar flares. Meanwhile I started my collaboration with Dr. J. M. Miller and Prof. R. Ramaty about acceleration of electrons in the deep solar corona by offering J. Miller to participate in a paper about the interaction of electrons with parallel propagating transversal waves in a cold collisionless plasma. Although I had already prepared the derivation of the Fokker-Planck coefficients of this interaction, we found in extended discussions the correct representation of the dispersion relation of all transversal plasma modes, which are important in plasmas like the corona. We formulated the resonance condition and plotted them for different cases of electron pitch angle and velocity explaining the resonance of electrons with both Alfvén and Whistler waves in an illuminating way. Due to the fact that this resonance condition is a quartic equation, we had to write a program to calculate the roots for the two possible polarization modes. I finished the main program to calculate the resulting Fokker-Planck coefficients.

Together with R. Ramaty I started working about lineless gamma ray spectra of solar flares, which are supposed to be produced mainly by bremsstrahlung interaction of accelerated electrons with the background ions. These electrons should lose also energy by radiating synchrotron emission in the magnetic field leading to a radio spectrum, which is rather flat and indeed

these spectra are seen in some flares together with a sharp low-frequency cut-off due to the Razin-Tsytoich suppression close to the plasma frequency. I wrote a program to find an approximate description of the bremsstrahlungs data and to reduce the producing electron spectrum.

We inserted the root finding program of the resonance condition between solar flare electrons and transverse parallel propagating cold plasma waves into our program for the Fokker-Planck coefficients. We plotted the coefficients as a function of electron pitchangle and energy using the new plot program IDL. Discussing different wave spectra we compared our results with findings in previous papers. Because of their importance for a wealth of applications we used the coefficients to calculate the mean free path and the momentum diffusion coefficient. We found that high frequency waves are necessary to accelerate electrons from thermal to relativistic energies via gyroresonance. Although the acceleration efficiency increases with frequency, the increasing diffusion time scale also implies a possible break down of the diffusion approximation. We completed a paper about our results and submitted it together with 25 figures to ApJ Main Journal. This paper is now published.

Together with J. Miller, we wrote a second paper investigating the influence of thermal corrections on our results. The low plasma beta in the acceleration region of solar flares guarantees the validity of the cold plasma approximation, because the temperature effects are small compared to the influence of the strong magnetic field, except in the frequency region close to the gyro frequencies. We found analytical expressions for the warm plasma dispersion relation and the damping rates in the high frequency range in the weak-damping limit. Determining the cutoff in the wave spectrum due to thermal damping we were able to

estimate realistic threshold energies and total numbers of accelerated electrons for gyroresonant acceleration in solar flares and therefore to address the important question of preacceleration in general. We basically found, that one needs a unusual high intensity of high frequency waves or an additional preacceleration mechanism to account for the observed numbers of electrons accelerated in a typical solar flare. This paper was send to ApJ, is now accepted and in press.

Together with A. Campeanu I investigated oblique plasma waves and their polarization states. This provides us with the knowledge to determine, if the stochastic acceleration model for gyroresonant interaction is able to explain the observed ion abundances in impulsive solar flares. In a collaboration with J.-P. Meyer I calculated the complex warm plasma dispersion relation for transverse parallel waves in an realistic solar flare plasma with 21 ion species. I determined the thermal range of every ion species using the gyro resonance condition and thermal speed at a given density derived by the Maxwellian distribution. I estimated the damping time scales and the properties of every possible parallel warm plasma mode in this multi-ion solar flare plasma for different temperatures. Together with A. Campeanu I generalized this calculation to oblique waves propagating with an angle to the magnetic field and simultaneously restricting our model to a He-p-e plasma to determine the so-called "Helium valley". We found the limits of this valley for every temperature and angle. Comparing this limits to the mean gyro frequencies we were able to determine the temperature range, in which the gyroresonant acceleration model accounts for the observed ion abundances in impulsive solar flares. I discussed the essential observational facts with D. Reames, who provided us with most of the observational data. Together with him, J-P. Meyer, A.

Campeanu and J. Miller I am now finishing a paper about the Helium Valley, which will be submitted to ApJ.

Together with R. Schlickeiser and U. Jaekel I have written a paper about the stochastic acceleration of ions in impulsive flares using a "cone model" and an arbitrary power law spectrum for the turbulence. We generalize earlier treatments to investigate, if the resulting particle spectra show any significant deviation under these less restrictive approximations. We discuss our results with respect to observed spectra and give a method to determine the spectral index of the turbulence. This paper has been submitted to ApJ and is now in the process of being refereed.

Parts of this work we presented at conferences in New Hampshire, Bartol, Delaware, Columbus, Ohio, and at an internal meeting of the theory group in May 1992. Together with J. Miller I contributed a paper about proton acceleration in a low-beta plasma to the proceedings for the conference in Bartol.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/1992)

TRACEY JANE TURNER

TASK NUMBER:

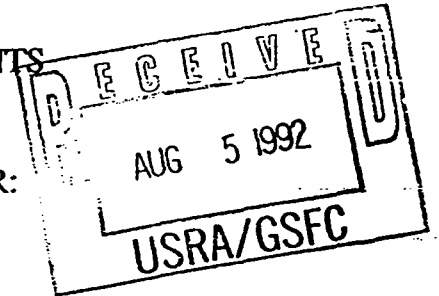
General Description of Research Activities:

**ROSAT: Project work**

In ROSAT programmatic work this year I have concentrated on the Position Sensitive Proportional Counter (PSPC) calibration issues. The most important issues to be dealt with have been the parameterization of the point spread function (psf) of the ROSAT PSPC detector. This has been a collaborative effort with Ian George (GSFC) and Guenther Hasinger plus Gunther Boese at MPE. The attached technical memo details the elements of the PSPC psf based on ground calibration data, and shows the mathematical parameterization of the psf components. Comparisons of these functional forms with ground and in-flight calibration data are also shown. Work continues on the off-axis psf.

Another important calibration concern has been the PSPC spectra. Working on in-house, calibration and PV data, and collaborating with Andy Fabian and Paul Nandra at Cambridge (UK) we have established the existence of a systematic deficit of photons around 0.27 keV in the observed spectra of a variety of source types. The existence of this deficit so close to the carbon edge energy suggests that the effect could be closely related to the calibration of the PSPC, which contains carbon in the detector window, and in the detector gas. We are currently working with MPE to identifying the origin of the problem. Thus far we have eliminated atmospheric oxygen line emission; background subtraction problems; detector window thickness calibration and the width of the spectral response (in the detector response matrix) as the origin of the problem. Areas requiring further investigation include the photon by photon gain correction and ground calibrations.

As always, working with ROSAT Guest Observers continues to be an important part of my project work. Visitors are dealt with on a rotating schedule basis between the four duty scientists. A



significant amount of time is also spent on answering remote observer queries on ROSAT issues, received via email or phone messages.

Other duties include issuing a ROSAT status report to the members of the US community (approximately every two weeks).

### Research:

One important area of my research involves the detailed analysis and interpretation of the soft X-ray spectra of a sample of active galaxies, observed by ROSAT. The spectra of Seyfert 1 galaxies are systematically steeper in the ROSAT 0.1-2.0 keV band than the 2-10 keV band, as suggested by EXOSAT observations. The mean photon index of  $2.41 \pm 0.33$  could be explained in a variety of ways. One appealing possibility is that we are observing reprocessed emission from the hypothesised accretion disk. Ross and Fabian (MNRAS 1992 in press) show that such a scenario could produce the steep soft X-ray spectra observed, with the superposition of soft X-ray line emission as suggested by the old Einstein SSS+MPC data. The comparison of the Seyfert spectra with the spectrum of the diffuse component of the X-ray background also suggests that the excess and as yet unexplained X-ray background emission in the 0.5-1.0 keV band (thought to contain a significant extragalactic component) could be easily explained as a combination of the soft X-ray emission from Seyfert 1 and 2 galaxies. The problems with the PSPC spectral calibration, of course, put a hold on publication of all of the aforementioned results.

Work is also in progress on the analysis of ROSAT observations of Seyfert 2 galaxies; archival analysis of soft X-ray spectra of AGN with an interpretation using pair cascade models; and multiwaveband monitoring of AGN (all detailed in the "collaborations" section).

### Significant Recognition of your work:

I list citations ONLY to papers on which I am first author and which have multiple citations:

1987 "Dramatic X-ray variability in the Narrow Emission Line Galaxy NGC7314", T.J.Turner, MNRAS 226, 9p 9 citations



1988 Variability of the Soft Excess in the Seyfert 1 Galaxy Mkn335",  
T.J.Turner and K.A.Pounds MNRAS 232, 463. 10 citations

1989 "The EXOSAT Spectral Survey of AGN" T.J.Turner and  
K.A.Pounds MNRAS 240, 833. 136 citations

1991 T.J. Turner, R.F. Mushotzky, K.A. Weaver, S.S. Holt & G.M. Madejski  
*Einstein Observatory SSS & MPC observations of the Complex X-ray Spectra of Seyfert  
Galaxies* 1991 Ap.J. 381, 85. 5 citations

Number of citations reflects the citations to date including the 1991  
citation listing.

Honors or awards:

Papers published or accepted for publication:

T.J. Turner, R.F. Mushotzky, K.A. Weaver, S.S. Holt & G.M. Madejski  
*Einstein Observatory SSS & MPC observations of the Complex X-ray Spectra of Seyfert  
Galaxies* 1991 Ap.J. 381, 85 .

T.J.Turner, C.Done, R.F.Mushotzky and G.M.Madejski  
*Evidence for an ionized Reprocessor in NGC6814.*  
Ap.J. (1992) 391, 102.

C.Done, G.M.Madejski, R.F.Mushotzky, T.J.Turner, K.Koyama and H.Kunieda  
*The X-ray Variability of NGC6814: Power Spectra*  
Ap.J. In Press

I.M.George, K. Nandra, A.C.Fabian, T.J.Turner, C.Done and C.Day  
*Dramatic X-ray and Spectral Variability in Mkn841.*  
Mon.Not.R.astr.Soc. In Press.

B.M.Peterson et al.  
*Steps toward determination of the size and structure of the Broad-Line Region in Active  
Galactic Nuclei. III Further Observations of NGC5548 at optical wavelengths.*  
Ap.J In Press.

C.Done, G.M.Madejski, R.F.Mushotzky, T.J.Turner and H.Kunieda  
*The X-ray Variability of AGN and the anomalous behaviour of NGC6814*

submitted to the Proceedings of the Oct 1991 University of Maryland meeting "Testing the AGN Paradigm".

G.Hasinger, T.J.Turner, I.M.George  
*The On-Axis Point Spread Function : In-Flight Comparison with the PANTER results.*  
OGIP Calibration Memo CAL/ROS/92-001  
Appearing in Legacy #1

Papers submitted but not yet accepted for Publication:

T.J.Turner, K. Nandra, K. Jahoda, G.M. Madejski, F. Marshall, R.F.Mushotzky, R.Petre, K.A.Pounds, A.P. Smale, P. Serlemitsos, K.Weaver, and A.A.Zdziarski  
*BBXRT and Ginga Observations of the Seyfert 1 galaxy Mrk335.*  
Submitted to ApJ. in May 1992

Papers presented at scientific meetings:

*Invited papers:*

Invited Review Talk entitled " X-Ray Variability in Active Galactic Nuclei" presented at the 33rd Herstmonceux Meeting on " The Nature of Compact Objects and Starbursts in AGN", Cambridge, UK. July 16-22nd 1992.

*Contributed Papers:*

"*ROSAT Spectra of Seyfert 1 Galaxies*"  
A Poster to appear at the COSPAR Meeting "Recent Results in X-ray and EUV Astronomy". Washington DC, Aug 27th-Sept 3rd

Colloquia, seminars and Special Lectures since September 1991:

Seminar: "Ginga and BBXRT Observations of AGN "  
University of California, Los Angeles Feb 4th 1992

COMMUNITY SERVICE:

Served as ROSAT Technical Advisor for the 3rd ROSAT Proposal Peer Review, Tysons Corner, April 2nd-5th.

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OF POOR QUALITY

Collaborations with University Groups:

-with Andy Fabian and Paul Nandra-Institute of Astronomy, Cambridge, England.

ROSAT Observations of Mkn841:

An X-ray Observation of Mkn841 was won by both the Goddard Group (PI Turner) and the IOA Group (PI Fabian) at their respective National AO1 reviews. The International Users Committee decided to award data to both groups, taken from the same 20,000 second observation. The two groups decided to pool the data and we are currently working on a collaborative paper. As a follow up program the Goddard Group (PI George) were awarded a 9 observation monitoring program for Mkn841, to be supported by IUE and optical observations.

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- with Matt Malkan and Ed Rosenblatt- University of California, Los Angeles:

Multiwaveband Observations of Seyfert Galaxies:

Optical and IUE Observations have been made for many of the ROSAT targets, we are compiling databases of IUE and optical data for these sources.

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-with Wei-Hsin Sun- National Central University, Taiwan

X-ray, IUE and Optical Observations of Mkn335:

3 years of simultaneous IUE /optical observations of Mkn335 are currently being analysed.

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- with Prof. K.A.Pounds- University of Leicester, England  
ROSAT Observations of Mkn335:

A long (25,000 second) observation of this source is currently being analysed by the authors (PI Turner).

Non University Collaborations (outside of Goddard):

with Meg Urry- Space Telescope Sciences Institute  
ROSAT Observations of Seyfert 2 Galaxies:

We were granted two more ROSAT observations of Seyfert 2 galaxies during the AO3 proposal review. Combined with our AO1 targets we will have a sample of five sources. Data in hand are Mkn3, Mkn78 and Mkn573, analysis is in progress.

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-with A. Zdziarski- N.Copernicus Astronomical Center,  
Warsaw, Poland (formerly Space Telescope Science Institute).  
Modelling of Soft Excess Components in Seyfert Galaxies:

An ADP proposal (PI Greg Madejski) was won for a collaborative project in which all soft excess data to date (including Einstein SSS, IPC; EXOSAT; ROSAT) will be used to constrain nonthermal electron-positron pair cascade models for soft excess emission.

(The soft excess models will also be applied to the new ROSAT data awarded on other projects involving the same investigators).

**Additional Information:**

Visiting ROSAT Guest Observers fill out an assesment form after their visit, giving their impressions of their visit and the help they received. The completed forms are available for USRA examination on request to Karen Smale.

*There follow the abstracts from papers  
published, accepted or submitted this year*

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Submitted to ApJ

N93-18710

## BBXRT AND GINGA OBSERVATIONS OF THE SEYFERT 1 GALAXY MRK 335

T. J. Turner<sup>1,3</sup>, K. Nandra<sup>2,4</sup>, K. Jahoda<sup>1</sup>, G. M. Madejski<sup>1,3</sup>, F. Marshall<sup>1</sup>,  
R. F. Mushotzky<sup>1</sup>, R. Petre<sup>1</sup>, K. A. Pounds<sup>2</sup>, A. P. Smale<sup>1,3</sup>,  
P. Serlemitsos<sup>1</sup>, K. Weaver<sup>1,5</sup>, and A. A. Zdziarski<sup>1,6</sup>

- <sup>1</sup> Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center,  
Greenbelt, MD 20771  
<sup>2</sup> Department of Physics, Leicester University, Leicester, England  
<sup>3</sup> Universities Space Research Association  
<sup>4</sup> Institute of Astronomy, Cambridge University, Cambridge, England  
<sup>5</sup> Department of Astronomy, University of Maryland, College Park, Maryland  
<sup>6</sup> N. Copernicus Astronomical Center, Warsaw, Poland

### ABSTRACT

We present new X-ray observations of Mrk 335 in the 0.4–10 keV band using *BBXRT* and in the 2–18 keV band with *Ginga*. The *BBXRT* data show a gradual steepening of the spectrum to softer energies. We suggest that the nuclear emission can be explained by a self-consistent pair cascade model as developed by Zdziarski *et al.* (1991) and Zdziarski & Coppi (1991). The *Ginga* data show evidence for variability in absorption, uncorrelated with flux changes of the continuum source. The inconsistency between the opacity observed at the iron K edge and at softer X-ray energies implies that the absorber has an ionization state  $\lesssim \text{FeXV}$ .

### 1. INTRODUCTION

The Seyfert 1 galaxy Mrk 335 ( $z = 0.026$ ; RA (1950) = 00 03 45.0, Dec (1950) = 19 55 30) was first detected in X-rays by *UHURU* (Tananbaum *et al.* 1978). It was observed with the *Einstein* Observatory (Halpern 1982), where it exhibited a soft X-ray flare lasting  $\sim 10$  ksec (Lee *et al.* 1988). Subsequent *EXOSAT* observations by Pounds *et al.* (1987) (see also Turner and Pounds 1988, hereafter TP88, and Turner and Pounds 1989) established the existence of a two component X-ray spectrum in the 0.1–10 keV band, including a steep spectral component dominating the soft X-ray spectrum. Neither the form of this soft component nor the break energy between the two components could be well determined, as the *EXOSAT* LE detector/filter combination had very poor energy resolution. *EXOSAT* also observed rapid variability in the soft excess component, with a factor of  $\sim 2$  increase in 10 hours during a long observation. Soft X-ray excess components have been hypothesized to originate in the inner regions of an accretion disk. In support of that idea, other waveband data have suggested that an accretion disk does exist in Mrk 335. IUE observations have shown Mrk 335 to turn up in the ultraviolet, having an excess continuum component near 3000 Å (Malkan & Sargent 1982). In addition, Van Groningen (1987) suggested a compact and dense accretion disk to explain the asymmetric optical line profiles observed in this object. Pounds *et al.* (1987) go on to suggest that the observed strong UV component and the X-ray soft excess could

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## The Broad-band X-ray Spectral Variability of Mkn 841

I.M. George<sup>1,2†</sup>, K.Nandra<sup>3,1</sup>, A.C. Fabian<sup>1</sup>, T.J. Turner<sup>2†</sup> C. Done<sup>2,3</sup>  
& C.S.R. Day<sup>4,2†</sup>

<sup>1</sup>*Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, U.K.*

<sup>2</sup>*Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center, Greenbelt, Maryland, MD20771, U.S.A.*

<sup>3</sup>*X-ray Astronomy Group, Department of Physics & Astronomy, University of Leicester, University Road, Leicester LE1 7RH, U.K.*

<sup>4</sup>*Institute of Space and Astronautical Science, 3-1-1 Yoshinodai, Sagami-hara, Kanagawa-ken 229, Japan.*

### SUMMARY

The results of a detailed spectral analysis of four X-ray observations of the luminous Seyfert 1.5 galaxy Mkn 841 performed using the *EXOSAT* and *Ginga* satellites over the period 1984 June to 1990 July are reported. Preliminary results from a short *ROSAT* PSPC observation of Mkn 841 in 1990 July are also presented.

Variability is apparent in both the soft (0.1–1.0 keV) and medium (1–20 keV) energy bands. Above 1 keV, the spectra are adequately modelled by a power-law with a strong emission line of equivalent width  $\sim 450$  eV. The energy of the line ( $\sim 6.4$  keV) is indicative of *K*-shell fluorescence from neutral iron, leading to the interpretation that the line arises via X-ray illumination of cold material surrounding the source. In addition to the flux variability, the continuum shape also changes in a dramatic fashion, with variations in the apparent photon index  $\Delta\Gamma \sim 0.6$ .

The large equivalent width of the emission line clearly indicates a strongly enhanced reflection component in this source, compared to other Seyferts observed with *Ginga*. The spectral changes are interpreted in terms of a variable power-law continuum superimposed on a flatter reflection component. For one *Ginga* observation, the reflected flux appears to dominate the medium energy X-ray emission, resulting in an unusually flat slope ( $\Gamma \sim 1.0$ ).

The soft X-ray excess reported by Arnaud *et al.*, is found to be highly variable by a factor  $\sim 10$ . These variations are not correlated with the hard flux, but it seems likely that the soft component arises via reprocessing of the hard X-rays. We find no evidence for intrinsic absorption, with the equivalent hydrogen column density constrained to be  $\lesssim \text{few} \times 10^{20} \text{ cm}^{-2}$ .

The implications of these results for physical models for the emission regions in this and other X-ray bright Seyferts are briefly discussed.

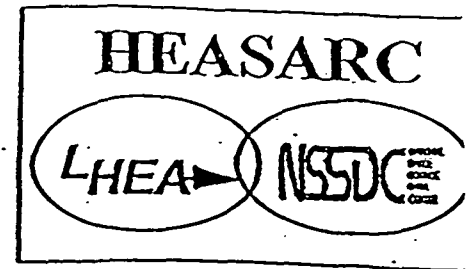
<sup>†</sup> Universities Space Research Association

NASA

Goddard Space Flight Center

OGIP Calibration Memo CAL/ROS/92-001

NIS



ROSAT PSPC

# The On-Axis Point Spread Function:

In-flight comparison with the PANTER results

Günther Hasinger, T. Jane Turner, Ian M George & Günter Boese

Code 668,  
NASA/GSFC,  
Greenbelt, MD20771

Version: 1992 May 11

## SUMMARY

The components of the *ROSAT* PSPC on-axis point spread function (*psf*) are discussed, and a direct comparison made between the predicted *psf* from ground calibration measurements and in-flight data obtained during the early part of the mission. It is found that the analytical functions derived from the ground calibration data satisfactorily describe the 5 in-flight datasets tested here.

It should be noted that this is not intended to be the definitive write-up of the PSPC *psf*. Rather, the aim of the memo is to distribute the currently available information to *ROSAT*PIs in a timely fashion. The author list does not reflect the input of all the people involved with the PANTER data. It is expected that a full write-up will appear at a later date.

## Evidence for an Ionized Reprocessor in NGC 6814

T. Jane Turner<sup>1</sup>, Christine Doné<sup>2</sup>, Richard Mushotzky, Greg Madejski<sup>1</sup>

Laboratory for High Energy Astrophysics, NASA/Goddard Space Flight Center,  
Greenbelt, MD 20771

and

Hideyo Kunieda

Department of Astrophysics, Nagoya University, Nagoya, Japan

<sup>1</sup> Universities Space Research Association

<sup>2</sup> NAS/NRC Resident Research Associate

To appear in the May 1<sup>st</sup>, 1992 issue of the *Astrophysical Journal*

### Abstract

We report a detailed spectroscopic analysis of a *Ginga* observation of the Seyfert galaxy NGC 6814. We show that the X-ray data are consistent with a scenario in which the continuum radiation is reprocessed in a highly ionized medium, which can either be an accretion disk or a shell of absorbing material. Both of these can produce the strong observed iron  $K\alpha$  line, which must originate within 200 light seconds of the continuum source. Significant iron  $K\beta$  and nickel  $K\alpha$  are predicted, based on the iron  $K\alpha$  line strength, and these lines partially conceal the iron edge in this source. The spectral variability below  $\sim 4$  keV, where the apparent absorption increases as the continuum flux decreases, is probably caused by a warm absorber covering the reprocessing system.

### 1. Introduction

NGC 6814, a low luminosity Seyfert galaxy ( $L_x \sim 10^{41-43}$  erg  $s^{-1}$ ), was discovered to exhibit rapid X-ray variability in the HEAO-A2 data, with a time scale of  $\sim 100$  seconds (Tennant *et al.* 1981). X-ray flares were observed in a long (1 day) EXOSAT observation, and a period of 12,000 seconds was suggested for these events (Mittaz and Branduardi-Raymont 1989; Fiore, Massaro, and Barone 1991).

A 3 day observation of NGC 6814 was made with the Large Area Proportional Counter (LAC) on the Japanese X-ray astronomy satellite *Ginga* over the period April 28 -30 1989, covering the energy range 1.5 to 37 keV. A preliminary analysis of these data showed rapid and chaotic variations (up to a factor of five) throughout the observation (Kunieda *et al.* 1990, hereafter K90). As reported by K90 and Turner *et al.* (1991), the flat spectral index ( $\alpha \sim 0.4$ ) and large equivalent width ( $W_\alpha$ ) of the iron  $K\alpha$  line ( $\sim 350$  eV) are not consistent with the spectra seen in



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**THE X-RAY VARIABILITY OF NGC6814: POWER SPECTRA**

**C. DONE, G.M. MADEJSKI, R.F. MUSHOTZKY AND T.J. TURNER**

NASA/GSFC, LHEA-code 660, Greenbelt, MD20771, USA

**K. KOYAMA AND H. KUNIEDA**

Department of Astrophysics, Nagoya University, Chikusa-Ku, Nagoya 464, Japan.

**ABSTRACT**

Simulation techniques are used to obtain the X-ray variability power spectrum of unevenly sampled *GINGA* data from NGC6814. A simple power law is not an adequate description of the power spectrum, with the residuals showing excess power on timescales consistent with the periodicity seen in EXOSAT observations of this object. However the shape of the folded lightcurve is very different, with 3 main peaks, two of which are separated by an extremely sharp dip instead of the single peak and small harmonic structure observed by EXOSAT. Using the dip as a fiducial mark, a second *GINGA* observation of this source taken one year later is found to be consistent with being completely periodic and phase coherent with this first *GINGA* observation. Thus the period is consistent with being constant over a period of 6 years, but phase coherence is only maintained on timescales of  $\sim 1$  year.

Over 75 per cent of the total source variability is due to the periodic component (r.m.s amplitude of 36 per cent). The residual variability can be described as the more usual

"flicker noise"  $f^{-1.1}$  power law. This shows no apparent high frequency break on timescales greater than 300 seconds.

Subtle differences in the shape of the folded light curve with energy, and the very large amount of power in the periodic component suggest occultation as its origin, though amplification of variability from an X-ray emitting "hot spot" at the disk inner radius through gravitational lensing is also possible. The former suffers from the very arbitrary nature of the periodic timescale, while the latter is unattractive as it cannot simply explain the lack of high frequency break in the residual power. That these models probably fail to provide an adequate explanation may be due to the added complexity of anisotropy of the X-ray emission, suggested by the discrepancy between the lack of soft photons implied by the flat spectrum and the copious source of soft photons available from reprocessing in the iron line producing material.

92A 43711

# ROYAL GREENWICH OBSERVATORY

CAMBRIDGE • LA PALMA

## Steps toward determination of the size and structure of the Broad-Line Region in Active Galactic Nuclei. III Further observations of NGC 5548 at optical wavelengths

B M Peterson,<sup>1</sup> D Alloin,<sup>2</sup> D Axon,<sup>3</sup> T J Balonek,<sup>4</sup> R Bertram,<sup>1,5</sup> T A Boroson,<sup>6</sup>  
J A Christensen,<sup>4,7</sup> S D Clements,<sup>8</sup> M Dietrich,<sup>9</sup> M Elvis,<sup>10</sup> A V Filippenko,<sup>11</sup>  
C M Gaskell,<sup>12,13</sup> C A Haswell,<sup>14</sup> J P Huchra,<sup>10</sup> N Jackson,<sup>3</sup> W Kollatschny,<sup>9</sup> K T Korista,<sup>1,15</sup>  
N J Lane,<sup>1</sup> R J Leacock,<sup>8</sup> S-N Lin,<sup>16</sup> M A Malkan,<sup>17</sup> A S Monk,<sup>18</sup> M V Penston,<sup>18,19</sup>  
R W Pogge,<sup>1</sup> A Robinson,<sup>20</sup> E I Rosenblatt,<sup>21</sup> J C Shields,<sup>11,22</sup> A G Smith,<sup>8</sup> G M Stirpe,<sup>23</sup>  
W-H Sun,<sup>16</sup> T J Turner,<sup>24</sup> R M Wagner,<sup>15</sup> B J Wilkes,<sup>10</sup> and B J Wills<sup>14</sup>

<sup>1</sup>Department of Astronomy, The Ohio State University, 174 West 18th Avenue, Columbus, OH 43210, USA

<sup>2</sup>Observatoire de Paris, URA173 CNRS, 92195 Meudon, France

<sup>3</sup>University of Manchester, Nuffield Radio Astronomy Laboratories, Macclesfield, Cheshire, SK11 9DL, UK

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*Accepted for publication in Astrophysical Journal*

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<sup>18</sup>Department of Astronomy, University of California, Math-Science Building, Los Angeles, CA 90024.

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<sup>20</sup>Deceased, 1990 December 23.

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<sup>24</sup>Osservatorio Astronomico di Bologna, Via Zamboni 33, I-40126, Bologna, Italy.

<sup>25</sup>Laboratory for High Energy Astrophysics, Goddard Space Flight Center NASA, Code 668, Greenbelt, MD 20771.

## ABSTRACT

We report on the results of the second year of an intensive ground-based spectroscopic and photometric study of variability in the bright Seyfert 1 galaxy NGC 5548, which has been undertaken in order to study the relationship between continuum and emission-line variability. Relative to the first year of this monitoring program, the nucleus of NGC 5548 was considerably fainter and the continuum variations slower during the second year, but the continuum- $H\beta$  cross-correlation results for the two years are nearly identical. The variations in the broad  $H\beta$  emission line lag behind those in the continuum by somewhat less than 20 days, as concluded from the first year's data.

Subject headings: galaxies: individual (NGC 5548) — galaxies: Seyfert — quasars: emission lines

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Conf. Proceedings  
N93-18713

## THE X-RAY VARIABILITY OF AGN AND THE ANOMALOUS BEHAVIOR OF NGC6814

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### ABSTRACT

The power spectra of the X-ray variable AGN are typically scale invariant with no characteristic timescale. The one strong exception to this is NGC6814, where the EXOSAT data showed evidence for a periodic component at  $12200 \pm 100$  seconds. The power spectra of a *GINGA* lightcurve from this source, found using simulation techniques to account for the uneven sampling, also cannot be well fit by a single power law. A folded light curve analysis of the *GINGA* data shows a strong peak in the variance, indicative of a periodic component, at  $12130.9 \pm 0.6$  seconds. A second *GINGA* observation of this source taken one year later is consistent with the periodicity maintaining phase coherence for 7 periods in the range of 12110–12145 seconds. Including the limits from the folding selects a period of  $12130.39 \pm 0.05$  seconds. Phase coherence is not maintained between this and the EXOSAT observations, as the structure of the folded light curves is very different. Thus the periodicity is long lived and stable, but phase coherence is only maintained on timescales of  $\sim 1$  year.

### 1. INTRODUCTION

The X-ray emission from Active Galactic Nuclei (AGN) provides a large contribution ( $\sim 10$  per cent) to their total bolometric luminosity, suggesting that the X-rays are closely associated with the primary energy generation source. This emission is also highly variable on short timescales, so by light crossing time arguments implies a very small size scale for the emission region. Thus, rapid X-ray variability provides the strongest evidence in support of the standard theory that all the activity seen is ultimately powered by accretion onto a black hole. No other spectral region in radio-quiet AGN varies so rapidly, indicating that the X-rays are a probe of the smallest size scales and hence of the environment and energy generation processes close to the central engine.

The EXOSAT satellite provided the best data with which to study X-ray variability, being able to observe a source continuously for up to 3 days. The nature of the variability could then be determined from a power spectral analysis. These showed that power was present on all timescales, from  $10^3$  seconds (where the source power was typically lost in the Poisson noise) to days. The power spectra are well fit by a power law in most cases, with  $P(f) \propto f^{-1}$ , showing

# Einstein Observatory SSS and MPC Observations of the Complex X-ray Spectra of Seyfert Galaxies

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<sup>2</sup>Also with the University of Maryland

Accepted for publication in the *Astrophysical Journal*

## Abstract

We have re-investigated the X-ray spectra of 25 Seyfert galaxies measured with the Solid State Spectrometer on the *Einstein* Observatory. This new investigation utilizes simultaneous data from the Monitor Proportional Counter, and automatic correction for systematic effects in the Solid State Spectrometer which were previously handled subjectively. We find that the best-fit single power law indices generally agree with those previously reported, but that soft excesses of some form are inferred for  $\sim 48\%$  of the sources. One possible explanation of the soft excess emission is a blend of soft X-rays lines, centered around 0.8 keV. The implications of these results for accretion disk models are discussed.

## I. Introduction.

The *Einstein* Solid State Spectrometer (SSS) was a cryogenically-cooled Si(Li) detector operating at the focus of the *Einstein* Observatory telescope with high efficiency (*cf.* Figure A-2) over the entire band for which it could detect photons, *i.e.* 0.6 – 4 keV (for a detailed description of the instrument see Joyce *et al.* 1978 and Holt *et al.* 1979). This instrument yielded moderate energy resolution spectra ( $\sim 160$  eV FWHM) from sources brighter than a few tenths of a photon per second in its operational bandpass. Previous reports of the SSS spectra of Seyfert galaxies are given in Holt *et al.* (1980), Petre *et al.* (1984), and Reichert *et al.* (1985). In general, the spectra reported in these papers are consistent with the “canonical” power law with the photon index  $\Gamma$  (defined such that the differential photon flux  $N(E) \propto E^{-\Gamma}$ ) of 1.7, apparently extending out to  $\sim 100$  keV for Seyfert galaxies (Rothschild *et al.* 1982; Mushotzky 1984; Turner and Pounds 1989, hereafter referred to as TP89).

Two deficiencies of these previous analyses are 1) the SSS covers only the limited bandpass  $\sim 0.6 - 4$  keV, and 2) somewhat subjective corrections for systematic effects were required. The former deficiency is improved here with the utilization of simultaneously collected, reliable data from the Monitor Proportional Counter (MPC) on the *Einstein* Observatory (K. Arnaud, NASA technical memo, in preparation; also see Appendix A). This extends the energy range

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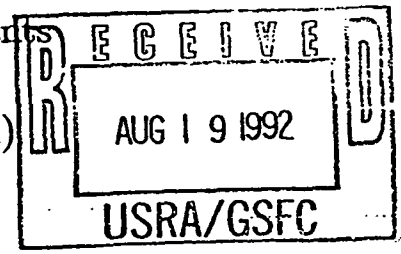
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Universities Space Research Association  
Goddard Visiting Scientist Program

Employee Summary of Accomplishments  
for the year ending 9/30/92

Dr. Alan P. Smale (task # 660-004)



Description of Research Activities

**Summary:** In the past year I: (a) completed a large part of the work required to convert the BBXRT data into FITS format for community release; (b) co-directed the design and implementation of software to process and analyze data from the Japanese Astro-D mission; (c) obtained significant scientific results from BBXRT, *Ginga* and *Vela 5B*, leading to the acceptance of several papers in refereed journals and (d) worked on ROSAT data and served on the proposal review panel.

I also received a Peer Award from the Laboratory for High Energy Astrophysics for my work on BBXRT.

In more detail:

(i). Programmatic responsibilities - BBXRT

The programmatic part of my BBXRT activities this year divides into two main categories; calibration, and conversion.

The determination of an accurate instrumental response for BBXRT has been a long and detailed process. This assessment year we have performed several long postflight calibration runs with the flight instruments in the beam facility here at Goddard, and also at NIST, and I processed these data for analysis. Aside from complications with incomplete charge collection in the detector, we became aware that a residual effect was present in the data at 8 keV due to the nickel mesh in the detector. This effect was previously thought to be negligible, but it turns out to be very important for the proper determination of the parameters of the 6.7 keV iron emission observed in many cosmic X-ray sources. At the beginning of June the BBXRT response matrix was finalized, and now contains no systematic deviations greater than 5% between 0.5-10 keV in all pixels. We are now satisfied that we understand the matrix sufficiently to start publishing our results, and the BBXRT team as a whole is now hurrying to complete and submit a series of papers before the data becomes available to the community (see later in this report for my scientific report on BBXRT data analysis).

The final stage of the BBXRT data processing is the conversion of the data from its current telemetry-based format into the standard FITS format required by the High Energy Astrophysics Science Archive Research Center (HEASARC) and the NSSDC, and accepted throughout the community. In December I wrote up the requirements and

specifications for this conversion and presented the strategy to the HEASARC Users Group, a steering committee made up of scientists from many research groups, who approved it.

The data release to the community will take place in two parts. In September 1992, I will release the Level 2 ("Products") database. This will include: a complete observation list; one spectrum per pixel per observation; one light curve per pixel per observation; response matrices and background files to be used with these spectra; and documentation. In 1993 February, I will release the Level 1 ("Photons") database, which is much more extensive, and includes: photon list files; housekeeping data - temperatures, guard rate and other mechanical/technical information from the instruments; pointing data - RA, Dec and roll angle of the pointing position of the instrument; mission quality data - Sun angle, Earth angle, orbit day/night etc; complete BBXRT mission documentation; SELECTOR software (see later) and userguide.

I am currently ahead of schedule on most of the above. I have completed the observation catalogue, defining exact start/stop times, exposure times, day/night flags, count rates, mean aspect solutions and guard rates, etc. Code has been designed, written and tested for the event data, pointing data, mission quality data, light curves and spectra. The spectral and light curve file formats require 'tweaking' to bring them into line with the HEASARC standards (which I am currently helping to define). Apart from these tweaks, the main outstanding tasks are to get the housekeeping data and response matrix files in the correct formats. Both of these are major tasks, requiring detailed interaction with HEASARCers. In addition, I need to spend a considerable amount of time writing documentation for the new user unfamiliar with BBXRT.

As was the case last year, the "software team" has consisted of myself plus a junior programmer. I do all of the software specifications, a large fraction of the new programming, and all of the maintenance programming, myself.

## (ii). Programmatic responsibilities - Astro-D

This year there has been an explosion of effort on the software for Astro-D, an American-Japanese collaboration due to be launched in 1993 February. The software effort for Astro-D at Goddard is being led by Bill Pence (USRA) and myself; there are currently two programmers working full time and two part-time on the project under us. The suite of programs as a whole is known as SELECTOR, and we have now completed the third "build" or milestone in terms of number of individual modules or FTOOLS written, each routine performing a single analysis task. We successfully negotiated end-to-end tests on the software in the U.S. on April 28th and in Japan in July.

The FTOOLS tasks can be run either as standalone tasks, under IRAF, or under a user interface called XSELECT. I am the principal mover behind XSELECT; it is superficially similar to, and builds upon, my experience with BBXRT, and provides a user-friendly interface to these tasks in a XANADU-type environment, and will support a graphical user interface. Using XSELECT and the FTOOLS, one can already merge datasets, filter data according to arbitrarily complex Boolean expressions, create light curves and spectra, and plot them. Other FTOOLS enable users to perform many FITS file



manipulation tasks. Future enhancements include interfaces to image processing programs, scripts to tie these tasks together, and a lot of documentation and fine tuning. SELECTOR is designed to be mission-independent, and will ultimately replace and enlarge upon the current CHIP program for BBXRT archival data analysis. The final release of BBXRT data to the community will include access to the SELECTOR suite.

I recently went to Japan to present and demonstrate our progress to our Japanese co-investigators. I am also a member of the X-ray binaries subgroup for the performance verification phase of the mission; on the same visit I participated in a review of the targets to be observed during the first eight months of the mission to achieve calibration and first-cut science objectives.

### (iii). Scientific research – BBXRT data

At the beginning of this year I presented a paper on results of BBXRT analysis of X-ray binaries at the Atlanta AAS meeting. Since then, I have completed the analysis for my paper on the BBXRT observations of Cygnus X-2, and am now attempting to improve the discussion section prior to publication. I am also working hard on the analysis of another source, Cygnus X-3, for an additional paper that I hope to finish by the end of September. I have analyzed the continuum and line emission from almost all of the X-ray binaries and several other sources, and am a co-author on already-submitted papers on NGC 1068 (Marshall *et al*), Markarian 335 (Turner *et al*), NGC4151 (Weaver *et al*) and X Per (Schlegel *et al*).

### (iv). Scientific research – non-BBXRT

I have worked on several non-BBXRT projects this year.

(1) I completed and submitted a paper on long-term variability in low-mass X-ray binaries based on a reanalysis and reinterpretation of data from *Vela 5B*, in collaboration with Lochner (LANL, now GSFC/USRA). We examined the data from all LMXBs with no near X-ray bright neighbours using a variety of time-series analysis techniques, to study the nature of changes in the mass transfer rate and luminosity of the systems and the effects they have on binary evolution. We find that long-term cyclic variability is a rare occurrence in these systems. Of the seventeen sources studied, periodicities of order hundreds of days are observed in three: X1820–30, Cygnus X-2 and possibly X1916–053. The paper appears in the August 20th edition of *Astrophysical Journal*, and a preprint accompanies this assessment.

(2) I also completed a major paper on the X-ray emission from the dipping binaries X1916–053 and EXO0748–676 using data from the Japanese *Ginga* satellite. The X-ray bursts observed in the former system appear to cause an almost instantaneous ionization of the absorbing, dip-causing material at the disk edge. In addition, the bursts illuminate the disk and cause a three-fold increase in the disk emission. Detailed simulations of both sources show that mixing of rapidly-varying absorption states can produce an apparent low-energy spectral component. This paper has been accepted by the *Astrophysical Journal*; again, I enclose a preprint.

(3) In June, I received a tape containing the data from my ROSAT observation of X1822-371, performed at the beginning of March. I have begun the analysis of these data, although possible problems with the ROSAT PSPC matrix may hold me back for a while. X1822-371 is a 5.57-hr-period partially-eclipsing binary with an accretion disk corona. My ROSAT observation was designed to observe the temperature structure of the accretion disk corona during the partial eclipse, and despite being mis-scheduled by the German team, I actually succeeded (by pure luck) in observing the eclipse. Ultimately I will be able to determine the coronal structure from these data, and in addition will be sensitive to small temperature changes around the rest of the binary cycle. Finally, I will be able to refine the ephemeris of the source and study the period change of the system.

In April 1992, I served on the ROSAT AO-3 Peer Review, on one of the two Galactic panels. which involved reading and grading 100 proposals and arguing their merits in committee. I was invited onto other peer review panels, but declined due to pressure of other commitments.

(4) In addition, this year my paper "A study of the H $\alpha$  line in X1735-444" appeared in ApJ, and a paper on "Optical and X-ray observations of the LMXB EXO0748-676" by Thomas (Penn State) *et al* was submitted. I have submitted successful service observation proposals for optical observations of X1916-053 (spectroscopy, 4.2m, La Palma) and X1323-62 (IR photometry, Anglo-Australian Telescope). My ROSAT proposal, "Probing the accretion disk in X1916-053", was accepted.

### Significant Recognition of Work

The following information was obtained from citation indices. Each of my lead-authored papers is referred to by its number on the accompanying resumé, followed by its year of publication, and the total number of citations to the end of 1991.

#1 (1984): 4. #2 (1984): 4. #4 (1986): 5. #8 (1986): 5. #9 (1987): 4.  
#13 (1988): 9. #15 (1988): 14. #16 (1988): 12. #21 (1989): 3. #24 (1989): 2.  
#34 (1991): 1.

Adding citations of conference proceedings, IAU Circulars, and my thesis, the total to date is 71.

### Honors or Awards Received

In July 1992 I received a Peer Award from the Goddard Space Flight Center Laboratories for High Energy Astrophysics, for my work on the planning, mission operations, software development and other efforts towards the successful flight of BBXRT. The award citation reads: "Peer Award presented to Dr. Alan Smale for innovative solutions to challenging problems on BBXRT; your cheerfulness, understanding and patience are an inspiration to us all."

I also received two Group Achievement Awards in 1991, signed by the Director of GSFC; for the BBXRT Payload Development and Operations Team, and for the Astro-1 Investigators Team.

## Papers published or accepted for publication

The numbering scheme employed below matches that used in my resumé.

35. 1991 "A study of the H $\alpha$  line in X1735-444", Smale, A.P. & Corbet, R.H.D.; *Astrophys. J.*, 383, 853.
36. 1992 "Long-term variability in LMXBs; a study using data from *Vela 5B*", Smale, A.P., & Lochner, J.C.; *Astrophys. J.*, 395, 582.
37. 1992 "*Ginga* observations of the dipping low mass X-ray binaries XB1916-053 and EXO0748-676", Smale, A.P., Mukai, K., Williams, O.R., Jones, M.H. & Corbet, R.H.D.; *Astrophys. J.*, to appear in the Nov 20th issue.

## Papers submitted but not yet accepted for publication

The numbering scheme employed below matches that used in my resumé.

38. 1992 "A new X-ray spectral observation of NGC 1068", Marshall, F.E., Netzer, H., Arnaud, K., Boldt, E.A., Holt, S.S., Jahoda, K.M., Kelley, R., Mushotzky, R.F., Petre, R., Serlemitsos, P.J., Smale, A.P., Swank, J.H., Szymkowiak, A.E., & Weaver, K.A.; *Astrophys. J.*, submitted.
39. 1992 "Optical and X-ray observations of the low-mass X-ray binary EXO0748-676", Thomas, B., Corbet, R., Augusteijn, T., Callanan, P. & Smale, A.P.; *Astrophys. J.*, submitted.
- xx. 1992 "*BBXRT* and *Ginga* observations of the Seyfert I galaxy Mrk 335", Turner, T.J., Nandra, K., Madejski, G.M., Marshall, F., Mushotzky, R.F., Petre, R., Pounds, K.A., Smale, A.P., Serlemitsos, P., Weaver, K., & Zdziarski, A.A.; *Astrophys. J.*, submitted.
- xx. 1992 "*BBXRT* observations of NGC4151: I. Iron line diagnostics", Weaver, K.A., Mushotzky, R.F., Arnaud, K.A., Serlemitsos, P.J., Marshall, F.E., Petre, R., Jahoda, K.M., Boldt, E.A., Holt, S.S., Swank, J., Szymkowiak, A.E., Kelley, R., Smale, A.P. & Done, C.; *Astrophys. J.*, submitted.
- xx. 1992 "A *BBXRT* spectrum of the massive X-ray binary X Per", Schlegel, E.M., Serlemitsos, P.J., Jahoda, K., Marshall, F., Petre, R., Boldt, E.A., Mushotzky, R., Swank, J., Szymkowiak, A., Smale, A. & Weaver, K., *Astrophys. J.*, submitted.

## Papers presented at scientific meetings

Atlanta AAS meeting, January 1992: "BBXRT observations of X-ray binaries", Smale, A.P.; *Bull. Amer. Astr. Soc.*, 23, 1319.

## University collaborations

In the "Description of Research Activities" above, I cover several projects on which I am collaborating with workers at universities in the U.S. and Europe. My *Ginga* work was done in collaboration with Mukai (then at UC Berkeley), Williams (ESTEC, The Netherlands), Jones (Queen Mary and Westfield College, London) and Corbet (Penn State University). The paper on optical and X-ray observations of EXO0748-676 is being led by Thomas and Corbet of Penn State with collaborators from the University of Amsterdam, the Netherlands, and the Center for Astrophysics, Cambridge, Mass. A previous paper on X1735-44, published this year, was written in collaboration with Corbet (PSU). I also have frequent informal discussions about data analysis and computing techniques with colleagues in other institutions.

## Other collaborative activities

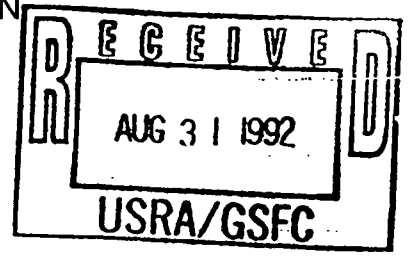
My software development and scientific input towards the Astro-D mission is done in consultation with the Institute for Space and Astronautical Science, Tokyo, Japan.

The principal collaborative scientific work performed this year was the *Vela 5B* paper with Lochner (then at LANL). Other papers worked on during this assessment period include collaborators from the European Space Agency, etc., as described above.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Eric R. Christian  
Task Number:

General Description of Research Activities:

**ALICE (A Large Isotopic Composition Experiment):** ALICE is a balloon-borne experiment designed to measure the isotopic composition of galactic cosmic rays in the charge range Silicon to Nickel between 400 and 800 MeV/nucleon. It is a collaboration with the U. of Siegen in Germany. Although I was not involved in the 1987 flight operations of the ALICE instrument, I am assisting on the data analysis, and with the writing of the papers. The analysis of the elemental composition has been completed, and the corresponding paper is in press in the refereed journal *Astroparticle Physics*. The isotope analysis of iron and silicon is near completion. The mass resolution obtained is better than any previous work at our energies. There should be a paper in a refereed journal (probably *The Astrophysical Journal*) submitted by the end of 1992. There will be another paper on the isotopic composition of the other elements following, and I will be heavily involved in the analysis needed for this subsequent paper.

**IMAX (Isotope Matter-Antimatter eXperiment):** IMAX is a balloon experiment which we are working on with Caltech, U. of Siegen, and NMSU to measure the fluxes of anti-protons, and Hydrogen and Helium isotopes over a wide energy range. My primary work was on the design of magnetic shields for the photomultiplier tubes, an in-flight calibration system, and one of the scintillation counters, as well as supporting a scintillating optical fiber hodoscope plane (which did not fly), and helping refurbish one of the Cherenkov counters. Much of my time this last year has been working on the integration of this experiment, and the support of the flight this last summer. Integration included a two month trip out to New Mexico State University, and 5 weeks were spent up in Lynn Lake, Manitoba, Canada for the flight. The flight on July 16-17 was successful with 16 hours of data taken at 119,000 feet. I will be involved with the data analysis that is just now being started.

**ACE (Advanced Composition Explorer):** ACE is a SMEX (SMall EXplorer) that is planned for launch in 1997 to study the solar wind, and heliospheric and low-energy-galactic cosmic rays. I am assisting Jon Ormes (ACE Project Scientist) with the Phase B work on this project in much the same way as

I was working on the now-defunct ASTROMAG.

**SIAM:** SIAM is an experiment to look at the isotopic composition of elements from Beryllium to Silicon in the cosmic rays. During the past few years, it has been in a study phase, leading up to a proposal this fall. It originally involved our group (I was a Co-investigator), Louisiana State University, MIT, U. of Berkeley, and the U. of Siegen in Germany. During the last year, I conducted a series of tests on Cherenkov counters in order to optimize a Cherenkov design for the proposal. However, the Goddard group (and the U. of Siegen group) have pulled out of this project in order to pursue the ISOMAX experiment (see below). To fulfill our part of the study, I wrote the Cherenkov section of the SIAM technical report detailing my tests and giving my conclusions on the design for the proposal.

**ISOMAX (ISotope Magnet eXperiment):** The last part of July and the first three weeks of August 1992 have been spent working on a proposal (submitted) for a new experiment to look at the isotopic composition of cosmic rays, including the very important, but rare, clock isotope  $^{10}\text{Be}$ . The Goddard High-Energy Cosmic Ray Group is taking the lead on this completely new experiment, and I am a Co-investigator. The California Institute of Technology and the University of Siegen, Germany are also collaborating on this project.

**Partially Ionized Iron:** I did some theoretical work to try to explain observations of partially ionized iron and sub-iron cosmic rays by Biswas et al. on their Spacelab experiment. After examining my ideas in detail, I discovered that they couldn't work, and indeed, most of the explanations proposed by Biswas et al. were also impossible by the same arguments. I presented these findings at the yearly meeting of the American Physical Society in Washington D.C..

#### Papers Accepted for Publication

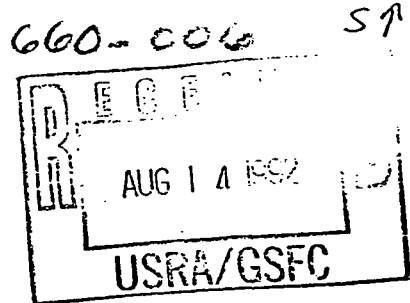
1992 "The ALICE Instrument and the Measured Cosmic Ray Elemental Abundances", J.A. Esposito, E.R. Christian, V.K. Balasubrahmanyam, L.M. Barbier, J.F. Ormes, R.E. Streitmatter, B. Acharya, B. Luzietti, A. Hesse, U. Heinbach, W. Heinrich, M. Henkel, C. Pfeifer, C. Koch, M. Simon, In Press with Astroparticle Physics (Refereed).

#### Papers Presented (contributed) at Scientific Meetings:

1991 "Re-modulated Cosmic Rays", E.R. Christian, American Physical Society meeting, Washington D.C., April 1992.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: LALIT JALOTA Task Number: 660-006

General Description of Your Research Activities: (Include a Paragraph on each Activity).

**ASTRO-D.** This constituted the major part of my work this year. Five X-ray telescopes were built here at Goddard which were successfully completed on schedule and within budget, finishing in February 1992. My contributions included supervising the technicians and coordinating the day to day production, managing hardware requirements, quality control and selection of the finished mirrors, and finally integration, alignment, and testing of the telescopes. In November 1991, I spent an intensive 15 days in Japan aligning the telescopes using a facility where the effects of gravitational distortion are avoided which more accurately simulates the flight conditions. In February and March, proposals were solicited for sources to be used as calibration and innovative science targets in the post launch performance and verification phase. I was involved with six proposals, some with other scientists, and also a member of the team which assessed proposals dealing with observations of stars. In August 1992 an Astro-D mirror and a flight spare detector will be tested together for the first time at a facility at White Sands in New Mexico and I have been heavily involved in the planning and organization of this expedition. The tests are anticipated to last six weeks and I expect to spend four weeks there. This will be the first test of its kind and should yield very valuable information regarding the expected in flight performance of the Astro-D mission and a first attempt to analyze the novel data products expected from the mission. I have also taken part in several acoustic tests for Astro-D where I was the main liaison between the Japanese scientists and Goddard engineers.

**Mirror Development.** Work has continued to understand and improve the image quality from the mirrors. Several approaches have been tried involving new substrates and new production methods. Although generally unsuccessful, the trials have been informative and the sources of blurring to the image are now better understood which should help concentrate the efforts more usefully. One technique developed by Peter Serlemitsos using a replication technique has shown great promise and increasing effort is now being put into developing it for the next generation of telescopes.

**BBXRT data analysis.** I was given some data from an observation of a cluster of galaxies made by the BBXT observatory to analyze. Since I do not have much experience in this kind of work it has proved very educational and interesting. To date I have been trying to generate a good model for the background and continue with spectral fitting. Another aspect of this analysis involved understanding how an extended source was imaged by the moderate resolution mirrors which is important when trying to determine difference in the energy spectra from different regions. This work should naturally have implications for the Astro-D data analysis.

1991 "The Isotopic Composition of Silicon and Iron in the Cosmic Radiation as Measured with the ALICE Experiment", J.A. Esposito, A. Hesse, B. S. Acharya, U. Heibach, W. Heinrich, M. Henkel, C. Koch, B. Luzziatti, and M. Simon, V. K. Balasubrahmanyam, L. M. Barbier, E. R. Christian, J. F. Ormes, R. E. Streitmatter, American Physical Society meeting, Washington D.C., April 1992.

### Community Service

Gave lecture on "Galactic Cosmic Rays" to a undergraduate conference run by the Society of Physics Students at the U. of Maryland, April 11, 1992.

Presented the "Introducing Goddard" public talk on the Advanced Composition Explorer at the Goddard Visitor Center, May 24, 1992.

### University Collaborations:

ALICE with U. of Siegen, Germany.

IMAX with California Institute of Technology and New Mexico State U.  
Secondary collaborators include U. of Arizona, U. of Siegen in Germany, and the Danish Space Research Institute. I spent several months at NMSU this year working on testing and integration of the IMAX instrument and 5 weeks in northern Canada for the successful flight of this instrument

SIAM with LSU, U. of California Berkeley, MIT, and U. of Siegen. Authored one section of the SIAM study technical report (on Cherenkov counters) which will be submitted this fall.

ACE: Although the ACE project is a collaboration of many universities, I am currently working only on the management end, and so I am not presently collaborating with any of them. This may change in the near future.

ISOMAX: Caltech and the University of Siegen, Germany



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAMEMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: YANG SOONG Task Number: 5000-606

General Description of Your Research Activities: (Include a Paragraph on each Activity).

I) making the Astro-D mirrors

Last year was the busiest year for the Astro-D project in terms of mirror fabrication, calibration, and ground performance verification. We have finished all five, four flight plus one spare, X-ray mirrors. The mirrors consist of 120 nested thin foils in each primary and secondary housings for one quadrant. Four quadrants makes one mirror unit. In all we have used 4800 (120x2x4x5) pieces of foils with various curvature. The quality of each individual foil before going into the housing was inspected by visual examination and optical testings. Total number of foil produced was about 10,000. The acceptance rate was about 50%.

The alignment of the mirrors was carried out in GSFC before being sent to our Japanese counterpart. Since the gravity distorted the thin foils in the housing and the image quality degraded by about 5-10% in terms of FWHM of the point spread function, the vertical beam facility in Nagoya University in Japan provided a better simulation for the space weightless condition, and the final tuning of the mirrors was carried out in that location. Three trips were taken in Sept. 91, Nov. 91, and Apr. 92 to participate in the final alignment and satelliete integration of 2-3 weeks each. The mirrors passed the vibration test and the 0.3 micron thin mylar thermal pre-collimator (provided by Nagoya Univ.) passed the acoustic test.

The ground test for a mirror plus the focal plane CCD detector will be carried out during the period of Aug. 17-Sept. 30 at White Sand Missile Range, New Mexico. We provide the spare mirror, mounting structure, monitoring counters, X-ray source with MIT providing CCD detector, data acquisition system. This calibration will provide the necessary understanding of the instrument in flight setup before the launch in Feb. 5, 1993.

II) further improvement of the conical thin foil mirrors  
The error terms in making conical X-ray mirrors are the shape error and the surface roughness error. The former has been largely reduced by heat treatment of the Aluminum foil which was pressed by one atmosphere pressure against a mandrel. The surface roughness was harder to remove since the coating material generally did not cover the underlying surface to be smooth as seen by X-ray photons of 1-10 Angstroms. We have developed a method which is to replicating on a smooth glass surface. The preliminary study by phase contrast scanning of WYKO and Bauer profilometer shows the roughness is greatly reduced. We will pursue along this line for the curved foil replication and step up to mirror making in the following year.

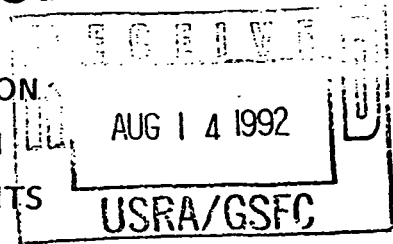
### III) XTE instrument calibration

XTE (X-ray Timing Explorer) is a satellite with three major instruments on board, namely, the large area proportional counter PCA (2-60 keV), the NaI scintillation detector HEXTE (20-200 keV), and the all sky monitor (2-10 keV). GSFC provides the PCA. It will be launched in 1996. We have studied the response of hexagonal collimator which will be placed in front of PCA. The response curve showed an energy dependence with low energy, say at 2.3 keV, showing a plateau near the peak, i.e.  $\pm 10$  arcminutes while the higher energy, say at 8 keV, response shows good agreement with the calculated geometrical response of FWHM of 1 degree. The reason for the low energy deviation is due to the X-ray reflection from the hex-cell Tin coated surface. This study is important to the calibration of the continuum of the source spectrum.

### IV) scientific research

We are continuing in analyzing the BBXRT data. Vela X-1, a binary X-ray pulsar, was observed for about 3,000 seconds, 10 times of its pulse period of 282 seconds. The iron line at 6.4 keV is clearly seen with low equivalent width of 70 eV. This data is the first line observation of Vela X-1 with moderately high energy resolution of 120 eV FWHM at 6 keV. We will go over its historical papers to check the significance of the line formation.

660-016 5↑



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Eric M. Schlegel      Task Number: 5000-616

**General Description of Your Research Activities:**

Substantial progress in research has been made in the past year, in spite of the programmatic pressures of *Rosat*. A brief description follows of the several areas of research I have been pursuing over the past year.

An x-ray spectrum of X Per obtained during the *Astro-1* mission flown on the space shuttle *Columbia* in December 1990 has proven to be rather interesting. The massive x-ray binary X Per, normally a Be star in appearance, turned off in the optical and infrared bandpasses sometime during the summer of 1990. The x-ray behavior, as inferred from the *BBXRT* data obtained, shows that X Per is essentially the same as ever, as reflected in the x-ray spectral parameters (power law index, hydrogen column absorption, power law cutoff energy). Previous x-ray observations did not occur when X Per was in its low state. Furthermore, the possible presence of an iron emission line in X Per has ensured that this system is a relatively high-priority target for any x-ray spectroscopy mission. The *BBXRT* spectrum has established an upper limit on the iron line's equivalent width of about 30-40 eV, a factor of ~2 below the best previous upper limit. I prepared a table of possible iron lines, varying the position and line width, to show exactly what the upper limits are as a function of line position and width throughout the 5.9 to 7.1 keV region. A paper describing these results has been submitted.

A *Rosat* observation of the Type Ia supernova SN 1992A in NGC 1380 was awarded Target-of-Opportunity status in January, and I was awarded the data rights during the AO-3 proposal review, with the proposal receiving the highest grade of the review. While the supernova was not detected, there is considerable interest in an upper limit on the x-ray emission from supernovae. To date, only three other supernovae have

been detected in x-rays: SN 1987A (the x-rays were Compton down-scattered  $\gamma$ -rays from  $^{60}\text{Co}$  decay), SN 1980K (two observations in the first 50 days due to an unknown emission mechanism), and SN 1986J (see below at 'NGC 1313'). From a theoretical view, Type Ia supernovae should emit no x-rays as the early x-ray emission is expected to be from the outgoing shock hitting the circumstellar gas deposited by the progenitor star's stellar wind. A paper describing the results of the observation has been submitted. The paper describes the results of setting an improved, by  $\sim 10\times$ , upper limit on the x-ray emission from Type Ia supernovae. This limit will likely remain until the launch of the X-ray Timing Explorer, in circa 1995, with its near-real time operations.

An atlas of cataclysmic variable accretion disks is nearing completion in work done in collaboration with researchers at Indiana University, Ball State University (Muncie, IN), STScI, and Oxford University. The images of the disks are obtained by back-projecting the emission line profiles in velocity coordinates. The result shows the kinematic areas of emission. The goal is to see whether the same areas in the binary system contribute to the emission. This can lead to improved understanding of cataclysmic variables, and of the accretion disk and its fundamental physics. Previous efforts in this area have demonstrated the utility of the approach, but this atlas will be the first comparison of all subtypes of cataclysmic variables. A preliminary version of the atlas was presented at the January AAS meeting in Atlanta. Refinements have occupied considerable time since then, but the text for the paper has been produced, and the huge number of figures are being produced.

I have been working with T. Kallman (NASA-GSFC) on a *BBXRT* spectrum of the magnetic cataclysmic variable BY Cam=H0538+608. The x-ray spectrum shows that an iron line is present, but not with the expected temperature and line width. This suggests that the models need revision to place the iron line at its observed energy ( $\sim 6.6$  keV) rather than the expected energy ( $\sim 6.4$  keV) for cold matter. Furthermore, the appearance of the line at its observed energy rules out any contribution from fluorescence on iron more neutral than Fe XVIII. A paper is about ready to be submitted, and the results will be presented at the COSPAR meeting at the end of August in Washington, DC.

A *Rosat* observation of the face-on barred spiral galaxy NGC 1313 has revealed the recent appearance of a new x-ray source. This work has been done in collaboration with University of Maryland graduate student Ed Colbert and R. Petre (NASA-GSFC). The corresponding field was observed with *Einstein* in 1980, and the new source was not present (the upper limit is quite confining). The flux and spectrum of the new source suggest that it is the impact of the shock from a supernova which is now hitting the circumstellar shell. There has only been one other observation of this theoretically predicted phenomenon, and that observation was made, using *Rosat*, on the edge-on galaxy NGC 891. There, SN 1986J appears as a bright x-ray source. SN 1986J was discovered in 1986 as a radio source, and realized to be a supernova which appears to have detonated in a cocoon of circumstellar gas and dust. The NGC 1313 object has similar optical properties, suggesting that there may be a class of supernovae which occur deep within a circumstellar cloud, thereby blocking the optical recognition of the explosion at the time of the explosion. A paper is in production in collaboration with the optical/radio team from Australia.

A *Rosat* observation of the supernova remnant W44 in our galaxy has been studied with J. Rho (University of Maryland) and R. Petre (GSFC). The observed x-ray emission has been compared to optical and radio (CO emission) maps of the region. Based upon spatial spectral extraction and fitting, the temperature is approximately constant throughout the nebula, in spite of an apparent difference, by a few factors, in the column density to and in the nebula. This work has been presented at the Columbus AAS meeting in June, and a paper is in preparation.

I have also been given 50,000 seconds of observing time to use *Rosat* to look at the nearby, face-on spiral galaxy NGC 6946. The data were obtained in late June, and I am awaiting the arrival of the tape.

**Describe any Significant Recognition of your work:**

The citation history of papers published is as follows (total citations with the number of years indicated). Note that the papers listed here are in the supernova and cataclysmic variable fields, in which there are approximately 70 workers for each of those research

fields. The cataclysmic atlas of data (ApJSup 1987) continues to attract imitators, who, unfortunately, seldom cite the atlas as the "first" appearance of the digitally-presented images of spectra.

Astrophys. J., 267, 239, 1983: 37 citations in 8.5 years  
Astrophys. J. Supp., 53, 397, 1983: 15 citations in 8.5 years  
Astrophys. J., 280, 235, 1984: 12 citations in 6 years  
Publ. Astro. Soc. Pac, 97, 1178, 1985: 15 citations in 6 years  
Astrophys. J., 302, 388, 1986: 23 citations in 5 years  
Astrophys. J. Supp., 65, 451, 1987: 19 citations in 4 years  
Astron. J., 98, 577, 1989: 15 citations in 2 years  
Mon. Not. R. Astr. Soc., 244, 637, 1990: 1 citation in 1.5 year  
Astrophys. J., 364, 637, 1990: 4 citations in 1.5 year

#### Honors or Awards Received:

A NASA special group award was given for the *Rosat* Guest Observer Facility activity, which forms the programmatic aspect of my position. This award was given in October 1991.

#### Papers Accepted for Publication

Honeycutt, R. K., Turner, G. W., Vesper, D. N. (Indiana Univ.), and Schlegel, Eric M. 1992. *PASP*, 000, November. "MR Per: A New Rotating, Spotted Flare Star"

#### Papers Submitted by not yet Accepted for Publication:

Schlegel, Eric M., Serlemitsos, P., *et al.* (NASA-GSFC) 1992. *ApJ*, xxx, 000. "A *BBXRT* Spectrum of the Massive X-ray Binary X Per"  
Schlegel, Eric M. and Petre, R. (NASA-GSFC) 1992. *ApJ*, xxx, L000. "A *Rosat* Upper Limit on X-ray Emission from SN 1992A in NGC 1380"

#### Papers Presented at Scientific Meetings:

#### Invited Papers:

none this year

### **Contributed Papers:**

1. "An Atlas of Cataclysmic Variable Accretion Disks", American Astronomical Society meeting, January 1992, Atlanta, GA. Schlegel, Eric M. (NASA-GSFC/USRA), Kaitchuck, R. H. (Ball State University), Honeycutt, R. K., White, J. (Indiana Univ.), Horne, K. (STScI), and Marsh, T. (Oxford Univ.)
2. "An Optical and X-ray Study of the Supernova Remnant W44", American Astronomical Society meeting, June 1992, Columbus, OH. Rho, J., Petre, R., Schlegel, Eric M. (NASA-GSFC), and Hester, J. J. (Arizona State University).
3. "An Luminous Blue Variable in NGC 1313?", Astronomical Society of the Pacific meeting on Massive Stars, June 1992, Madison, WI. Schlegel, Eric M. (NASA-GSFC/USRA), Colbert, E. (Univ. Maryland), and Petre, R. (NASA-GSFC)

### **Colloquia, Seminars, and Special Lectures:**

none this year

### **Community Service:**

During the past year, I again served as a "Scientist pen-pal" to seventh, eighth, and ninth grade students through the Scientist-Pen Pal program of the Science Museum of Virginia. This program originated at the Boston Museum of Science, and has since propagated around the country's science museums.

The program serves as a connection between a working scientist and students. It can provide students, not otherwise exposed to a particular field of research, with a person to answer their questions.

In addition, the Science Museum hosted a "Visit a Scientist for a Day" program in early June, which I attended. As in previous years, most of the scientists participating in this program are local to the Richmond area, where there are very few (read 'none') astrophysicists. I presented a poster on recent *Rosat* observations.

### University Collaborations:

There is a continuing collaboration with R. Kent Honeycutt (Indiana University) and Ron H. Kaitchuck (Ball State University) on time-resolved spectroscopy of cataclysmic variables. An atlas of cataclysmic variable accretions disks, obtained by back-projecting the data in velocity coordinates, is in preparation. It will likely be submitted for publication during the last quarter of 1992. In addition, a Space Telescope proposal is in preparation.

A continuing collaboration exists with R. Kirshner (Harvard University) on spectroscopy of supernovae. An atlas of data covering the years 1986 to 1988 is under revision, and the volume of data imply that additional studies can be done. A paper is under revision describing the ultraviolet behavior of supernovae of Type Ia, including the interesting results from IUE on SN 1990N and SN 1991T.

I have worked with three summer students from the University of Maryland for the past few months. The first student, E. Colbert, was directly advised by R. Petre (NASA-GSFC). However, the subject (x-ray sources in NGC 1313) required my expertise on supernovae as one of the sources is clearly a decade-old supernova in which the shock wave from the explosion is impacting the circumstellar gas shell and emitting x-rays. The second student, J. Rho, was also advised directly by R. Petre, however, I contributed considerably to the analysis of the data, largely by acquainting J. Rho with the use of IRAF/PROS. The third student, P. Mohanty, worked directly with me on spectroscopy of cataclysmic variables. We analyzed data from the dwarf nova U Gem, and the results will be described in a paper which will be prepared sometime this autumn.

### Other Collaborative Activities:

A collaboration has been established with D. Roussel-Dupre' (Los Alamos National Laboratory) on Be-star x-ray transients. This work has already resulted in one presentation at a AAS meeting. Some additional work is needed to convert that presentation into a paper, and that work is underway. A 20,000-second *Rosat* proposal was accepted for the third cycle of observations for February 1993 to look at the Be/x-ray binary transient V635 Cas=4U0115+63. This observation is designed to catch V635 Cas in its



outburst which should occur at that time. An international, multi-wavelength collaboration is being established to monitor this object, which has suffered in its understanding by not being adequately observed at multiple bandpasses during its outburst. All that is needed is the cooperation of the source.

A possible collaboration is being explored with faculty and post-docs at the University College London to observe the infrared spectral behavior of supernovae.

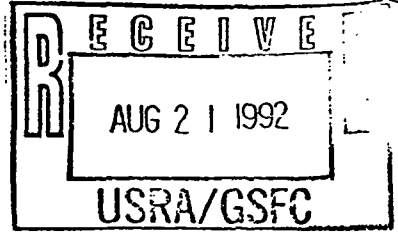
Additional collaborations exist with researchers at NASA-Ames, and other NASA-GSFC groups.

**Supply any Additional Information you Feel Would be Useful in evaluating your performance:**

There still has been an enormous amount of time spent on programmatic tasks. The main purpose of the task is the support of the *Rosat* Guest Observer Facility. The prime software package is PROS (Post-Reduction Offline Software), which works within the IRAF environment (Interactive Reduction and Analysis Facility).

The problem is that PROS is still incapable of handling several tasks which the guest observer is interested in using. This requires software development, often running within IRAF. Such software development often proceeds quickly once the job is sufficiently well-defined. However, it often takes quite some time to assemble the background knowledge. The programming staff is currently overwhelmed with archiving activities.

Many guest observers have been helped during the past year, in spite of the software limitations. I have personally worked with just under 50% of the guest observers who have arrived at the GSFC *Rosat* GOF. This percentage should be ~25%, based upon the number of *Rosat* Guest Observer scientists available to provide help. The "oversubscription" results from the fact that I have learned PROS more extensively than any of the other guest scientists, and in fact, have taught 2 of the 3 scientists a considerable fraction of what they know. This action does cut into my research time. I have compensated for this recently by staking out about half of each day for research. This "stake-out" has produced results, specifically, in the number of papers which have been submitted (3) and are within a month or two of being submitted (3).



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
 GODDARD VISITING SCIENTIST PROGRAM  
 EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
 (for the year ending 9/30/92)

Employee Name: DIPEN BHATTACHARYA Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Analysis of HEAO 3 all-sky data set. Searched for supernovae lines from starburst galaxies M82 and NGC 253. Upper limits to the line emissions are obtained.

Analysis of OSSE NGC253 gamma-ray data - basic spectral parameters are obtained. Gamma-ray emission mechanisms operating in starburst galaxies are being investigated.

Studies of inverse Compton effect off photon beams by electron field distributions. Analytical treatment of photon intensity as a function of the observing angles are being carried out.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

"A search for gamma-ray line and low energy continuum emission from Sco X-1", Proc. of 22<sup>nd</sup> ICRC, 1, 196  
Citation in Harris, H.J. + Shore, G.H. 1991, ApJ, 381, 439

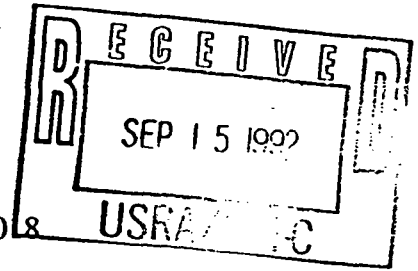
Honors or Awards Received:

Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

BHATTACHARYA, D., GEHRELS, N., WHEATON, W.A., MAHONEY, W.A., LEVENTHAL, M., AND GELDZAHLER, B.J. 1991, Proc. of 22<sup>nd</sup> ICRC, ~~1991~~ Vol 1, 196

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: John W. Mitchell

Task Number: 660-018

General Description of Research Activities:

The past year has been an especially productive one for me. Highlights have been two successful flights of balloon-borne cosmic ray experiments, the first data run of a major new accelerator-based particle physics experiment, and the conceptual development and proposal of two new balloon-borne cosmic ray instruments and a new detector development program. The details of these and other activities are given below.

I am involved in a variety of cosmic ray astrophysics and high-energy nuclear physics research projects, both as a part of my programmatic responsibilities at GSFC, and as independent activities. My task activities at GSFC over the past year have centered on experimental cosmic ray investigations (IMAX, MASS II, and MASS 92), and on the conceptual development, modelling and proposal of a new cosmic ray instrument, ISOMAX. In addition, I have been involved in two new detector development programs.

In the past year I have also been active in a number of new and ongoing research projects independent from my GSFC task. These include interpretation of results from an experimental cosmic ray study (SMILI), analysis of data from a number of nuclear physics experiments with astrophysical applications (E683H, E849H, E859H and E938H), a new antinucleus/exotic particle production search (E878), and a program of cosmic ray propagation studies. I have also been involved in the development and proposal of a new instrument for both accelerator-based investigations and balloon-borne cosmic ray studies, based on a liquid-Argon calorimeter.

My various research activities are described below, grouped by general research topic. For each, I have indicated some of my responsibilities, as well as whether the project is programmatic or independent in nature.

Composition of High Energy Galactic Cosmic Rays

This work is directed toward obtaining experimental information on the composition and energy spectra of high energy galactic cosmic rays using balloon-borne (IMAX, MASS, and SMILI) instruments.

IMAX (Isotope Matter-Antimatter eXperiment) - This instrument is the product of a NASA/GSFC led collaboration (P.I., Dr. Robert E. Streitmatter), which includes New Mexico State University, the California Institute of Technology, and the University of Siegen (Germany). Among other responsibilities, I acted as the Instrument Manager for this program and had the lead role in carrying out the development of the instrument. As a result, I find its ultimate success especially gratifying.

The IMAX instrument was designed primarily to study antimatter and the isotopes of H and He in the cosmic radiation over a wide energy range ultimately extending from about 200 MeV/nucleon to 4 GeV/nucleon. During the first flight, in July, 1992, the energy range from 200 MeV/nucleon to 2.7 GeV/nucleon was covered. It is expected that this investigation will answer a number of outstanding questions concerning the origin of

cosmic ray antimatter, as well as providing an accurate determination of the abundances and energy spectra of the H and He isotopes. In addition, information obtained from the IMAX flight will be used by Prof. Ted Bowen of the University of Arizona in a search for neutralized, charged, massive particles (NeutraChamps), a current dark-matter candidate. This search, using the IMAX scintillators with specialized timing electronics developed at UA, took place in parallel with normal data-taking during the IMAX flight and should provide enough data for a critical test of the Neutrachamp hypothesis.

The IMAX instrument is a magnetic spectrometer, built around the NASA/NMSU Balloon-Borne Magnet Facility (BBMF). Particle mass identification is by velocity vs. magnetic rigidity. IMAX incorporates two independent trajectory systems for determining magnetic rigidity, while velocity information is derived from a fast, plastic-scintillator-based, time-of-flight system and from Cherenkov radiation detectors with two different optical indices. Particle charge is determined by two light-integration scintillation systems and by the time-of-flight system.

IMAX was integrated at NMSU during February and March, 1992, and final preparations for flight were accomplished in Lynn Lake, Manitoba, Canada, during June and July, 1992. The instrument was declared ready for flight on 7/13/92, *two days ahead of the nominal schedule*, and launch took place on 7/16/92 at 21:33 CDT. After a long climbout, IMAX reached a float altitude of 119,000 feet at 4:45 CDT on 7/17, and stayed at float for sixteen hours. Landing was just after midnight on 7/18/92, near Peace River, Alberta.

Since I am the Instrument Manager for this program, IMAX pre-flight preparation and flight activities have accounted for much of my programmatic effort during this year. I was responsible for overseeing all aspects of the instrument except for the BBMF payload itself and the individual detector development efforts of Caltech, NMSU, and the University of Siegen. I was responsible for insuring that all needed materials and systems were obtained or developed in time for integration and flight. Finally, I directed IMAX integration with the BBMF payload, as well as flight operations.

In addition to my general responsibilities, I was directly responsible for several particular aspects of the experiment including: design and construction of the time-of-flight system, design and implementation of the event trigger-logic electronics, and the general experiment electronics. As part of my electronics effort, I developed new delay modules based on lumped element LC delay lines which resulted in a weight savings to the instrument of about 60 pounds. This savings proved to be critical to the success of the flight.

The time-of-flight (TOF) system which I developed for IMAX is very much state-of-the-art for detectors of this kind. In testing with ground level muons during instrument integration and pre-flight testing, a flight time resolution of 130 picoseconds was obtained with minimal corrections. It is expected that with full corrections the resolution will be better than 110 picoseconds. This performance is superior to that of any similar system currently used in cosmic ray research.

The IMAX TOF system will be used in a future flight of the WiZard instrument (see New Proposals, below). The design of the TOF system to be built by GSFC for the newly proposed ISOMAX instrument (see New Proposals, below) will be based, in part, on the IMAX TOF, and the IMAX system will be used for some of the initial ISOMAX test program.

No additional flights of IMAX are planned at this time, since it is the judgement of the collaborators that the major goals of the program will likely be met by the first flight. However, the detectors and systems are being maintained in flight condition, so that

another flight could be staged easily if analysis of the initial data reveals any particularly interesting phenomena.

One of the highest priorities for members of the IMAX collaboration in the coming year is the analysis and interpretation of the flight dataset. As a continuation of my IMAX responsibilities, I will lead the post-flight data analysis and interpretation effort.

MASS II and MASS 92- Matter Antimatter Spectrometer System: These are the second and third in a series of experiments performed by a collaboration led by New Mexico State University (P.I. Dr. Robert L. Golden) and including researchers from GSFC, INFN - Frascati (Italy), University of Firenze (Italy), and the University of Siegen (Germany). These experiments will be continued under the name WiZard (see New Proposals, below) in the future to emphasize the connection of these experiments to the WiZard experiment on the (now postponed) Astromag platform.

The MASS experiments are directed toward measurements of high energy cosmic ray antiprotons and positrons. The antiproton measurements, in particular, provide an important test of various models of cosmic ray origin and propagation. MASS uses the NMSU balloon-borne magnet payload with the same particle tracking systems as IMAX. A GSFC built time-of-flight system is used to distinguish upward-moving from downward-moving particles while a combination of an atmospheric-pressure Freon Cherenkov detector and a tracking calorimeter are used to distinguish particle types. Some of the refinements that have been incorporated in the MASS II and MASS 92 instruments are a deeper tracking calorimeter and improved gas Cherenkov counter performance.

I have been involved in several aspects of MASS development and flight preparation. For MASS II, I designed and built a new lower time-of-flight array to give a better interface with the calorimeter. I also designed and implemented a new fast-trigger logic for the experiment. The TOF and logic will be used in MASS 92 as well.

One of my main efforts in MASS II development was directed toward improving the gas Cherenkov detector, which is critical to the performance of the instrument. In the past, the main failure of this counter has been some uncertainty in the amount of light collected from the passage of a high energy particle. I spent considerable time working to improve its performance, with the result that an absolute calibration of the photoelectron yield of the counter can now be obtained. I expect to take the lead in analyzing the data from this counter for both the MASS II and MASS 92 flights.

For MASS 92, I also designed and built a new upper TOF array to complement the lower TOF built for MASS II. This new system will also interface well with the transition radiation detector (TRD) to be incorporated in 1993 under the WiZard program.

MASS II was flown from Ft. Sumner, New Mexico, in September, 1991. MASS 92 is being prepared for flight in September, 1992, from Ft. Sumner, NM. I participated in the integration of the instrument and will be involved in pre-flight checkout and flight operations.

SMILI (Superconducting Magnet Instrument for Light Isotopes): SMILI was built by a collaboration led by Boston University (Dr. James J. Beatty, P.I., now at Washington University) and including Indiana University, Louisiana State University, and the University of Michigan.

SMILI was a balloon-borne magnetic spectrometer designed to study the composition and energy spectra of cosmic ray isotopes in the range from He to Ne, over an energy range

extending from about 200 MeV/nucleon to over 1 GeV/nucleon. The instrument used a drift tube hodoscope for tracking with a fast, plastic-scintillator-based TOF system for particle charge and velocity measurements. A water Cherenkov detector provided additional velocity information at higher energies. An additional scintillator system, "S3", was located below the Cherenkov counter to allow charge changing nuclear interactions in the Cherenkov counter to be detected. While at LSU, prior to coming to GSFC, I designed and constructed the SMILI TOF detector system and the "S3" charge analysis detector as well as some of the experiment electronics.

The instrument has now been flown twice: in August, 1989, and in August, 1991. Results from the first flight were reported at the 22nd International Cosmic Ray Conference in Dublin, Ireland, in August, 1991. During the past year, SMILI activities have centered on interpretation of the results from the first flight and preparation for publication. This effort has resulted in a paper which has been submitted to the Astrophysical Journal.

SIAM: This was a study project which was intended to lead to an experiment to measure the isotopic composition of cosmic rays over a charge range from Be to Si and an energy range from about 200 MeV/nucleon to 1 GeV/nucleon. The SIAM study involved a Louisiana State University led collaboration (Dr. T. Gregory Guzik, P.I.) including GSFC, University of California - Berkeley, the Massachusetts Institute of Technology, and University of Siegen (Germany). Neither GSFC or University of Siegen will continue after 1992. However, the study will result in a report to be released in Fall, 1992, to which GSFC and University of Siegen will contribute. Preliminary work on the Cherenkov system described in this report was based partially on a series of measurements that I made in at NMSU in February and March, 1992.

#### Antinucleus/Exotic Particle Production in High Energy Heavy Ion Collisions

This is a new program of experiments at the Brookhaven National Laboratory Alternating Gradient Synchrotron (AGS), which are designed to obtain the heavy ion collision production spectrum of pions, kaons and antiprotons in the energy range from 1.5 GV to 24 GV, as well as to conduct a high statistics search for the production of antideuterons or exotic particles in this range. This program is an evolutionary development of the Brookhaven E858 experiment and is being conducted by a collaboration which includes researchers from University of California - Berkeley, Brookhaven National Laboratory, University of California - LA, Columbia University, Lawrence Berkeley Laboratory, Johns Hopkins University, Yale, GSFC/USRA, KEK (Japan), and Waseda (Japan). I am the only participant from GSFC, and the work is independent from my programmatic task. However, the techniques involved are very similar to those used in our experimental program at GSFC, and this program allows me to remain current in new developments in high energy physics instrumentation. Initial results from the E858 experiment were presented at the 1992 spring meeting of the American Physical Society.

For 1992, the E878 program was granted 200 hours of heavy ion beam time (Si beam) and 100 hours of proton beam time by the Brookhaven Program Advisory Council. E878 obtained additional time with a gold beam as apart of an AGS development project. The experiment is supported under a DOE contract.

My primary responsibilities are the experiment trigger (with LBL) and the tracking system (with BNL). In the past year, I worked on the electronics and circuit for the logic and on a unique new drift chamber tracking system, which was built at BNL. I participated in a test run of the tracking system, which took place in December, 1991 at LBL. In addition, I rebuilt the two aerogel Cherenkov detectors which are used in the first level experiment trigger.

The E878 experiment conducted a series of three experimental runs between April and June, 1992, using a silicon beam, a gold beam, and a proton beam. While I was not able to participate directly in the proton run, due to IMAX responsibilities, I participated in both the Si and Au runs. During these runs, I was one of two experiment shift leaders and was responsible for the general operation of the experiment as well as for interactions with the AGS staff.

A second series of runs of E878 is planned for spring 1993. In preparation for these runs, I intend to build a new pair of aerogel Cherenkov counters. I will participate in the 1993 runs as well as in the analysis of the existing dataset.

### Projectile Fragmentation in Relativistic Heavy Ion Collisions

This work is directed toward a systematic study of energy, projectile, and target dependences in nuclear fragmentation reactions. The aim is to answer outstanding questions regarding the mechanism(s) involved and to apply the results to solving outstanding questions in high energy particle astrophysics. My work in this area is entirely independent from my GSFC programmatic responsibilities. This effort is complimentary to my work at GSFC, however, since the astrophysical applications are considerable.

Experiments E683H and E849H: These experiments were performed in the Beam 40 Zero Degree Spectrometer Facility at the Lawrence Berkeley Laboratory Bevalac heavy ion accelerator, using a solid state detector telescope and a dE vs. total E method of particle mass identification. They were performed by researchers from Louisiana State University, Lawrence Berkeley Laboratory, University of California - Berkeley, and the University of Siegen (Germany). I am the only GSFC participant. The experiments were designed to obtain reaction cross sections and fragment momentum distributions, as a probe of the projectile fragmentation process, using O, Si, and Fe beams, at several different energies, incident on C and CH<sub>2</sub> targets. Reaction cross sections for a hydrogen target are obtained by (CH<sub>2</sub>-C) subtraction.

I was responsible for the overall experiment electronics, the detectors and detector electronics, the experiment mechanical design and integration, and the event trigger logic for these experiments. In addition, for E849H, I was responsible for overall conduct of the experiment. There were no experimental runs in the past year and activities centered on data analysis. I am responsible for directing several phases of this effort. In addition, I am responsible for Monte Carlo modeling of the experiment, as well as for interpretation of the results in terms of nuclear scattering and fragmentation theory. The initial E849H analysis has been completed and the results are now being prepared for publication.

Experiment E859H: This experiment was performed using the Heavy Ion Spectrometer System (HISS) in Beam 42 of the LBL Bevalac by researchers from Louisiana State University, Lawrence Berkeley Laboratory, University of California - Berkeley, University of California - Riverside, University of New Hampshire, and Boston University. I am the only GSFC participant. The primary goal was to obtain reaction cross sections, as well as information on specific reaction channels in the projectile fragmentation process, using He and Ne beams incident on C and CH<sub>2</sub> targets. Reaction cross sections for a hydrogen target are obtained by (CH<sub>2</sub>-C) subtraction. The main goal is to probe the underlying nuclear physics, although the cross sections obtained, particularly those with the He beam, will be of astrophysical importance. In this experiment, I was responsible for the upstream (pre-target) detectors, as well as overseeing the design and implementation of the trigger logic. Analysis of the data from this experiment has continued over the past year.



Experiment E938H: This is again a HISS based experiment, directed toward obtaining information on the energy dependence of the reaction cross sections of a variety of nuclear species of astrophysical importance incident on a liquid H target (simulating the ISM). The experiment is performed by the NASA supported "Transport" collaboration which includes Louisiana State University, Lawrence Berkeley Laboratory, University of California - Berkeley, New Mexico State University, University of Minnesota, GSFC, University of Frankfurt (Germany), University of Catania (Italy), and CEN-Saclay (France).

Transport involves both an experimental program and a program of theoretical modeling. I am a co-investigator, and the only GSFC participant in the experimental program, although Dr. Frank Jones of GSFC is involved in the theoretical program. The Transport proposal was funded by NASA for FY92-FY94.

In this program, I have overall responsibility for: the experiment electronics, experiment logic design and implementation, design and implementation of the beam veto/fragment charge subsystem, operation of the upstream scintillation detectors, and electronic/mechanical coordination. In addition, I often act as shift leader for the experimental runs. E938H had its first experimental run in April, 1990, and took data on six beam/energy combinations. The preliminary results from this run were presented at the 1991 spring meeting of the American Physical Society and at the 22nd. International Cosmic Ray Conference.

The second experimental run of E938H took place in April, 1991, with over 300 hours of data taken on fifteen beam/energy combinations. This is the most successful run of the HISS system to date and, taken together with the 1990 run, makes this program the most successful in the history of the HISS facility, as well as the most successful program of nuclear cross section measurements at the Bevalac in the past decade. Initial results from the 1991 run were presented at the 1992 spring meeting of the American Physical Society.

Full analysis of the existing data from E938H will take at least two more years. Future runs of the experiment will depend on the availability of the Bevalac or the development of a parallel program at another accelerator.

#### Confinement, Propagation and Acceleration of Galactic Cosmic Rays

This work is directed toward an investigation of the mechanisms of galactic cosmic ray acceleration and transport. I am part of a collaboration which also includes researchers from Louisiana State University and Washington University. This group is preparing a paper on the effects of distributed acceleration on the measured spectra of cosmic rays. The work over the past year has concentrated on understanding the physical implications of the results calculated using a weighted slab model with distributed acceleration added.

In addition, I am a co-investigator with Dr. Frank Jones on the GSFC portion of a project to improve the state-of-the art of cosmic ray transport calculations, both by an update of the weighted slab calculational method and by inclusion of the most current models of the nuclear reaction cross sections. This work is done as part of the Transport collaboration.

## New Detector Development

Cherenkov Detector Development: This work is directed toward developing new materials and techniques for the detection of Cherenkov radiation.

Under a DDF proposal (see New Proposals, below) Dr. Louis Barbier and I have been working on the development of new materials based on pressed optical powders. These materials, with optical indices between 1.06 and 1.2, are suitable for use in Cherenkov radiation detectors and may provide improved performance over sintered aerogel radiators in this index range. This work will continue in the next year.

In addition, during February, and March, 1992, I performed a series of tests on Cherenkov radiator materials at New Mexico State University, aided by Drs. Eric Christian, Steve Stochaj and Bill Webber. These tests were directed toward understanding and quantifying the performance of various radiator materials and geometries in Cherenkov radiation detection. These tests were used, in part, to satisfy GSFC's obligation to the SIAM project (above). During the next year, we expect to complete these measurements and prepare the results for publication.

Solid State Timing Detector: I devised a system to obtain particle transit time information from a 40  $\mu\text{m}$  thick solid state detector for use in high-energy particle physics experiments. I tested this system during a run at the LBL Bevalac in December, 1991, and obtained a timing resolution of 120 picoseconds using a Iron beam. The system was also tested during a set-up run of the Brookhaven E866 experiment in April, 1992. The results of this test were encouraging and may lead to the system's incorporation in a future data run of E866.

Development of Solid State Detectors for Charged Particle Measurements in Space: This work involves development and testing of the "next-generation" of solid state position sensing detectors and associated readout electronics. This is an entirely GSFC effort with Dr. Tycho T. von Rosenvinge as P.I. I am a coinvestigator on this project, along with Dr. Louis M. Barbier, Maureen P. Madden, and Dr. Robert E. Streitmatter. This work was funded by NASA for FY92-FY94.

## Modelling of Multiple Coulomb Scattering

During the past year I worked with and directed an NRC post-doctoral researcher (Dr. Banashree Mitre) in a project to improve the way in which the effects of multiple scattering of charged particles are accounted for in Monte Carlo simulation codes. The result is a subroutine whose performance is being checked relative to other subroutines and to the basic theory.

### Papers Submitted but not yet Accepted for Publication:

"The Cosmic Ray  $^3\text{He}/^4\text{He}$  Ratio from 100 MeV/AMU to 1300 meV/AMU", Beatty, J.J., *et al.*, *Astrophysical Journal* (SMILI collaboration - full author list not final, submitted 9/20/92)

### Citations of Papers:

"Magnetospheric Particle Detection Efficiency of a Conical Telescope" - 2 citations in 1991

"A Drift Chamber Telescope for Heavy Ion Track Detection with High Spatial Resolution" - 1 citation in 1991

Papers Presented at Scientific Meetings:

*Contributed Papers Presented by Others:*

"Production of Light Nuclei and Antinuclei in AA Collisions at the AGS", Bull. Am. Phys. Soc. 37, 946 (1992).

"pbar Reabsorption in Si+Au Collisions at 14.6 A\*GeV/c", Bull. Am. Phys. Soc. 37, 946 (1992).

"Calculation of the dbar/pbar Ratio from Direct Production in Si+Au collisions at 14.6 A\*GeV/c", Bull. Am. Phys. Soc. 37, 946 (1992).

"Charge-Changing Total Cross Sections of Heavy Ions on a Liquid Hydrogen Target", Bull. Am. Phys. Soc. 37, 964 (1992).

"Elemental Production Cross Sections from Neon to Nickel", Bull. Am. Phys. Soc. 37, 1002 (1992).

"Isotopic Production Cross Sections from Projectile Fragmentation of  $^{32}\text{S}$  in a Liquid Hydrogen Target", Bull. Am. Phys. Soc. 37, 1002 (1992).

University Collaborations:

Most of my research activities involve collaborations with universities, both in the U.S. and in other countries. These institutions are listed under the descriptions of my activities above. In the course of my work on these projects, I have spent considerable time working at various universities, in particular New Mexico State University and the University of California - Berkeley. During the next year, I also expect to travel to the California Institute of Technology and the University of Siegen ( Germany) to work with researchers at these institutions on the analysis of IMAX and MASS data.

I have entered into two new collaborations involving university researchers, both of which are described under New Proposals, below.

Other Collaborative Activities:

I am a member of a number of collaborations involving non-university researchers. These are listed under the descriptions of my activities above.

New Proposals:

Innovative Approach to the Development of Cherenkov Radiator Materials with Intermediate Indices of Refraction: I am the P.I. on this proposal, which includes Dr. Louis Barbier of GSFC as coinvestigator. The proposal was submitted to the Goddard Space Flight Center Directors Discretionary Fund in October, 1991. It received a high score in reviews and was funded for FY92. We are considering submitting a renewal proposal for FY93 to continue this work.

A Program to Study Beryllium and Other Light Isotopes in the Cosmic Radiation: I am a coinvestigator on this proposal, which was submitted to NASA in August, 1992, in response to NRA-92-OSSA-10 Supporting Research and Technology (SR&T). Under the proposal, a new balloon-borne cosmic ray instrument (named ISOMAX - Isotope Magnet Experiment) will be developed by GSFC (Dr. Robert Streitmatter, P.I.) in collaboration with the California Institute of Technology and the University of Siegen (Germany). Initially this program will be directed toward measurements of the isotopic abundances of beryllium and other cosmic ray constituents between lithium and oxygen. With some modifications, the instrument is capable of making measurements up to the isotopes of silicon.

The experiment will be built around a new superconducting magnet payload, to be developed at GSFC, and will use detectors supplied by GSFC and by the other two collaborating institutions. The instrument will be the first balloon-borne magnetic spectrometer designed from the outset to take advantage of the emerging capabilities of the NASA Long Duration Balloon Program.

In addition to the development of ISOMAX, this proposal covers the continuing activities of the GSFC high energy cosmic ray group in analysis of the IMAX and MASS datasets and support of MASS/WiZard flights.

WiZard-Related Balloon Program: This is a program of balloon flights led by New Mexico State University (Dr. Robert Golden P.I.) using the NMSU balloon-borne magnet spectrometer payload (no longer called BBMF). The program is a continuation of the MASS program and involves collaborators from Italy, Sweden, India, and the U.S. (NMSU and GSFC). Flights are planned in 1993 using a transition radiation detector (WiZard-TRD) and in 1994 using a ring-imaging Cherenkov counter (WiZard-Caprice). GSFC responsibilities to this program include the time-of-flight system, flight support, data analysis, and scientific interpretation. These activities are covered under the GSFC 1992 SR&T proposal (discussed above).

LArC - A Liquid Argon Calorimeter for Astrophysics: Under this proposal, submitted to NASA in response to NRA-92-OSSA-10, a fully active liquid-argon calorimeter would be developed and tested for balloon flight applications. The instrument is to be developed by a University of California - Berkeley led (Dr. Henry J. Crawford, P.I.) collaboration which includes researchers from GSFC/USRA, Louisiana State University, University of Minnesota, Waseda University (Japan), Ehime University (Japan), and Saitama College (Japan). The period of this proposal covers accelerator testing of a prototype calorimeter and initial development and testing of the flight calorimeter. In addition, a program of accelerator-based reaction cross section measurements is planned using either the prototype detector or the flight detector. I am the sole coinvestigator from GSFC on this proposal.

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## PROTO-TYPING ASTRONOMICAL SOFTWARE IN *KHOROS*

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**ABSTRACT** We consider the requirements for software proto-typing tools for the XTE Science Operations Center. We conclude that *Khoros* meets these requirements and describe its characteristics.

### INTRODUCTION

The X-ray Timing Explorer (XTE) is a 100% guest investigator mission that is slated for launch in April 1996. It will carry three instruments, two of which are pointed instruments with a spatial resolution of 1° and an instantaneous energy range coverage of 2-200 keV, at a time resolution of the order of 1  $\mu$ s; the third instrument provides an image of about 70% of the sky in the energy band 2-10 keV at moderate resolution every 90-100 minutes.

The data will be processed in the XTE Science Operations Center (SOC) at Goddard Space Flight Center, as soon as the telemetry is received. The software to be developed will have to satisfy two basic requirements: that it serves the full spectrum of the diverse tasks to be performed at the SOC; and that it be adequate (*i.e.*, not obsolete) during the full life of the mission. Consequently, we are not interested in the software that is in use today, but in the software that will be used five years from now. In order to investigate the software requirements for such a future package we decided to first mount a modest proto-typing effort. This project is intended to aid in our system analysis and formulation of the final design specification. Special emphasis is put on an "open" system design (easy expandibility), easy application programming, easy maintenance, and a thoroughly modern user interface.

### REQUIREMENTS FOR A PROTO-TYPING ENVIRONMENT

A proto-typing environment for (astronomical) software should offer support in the following areas:

- Easy to add code
- Include a user interface

transfer between modules is effected through permanent files, temporary files, or shared memory.

From the *software developer's* point of view *Khoros* provides:

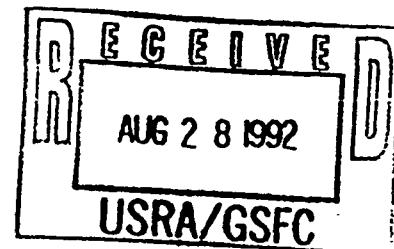
- A proto-typing tool for user interface specification.
  - Code generators for graphical user interface, command line interface, and system interface.
  - Maintenance and installation tools.
  - Tools for generating and maintaining documentation.
  - An extensive subroutine library (including FITS).
  - Configuration management that allows for heterogeneous networks.
  - A reasonable selection of ready-to-use applications, tools, and utilities.
- Khoros* was developed in the context of remote sensing and digital signal processing. Its current application toolkit is therefore not optimal for astronomical purposes, but quite adequate for rapid proto-typing.

### COMMENTS

*Khoros* fulfills essentially all requirements. Experience so far indicates that the system is very robust and easy to use. The task of actually implementing one's first, simple *Khoros* application, including the GUI, does not take more than a day's work. *Khoros* can be used in conjunction with other software development tools like debuggers. There are a number of draw-backs, however. In particular, we would have preferred a system that fully supports C++ and one that supports inter-proces communication. *Khoros* supports neither. Also, as noted before, the included applications and utilities are not optimal for our use. We feel, though, that these shortcomings are acceptable for a proto-typing environment; and it is quite conceivable that the support may eventually be added.

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# Universities Space Research Association Goddard Visiting Scientist Program Summary of Accomplishments

Arnold H. Rots

28 August 1992

## 1 General Description of Research Activities

Three important things happened during the past year in the XTE project that strongly affected my activities:

- XTE was put on its own free-flying spacecraft.
- XTE's launch was advanced from April 1996 to August 1995.
- A reorganization of the XTE-SOC was started.

With the new spacecraft, the flexibility of XTE as an observatory (and thus its scientific potential) has increased considerably. This bonus does not come for free, though. The increased complexity in operations and data processing puts greater demands on the software in the Science Operations Center. This, combined with the considerable compression of the project schedule due to the advancement of the launch date, has greatly increased the work load and pressure for us who work on the XTE-SOC software. In the first half of this fiscal year, it was decided to split the XTE-SOC into a Science Operations Facility, under Code 666, and a Guest Observer Facility, under

**Khoros** After considerable research in the areas of software tools and user interface design, I concluded that Khoros, a freely available product of the University of New Mexico, would be eminently suited for our prototype design, if not our production software. I installed the system and did a fair amount of customization.

**Prototyping** To explore the use of the visual programming interface available in Khoros, I developed, with Rick Leone, a prototype X-ray spectral fitting application. The prototype has similar, albeit more rudimentary, functionality as XSPEC, the X-ray world's standard, using a Levenberg-Marquardt minimization algorithm.

**Documents** With the various uncertainties that surrounded XTE's operating mode until the decision on the spacecraft was taken, the SOC document library lived in a suspended state for some time. This, combined with the reorganization and the accelerated launch schedule, caused a pressing need for document writing during this past year. I participated in the writing of the XTE Project Data Management Plan (PDMP); SOC, SOF, and GOF requirements documents; the SOC Preliminary Design Review (PDR) which is scheduled for September 3 and 4. I authored a software development plan for the GOF and am closely involved in the class library specification which will be the centerpiece of the overall SOC software design plan.

**Class Library Design** I have always argued strongly for an object-oriented design of the SOC software. This paradigm, though relatively new to scientific environments, is expected to lead to the generation of superior software. The gains are expected to be in the following areas: easier implementation; much more flexible extensibility; dramatically reduced maintenance cost. Thus, its application is attractive from the points of view of the scientific community, quality assurance, and budget control. The use of object-oriented design methodology and programming language has been provisionally accepted and I am currently in charge of the design and specification of the SOC's class library, an activity that has to be completed by the middle of December 1992 and requires intensive consultation with XTE's instrument teams at GSFC, MIT, and UCSD. Such a schedule is extremely compressed and even though



## 4 Papers Submitted

The last paper in the bibliography (designated as *Astron. Astrophys., in press, 1992*) has not yet been accepted.

## 5 Papers Presented at Scientific Meetings

I presented the contributed paper on *Proto-typing Astronomical Software in Khoros* at the conference *Astronomical Data Analysis Software and Systems I* in Tucson, AZ, in November 1991.

## 6 Community Service

My activities in this area have included:

- Refereeing astronomical papers

## 7 Collaborations

Since most of my collaborations involve university as well as non-university co-workers, there seems little point in trying to discriminate between the two.

Wrapping up the VLA HI observations of M 81 is a project that currently involves Butler Hine (NASA-Ames), David Westpfahl (NRAO and NMIMT), and Frank Bash (UT Austin).

I am collaborating with Mark Holdaway (NRAO) and David Westpfahl (NRAO and NMIMT) on a project involving the HI in the spiral galaxy IC 342.

I have formed a loose relationship with the Khoros development group at the EECE department of the University of New Mexico concerning the use and design of Khoros.

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"Radio Properties and Extinction of the HII Regions in M51", J.M. van der Hulst, R.C. Kennicutt, P.C. Crane, and A.H. Rots; 1988, *Astron. Astrophys.* 195, 38.

"Distributions and Motions of Atomic Hydrogen in Lenticular Galaxies VII. The SO/a-Sa Galaxies NGC 1291, NGC 5101, and IC 5267", W. van Driel, and A.H. Rots, H. van Woerden; 1988, *Astron. Astrophys.* 204, 39.

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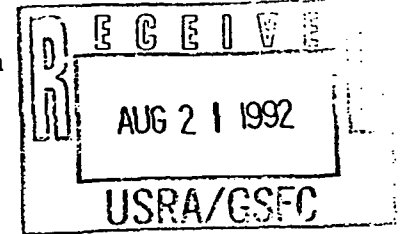
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"Distribution and Motions of Atomic Hydrogen in Lenticular Galaxies X. The Blue S0 Galaxy NGC 5102"; H. van Woerden, W. van Driel, R. Braun, and A.H. Rots; 1992, *Astron. Astrophys.*, in press.

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OF POOR QUALITY

University Space Research Association  
Goddard Visiting Scientist Program



Employee name: Lorella Angelini Task Number: 5000-623

General description of activities

*Software Development and Maintenance*

I am working on the development and maintenance of the two analysis software package XIMAGE (imaging) and XRONOS (timing). XIMAGE is the imaging software package used in the on-line HEASARC service. It is a collection of X-ray image manipulation and analysis routines that has been assembled into a command driven environment. XIMAGE was originally written for the EXOSAT data under VMS operating system and generalized to support Einstein data. I ported the XIMAGE code under UNIX operating system (e.g. SUN/UNIX, DEC/ULTRIX NEXT/UNIX) and I also worked to improve the XIMAGE multi-mission capability such that it will be easier to deal with different imaging detector and their peculiarity. An important step in this direction was to upgrade the input/output reader/writer to use the FITS standard format for images and for photon files. The missions supported at the moment are ROSAT (HRI and PSPC), Einstein (HRI and IPC), EXOSAT (CMA1 and CMA2), COSB and it will be use by ASTO-D mission. Most of the implementation regard how to insert the calibration measurement (exposure, vignetting, point spread function) which change from mission to mission. A facility to extract time selected spectra and light curves has been include to XIMAGE; selection in phase, exposure, and intensity will be add soon. The output format for spectra and light curves is suitable for XSPEC (spectral fitting package) and XRONOS (timing analysis package). The new realise of the package will be put in the on-line HEASARC service and distribute to the scientific community. This work is done in collaboration with Paolo Giommi ESRIN/ESA Frascati ITALY and Bruce O'Neel STX/GSFC. XRONOS is the timing package used in the on-line HEASARC service. It is a collection of programs which can be run stand alone or under a command driven environment. It is been written originally under VMS to analysed the EXOSAT data. In the past year I finished porting the software under UNIX, change part of the internal structure to insert exposure file. Currently a FITS input format file in under development and the first realise it will be ready at the end of august. New task to search periodicities in presence of red noise is under development. This work is done in collaboration with L. Stella located at Brera Observatory in Milan ITALY and with O. Day (STX/GSFC) for the FITS interface.

*EXOSAT Low Energy Catalogues*

The catalogue is based on a list of detection collected into a database, created running an automatic procedures on all the images in all the filter obtained for each EXOSAT observations (this was done at the EXOSAT observatory from 1987-1990). The total number of detection were 7352. In this number are included real sources (detected maybe several times, because EXOSAT pointed at that position more than ones or because different filter were used) for which the probability to be a background fluctuation is higher them  $1 \times 10^{-6}$ , 'marginal' for which the detection probability is lower  $1 \times 10^{-6}$  and 'spurious'

which are connected either with detector defects or scatter from a strong source.

For each of these detections - in particular for the one that has a low ratio signal to noise - the image was re-analysed and the positions found were cross-correlated with optical, radio and X-ray catalogues. A classification was established based on the analysis results and different samples, containing the X-ray detected position, were created. For each sample a quality flag was attached which denotes the probability that the detection is not a background fluctuation. To create the final list of 'good' sources observed with EXOSAT some work is still needed: manipulate the samples with an algorithm which will calculate and assign a single catalogue position from the positions derived separately from multiple observations, taking into account the errors on the positions themselves. This work was started in 1988 at the EXOSAT Observatory in collaboration with P. Giommi (ESA/ESRIN, Frascati, ITALY), G. Tagliaferri (ESA/ESTEC, Noordwijk) N. White (HEASARC/GSFC), The Netherlands), but it also has been carrying out by Rupali Chandar in the last year.

#### *HEASRC Support Scientist*

This task requires to assist scientist, which are using the archived data products through the database system, in answering questions related either to software or analysis problems.

#### *Current Scientific Research*

The main scientific projects on which I am working, concerns the study of variability on short and long timescale for X-ray pulsars, black hole candidate, low mass X-ray binaries observed during the EXOSAT life-time, using Fourier analysis and spectral analysis.

One of the most popular explanation for Quasi Period Oscillation found in the power spectra of LMRXB was most often discussed in terms of magnetospheric origin. In particular it was suggested that the QPO frequency arise from the modulation of the accretion onto a weakly magnetized, fast rotating neutron star, at the beat frequency between  $\nu_K$ , the Keplearin frequency at the inner edge of the disk, and the spin frequency  $\nu_S$  of the neutron star (beat frequency model, BFM) and also correlation between luminosity (which imply mass accretion rate) and QPO is expected. In this contest I started to look systematically for this kind of phenomena in X-ray pulsars for which the spin period is known as also other parameters like the magnetic field. I found QPO in the following X-ray pulsars EXO2030+375, SMCX-1, OAO1653-40 (published already for the first two sources, in preparation for the last one), but only EXO2030-375 can be explained in term of the BFM.

I also worked on the time variability of black-hole candidate Cygnus X-1, in which 0.04 Hz QPO were found (1-20 keV). The QPO seems non correlated with the overall intensity state or orbital phase. This results was announced with a IAU circular and it will be presented at the COSPAR meeting in august. The same phenomena was found also in the SIGMA data (40-70 keV) and in the BATSE data (20-110 keV). The QPO phenomenon in the case of black hole candidate can not be discussed in term of magnetospheric model (no magnetospher exist), but most likely can be due to instability in the accretion disk.

I have been also analysed data from the X-ray transient EXO1847-031 (presented by A. Parmar at the 'Black Hole' meeting, Aspen January 1991), and the LMXRB 4U0614+09.

I have collaborating with S. Pravdo on a paper, which will be submitted in two weeks

to Ap. J., using data for the Herbig-Haro 1 region (HH 1, in Orion), taken with the high resolution instrument (HRI) on board of ROSAT. The HH regions are knots of optically bright matter formed in the interaction of the stellar winds or jets of outflowing material with an ambient medium.

I have been also collaborating with Fabrizio Fiore (CFA), C. Done (University of Leicester), R. Edelson (LHEA/GSFC) to develop a new methods to evaluate features in the power spectra density (PSD) in the case of unevenly sampled data. In particular the method gives a better estimate of the spurious power in the measured PSD introduced by the non equispaced data set. The best estimate of the intrinsic PSD is obtained by convolving the model PSD with a window function and compared with the observed PSD. This methods is applied to power spectra obtained with GINGA data for Seyfert Galaxies and has been tested with EXOSAT data. The paper will be submitted within one month. Two ROSAT proposals, has been accepted. One is to study the low energy emission line found in the SSS data of the pulsar LMXRB 4U1626-47, the second on study the spectral behaviour of 3 dippers.

#### Papers published in Proceedings and IAU Circular

"Cygnus X-1" L. Angelini, N. White, L. Stella, 1992 *IAU Circ.* 5580.

'XRONOS: a timing analysis software', L. Stella, L. Angelini, in 'Data Analysis in Astronomy', (Erice April 1991), ed. V. Di Gesu', L. Scarsi, R. Buccheri, P. Crane, M. C. Maccarone, Plenum Publishing Corporation, in press.

'XIMAGE, a Multi-Mission X-ray Image Analysis Package', P. Giommi, G. Tagliaferri, L. Angelini and P. Jacobs, in 'Astronomical Data Analysis Software and Systems 1', ed. D.W. Worrall, C. Biemesderfer and J. Barnes, Astronomical Society of the Pacific Conference Series 25, 100.

'XRONOS, a timing analysis software', L. Stella and L. Angelini, 'Astronomical Data Analysis Software and Systems 1', ed. D.W. Worrall, C. Biemesderfer and J. Barnes, Astronomical Society of the Pacific Conference Series 25, 103.

#### To be Submitted and working paper

'X-rays From Emission-line Stars in the Herbig-Haro 1 region' S.H. Pravdo, L. Angelini, to be submitted, 1992

'An Interactive Deconvolution Technique for Measuring Broad Band Fluctuation Power Density Spectra with Unevenly Sampled Time Series', F. Fiore, C. Done, R. Edelson and L. Angelini, to be submitted, 1992.

'Time variability in Cygnus X-1', L. Angelini, N. White, L. Stella to be submitted

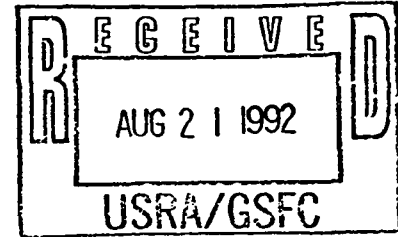
'The EXOSAT Observations of the LMXRB 4U0614+09', L. Angelini, L. Stella and N. E. White, to be submitted.

'The discovery of the X-ray Transient EXO1847-031', A. Parmar, L. Angelini, N. White, to be submitted.

'QPO and spectral changing behaviour from the X-ray pulsar OAO1653-40', L. Angelini, L. Stella and A. Parmar, to be submitted.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Paul E Barrett

Task Number: 5000-623

General Description of Your Research Activities: (Include a Paragraph on each Activity).

*Cataclysmic Variables and Single White Dwarfs*

In association with Okkie DeJager, Eric Schlegel and Andrezj Zdziarski, a proposal to use the Compton Gamma-Ray Observatory was submitted on 20 December 1991 to NASA with myself as Principal Investigator. The proposal is *Gamma-ray Observations of Intermediate Polars*. It was our intention to obtain as much observational data as possible of known Intermediate Polars (IPs), which are asynchronously-rotating, magnetic Cataclysmic Variables, by making observations with the OSSE, COMPTEL and EGRET instruments and by supplementing these observations with archival data. In the proposal we suggest that IPs are detectable  $\gamma$ -ray emitters and that observations from 50 keV to 30 GeV will discriminate between several possible  $\gamma$ -ray producing mechanisms. Initially the proposal was not accepted due to a limitation of funds, but later, was accepted for COMPTEL and EGRET observations without funding, because the amount of time for Guest Observer Proposals on these instruments was under-allocated. The archival aspect of our proposal was not affected, because there was no intention to allow access to this data prior to it being made public as we originally believed.

During the 13-16 January 1992, I attended the *179th Meeting of the American Astronomical Society* and presented a poster paper entitled *Photopolarimetry of FO Aquarii*. This paper discussed some preliminary results of optical photometry and polarimetry of the Cataclysmic Variable, FO Aquarii. An analysis of pulse-timings of the 20 minute pulse period agrees with the ephemeris of other authors. A new upper limit of the observed optical polarization is also given which places stronger constraints on the magnetic field of the white dwarf. A paper on this star is in preparation, but has been delayed due to increased task work.

In association with Eric Schlegel, Lorella Angelini and Jyoti Singh, a proposal to use *ROSAT* (Roentgen-X-ray satellite) was accepted. The title of the proposal is *A soft X-ray search for the precessing disk in TV Col* with myself as principal investigator. This was a modified version of proposal submitted and not accepted during the previous Announcement of Opportunity. Using X-ray data from a previous missions, we show that the soft X-ray component of the spectrum varies with the 4 day optical period and that a large fraction of the phase of the 4 day period has not been observed. *ROSAT* is therefore an excellent instrument to use for this study.

In association with Steve Drake (Principal Investigator) and Keith Arnaud, a proposal entitled *An X-band Survey of Single, Magnetic, Cool White Dwarfs* was submitted to the VLA (Very Large Array) radio telescope. The motivation for this proposal is the recently reported detection of one cool white dwarf with a MegaGauss magnetic field as an X-ray source. These stars are too cool to be photospheric X-ray emitters and therefore the radiation must be non-thermal.

Radio observations should test this hypothesis.

A proposal entitled *Photopolarimetry of TV Columbae and other Intermediate Polars* with Eric Schlegel and myself as Principal Investigator was accepted by the South African Astronomical Observatory. We requested two weeks of dark (no moon) time, one in November and one in December to observe as the primary target TV Columbae and as secondary targets CVs which have no published photopolarimetry and should therefore be of interest.

During the months of June and July, programs were written for the reduction of polarimetry data. These programs will be useful to myself and to users of the UCT photometer and polarimeter module at the South African Astronomical Observatory.

#### SN 1987A

I refereed a paper submitted to the *Astrophysical Journal* during December 1991. The subject of the paper was polarimetry of SN1987A, an object of which I made extensive polarimetric observations during 1987-88.

#### *Photopolarimetry of Pre-Main Sequence Stars*

In association with A. Evans, J.S. Albinson, J.K. Davies, M.J. Goldsmith, M.G. Hutchinson, and R.C. Maddison, work was completed on a paper accepted for publication in the *Journal of Astronomy and Astrophysics* and titled *The Reddening and Variability of XX Oph*. This paper contains simultaneous infrared and optical photometry and optical polarimetry of the pre-main sequence star XX Oph. It was the first time simultaneous photometry and polarimetry of such stars had been done. The photometric variability of these stars is thought due to changes in their circumstellar dust shells, which should also produce polarimetric changes as was observed.

In association with M. Shenton, J.S. Albinson, J.K. Davies, A. Evans, M.J. Goldsmith, M.G. Hutchinson, R.C. Maddison, A. Weight a paper entitled *Multiwavelength observations of RV Tauri stars: I. AC Her* is in press to the *Journal of Astronomy and Astrophysics*. This paper contains the first simultaneous infrared and optical photometry along with optical polarimetry of the star AC Her. The observations show a correlation of the photometry and polarimetry.

In association with M.G. Hutchinson, J.S. Albinson, J.K. Davies, A. Evans, M.J. Goldsmith, R.C. Maddison, papers on photometry and polarimetry of pre-main-sequence stars and multiwavelength observations of pre-main-sequence stars in the Coronae Australis region are in preparation.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded references, and the number of citations for each).

#### *Citations (in 1991):*

Year	Journal	Citations
1989	<i>Ap.J. Supp.</i> 71, 323.	2
1989	<i>MNRAS</i> 238, 1107.	5

1988	<i>MNRAS</i> 231, 1.	2
1988	<i>MNRAS</i> 233, 759.	5
1988	<i>MNRAS</i> 234, 937.	2
1987	<i>ESO Workshop on SN 1987A</i> .	1
1985	<i>Ap.J.</i> 298, 743.	1
1984	<i>MNRAS</i> 210, P15.	2
1984	<i>Ap.J.</i> 278, 298.	1

Honors/Awards Received

None.....

Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

*Refereed Journals:*

1. *Photometry, Polarimetry, Spectroscopy and Spectropolarimetry of the Enigmatic Wolf-Rayet Star EZ Canis Majoris*  
Robert, C., Moffat, A.F.J., Drissen, L., Lamontagne, R., Seggewiss, W., Niemela, V.S., Cerruti, M.A., Barrett, P., Bailey, J., Garcia, J. and Tapia, S.,  
1992. *Astrophys. J.*, in press.
2. *The reddening and variability of XX Oph*  
Evans, A., Albinson, J.S., Barrett, P., Davies, J.K. Goldsmith, M.J., Hutchinson, M.G. and Maddison, R.C.,  
1992. *Astron. & Astrophys.*, in press.
3. *Multiwavelength Observations of RV Tauri Stars. I. AC Her.*  
Shenton, M., Albinson, J.S., Barrett, P., Davies, J.K., Evans, A., Goldsmith, M.J., Hutchinson, M.G., Maddison, R.C., Weight, A.,  
1992. *Astron. & Astrophys.*, in press.

*Non-Refereed Journals, Conference Proceedings etc:*

1. *Photopolarimetry of FO Aquarii*  
Barrett, P., 1992. In Bull. American Astron. Soc.

*Other Articles:*

None

Papers Submitted, but not yet Accepted for Publication: (please include full title, co-authors [with affiliations], publications and submission date).



1. *Photometry and Polarimetry of Pre-Main Sequence Stars*  
Hutchinson, M.G., Albinson, J.S., Barrett, P., Davies, J.K., Evans, A., Goldsmith, M.J., Maddison, R.C., 1992. *Astron. & Astrophys.*, submitted.
2. *Multiwavelength Observations of Pre-Main Sequence Stars in the Coronae Australis Region*  
Hutchinson, M.G., Albinson, J.S., Barrett, P., Davies, J.K., Evans, A., Goldsmith, M.J., Maddison, R.C., 1992. *Astron. & Astrophys.*, submitted.

Papers Presented at Scientific Meetings:

*Invited Papers:* (Include title of talk, meeting name, date and any special meeting role, e.g. session chair, rapporteur).

None

*Contributed Papers:* (Include title, meeting and date).

None

*Colloquia, Seminars and Special Lectures:* (Provide title, date and place).

None

Community Service: (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.).

None

University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

None

Other Collaborative Activities: Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s).

None

Supply any Additional Information you Feel Would be Useful in evaluating your performance:

The following are task related activities:

*Generic Graphical User Interface Project*

I directed Paul Jacobs on the development of a generic GUI. The first phase of this project is nearly complete.

I also attended two conferences associated with GUIs:

During November 6-8, 1991, I attended the *1st Conference on Astronomical Data Analysis Software and Systems* in Tucson, AZ. I assisted with a demonstration of HEASARC software on a local workstation and attended many of the oral talks. This conference was a great success and second is planned for November 1992 in Boston.

During April 14-15, 1992, I attended the *User Interface Workshop* held here at Goddard SFC. Along with Nick White I gave an oral presentation of our plans for a generic Graphical User Interface (GUI) to be placed on top of the BROWSE database program.

#### *Astrophysical Data System*

I directed Paul Jacobs on the management and installation of the Astrophysical Data System. This distributed database server program was installed in April and soon afterwards HEASARC became a node. Ten catalogs have been available with the initial release and many more are expected during the next year.

In addition to the day-to-day management of this task I also attended two meetings:

During 7-8 May 1992, I attended the *ADS User's and Node's Meeting* near Baltimore. I gave a ten minute oral presentation summarizing HEASARC's ADS efforts up to that date and briefly described planned enhancements to the HEASARC node.

During 13-17 July, 1992, Paul Jacobs and I attended the *ADS GUI Workshop* in Boulder, Colorado. The first two days were a review of the current ADS and some planned enhancements. The last few days involved discussions on the design and development of the GUI to be included in the next software release of ADS. We also had some time to work on the "widgets" or windows. The work was completed after returning to Goddard on August 21, 1992.

#### *COS-B and SAS-2 Data*

I directed Brendan Perry on the resurrection of the SAS-2  $\gamma$ -ray data. This project had proceeded slowly until recently. The lack of progress was due to our time being redirected towards other tasks of higher priority and problems with the computer system. It is expected that the COS-B and SAS-2 data will be put into the FITS standard for  $\gamma$ -ray data by the end of this year. In addition a set of programs will be written to read and display the data.

#### *Next Generation BROWSE*

Work on the Next Generation BROWSE is proceeding at a slow pace because of demands from other task work of higher priority. Some progress has been made in the prototype stage of program development.

#### *Structured Data Protocol*

Lastly, the concept and design of a new data protocol for storing and transferring data were made. Arnold Rots and I are working on this project. The aim is to design a data transfer

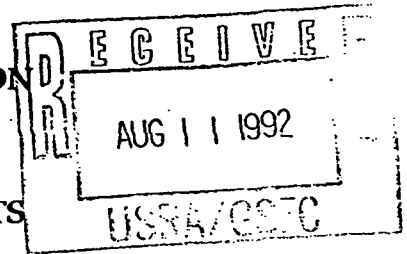
protocol which would be an alternative to the present FITS (Flexible Image Transport System) standard. It is hoped that a workable system will be completed by the end of the year.

*Compton Gamma-Ray Observatory Science Support Center*

During the 16-18 October 1992, I attended the *Compton Gamma-Ray Observatory Burst Workshop* in Huntsville, AL. No scientific results were presented at this meeting. The intention for attending was to stay abreast of current  $\gamma$ -ray research during my assignment to the Compton Gamma-Ray Observatory Science Support Center. It was soon after this meeting that I learn of my new task assignment.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 30 September 1992)

Employee name: Charles Day

Task number: 5000-624

General description of research activities

My work is centered on the analysis of X-ray data from various sorts of astronomical objects - X-ray binaries, active galactic nuclei and clusters of galaxies. The general problem which interests me is spectral variability, that is, how the X-ray spectrum of an astronomical object changes with time and position. For it often turns out that while the average spectrum of an object - say, an X-ray pulsar in an interacting binary system - is theoretically very complex, the changes the spectrum undergoes, with pulsar phase or with orbital phase, are much simpler and more tractable analytically.

Two similar papers which my collaborators and I finished in autumn last year concern massive X-ray binaries, namely Centaurus X-3 and 4U 1700-37. Both were based on the analysis of data taken by the Japanese X-ray astronomy satellite *Ginga*.

Nagase, Corbet, Day *et al.* (1992), for the first time, were able to resolve the X-ray spectrum of Cen X-3 into three distinct components: the direct emission from the X-ray pulsar, X-rays scattered in the wind of the companion star, and a low-temperature thermal component of uncertain origin. We were also able to constrain the sizes of the iron line emission regions by examining how the iron lines go in and out of eclipse. The fluorescent (6.4 keV) iron line, associated with the pulsar, has an abrupt eclipse egress lasting only ten minutes, implying that it comes from a region no bigger than  $3 \times 10^{10}$  cm. The most likely candidate is material piled up on the Alfvén shell. On the other hand, the thermal iron line (6.7 keV), associated with the low-temperature thermal component, has a partial eclipse and gradual egress, implying that it comes from a region at least as big as the optical companion.

Dr. Frank Haberl (MPE) and I, in our study of 4U 1700-37 (Haberl & Day 1992), found that the X-ray spectrum of this source could also be resolved into the same three distinct components as seen in Cen X-3. In addition, we discovered that the luminosity of the source had doubled since EXOSAT observed it and that the luminosity of the low-temperature thermal component had increased by a factor of five.

According to Prof. George Clark and Mr. Jonathan Woo of MIT (private communication), low-temperature thermal components have also been seen in the

Interestingly, one of our sample of three clusters, A1795, did not show this effect; nor did it show the intrinsic absorption attributed to accumulated matter. This leads us to speculate that the cooling flow in this cluster is younger than in the other two (A496 & A2142). Dr. White will be visiting the ROSAT Guest Observer Facility at GSFC 17-23 August during which time we will finish the paper.

Most recently, Prof. Nagase, Ms. Asai (ISAS), Dr. Takeshima (RIKEN) and I have discovered in the *Ginga* data from Cen X-3 that the intensity of the fluorescent iron line varies with pulse phase. Previous observations did not have the sensitivity to measure the pulsations which imply that the iron line originates in a small region. With my collaborators, I am in the middle of attempting to devise a rudimentary model for the origin of the line which is consistent with the full set of observational constraints. The current incarnation of the paper is a first draft.

In this account of my research activities, I have not included two papers, Day, Fabian, Edge & Raychaudhury (1991) and Day & Done (1991). Although these papers were published after 30 September 1991, they describe work done entirely before that date. The abstracts, however, are included at the end of this report for completeness.

#### Papers published or accepted for publication

- Day, C. S. R., Fabian, A. C.<sup>1</sup>, Edge, A. C.<sup>1</sup> & Raychaudhury, S.<sup>1</sup>, 1991. "GINGA observations of the Shapley Supercluster," *Mon. Not. R. astr. Soc.*, 252, 394.
- Day, C. S. R. & Done, C.<sup>7</sup>, 1991. "A disc-reflection component in the spectra of X-ray bursters," *Mon. Not. R. astr. Soc.*, 253, 35P.
- Day, C. S. R., Fabian, A. C.<sup>1</sup> & Ross, R. R.<sup>2</sup>, 1992. "A search for the iron absorption edge in the tail of an X-ray burst from X1636-53," *Mon. Not. R. astr. Soc.*, 257, 471.
- Haberl, F.<sup>3</sup> & Day, C. S. R., 1992. "A GINGA observation of the supergiant X-ray binary system 4U 1700-37/HD 153919," *Astron. Astrophys.*, 263, 000.
- Nagase, F.<sup>4</sup>, Corbet, R. H. D.<sup>5</sup>, Day, C. S. R., Inoue, H.<sup>4</sup>, Takeshima, T.<sup>6</sup>, Yoshida, K.<sup>4</sup> & Mihara, T.<sup>6</sup>, 1992. "Ginga observations of Centaurus X-3," *Astrophys. J.*, 395, 000.
- George, I. M.<sup>7</sup>, Nandra K.<sup>1</sup>, Fabian, A. C.<sup>1</sup>, Turner, T. J.<sup>7</sup>, Done, C.<sup>8</sup> & Day, C. S. R., 1992. "The broad-band X-ray spectral variability of Mkn 841," *Mon. Not. R. astr. Soc.*, accepted June 1992.
- Day, C. S. R. & Stevens, L. R.<sup>1</sup>, 1993. "An X-ray excited wind in Centaurus X-3," *Astrophys. J.*, to be published January 1993.

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<sup>1</sup> Institute of Astronomy, University of Cambridge, England

<sup>2</sup> Physics Dept., College of the Holy Cross, Worcester, MA

<sup>3</sup> Max-Planck Institut fuer extraterrestrische Physik, Garching bei Muenchen

<sup>4</sup> Institute of Space and Astronautical Science, Sagamihara, Japan

<sup>5</sup> Pennsylvania State University, University Park, PA

<sup>6</sup> Institute of Physical and Chemical Research, Wako, Japan

<sup>7</sup> Laboratory of High Energy Astrophysics, NASA GSFC

<sup>8</sup> University of Leicester, Leicester, England

Abstracts of papers published or accepted for publication

A DISC-REFLECTED COMPONENT IN THE SPECTRA OF X-RAY BURSTERS

C. S. R. Day and C. Done

ABSTRACT

We show that a disc reflection component, as seen in AGN, can be detected in the spectrum of X-ray bursts during the burst tail and speculate on the use of the concomitant absorption edge as a diagnostic of the accretion disc.

AN X-RAY EXCITED WIND IN CENTAURUS X-3

C. S. R. Day and Ian R. Stevens

ABSTRACT

We propose a new interpretation of the behavior of the notable X-ray binary source Centaurus X-3. Based on both theoretical and observational arguments (*EXOSAT* data), we suggest that an X-ray excited wind emanating from the O-star is present in this system. Further, we suggest that this wind is responsible for the mass-transfer in the system rather than Roche-lobe overflow or a normal radiatively driven stellar wind. We show that the ionization conditions in Cen X-3 are too extreme to permit a normal radiatively driven wind to emanate from portions of the stellar surface facing toward the neutron star. In addition, the flux of X-rays from the neutron star is strong enough to drive a thermal wind from the O-star with sufficient mass-flux to power the X-ray source. We find that this model can reasonably account for the long duration of the eclipse transitions and other observed features of Cen X-3.

If confirmed, this will be the first example of an X-ray excited wind in a massive binary. We also discuss the relationship between the excited wind in Cen X-3 to the situation in eclipsing millisecond pulsars, where an excited wind is also believed to be present.

A SEARCH FOR THE IRON ABSORPTION EDGE IN THE TAIL OF AN X-RAY BURST FROM X1636-53

C. S. R. Day, A. C. Fabian, and R. R. Ross

ABSTRACT

Model atmosphere calculations of the spectrum of a neutron star cooling after an X-ray burst show that the photoelectric edge of iron should be prominent. We find no clear evidence for such a redshifted feature in the spectrum of a burst from X1636-53 and conclude that the iron abundance there must be less than 0.3 Solar. There is marginal evidence for a weak edge redshifted to  $5.75 \pm 0.5$  keV. Unless the iron abundance of the surface matter on the neutron star is highly time-dependent, our result argues against the 4.1-keV absorption line seen in some bursts from X1636-53 by Waki *et al.* being due to iron. We note that the iron edge will be a powerful diagnostic of the surface redshift of the neutron star in burst sources where the iron abundance is more nearly Solar.

cold matter located relatively close to the neutron star, whereas the 6.7-keV line is attributed to the hot highly ionized plasma spread out over the surface of the companion. The present observations give an estimate for the size of such a hot plasma zone formed by the X-ray irradiation:  $D_{6.7\text{-keV}} > 8 \times 10^{11}$  cm.

#### THE BROAD-BAND X-RAY SPECTRAL VARIABILITY OF MKN 841

L. M. George, K. Nandra, A. C. Fabian, T. J. Turner, C. Done and C. S. R. Day

##### ABSTRACT

The results of a detailed spectral analysis of four X-ray observations of the luminous Seyfert 1.5 galaxy Mkn 841 performed using the *EXOSAT* and *Ginga* satellites over the period 1984 June to 1990 July are reported. Preliminary results from a short *ROSAT* PSPC observation of Mkn 841 are also presented.

Variability is apparent in both the soft (0.1-1.0 keV) and medium (1-20 keV) energy bands. Above 1 keV, the spectra are adequately modeled by a power law with a strong emission line of equivalent width  $\sim 450$  eV. The energy of the line ( $\sim 6.4$  keV) is indicative of K-shell fluorescence from neutral iron, leading to the interpretation that the line arises via X-ray illumination of cold material surrounding the source. In addition to the flux variability, the continuum shape also changes in a dramatic fashion, with variations in the apparent photon index  $\Delta\Gamma \sim 0.6$ .

The large equivalent width of the emission line clearly indicates a strongly enhanced reflection component in this source, compared to other Seyferts observed with *Ginga*. The spectral changes are interpreted in terms of a variable power law continuum superimposed on a flatter reflection component. For one *Ginga* observation, the reflected flux appears to dominate the medium energy X-ray emission, resulting in an unusually flat slope ( $\Gamma \sim 1.0$ ).

The soft excess reported by Arnaud *et al.* is found to be highly variable by a factor of  $\sim 10$ . These variations are not correlated with the hard flux, but it seems likely that the soft component arises via reprocessing of hard X-rays. We find no evidence for intrinsic absorption, with the equivalent hydrogen column density constrained to be less than  $10^{20}$  cm $^{-2}$ .

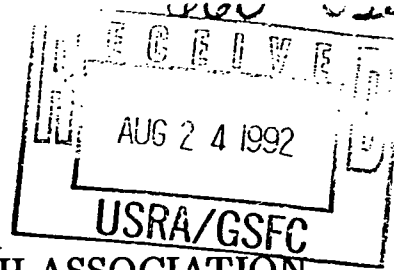
The implications of these results for physical models for the emission regions in this and other X-ray bright Seyferts are briefly discussed.

#### GINGA OBSERVATIONS OF THE SHAPLEY SUPERCLUSTER

C. S. R. Day, A. C. Fabian, A. C. Edge and S. Raychaudhury

##### ABSTRACT

We present the results of analysing scanning and pointed observations of a region of about 40 square degrees in the vicinity of Shapley 8, the largest cluster of galaxies in Shapley's concentration of clusters.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

*Employee Name:* Ken EBISAWA *Task Number:* 660-024

*General Description of Your Research Activities:(Include a Paragraphs on each Activity).*

I have joined the Laboratory for High Energy Astrophysics (LHEA) in April 1992 after finishing the Ph-D study in 1990 March at the Institute of Space and Astronautical Science (ISAS) in Japan and spending the following one year as a post doctoral fellow in ISAS. In ISAS, I mainly studied energy spectra of low mass X-ray binaries and black hole candidates with the data taken by the Japanese X-ray satellite Ginga. Additionally, I was working on the development of the Gas Imaging Scintillation counters (GIS), which is one of the two focal plane instruments for the Astro-D satellite. After joining the LHEA, I have been carrying on the study of low mass X-ray binaries and black hole candidates using the Ginga data, and working on development of the Astro-D calibration and data analysis system.

*Scientific Research Activity:*

I have studied long term spectral variations of the black hole candidates LMC X-3 (collaboration with Drs. F. Makino, K. Mitsuda, T. Belloni, A. Cowley, P. Schmidke, and A. Treves). We found that (1) the energy spectrum below  $\sim 9$  keV shows clear intensity-hardness correlation, and (2) the hard-tail component, which is conspicuous above  $\sim 10$  keV, is highly variable independently of the soft component. We showed the spectral variation of the soft component is successfully explained with an optically thick accretion disk model whose innermost radius is constant against the variable mass accretion rate. We showed the innermost radius of the disk is consistent with the least stable Keplerian orbit around a  $\sim 5.5 M_{\odot}$  black hole.

I have investigated quiescent states of the X-ray novae GS2000+25 and GS2023+338 (collaboration with Drs. S. Mineshige, M. Takizawa, Y. Tanaka, K. Hayashida, K. Kitamoto, S. Miyamoto and K. Terada). X-ray luminosity of quiescent X-ray novae is a clue to discriminate two competing models for the triggering mechanism of X-ray novae. We obtained relatively small upper-limits of the quiescent luminosity, which favour the disk instability model against the mass-overflow instability model.

I have observed two adjacent X-ray novae simultaneously discovered in the Vela-Puppis region in November 1990, with Drs. T. Aoki, T. Dotani, M. Itoh, F. Makino, F. Nagase, F., T. Takeshima, T. Mihara, and S. Kitamoto. We proved the southern source (GS0834-430) is an X-ray pulsar and the northern one (GS0836-429) is an X-ray burster, contrary to the earlier ROSAT report which claimed the opposite identification. Spectral and timing characteristics of each source are studied.

With Drs. T. Yaqoob and K. Mitsuda, I have studied energy spectra of X1957+11, whose characteristics are thus far not understood well. We compared its energy spectrum with those



of other low mass X-ray binaries and black hole candidates, applying a simple optically thick accretion disk model. We showed the parameters of the accretion disk are rather similar to those of low mass X-ray binaries than to black hole candidates. We interpreted the difference of the disk parameters as due to the difference of the masses of the central objects, and concluded that the compact object in X1957+11 is likely to be a neutron star, rather than a black hole.

I have been studying X-ray characteristics of GS1124-68 (Nova Muscae), a bright X-ray nova, which was discovered in Jan. 1991 and observed with Ginga until the diminution in October 1991 (collaboration with Drs. T. Aoki, T. Dotani, K. Mitsuda, M. Takizawa, M. Ogawa, K. Makishima, S. Miyamoto, K. Yoshida, S. Iga, K. Terada, S. Kitamoto and K. Hayashida). Near the maximum luminosity, the source exhibited characteristic spectral branches and 6 – 8 Hz Quasi Periodic Oscillations associated with the branches. Furthermore, the source exhibited a dramatic high-low transition in May 1991. The transition is very similar to those transitions thus far reported in the black hole candidates Cyg X-1 and GX339-4. I am preparing to publish these results with the collaborators. Additionally, I have been working on combine spectral fitting of GS1124-68 on the data taken by Ginga and ROSAT (collaboration with Dr. J. Greiner).

With Drs. K. Mitsuda, K. Yoshida, T. Yaqoob, Y. Ueda, I have been studying the low state energy spectra of the black hole candidates Cyg X-1, GX339-4 and the low mass X-ray binary X1608-522. These energy spectra exhibit characteristic broad absorption feature in 7 – 20 keV and an iron emission line at  $\sim 6.4$  keV, as a significant deviation from a simple power-law spectrum. These spectral features are successfully explained with a reflection model, in which a part of incident X-rays is reflected by optically thick matter. Applying the reflection model developed by Dr. C. Done to these data, we detected a clear correlation between the X-ray luminosity and ionization state of the reflector. This is considered to be an evidence of photoionization of the optically thick accretion disk around the central object by the incident X-rays. These results on GX339-4 and X1608-522 are being prepared to be published. On Cyg X-1, I am working with Dr. C. Done to improve the model to explain slight, but systematic deviations of the data from the simple reflection model.

I have started a project to develop an accurate spectral model of an optically thick accretion disk and apply it to the Ginga data of the black hole candidates LMC X-3, GS2000+25 and GS1124-68 (collaboration with Drs. N. White, L. Titarchuk and K. Mitsuda). If a simple accretion disk spectral model in which color to the effective temperature ratio is assumed to be constant is applied to these data, the innermost radius of the disk is kept constant in the course of large spectral variations, suggesting the innermost radius is related to the mass of the central object. Recently, the color to the effective temperature ratio in accretion disks was precisely calculated by Dr. Titarchuk as a function of X-ray luminosity. Using this result, we expect physical parameters of accretion disks (e.g., viscosity parameter, mass of the central object) can be obtained. I have been working on developing an accretion disk model implementing the calculation by the Dr. Titarchuk. Furthermore, I have submitted a research proposal to the fifth NASA Ginga Visiting Investigator Program to use the Ginga data.

I have started working on the simultaneous observation data of Cyg X-1 taken in June, 1991 by Ginga and EGRET onboard GRO (collaboration with Dr. P. Michelson, K. Mitsuda, Y. Ueda and K. Wood).

*Project Works:*

I have converted the preliminary GIS response function supplied by the GIS hardware team in the University of Tokyo to the format for the XSPEC spectral fitting package, so that it can be used in the Astro-D spectral and imaging simulation.

In July 1992, I have visited Institute of Space and Astronautical Science (ISAS) and the University of Tokyo. In ISAS, I participated the Astro-D software meeting and gave a presentation on the Astro-D calibration system. I took part in a panel to select appropriate binary sources to be observed in the Astro-D performance verification phase. In the University of Tokyo, I discussed with Dr. E. Gotthelf (GSFC) and the GIS hardware team how to build the GIS response function and formats of the GIS calibration database.

I have been working on developing a program to convert Ginga spectral data and response function to the standard data and response file format for the XSPEC spectral fitting package.

I have started developing the Astro-D Standard Data Analysis package which will supply all the Astro-D Guest Observers the first quick look results of their own data.

*Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).*

According to the Science Citation Index, numbers of citations of some of my recent publications are the following:

Ebisawa, K., Mitsuda, K. Inoue, H. and Dotani, T. 1988,  
*Discovery of the 0.08 Hz Quasi Periodic Oscillation from the Black Hole Candidates LMC X-1*

in PHYSICS OF NEUTRON STARS AND BLACK HOLES, edited by Y. Tanaka,  
Universal Academy Press, Tokyo, Japan.

•Number of Citations: 1990 - 1; 1991 - 1.

Ebisawa, K., Mitsuda and K. Inoue, H. 1989, PASJ, 41, 519

*Discovery of 0.08 Hz Quasi-Periodic Oscillations from the Black-Hole Candidates LMC X-1*

•Number of Citations: 1990 - 2; 1991 - 7.

Hasinger, G., van der Klis, M., Ebisawa, K., Dotani, T. and Mitsuda, K. 1990, A& A, 235, 131

*Multi-frequency Observations of Cygnus X-2: X-ray Observations with Ginga*

•Number of Citations: 1990 - 3; 1991 - 8; 1992 (Jan. - June) - 1.

Treves, A., Belloni, T., Corbet, R. H. D., Ebisawa, K., Falomo, R., Makino, F., Makishima, K., Maraschi, L., Miyamoto, S. and Tanzi, E. G. 1990, ApJ, 364, 266

*Simultaneous X-ray, Ultraviolet, and Optical Observations of LMC X-3*

•Number of Citations: 1991 - 1.

Ebisawa, K., Mitsuda, K. and Hanawa, T. 1991, ApJ, 367, 213

*Application of a General Relativistic Accretion Disk Model to LMC X-1, LMC X-3, X1608-522, and X1636-536*

•Number of Citations: 1992 (Jan. - June) - 2.

Ebisawa, K., Makino, F., Mitsuda, K., Belloni, T. Cowley, A., Schmidke, P. and Treves, A. 1991,

*Spectral Variation of LMC X-3 observed with Ginga,*

in FRONTIERS OF X-RAY ASTRONOMY, p.351, edited by Y. Tanaka and K. Koyama, Universal Academy Press, Tokyo, Japan.

•Number of Citations: 1991 - 1.

Ebisawa, K., Inoue, H., Mitsuda, K., Nagase, F., Tanaka, Y., Yaqoob T. and Yoshida, K. 1991,

*Broad Absorption Structure in Energy Spectra of Binary X-ray Sources,*

in FRONTIERS OF X-RAY ASTRONOMY, p.301, edited by Y. Tanaka and K. Koyama, Universal Academy Press, Tokyo, Japan.

•Number of Citations: 1991 - 1.

Miyamoto, S., Kimura, K., Kitamoto, S., Dotani, T. and Ebisawa, K. 1991, ApJ, 383, 784  
*X-ray Variability of GX339-4 in its Very High State*

•Number of Citations: 1992 (Jan. - June) - 1.

#### *Honors or Awards Received:*

Nothing to be mentioned.

*Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).*

Miyamoto, S., Kimura, K., Kitamoto, S. (Osaka Univ.), Dotani, T. and Ebisawa, K. (Institute of Space and Astronautical Science) 1991, ApJ, 383, 784  
*X-ray Variability of GX339-4 in its Very High State*

Cowley, A. P., Schmidtke, P. C. (Arizona States Univ.), Ebisawa, K., Makino (ISAS), F., Crampton, D., Hutchings, J. B., Remillard, R. (MIT), Kitamoto, S. (Osaka Univ.) and Treves, A. (International School for Advanced Studies), 1991, ApJ 381, 526  
*Discovery of a Long-term Periodic Variation of LMC X-3*

Mineshige, S. (Ibaraki Univ.), Ebisawa, K., Takizawa, M., Tanaka, Y. (ISAS), Hayashida, K., Kitamoto, S., Miyamoto, S. and Terada, K. (Osaka Univ.), 1992, PASJ, 44, 117  
*On X-ray luminosities of the Quiescent X-ray Novae: GS2000+25 and GS2023+338*

Aoki, T., Dotani, T., Ebisawa, K. Itoh, M., Makino, F., Nagase, F., Takeshima, T. (ISAS), Mihara, T. (Tokyo Univ.) and Kitamoto, S. (Osaka Univ.), 1992, PASJ, accepted  
*Discovery of two Transient X-ray Sources in Vela-Puppis Region: Pulsar GS0834-430 and Burster GS0836-429*

Ebisawa, K., Makino, F., Mitsuda, K. (ISAS), Belloni, T. (MPE), Cowley, A., Schmidke, P. (Arizona State Univ.) and Treves, A. (International school for Advanced Studies) 1992, ApJ, accepted  
*Spectral Variation of LMC X-3 observed with Ginga*

*Papers Submitted but not yet Accepted for Publication: (please include full title, co-authors [with affiliations], publication, and submission date*

Yaqoob, T., Ebisawa, K. and Mitsuda, K. (ISAS) 1992, MNRAS submitted in Jan. 1992  
*Is X1957+11 a Black Hole Candidate ?*

*Papers Presented at Scientific Meetings:*

*Invited Papers : (Include title of talk, meeting name, date, and any special meeting role, e.g. session chair, rapporteur).*

Nothing to be mentioned.

*Contributed Papers: (Include title, meeting, and date)*

"Ginga observation of the low mass X-ray binary X1957+11"  
in the Japan Astronomical Society Meeting, on Oct. 1991, in Mito, Ibaraki, Japan.

*Colloquia, Seminars, and Special Lectures: (Provide title, date, and place)*

A colloquium on the title of "Spectral Study of Black Hole Candidates Observed with GINGA", on May 19th, 1992 at NASA/GSFC.

*Community Service (e.g., Offices in professional societies, lectures to community or educational groups, consultation, etc.)*

Nothing to be mentioned.

*University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborator(s), course, taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here*

I have started to analyze the Cyg X-1 data simultaneously taken by Ginga and EGRET in June 1991, in collaboration with the EGRET team in the Stanford University (collaborator Dr. P. Michelson).

I have been working on development of the Astro-D GIS system in close collaboration with the GIS hardware team (lead by Prof. K. Makishima and Dr. T. Ohashi) in the University of Tokyo.

From 1991 March to 1992 February, in ISAS, I was the adviser of the master course graduate student from the Rikkyo University, M. Ogawa. M. Ogawa wrote a master thesis entitled "Ginga Observation of an X-ray Nova GS1124-68" in February 1992.

*Other Collaborative Activities: Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s).*

I have started to analyze the Cyg X-1 data simultaneously taken by Ginga and EGRET in June 1991. One of the collaborators is Dr. K. Wood in the Naval Research Laboratory.

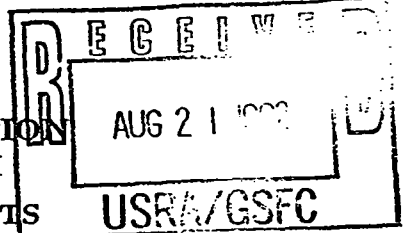
*Supply any Additional Information you Feel Would be Useful in Evaluating your Performance.*

Recently, I noticed that my current annual salary, \$33,000, is the standard figure USRA usually offers to *fresh* Ph.D.s. However, before I started working in GSFC in March 1992, I had been working for one year as a post doctoral fellow in the Institute of Space and Astronautical Science, Japan, after obtaining the doctoral degree in March, 1991.

I am afraid that the one year working experience before starting the current job is not properly appreciated by USRA in my current salary. I think I should have told this when I accepted the present job offer, but I hope this factor is considered in the assessment of my salary in the next term.

I will attach the original e-mail I received from Dr. Frank J. Kerr which offered me the current job and informed me the amount of the annual salary for the first year.

660-024 SV



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the period 1/2/92 to 9/30/92)

Employee Name: Koji Mukai

Task Number: 660-024

General Description of Activities

ASTRO-D matters:

- OGIP Fortran Programming Standard: I have circulated an early draft of "OGIP Fortran Programming Standard," to establish a list of acceptable extension of the Fortran 77 standard, and to promote good programming practices.
- PIMMS (Portable, Interactive, Multi-Mission Simulator): I have coded a prototype of this data simulator, aimed at aiding prospective guest observers to figure out the best use of ASTRO-D and other missions. This currently is my major responsibility.
- ASTRO-D Calibration: I am part of a team establishing what calibration data are necessary for ASTRO-D, and specifying their format. I am preparing to participate in the ground calibration at White Sands during September.
- Proposal Submission and Processing Aids: I have the responsibility over the proposal submission utility and database systems, in conjunction with Dr. Petre and Ms. Duesterhaus. Currently, I am working on establishing the interface between Goddard-based proposal data base and the Observation and Command Database at ISAS.

Research Activities:

- Proposals: I have written two observing proposals for ROSAT AO-3 as PI of which one was accepted, two proposals for EUVE AO-1 as PI (no decisions yet), as well as several others for the abovementioned satellites and a ground-based telescope as a co-I.
- Intermediate Polars: I have completed my part in the analysis of an international campaign on FO Aqr, which took place in October 1989. My collaborators are working hard to produce a draft paper to be submitted to Ap.J.
- Old Novae: Dr. Naylor, myself and others have completed a paper on old novae CK Vul and WY Sge, which is now in press in Monthly Notices. This line of work is continuing with a UKIRT observing run on WY Sge in late August.
- Dipping LMXBs: Dr. Smale, myself and others have submitted a paper on Ginga observation of XB1916-053 and EXO0748-676 to Ap.J.; it has since been accepted for publication.
- EXOSAT ME sample of Dwarf Novae: Mr. Shiokawa and myself are analyzing the EXOSAT ME data on dwarf novae, with data taken from the HEASARC archive. Despite the generally poor data quality, we hope to be able to draw important conclusions.

## Significan Recognitions

Citation of papers in refereed journals that were lead-authored by myself:

No.	Year Published	Citations in 1991	Citations (total)	No.	Year Published	Citations in 1991	Citations (total)
1	85	2	12	11	88	1	10
3	86	1	16	13	88	1	5
4	86	2	15	18	90	2	5
5	87	3	5	20	90	2	3
8	87	5	25	26	91	1	1
10	88	1	3	27	92		

(Paper numbers refer to those in the attached publications list.)

## Honors or Awards Received

### Papers Published or Accepted for Publication

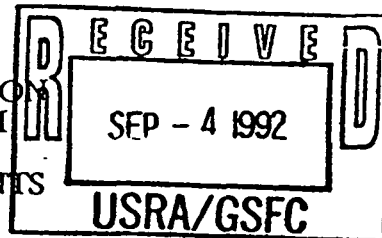
Mukai, K. & Hellier, C. 1992, "On Martell & Kaitchuck's model for the intermediate polar FO Aquarii," *Ap.J.* 291, 295.

Naylor, T., Charles, P.A., Mukai, K. & Evans, A. 1992, "An observational case against nova hibernation," *MNRAS*, in press.

Smale, A.P., Mukai, K., Williams, O.R., Jones, M.H. & Corbet, R.H.D. 1992, "Ginga observations of dipping low mass X-ray binaries X1916-053 and EXO0749-676," *ApJ*, in press.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: GAIL REICHERT

Task Number: 5000-625

General Description of Your Research Activities: (Include a Paragraph on each Activity).

1. Ultraviolet, Optical, and X-ray Observations of LINER (and related) galaxies:

LINER galaxies comprise one of three major classes of galaxies with activity within their nuclei. However, the origin(s) and physical nature of this activity remain poorly understood. I am actively involved in a number of multi-wavelength studies of LINER galaxies. With colleagues at MSSL and CSC, I have obtained very long exposure IUE images of a sample of LINERS. Dr. Altner (CSC) and I have developed new software techniques to separate IUE spectra from spatially complex images. I am now using these techniques to study the nuclear spectra of our sample of LINERS. These nuclear spectra are being combined with optical spectra obtained by Dr. Filippenko at UCB. With colleagues at NASA/GSFC, ESTEC, and UCB, I have also obtained ROSAT observations of several X-ray bright LINERS, and am relating their X-ray properties with those at other wavelengths.

The software techniques used to study the LINER spectra hold promise for a wide range of astronomical objects whose IUE images show spatial structure. I am working with Dr. Shore (CSC), to apply these techniques to the study of starburst galaxies, and with Dr. Filippenko and Dr. Sargent (CIT) to study the Wolf Rayet galaxy NGC 4314.

2. Coordinated, multi-wavelength monitoring of active galactic nuclei (AGN):

The emission from AGN is both highly variable and spread over a wide range of energies, from radio to X-rays. Coordinated, multi-wavelength monitoring of AGN is thus indispensable if we are to unravel this complex emission and understand the physical nature of these objects. I have played key roles in monitoring campaigns of several AGN, including NGC 5548 (1988-1989, 1990), PKS 2155-304 (1991), and NGC 3783 (1991-1992). These campaigns covered all wavelengths from radio to X-rays. I am currently extracting and analyzing the ultraviolet data for the NGC 3783 campaign, and will take the lead in writing the initial paper presenting the results. I expect to be involved in a campaign to obtain further observations of NGC 5548, in spring of 1993.

The results of previous monitoring campaigns pose problems for conventional accretion disk models of AGN, which explain the UV radiation as thermal emission generated by viscous processes within the disk. New models suggest that the bulk of the UV radiation may be due to reprocessing of a primary gamma-ray continuum, and make specific predictions as to how the UV, x-ray, and gamma-ray emission from AGN should be related. Colleagues at NASA/GSFC and NRL and I have been awarded coordinated IUE, Rosat, and GRO observations of several AGN in order to test these predictions.

Our inability to observe nearby objects in the extreme ultraviolet (shortward of 1200 angstroms) is another barrier to our understanding of AGN. With colleagues at NASA/GSFC and UCB, I am continuing to obtain Voyager observations of very bright AGN, in order to characterize their spectra down to wavelengths of 912 angstroms.



Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Citations in the Science Citations Index, 1990-1991:

81 Ap J 247 803 (1)  
82 Ap J 260 437 (7)  
82 Ap J 264 575 (2)  
85 Ap J 296 69 (17)  
86 Ap J 303 87 (5)  
88 Active Galactic Nucl (2)  
88 Ap J 325 671 (4)  
88 Decade UV Astronomy (4)  
88 ESA SP281 (1)

Honors or Awards Received:

Admitted to IAU Membership, Spring, 1991.

Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

"Spatially Resolved Ultraviolet Spectroscopy of the LINER Galaxy NGC 3998"  
G. A. Reichert, G. Branduardi-Raymont (MSSL, UCL), A. V. Filippenko (UCB),  
K. O. Mason (MSSL, UCB), E. M. Puchnarewicz (MSSL, UCB), and C. C. Wu (CSC),  
1992, Ap. J. 387, 536.

"Correlated Hard X-ray and UV Variability in NGC 5548"  
J. Clavel (ISO Observatory), K. Nandra (University of Leicester), F. Makino  
(ISAS), K. Pounds (University of Leicester), G. A. Reichert, C. M. Urry  
(STScI), W. Wamsteker (ESA IUE Observatory), M. Peracaula--Bosch (Escola  
Tecnica Superior Engineers)  
1992, Ap. J. (in press).

*Colloquia, Seminars, and Special Lectures: (Provide title, date, and place)*

"Ultraviolet and X-ray Observations of LINER Galaxies",  
Astronomy Department, Tel Aviv University, Israel, May 21, 1992.

Community Service: (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.)

Member, IUE Users' Committee (since Spring, 1991). Last fall this involved helping to write a proposal for the NASA Senior Review, in which the IUE Observatory was one of the five projects reviewed.

University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

1. A program to study ultraviolet and optical spectra of LINERs, with K. O. Mason, E. M. Puchnarewicz, G. Branduardi-Raymont (MSSL, University College London) and A. V. Filippenko (UC Berkeley). We presented some of this work at the Workshop on the Connection between Starbursts and AGN, held in Taipei in March, 1991, and at the conference The Closest Active Galaxies, held in Madrid in May, 1992. Papers will appear in the conference proceedings for each meeting. Several research papers are also in progress. Last December we submitted a grant proposal to obtain IUE observations of more objects (which was awarded time). Last August we submitted a proposal to obtain higher resolution UV spectra using the Hubble Space Telescope; the proposal came very close to being awarded time and we have just resubmitted it.

2. A program to study Rosat X-ray spectra of LINERs, with R. F. Mushotzky (NASA/GSFC), P. Barr (ESTEC), and A. V. Filippenko (UC Berkeley). We have received most of the data from our AO-1 and AO-2 observations and have begun our analysis. Last Feb we submitted a grant proposal to obtain time during AO-3 (which was conditionally successful).

(continued on next page)

University Collaborations (continued):

3. A program to spatially separate IUE spectra of the Wolf Rayet galaxy NGC 4314, with A. V. Filippenko (UC Berkeley) and W. L. W. Sargent (CIT). We have observed NGC 4314 with IUE, and have begun to extract the spectra. The results of our spatial analysis will determine our strategy for our cycle 2 HST observations.

4. Multi-wavelength monitoring of Seyfert Galaxies, with B. M. Peterson (Ohio State University), J. Clavel (ESA), M. Malkan (UCLA), and many others. Since last December, I have been reducing and extracting the ultraviolet data from the multiwavelength monitoring campaign on NGC 3783. We have just completed the IUE observations, and I am now analyzing the results. Last February, H. Netzer (Tel Aviv University) and I submitted a proposal to obtain Rosat observations in support of this campaign (which was unsuccessful). In May, with W. Wamsteker (ESA), R. Polidan (NASA/GSFC), T. Carone (UC Berkeley), and H. Netzer, I submitted a proposal to obtain Voyager observations of NGC 3783 as part of the World Astronomy Days program (which was successful).

5. Multi-wavelength monitoring of BL Lacs and OVV's, with G. Majeski (USRA/GSFC), C. M. Urry (STScI), R. Edelson (NAS/NRC), A. Wehrle (JPL), and many others. We obtained multiwavelength observations of the BL Lac PKS 2155-304 during Nov, 1991. Papers presenting the results of the IUE, X-ray, optical, and radio observations, and the results of the analysis of the complete spectrum, are in preparation. We have also been awarded IUE, Rosat, and GRO time for 1993 to carry out a second multi-wavelength campaign, on the OVV quasar 3C 279.

6. A program to obtain coordinated IUE and Voyager observations of bright AGN, with T. Carone (UC Berkeley), R. Polidan (NASA/GSFC), and C.-C. Wu (CSC/STScI). In May 1992, we submitted a proposal to obtain further Voyager observations, which was successful.

Other Collaborative Activities: Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

7. A program to spatially separate IUE spectra of starburst galaxies, with S. M. Shore (CSC/GSFC). We are modifying the techniques in order to be able to spatially separate the short wavelength spectra.

8. A program to obtain high resolution ultraviolet spectra of several bright AGN, using the High Resolution Spectrometer on board the Hubble Space Telescope, with S. Maran, R. F. Mushotzky (NASA/GSFC), R. Weymann (MWLCO), and others. The purpose of this program is to observe UV absorption lines from the X-ray absorbing material, and to monitor the UV absorption properties. The observations are currently scheduled to begin in February 1993.

9. A program to obtain coordinated IUE, Rosat, and GRO observations of selected bright AGN, with R. Petre, R. Mushotzky, N. Gehrels (NASA/GSFC), and J. Kurfess (NRL). The purpose of this program is to test models in which the UV and x-ray continuum emission from AGN arise from reprocessing of a primary gamma-ray continuum.

Supply any Additional Information you Feel Would be Useful in evaluating your performance:

Programmatic Activities:

In addition to my research activities, I have been actively engaged in a number of programmatic activities at the Rosat Guest Observer Facility (GOF) and High Energy Science Archive Research Center (HEASRC), including the following:

1. I am one of four technical support people for the GOF, whose responsibilities are to show guest observers how to use the various software packages at the GOF, answer questions pertaining to Rosat and Rosat data analysis, and generally provide information concerning Rosat to the astronomical community. These responsibilities also include technical support for the Rosat Proposal Peer Reviews. The last review (April, 1992) involved technically evaluating about 100 guest observer proposals, providing technical expertise to the proposal reviewers during the four day review, and assisting in later stages of the evaluation and selection process.

2. One of my chief programmatic responsibilities has been to expand the capabilities of the GOF by finding and developing ways for users to perform analysis which is not yet possible under PROS/IRAF. As a result of my efforts, the Rosat IDL Library now contains procedures to

a) allow users to access, plot, and manipulate history and calibration data, from files processed by MPE as well as by the US Data Processing Center,

b) calculate HRI and PSPC point spread functions for comparison with their imaging data (these can be written to files for use in PROS/IRAF, as well as in IDL),

c) inspect the results of the SASS processing,

d) access photon events data in very large files (where all of the data cannot fit within 32 Mbytes of memory),

(continued on next page)

Additional Useful Information (continued):

- e) convert detector to sky coordinates, and
- f) calculate satellite viewing geometry for PSPC observations.

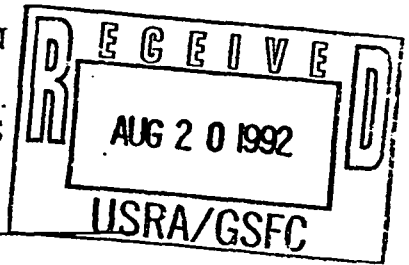
I have also implemented a parameter interface for use in higher level routines, which resembles IRAF and makes the routines easier for beginners to use. In November, I installed the Rosat IDL library on the LHEA Sun cluster, and helped to set up a tar file for distributing the IDL library through the Rosat GOF anonymous ftp account. I maintain up to date documentation in the GOF Vax and Sun libraries and ftp account, and make sure that both Vax and Sun libraries contain the most recent versions of the routines in the IDL Astronomical Users' Library. I have also written several guides to assist users who wish to use IDL in manipulating their Rosat data, and most recently have written a 30 page "cookbook" which explains the IDL procedures in detail and illustrates their use. I am now attempting to more precisely determine the positions of the wires in the grids which cover the PSPC, so that users can perform timing analysis of their data. This has proven to be a very difficult problem, and the work is still ongoing.

In addition, I am also responsible for creating a data base to be used in various trends analysis for Rosat. I am also one of several editors who will oversee the compilation of a Rosat Users' Guide, which we envision as a general users' guide to the satellite, instruments, data reduction software, and resulting data.

In November, I will present a demonstration using Rosat IDL routines at the meeting on Astronomical Software (in Cambridge, MA).

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: M. LORING Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My research for the X-ray branch of the Laboratory for High Energy Astrophysics at Goddard over the past year focussed on X-ray observations of hot plasma in two classes of astronomical objects: (1) elliptical galaxies, and (2) clusters of galaxies. While this work is not formally "programmatic", I have concentrated on using my theoretical background to develop sophisticated tools for use both in the direct analysis of data from past and future X-ray missions and in post-analysis interpretation. Among other things, this has led me to become peripherally involved in defining the scientific goals and opportunities for studying these objects with *Astro-D* and *AXAF*.

Just as 21 cm observations of extended HI disks are the most effective way of deducing the dark matter content in spiral galaxies, X-ray observations of extended hot gas halos can be used in a straightforward way to derive the amount of dark matter in elliptical galaxies under the assumption of gravitational equilibrium. In fact, it is the combination of optical and X-ray data that provide the most accurate dark matter constraints, and I have developed a synthetic method of analysis and applied it to the two galaxies that presently have the highest quality X-ray spectra. Using this method, I found that at least two-thirds of the matter in both NGC 4472 (*Astrophysical Journal*, 384, 474) and NGC 1399 (Serlemitsos *et al.* 1992, *Astrophysical Journal*, submitted) must be non-luminous. This method is directly applicable to soon-to-be-available *ROSAT* and *Astro-D* data.

Another issue of interest is the evolution of the hot ISM in elliptical galaxies. Because the mass, energy, and metals in the ISM originate in stars and supernovae, densities, temperatures, and abundances are reflections of the evolution of galactic stars and of the supernova rate. I have developed a time-dependent hydro-code to simulate the evolution of the hot gas for general self-consistent spherical stellar-plus-dark matter systems whose parameters are determined by observations of the actual galaxies to be simulated. The output includes x-ray surface brightness, gas temperature, and gas metallicity distributions that can be compared with X-ray observations to estimate the otherwise unconstrainable dark matter distribution and supernova rate. This code is currently being applied to NGC 1399, the only galaxy with sufficiently complete X-ray data, and will have wide application to observations by *Astro-D*, *ROSAT*, and other future missions.

The study of the physics of cooling flows in galaxy clusters is my other primary area of interest. My goal is to develop models as sophisticated as the X-ray spectral data will "allow" in order to extract the maximum possible physical information about the cooling flow for confrontation with various theories (all of which are somewhat controversial at the present time). Cooling flow models predict specific integrated global X-ray emission characteristics as well as specific spatial and temperature distributions of X-ray emission. I am working on constructing cooling flow models for integration into the XSPEC X-ray spectral fitting package (currently, these are modifications of models developed at the University of Cambridge Institute of Astronomy), and also on post-analysis interpretive tools to place the spectral analysis results in their theoretical context. With Drs. Mushotzky and Arnaud, I am applying these techniques to *BBXRT* cluster observations; and we have obtained preliminary results on the Perseus cluster that are consistent with a multi-phase cooling flow model.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

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Citations to some recent papers in the past year:

1. 1987: "Evolution of Hot Galactic Flows", M. Loewenstein and W. G. Mathews (ApJ,319,614): 7 citations.
  2. 1989: "Evolution of Overdense Regions In Cluster Cooling Flows," M. Loewenstein (MNRAS,238,15): 5 citations.
  3. 1990: "The Kinematics of Warm Clouds in Cooling Flows; a Case for Turbulence," M. Loewenstein and A. C. Fabian (MNRAS,242,120): 12 citations.
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Honors or Awards Received:

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Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

"Dark Matter in NGC 4472," M. Loewenstein; *Ap. J.*, 384, 474.

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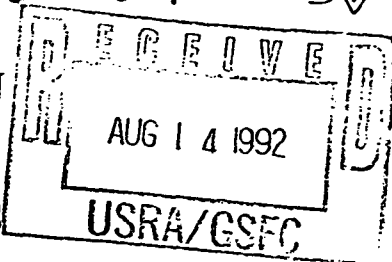


## ABSTRACT

I attempt to constrain the total mass distribution of the well-observed giant elliptical galaxy NGC 4472 by constructing simultaneous equilibrium models for the gas and stars using all available relevant optical and X-ray data. The value of  $\langle \epsilon \rangle$ , the emission-weighted average value of  $kT$ , derived from the *Ginga* spectrum -  $\langle \epsilon \rangle = 1.9 \pm 0.2$  keV (Awaki *et al.*) - can be reproduced only in hydrostatic models where nonluminous matter comprises at least 90% of the total mass. However, in general, these mass models are not consistent with observed projected stellar and globular cluster velocity dispersions at moderate radii (0.5 - 4.0). Mass models with hydrostatic gas distributions that have  $\langle \epsilon \rangle = 1.5$  keV are marginally consistent with the stellar velocity dispersion data; and I discuss how contributions to the X-ray spectrum from additional high-temperature components such as supernova bubbles, X-ray binaries, and encroaching intracluster gas may cause simple one-component analysis of X-ray spectra to systematically overestimate the true hydrostatic gas temperature. These effects, however, cannot be important enough to reduce the required amount of dark matter below 70% of the total mass; models without dark matter have  $\langle \epsilon \rangle < 0.8$  keV. If the true value of  $\langle \epsilon \rangle$  is 1.5 keV or greater, the range of dark matter distributions consistent with both X-ray and optical spectra is very small, essentially consisting of a line in the halo scale length - total mass plane, and the inferred minimum mass-to-light ratio is  $40h_{50}$  in solar units where  $h_{50}$  is the Hubble constant in units of  $50 \text{ km s}^{-1} \text{ Mpc}^{-1}$ .

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 1992 Sept 30)



Employee Name: Ian M George

Task Number: 660-030

1) General Description of 1991/92 Research Activities

In collaboration with McHardy (Southampton), Luppino (Hawaii), Abraham (Oxford) and Cooke (Leicester), we have finally finished and published a paper on the X-ray bright BL Lac object H0414+009. This work has been underway for several years, dating back to my PhD thesis days at Leicester. From detailed radio, optical and X-ray observations, it is found that H0414+009 resides in a cluster of galaxies, suggesting BL Lacs do not avoid the cluster environment as has been previously suggested. VLA observations indicate the existence of a large (220 kpc), gently bending radio jet on one side of the core, presumably due to the relativistic plasma outflow from the central engine interacting with the ambient cluster gas. Interestingly however using *EXOSAT* observations we find no evidence for X-ray emission as may be expected within such a scenario. A *ROSAT* HRI observation is planned to be submitted for AO-4.

During the period 1991 Oct 14 - 16, I attended The 2nd Annual October Astrophysics Conference in Maryland entitled "Testing the AGN Paradigm" which proved both scientifically rewarding and enjoyable. I was a co-author on a poster paper to appear in the proceedings (see below).

In collaboration with Edelson (GSFC) *et al.*, I submitted an *IUE* proposal to intensively monitor the BL Lac objects Mkn 421 and OJ 287 simultaneously in all wavebands. This follows from a highly successful similar campaign on PKS 2155-304 carried out in 1991 Oct, the data from which I am helping to collate and interpret (see below). Observing time was awarded to this project and detailed planning of the co-ordinated observations (to be performed early in 1993) is underway.

In collaboration with Owens (GSFC), Nandra & Sembay (Leicester), and Ward (Oxford), I submitted a *GRO* OSSE proposal to observe 2 Seyfert galaxies and a narrow line radio galaxy. Unfortunately this proposal was not awarded time in the fierce competition for *GRO* time. I am anticipating submitting a similar proposal in the next AO round.

In collaboration with numerous other workers both inside GSFC and elsewhere, I played a part in the submission of 10 proposals for *ROSAT* AO-3 time. Happily, the following proposals for which I was Principle Investigator were awarded observing time:

1. *Completion of the ROSAT soft X-ray survey of Piccinotti AGN*  
George, Turner, White, Nandra & Fabian  
6 objects (25.8 ksec) priority A, 3 targets (39.4 ksec) priority C

2. *Monitoring the variable soft X-ray excess in the Seyfert galaxy Mkn841*  
George, Turner, Shrader, Sun & Fabian  
1 object (18 ksec) time-critical priority B.
3. *Long term spectral monitoring of X-ray bright BL Lac objects*  
George, Edelson & Rhode  
1 object (10 ksec) priority A, 2 objects (20 ksec) priority C.

These proposals resulted in a total funding of 30 000 dollars, and a number of the observational datasets recently recieved.

In collaboration with Turner (GSFC), Fabian & Celotti (IoA), Sembay & Warwick (Leicester) I have almost finished the analysis of a *ROSAT* AO-2 observation of the BL Lac object 4U1427, performed at the beginning of the year. Detailed data analysis has revealed a complex spectrum, with evidence for *either* an absorption feature, *or* an emission feature superimposed on the underlying power-law (!). When parameterized by an absorption edge, it's energy is  $\sim 0.3$  keV, *i.e.* leading to a tentative indentification as a carbon *K*-shell feature, and exciting astrophysical implications. However, unfortunately the window of the PSPC detector contains a polypropylene substrate, and the detector itself contains methane. Thus a less dramatic, but more likely, possibility is that the feature is the result of a mis-calibration of the detector. This clearly has important consequences for the spectral analysis of all PSPC data, and hence is the subject of intestive investigation by myself and the *ROSAT* GOF (primarily Jane Turner) at GSFC. Such activities obviously contain a large (and useful) overlap with my programatic responsibilities. Parameterization of the spectral feature as an emission line leads to the interesting possibility that hot ( $\sim 10^8$  K) X-ray emission from the host galaxy has been detected. It is hoped that a paper containing these results will be submitted for publication within the next few months.

In collaboration with Urry (STScI) and many others, I have played a part in the interpretation of an intensive multi-waveband campaign (involving many workers from all over the globe) to monitor the BL Lac object PKS 2155-304 carried out in 1991 Oct. A paper reporting a preliminary analysis of (initially) the *IUE* data (only) is currently being prepared for publication. It is anticipated that further interpretational work will be carried out and reported in the near future.

In collaboration with Nandra & Fabian (IoA), Turner & Day (GSFC), and Done (Leicester) I have completed a detailed spectral analysis of 5 X-ray observations of the luminous Seyfert galaxy Mkn 841, and the results have been accepted for publication. We find dramatic spectral variability is apparent in both the soft ( $\lesssim 1$  keV) and hard X-ray bands, with variations in the apparent photon index of  $\Delta\Gamma \sim 0.6$ . Furthermore a number of the observations contain an intense iron K-shell emission line. This lead us to conclude that the line and spectral variability may arise as the result of time-dependent X-ray illumination of cold material surrounding the source.

In collaboration with Nandra & Fabian (IoA), Turner (GSFC) and many other workers, a paper has been accepted for publication reporting the results from a *ROSAT* PVC-phase PSPC observation of the Seyfert galaxy NGC 5548. The most interesting aspect of these results is that the spectrum of this AGN was found to be particularly complex, with a two component model favoured. The presence of a "soft excess" was confirmed in the source, but an absorption

feature probably arising from highly ionized oxygen in the line-of-sight was also detected. Such a feature is consistent with an origin within a "warm absorber" which has been hypothesized to be common in other AGN within the Syfert class. The energy and depth of the feature allow constraints to be placed of the density and geometry of the gas lying close to the central AGN "powerhouse". A number of interesting sources serendipitously detected within the PSPC 2° field-of-view were also discussed.

During the period 1992 Jul 16 – 22, I attended The 33rd Herstmonceux Conference held at the IoA & RGO, Cambridge, UK entitled "The Nature of Compact Objects in AGN". My contribution to the meeting was the presentation of a poster which will also appear in the proceedings (see below). The meeting centred around discussions of multiwaveband observations and interpretation of Active Galactic Nuclei (AGN). In particular the programme was designed to address whether the fundamental power source in these objects can be explained by the emission from starbursts and/or supernovae in a very dense medium. Such a scenario contrasts dramatically from the 'standard' supermassive black hole paradigm which has been adopted by most workers for the last few decades. I (and most other X-ray astronomers) strongly believe that X- &  $\gamma$ -ray observations play a key role in this debate, and strongly support black hole models. Excellent talks to this effect were given by Turner, Fabian & Papadakis. Following the meeting I stayed in Cambridge for 3 days in order to work on a number of programatic and scientific collaborations with members of the IoA X-ray group.

In collaboration with Turner & Mushotzky (GSFC) I have recently completed the analysis and submitted the results for publication of ROSAT PSPC (AO-2) observations of 6 Seyfert-1 galaxies. We confirmed that all the sources pocesses a steeper spectral index in the soft X-ray band ( $\lesssim 1$  keV) than that observed at higher energies (the well-known "soft excesses" found in  $\sim 50\%$  of all Seyferts). However, we also found evidence for spectral features in 3 of the sources. Despite some uncertainties in the spectral calibration of the PSPC (see above), we suggest that these are due to line emission and absorption features as has been proposed to exist from theoretical calculations by other workers. Furthermore, given such features, we point out that that Seyfert galaxies provide a class of object whose spectra are very similar to the diffuse X-ray background in the soft X-ray band. This provides the first direct evidence that the sources which dominate the background differ as a function of energy.

### Recognition of Research Activities

*Cumulative number of citations (as of 1992 Dec):*

George, Warwick & Bromage (1987) ( <i>conf proc</i> )	3
George (1988) ( <i>conf proc</i> )	3
George, Warwick & Bromage (1988)	18
George, Warwick & Bromage (1988) ( <i>conf proc</i> )	3
George, Wawick & McHardy (1988)	3
George (1998) ( <i>PhD Thesis</i> )	1
George <i>et al.</i> (1989) ( <i>conf proc</i> )	1
George, Nandra & Fabian (1990)	13
George & Eabian (1991)	9

## Honors/Awards Received

None

## 2) Papers Published/Accepted (in year ending 1992 Sept 30)

(Abstracts Attached)

### *Refereed Journals:*

1. H0414+009 – An X-ray bright BL Lac Object with a Radio Trail in a Distant Cluster of Galaxies.  
McHardy, I.M., Luppino, G.A., George, I.M., Abraham, R.G. & Cooke, B.A.  
1992, *Mon. Not. R. astr. Soc.*, 256, 655.
2. The role of Electron-Positron Pairs in Parsec-scale Radio Jets  
Ghisellini, G., Celotti, A., George, I.M. & Fabian, A.C.,  
1992. *Mon. Not. R. astr. Soc.*, in press.
3. The Broad-Band X-ray Spectral Variability of Mkn 841  
George, I.M., Nandra, K., Fabian, A.C., Turner, T.J., Done, C. & Day, C.S.R.,  
1992. *Mon. Not. R. astr. Soc.*, in press.
4. The X-ray Spectral Variability of the BL Lacertae type object PKS 2155-304  
Sembay, S., Warwick, R.S., Urry, C.M., Sokoloski, J., George, I.M.,  
Makino, F. & Ohasji, T.,  
1992. *Astrophys. J.*, in press.
5. A ROSAT Observation of NGC 5548  
Nandra, K., Fabian, A.C., George, I.M., Branduardi-Raymont, G., Lawrence, A.,  
Mason, K.O., McHardy, I.M., Pounds, K.A., Stewart, G.C., Ward, M.J. & Warwick, R.S.,  
1992. *Mon. Not. R. astr. Soc.*, in press.

### *Non-Refereed Journals, Conference Proceedings etc:*

1. Time-Dependent Inhomogeneous Jet Models for BL Lac Objects.  
Marlowe, A.T., Urry, C.M. & George, I.M.,  
1992. In *Testing the AGN Paradigm*,  
eds. Holt, S.S., Neff, S.J. & Urry, C.M., AIP Conference Proceedings 254, p447.
2. The Dramatic X-ray Spectral Variability of Mkn 841  
George, I.M., Nandra, K., Fabian, A.C., Turner, T.J., Done, C. & Day, C.S.R.,  
1992, in *Proc. of 33rd Herstmonceux Conference on "The Nature of Compact Objects in AGN"*, to be submitted.

*Other Articles:* None

## 3) Papers Submitted, not yet accepted by Refereed Journals

1. *ROSAT* PSPC Spectra of Six Seyfert 1 Galaxies  
Turner, T.J., George, I.M. & Mushotzky, R.F.,  
1992. *Mon. Not. R. astr. Soc.*, submitted.

4) Oral Papers Presented at Scientific Meetings:

*Invited Oral Papers:* None

*Contributed Oral Papers:* None

*Colloquia, Seminars & Special Lectures:* None

5) Community Service:

None

6) 1990/91 University Collaborations:

*Research Collaborator(s) & Activities:* (not included in 1) above) None

7) Other (non-university) Collaborations: (not included in 1) or 6) above)

None

8) Additional Information:

None

## H0414 + 009 – an X-ray bright BL Lac with a radio tail in a distant cluster of galaxies

I. M. McHardy,<sup>1</sup>\*† G. A. Luppino,<sup>2</sup>‡ I. M. George,<sup>3</sup>\*§ R. G. Abraham<sup>4</sup>¶ and B. A. Cooke<sup>5</sup>†

<sup>1</sup>Department of Physics, University of Southampton, Southampton SO9 5NH

<sup>2</sup>Institute for Astronomy, University of Hawaii, Honolulu, Hawaii 96822, USA

<sup>3</sup>Institute of Astronomy, Madingley Road, Cambridge CB3 0HA

<sup>4</sup>Department of Astrophysics, University of Oxford, Oxford OX1 3RH

<sup>5</sup>Department of Physics, University of Leicester, Leicester LE1 7RH

Accepted 1992 January 6. Received 1991 November 21

### SUMMARY

VLA observations of the X-ray selected BL Lac H0414 + 009 at 6, 20 and 90 cm show that it has a steep-spectrum ( $\alpha \approx 1$ ;  $f_\nu \propto \nu^{-\alpha}$ ) radio tail. The tail extends  $\sim 40$  arcsec from the core, in a gentle curve. There is no evidence of extended emission on the opposite side of the core. This is by far the clearest example of a single-sided radio tail associated with a BL Lac source. The low radio luminosity ( $1.6 \times 10^{25}$  W Hz<sup>-1</sup> at 20 cm for  $H_0 = 50$  km s<sup>-1</sup> Mpc<sup>-1</sup> and  $q_0 = 1/2$  at  $z = 0.287$ ) and morphology of the extended emission strengthens the proposed association of BL Lacs with Fanaroff–Riley type I (FR I) radio sources.

Deep  $V$ ,  $R$  and  $I$  CCD images show that the BL Lac is located in a galaxy whose surface brightness and colours are best fitted by an elliptical model with absolute total magnitude  $M_r = -23.53$ . The elliptical host galaxy is the brightest of a poor cluster. We confirm the recently published redshift ( $z = 0.287$ ) for the BL Lac and find similar redshifts for five of the surrounding, faint galaxies, supporting the conclusion that the BL Lac and the cluster are physically associated and are not merely a chance superposition. We conclude, contrary to earlier suggestions, that BL Lacs do not avoid the cluster environment but are found in groups and clusters just as often as are normal radio galaxies, consistent with the hypothesis that BL Lacs are simply normal radio galaxies seen ‘end-on’.

The appearance of the cluster is striking, containing a number of ‘twin’ galaxy pairs. It has been suggested that the pairs could be the result of gravitational lensing by a foreground cosmic string, but our observations do not support this hypothesis.

We have analysed the cluster properties and present  $VRI$  CCD photometry for 108 galaxies fainter than the BL Lac host galaxy in the CCD images ( $1.1 \times 1.2$  Mpc<sup>2</sup>). In the Bautz–Morgan morphological classification scheme we classify this cluster as BM I. The cluster could be as rich as Abell class 0, however, the richness may be lower due to considerable uncertainties in the corrections for the field galaxy background and the small field of view of the CCD.

We have searched deep *EXOSAT* images for evidence of extended X-ray emission from a hot intracluster medium, but find none. The upper limit to the luminosity of

\* Visiting Astronomer, Very Large Array (VLA), National Radio Astronomy Observatories, operated by AURA under contract with the National Science Foundation.

† Observer, 2.4-m telescope, Michigan–Dartmouth–MIT (MDM) Observatory.

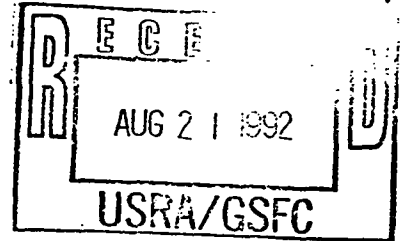
‡ Visiting Astronomer, KPNO 4-m telescope, National Optical Astronomy Observatories, operated by AURA under contract with the National Science Foundation.

§ Present Address: Laboratory for High Energy Astrophysics, Code 668, NASA/Goddard Space Flight Center, Greenbelt, MD 20771, USA.

¶ Present Address: Dominion Astrophysical Observatory, National Research Council of Canada, Herzberg Institute of Astrophysics, 5071 West Saanich Road, Victoria, BC, V8X 4M6, Canada.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: William D. Pence Task Number: 5000-628

General Description of Your Research Activities: (Include a Paragraph on each Activity).

**FITSIO:** One of my main accomplishments this year was to continue to improve my FITSIO software package for reading and writing data files in FITS (Flexible Image Transport System) format. FITS is the primary data format used in astronomical data analysis, and FITSIO has become the defacto software standard for accessing these files. The FITSIO package has grown to more than 20,000 lines of code in more than 250 subroutines and has been ported to run on more than half a dozen of the most widely used operating systems (computers) used by astronomers. The FITSIO software has been copied and used by programmers at hundreds of computer sites around the world, including many of the current NASA astronomy missions. I released two major and one minor update to the FITSIO package this year: version 3.10 (4 November 1991), version 3.20 (30 March 1992) and version 3.21 (8 July 1992). Most recently I have just about finished both a C-language and an SPP-language (used by the IRAF data analysis system) version of FITSIO. These 2 new dialects of FITSIO will make the package available to programmers using any of the 3 main programming languages used in astronomy.

**CDROMS:** This year marked the completion of a long project to convert archival X-ray data sets from the Einstein SSS, MPC, and FPCS instruments into FITS format. I managed this CDROM production project, which involve designing the new FITS formats for the data, converting the data to FITS, collecting and writing the documentation, copying the data to the CDROM pre-master tape, and then working with the outside contractor which produced the actual CDROM disks.

Many other people contributed to this effort, most notably USRA astronomer Steve Drake and STX employees Bruce O'Neel, Kent Blackburn, and Karen Smale. About 150 copies of the CDROM were distributed at the June AAS meeting in Columbus, Ohio. As well as providing useful X-Ray data in a very convenient format, the CDROM also served as an inexpensive way to advertise and promote the services provided by the HEASARC.

**FITS 'SELECTOR' SOFTWARE DEVELOPMENT:** The project which has taken up most of my time this year has been to provide the technical and managerial leadership for the task of developing the software to process the data from the Astro-D spacecraft, which is to be launched in Japan in February 1993. This project involves directing the efforts of 3 STX programmers and coordinating their work with that being done by other STX and USRA programmers and scientists in the OGIP. As well as directing the project, I have also written a significant fraction of the software. This software uses the FITSIO package to access the FITS files, and will provide a modular set of software tools for processing any FITS format file. Thus, the software will be useful for processing datasets from other past or future missions, not just Astro-D. This project has also required that I travel to Japan on 2 occasions to meet with our Japanese counterparts on the status of the project.

**CONVERSION OF ARCHIVAL DATA TO FITS FORMAT:** One of the main responsibilities of the HEASARC is to convert archival data into FITS format to make it more widely accessible to researchers. I have played a leading role in designing the new FITS formats for many data sets, include those from ROSAT, Einstein, EXOSAT, GRO and other experiments. In the process, I have been helping to define more general FITS format standards for different types of data (e.g., spectra,



## Activities (cont.)

or lightcurves) to bring some homogeneity to the current bewildering chaos of different data formats within high-energy astrophysics. The eventual goal of this work is to develop general format standards which can be used by the whole high-energy astrophysics community.

**ROSAT OBSERVING PROPOSALS:** In collaboration with Arnold Rots, I submitted 2 observing proposals for cycle 3 of ROSAT observing time to observe gravitationally interacting galaxies and their effect on the intercluster gas. One of our proposals was awarded observing time, and we expect to begin analysing the data once it is obtained within the next year.

**MEETINGS:** During the year I contributed to many meetings on astronomical data analysis and related topics. At most of the meetings I presented a paper describing the various FITS related activities going on at the HEASARC. Some of the main meetings that I attended were:

- 6-8 November 1991: The "Astronomical Data Analysis Software and Systems" conference in Tucson, Arizona.
- 30-31 January 1992: 2nd Astro-D software team meeting in Tokyo, Japan
- 14-15 April 1992: "User Interfaces in Astronomy", GSFC
- 8-11 June 1992: the American Astronomical Society meeting in Columbus, OH
- 18 June 1992: the Astrophysical Data System (ADS) users meeting held near the BWI airport

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

The FITSIO package has become the international standard for software to access FITS format files. I typically receive 2 - 3 mail messages each week from new users of the package who either have questions about it or compliment me for making it available. This package is being used by many major NASA projects (COBE, GRO, ROSAT) as well as other smaller projects and has no doubt saved many hours of programmer time for groups needing to deal with FITS format files.

Honors or Awards Received:

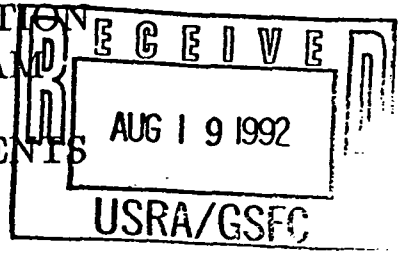
None

Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

None

660-029 54

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 1992 Sept 30)

Employee Name: Stephen A. Drake

Task Number: 5000-629

1) General Description of 1991/92 Research Activities

Since starting with USRA in January 1991, I have been working on a number of research projects using various instruments (ROSAT, VLA, Einstein IPC and SSS, etc.), some of which are continuations of collaborations predating my USRA employemnt, while others are new starts.

I completed a study with Ted Simon (U. Hawaii) and Jeff Linsky (U. Colorado) of the radio and X-ray properties of RS CVn binary stars that culminated in a paper published in the September 1992 issue of Ap. J. Suppl. (hereafter ApJS). We confirmed the radio versus X-ray emissions correlation that we first presented in our 1989 ApJS paper, and discussed various scenarios as to the origin of the radio emission. In the course of this study, I used the HEASARC database to examine the new IPC Slew Catalog at the positions of several hundred active stars to find those that were serendipitously detected.

I and Nick White (GSFC) have been studying the *Einstein* Solid State Spectrometer (SSS) spectrum of the nearby active binary system Capella. This new study supersedes that done over a decade ago, making use of the improved understanding of the instrument's characteristics and the way that the build-up of ice on the detector window affected the observed spectrum. We now find that it is impossible to fit the spectrum of the relatively soft X-ray source associated with this binary using the standard 2-thermal component model *and* a realistic value for the (low) interstellar column density towards Capella. That this is not an instrumental artifact has been demonstrated by the fact that the Broad-Band X-Ray Telescope (BBXRT) spectrum of Capella is similarly ill-fit by such a model (Mike Corcoran (USRA), private communication). We are exploring various explanations for this failure of such models to fit the data, such as that the corona of Capella exhibits abundance peculiarities relative to its photosphere that are similar (or perhaps even more extreme) to those seen in the Sun, or that there are deficiencies in the plasma codes' atomic physics in the 0.4 to 1.0 KeV region.

I have been working with Jeff Linsky and Tim Bastian (NRAO) on a study of the radio emission properties of magnetic Bp and Ap stars, and with Linsky and Jurgen Schmitt (MPE) on the X-ray properties of these same stars using ROSAT data (both All-Sky Survey (RASS) and pointed observations). A paper discussing all of our radio data on 61 such stars that had been obtained prior to 1992 has just been published in Ap.J. (v. 393, 341). This paper also presented a magnetospheric model to explain the observed radio emission which predicts roughly the observed dependence of radio emission on mass loss rate, magnetic field strength, and rotation rate. I have additional VLA and Australia Telescope Compact Array (ATCA) data on about 48 more magnetic Bp stars that were obtained in early 1992. To date, I have found an additional 7-11

radio-emitters that were previously not known, and the final sample of 110 radio-observed stars should have about 24 to 28 new detections. A paper discussing the RASS X-ray observations of these stars has been submitted to Ap. J. Letts. (ApJL hereafter), and is in the process of being revised: it presents evidence that the same types of magnetic stars that are strong radio emitters (the Helium-Weak and Silicon-Strong subclasses) are also a new class of X-ray emitting stars. Two pointed ROSAT observations of 2 of these stars are presently also being analyzed.

I have submitted to ApJ a paper (co-authored with Ted Simon (U. Hawaii) and Alex Brown (U. Colo)) that describes our results from a very deep (more than 9 hours total on-source time) X-band observation of Procyon, a nearby F dwarf star. Summing all but our first 1 hour observation of this star, we detect it at a level of  $33 \pm 8 \mu\text{Jy}$  which is almost exactly what is predicted to be emitted (thermally) by its chromosphere and corona. This detection is the weakest VLA detection of any stellar source to the best of my knowledge. The first 1-hour observation of Procyon a week earlier found it to be a  $115 \pm 28 \mu\text{Jy}$  radio source, consistent with either a radio flare or the rotation onto the disc of a plage-like region of enhanced radio brightness temperature. Our 'quiescent' radio detection constrains the ionized mass loss rate of any stellar wind from Procyon to be  $\leq 2 \times 10^{-11}$  solar masses per year.

I have had 43.5 hours of observing time on the National Radio Astronomy Observatory (NRAO) Very Large Array in nine separate segments in the first six months of 1992, and 32 hours of observing time in one piece on the ATCA. The observational sequences were set up and executed remotely. I reduced the bulk of these data (and some previously unanalyzed data obtained in 1991) in the course of 2 trips to NRAO Headquarters in Charlottesville, VA in December 1991 and August 1992. Some 18.5 hours of VLA time and 32 hours of ATCA time were devoted to the observations of magnetic Bp stars discussed above. 21 hours of VLA time were devoted to a joint ROSAT/VLA program to study X-ray emitting Algol systems, including the prototype. The data obtained during this program (a collaboration of myself, Nick White and Frank Marshall (GSFC), Lorella Angelini (USRA), and Steve Pravdo (JPL)) are presently being analyzed. The final 4 hours of VLA time were 'spare time' given to me by Barry Clark (NRAO) which I used to look at miscellaneous stars from several programs.

I attended the 7th Cambridge Cool Stars Workshop held in Tucson, AZ from the 9th to the 12th of October 1991, and gave two poster papers. I wrote up the poster about a 4-year monitoring program of the radio emission from the M supergiant  $\alpha$  Orionis, and it has just been published in the proceedings of the Workshop. Our failure to detect any enhancements significantly more than the noise in the radio flux of this massive star over the course of 50 or more separate observations casts grave doubts on the reality of claimed single-dish massive (Jansky level) flares of this star that were published in the 1960's and 1970's. The only type of variability found was in the form of drops of up to 40% of the typical radio flux of this star that may indicate that the extended, radio-emitting chromosphere of this star is subject to an instability known as the molecular catastrophe.

I attended the G.S. Vaiana Memorial Symposium on Advances in Stellar and Solar Coronal Physics held in Palermo, Italy from the 22nd through the 26th of June, 1992. I gave an invited review talk on Radio Emission from Coronal Stars.

My programmatic responsibilities primarily involved the Einstein SSS and Monitor Proportional Counter (MPC) databases.

I spent a considerable fraction of my time working on getting the Einstein Solid State Spectrometer (SSS) data into shape, prior to its release on CD-ROM. About 50 of the 632 SSS observations in the then current version of the SSS database contained anomalies such as spikes, dropouts, and/or mode change-related artifacts. I used the SSS software package on the NSSDC's IBM computer and the complete original SSS data resident on the so-called HME tapes to re-extract these contaminated observations with time filters set so as to exclude the bad data. After these 'cleaned' lightcurves and spectra were created on the IBM, they were copied to the HEASARC's Vax computer, where they were processed through the same software pipeline that I had used previously to create this database in 1991, with the end product being spectra in XSPEC format and lightcurves in XRONOS format. In those cases where it was necessary I also created new 'associated' MPC spectra and lightcurves for the revised SSS observations. As part of the documentation for the SSS database on the CD-ROM, I wrote an explanation of the process which created these files, and provided a table of cross-identifications for all of the SSS targets. I renamed all of the SSS targets using a standard naming convention, whenever possible, that adhered to the IAU guidelines for astronomical names. I also improved the HEASARC classifications for many of the targets. In addition, I updated the file describing the SSS data resident in the HEASARC database, and wrote an article for LEGACY that described how to access, extract, and do science with the SSS data.

The Einstein MPC data have basically been unavailable to the general community for the last decade, except for about 10% of the observations, those made simultaneously with the SSS, which are available in a lower than the original time-resolution format as an associated data product of the SSS database on the HEASARC. In July through September 1992, I created a new MPC database with the same time resolution as that already created for the SSS database, but for all 5659 EINSTEIN observational sequences (most sequences consist of a single EINSTEIN observation, but about 10 - 15 % consist of concatenated multiple observations). This process involved multistep processing, usually making use of scripts, beginning with pCHIP, Keith Arnaud's MPC analysis software, and culminating with the generation for each Einstein Sequence of (a) an MPC source spectrum, (b) an MPC background spectrum, (c) a background-corrected MPC lightcurve for the full 2 - 20 keV energy range of the instrument, and (d) background-corrected MPC lightcurves for 4 individual channel pairs of this 8 channel proportional counter.

For the ROSAT AO3 Guest Investigator Program, I submitted two proposals as Principal Investigator, and, in addition, I was listed as a Co-Investigator on 5 other proposals. Happily, both proposals for which I was PI were awarded observing time:

1. *X-Ray Observations of Selected RS CVn Stars: What Factors Determine their X-Ray Emission?*  
Drake, White, Simon, Linsky & Dempsey  
2 objects (23.4 ksec) priority B, 4 targets (47.7 ksec) priority C
2. *A New Class of Soft X-ray Source: Magnetic Bp Stars*  
Drake, Linsky, Lim, Bookbinder, Schmitt & Fleming  
4 objects (37.5 ksec) priority A, 2 targets (19.5 ksec) priority C

These proposals resulted in a total funding of 22,084 dollars to USRA

Two of the 5 AO3 proposals of which I was Co-I received observing time: the first written by

Ted Simon (U. Hawaii) to observe A and F stars was awarded 6 priority A targets and 1 priority C target, and the second written by Mike Corcoran (USRA) was awarded 1 priority C target.

In addition to the ROSAT proposals, I wrote 5 VLA proposals in the period covered by this report. One was awarded 21 hours of VLA time (to observe Algol binaries near-simultaneously with ROSAT observations of these systems) in February 1992 and the other 4 proposals were to be reviewed in September 1992.

Describe Any Significant Recognition of Your Work:

*Papers refereed:*

I served as referee for 2 papers (one submitted to Astrophysical Journal, the other to Astronomical Journal) in the period covered by this report.

*Peer Review Panels served on:*

I served as a reviewer for the GRO Guest Investigator Program Proposal Reviews that were held in Greenbelt in February, 1992, and will be serving as a reviewer for the EUVE GIP reviews to be held in October 1992.

*Cumulative number of citations (from Science Citation Index for the calendar years 1985 through 1991 inclusive) for selected articles of which I was the first author, and excluding self-citations:*

Drake & Ulrich (1980): 43 citations.

Drake & Linsky (1983a) [ApJ, 273, 299.]: 11 citations.

Drake & Linsky (1983b) [ApJL, 274, L77.]: 12 citations.

Drake, Brown & Linsky (1984a) [ApJ, 284, 774.]: 13 citations.

Drake, Simon & Linsky (1985): 10 citations.

Drake (1985): 15 citations.

Drake & Linsky (1986a) [AJ, 91, 602]: 29 citations.

Drake, Simon & Linsky (1986): 17 citations.

Drake, Abbott, Bastian, Biegging, Churchwell, Dulk & Linsky (1987): 25 citations.

Drake, Simon & Linsky (1989): 10 citations.

Total number of citations of articles of which I was the first author in 7 calendar years 1985 - 1991: 223.

Average number of citations per year: 32

## Honors/Awards Received

None

## 2) Papers Published/Accepted (in year ending 1992 Sept 30)

(Abstracts Attached)

### *Refereed Journals:*

1. **Radio Emission from Chemically Peculiar Stars.**  
Linsky, J.L. [U. Colo], Drake, S.A., & Bastian, T.S. [NRAO]  
1992, *ApJ*, 393, 341.
2. **Radio Continuum and X-Ray Properties of the Coronae of RS Canum Venaticorum and Related Active Binary Systems.**  
Drake, S.A., Simon, T. [U. Hawaii], & Linsky, J.L. [U. Colo]  
1992. *ApJSupp*, in press.

### *Non-Refereed Journals, Conference Proceedings etc:*

1. **The Class of Radio-Emitting Magnetic Bp Stars and a Wind-Fed Magnetosphere Model.**  
Linsky, J.L. [U. Colo], Drake, S.A., & Bastian, T.S. [NRAO]  
1992. In *Cool Stars, Stellar Systems, and the Sun: Proceedings of the Seventh Cambridge Workshop*,  
eds. Giampapa, M.S. & Bookbinder, J.A., ASP Conference Series, Vol. 26, p. 325.
2. **Four Years of Monitoring  $\alpha$  Orionis: Where Have All the Flares Gone?**  
Drake, S.A., Bookbinder, J.A. [SAO], Florkowski, D.R. [USNO], Linsky, J.L. [U. Colo.],  
Simon, T. [U. Hawaii] & Stencel, R.E. [U. Colo.]  
1992. In *Cool Stars, Stellar Systems, and the Sun: Proceedings of the Seventh Cambridge Workshop*,  
eds. Giampapa, M.S. & Bookbinder, J.A., ASP Conference Series, Vol. 26, p. 455.
3. **Radio Emission from Coronal Stars.**  
Drake, S.A.  
1992. In *Advances in Stellar and Solar Coronal Physics: G.S. Vaiana Memorial Symposium*,  
eds. Linsky, J.L. & Serio, S., in press.

## 3) Papers Submitted, not yet accepted by Refereed Journals

(Preprints Attached)

1. **Detection of Radio Continuum Emission from Procyon,**  
Drake, S.A., Simon, T. [U. Hawaii], and Brown, A. [U. Colo],  
1992. *ApJ*, submitted.

2. **X-Ray Emission from Chemically Peculiar Stars**,  
Drake, S.A., Linsky, J.L. [U. Colo], Schmitt, J.H.M.M. [MPE] & Rosso, C. [MPE],  
1992. *ApJL*ets, submitted.

**4) Oral Papers Presented at Scientific Meetings:**

*Invited Oral Papers:*

1. **Radio Emission from Coronal Stars**, an invited review talk at the Vaiana Memorial Symposium [See above].

*Contributed Oral Papers:* None

*Colloquia, Seminars & Special Lectures:* None

**5) Community Service:**

As described above, I have served as referee for 2 papers submitted to the journals in the last year, and have served on 2 Peer Review Panels.

**6) 1990/91 University Collaborations:**

*Research Collaborator(s) & Activities:* (not included in 1) above)

I have been participating as Co-investigator on projects initiated by members of the University of Maryland: e.g., an ATCA proposal written by Stephen White to observe the  $\eta$  Carinae region with high spatial resolution at radio wavelengths, and a VLA proposal written by Jeremy Lim to re-observe some of the magnetic Bp stars that I discovered were radio emitters so as to search for dependence of their radio emission on their rotational phase. I am also a Co-I on an active NSF proposal spearheaded by Alex Brown of the University of Colorado to support travel to and research on the Australia Telescope.

**7) Other (non-university) Collaborations:** (not included in 1) or 6) above)

I am collaborating with Dr. Joseph Gurman (Code 680, GSFC) on an active Solar Maximum Mission Guest Investigator Program to model the solar umbral Magnesium II resonance lines as observed by the Ultraviolet Spectrometer on SMM using a radiative transfer code that includes partial frequency redistribution effects.

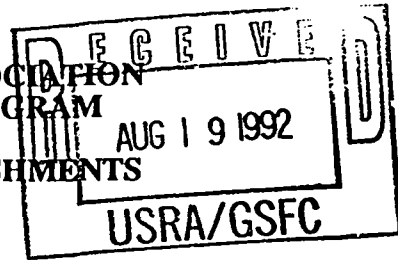
**8) Additional Information:**

None



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



**Employee Name:** Laura A. Whitlock      **Task Number:** 5000 - 630

**General Description of Your Research Activities: (Include a paragraph on each activity).**

I am processing into HEASARC the data from the all-sky monitors aboard Vela 5B, Ariel 5, and the GRO BATSE experiment. (I am also pursuing the gamma-ray spectrometer data from HEAO 3.) In the time I have been with USRA, the software to convert the Ariel 5 lightcurves for ~ 80 sources into FITS format was written (by Kathy Rhode of STX), tested, and the conversion begun. These files should be online by the end of September. I generated a list of sources which would be alone in the 6° x 6° field-of-view of the Vela 5B detector and the lightcurves for these ~35 sources are now being extracted using software written for that purpose. Extraction of these lightcurves will be completed by 1 September. Software similar to that written for Ariel 5 will be used to convert these data files into FITS format and the resulting files should be online in November. The software to do 2-D fits to areas of the sky containing more than 1 X-ray source is under development and testing. The one remaining problem with the function of the code, as it stands now, is the possibility that the algorithm introduces long-period modulations into the lightcurves of the fitted sources. I expect this problem to be resolved and the processing of the 2-D maps to begin in soon.

Meanwhile, analysis of the Vela 5B data for some of the so-called "single" sources is underway. Sources I am looking at include SMC X-1, Vela X-1, and GX301-2. Much to my surprise, the 3.9 day period of SMC X-1 popped out of the data. It is very low-level and requires some "intelligent manipulation", based on *ad hoc* knowledge of how the Vela data respond to standard analysis techniques to see it, but it is there. I expect to collaborate on a paper about this source with Jim Lochner (USRA). The analysis of Vela X-1 is much easier due to a stronger signal. Both the pulse and orbital periods are readily evident. Hopefully, I will be able to correlate the source intensity or orbital lightcurve to the spin ups and downs seen in the pulse period over the ten years. It is not clear to me yet how many observational sequences in the data set will allow this type of analysis and so whether or not I'll have enough data points from which to draw a conclusion is unknown. There is hope, though, since data coverage of Vela X-1 is good. I am updating work I did, but never published, on GX301-2 to include an application of the Vela 5B data to a model suggested earlier this year for this source. The model attempts to explain the predominance of X-ray luminosity maxima at orbital phases before periastron. Consequences of the model at other orbital phases should be visible in the Vela 5B data, if they exist. This will make a nice inclusion in the paper on my analysis of the ten-year lightcurve.

I am continuing my collaboration with Jim Imamura (U. Oregon), John Middleditch (LANL), and Tom Steiman-Cameron (NASA/Ames) to observe millisecond variations in the optical emissions of white dwarf stars and potential pulsars. Statistics from our 1990 and 1991 data on VV Puppis proved to be too poor to draw firm conclusions on the interesting behavior we saw in that source. Yet, they were good enough to inspire us to propose to go back to CTIO and make additional observations. We should hear soon if we were granted simultaneous time on the 1.0 and 1.5 m telescopes at CTIO this winter.

I, in collaboration with Charles Simon and Penny Haskins (SAL/ISST), have proposed to the DoD to perform some experiments to parameterize the effects of particles impacting on a sensor system surface. This is part of the development and validation of the PEARLSS simulation of contamination effects on sensor performance I developed at Nichols Research.

## **PEARLSS, A Model for Contamination Effects : Description and Results**

Laura A. Whitlock and John Larkin Jackson

### **ABSTRACT**

A method has been developed which allows optical system designers to determine the effects at the focal plane from noise generated due to contamination in a sensor's near field-of-view and deposited on system mirrors. This method is embodied in the PEARLSS code, which allows an 'end to end' simulation of contamination generation, transport, deposition, and the resulting performance degradation for spaceborne optical systems. The code is constructed in such a way as to allow trade studies over parameters such as system materials, dimensions, operating temperatures and wavebands, pointing directions, orbital locations, and ground-processing cleanliness levels. PEARLSS outputs include a 2-D map of the scattered/emitted noise at the first mirror, the BRDF there due to particle deposition, and a map of the structured noise on the focal plane of the sensor system. All of these outputs are generated as functions of time. A simple test case is run through the code to demonstrate its various capabilities.

## **4BOUNCE and VBOUNCE: Models for the Study of Contamination Transport and Dynamics**

Laura A. Whitlock, Lori B. Glasgow, and John Larkin Jackson

### **ABSTRACT**

Once a particle is released into the telescope field-of-view, regardless of the phenomena responsible for dislodging it from the surface, it will move through the baffle tube volume until it either leaves the open end of the tube or strikes another surface. Upon impact with a surface the particle will either stick to it or rebound at some angle and with some associated energy loss. 4BOUNCE and VBOUNCE are codes which model contamination transport in spaceborne sensors. 4BOUNCE is a fast-running code which uses a smooth cylinder and parameterizes the effects of baffle vanes. VBOUNCE models all surfaces explicitly, including vanes. Both models are intended to track particles of various materials, mass and velocity combinations as they bounce within a sensor. Trade studies were made to identify the important parameters based on the output sensitivity to the varied parameter. The results of interest for contamination impact on sensor performance is the fraction of particles remaining within the sensor view as a function of time and mass.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

660-031 S↓

RECEIVED
AUG 21 1992
660-03 USRA/GSFC

Employee Name: KEVIN BLACK Task Number: 660-03 USRA/GSFC

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My research activities this year have almost exclusively been confined to developing detectors, flight electronics, and flight software for the MOXE experiment and its interfaces to the Spectrum-X-Gamma spacecraft and ground station. Toward the end of last year, I demonstrated that charge-division encoding would improve both the position resolution and the linearity of the position-sensitive MOXE detectors by about a factor of two over the rise-time encoding technique that was being used. The collaboration decided to switch to charge division, and I have primarily been working on implementing charge division in a flight system, including the detectors themselves, detector electronics, and flight software.

Detectors: I have identified and found solutions to several problems with the MOXE proportional counters. First, I recognized that by wiring the detector cathodes in a different way (actually the way the contractor normally wires them) we could increase the cathode resistance, thus improving performance with less demands on the electronics. The flight detectors are now being wired this way to increase the resistance. I also studied the anti-coincidence counter and found that cross-talk from the position-sensitive counter was cancelling some of the anti-coincidence signal, reducing the anti efficiency to about ninety percent. I then proposed a technique for cancelling this cross-talk in the detector, which was tested by the contractor and found to work. I also identified a problem that caused the position-sensitive signals to be lost near the edges of the detector. This was solved by a combination of improvements to the detector bias and to the preamplifiers. Further, I studied the technique of pulse shape discrimination for background rejection in the MOXE detector and found it to be quite powerful: over seventy five percent of the particle background can be eliminated with only a few percent loss of x-ray data with even a simple discrimination technique.

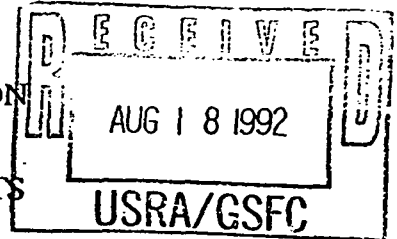
Electronics: The largest fraction of my time has been spent developing the electronics for implementing charge division in flight electronics. This included the charge-sensitive preamplifiers, shaping amplifiers, and digital circuitry for converting analog to digital. The charge-sensitive preamplifiers are probably the most critical aspect in the performance of charge division. I found the original preamps provided by the contractor building the MOXE proportional counters to be inadequate largely in terms of input impedance (which needs to be small compared to the line impedance). By computer modeling and by testing on a detector simulator and a detector itself, I found ways to improve the preamp adequately by using a higher transconductance FET, a larger feedback capacitor, and different front-end biasing. I also tested a different input protection scheme for the preamps that was also implemented. I developed and tested a semi-gaussian shaping amplifier for the flight electronics (adapted from the XTE design) and tested this for an optimum shaping time. I then designed a digital system to digitize the four signals from these shaping amplifiers, and store them in a stack memory that can be read by the on-board processor to calculate positions and energies of individual events. This digital system also can abort events if it receives a signal from the anti-coincidence or from the pulse-shape discrimination circuitry. This system has been prototyped and tested.

Software: I have served as the interface between Los Alamos, where the flight software was designed, and Goddard, where it has been coded and is being tested. I have helped to design and perform tests of the software, where a number of problems have been identified and solved.

I have also worked on the interfaces between MOXE and Spectrum-X-Gamma. This usually took the form of interface meetings with the Russians (who provide the spacecraft) and other instrument teams on Spectrum-X-Gamma and involves agreeing on power and mass budgets, test procedures, operating procedures, and scheduling. I participated in a two-week meeting with the Russians and Hungarians (designers of the spacecraft's on-board computer) here and in a Spectrum-X-Gamma project manager's meeting in Copenhagen.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: WEIPING ZHANG Task Number: 5000-632

General Description of Your Research Activities: (Include a Paragraph on each Activity).

XTE/PCA: 1) I studied the effects of ERGENICS getter material on methane gas. The XTE/PCA proportional counter gas is a mixture of Xe and methane. Maintaining the Xe/methane mixing proportion is critical to maintaining the gain stability of the detectors. The detectors had been designed to have a Zr-Al alloy getter in order to maintain their energy resolution. But the getter has an inadvertent effect of getting methane over a long period of time. Thus the long term gain stability of the detectors is lost. I devised to have two kinds of getter materials, which have slightly different compositions, tested. After a few months of experimenting and monitoring, I concluded that ERGENICS Hy-Stor 404 is the ideal getter material. The significance of the experiment is of two folds: on the one hand we have identified the getter material that satisfies the XTE/PCA mission, on the other hand we have discovered the methane getting capacity of the ERGENICS Hy-Stor 405. This later piece of information, which will be written up and submitted for publication soon, is of general value to the detector development community. 2) I investigated the alternative windows for XTE/PCA. XTE/PCA had been designed with windows of two sheets of metalized mylar, each of which consists of a one mil mylar sheet with 700A of aluminum deposited on either side. The windows have to meet two conflicting requirements: on the one hand they have to hold the gas under pressure, requiring them be thick, on the other hand they have to be transparent to low energy x-rays, requiring them be thin. It is critically important to strike a balance between the two so that the windows can hold the gas in place and have maximum x-ray transmission. I had 0.5-mil aluminized (1200A on either side) mylar made and tested. The preliminary results show that it is satisfactory in several respects. But further studies are needed, mainly for safety reasons, to completely justify the switch from 1-mil to 0.5-mil mylar.

ROSAT AO3 Proposal: Dr. P. Serlemitsos, Dr. R. Petre, Dr. R. Mushotkzy, Dr. J. Swank, Dr. P. Ghosh, and I proposed to ROSAT a "Simultaneous ROSAT/Astro-D Observations of Galactic X-Ray Sources". This proposal has been peer-reviewed and funded by NASA and accepted by ROSAT. It is scheduled to be carried out some time in 1993. The Astro-D part will certainly be carried out because that Dr. P. Serlemitsos is one of the Co-PIs. We expect data from both ROSAT and Astro-D to arrive at Goddard for analysis in the middle of 1993.

CYGNUS Air Shower Experiment: I spent time writing up some of the scientific results which I obtained while at the Los Alamos National Laboratory. The writing has been done in close collaboration with my colleagues at University of Maryland (Prof. J. Goodman and Dr. T. Haines), National Science Foundation (Dr. D. Berley), Los Alamos National Lab (Drs. C. Hoffman and Gus Sinnis), University of California at Irvine (Prof. G. Yodh), and George Mason University (Prof. R. Ellsworth). In the last year or so, five papers have been written, three of which have been published (see next page), and the other two have been submitted for publication.

KAMIOKANDE-II: I have also kept close collaboration with Professor A. K. Mann of the University of Pennsylvania in continuing analysis of the KAMIOKANDE-II data which we collected in collaboration with our colleagues from the University of Tokyo and a few other Japanese universities. Years of intensive detector works are paying off. We published seven peer-reviewed papers in 1991 and the first half of 1992 (see next page for publication list).

## Papers Published

"Search for Neutralino Dark Matter in Kamiokande," Mori-M Nojiri-MM Oyama-Y Suzuki-A Takahashi-K Yamada-M Takei-H Miyano-K Miyata-H Hirata-KS Inoue-K Ishida-T Kajita-T Kihara-K Nakahata-M Nakamura-K Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Koshihara-M Nishijima-K Suda-T Tajima-T Fukuda-Y Koderia-E Nagashima-Y Takita-M Kaneyuki-K Tanimori-T Beier-EW Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICS LETTERS B, Vol 270 pp 89-96(1991). ABSTRACT: *A search has been made for upward-going muons in the Kamiokande detector as a possible signal from neutralino dark matter captured on the Earth. We found the upward-going muon flux from the Earth is consistent with that produced by the atmospheric neutrinos. Assuming the galactic halo contains neutralino dark matter, this result provides limits on the neutralino mass in the region 30-80 GeV and gives stringent constraints on the allowed regions of the parameter space in the framework of the minimal supersymmetric standard model.*

"Mass Limits for Dark-Matter Particles Derived from High-Energy Neutrinos from the Sun," Sato-N Hirata-KS Kajita-T Kifune-T Kihara-K Nakahata-M Nakamura-K Ohara-S Suzuki-Y Totsuka-Y Yaginuma-Y Mori-M Oyama-Y Suzuki-A Takahashi-K Takei-H Tanimori-T Koshihara-M Suda-T Tajima-T Miyano-K Miyata-H Yamada-M Fukuda-Y Kaneyuki-K Nagashima-Y Takita-M Beier-EW Feldscher-LR Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICAL REVIEW D, Vol 44 pp 2220-2240(1991). ABSTRACT: *High-energy neutrinos could be emitted from the center of the Sun as annihilation products of heavy galactic dark-matter particles. We analyse neutrino events observed by the Kamiokande detector to search for such neutrinos. The observed upper-limits on solar heavy neutrinos from these data set limits on the mass and density of certain galactic dark matter. The particles analyzed are heavy Dirac neutrinos ( $\nu_D$ ), heavy Majorana neutrinos ( $\nu_M$ ), Higgsinos ( $\tilde{h}$ ), sneutrinos ( $\tilde{\nu}$ ) with three flavors, and photinos ( $\tilde{\gamma}$ ) as the lightest supersymmetric particles. Excluded mass regions are obtained for each dark-matter candidate:  $3\text{GeV} < m_{\nu_D} < 100\text{GeV}$ ,  $3\text{GeV} < m_{\nu_M} < 90\text{GeV}$ ,  $3\text{GeV} < m_{\tilde{\nu}_e} < 90\text{GeV}$ ,  $3\text{GeV} < m_{\tilde{\nu}_\mu} < 90\text{GeV}$ , and  $4\text{GeV} < m_{\tilde{\nu}_\tau} < 90\text{GeV}$ .*

"Real-Time- Directional Measurement of B-8 Solar Neutrinos in the Kamiokande-II Detector," Hirata-KS Inoue-K Ishida-T Kajita-T Kihara-K Nakahata-M Nakamura-K Ohara-S Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Mori-M Oyama-Y Suzuki-A Takahashi-K Yamada-M Koshihara-M Nishijima-K Suda-T Tajima-T Miyano-K Miyata-H Takei-H Fukuda-Y Koderia-E Nagashima-Y Takita-M Kaneyuki-K Tanimori-T Beier-EW Feldscher-LR Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICAL REVIEW D, Vol 44 pp 2241-2260(1991). ABSTRACT: *The method of  $^8\text{B}$  solar-neutrino measurement by means of the reaction  $\nu_e e \rightarrow \nu_e e$  in the Kamiokande-II detector is described in detail. A data sample of 1040 live detector days in the time period January 1987 through April 1990 yields a clear directional correlation of the solar-neutrino-induced electron events with respect to the Sun and a measurement of the differential electron energy distribution. The measured flux of  $^8\text{B}$  solar neutrinos from the subsamples of 450 days at electron energy threshold  $E_e \geq 9.3\text{MeV}$ , and 590 days at  $E_e \geq 7.5\text{MeV}$  relative to calculations of the  $^8\text{B}$  flux based on the standard solar model are  $0.46 \pm 0.05(\text{stat}) \pm 0.06(\text{syst})$  times the prediction of Bahcall and Ulrich, and  $0.70 \pm (\text{stat}) \pm 0.09(\text{syst})$  times the prediction of Turck-Chieze et al. The shape of the recoil electron energy distribution is consistent with that expected from the product of the known shape of the neutrino flux from  $^8\text{B}$   $\beta$  decay and the cross section for  $\nu_e e \rightarrow \nu_e e$  scattering. Within the statistical error, there is no evidence in the solar-neutrino signal for a significant time variation.*

"Measurements of the Charge Ratio and Polarization of 1.2- TeV/C Cosmic-Ray Muons

*with the Kamiokande-II Detector," Yamada-M Miyano-K Miyata-H Takei-H Mori-M Oyama-Y Suzuki-A Takahashi-K Hirata-KS Kajita-T Kifune-T Kihara-K Nakahata-M Nakamura-K Ohara-S Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Koshiha-M Suda-T Tajima-T Fukuda-Y Nagashima-Y Takita-M Kaneyuki-K Tanimori-T Beier-EW Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICAL REVIEW D, Vol 44 pp 617-621(1991). ABSTRACT: We measured the charge ratio and polarization of the high energy cosmic-ray muons arriving with zenith angles from  $0^\circ$  to  $90^\circ$  in the large underground water Cherenkov detector, Kamiokande-II. The charge ratio,  $R(\mu^+/\mu^-)$ , and the polarization ( $P_0$ ) are found to be  $1.37 \pm 0.06(\text{stat}) \pm 0.01(\text{syst})$  and  $0.26 \pm 0.04(\text{stat}) \pm 0.05(\text{syst})$ , respectively, at the sea level momentum of  $1.2 \text{ TeV}/c$ . This result for the charge ratio is in good agreement with those previously obtained in experiments using magnetic spectrometers at sea level and underground. This is the first measurement of the polarization of the cosmic-ray muons in the TeV region.*

*"Search for Fractionally Charged-Particles in Kamiokande-II," Mori-M Oyama-Y Suzuki-A Takahashi-K Yamada-M Miyano-K Miyata-H Takei-H Hirata-KS Kajita-T Kihara-K Nakahata-M Nakamura-K Ohara-S Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Koshiha-M Suda-T Tajima-T Fukuda-Y Nagashima-Y Takita-M Kaneyuki-K Tanimori-T Beier-EW Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICAL REVIEW D, Vol 43 pp 2843-2846(1991). ABSTRACT: A search has been made for fractionally charged particles with  $|Q| = \frac{1}{3}$  and  $|Q| = \frac{2}{3}$  which might have passed through the Kamiokande-II detector. No positive evidence for such a particle is observed in 1009 days of observation. The 90%on the fluxes of fractionally charged particles are  $2.1 \times 10^{-15} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$  for  $|Q| = \frac{1}{3}$  and  $2.3 \times 10^{-15} \text{ cm}^{-2} \text{ s}^{-1} \text{ sr}^{-1}$  for  $|Q| = \frac{2}{3}$ , improving the existing limits by two orders of magnitude.*

*"Observation of Shadowing of Ultrahigh-Energy Cosmic-Rays by the Moon and the Sun," Alexandreas-DE Allen-RC Berley-D Biller-SD Burman-RL Cady-DR Chang-CY Dingus-BL Dion-GM Ellsworth-RW Gilra-MK Goodman-JA Gupta-S Haines-TJ Hoffman-CM Krakauer-DA Kwok-P Lloydevans-J Lü-XQ Nagle-DE Potter-ME Sandberg-VD Stark-MJ Talaga-RL Vishwanath-PR Yodh-GB Zhang-W, PHYSICAL REVIEW D, Vol 43 pp 1735-1738(1991). ABSTRACT: Data from an extensive air shower detector of ultra-high-energy cosmic rays shows shadowing of the cosmic-ray flux by the moon and the sun with significance of 4.9 standard deviations. This is the first observation of such shadowing. The effect has been used to determine that the angular resolution of the detector is  $0.75^{+0.13}_{-0.09}^\circ$ .*

*"Search for Day-Night and Semiannual Variations in the Solar Neutrino Flux Observed in the Kamiokande-II Detector," Hirata-KS Inoue-K Kajita-T Kihara-K Nakahata-M Nakamura-K Ohara-S Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Mori-M Oyama-Y Suzuki-A Takahashi-K Yamada-M Koshiha-M Nishijima-K Suda-T Tajima-T Miyano-K Miyata-H Takei-H Fukuda-Y Koderu-E Nagashima-Y Takita-M Kaneyuki-K Tanimori-T Beier-EW Feldscher-LR Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICAL REVIEW LETTERS, Vol 66 pp 9-12(1991). ABSTRACT: Searches for possible day-night and semiannual variations of the  $^8\text{B}$  solar neutrino flux are reported based on 1040 days of Kamiokande-II data. Within statistical error, no such short-time variations were observed. The limit on the day-night difference sets a constraint on neutrino oscillation parameters. A region defined by  $\sin^2\theta \geq 0.02$  and  $2 \times 10^{-6} \leq \Delta m^2 \leq 10^{-5} \text{ eV}^2$  is excluded at 90% the expected solar neutrino flux.*

*"Observation of a Small Atmospheric  $\nu_\mu/\nu_e$  Ratio in Kamiokande," Hirata-KS Inoue-K*

Ishida-T Kajita-T Kihara-K Nakahata-M Nakamura-K Ohara-S Sakai-A Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Mori-M Oyama-Y Suzuki-A Takahashi-K Yamada-M Koshihara-M Nishijima-K Kajimura-T Suda-T Tajima-T Miyano-K Miyata-H Takei-H Fukuda-Y Koderer-E Nagashima-Y Takita-M Yokoyama-H Kaneyuki-K Takeuchi-Y Tanimori-T Beier-EW Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICS LETTERS B, Vol 280 pp 146-152(1992). ABSTRACT: Results are presented of the observation of atmospheric neutrino interactions in the Kamikande detector in an exposure of 4.92 kt-yr. The observed ratio of single ring  $\mu$ -events to  $e$ -events  $(\mu/e)_{data}/(\mu/e)_{MC} = 0.60_{-0.06}^{+0.07}(stat) \pm 0.05(syst)$  suggests that the atmospheric  $\nu_{\mu}/\nu_e$  ratio is smaller than expected. The implications of these results for neutrino oscillations are discussed.

"Search for Neutrino-Induced Low-Energy-Electron-Event Clusters in Kamiokande-II," Hirata-KS Inoue-K Ishida-T Kajita-T Kihara-K Nakahata-M Nakamura-K Ohara-S Sato-N Suzuki-Y Totsuka-Y Yaginuma-Y Mori-M Oyama-Y Suzuki-A Takahashi-K Yamada-M Suda-T Tajima-T Miyano-K Miyata-H Takei-H Fukuda-Y Koderer-E Nagashima-Y Takita-M Kaneyuki-K Tanimori-T Beier-EW Frank-ED Frati-W Kim-SB Mann-AK Newcomer-FM Vanberg-R Zhang-W, PHYSICAL REVIEW D, Vol 45 pp 3355-3360(1992). ABSTRACT: Following earlier searches by the Kamiokande-II Collaboration for neutrino-induced events of special interest, a further intensive search has been made for electron events in the energy interval  $6 \leq E_e \leq 30$  MeV, which are clustered in time. No time cluster which might be interpreted as a neutrino burst was found in 2.8 yr data apart from the burst from SN1987A. An unusual group of events, not the result of a neutrino interaction in the detector, but clustered in time and space within the detector was observed; information concerning it is presented here.

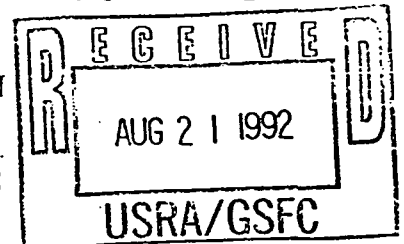
"A Search of the Northern Sky for Ultra High-Energy Point Sources," Alexandreas-DE Berley-D Biller-S Burman-RL Cady-DR Chang-CY Dingus-BL Dion-CL Dion-GM Ellsworth-RW Freedman-SJ Fujikawa-BK Goodman-JA Haines-TJ Hoffman-CM Krakauer-DA Kwok-PW Lu-XQ Nagle-DE Potter-M Sandberg-VD Sennis-C Stark-MJ Vishwanath-PR Yodh-GB Zhang-W, ASTROPHYSICAL JOURNAL, Vol 383 pp L53-L56(1991). ABSTRACT: A search has been made for steady emission of ultra-high-energy radiation from individual point sources over most of the northern sky. Over  $2 \times 10^8$  air showers induced by primary particles of energy greater than about 10 TeV were recorded from 1986 April until 1991 May by the CYGNUS air shower array. No statistically significant excess above the background from the isotropic flux of cosmic-rays was found for any direction in the sky from  $0^\circ$  to  $80^\circ$  in declination. In addition, 49 specific potential sources were examined, and none showed a statistically significant excess of events. 90% flux upper limits are established for the continuous emission from these sources; for a source that transits the zenith, a representative upper limit corresponds to an integral flux above 40 TeV of about  $1.7 \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1}$  (0.5 within an angular area of  $1.8^{-3} \text{ sr}$ ) assuming a power-law energy spectrum with a differential spectral index of -2.7.

"The Cygnus Extensive Air-Shower Experiment," Alexandreas-DE Allen-RC Biller-SD Delay-RS Dion-GM Lu-XQ Vishwanath-PR Yodh-GB Berley-D Chang-CY Dingus-BL Goodman-JA Haines-TJ Gupta-S Krakauer-DA Stark-MJ Talaga-RL Burman-RL Butterfield-K Cady-R Hoffman-CM Lloyddevans-J Nagle-DE Potter-ME Sandberg-VD Sennis-C Stanislaus-S Thompson-TN Wilkinson-CA Zhang-W Ellsworth-RW, NUCL. INSTRU. METHODS, Vol 311 pp 350-367(1992). ABSTRACT: The CYGNUS extensive air-shower experiment is described. The design criteria, construction and operation details, and performance characteristics are presented. A discussion of data analysis techniques is given. Finally, several enhancements and improvements in the apparatus are described.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Brenda L. Dingus Task Number: 660-035

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My task is split into two parts -- development of the next generation high energy gamma-ray telescope, AGATE, and analysis of data from the current generation high energy gamma-ray telescope, EGRET. My work on AGATE can be further subdivided into (1) the assembly and operation of 1/2 m x 1/2 m drift chambers, (2) the construction of 1/2 m x 2 m drift chambers, (3) development of the triggering and anticoincidence system, and (4) the design of the spacecraft.

The development of the 2 m x 2 m tracking detector for AGATE has proceeded in stages. Drift chambers are the most promising type of tracking detector due to low deadtime and small number of wires to be read out. In order to learn about drift chambers a detector of 1/2 m x 1/2 m x 16 layers was built prior to my joining the group, but has never been operated. I have worked with an electrical engineer in trying to make these drift chambers, and their associated electronics, operational. We have not yet succeeded, but are making progress. The amplitude of the signals is small, and the noise is large. We have eliminated some of the noise sources such as a power supply with excessive ripple and an improperly terminated signal cable, and we have increased the signal by increasing the gas gain and removing the termination of the anode wire opposite the amplifier. However, we still have problems with discriminator oscillations and are considering modifying the circuit.

A 1/2 m x 2 m x 8 layer detector is also being built, mostly to test the mechanical design of a 2 m x 2 m drift chamber. Four of the layers have 2 m long wires which must have a sufficient tension to prevent sagging in the middle. The wires are placed to within 100 microns and soldered. Some of the wires have begun pulling through the solder joint, so glue must also be used to maintain the tension. I have been supervising the work of two technicians and a summer student in order to accomplish this task.

A gamma-ray telescope must have a fast trigger to initiate readout of the tracking detector. Scintillators with photomultiplier tubes have been used in the past. However, due to the large size of AGATE a large number of photomultiplier tubes would be required. I have worked with an engineer at Radiation Monitoring Devices to study the possibility of using avalanche photodiodes instead of photomultiplier tubes. Avalanche photodiodes are much smaller and simpler to use than photomultiplier tubes, but may not have sufficient signal to noise or speed. Another alternative to reduce the number of phototubes requires placing two phototubes at the ends of a long strip of scintillator. I am overseeing the work of a summer student who is using such a system to determine its timing and position resolution.

The preliminary design of the spacecraft is being done by a contractor, and I have been attending the monthly meetings. We have discussed issues such as mechanical design, power and thermal requirements, gas circulation system, pointing and aspect control, and launch vehicle.

A large part of my analysis of EGRET data has consisted of learning the operation of the many available software tools; however, I have completed a study of the solar flux during the June 11 flare and am beginning to examine the EGRET detection of the quasar 0454-463. I have also scanned the housekeeping as well as the spark chamber data for evidence of gamma ray bursts. I also plan to write a paper on flux limits for astrophysical sources reported by ground based gamma-ray telescopes which are sensitive to higher energies.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Citations in 1991:

- 6 for "Search for Signals from Cygnus X-3 at Energies Above 50 TeV"
  - 16 for "Ultra High Energy Pulsed Emission from Hercules X-1 with Anomolous Muon Content"
  - 2 for "Study of Cygnus X-3 at Ultrahigh Energies during the 1989 Radio Outbursts"
  - 1 for "Observation of Shadowing of Ultrahigh Energy Cosmic Rays by the Moon and the Sun"
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Honors or Awards Received:

I received the 1991 Goddard Space Flight Center Group Achievement Award to the BBXRT Payload Development and Operations Team for the work I did with the x-ray group of the Laboratory of High Energy Astrophysics as a National Research Council associate.

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Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the

"A Search of the Northern Sky for Ultra-High-Energy Point Sources", Alexandreas, D. E., Berley, D., Biller, S. D., Burman, R. L., Cady, D. R., Chang, C. Y., Dingus, B. L., Dion, C. L., Dion, G. M., Ellsworth, R. W., Freedman, S. J., Fujikawa, B. K., Goodman, J. A., Haines, T. J., Hoffman, C. M., Krakauer, D. A., Kwok, P. W., Lu, X-Q., Nagle, D. E., Potter, M. E., Sandberg, V. D., Sinnis, C., Stark, M. J., Vishwanath, P. R., Yodh, G. B., Zhang, W. P., 1991, ApJ, 383, L53

"The CYGNUS Extensive Air-Shower Experiment", Alexandreas, D. E., Allen, R. C., Biller, S. D., Berley, D., Burman, R. L., Butterfield, K., Cady, D. R., Chang, C. Y., Delay, R. S., Dingus, B. L., Dion, G. M., Ellsworth, R. W., Goodman, A., Gupta, S., Haines, T. J., Hoffman, C. M., Krakauer, D. A., Lloyd Evans, J., Lu, X-Q., Nagle, D. E., Potter, M. E., Sandberg, D., Sinnis, C., Stanislaus, S., Stark, M. J., Talaga, R. L., Thompson, T. N., Vishwanath, P. R., Wilkinson, C. A., Yodh, G. B., Zhang, W. P., 1992, NIM, Vol. A311, p. 350

"Use of a Neutrino Detector for Muon Identification by the CYGNUS Air-Shower Array", Allen, R. C., Burman, R. L., Cady, D. R., Chang, C. Y., Delay, R. S., Dingus, B. L., Ellsworth, R. W., Goodman, J. A., Gupta, S., Haines, T. J., Krakauer, D. A., Lloyd Evans, J., Lu, X-Q., Nagle, D. E., Potter, M. E., Sandberg, V. D., Sena, A. J., Talaga, R. L., Thompson, T. N., Yodh, G. B., 1992, NIM, Vol. A311, p. 368

## A SEARCH OF THE NORTHERN SKY FOR ULTRA-HIGH-ENERGY POINT SOURCES

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T. J. HAINES,<sup>2</sup> C. M. HOFFMAN,<sup>4</sup> D. A. KRAKAUER,<sup>7</sup> P. W. KWOK,<sup>2</sup> X-Q LU,<sup>1</sup> D. E. NAGLE,<sup>4</sup>  
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### ABSTRACT

A search has been made for steady emission of ultra-high-energy radiation from individual point sources over most of the northern sky. Over  $2 \times 10^8$  air showers induced by primary particles of energy greater than about 10 TeV were recorded from 1986 April until 1991 May by the CYGNUS air shower array. No statistically significant excess above the background from the isotropic flux of cosmic rays was found for any direction in the sky from  $0^\circ$  to  $80^\circ$  declination. In addition, 49 specific potential sources were examined, and none showed a statistically significant excess of events. 90% confidence level flux upper limits are established for the continuous emission from these sources; for a source that transits the zenith, a representative upper limit corresponds to an integral flux above 40 TeV of about  $1.7 \times 10^{-13} \text{ cm}^{-2} \text{ s}^{-1}$  (0.5% of the cosmic-ray flux within an angular area of  $1.8 \times 10^{-3} \text{ sr}$ ) assuming a power-law energy spectrum with a differential spectral index of  $-2.7$ .

*Subject headings:* cosmic rays: general — gamma rays: general

There is great interest in point sources of very energetic (above about 1 TeV)  $\gamma$ -rays. Aside from the possibility of increasing what is known about sources of X-rays and lower energy  $\gamma$ -rays, it may be that compact astrophysical systems are capable of producing most or all of the high-energy cosmic rays. If a steady point source of very energetic  $\gamma$ -rays is found, it may provide a good source of high-energy particles for the study of particle interactions in the atmosphere.

Although there have been detections reported of either steady, pulsed, or episodic emission at energies above about 1 TeV from many different sources (Fegan 1990), only two have been observed as constant sources by at least two independent observations: Cygnus X-3 by Samorski & Stamm (1983) and by Lloyd-Evans et al. (1983) and the Crab by Vacanti et al. (1991) and by Akerlof et al. (1990). Moreover, Cygnus X-3 is apparently no longer a source at these energies (Dingus et al. 1988; Alexandreas et al. 1990). Nevertheless, because cosmic-ray particle acceleration to energies above tens of TeV is not well understood (Harding 1990), it is important to know which astrophysical objects are potential sources at these energies; thus, the need to search for emission from a variety of previously identified lower energy sources and from undiscovered sources, i.e., an "all-sky" survey.

The CYGNUS air shower experiment operates nearly continuously and has collected about  $2.1 \times 10^8$  ultra-high-energy (UHE) air shower events during the time period between 1986

April and 1991 May. While the experiment has been described in detail elsewhere (Alexandreas et al. 1991a; Allen et al. 1991), the most important features will be outlined here. The experiment is located at an altitude of 7000 feet ( $\sim 2135 \text{ m}$ ) (overburden of  $800 \text{ g cm}^{-2}$ ) in Los Alamos, NM ( $106^\circ 3' \text{ W}$ ,  $35^\circ 9' \text{ N}$ ), so the entire northern sky passes overhead each day.

The experiment began operation with 50 scintillation counters, each about  $1 \text{ m}^2$  area, deployed over an area of about  $10,000 \text{ m}^2$  and operating at a trigger rate of about  $0.5 \text{ s}^{-1}$ . Since that time, the experiment has undergone several expansions and now consists of 204 lead-covered counters deployed with a graded spacing over a total area of about  $85,000 \text{ m}^2$  with an air shower trigger rate of about  $5 \text{ s}^{-1}$ .

The average angular resolution of the array, determined by observations of cosmic-ray shadowing by the Sun and Moon, is  $0^\circ 75$  (Alexandreas et al. 1991b; Alexandreas et al. 1991c). According to simulations, the acceptance of the array begins for primary energies of about 10 TeV, while the most probable energy of a detected cosmic ray is about 40 TeV (averaged over all zenith angles) corresponding to a shower size of about  $10^4$  particles. The combination of large area, low threshold, and good angular resolution make the experiment well suited for searching for point sources of radiation at these energies.

For each candidate point source position, the analysis must be able to predict the expected number of air shower events assuming there is no source (the expected background from cosmic rays); this can then be compared with the observed number of events to determine if there is an excess due to a source at that position. There are many effects in an air shower experiment that, if not handled properly, could cause possible large systematic errors that could either hide a real point source or apparently create one where none actually exists. These effects include (1) times when the experiment was not operating; (2) short- and long-term event rate variations due to local air pressure changes and detector upgrades, respectively; and (3) nonuniformities in the acceptance of the array to air showers, which depends on, for example, the precise way the

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## The CYGNUS extensive air-shower experiment

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The CYGNUS extensive air-shower experiment is described. The design criteria, construction and operation details, and performance characteristics are presented. A discussion of the data analysis techniques is given. Finally, several enhancements and improvements in the apparatus are described.

### 1. Introduction

Ultra high energy (UHE:  $100 \text{ TeV} \leq E \leq 10 \text{ PeV}$ ) gamma-ray astronomy represents a new window on the universe. The first observation of UHE emission from a point source was reported in 1983 by a group at the University of Kiel [1]. They observed an excess of events during 1976-1980 from the direction of Cygnus X-3, an X-ray binary; the events also exhibited a corre-

lation with the well-known 4.8 h period. This result was quickly confirmed by the Haverah Park group [2] based on observations from 1978 to 1982. The Kiel measurement also indicated that the extensive air showers (EAS) generated by the interaction of cosmic particles with the earth's atmosphere produced far more muons than was expected for incident photons. The large fluxes implied by these measurements led experimenters to believe that larger experiments could easily detect and study many UHE sources. The CYGNUS experiment was specifically designed to be able observe a large excess from UHE point sources with fluxes such as those measured by the Kiel and Haverah Park groups for Cygnus X-3, and to study the muon content of the EAS.

### 2. Principles of operation

In order to search for sources of UHE particles, it is necessary to determine the incident direction of the primary particles and to point them back towards their

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<sup>4</sup> Now at Goddard Space Flight Center, Code 666, Greenbelt, MD 20771, USA.

<sup>5</sup> Now at Argonne National Laboratory, Argonne, IL 60439, USA.

<sup>6</sup> Now at the University of Notre Dame, Notre Dame, IN 46556, USA.

<sup>7</sup> Permanent address: The University of Leeds, Leeds, UK.

## Use of a neutrino detector for muon identification by the CYGNUS air-shower array

R.C. Allen <sup>a,1</sup>, R.L. Burman <sup>b</sup>, D.R. Cady <sup>b,2</sup>, C.Y. Chang <sup>c</sup>, R.S. DeLay <sup>a</sup>, B.L. Dingus <sup>c,3</sup>, R.W. Ellsworth <sup>d</sup>, S. Gupta <sup>c,4</sup>, J.A. Goodman <sup>c</sup>, T.J. Haines <sup>c</sup>, D.A. Krakauer <sup>c,5</sup>, J. Lloyd-Evans <sup>b,6</sup>, X-Q. Lu <sup>a</sup>, D.E. Nagle <sup>b</sup>, M.E. Potter <sup>a,b</sup>, V.D. Sandberg <sup>b</sup>, A.J. Sena <sup>b</sup>, R.L. Talaga <sup>c,5</sup>, T.N. Thompson <sup>a,b</sup> and G.B. Yodh <sup>a</sup>

<sup>a</sup> The University of California, Irvine, California 92717, USA

<sup>b</sup> Los Alamos National Laboratory, Los Alamos, New Mexico 87545, USA

<sup>c</sup> The University of Maryland, College Park, Maryland 20742, USA

<sup>d</sup> George Mason University, Fairfax, Virginia 22030, USA

Received 11 July 1991

The muon content of extensive air showers observed by the CYGNUS experiment are measured by a well-shielded apparatus, originally used for accelerator neutrino detection. Primary identification and counting of muons relies on a 44 m<sup>2</sup> array of multiwire proportional counters that has operated continuously since the experiment's inception to the present time. During the experiment's first 20 months, the central detector, consisting of flash-tube chambers, was used for high-resolution reconstruction of muon trajectories for a limited subsample of air showers. The ability to distinguish individual muons in the tracking device enabled verification and calibration of the muon counting by the proportional-counter system. The tracking capability was also used to verify the systematic pointing accuracy of the extensive air-shower arrival direction, as determined by the CYGNUS array, to better than 0.5°.

### 1. Introduction

The CYGNUS collaboration has reported observation of ultra-high-energy (UHE, 100–10 000 TeV) pulsed emissions from Hercules X-1 [1]. Two bursts of extensive air showers (EAS) emanating from the direction of Hercules X-1 were detected on July 24, 1986 by the scintillation counter array operating in Los Alamos, New Mexico. The event timing revealed a strong periodicity of 1.23568 s, close to the contemporaneous X-ray period for Hercules X-1. The most puzzling feature of the CYGNUS experiment's observation was

the muon content of the burst events being much larger than expected for  $\gamma$ -ray initiated showers.

Unambiguous identification and counting of muons in EAS is essential to the understanding of the physics associated with UHE emission from compact sources. To maintain its direction and continue to point to the source after traversing the galactic magnetic fields the observed particles must be neutral. The only known neutral particles stable enough to survive the transit from the source are neutrinos and photons; only photons are expected to interact strongly enough to initiate a substantial number of air showers. It is expected that gamma-ray induced air showers have a muon content more than an order of magnitude smaller than hadron-induced showers of the same energy [2]. The observed deviations from these initial expectations may indicate anomalously low thresholds for hadron-like photon interactions, or may signal the existence of previously unknown particles or interactions in ultra-high-energy cosmic-ray collisions [3]. In this article, we describe in detail the structure and properties of the muon identifier used in the CYGNUS experiment during the time when the reported burst of UHE emission from Hercules X-1 was detected.

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<sup>2</sup> Now at the University of Notre Dame, Notre Dame, IN 46556, USA.

<sup>3</sup> Now at Goddard Space Flight Center, Code 666, Greenbelt, MD 20771, USA.

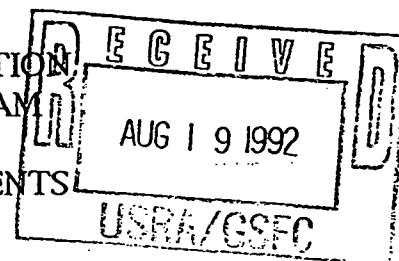
<sup>4</sup> Permanent address: Tata Institute of Fundamental Research, Bombay, India.

<sup>5</sup> Now at Argonne National Laboratory, Argonne, IL 60439, USA.

<sup>6</sup> Permanent address: The University of Leeds, Leeds, UK.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Dr. Michael F. Corcoran

Task Number: 660-038

General Description of Research Activities:

1) Analysis of IUE spectra of 1700-37 = HD 153919: The massive X-ray binary 1700-37 is unusual since the standard picture suggests that the optical companion, HD 153919, is a factor of 2 less massive than its spectral type (O6f) would suggest. Heap and Corcoran made a re-determination of the mass of the O star based on analysis of the stellar wind lines in the IUE spectra of HD 153919 and showed that the star may not be undermassive due to X-ray absorption by the wind near the star. These results were published in ApJ 387, 340.

2) ROSAT X-ray Observations of V444 Cyg: Corcoran was the PI on a successful ROSAT proposal to obtain phase-resolved X-ray fluxes of the WR +O binary V444 Cygni. This proposal was accepted as in the highly competitive time-constrained category by the ROSAT peer review. The observation was performed in May and November 1991. The data show that the X-ray flux is variable, showing minima at O star and WR star eclipse. This suggests that at least some of the X-ray emission arises from wind collisions between the stars. The data also show that the star is significantly softer inside eclipse, which qualitatively agrees with theory. These results have been submitted to the PASP for publication as part of the proceedings of the "Massive Stars: Their Lives in the Interstellar Medium" workshop held in June 92 in Madison, WI.

3) BBXRT observations of hot stars: Corcoran, as part of the BBXRT mission, has taken the lead in the analysis of the BBXRT spectra of 3 hot stars ( $\zeta$  Pup,  $\zeta$  Ori and EZ CMa). The BBXRT spectra in general show evidence of circumstellar absorption probably arising in the wind from these massive stars. X-ray line emission suggests abundance anomalies in at least  $\zeta$  Pup, and the presence of an O edge in the  $\zeta$  Pup spectrum was used by Corcoran et al. to determine the

ionization state of the wind. Though a compact companion to EZ CMa has been claimed by various authors, examination of the high energy ( $E > 1\text{keV}$ ) emission showed no evidence for a compact companion. Publication of these results is in preparation.

4) ROSAT observation of Sco OB1: Corcoran was PI on a ROSAT observation to examine the X-ray emission from the OB association Sco OB1. The observation was concluded in 1991. ROSAT detected emission from the hot stars down to a luminosity limit of about  $L_X = 10^{31}$  ergs/s, which included about a dozen sources. Diffuse emission of as yet unknown origin is also apparent. Corcoran and collaborators are using this observation to examine the X-ray luminosity function for the hot stars and to correlate the presence of diffuse emission with the location of stars with seemingly enhanced stellar winds. Publication of these results is in preparation.

5) Observations of Eta Carina: Swank and Corcoran are presently engaged in analysis of BBXRT spectra of Eta Carina and associated stars and diffuse emission. In addition, Swank, Petre, Rawley, and Corcoran are analyzing a deep ROSAT observation of the Eta Car region. This work is in progress.

6) X-rays from HD229041: Examination of Einstein IPC and ROSAT PSPC images of V444 Cygni seem to indicate that the early F star HD229041 is an X-ray source. If true, this is a significant discovery, since no early F star is a known X-ray source. Corcoran is the PI on a successful proposal to use the ROSAT HRI to pin down the location of the X-ray source to determine if in fact the X-rays are coming from HD 229041. Corcoran and collaborators are also monitoring the star in the visible to look for evidence of binarity and to confirm the spectral classification of the star. Followup observations in the UV are planned.

Significant Recognition of Work:

Citations in FY92 as noted in Science Citation Index:

Blondin JM ApJ 371, 684

Stevens, IR, ApJ 379, 310

Gies, DR, ApJ 375, 321.

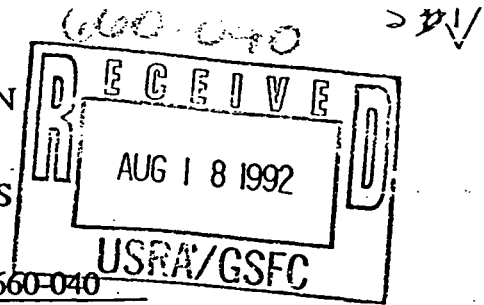
Honors or Awards Received:

National Research Council Resident Research Associateship, Goddard  
Space Flight Center, 1989-1990



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Hisamitsu Awaki Task Number: 660-040

General Description of Your Research Activities: (Include a Paragraph on each Activity).

I have worked on Astro-D Mirror Project with Dr. P.I. Serlemitsos. The X-ray telescope (hereafter XRT) prepared by Goddard Space Flight Center will be carried on Japanese X-ray satellite called Astro-D. Using a computer simulation so called ray tracing, I evaluated the image quality of the XRT at on-axis. It is found that the point spread function of XRT is well described by a function of radius (x), which is  $(1/x) \exp(-ax)$  as mentioned by Dr. Serlemitsos. The shape of image response has a complex shape similar to clover. Next, I investigated the dependence of the effective area and the point spread function on the energy, off-axis angle and azimuthal angle. It is found that they complexly depend on the energy, off-axis, and azimuthal angles, while the point spread function is less dependent on the energy. I also collaborate the X-ray ground calibration of the XRT at White Sands in New Mexico.

I am also interested in the active galactic nuclei, specially unified Model of Seyfert galaxy. Seyfert galaxies are divided into two types, Seyfert 1 and Seyfert 2 galaxies, based on the presence of broad lines in the optical spectra. Since the middle of 1980s, the unification for these two types of Seyfert galaxies has been investigated. The X-ray observations for Seyfert galaxies are crucial test for the model. I proposed the observation of Seyfert 2 galaxies with the Japanese X-ray satellite Ginga. In this year, I have compiled the observational results. These results will be presented at COSPAR meeting in Washington from 28 August - 5 September 1992.

Universities Space Research Association  
Goddard Visiting Scientist Program

Employee Summary of Accomplishments  
(for the year ending 9/30/92)

Employee name: Gregory F. Pike                      Task Number:

General Description of Research Activities:

*IUE*: An archive of Active Galactic Nuclei spectra

Over the last year, I worked closely with NASA/GSFC and University of Colorado scientists to continue development of a comprehensive database of ultraviolet *IUE* spectra of Active Galactic Nuclei (AGN). I have designed and implemented a system that extracts spectra, measures line and continuum fluxes and writes the results into a sophisticated relational database. I used this complete data set to test the accuracy of the three most popular *IUE* absolute calibration algorithms presently available to scientists as well as to survey ultraviolet variability in BL Lac objects. Daily tasks include archiving of new data as it becomes available and altering the database structure to accommodate expanding user needs. In addition, I am continually processing information retrieval requests. I am currently working on a new flux measurement routine as well as beginning to port the system to the SUN IDL environment for compatability with the Astronomical Data System.

In collaboration with Dr. Rick Edelson, the database (named IUEAGN) was used to study the variability properties of BL Lacertae objects. A search of the available spectra yielded nine rapid variability events with doubling time scales of 0.5-7 days. The archive also indicated a clear correlation between strength of the ultraviolet variability and its apparent luminosity or degree of optical polarization. These data provide the best evidence to date for ultraviolet beaming in BL Lacs.

Contributions to Monitoring Campaign of PKS 2155-304

I participated in the November 1991 *IUE* monitoring campaign of BL Lacertae object PKS 2155-304. By observing the object every night, I reduced fluxes in almost "real-time", thus detecting potential problems prior to future observing shifts. I was also able to provide preliminary flux measurements for collaborators thereby increasing quality of the associated multi-wavelength observations. Over the month long campaign, the ultraviolet flux doubled, with smaller, rapid fluctuations superimposed. No apparent lag was seen between short- and long-wavelength light curves, suggesting that the emission region is highly homogeneous.

ROSAT Medium Survey:

I have began work on a algorithm to extract spectra and light curves from the *ROSAT* archives. Initial work included development of a "pipeline" which allows me to extract information from the *ROSAT* archives. In addition, I constructed the groundwork for a future *ROSAT* relational database to organize this data.

Significant Recognition of your work:

(none)

Awards or Honors:

(none)

Papers Published or Accepted for Publication:

*Broadband Properties of the CfA Seyfert Galaxies: III. Ultraviolet Variability*  
R. Edelson, J. Krolik and G. Pike 1990, *Ap. J.*, 359, 86.

*Evidence for Rapid Ultraviolet Variability in the BL Lacertae Object PKS 2155-304*  
R. Edelson, J. Saken, G. Pike, C. M. Urry, I. George, R. Warwick, H. R. Miller, M. Carini and J. Webb 1991, *Ap. J. Lett.*, 372, L9.

*The Colorado IUE Active Galaxy Survey: I. BL Lacertae Objects*  
R. Edelson, G. Pike, J. Saken, A. Kinney and J. M. Shull 1992, *Ap. J. Supp.*, 83, in press.

Papers Submitted but not yet Accepted for Publication:

(none)

Papers Presented at Scientific Meetings:

*Invited Papers:*

(none)

*Contributed Papers:*

*A Database of IUE Spectra of Active Galactic Nuclei*  
G. Pike and J. Saken, R. Edelson, A. Koratkar, A. Kinney 1991, *B.A.A.S.*, 23, #2, 894.

*A Database of IUE Spectra of Active Galactic Nuclei: The Results for Quasars*  
A. Koratkar, A. Kinney, R. Bohlin, R. Edelson, J. Saken G. Pike 1991, *B.A.A.S.*, 23, #2, 894.

*Evidence for Rapid Ultraviolet Variability in the BL Lacertae Object PKS 2155-304*  
R. Edelson, G. Pike and J. Saken 1991, *B.A.A.S.*, 23, #2, 927.

*Initial Results from the Colorado IUE AGN Database: Ultraviolet Variability*  
G. Pike and R. Edelson 1991, in *Variability of Active Galactic Nuclei*, ed. H. R. Miller and P. Wiita, (Cambridge: Cambridge University Press), p. 381.

*Ultraviolet Variability in Blazars*

R. Edelson, G. Pike, J. Saken, J. M. Shull, A. Kinney, C. M. Urry, L. Maraschi 1992, *B.A.A.S.*, 24, #2, 744.

*Intensive UV Monitoring of the BL Lac Object PKS 2155-304*

C. M. Urry, L. Maraschi, R. Bohlin, A. Koratkar, L. Chiappetti, E. Pian, A. Treves, R. Edelson, G. Madejski, G. Pike, G. Reichert, J. Krolik, W. Wamsteker 1992, *B.A.A.S.*, 24, #2, 744.

*IUEAGN: A Database of UV Spectra of Active Galactic Nuclei*

G. F. Pike, J. Saken, J. M. Shull, R. Edelson, A. Koratkar 1992, in *Evolution of Galaxies and their Environment*, ed. J. M. Shull, in press.

Colloquia, seminars and Special Lectures since September 1991:

(none)

Community Service:

(none)

Collaborations with University Groups:

**J. Michael Shull, University of Colorado:** Performed *IUE* observations of PG-QSOs and Seyfert Galaxies to probe for intrinsic CIV Absorption. The IUEAGN database was expanded to include absorption properties as well as the existing emission data. Future observations are planned and the data is presently being reduced.

Non University Collaboration (outside of Goddard):

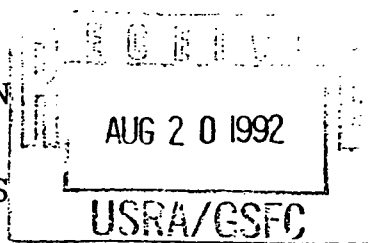
**C. Megan Urry, Space Telescope Science Institute:** I was involved in the day to day observation, extraction and analysis of *IUE* spectra during a month long monitoring campaign of the BL Lacertae object PKS 2155-304.

Additional Information:

(none)

660-042 5 ↓

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Robert Nemiroff

Task Number: 660-042

General Description of Research Activities:

I have investigated the visual distortion effects that occur near the surface of a neutron star and black hole due to the strong gravity. I have written computer codes that simulated these effects and display numerical and graphical results. I wrote and submitted a paper to the American Journal of Physics on this topic.

I helped investigate somewhat unusual properties that would occur in and around extremely compact neutron stars. These effects included unusual light curves that would be caused by hot spots on the stellar surface, a change in the usual Eddington luminosity, and the creation of a neutrino sphere and a neutrino cloud where particles which could traverse the inside of the neutron star would be trapped in gravitationally bound, stable orbits. This work was completed, submitted and accepted by The Astrophysical Journal. The current reference is: Nemiroff, R.J., Becker, P.A., Wood, K.S. 1992, Properties of Extremely Compact Neutron Stars, in press.

I continued research into coded aperture theory - how to image X-rays and gamma-rays by selectively blocking portions of the light reaching a position sensitive detector. I have held conversations with Dr. Jay Norris, Dr. Uppenda Desai, Dr. Kent Wood, and Dr. Uri Feldman. A paper discussing one particular design was published. The current reference is: Wood, K. Feldman, U., Becker, P., Nemiroff, R., and Kania, D. 1992, A Fourier Transform Microscope for X-ray Imaging, Review of Scientific Instruments, in press.

I am participating in a search for gravitational lens echoes of gamma ray bursts. This is part of a Phase 2 *Compton* Gamma Ray Observatory proposal where I am a co-investigator. Much software has been written and many bursts have been compared, but no echo has yet been positively identified. I plan to report on the progress of this search and how the lack of an echo limits the amount and types of dark matter in the universe at the October meeting on the *Compton* Observatory.

I have been investigating the nature of the unusual gamma ray object labelled 2CG010-31. So far, a search of past observations has not been able to uncover its origin. I have been approved, however, as Principal Investigator for a Phase 2 proposal on the *Compton* Gamma Ray Observatory to view this object. This observation is currently scheduled to take place next June.

With Jay Norris and several scientists at Marshall Space Flight Center (MSFC) I have been helping to investigate timing effects on gamma ray bursts. In particular, we have been investigating whether a time stretching factor due to cosmology can be seen in relatively dim gamma ray bursts. Jay Norris plans to speak on this subject at the October meeting on the *Compton* Observatory.

With Thulsi Wickramasinghe, Jay Norris, and several scientists at MSFC I have been helping to investigate whether the number - peak brightness of gamma ray bursts follow any specific cosmology. This work will be reported on by Thulsi Wickramasinghe at the October meeting on the *Compton* Observatory.

I have been helping to supervise a graduate student from the University of Pennsylvania named Thulsi Wickramasinghe on researches into timing, gravitational physics, and gamma ray bursts.

**Describe any Significant Recognition of your work:** I was asked to hold a special press conference on my poster "Trip to a Neutron Star: The Movie" that I delivered at the January 1992 meeting of the American Astronomical Society. A small portion of the video tape I had made subsequently aired on CNN Headline News during the weekend of January 17th.

**Honors or Awards Received:** I have spoken on my research while at the Marshall Space Flight Center as part of an afternoon colloquium and also at the University of Pennsylvania at an afternoon colloquium. I have addressed informal lunch gatherings on my research twice while here at Goddard, and I will be addressing similar audiences at the University of California at Santa Cruz and at the California Institute of Technology.

**Papers Published or Accepted for Publication:**

Wood, K. Feldman, U., Becker, P., Nemiroff, R., and Kania, D. 1992, A Fourier Transform Microscope for X-ray Imaging, *Review of Scientific Instruments*, in press.

Nemiroff, R.J., Becker, P.A., Wood, K.S. 1992, Properties of Extremely Compact Neutron Stars, in press.

**Papers Submitted but not yet Accepted for Publication:**

Nemiroff, R. J., 1992, Visual Distortion Effects Near a Neutron Star and Black Hole, *American Journal of Physics*, submitted.

**Papers Presented at Scientific Meetings: *Contributed Papers:***

Norris, J.P., Nemiroff, R.J., Kouveliotou, C., Fishman, G.J., Meegan, C.A., Wilson, R.B., and Paciesas, W.S., Search for Time Dilation in Gamma Ray Bursts, *Compton Observatory Symposium*, October 1992.

Wickramasinghe, W.A.D.T., Nemiroff, R.J., Kouveliotou, C., Norris, J.P., Fishman, G.J., Meegan, C.A., Wilson, R.B., and Paciesas, W.S., The Consistency of Standard Cosmology and the BATSE Number vs. Brightness Relation, *Compton Observatory Symposium*, October 1992.

Nemiroff, R.J., Horack, J.M., Norris, J.P., Fishman, G.J., Meegan, C.A., Wilson, R.B., Kouveliotou, C., Paciesas, W.S., and Wickramasinghe, W.A.D.T., Search for Echoes in Gamma Ray Bursts *Compton Observatory Symposium*, October 1992.

Nemiroff, R. J. 1992, Trip to a Neutron Star: The Movie, *B. A. A. S.*, Atlanta, January 1992.

*Colloquia, Seminars and Special Lectures:*

Trip to a Neutron Star, GSFC, January 1992.

Press Conference on "Trip to a Neutron Star: The Movie", Atlanta AAS, January 1992.

Visual Distortions in a Neutron Star Environment, GSFC, February 1992.

Cosmology and Gamma Ray Bursts, University of Pennsylvania, March 1992.

Gravitational Lensing, Cosmology, and Gamma Ray Bursts, MSFC, July, 1992.

Gamma Ray Bursts and Cosmology, University of California, Santa Cruz, September 1992.

Gravitational Lensing and Limits on Compact Dark Matter from Gamma Ray Bursts, California Institute of Technology, September 1992.

**Community Service:**

I have been sending out and answering questions about my video tape: "Fantasy Trip to a Neutron Star." I receive no money for either the tape or the consultation. I have sent out over 100 tapes, and received requests for permission to copy the tape, which I grant. A small portion of the tape aired on CNN Headline News the weekend of January 17, after the Atlanta meeting of the American Astronomical Society.

I am due to have a humorous, didactical, and scientifically accurate article titled "What's the Matter with the Universe, Adventures with Random Data" published in Astronomy Magazine. They promise this article will be published soon, but as of this writing it has not yet appeared.

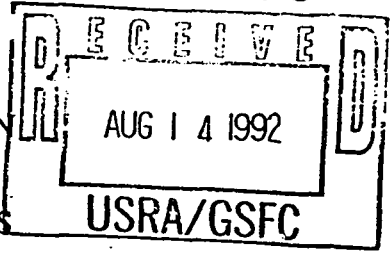
**University Collaboration:**

I presently collaborate with Thulsi Wickramasinghe, a graduate student at the University of Pennsylvania. I also meet frequently with and collaborate with Professor Bohdan Paczynski of Princeton University.

**Other Collaborative Activities:**

I collaborate most closely with Dr. Jay Norris here at GSFC. I participate in a Phase 2 *Compton* proposal with Dr. Eric Chipman of the Computer Science Corporation working here at GSFC. I also am collaborating with several scientists from MSFC, headed by Dr. Gerald Fishman, on scientific analysis of gamma ray bursts. I also have a continuing collaboration with Dr. Kent Wood from the Naval Research Laboratory on coded aperture design and effects near neutron stars and black holes.

000-043



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Wan Chen Task Number: 5000-643

General Description of Your Research Activities: (Include a Paragraph on each Activity).

(i) Black hole mass in X-ray Nova Muscae 1991.

In the course of trying to interpret the observed narrow line width of the annihilation feature in the hard X-ray spectrum of Nova Muscae (from SIGMA observations), I found that we can use the line redshift and width to constrain the accreting disk inclination angle and therefore to estimate the black hole mass in the system. The result is that this is probably a massive ( $> 10 M_{\odot}$ ) black hole. A paper is submitted to ApJ Letters. (see attached manuscript)

(ii) Jets and pair production in the Galactic Center source 1E1740.7-2942.

From newly discovered radio jets from 1E1740.7-2942, I estimate the jet-ISM interaction and then the momentum flux in the jets. I find that the jet has to be made of a normal proton-electron plasma with  $e^+e^-$  pairs. The observed variable narrow 511 keV line in the mixed Galactic Center region requires the pair/proton ratio in the jet is of order of unity. I also investigate the physical mechanisms to produce pairs and annihilate them in an accretion disk for a time period of a few days. This is a very interesting but extremely hard problem. The work is still in progress.



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# EVIDENCE FOR A MASSIVE STELLAR BLACK HOLE IN X-RAY NOVA MUSCAE

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*NASA/Goddard Space Flight Center, Greenbelt, Maryland 20771*

and

F.H. Cheng

*Space Telescope Science Institute, Baltimore, Maryland 21218, and*

*Center for Astrophysics, University of Science and Technology of China, Hefei, China*

Submitted to *The Astrophysical Journal, Letters*

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<sup>1</sup>Universities Space Research Association

## Abstract

We present evidence that the X-ray Nova Muscae system contains a massive,  $> 10M_{\odot}$ , black hole. The recently measured photometric binary mass function of Remillard, McClintock, & Bailyn (1992) gives the black hole mass for this system as a function of orbital inclination angle. From the spectral redshift and width of the positron annihilation  $\gamma$ -ray line observed by GRANAT/SIGMA, we find the accretion disk inclination angle to be  $22^{\circ} \pm 18^{\circ}$ . Assuming the accretion disk lies in the orbital plane of the system, the black hole mass is found to have a lower limit of  $14 M_{\odot}$  although statistics are poor. This is supported by spectral modeling of combined optical/UV/x-ray/ $\gamma$ -ray data and by a new Nova Muscae distance limit we derive of  $> 3$  kpc. The large mass for this black hole and the high binary mass ratio it implies ( $> 20$ ) raise a serious challenge to theoretical models of the formation and evolution of massive binaries. The  $\gamma$ -ray line technique introduced here can give tight constraints on orbital parameters when high-sensitivity line measurements are made by such missions as *GRO*.

## 1 INTRODUCTION

The X-ray Nova Muscae 1991 (GRS1121-68=GS1124-683, hereafter XN Mus) was discovered on 9 January 1991 by the all-sky monitors onboard both the GRANAT and Ginga satellites (Lund & Brandt 1991; Makino 1991), and was subsequently observed by all the X-ray and  $\gamma$ -ray instruments in orbit: by ART-P and SIGMA on GRANAT in 3-1300 keV (Grebenev, Sunyaev, & Pavlinsky 1991; Gilfanov et al. 1991), by GINGA in 4-37 keV (Tanaka, Makino, & Dotani 1991), and by ROSAT in 0.4-2.3 keV (Greiner et al. 1991). The early optical and X-ray light curve and spectral behavior of XN Mus are remarkably similar to that of the black hole system A0620-00 (=V616 Mon; Tanaka, Makino, & Dotani 1991), which suggests that XN Mus also contains a black hole. Observations at ESO (Della Valle, Jarvis, & West 1991a,b) have identified the optical counterpart of XN Mus both before and

after the outburst as a K-M dwarf orbiting a compact object, probably a black hole (Della Valle, Jarvis, & West 1991b), located at an estimated distance of 1.4 kpc. The binary period of the system was later found to be 10.5 hours (Bailyn 1992). By modeling the HST/FOS observation of XN Mus together with the spectra from ART-P, NTT (Della Valle, Jarvis, & West 1991a) and IUE (Shrader & Gonzales-Riestra 1991), Cheng et al. (1992) found that the broadband spectrum and its evolution can be well fitted by a standard black-body thin accretion disk model (Czerny, Czerny, & Grindlay 1986). The *minimum* compact object mass in this analysis is found to be  $12.5 M_{\odot}$  using the observed orbital period and a distance of  $\sim 5$  kpc.

Yet the ultimate proof of the presence of a black hole in XN Mus relies on the dynamic evidence of the mass of the compact object. Optical photometry and spectroscopy of XN Mus in quiescence obtained recently at CTIO (Remillard, McClintock, & Bailyn 1992) give a mass function,

$$f \equiv \frac{(M \sin i)^3}{(M + M_c)^2} = 3.07 \pm 0.4 M_{\odot}, \quad (1)$$

where  $M$  and  $M_c$  are the masses of the primary and companion, and  $i$  is the orbital inclination angle of the system ( $i = 0$  is face-on). For reasonable values of the mass range for the K0V-K4V dwarf companion ( $0.3-0.7 M_{\odot}$ ) and the orbital inclination angle ( $i < 80^{\circ}$  for lack of optical and X-ray eclipses), the compact primary has a mass  $M > 3.75 M_{\odot}$  and is therefore very likely a black hole. To further pin down the primary mass, one needs to know more about the orbital inclination angle of the system which, unlike the partially eclipsing binary A0620-00 (Haswell 1991), cannot be obtained from optical photometry or spectroscopy for XN Mus. In this letter we show that such geometric information can be inferred from the central energy and width of a  $\gamma$ -ray emission line from XN Mus.

## 2 MODEL

Twelve days after the hard X-ray outburst, a most remarkable transient emission feature was observed in the high energy spectrum of XN Mus by SIGMA (Sunyaev et al. 1992; Goldwurm et al. 1992). The line radiation was seen only for a few hours, with central energy  $\sim 480$  keV and a FWHM  $\sim 60$  keV. The most natural interpretation is that it is a positron annihilation line (rest-frame energy  $E_0 = 511$  keV) radiated from the vicinity of a compact object and so is gravitationally redshifted by about 6%. An emission line of energy  $E_0$  radiated at a distance  $r$  from the compact object is observed to be redshifted to  $E = E_0 - \Delta E$  where  $\Delta E/E_0 = 1 - (1 - r_s/r)^{1/2}$  and  $r_s = 2GM/c^2$  is the Schwartzchild radius. For XN Mus, the reported annihilation radiation is centered at  $E = 481 \pm 22$  keV from Goldwurm et al. (1992) and at  $476 \pm 15$  keV from Sunyaev et al. (1992). If we adopt the mean value,  $479 \pm 13$  keV, the redshift is then  $z = \Delta E/E = 0.068 \pm 0.030$  and the annihilation radius  $r = 8.2 \pm 3.5 r_s$ .

There is other observational evidence that the annihilation photons are produced near the black hole. First, there is a narrow emission feature  $\sim 200$  keV that appeared in the high energy spectrum of XN Mus at the same time as the annihilation feature (Sunyaev et al. 1992; Goldwurm et al. 1992). This can be attributed to annihilation photons escaping from the inner region of the accretion disk and then being Compton reflected by the outer part of the disk (Lingenfelter & Hua 1991). Second, no three-photon positronium continuum is found in the annihilation spectrum of XN Mus (Grebenev, Sunyaev, & Pavlinsky 1991), suggesting that the annihilation site is hotter than  $10^5$  K (Bussard, Ramaty, & Drachman 1979) or denser than  $10^{14}$  cm $^{-3}$  (Crannel et al. 1976) and is therefore near the black hole.

One may argue that the line redshift is due to the Doppler effect of a jet of annihilating  $e^+ - e^-$  pairs emanating from the system, but we believe this is unlikely. Accretion systems usually have, if any, *two* jets in opposite directions, so we should see both blueshifted and

redshifted lines. However, in XN Mus only a redshifted component was seen. All the physical mechanisms for hiding one jet (e.g., Lorentz boosting or disk shadowing) would allow the observer preferentially to see the one which is *blueshifted* rather than the redshifted one. So the line redshift is not due to the Doppler effect unless the system produces only a single jet which happens to be moving away from us and is not obscured by the accretion disk in the system. We also draw the reader's attention to similar *transient* and *redshifted* annihilation radiation observed from the Galactic Center  $\gamma$ -ray source 1E1740.7-2942 by SIGMA (Bouchet et al. 1991) and from a hard X-ray source observed by HEAO A-4 instrument (Briggs 1991). For comparison, we plot the original spectra of the three sources together in Fig. 1. The redshifts in all three detected annihilation features are quite similar which favors their gravitational origin.

Is the annihilation site more likely in a pair cloud surrounding the black hole or in the inner region of the accretion disk? From a theoretical point of view, the accretion disk is undoubtedly the favorite choice. Near the black hole, high energy  $e^+ - e^-$  pairs are thought to be created via  $\gamma - \gamma$  collisions to form a pair cloud (e.g., Liang 1991) and subsequently blown away by radiation pressure (Sunyaev et al. 1992). In the inner region of the accretion disk with densities of order  $10^{18} - 10^{20} \text{cm}^{-3}$  (Czerny, Czerny, & Grindlay 1986), the high energy positrons intercepted by the disk slow down and annihilate within a few  $r_g$ . Such an idea has recently been proposed by Ramaty et al. (1992) to explain the annihilation feature observed in 1E1740.7-2942. There is actually direct observational evidence that the annihilation in XN Mus takes place in an accretion disk. Gilfanov et al. (1991) report that the line shape may be more complicated than a simple Gaussian profile if the data are binned in the narrowest ( $\Delta E \sim 15 - 20 \text{keV}$ ) detector channels (see the inset graph in Fig. 1(a)). The line shape can be better described by *two narrow components* than by a single broad line. A double-peaked line profile is exactly what one would expect from the Doppler effect of Keplerian motion in an accretion disk (Chen & Halpern 1989; Bhattacharya & Gehrels

1991). Although the relatively poor statistics in the line does not allow a firm conclusion, we regard this as an important clue.

The width of an emission line from an accretion disk is affected by both thermal broadening and disk rotation. If in XN Mus the maximum disk temperature is  $\sim 0.8$  keV from ROSAT spectral fitting (Greiner et al. 1991), the thermal contribution to the line width is  $\sim 30$  keV. Since the line radiation comes  $\leq 10r_s$  from the black hole, the large Keplerian velocity of the disk rotation may broaden the line to as wide as  $> 100$  keV. However, the observed line width of the annihilation feature is much less, about 60 keV (see below). If one believes the gravitational origin of the line redshift, the only way to reconcile the discrepancy is to assume the accretion disk in XN Mus has a small inclination angle to our line of sight. Thus, the observed narrow annihilation line width of XN Mus provides a rare and unique opportunity for us to estimate the orbital inclination angle of the system (and so the mass of the black hole!) since the disk usually lies in the orbital plane.

The reported annihilation line has a FWHM =  $58 \pm 34$  keV from Sunyaev et al. (1992). Using the instrument spectral resolution at 500 keV of about 9% (Paul et al. 1991), one derives an intrinsic line width of  $\Delta E = 37 \pm 43$  keV, which differs somewhat from that reported by Goldwurm et al. (1992),  $54 \pm 54$  keV. The rotational line broadening,  $(\Delta E)_K$ , is related to the total intrinsic line width,  $\Delta E$ , and the disk inclination angle by  $\Delta E = [(\Delta E)_T^2 + (\Delta E)_K^2]^{1/2}$  and  $(\Delta E)_K/E \sim v/c \cdot \sin i$ , where  $(\Delta E)_T = 37$  keV  $(T/\text{keV})^{1/2}$  is the thermal broadening,  $E$  is the redshifted line center energy, and  $v/c = (GM/c^2r)^{1/2} = (r_s/2r)^{1/2}$  is the Keplerian velocity at radius  $r$ . This gives  $\sin i = (2r/r_s)^{1/2}(\Delta E)_K/E$ , which can be used with eq. 1 to calculate the mass of the compact primary,  $M$ , assuming a companion mass  $M_c = 0.5 \pm 0.2M_\odot$ . The results are listed in Table 1. Because of the large uncertainties in the line widths, we can not use the first-order error propagation method. Instead, we assume a Gaussian error distribution in the line width and calculate the mean and standard deviation of the derived parameters using exact formulae. Since both reported

line widths allow arbitrarily small inclination angle, no upper limit on the black hole mass can be derived. The lower limits on the black hole mass listed in Table 1 are calculated from the largest inclination angle  $\sin i + \Delta \sin i$ .

Indirect evidence of a large black hole mass in XN Mus can also be obtained by modeling the broad band optical-to-hard-X-ray spectrum. Using a standard thin accretion disk model Cheng et al. (1992) found a lower limit for the mass of the black hole of  $12.5 M_{\odot}$ . However, we have included the ROSAT soft X-ray data and find that the simple thin blackbody disk model is no longer valid. Although the ROSAT spectrum by itself can be fitted by a thin disk model (Greiner et al. 1991), the observed soft X-ray flux is almost an order of magnitude less than the extrapolation from the optical and UV data. On the other hand, the relatively large absorption column also allows the ROSAT spectrum to be equally well fitted by a power law (Greiner et al. 1991). In this case, if we require that the extrapolation of the UV disk emission to soft X-rays does not exceed the power law flux, we get a lower limit on the black hole mass of  $\sim 30 M_{\odot}$ . Further detailed modeling is underway.

### 3 DISCUSSION

Under the assumptions that (1) the annihilation line centroid redshift is purely gravitational and (2) the line width is caused by the combined effect of temperature broadening and accretion disk rotation, we are able to estimate the orbital inclination angle of the XN Mus system and then to constrain the black hole mass. The major uncertainties in our results are due to the uncertainties in the reported line widths. Because of the measured narrow line width, the inclination angles are small and we conclude that the black hole mass is probably  $> 10 M_{\odot}$ . The mass ratio in this binary system reaches a new record,  $> 20$  (assuming the companion mass of  $0.5 M_{\odot}$ ). This is the first time a  $\gamma$ -ray line has ever been used to determine the geometry of an accretion disk system, though the poor photon statistics in

this data set introduces large uncertainties in the deduced black hole mass. This technique, however, can certainly be used in future, more sensitive  $\gamma$ -ray line observations such as those performed by the *Compton Gamma Ray Observatory* to achieve much better precision.

An interesting complication to our interpretation is Compton scattering (Leventhal 1992). As the annihilation photons make their way out of the accretion disk, they can be Compton back-scattered to produce the 200 keV feature observed in the XN Mus spectrum. The forward-scattered photons will form a continuum (similar to that caused by the positronium three-photon annihilation) at energies below 511 keV (Lingenfelter & Hua 1991). When this continuum plus line are convolved with the finite detector energy resolution, the measured line can be redshifted and broadened (Leventhal 1973). However, the lack of positronium continuum below the line and the low value ( $< 0.3$ ) of the observed line flux ratio between the 200 keV and 480 keV features indicate a small Compton optical depth (Lingenfelter & Hua 1991) and thereby a small contribution to the annihilation line profile.

The distance to XN Mus is not well determined. Della Valle, Jarvis, & West (1991a) give an estimate of 1.4 kpc using optical data. Grebenev, Sunyaev, & Pavlinsky (1991) confine it within  $0.5 < D < 5$  kpc from ART-P data. Cheng et al. (1992) derive a large value of 8 kpc from the pre-nova companion brightness. The reported column density towards XN Mus from ROSAT observations (Greiner et al. 1991) is  $1.45 \times 10^{21} \text{cm}^{-2}$  which is consistent with the color excess  $E(B - V) = 0.29$  measured with IUE and HST (Cheng et al. 1992). Using the empirical relationship between column density, galactic latitude and the distance above the galactic plane (Diplas 1992), we find that XN Mus ( $b'' = -7.1^\circ$ ) has reached the *maximum* absorption for that latitude and is at least 300-400 pc above the galactic plane. This implies a *minimum* distance of 3 kpc and is fully consistent with 8 kpc. A nearby star, GS Mus, at the same galactic latitude and having similar column density has a distance of 5.2 kpc. The combined X-ray luminosity from both ROSAT and ART-P taken about two weeks after the hard X-ray continuum outburst is  $\sim 1.3 \times 10^{38} \text{ergs s}^{-1} (D/3\text{kpc})^2$ . If we



require that the total X-ray luminosity at that time does not exceed 20% of the Eddington limit, as indicated by its hard X-ray luminosity evolution (Grebenev, Sunyaev, & Pavlinsky 1991) and ROSAT spectral fitting (Greiner et al. 1991), the black hole mass is found to be  $M \geq 4.5M_{\odot}(D/3\text{kpc})^2$ . If the distance is 8 kpc as suggested by Cheng et al. (1992), the lower limit is then  $32M_{\odot}$ .

The large mass of the black hole in XN Mus conjectured in this paper may be pushing the current theoretical tolerance on the mass of a stellar-sized black hole and the mass ratio in a binary system. In the current massive star evolution model, the iron core mass at the end of the evolutionary track determines whether the final product becomes a black hole or not. If the core is greater than about  $1.4M_{\odot}$ , it will collapse into a black hole rather than form a neutron star. When this happens, the lack of a hard shell surface to bounce back the collapsing mass will prevent a massive supernova explosion and the whole remnant star can fall into the black hole in a more or less spherical fashion. Thus, one might expect that massive black holes are common since the main sequence mass spectrum extends to above  $100M_{\odot}$ . The problem is that most theoretical models predict all massive stars of solar abundance go through a Wolf-Rayet phase during which mass loss is severe. The mass left at the end of the evolution becomes very small ( $< 10M_{\odot}$ ) for almost the entire mass spectrum. The more massive a star is, the more severe its mass loss. So the most massive stars may not necessarily produce the most massive black holes. One way out of this dilemma is to let the star collapse before it enters the Wolf-Rayet stage, e.g. in the blue supergiant phase as in the case of SN 1987A. But how this is done for stars of solar abundance is still an open question.

Another alternative is to produce a massive black hole through binary interaction. This is also directly related to our second problem of producing a close binary system of extreme mass ratio. A particularly interesting model (Eggleton & Verbunt 1986) has been proposed specifically for the black hole system A0620-00 in which a triple star system goes through

two common envelope phases to form a black hole and a low mass close companion. In this scenario, the progenitors are two massive stars in a close orbit joined by a late dwarf at large distance. The massive binary first evolves into a normal high mass X-ray binary, and the compact object (either a black hole or a neutron star) spirals into and merges with the core of its companion when the latter evolves into a supergiant. When the envelope of the companion reaches the late-dwarf orbit, the latter spirals in to form a low mass close binary. Since the compact object directly accretes matter from its massive companion, it can become a black hole with much more mass than single star evolution would allow. This picture may be plausible if one considers that triple stars occur in as many as 15-20% of the stellar systems.

We are grateful to Jim Pringle and Mario Livio for helpful conversations, and to Michael Briggs for permission to use a figure from his thesis and for useful conversations. We thank Athanaasios Diplas for providing the extinction curve and especially Marvin Leventhal for a critical reading of the manuscript.

TABLE 1      Annihilation line parameters and derived black hole mass

Parameters	Groups		
	Goldwurm et al.	Sunyaev et al.	Mean
Line center $E$ (keV)	$481 \pm 22$	$476 \pm 15$	$479 \pm 13$
Center redshift $z$	$0.062 \pm 0.049$	$0.074 \pm 0.034$	$0.068 \pm 0.030$
Annihilation radius ( $r_s$ )	$8.8 \pm 6.2$	$7.6 \pm 3.1$	$8.2 \pm 3.5$
Intrinsic FWHM (keV)	$54 \pm 54$	$39 \pm 37^a$	$47 \pm 33$
Rotational FWHM <sup>b</sup> (keV)	$46 \pm 50$	$31 \pm 36$	$38 \pm 31$
$\sin i$	$0.38 \pm 0.41$	$0.25 \pm 0.29$	$0.32 \pm 0.25$
Inclination angle $i$	$27^\circ \pm 31^\circ$	$16^\circ \pm 20^\circ$	$22^\circ \pm 18^\circ$
Black hole mass ( $M_\odot$ )			
Lower limit ( $1 \sigma$ )	7.2	20	14

<sup>a</sup> Derived from the observed FWHM by removing the instrumental width.

<sup>b</sup> After removing thermal broadening from the intrinsic width.

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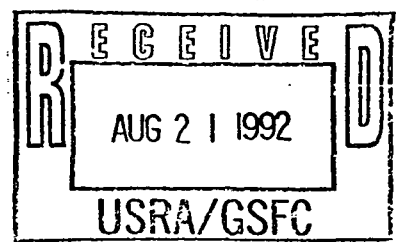
## FIGURE CAPTIONS

Fig. 1 The photon spectra of the three known hard X-ray sources that have shown positron annihilation features. (a) X-ray Nova Muscae 1991 (from Goldwurm et al. 1992); (b) 1E1740.7-2942 (from Bouchet et al. 1991); and (c) HEAO A-4 source (from Briggs 1991). The *solid* lines are the best fit continuum plus a Gaussian annihilation profile. A *dashed* vertical line is drawn at 511 keV as a reference to show the redshift of the lines. The annihilation lines in both (b) and (c) are very broad which is consistent with disk broadening at a large viewing angle (edge-on systems). The emission feature in XN Mus is considerably narrower, indicating a face-on system (see text). In panel (a), there is also a possible Compton reflection feature near 200 keV. The inset graph shows the SIGMA count spectrum of the annihilation feature after removing the power-law continuum (adopted from Gilfanov et al. 1991).

SV

660-044

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
 GODDARD VISITING SCIENTIST PROGRAM  
 EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
 (for the year ending 9/30/92)



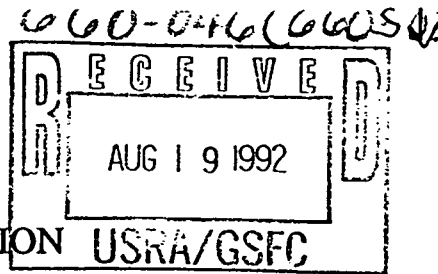
Employee Name: Helmut Seifert Task Number: 660-044

General Description of Your Research Activities: (Include a Paragraph on each Activity).

As instrument scientist I have been working on various aspects of the instrument development for The Transient Gamma-Ray Spectrometer (TGRS) which has been chosen, under the Global Geospace Science (GGS) mission, to fly on the WIND spacecraft due to be launched in fall of 1993, and is designed to perform high resolution studies of gamma-ray burst spectra.

I have been leading and supervising the design, development, implementation, and testing of a data analysis package for TGRS, as well as the completion of the Ground Support Equipment (GSE) software. This included writing requirements/specifications documents, and the development and testing of the algorithms which are used by our software. My other responsibilities in the laboratory are to lead the testing of the experiment analog/digital electronics, and the flight software.

I am actively involved in the planning and preparations for the various tests during the integration phase of TGRS. I am taking a leading part in carrying out these tests, as well as all the necessary calibrations of the instrument. After the launch of TGRS, I will participate in the scientific analysis and interpretation of the experimental data.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENCE PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: James Lochner

Task Number: 5000-646

General Description of Activities:

**Summary:** I hired on with USRA in late October 1991, having just completed a post-doctoral position with the Space Astronomy and Astrophysics group at Los Alamos National Laboratory. In the past year my programmatic USRA activities have been with the High Energy Astrophysics Science Archive Research Center (HEASARC), and with the X-ray Timing Explorer Guest Observer Facility (XTE GOF). My major programmatic accomplishments include: 1) transferring the *Vela 5B* All Sky Monitor data from Los Alamos to the HEASARC; 2) developing a plan for user access to these data; 3) transferring the *Ariel 5* All Sky Monitor data from the GSFC IBM 3081 to the HEASARC; and; 4) developing requirements and implementation plans for the XTE GOF. Research activities have centered on utilizing the *Vela 5B* data in the study of the soft x-ray transient 4U 1608, and in monitoring the previous history of new sources and new reports of long term periodicities.

**Vela 5B**

The *Vela 5B* All Sky Monitor data base offers a unique 10 year history of the x-ray sky from 1969 - 1979. The inclusion of this data base into the HEASARC represents a major contribution in its efforts to assemble and make available data from past missions. While at Los Alamos, I utilized this data base in my research of long term variability of galactic x-ray sources. During my first two months with USRA, I remained at Los Alamos to carry out the transfer of the data base to the HEASARC. This was accomplished through coordinating the data transfer with system personnel at Los Alamos and at Goddard's National Space Science Data Center Data Archive and Distribution Service (NDADS). By Dec 31, 1991 the 6 Gbyte database had been transferred via computer networks to optical platter on the NDADS system and became part of the newly created Automatic Retrieval Mail System. The *Vela 5B* data were the first non-GSFC resident data to be made a part of that system, and demonstrated the ease with which such a transfer is possible.

While at Los Alamos, I also developed a plan for user access to the *Vela* data. The plan includes producing products in the form of light curves for sources of general interest. Because of the nature of the *Vela 5B* data, these light curves are obtained in one of two ways: either a simple



extraction from the data base for isolated x-ray sources, or a fitting of an intensity map for more crowded regions of the sky. The plan lists approximately 70 x-ray sources, divided into those two categories. The plan includes criteria for acceptance of the data from the sky fits, and algorithms for implementing these criteria were initiated while I was at Los Alamos. The plan also includes a means for users to obtain light curves for sources not part of the pre-selected list.

Once at Goddard, I set up an environment on the HEASARC computers in which to gain access to the data on the NDADS platters. I implemented algorithms used at Los Alamos for constructing the isolated source light curves and for fitting the sky maps. Such an environment and such computer code not only facilitate the creation of the data products, but will also ultimately be the basis for user access to new sources.

In April, shifted the bulk of my time to the XTE-GOF (see below), handing over the *Vela 5B* project to Dr. Laura Whitlock (USRA). Since then, I have collaborated with Dr. Whitlock on policy issues and pragmatics concerning the development of this data base in the HEASARC.

### **Ariel 5 All Sky Monitor**

The All Sky Monitor aboard the *Ariel 5* satellite adds to the *Vela 5B* history of the x-ray sky from 1974 - 1980. These data have long been resident in the tape library of the GSFC IBM 3081, but with changes in the IBM system these data were threatened with extinction. I worked with Katherine Rhode (STX-HEASARC) to rescue these data and transfer them to the HEASARC system. Because the data were already in the form of light curves, we needed only to identify the sources of interest, matching this list to that for the *Vela 5B* data. Once transferred to the HEASARC system, we defined FITS format definitions for these light curves to conform to the format for data products in the HEASARC system. The conversion of the files to these formats was taking place at fiscal year end.

The *Ariel 5* effort is another task taken over by Dr. Whitlock, with myself acting in consultation.

### **XTE Guest Observer Facility**

In April, I shifted my programmatic efforts to the XTE Guest Observer Facility. This new facility within the XTE Science Operations Center (SOC) was created to separate out functions serving guest observers from the day-to-day operations of the satellite. The Office of Guest Investigator Programs (OGIP) in the Lab for High Energy Astrophysics oversees the operation of the GOF (as well as of the HEASARC).

Upon joining the GOF, I took the lead in writing a document describing the GOF's responsibilities and requirements. This was done through a series of meetings with the other GOF personnel, the Science Operations Facility (SOF) personnel and the manager of the SOC. We successfully identified the GOF requirements, and its interfaces to the SOF, the HEASARC and to NASA Headquarters. I also participated in the development of the SOC software build plan, which describes a schedule for implementing the SOC requirements, including those of the GOF. This work has necessitated discussions with the software personnel for the three instrument teams

("PIs") which make up the XTE satellite. I have also participated in the group effort to design the software system using an object-oriented environment.

I have also played an active role in a number of important XTE meetings. At the XTE Science Working Group meeting June 23-25, I presented a summary of the GOF requirements. I organized and conducted the second of the SOC-PI Software Interface meetings Aug 13-14, and gave a presentation of the implementation plan to the SOC Preliminary Design Review Sept. 3-4.

#### **Non-programmatic Research Activities**

**4U 1608-52:** The *Vela 5B* data augments the outburst history of the soft x-ray transient 4U1608-52. I and Dr. Diane Roussel-Dupré (Los Alamos) have been studying the history of the transient during the time observed by the *Vela 5B* satellite. These data present four previously unknown transient outbursts in the early 1970's. The history of the outbursts reveals a possibly 20 day underlying cycle, but one in which outbursts do not always occur on the cycle. Further, one outburst in 1970 is particularly peculiar, since it is symmetric in its time profile rather than having a rapid rise and exponential decay. This outburst also reveals the presence of a 4.14 day orbital period, and another 20 day period presumably due to precession of an accretion disk. Both periods are new results for this system, and we interpret them in terms of a disk outburst model. This work is being submitted for publication as this review period comes to a close.

**Miscellaneous:** I continue to use the *Vela 5B* data to investigate reports of long term periods x-ray sources, and to look for previous outbursts of new transients. Among such work this past year, I examined LMC X-3 for a ~ 190 d period (Cowley, A. P. *et al*, 1991, *Ap.J.*, 381, 526). Because of limitations in the data, I obtained a null result. In addition, I looked into the past history of some of the transients seen by the Ginga satellite. I also renewed a project to examine the evolution of the binary light curve of Circinus X-1, in an attempt to understand the orbital properties of the system.

#### **Recognition of Work:**

Recent Science Citations (1989 - 1991) show 6 references to my thesis work, published in 1989, *ApJ*, 337, 823.

#### **Papers Published or Accepted for Publication:**

"Long-Term Variability in Low Mass X-ray Binaries: A Study using Data from *Vela 5B*,"  
Smale, A. P. (USRA-GSFC) and Lochner, J. C. (USRA-GSFC) 1992, *ApJ*, 395, 582. [abstract enclosed]

**Papers Submitted but not yet Accepted for Publication:**

"Recurrence times and Periodicities in 4U 1608-52 as Observed by *Vela 5B*," Lochner, J. C. (USRA-GSFC) & Roussel-Dupré, D. (Los Alamos), Submitted to ApJ. Sept. 15, 1992.

**Papers Presented at Scientific Meetings:**

*Invited Papers*

"Strange Attractors and You," Lochner, J. C., presented at the 1992 Aspen Winter Physics Conference on Astrophysics: "X-ray and Gamma Ray Signatures of Black Holes vs. Neutron Stars", Jan 19 - 25, 1992

*Contributed Papers*

"Properties of Multiple Event Gamma Ray Bursts", Lochner, J. C., Proc. 1991 Huntsville Gamma Ray Burst Workshop, eds. W.C. Paciesas and G.J. Fishman (AIP: New York), 1992, in press.

*Colloquia, Seminars, and Special Lectures*

"Analyzing Light Curves for Chaos", Aug 31, 1992, to the LHEA Noontime Gamma-Ray Lunch

**Community Service:**

I am a member and Vice President for Education of the Triple Crown Toastmasters Club in Bowie Maryland. I often use opportunities in the club to promote a general understanding of science and science issues.

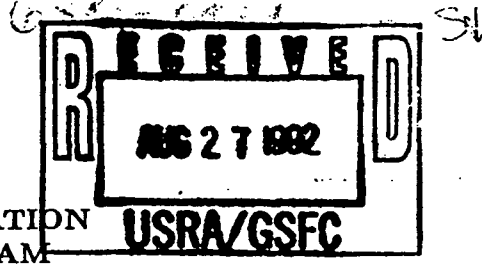
**University Collaborations:**

- None -

**Other Collaborative Activities:**

Under Research Activities, I have discussed my collaboration with Dr. D. Roussel-Dupré at Los Alamos National Lab.

The work done on LMC X-3 was done in collaborations with Dr. Tomaso Belloni of the Max Plank Institut in Germany



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Ivan HUBENY                      Task Number: 5000-807

General Description of Your research Activities:

1. *Stellar atmospheres*

- Basic theory of stellar atmospheres: During this period, when new observations of hot stars taken by Hubble Space Telescope became available it became clear that these high signal-to-noise and high-resolution observations have to be interpreted using more sophisticated model stellar atmospheres than those constructed so far. The most important task is to incorporate the effect of thousands to millions of spectral lines, without assuming local thermodynamic equilibrium (LTE), to model atmospheres - the so called non-LTE line blanketing. I have therefore concentrated, mostly in collaboration with Dr. T. Lanz (NRC), on developing the methodology for treating this difficult problem. We have indeed succeeded in developing several new, sophisticated methods which make calculations of non-LTE line blanketed model possible. One such method is the so-called accelerated complete linearization (Ref. 4), the other is a hybrid method between the Accelerated Lambda Iteration (ALI) methods (reviewed in Ref. 3), and complete linearization. The method and the first results are briefly described in Ref. 6, but several other, more detailed, papers are currently in preparation. Generally speaking, the first results look very promising, indicating that the new methods represents a real breakthrough in the field. - etc
- Collaboration with the GHRS group (Drs. S. Heap, B. Altner): A work has continued on interpreting individual hot stars observed by HST (the hot subdwarf BD+75 325 - some results are presented in Ref. 10; the analysis is expected to be finished later this fall), and by other instruments (IUE, optical) - the central star of NGC 6826 (Ref. 11). -
- I have worked with Dr. W. Schmutz (ETH Zurich, Switzerland), during his visit to GSFC this spring, on combining his stellar wind computer program with my synthetic spectrum program with the aim to develop a general spectrum synthesis program for spherical, expanding stars. The work still continues.
- I have worked with researchers from Space Telescope Science Institute (groups of Drs. K. Long and K. Horne) on model atmospheres for solar-composition white dwarfs which are found in some cataclysmic variable systems, observed by Hopkins Ultraviolet Telescope and Hubble Space Telescope (Refs. 5 and 8). - etc
- Dr. D. Mihalas, the leading world authority in the field of stellar atmospheres, has invited me to write with him the third edition of his famous textbook-monograph "Stellar Atmospheres". The second edition was published in 1978, and in between an enormous progress in the field was achieved. During my stay in Boulder in August, we have already started actual work, and prepared a detailed outline of a completely changed book, taking into account all recent developments. - etc

## 2. *Accretion disks*

- I have continued in a collaboration with Dr. M. Plavec (UCLA) in modeling spectra of accretion disks in the Algol and W Serpentis classes of close binary systems.
- I have worked with Dr. A. Linnell (Michigan State University) on implementing my accretion disk program and the synthetic spectrum program SYNSPEC to his package of programs for calculating light curves of close binaries. The work still continues.
- I have worked with Dr. G. Rybicki (Harvard-Smithsonian CfA) on developing simple and useful models of accretion disks, based on the so-called multi-gray formalism. Results are expected to be published in the near future.
- I have started a collaboration with Dr. R. Wade (Penn State) on various aspects of theoretical modeling of accretion disks and interpreting observations of selected cataclysmic variables.

## 3. *Radiative transfer*

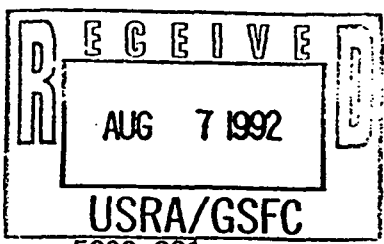
- I have continued to work with Dr. B. Lites (HAO, NCAR, Boulder) on developing a new computer program for including effects of partial redistribution to the multilevel, non-LTE line formation problems. The work still continues.
- I have been asked to write a chapter about "Solution of the radiative transfer problem" to the intended book "Numerical Astrophysics". The editors also ask all contributors to include a corresponding computer program, which will then serve as a benchmark computer program in the corresponding research fields for all other workers (similarly to "Numerical recipes" in numerical mathematics). I have already begun working on this project.

680-021

SV

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee name: Gary Hinshaw

Task Number: 5000-821

General description of your research activities:

During the 1992 fiscal year my activities have been primarily devoted to support for the DMR experiment on COBE, I have also been spending part of my time analyzing some of the galactic data from the FIRAS experiment on COBE.

I spent a good deal of my time in the early part of the fiscal year working with the DMR team preparing the final drafts of 4 scientific papers which summarize the first positive detection of anisotropies in the Cosmic Microwave Background radiation. These papers were submitted to the Astrophysical Journal (3 Letters and 1 paper) on 1992 April 21, and were accepted on 1992 June 12. I am a co-author on all four of the papers. I was also one of five speakers from the DMR team to announce our results at the Spring meeting of the American Physical Society on April 23. Since the time of our announcement I have given several talks on our results, including a joint Physics and Astronomy Colloquium at Yale University.

The most important contribution I made to the analysis of the DMR data was to demonstrate, in collaboration with Chuck Bennett, that the signals seen in the DMR maps could not be attributed to galactic foreground emission. In addition to bolstering our confidence in a landmark cosmological result, we learned a great deal about the nature of galactic emission at microwave frequencies. For example, we learned that free-free emission from diffuse ionized hydrogen clouds are the dominant galactic signal in the frequency range from about 20 - 80 GHz, a result that was not entirely expected. In addition we learned that any significant abundance of cold dust must be distributed differently than the hot dust at high galactic latitudes.

My present work is focusing on further analysis of the COBE data, again mostly in collaboration with Chuck Bennett. The first project involves gathering a variety of extra-galactic source catalogues (eg. 5 GHz point sources, Abell clusters, x-ray surveys, and so forth) and cross-correlating them with the DMR sky maps to place more specific limits on the extra-galactic contribution to our maps. The second project is a study of the full FIRAS spectrum data with which we will attempt to map the galactic distribution of various emission line features seen in the data. This work has important ramifications for the large scale distribution of the ionized component of our Galaxy. The final project is to write a paper for the Review of Scientific Instruments which summarizes the performance of the DMR instruments in flight. The information in this paper will hopefully be of use to workers planning future long-term mission with radiometers in space.

In addition to the above projects I have been spending a reasonable portion of my time recently consulting some of the newer members of our team on programming and systematic error analysis. I suppose it is the teacher in me (left over from my days at Oberlin College) that enjoys this aspect of the job.

Describe any Significant Recognition of your work:

We announced the results from our first year of data at the Spring APS meeting on 23 April, 1992. Following the announcement, virtually every major newspaper in the world covered the story as front page news. Many of the stories carried quotes from prominent cosmologists, for example:

"What these people have found is what I would call the Holy Grail of modern cosmology", Micheal Turner, University of Chicago

"It is the discovery of the century, if not of all time", Stephen Hawking, University of Cambridge

While these quotes are no doubt exaggerations, it does give one an idea of the excitement generated within the community at the time of our announcement.

Our sky maps also appeared on the cover of the June 1992 issue of Physics Today, the main news periodical for the broader community of physicists.

Honors or Awards Received:

Biography included in Who's Who in Science and Engineering, 1992

Papers published or Accepted for Publication:

(Abstracts are appended to this document.)

"COBE Differential Microwave Radiometers (DMR): Calibration Techniques."

Astrophysical Journal, 391, 467, (1992)

C.L. Bennett, NASA Goddard Space Flight Center

G.F. Smoot, University of California, Berkeley

M. Janssen, Jet Propulsion Laboratory

S. Gulbis, Jet Propulsion Laboratory

A. Kogut, Universities Space Research Association

G. Hinshaw, Universities Space Research Association

C. Backus, Hughes/STX Corporation

M.G. Hauser, NASA Goddard Space Flight Center

J.C. Mather, NASA Goddard Space Flight Center

L. Rokke, Hughes/STX Corporation

L. Tenorio, University of California, Berkeley

R. Weiss, Massachusetts Institute of Technology

D.T. Wilkinson, Princeton University

E.L. Wright, University of California, Los Angeles

G. DeAmici, University of California, Berkeley

N.W. Boggess, NASA Goddard Space Flight Center

E.S. Cheng, NASA Goddard Space Flight Center

P.D. Jackson, Hughes/STX Corporation

P. Keegstra, Hughes/STX Corporation

T. Kelsall, NASA Goddard Space Flight Center

R. Kummerer, Hughes/STX Corporation

C. Lineweaver, University of California, Berkeley

S.H. Mosely, NASA Goddard Space Flight Center

T.L. Murdock, General Research Corporation

J. Santana, Hughes/STX Corporation

R.A. Shafer, NASA Goddard Space Flight Center

R.F. Silverberg, NASA Goddard Space Flight Center

**"Structure in the COBE DMR First Year Maps."**

Astrophysical Journal Letters (1992) (To appear 1 September 1992)

G.F. Smoot, University of California, Berkeley  
C.L. Bennett, NASA Goddard Space Flight Center  
A. Kogut, Universities Space Research Association  
E.L. Wright, University of California, Los Angeles  
J. Aymon, University of California, Berkeley  
N.W. Boggess, NASA Goddard Space Flight Center  
E.S. Cheng, NASA Goddard Space Flight Center  
G. DeAmici, University of California, Berkeley  
S. Gulkis, Jet Propulsion Laboratory  
M.G. Hauser, NASA Goddard Space Flight Center  
G. Hinshaw, Universities Space Research Association  
C. Lineweaver, University of California, Berkeley  
K. Loewenstein, Hughes/STX Corporation  
P.D. Jackson, Hughes/STX Corporation  
M. Janssen, Jet Propulsion Laboratory  
E. Kaita, Hughes/STX Corporation  
T. Kelsall, NASA Goddard Space Flight Center  
P. Keegstra, Hughes/STX Corporation  
P. Lubin, University of California, Santa Barbara  
J.C. Mather, NASA Goddard Space Flight Center  
S.S. Meyer, Massachusetts Institute of Technology  
S.H. Mosely, NASA Goddard Space Flight Center  
T.L. Murdock, General Research Corporation  
L. Rokke, Hughes/STX Corporation  
R.F. Silverberg, NASA Goddard Space Flight Center  
L. Tenorio, University of California, Berkeley  
R. Weiss, Massachusetts Institute of Technology  
D.T. Wilkinson, Princeton University

**"Preliminary Separation of Galactic and Cosmic Microwave Emission for the COBE DMR."**

Astrophysical Journal Letters (1992) (To appear 1 September 1992)

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J.C. Mather, NASA Goddard Space Flight Center  
S.H. Mosely, NASA Goddard Space Flight Center  
T.L. Murdock, General Research Corporation  
R.F. Silverberg, NASA Goddard Space Flight Center



**"Interpretation of the CMB Anisotropy Detected by the COBE DMR."**

Astrophysical Journal Letters (1992) (To appear 1 September 1992)

E.L. Wright, University of California, Los Angeles  
S.S. Meyer, Massachusetts Institute of Technology  
C.L. Bennett, NASA Goddard Space Flight Center  
N.W. Boggess, NASA Goddard Space Flight Center  
E.S. Cheng, NASA Goddard Space Flight Center  
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T.L. Murdock, General Research Corporation  
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R.F. Silverberg, NASA Goddard Space Flight Center  
D.T. Wilkinson, Princeton University

**"COBE Differential Microwave Radiometers (DMR): Preliminary Systematic Error Analysis."**

Astrophysical Journal, TBD, (1992)

A. Kogut, Universities Space Research Association  
G.F. Smoot, University of California, Berkeley  
C.L. Bennett, NASA Goddard Space Flight Center  
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J.C. Mather, NASA Goddard Space Flight Center  
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S.H. Mosely, NASA Goddard Space Flight Center  
T.L. Murdock, General Research Corporation  
R.A. Shafer, NASA Goddard Space Flight Center  
R.F. Silverberg, NASA Goddard Space Flight Center  
R. Weiss, Massachusetts Institute of Technology  
D.T. Wilkinson, Princeton University

"COBE DMR Data Processing Techniques."

1st Ann. Astron. Data Anal. Conf., Tucson (1991)  
P.D. Jackson, Hughes/STX Corporation  
G.F. Smoot, University of California, Berkeley  
C.L. Bennett, NASA Goddard Space Flight Center  
J. Aymon, University of California, Berkeley  
C. Backus, Hughes/STX Corporation  
G. DeAmici, University of California, Berkeley  
G. Hinshaw, Universities Space Research Association  
P. Keegstra, Hughes/STX Corporation  
A. Kogut, Universities Space Research Association  
C. Lineweaver, University of California, Berkeley  
L. Rokke, Hughes/STX Corporation  
L. Tenorio, University of California, Berkeley

"Daily Quality Assurance Software for a Satellite Radiometer System."

1st Ann. Astron. Data Anal. Conf., Tucson (1991)  
P. Keegstra, Hughes/STX Corporation  
G.F. Smoot, University of California, Berkeley  
C.L. Bennett, NASA Goddard Space Flight Center  
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C. Lineweaver, University of California, Berkeley  
L. Rokke, Hughes/STX Corporation  
J. Santana, Hughes/STX Corporation  
L. Tenorio, University of California, Berkeley

Papers Submitted but not yet Accepted for Publication:

None

Papers Presented at Scientific Meetings:

Invited papers:

None

Contributed papers:

"COBE DMR Instrument Performance and Systematic Error Analysis."

Contributed Paper, Spring Meeting of the American Physical Society  
23 April 1992

Colloquia, Seminars, and Special Lectures:

"COBE DMR Observations of Cosmic Microwave Background Anisotropies."

Special Seminar, Goddard Space Flight Center JOVE Retreat  
23 July 1992

Joint Physics and Astronomy Colloquium, Yale University  
7 May 1992

Special Seminar, Cosmology Data Analysis Center  
6 May 1992

"COBE DMR First-Year Sky Maps."

Research Presentation to USRA Board of Trustees  
23 April 1992

Community Service:

"COBE DMR Observations of Cosmic Microwave Background Anisotropies."  
Invited Talk, Annual Meeting of the National Capital Astronomers  
12 September 1992

University Collaborations:

The principle investigator for the DMR instrument, George Smoot, is a University of California employee. Thus I am collaborating on a daily basis with George and other members of his U.C. group in the course of analyzing the DMR data.

Other Collaborative Activities:

None

Supply any Additional Information you Feel Would be Useful in evaluating your performance:

None

"COBE Differential Microwave Radiometers (DMR):  
Calibration Techniques."

**ABSTRACT**

The *COBE* spacecraft was launched 18 November 1989 U.T. carrying three scientific instruments into Earth orbit for studies of cosmology. One of these instruments, the Differential Microwave Radiometer (DMR), is designed to measure the large-angular-scale temperature anisotropy of the cosmic microwave background radiation at three frequencies (31.5, 53, and 90 GHz). In this paper we present three methods used to calibrate the DMR. First, the signal difference between beam-filling hot and cold targets observed on the ground provides a primary calibration that is transferred to space by noise sources internal to the instrument. Second, the Moon is used in flight as an external calibration source. Third, the signal arising from the Doppler effect due to the Earth's motion around the barycenter of the solar system is used as an external calibration source. Preliminary analysis of the external source calibration techniques confirms the accuracy of the currently more precise ground-based calibration. Assuming the noise source behavior did not change from the ground-based calibration to flight we derive a 0.1-0.4 % relative and 0.7-2.5 % absolute calibration uncertainty, depending on radiometer channel.

Subject headings: cosmic microwave background - instrumentation:detectors

# "Structure in the COBE DMR First Year Maps"

## ABSTRACT

We have analyzed the first year of data from the Differential Microwave Radiometers (DMR) on the Cosmic Background Explorer (COBE). We observe the dipole anisotropy, Galactic emission, instrument noise, and detect statistically significant ( $> 7\sigma$ ) structure that is well-described as scale-invariant fluctuations with a Gaussian distribution. The major portion of the observed structure cannot be attributed to known systematic errors in the instrument, artifacts generated in the data processing or known Galactic emission. The structure is consistent with a thermal spectrum at 31, 53, and 90 GHz as expected for cosmic microwave background anisotropy.

We select the data with Galactic latitude  $|b| > 20^\circ$  and remove the mean and dipole anisotropy. The rms sky variation, smoothed to a total  $10^\circ$  FWHM Gaussian, is  $30 \pm 5 \mu\text{K}$ . The rms quadrupole amplitude is  $13 \pm 4 \mu\text{K}$ . The angular auto-correlation of the signal in each radiometer channel and cross-correlation between channels are consistent and give an angular power-law spectrum with index  $n = 1.1 \pm 0.5$ , and an rms-quadrupole-normalized amplitude of  $16 \pm 4 \mu\text{K}(\Delta T/T \approx 6 \times 10^{-6})$ . These features are in accord with the Harrison-Zel'dovich (scale-invariant,  $n = 1$ ) spectrum predicted by models of inflationary cosmology. The overall fluctuation amplitude is consistent with predictions by minimal theories of structure formation based on gravitational instability.

" Preliminary Separation of Galactic and Cosmic  
Microwave Emission for the COBE DMR."

ABSTRACT

The *COBE* Differential Microwave Radiometers (DMR) anisotropy experiment is sufficiently sensitive and free from systematic errors that our knowledge of Galactic emission is a limiting factor in interpreting the measurements of the 1-year DMR maps (Smoot et al. 1992). In this paper we construct preliminary models of microwave emission from our Galaxy based on *COBE* and other data for the purpose of distinguishing cosmic and Galactic signals. DMR maps, with the modeled Galactic emission removed, are fit for a quadrupole distribution. Our best estimate of the cosmic quadrupole is found to be  $Q_{rms} = 13 \pm 4 \mu\text{K}$ ,  $(\Delta T/T)_Q = (4.8 \pm 1.5) \times 10^{-6}$ . Autocorrelation functions for individual Galactic components are presented. When Galactic emission is removed from the DMR data, the residual fluctuations are virtually unaffected and therefore they are not dominated by any known Galactic emission component.

*Subject headings:* cosmology - cosmic background radiation - Galaxies: Milky

Way

# Interpretation of the CMB Anisotropy Detected by the COBE DMR.

2

## ABSTRACT

We compare the large scale cosmic background anisotropy detected by the *COBE* DMR instrument to the sensitive previous measurements on various angular scales, and to the predictions of a wide variety of models of structure formation driven by gravitational instability. The observed anisotropy is consistent with all previously measured upper limits and with a number of dynamical models of structure formation. For example, the data agree with an unbiased Cold Dark Matter (CDM) model with  $H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1}$  and  $\Delta M/M = 1$  in a 16 Mpc radius sphere. Other models, such as CDM plus massive neutrinos (Hot Dark Matter), or CDM with a non-zero cosmological constant are also consistent with the *COBE* detection, and can provide the extra power seen on  $5-10,000 \text{ km s}^{-1}$  scales.

*Subject headings:* cosmology – cosmic background radiation

"COBE Differential Microwave Radiometers (DMR):  
Preliminary Systematic Error Analysis."

Abstract

The Differential Microwave Radiometers (DMR) instrument aboard the Cosmic Background Explorer (COBE) maps the full microwave sky in order to measure the large-angular-scale anisotropy of the cosmic microwave background radiation. Solar system foreground sources, instrumental effects, as well as data recovery and processing can combine to create statistically significant artifacts in the analyzed data. We discuss the techniques available for the identification and subtraction of these effects from the DMR data and present preliminary limits on their magnitude in the DMR one-year maps (Smoot et al. 1992). The largest effect is the instrument response to the Earth's magnetic field, which contributes up to 375  $\mu\text{K}$  to the raw data in the worst channel. Emission from the Earth is weak (less than 47  $\mu\text{K}$  in the raw data at 95% confidence). Residual uncertainties in the best DMR sky maps, after correcting the raw data for systematic effects, are less than 6  $\mu\text{K}$  for the pixel rms variation, less than 3  $\mu\text{K}$  for the rms quadrupole amplitude of a spherical harmonic expansion, and less than 30  $\mu\text{K}^2$  for the correlation function (all limits 95% confidence level). These limits are a factor of 5—40 lower than the level of anisotropy in the microwave background detected in the one-year DMR sky maps:  $30 \pm 5$   $\mu\text{K}$  rms,  $13 \pm 4$   $\mu\text{K}$  quadrupole, and  $1194 \pm 499$   $\mu\text{K}^2$  for the correlation function (Smoot et al. 1992, Bennett et al. 1992b, Wright et al. 1992).

*Subject headings:* cosmic background radiation



## COBE DIFFERENTIAL MICROWAVE RADIOMETER (DMR) DATA PROCESSING TECHNIQUES

P.D. JACKSON (HUGHES STX), G.F. SMOOT (UCB/LBL), C.L. BENNETT (NASA/GSFC), J. AYMEN (UCB/LBL), C. BACKUS (HUGHES STX), G. DE AMICI (UCB/LBL), G. HINSHAW (USRA), P. B. KEEGSTRA (HUGHES STX), A. KOGUT (NRC/NASA), C. LINEWEAVER (UCB/LBL), L.A. ROKKE (HUGHES STX), AND L. TENORIO (UCB/LBL)

**ABSTRACT** The purpose of the Differential Microwave Radiometer (DMR) experiment on the Cosmic Background Explorer (COBE) satellite is to make whole-sky maps, at frequencies of 31.5, 53, and 90 GHz, of any departures of the Cosmic Microwave Background (CMB) from its mean value of 2.735 K. An elaborate software system is necessary to calibrate and invert the differential measurements, so as to make sky maps free from large scale systematic errors to levels less than a millionth of the CMB.

### INTRODUCTION

The DMR instrument, which employs passive cooling and needs no cryogen, has been running continuously since launch on 18 Nov 1989. Early results, including skymaps showing the smoothness of the CMB to within one-part-in-thirty thousand, been published by Smoot et al (1991). A description of the software system in place near the time of launch was given by Torres et al (1989), and details of the techniques we use to invert the sparse matrix of skymap pixels and systematic error functions, are given by Gulkis and Janssen (1991). In this paper, we give an update of the status of the software system as it currently stands.

### DMR TELEMETRY

For each of the six DMR channels (two independent receivers at each frequency), the telemetry information consists of measurements, converted to integers in the range 0 to 4095, of the differential intensity (referred to as differential temperatures, or DT's) every 0.5 second, between two 7-degree portions of sky separated by 60 degrees. The spacecraft spin axis is nearly parallel to the local vertical and nearly perpendicular to the earth-sun direction; as the spacecraft spins, once every 75 seconds, the positive and negative horns, each pointed 30 degrees away from the spin axis, describe a spiral pattern on the sky as the spacecraft makes its near-polar orbit every 103 minutes. While half the sky is covered in a single orbit, it takes six months for the spin axis to point towards all parts of the sky

487214  
B314  
N93-18716

## DAILY QUALITY ASSURANCE SOFTWARE FOR A SATELLITE RADIOMETER SYSTEM

P.B. KEEGSTRA, G.F. SMOOT, C.L. BENNETT, J. AYMON, C. BACKUS,  
G. DE AMICI, G. HINSHAW, P.D. JACKSON, A. KOGUT, C. LINEWEAVER,  
L.A. ROKKE, J. SANTANA, L. TENORIO  
Astronomy Department, University of California, Berkeley, CA 94720

### ABSTRACT

Six Differential Microwave Radiometers (DMR) on COBE (Cosmic Background Explorer) measure the large-angular-scale isotropy of the cosmic microwave background (CMB) at 31.5, 53, and 90 GHz. Quality assurance software analyzes the daily telemetry from the spacecraft to ensure that the instrument is operating correctly and that the data are not corrupted. Quality assurance for DMR poses challenging requirements. The data are differential, so a single bad point can affect a large region of the sky, yet the CMB isotropy requires lengthy integration times ( $> 1$  year) to limit potential CMB anisotropies. Celestial sources (with the exception of the moon) are not, in general, visible in the raw differential data.

A "quicklook" software system has been developed that, in addition to basic plotting and limit-checking, implements a collection of data tests as well as long-term trending. Some of the key capabilities include (i) stability analysis showing how well the data RMS averages down with increased data, (ii) a Fourier analysis and autocorrelation routine to plot the power spectrum and confirm the presence of the 3 mK "cosmic" dipole signal, (iii) binning of the data against basic spacecraft quantities such as orbit angle, (iv) long-term trending, and (v) dipole fits to confirm the spacecraft attitude azimuth angle.

### INTRODUCTION

The purpose of the Differential Microwave Radiometer (DMR) experiment on COBE is to measure the large angular scale anisotropy of the cosmic microwave background (CMB) at frequencies of 31.5, 53, and 90 GHz. In addition to basic plotting and limit-checking, DMR implements a collection of more specialized programs to perform data tests as well as long-term trending.

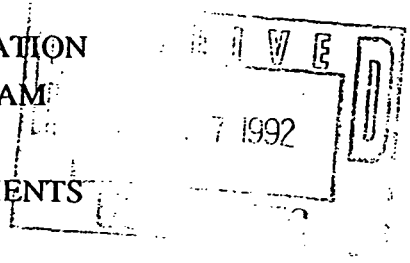
### STABILITY ANALYSIS

As soon as a day's telemetry is available, a small number of tests is run to insure that the instrument is functioning properly and that the data are scientifically

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Alan J. Kogut

Task Number: 5000-821

**General Description of Research Activities (Include a Paragraph on each Activity)**

My primary research activity for the year October 1, 1992—September 30, 1992 has been the production, verification, and analysis of the full-sky maps from the Differential Microwave Radiometers (DMR) aboard NASA's Cosmic Background Explorer (COBE), leading to the detection of anisotropy in the cosmic microwave background radiation (CMB). I have continued to participate in programs to measure the CMB spectrum, and have recently initiated a proposal for a Small Explorer satellite to measure the CMB spectrum at cm wavelengths.

The DMR has measured CMB anisotropy at levels  $\Delta T/T \sim 10^{-5}$  or smaller. Scientific acceptance of the results rests upon the demonstration that the detected signals are, in fact, cosmic and are not artifacts of foreground emission, the instrument, or data processing. I have led the search for systematic effects in the DMR maps and have used the in-flight data to place upper limits on some 20 individual sources and the combined effect from all sources. The results limit systematic artifacts to typical values  $\Delta T/T < 10^{-6}$  at 95% confidence level, a factor of 20 improvement over previous upper limits, and allow the DMR maps to be used for significant new cosmological studies. I am lead author on the paper describing the systematic error analysis for DMR, accepted for publication in *The Astrophysical Journal*.

I have also been an active participant in the analysis of the DMR maps and cosmological interpretation of the CMB anisotropy. At the highest angular resolution ( $2.8^\circ$ ), the DMR maps are dominated by random detector noise. I have provided analyses quantifying the cosmic anisotropy and its statistical uncertainty on various angular scales, both as point-to-point rms variations across the sky and as the two-point angular correlation function. These results have been published with the papers presenting the DMR detection of anisotropy in the CMB. More recently, I have begun a search for weak non-Gaussian signals in the DMR maps, including the higher-order correlation functions and a search for isolated point sources. These limits should provide a test for theories of

seeded structure formation in the Universe, including textures and cosmic strings. I expect publication in early 1993.

The current DMR results are based on a single year of data. As more data accumulate, the increased sensitivity requires a more sophisticated treatment of weak non-cosmic signals. The DMR team is currently preparing the next generation software to produce these maps from 3 or more years of data. I have played a leading role in the design and production of the current software and expect to continue with the next generation. The absolute calibration is crucial. I have begun analysis of the in-flight calibration data and expect an improved instrument calibration in the near future.

I have continued to participate in various collaborations to measure the low-frequency spectrum of the CMB. Ground-based measurements from the South Pole confirm the general Planckian (blackbody) nature of the CMB below 10 GHz; however, these measurements have reached the limit of sensitivity and still allow potential distortions as large as 30%. Consequently, I have proposed an instrument to fly on a Small Explorer satellite, to measure the CMB spectrum at cm wavelengths to 0.1% precision.

**Significant Recognition of Research** (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

The papers accepted for publication during the last year (Oct 1991—Sept 1992) do not appear in the June 1992 Science Citation Index, since they appear after June 1992. Recognition of this work can be estimated from my previous papers on the spectrum and anisotropy of the CMB. See the attached C.V. for the titles for each numbered paper.

Paper	CMB Spectrum		Paper	CMB Anisotropy	
		Citations			Citations
2		35	11		35
3		15	12		2
4		14			
5		9			
6		4			
8		1			
9		1			
10		3			
Total Spectrum: 82 Citations			Total Anisotropy: 37 Citations		

The DMR detection of CMB anisotropy has generated significant coverage in the press, including front-page news coverage and a cover story in *Physics Today*. I fully expect these papers will exceed the 37 citations for previous DMR upper limits.

#### Honors or Awards Received

NASA Group Achievement Award for COBE Project Team

**Papers Published or Accepted for Publication** (Please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

1. "COBE Differential Microwave Radiometers (DMR): Calibration Techniques", C.L. Bennett<sup>4</sup>, G.F. Smoot<sup>1</sup>, M. Janssen<sup>6</sup>, S. Gulkis<sup>6</sup>, A. Kogut<sup>12</sup>, G. Hinshaw<sup>3</sup>, C. Backus<sup>5</sup>, M.G. Hauser<sup>4</sup>, J.C. Mather<sup>4</sup>, L. Rokke<sup>5</sup>, L. Tenorio<sup>1</sup>, R. Weiss<sup>7</sup>, D.T. Wilkinson<sup>8</sup>, E.L. Wright<sup>9</sup>, G. De Amici<sup>1</sup>, N.W. Boggess<sup>4</sup>, E.S. Cheng<sup>4</sup>, P.D. Jackson<sup>5</sup>, P. Keegstra<sup>5</sup>, T. Kelsall<sup>4</sup>, R. Kummerer<sup>5</sup>, C. Lineweaver<sup>1</sup>, S.H. Moseley<sup>4</sup>, T.L. Murdock<sup>11</sup>, J. Santana<sup>5</sup>, R.A. Shafer<sup>4</sup>, and R.F. Silverberg<sup>4</sup>, *The Astrophysical Journal*, 391, 466, (1992).
2. "A Measurement of the Cosmic Microwave Background Temperature at 7.5 GHz", S. Levin<sup>6</sup>, M. Bensadoun<sup>1</sup>, M. Bersanelli<sup>2</sup>, G. De Amici<sup>1</sup>, A. Kogut<sup>3</sup>, M. Limon<sup>1</sup>, and G. Smoot<sup>1</sup>, *The Astrophysical Journal*, in press (1992).
3. "COBE Differential Microwave Radiometers (DMR): Preliminary Systematic Error Analysis", A. Kogut<sup>3</sup>, G.F. Smoot<sup>1</sup>, C.L. Bennett<sup>4</sup>, E. L. Wright<sup>9</sup>, J. Aymon<sup>1</sup>, G. De Amici<sup>1</sup>, G. Hinshaw<sup>3</sup>, P.D. Jackson<sup>5</sup>, E. Kaita<sup>5</sup>, P. Keegstra<sup>5</sup>, C. Lineweaver<sup>1</sup>, K. Loewenstein<sup>5</sup>, L. Rokke<sup>5</sup>, L. Tenorio<sup>1</sup>, N.W. Boggess<sup>4</sup>, E.S. Cheng<sup>4</sup>, S. Gulkis<sup>6</sup>, M.G. Hauser<sup>4</sup>, M.A. Janssen<sup>6</sup>, T. Kelsall<sup>4</sup>, J.C. Mather<sup>4</sup>, S. Meyer<sup>7</sup>, S.H. Moseley<sup>4</sup>, T.L. Murdock<sup>11</sup>, R.A. Shafer<sup>4</sup>, R.F. Silverberg<sup>4</sup>, R. Weiss<sup>7</sup>, and D.T. Wilkinson<sup>8</sup>, *The Astrophysical Journal*, 401 (in press) (1992).
4. "Structure in the COBE DMR First Year Maps", G.F. Smoot<sup>1</sup>, C.L. Bennett<sup>4</sup>, A. Kogut<sup>3</sup>, E. L. Wright<sup>9</sup>, J. Aymon<sup>1</sup>, N.W. Boggess<sup>4</sup>, E.S. Cheng<sup>4</sup>, G. De Amici<sup>1</sup>, S. Gulkis<sup>6</sup>, M.G. Hauser<sup>4</sup>, G. Hinshaw<sup>3</sup>, C. Lineweaver<sup>1</sup>, K. Loewenstein<sup>5</sup>, P.D. Jackson<sup>5</sup>, M. Janssen<sup>6</sup>, E. Kaita<sup>5</sup>, T. Kelsall<sup>4</sup>, P. Keegstra<sup>5</sup>, P. Lubin<sup>10</sup>, J. Mather<sup>4</sup>, S.S. Meyer<sup>7</sup>, S.H. Moseley<sup>4</sup>, T. Murdock<sup>11</sup>, L. Rokke<sup>5</sup>, R.F. Silverberg<sup>4</sup>, L. Tenorio<sup>1</sup>, R. Weiss<sup>7</sup>, and D.T. Wilkinson<sup>8</sup>, *The Astrophysical Journal Letters*, 396, L1 (1992).
5. "Preliminary Separation of Galactic and Cosmic Microwave Emission for the COBE-DMR", C.L. Bennett<sup>4</sup>, G.F. Smoot<sup>1</sup>, G. Hinshaw<sup>3</sup>, E. L. Wright<sup>9</sup>, A. Kogut<sup>3</sup>, G.

De Amici<sup>1</sup>, S.S. Meyer,<sup>7</sup> R. Weiss<sup>7</sup>, D.T. Wilkinson<sup>8</sup>, S. Gulkis<sup>6</sup>, M. Janssen<sup>6</sup>, N.W. Boggess<sup>4</sup>, E.S. Cheng<sup>4</sup>, M.G. Hauser<sup>4</sup>, T. Kelsall<sup>4</sup>, J.C. Mather<sup>4</sup>, S.H. Moseley, Jr.<sup>4</sup>, T.L. Murdock<sup>11</sup>, and R.F. Silverberg<sup>4</sup>, *The Astrophysical Journal Letters*, 396, L6 (1992).

6. "Interpretation of the CMB Anisotropy Detected by the COBE DMR", E. L. Wright<sup>9</sup>, S.S. Meyer<sup>7</sup>, C.L. Bennett<sup>4</sup>, N.W. Boggess<sup>4</sup>, E.S. Cheng<sup>4</sup>, M.G. Hauser<sup>4</sup>, A. Kogut<sup>3</sup>, C. Lineweaver<sup>1</sup>, J.C. Mather<sup>4</sup>, G.F. Smoot<sup>1</sup>, R. Weiss<sup>7</sup>, S. Gulkis<sup>6</sup>, G. Hinshaw<sup>3</sup>, M. Janssen<sup>6</sup>, T. Kelsall<sup>4</sup>, P.M. Lubin<sup>10</sup>, S.H. Moseley, Jr.<sup>4</sup>, T.L. Murdock<sup>11</sup>, R.A. Shafer<sup>4</sup>, R.F. Silverberg<sup>4</sup>, and D.T. Wilkinson<sup>8</sup>, *The Astrophysical Journal Letters*, 396, L13 (1992).
7. "A Liquid Helium-Cooled Absolute Reference Cold Load for Long-Wavelength Radiometric Calibration," M. Bensadoun<sup>1</sup>, C. Witebsky<sup>1</sup>, G. Smoot<sup>1</sup>, G. De Amici<sup>1</sup>, A. Kogut<sup>3</sup>, and S. Levin<sup>6</sup>, *Rev. Sci. Inst.*, in press (1992).

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- 10 University of California, Santa Barbara, CA
- 11 General Research Corporation, Danvers, MA
- 12 Universita di Milano, Italy

Abstracts are appended below. I have also included pre-prints of the COBE papers relevant to the detection of anisotropy in the CMB.

**Papers Submitted but not yet Accepted for Publication (Please include full title, co-authors [with affiliations], publication, and submission date).**

1. "Temperature of the South Celestial Pole and the Cosmic Microwave Background Temperature at Decimetric Wavelengths", G. Sironi<sup>12</sup>, G. Smoot<sup>1</sup>, M. Bensadoun<sup>1</sup>, M. Bersanelli<sup>2</sup>, G. Bonelli<sup>12</sup>, G. De Amici<sup>1</sup>, A. Kogut<sup>3</sup>, S. Levin<sup>6</sup>, and M. Limon<sup>1</sup>, *The Astrophysical Journal Letters*, submitted June 1992.
2. "Measurements of the Cosmic Microwave Background Temperature at 1.47 GHz", M. Bensadoun<sup>1</sup>, M. Bersanelli<sup>2</sup>, G. De Amici<sup>1</sup>, A. Kogut<sup>3</sup>, M. Limon<sup>1</sup>, S. Levin<sup>6</sup>, and G. Smoot<sup>1</sup>, *The Astrophysical Journal*, submitted July 1992.

Author institutions as above. Abstracts are appended.

### Papers Presented at Scientific Meetings

**Invited Papers** (Include title of talk, meeting name, and any special meeting role, e.g. session chair, rapporteur).

1. "Systematic Error Limits in DMR Sky Maps," A. Kogut, presented at the *Meeting on the Implications of the Measured Microwave background Fluctuations*, Princeton, NJ, June 12—13, 1992 (panelist).
2. "Spectrum of the Cosmic Microwave Background: Status and Prospects," A. Kogut, to be presented at the *International School of Astrophysics "D. Chalonge": Current Topics in Astrofundamental Physics*, Erice, Italy, September 3—11, 1992 (lecturer).

**Contributed Papers** (Include title, meeting, and date).

1. "Daily Quality Assurance Software for a Satellite Radiometer System", P.B. Keegstra, G.F. Smoot, C.L. Bennett, J. Aymon, C. Backus, G. De Amici, G. Hinshaw, P.D. Jackson, A. Kogut, C. Lineweaver, L.A. Rokke, J. Santana, and L. Tenorio, presented at the *Astronomical Data Analysis Software and Systems Conference*, Tucson, AZ (November 7-9, 1991)
2. "COBE Differential Microwave Radiometer (DMR) Data Processing Techniques", P.D. Jackson, G.F. Smoot, C.L. Bennett, J. Aymon, C. Backus, G. De Amici, G. Hinshaw, P.B. Keegstra, A. Kogut, C. Lineweaver, L.A. Rokke, J. Santana, and L. Tenorio, presented at the *Astronomical Data Analysis Software and Systems Conference*, Tucson, AZ (November 7-9, 1991)
3. "DMR Detection of CMB Anisotropy: Cosmological Implications," A. Kogut, presented at the American Physical Society annual meeting, Washington, D.C. (April 21-25, 1992)

**Colloquia, Seminars, and Special Lectures** (Provide title, date, and place).

1. "DMR Detection of CMB Anisotropy," University of Pennsylvania, Phila., PA (May 1992)
2. "Anisotropy in the Cosmic Microwave Background," Johns Hopkins University, Baltimore, MD (May 1992)
3. "DMR and the Big Bang: What's All the Fuss About?," NASA-GSFC, Greenbelt, MD (June 1992)
4. "Surveying the Sky with the Cosmic Background Explorer," NASA Graduate Student Researchers Symposium (June 1992)
5. "Structure in the Cosmic Microwave Background," Naval Research Laboratory, Washington, DC (June 1992).
6. "Ground-based Measurements of CMB Spectrum: Critical Review", Institute for Advanced Cosmological Studies, NASA-GSFC, Greenbelt, MD (August 1992).

**Community Service** (e.g. Offices in professional societies, lectures to community or educational groups, consultations, etc.)

None

**University Collaborations:** Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

I am currently starting a collaboration between Goddard Space Flight Center and the University of California to submit a proposal to the Small Explorer program. The Centimetric Radiometer Absolute Temperature Explorer (CRATE) consists of fixed-frequency radiometers at wavelengths 7.5, 3.8, and 2.5 cm (frequencies 4, 8, and 12 GHz), each of which will measure the temperature of the cosmic microwave background to precision 3 mK or better and map the diffuse sky emission (dominated by free-free radiation from the ionized regions of the Galaxy) to 50  $\mu$ K precision. CRATE addresses a growing discrepancy between precision measurements of the CMB spectrum near its peak (e.g. COBE-FIRAS, the COBRA spectrophotometer, and interstellar CN) and ground-based measurements at lower frequencies. The ground-based results are systematically colder than the higher-frequency results; however, it is not clear whether the difference results from a distortion from a blackbody CMB spectrum, or from systematic uncertainties in the calibration of either set of measurements. CRATE will provide the most precise measurement of the CMB temperature at any frequency, and will complement the COBE-FIRAS mission by extending precise CMB measurements to the lowest frequency possible given the known Galactic foregrounds. The proposal will be submitted in late autumn 1992. Current collaborators include G.F. Smoot (University of California), T. Kelsall (GSFC), J. Mather (GSFC), and R. Shafer (GSFC).

**Other Collaborative Activities:** Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s).

See CRATE collaboration, above.



## COBE DIFFERENTIAL MICROWAVE RADIOMETERS: CALIBRATION TECHNIQUES

C. L. BENNETT,<sup>1</sup> G. F. SMOOT,<sup>2</sup> M. JANSSEN,<sup>3</sup> S. GULKIS,<sup>3</sup> A. KOGUT,<sup>4</sup> G. HINSHAW,<sup>4</sup> C. BACKUS,<sup>5</sup>  
M. G. HAUSER,<sup>1</sup> J. C. MATHER,<sup>1</sup> L. ROKKE,<sup>5</sup> L. TENORIO,<sup>2</sup> R. WEISS,<sup>6</sup> D. T. WILKINSON,<sup>7</sup>  
E. L. WRIGHT,<sup>8</sup> G. DE AMICI,<sup>2</sup> N. W. BOGGESS,<sup>1</sup> E. S. CHENG,<sup>1</sup> P. D. JACKSON,<sup>5</sup>  
P. KEEGSTRA,<sup>5</sup> T. KELSALL,<sup>1</sup> R. KUMMERER,<sup>5</sup> C. LINEWEAVER,<sup>2</sup>  
S. H. MOSELEY,<sup>1</sup> T. L. MURDOCK,<sup>9</sup> J. SANTANA,<sup>5</sup>  
R. A. SHAFER,<sup>1</sup> AND R. F. SILVERBERG<sup>1</sup>

Received 1991 October 14; accepted 1991 December 4

### ABSTRACT

The *COBE* spacecraft was launched 1989 November 18 UT carrying three scientific instruments into Earth orbit for studies of cosmology. One of these instruments, the Differential Microwave Radiometer (DMR), is designed to measure the large-angular-scale temperature anisotropy of the cosmic microwave background radiation at three frequencies (31.5, 53, and 90 GHz). In this paper we present three methods used to calibrate the DMR. First, the signal difference between beam-filling hot and cold targets observed on the ground provides a primary calibration that is transferred to space by noise sources internal to the instrument. Second, the Moon is used in flight as an external calibration source. Third, the signal arising from the Doppler effect due to the Earth's motion around the barycenter of the solar system is used as an external calibration source. Preliminary analysis of the external source calibration techniques confirms the accuracy of the currently more precise ground-based calibration. Assuming the noise source behavior did not change from the ground-based calibration to flight we derive a 0.1%–0.4% relative and 0.7%–2.5% absolute calibration uncertainty, depending on radiometer channel.

*Subject headings:* cosmic microwave background — instrumentation: detectors

### 1. INTRODUCTION

The *Cosmic Background Explorer (COBE)*,<sup>10</sup> launched into near-polar Earth orbit on 1989 November 18, carries three scientific instruments to investigate fundamental questions in cosmology (Mather 1982; Mather & Kelsall 1980; Gulkis et al. 1990). The Differential Microwave Radiometer (DMR) instrument maps the large-angular-scale ( $\theta \gtrsim 3^\circ$ ) temperature of the cosmic microwave background (CMB) radiation with a  $7^\circ$  beam over the entire sky. The DMR scientific goals, instrument design, and implementation are discussed by Smoot et al. (1990) and early scientific results are reported by Smoot et al. (1991).

In this paper we discuss the techniques available for the calibration of the DMR instrument. The DMR instrument

includes radiometers operating at 31.5, 53, and 90 GHz (9.5, 5.7, and 3.3 mm). There are two independent radiometers at each of the three frequencies, henceforth referred to as *channels*, with the radiometers at 31.5 GHz maintained at 300 K and radiometers at 53 GHz and 90 GHz passively cooled to 140 K. This spectral regime was chosen to maximize the intensity ratio of the CMB to the competing galactic foreground emission. The data taken at these three frequencies will allow us to model and remove the local astrophysical radiation. The only celestial emissions detected to date ( $>4\sigma$ ) are from the CMB itself (including the dipole anisotropy of the CMB radiation, presumed due to our peculiar motion with respect to the comoving frame of the Hubble expansion), the Moon, and our Galaxy.

We present three independent methods that have been used to calibrate the *COBE* DMRs. The radiometers carry on-board noise sources that were calibrated in the laboratory prior to flight. The definitive analysis of that calibration is presented in this paper. Because that calibration was carried out 15 months before launch, a period of time that included spacecraft vibration testing and thermal cycling, it is desirable to confirm that the calibration did not change by checking the calibration independently in flight. We present two in-flight calibration techniques: (1) based on the microwave signal from the Moon, and (2) based on the microwave signal caused by the Earth-velocity Doppler-shifted CMB. The analysis of these two in-flight techniques is not final since the DMR continues to collect data, and current analysis will be improved, but the analyses to date are important for the choice of calibration for reporting scientific results while the instrument is still taking data. Further improvements, for example in *COBE* attitude solutions, will lead to improved results and analysis will continue.

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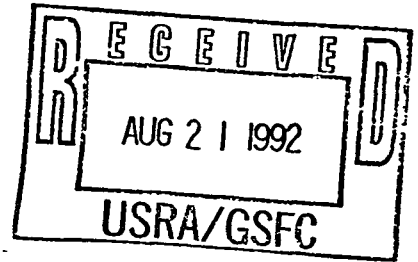
<sup>8</sup> UCLA, Astronomy Department, Los Angeles, CA 90024-1562.

<sup>9</sup> General Research Corporation, 5 Cherry Hill Drive, Suite 220, Danvers, MA 01923.

<sup>10</sup> The National Aeronautics and Space Administration/Goddard Space Flight Center (NASA/GSFC) is responsible for the design, development, and operations of the *Cosmic Background Explorer (COBE)*. Scientific guidance is provided by the *COBE* Science Working Group. GSFC is also responsible for the development of the analysis software and for the production of the mission data sets.

**Universities Space Research Association  
Goddard Visiting Scientist Program**

**Employee Summary of Accomplishments  
(for the year ending 9/30/92)**



Employee Name: A.J. Banday, Task Number: 5000-821

General Description of Your Research Activities:

Much of my time during the 6 months since I arrived from England has been devoted exclusively to providing support for the COBE space project.

As a newcomer to the COBE project, the majority of my time has been spent in learning instrument specific details and analysis techniques. However, one of my major tasks has been to study and attempt to understand a systematic error which affects the 31 GHz radiometers during the so-called 'eclipse' months. At this time the spacecraft flies through the Earth's shadow as it passes over the South Pole. This manifests itself as a drop in the recorded differential temperature, and studies have indicated that this drop may be correlated with signal variations for various voltage and current measuring devices on the spacecraft. A correlation analysis between the differential temperatures and these other signals suggest that a correction is possible, and the applied correction provides a 60 - 70 per cent improvement over previous attempts. Work is still in progress to increase this improvement still further. This would be very valuable since, at present, data from the eclipse months is excluded from the 31 GHz sky-maps. If the data can be included, the improvement in signal-to-noise would enable better models of the foreground Galactic emission to be constructed, since the 31 GHz signal is dominated by diffuse emission from thermal electrons in the interstellar medium, and is used as a measure of this signal. A 'cleaner' model of the Galactic emission in turn will lead to cosmological maps more demonstrably free from Galactic contamination.

I am providing input for the new software pipeline to reduce and analyse the data from the first 2 years of the COBE mission.

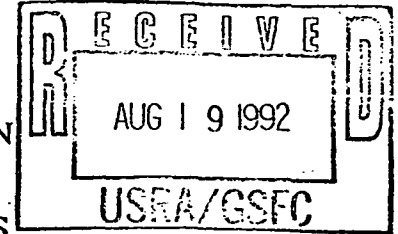
I am presently in the process of preparing a detailed comparison of the DMR skymaps with the previous best skymap due to the Russian RELICT satellite. This analysis provides no support for the RELICT team's claims that a large significant negative temperature anisotropy has been detected at high galactic latitudes. Further analysis suggests that the RELICT map is still too significantly contaminated by galactic contamination to claim detection of cosmic anisotropy in the absence of corroborating evidence (such as the DMR maps). The paper will be submitted to a major international journal soon.

Other work in progress includes an analysis of the cosmological multipole moment spectrum for a spherical harmonic decomposition of the sky-maps. This is at an early stage, but the key point is the interpretation of the multipole spectrum from skymaps which exclude the galactic plane as is required, since the noise in the maps tend to modify the spectrum from the theoretically expected values.

The remainder of my time is devoted to a collaboration with a colleague at Northwestern University, IL. This is concerned with a complete analysis of the Edinburgh/Durham Southern Galaxy Catalogue which records the angular position of galaxies for 60 UK Schmidt fields centred at the South Galactic Pole to a limiting magnitude of 19.5. We are investigating the plausible cosmological models to explain the observed angular correlation function, and the relationship of the observed structure to other observations of relevance eg. deep galaxy redshift surveys, Cosmic Microwave Background observations etc.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: David Falconer Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

During the last year I have been working on my dissertation by analyzing the SERTS 3 and 4 data set under the guidance of Joe Davila at NASA and George Goldenbaum at the University of Maryland. The SERTS 4 analysis has concern studying the solar corona off the solar limb and modeling it. The SERTS 3 analysis has been examining the possibility of taking line ratio of different lines for density diagnostics.

The SERTS 4 off the limb analysis is almost done and the temperature, emission measure and elemental abundance from 7 different spectral lines from 4 different elements have been determined. An isothermal, hydrostatic, spherically symmetric corona model can be fitted to the observations using a 2 million degree temperature corona. This temperature comes both from hydrostatic arguments and also from line ratio reasons. Some analysis from SERTS 3 off the limb will also be done soon.

The SERTS 3 density diagnostics study has been mainly examining the literature and determining what references has line ratios for lines observed by SERTS 3 rocket flight. Then determining what densities these ratios would indicate. So far they have mainly been used for line identification and confirmation in the SERTS 3 catalog. This work was put on hold until final calibration of the SERTS 3 data set was accomplished. This was finally finished during the summer and I am hoping to return to the analysis of this data set in the fall. Then this analysis can be applied to SERTS 4 data set.

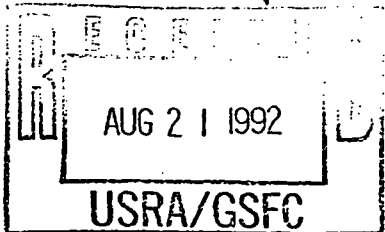
During the last year I have been working on my dissertation by analyzing the SERTS 3 and 4 data set under the guidance of Joe Davila at NASA and George Goldenbaum at the University of Maryland. The SERTS 4 analysis has concern studying the solar corona off the solar limb and modeling it. The SERTS 3 analysis has been examining the possibility of taking line ratio of different lines for density diagnostics.

The SERTS 4 off the limb analysis is almost done and the temperature, emission measure and elemental abundance from 7 different spectral lines from 4 different elements have been determined. An isothermal, hydrostatic, spherically symmetric corona model can be fitted to the observations using a 2 million degree temperature corona. This temperature comes both from hydrostatic arguments and also from line ratio reasons. Some analysis from SERTS 3 off the limb will also be done soon.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: David A. Cottingham Task Number: 680-028

General Description of Your Research Activities: (Include a Paragraph on each Activity).

The analysis of the 19 GHz full-sky survey was completed this year. (This is based on data obtained previously with a balloon-borne microwave telescope which was flown twice in the Northern hemisphere and twice in the Southern.) The result of the analysis is a map covering 95% of the sky at 3° angular resolution and at a typical sensitivity of 700 μK per 3° × 3° pixel. These data have already produced competitive upper limits on anisotropy of the cosmic microwave background (CMB) at angular scales greater than 3°, published this year. This map was used by the DMR team in modeling the Galactic contamination in their maps for their recently published detection of anisotropy in the CMB. This work is in collaboration with S. P. Boughn, E. S. Cheng, and D. J. Fixsen.

Working in collaboration with D. J. Fixsen, I have developed a new approach for deriving the calibration model parameters of the FIRAS instrument. This new method is more rapid than the previous method and determines the error matrix of the parameters more directly. Using this method we tested a number of variations on the instrument model with the result that, on the various calibration data sets, we were successful in reaching reduced  $\chi^2$  of between 1 and 4. Recently, the data reduction team released new software for deglitching, data selection, and robust averaging, and the calibration model program has proved useful in finding bugs and peculiarities in the resulting new data set. This new data generally does not fit as well with the instrument model as the old set; assessment of the new data is continuing. In any case, we have shown that the previous data set and its calibration model solution are of a high enough quality for the first public release of FIRAS data.

I have recently begun extending previous work by E. S. Cheng on studying the linearity of the DIRBE detectors by examining the internal reference source (IRS) data. The DIRBE team has noticed nonlinearities in some bands at low power levels. It is hoped that an understanding of the nonlinearity can be reached by fitting an instrument model to pre-flight and in-orbit IRS data.

We made two attempts to observe with the GSFC/MIT CMB anisotropy experiment, one of which met with success. This balloon-borne far IR telescope with 300 mK bolometric detectors in four spectral bands is designed to detect anisotropy on a 0.5° angular scale. Last fall we traveled to Fort Sumner, New Mexico for six weeks, but due to a combination of telescope pointing problems and bad weather we were unable to launch before the end of the turnaround season (when high altitude winds are low). This spring we made a renewed attempt in Palestine, Texas, and after eight weeks of work launched successfully. The flight lasted 11 hours, during which we scanned over the Coma cluster to attempt a detection of the Sunyaev-Zel'dovich effect, and spent 4.7 hours scanning a dark patch of sky to search for anisotropy in the CMB. We have completed a preliminary analysis of the Coma and CMB data, which indicate that the instrument had low noise and good offset stability, but we suffered more cosmic ray hits on the detectors than anticipated. In spite of this problem, at our current state of analysis we already have competitive sensitivity to CMB anisotropy. We are now concentrating on optimizing the removal of cosmic ray contamination from the data. We are also investigating methods of reducing the cosmic ray sensitivity of the detectors in anticipation of another flight next winter or spring. My collaborators on this project are E. Cheng, D. Fixsen, P. Gentieu, C. Inman, S. Meyer, L. Page, J. Puchalla, and R. Silverberg.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

From the Science Citation Index during the period July 1991 to June 1992:

"A Full Sky Survey at 19.2 GHz" (1992)	1 citation
"A Search for Anisotropy..." (1992)	1 citation
"Limits on Gaussian Fluctuations..." (1992)	3 citations
"A Bolometric Millimeter-wave System..." (1992)	1 citation
"A Balloon-borne 19 GHz Radiometer" (1990)	1 citation
"A Sky Temperature Survey at 19.2 GHz..." (1987)	2 citations

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Honors or Awards Received:

None

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Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

"A Bolometric Millimeter-wave System for Observations of Anisotropy in the Cosmic Microwave Background Radiation on Medium Angular Scales," M. L. Fischer (U. C. Berkeley), D. C. Alsop (U. C. Berkeley), E. S. Cheng (NASA/GSFC), A. C. Clapp (U. C. Berkeley), D. A. Cottingham (USRA), J. O. Gundersen (U. C. Santa Barbara), T. C. Koch (U. C. Santa Barbara), E. Kreysa (Max-Planck-Institut), P. R. Meinhold (U. C. Santa Barbara), A. E. Lange (U. C. Berkeley), P. M. Lubin (U. C. Santa Barbara), P. L. Richards (U. C. Berkeley), G. F. Smoot (U. C. Berkeley), *Astrophys. J.* 388 242 (1992).

"Limits on Gaussian Fluctuations in the Cosmic Microwave Background at 19.2 GHz," S. P. Boughn (Haverford), E. S. Cheng (NASA/GSFC), D. A. Cottingham (USRA), and D. J. Fixsen (USRA), *Astrophys. J.* 391 L49 (1992).

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## LIMITS ON GAUSSIAN FLUCTUATIONS IN THE COSMIC MICROWAVE BACKGROUND AT 19.2 GHz

S. P. BOUGHN

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Received 1990 October 23; accepted 1992 March 12

### ABSTRACT

The northern hemisphere data from the 19.2 GHz full sky survey are analyzed to place limits on the magnitude of Gaussian fluctuations in the cosmic microwave background implied by a variety of correlation functions. Included among the models tested are the monochromatic and Gaussian-shaped families, and those with power-law spectra for  $-2 \leq n \leq 1$ . We place an upper bound on the quadrupole anisotropy of  $\Delta T/T < 3.2 \times 10^{-5}$  rms, and an upper bound on scale-invariant ( $n = 1$ ) fluctuations of  $a_2 < 4.5 \times 10^{-5}$  (95% confidence level). There is significant contamination of these data from Galactic emission, and improvement of our modeling of the Galaxy could yield a significant reduction of these upper bounds.

*Subject heading:* cosmic microwave background

### 1. INTRODUCTION

Theories which attempt to trace the evolution of the present extremely inhomogeneous large-scale distribution of luminous matter in the universe have, as a general feature, implications about the size and form of anisotropies in the cosmic microwave background (CMB). Many of these theories of structure formation suggest that the fluctuations in the CMB would take the form of a two-dimensional random Gaussian field; other theories, notably those involving stringlike defects in the vacuum, lead to non-Gaussian statistics. To settle observationally the question of which of these theories is correct, and in particular whether the fluctuations are described by Gaussian statistics or not, will require an accurate measurement of the two- and three-point correlation functions of the anisotropy. There are at present no verified detections of any anisotropy (other than Sunyaev-Zel'dovich, a relatively local effect), much less a measured correlation function, so observational results thus far take the form of upper limits. However, the observed high level of isotropy of the CMB is already an important constraint on these theories.

In this *Letter* we present an analysis of the limits that can be set on fluctuations at angular scales greater than  $1^\circ$  by the northern hemisphere portion of the 19.2 GHz survey (Cottingham 1987; Boughn et al. 1990, 1992). This survey was carried out at an angular resolution of  $3^\circ$  FWHM and a typical sensitivity of 1.5 mK per resolution element. The northern hemisphere portion covers declinations  $-15^\circ < \delta < +75^\circ$ .

We consider only fluctuations which obey Gaussian statistics. A Gaussian field is completely specified by its two-point correlation function. As we discuss further, the upper limit that

a given experiment can place on the rms fluctuation depends on the assumed correlation function. To preserve this distinction, all of our results are stated as pertaining to a particular correlation function, and not just to an angular scale. Many conventions have been used for quoting the magnitude of fluctuations. We quote the size of fluctuations as  $\Delta T/T$  rms (with one noted exception). This convention is shared by others, e.g., Timbie & Wilkinson (1990) and Readhead et al. (1989). In § 2 we discuss the method of statistical analysis employed, and the manner in which the data set is prepared. The various correlation functions tested and the upper limits obtained are presented in § 3.

### 2. ANALYSIS

The method we use to place an upper bound on the magnitude of fluctuations present in the data is the familiar one of selecting a statistic, and seeing where the measured value of this statistic falls on the distribution predicted by a particular model. The rms of fluctuations in the model is adjusted so that the probability that we would have measured a larger value of the statistic is equal to the confidence level (say, 0.95); we then know that if the rms were larger than this value, our observation would be quite unlikely (probability  $< 0.05$ ) so this value of rms is a reasonable upper bound. A statistic is simply a function of the observations, so in order to determine its distribution we first need to know how the model predicts the observations are distributed.

Let  $T(\theta, \varphi)$  describe the temperature fluctuations in the sky predicted by a given model. A Gaussian model is completely specified by its correlation function  $C(\theta)$ . We find it convenient to separate the shape of  $C(\theta)$  from its magnitude; therefore we set  $C(0) = 1$ , so that the actual correlation function is  $\eta^2 C(\theta)$  where  $\eta$  is the total rms fluctuation predicted by the

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## A BOLOMETRIC MILLIMETER-WAVE SYSTEM FOR OBSERVATIONS OF ANISOTROPY IN THE COSMIC MICROWAVE BACKGROUND RADIATION ON MEDIUM ANGULAR SCALES

M. L. FISCHER,<sup>1</sup> D. C. ALSOP,<sup>1</sup> E. S. CHENG,<sup>3</sup> A. C. CLAPP,<sup>1</sup> D. A. COTTINGHAM,<sup>1</sup>  
J. O. GUNDERSEN,<sup>2</sup> T. C. KOCH,<sup>2</sup> E. KREYSA,<sup>4</sup> P. R. MEINHOLD,<sup>2</sup> A. E. LANGE,<sup>1</sup>  
P. M. LUBIN,<sup>2</sup> P. L. RICHARDS,<sup>1</sup> AND G. F. SMOOT<sup>1</sup>

Received 1991 August 8; accepted 1991 October 7

### ABSTRACT

We report the performance of a bolometric system designed to measure the anisotropy of the cosmic microwave background (CMB) radiation on angular scales from 0.3 to 3°. The system represents a collaborative effort combining a low-background 1 m diameter balloon-borne telescope with new multimode feed optics, a beam modulation mechanism with high stability, and a four-channel bolometric receiver with passbands centered near frequencies of 3 (90), 6 (180), 9 (270), and 12 (360) cm<sup>-1</sup> (GHz). The telescope has been flown three times with the bolometric receiver and has demonstrated detector noise limited performance capable of reaching sensitivity levels of  $\Delta T/T_{\text{CMB}} \approx 10^{-5}$  with detectors operated at  $T = 0.3$  K.

*Subject headings:* cosmic microwave background — instrumentation: photometers

### 1. INTRODUCTION

Measurements of the spectrum and isotropy of the cosmic microwave background (CMB) probe the evolution and homogeneity of the early universe. The spectrum of the CMB is consistent with a blackbody with a temperature of  $2.735 \pm 0.06$  K at frequencies from 1 to 20 cm<sup>-1</sup> (Mather et al. 1990; Gush, Halpern, & Wishnow 1990). Measurements of the isotropy of the CMB have found only a dipole component to the brightness distribution. Present upper limits to anisotropy on angular scales from arcminutes to the quadrupole are in the range of  $\Delta T/T_{\text{CMB}} \leq 1-5 \times 10^{-5}$  (Boughn et al. 1992; Meinhold & Lubin 1991; Meyer, Cheng, & Page 1991; Readhead et al. 1989; Smooth et al. 1991). The observed isotropy of the CMB contrasts with the abundant structure seen at optical wavelengths. Measurements of the CMB anisotropy provide one of the few critical tests of theoretical models of the formation of this structure in the early universe (Bond 1989). The angular scale of an anisotropy seen today can be related to the distance scale of the perturbation that generated it in the past. Angular scales from 10' to several degrees cover a range of distance scales from clusters of galaxies to beyond the largest structures seen in the universe today.

Experiments searching for CMB anisotropy have been steadily improving. New detector technologies already provide the necessary sensitivity to search for anisotropy below  $\Delta T/T_{\text{CMB}} = 10^{-5}$ . Instruments designed to utilize these detectors must provide stable, low-background environments with excellent rejection of radiation from the Earth, and from anthropogenic radio frequency interference. In addition both thermal and nonthermal sources of emission in our Galaxy must be identified and either shown to be negligible or subtracted. Finally, compact extragalactic objects provide yet

another layer of anisotropic emission which must also be understood and accounted for. The choice of measurement frequency is not critical for most types of cosmology, but has a dramatic effect on apparatus, observation strategies, and the amount of noncosmological background.

We have developed a bolometric receiver and multimode optics which fly on an existing (Meinhold & Lubin 1991) balloon-borne telescope to simultaneously measure the anisotropy in the CMB in four millimeter wavelength bands on angular scales from 0.3-3°. The scientific results from the first two flights of the bolometric receiver are described by Fischer et al. (1991) and Alsop et al. (1992a, b). There are several reasons for this design. First, simultaneous measurements of the sky at several frequencies are necessary in order to identify the spectrum of any anisotropic emission that is detected. Second, millimeter wavelengths minimize galactic confusion and allow the use of sensitive bolometric detectors. Third, careful placement of the individual bands can provide adequately low atmospheric emission at balloon altitudes. Fourth, balloon-borne experiments at millimeter wavelengths on these angular scales can use ~1 m diameter antennas. These measurements complement the large angular scale experiments conducted from spacecraft such as *COBE* and *RELICT*.

The relative brightness of the CMB and the competing sources of emission determine the range of frequency which provides the best opportunity for measurement of CMB anisotropy. The brightness of the 2.735 CMB and an anisotropy in the CMB of  $\Delta T/T = 10^{-5}$  are shown in Figure 1. From near millimeter to submillimeter wavelengths the dominant source of astrophysical confusion is likely to be thermal emission from interstellar dust (ISD) in our Galaxy. The curve labeled ISD in Figure 1 is an estimate of the average brightness of ISD at high Galactic latitudes based on measurements from the *IRAS* satellite at 100 cm<sup>-1</sup>, and balloon-borne measurements at millimeter to submillimeter wavelengths (Hauser et al. 1984; Page, Cheng, & Meyer 1990; Meinhold & Lubin 1991). The ISD spectrum assumes a dust temperature of 22 K and an emissivity  $\epsilon \propto \nu^{1.5}$ , where  $\nu$  is the frequency. The curve labeled Synchrotron in Figure 1 (which has a slope of  $\nu^{0.1}$ ) is an estimate of the average brightness of synchrotron emission at high

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<sup>2</sup> Department of Physics, University of California at Santa Barbara, Santa Barbara, CA 93106.

<sup>3</sup> NASA Goddard Space Flight Center, Code 685, Greenbelt, MD 20771.

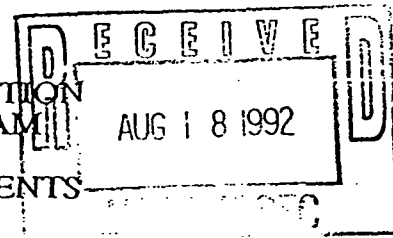
<sup>4</sup> Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-5300 Bonn, Germany.



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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Takeshi Namioka

Task Number: 680029

General Description of Your Research Activities: (Include a Paragraph on each Activity).

1. Development of the theory of the toroidal grating and its application to FUSE spectrographs. Analytical formulas were derived for the rms spread of the spots formed when an infinite number of rays are traced through a holographic or mechanically ruled toroidal grating with variable spacing and curved grooves. The theory enables one to minimize directly the aberration in spectral images by adjusting both the instrumental parameters (mounting and scanning mode) and the recording or ruling parameters of a planned grating. This theory was successfully applied to the design of ruled spherical concave gratings for a FUSE type and an in-plane Eagle type spectrograph. The results show resolving power of  $\sim 50000$  for the FUSE type and  $\sim 80000$  for the Eagle type, although the astigmatism was not fully corrected with the spherical gratings.

2. Theoretical study of the deformed ellipsoidal grating - Analytic optimization of the light path function. This work has been carried out in collaboration with Dr. D. Content of NASA/GSFC. Analytic formulas were derived for the semi-axes and the deformation coefficients of a deformed ellipsoidal grating which minimize aberration terms of the light path function over a given spectral range. The formulas were generalized to include off-Rowland circle mounts, as required for the FUSE spectrographs. These formulas were applied to the design of deformed ellipsoidal gratings for the FUSE spectrographs. The results show that the designed gratings can meet the requirements imposed on the FUSE spectrographs. These formulas, however, lack the capability of balancing the aberrations in spectral images, preventing from further improvements in the image quality.

3. Development of the theory of the deformed ellipsoidal grating. To overcome shortcoming mentioned above, a rigorous third-order aberration theory has been developed for the deformed ellipsoidal grating with variable spacing and curved grooves. The theory is based on the exact ray-tracing method and gives analytical expressions for spectral images formed on a flat or a cylindrical image plane. The theory enables one to balance aberrations as a whole, yielding the truly optimized ruling or holographic recording parameters.

4. Theoretical studies on the ellipsoidal holographic grating produced with aspheric wavefront recording. One approach to improve the quality of spectral images is the use of an ellipsoidal holographic grating produced by means of aspheric wavefront recording. The study has been initiated recently by directing its effort toward derivation of an analytic expression for the groove pattern recorded on an ellipsoidal blank with two aspheric waves. It is anticipated to obtain rigorous expressions for the recording geometry in the framework of the third-order aberration theory, and such expressions are of pressing need for the phase B study of the FUSE spectrographs.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

My work is recognized in the field of vacuum ultraviolet/soft x-ray optics for research in space astronomy and synchrotron radiation instrumentation to such a degree that I have been invited by several conference organizers, academic societies, and research institutions to give invited papers and also to participate in various committees and workshops.

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Honors or Awards Received:

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Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

1. "Multilayers for soft x-rayoptics," OSA Proc. Vol. 12, *Soft X-Ray Projection Lithography*, ed. J. Bokor, p. 87 (1991).
2. "Extended Rayleigh-Fano theory and its application to grating polarization" Appl. Opt. 30, 4528 (1991), M. Koike/Lawrence Berkeley Lab., S. Mitani/Osaka City Univ., and T. Namioka/Tohoku Univ.
3. "Performance of a wide-band soft x-ray polarizer," Appl. Opt. 30, 5018 (1991), T. Maehara, H. Kimura, H. Nomura, M. Yanagihara, and T. Namioka/Tohoku Univ.
4. "Analysis of polarization properties of shallow metallic gratings by an extended Rayleigh-Fano theory," Proc. SPIE 1545, 88 (1991), M. Koike/Lawrence Berkeley Lab. and T. Namioka/Tohoku Univ.
5. "High-resolution measurement of Beutler-Fano profiles for autoionizing Rydberg series of Xe," Phys. Rev. A45, 527 (1992), K. Maeda/Kumamoto Univ., K. Ueda, T. Namioka/Tohoku Univ., and K. Ito/Natl. Lab.

High Energy Physics.

6. "Full polarization measurement of synchrotron radiation with use of soft x-ray multilayers," *Rev. Sci. Instrum.* **63**, 1379 (1992), H. Kimura/Graduate Univ. for Advanced Studies, M. Yamamoto, M. Yanagihara, T. Maehara, and T. Namioka/ Tohoku Univ.

7. "Performance of a wideband multilayer polarizer for soft x-rays," *Rev. Sci. Instrum.* **63**, 1516 (1992), M. Yanagihara, T. Maehara, H. Nomura, M. Yamamoto, and T. Namioka/Tohoku Univ.

8. "A method for determining the column density from the pressure-broadened resonance lines," *Rev. Sci. Instrum.* **63**, 1690 (1992), K. Ueda, O. Sonobe, H. Chiba, Y. Sato, T. Namioka/Tohoku Univ., and K. Ito/Natl. Lab. High Energy Physics.

9. "Design of compact high-resolution far-ultraviolet spectrographs equipped with a spherical grating having variable spacing and curved grooves," Abstract, 10th Intl. Colloq. UV and X-Ray Spectroscopy of Astrophysical and Laboratory Plasmas, p. 98 (1992); to be published in the Proceedings of the Colloquium, T. Namioka/USRA and M. Koike/Lawrence Berkeley Lab.

10. "In situ performance tests of soft-x-ray multilayer mirrors exposed to synchrotron radiation from a bending magnet," *Appl. Opt.* **31**, 972 (1992), M. Yanagihara, T. Maehara, S. Gunadi, M. Asano, and T. Namioka/ Tohoku Univ.

11. "In situ ellipsometric study of optical properties of ultrathin films," *Appl. Opt.* **31**, 1612 (1992), M. Yamamoto and T. Namioka/Tohoku Univ.

12. "Layer-by-layer design method for soft-x-ray multilayers," *Appl. Opt.* **31**, 1622 (1992), M. Yamamoto and T. Namioka/Tohoku Univ.

13. "Analytical representation of spot diagrams and its application to the design of monochromators," *Nucl. Instr. Meth.* **A319**, 219 (1992), T. Namioka/USRA and M. Koike/Lawrence Berkeley Lab.

14. "X-ray imaging optics in Japan", *Proc. SPIE*, Vol. 1720, in press, T. Namioka/USRA, K. Yamashita/ Inst. Space & Astronautical Science, M. Yamamoto/Tohoku Univ., T. Matsushita/Natl. Lab. High Energy Physics, S. Aoki/Univ. of Tsukuba, and S. Sato/Tohoku Univ.

**General Description of Your Research Activities:**

Using both incompressible and compressible 2-D MHD simulations, Ghosh worked with M.L. Goldstein (Code 692) to show how the presence of an ambient transverse magnetic field can suppress magnetic reconnection. The results, reported at a scientific conference, can be applied to understand the formation of plasmoids in the earth's magnetotail.

Ghosh has worked with D. Spicer, S. Zalesak, and R. de Fainchtein (all Code 930-1) to compare the accuracy of 2-D adaptively-refined finite-element codes against 2-D spectral codes. This collaboration has resulted in Ghosh's participation in the (pending) High Performance Computing Challenge (HPCC) proposal under M.L. Goldstein. Ghosh will test the accuracy of 3-D adaptively-refined codes.

Ghosh's efforts in code development has resulted in a new pseudospectral algorithm for writing ideal-gas MHD codes. This algorithm, unlike existing algorithms, preserves all important global invariants including total energy, cross helicity, and magnetic helicity. Working with M. Hossain and W.H. Matthaeus (Bartol Res. Inst.), Ghosh has also identified the problems associated with developing a compressible MHD code using the Galerkin method. Papers have been published describing this research.

Collaborating with T. Stribling (NRC), W.H. Matthaeus and M.L. Goldstein, Ghosh has shown that magnetic helicity evolution in a compressible (polytropic) plasma at low Mach numbers behaves essentially the way it does in an incompressible plasma. A paper has been submitted.

Collaborating with A.F. Vinas, D.A. Roberts and M.L. Goldstein (all Code 692), Ghosh has studied the parametric instabilities of a large-amplitude circularly-polarized Alfvén wave and the development of a turbulent spectrum. An important discovery during this research is that oblique instabilities strongly influence the nonlinear saturation of parametric instabilities for high plasma beta. A paper has been submitted.

Collaborating with D.A. Roberts, M.L. Goldstein and W.H. Matthaeus, Ghosh showed that many solar-wind observations including cross helicity measurements and observed density fluctuations can be understood in terms of nearly-incompressible magnetohydrodynamics. In a separate, but related work, Ghosh [working with L.W. Klein (ARC), W.H. Matthaeus and M.R. Brown (Caltech)] showed that density fluctuations in solar-wind observations appear to scale according to pseudo-sound theory.

Ghosh has also participated as a co-investigator in writing the (pending) Space Physics Theory Program proposal submitted by M.L. Goldstein.

Papers Published or Accepted for Publication:

1. 1991 "MHD simulation of the radial evolution of stream structure of solar-wind turbulence," D.A. Roberts, S. Ghosh, M.L. Goldstein, and W.H. Matthaeus, Phys. Rev. Lett. 67, 3741.
2. 1992 "On computing high order Galerkin products," M. Hossain, W.H. Matthaeus, and S. Ghosh Comput. Phys. Commun. 69, 1.
3. 1992 "Low Mach number two-dimensional hydrodynamic turbulence: energy budgets and density fluctuations in a polytropic fluid," S. Ghosh and W.H. Matthaeus, Phys. Fluids A 4, 148.
4. 1992 "The application of spectral methods in simulating compressible fluid and magnetofluid turbulence," S. Ghosh, M. Hossain, and W.H. Matthaeus, Comput. Phys. Commun., (in press).
5. 1992 "Velocity-shear generation of solar wind turbulence," D.A. Roberts, M.L. Goldstein, W.H. Matthaeus, and S. Ghosh, J. Geophys. Res., (in press).

### General Description of Research Activities

My major area of research is about interplanetary magnetic clouds and their interactions with the Earth's magnetosphere. This work is carried out in association with Dr Leonard F. Burlaga of Goddard Space Flight Center. I also collaborated intensely with colleagues Dr Vladimir Osherovich, also of Goddard, and Dr Mervyn Freeman, now at the British Antarctic Survey, Cambridge, England. The work involves these various aspects: (1) Modelling the global field line topology of this class of mesoscale solar ejecta, addressing, in particular, the issue of whether the field lines are still attached to the Sun's surface; (2) Quantitative modelling of the evolution of magnetic clouds using ideal magnetohydrodynamic (MHD) theory; (3) A study of the suitability or otherwise of describing the energy transport in magnetic clouds by means of polytropic relationships; (4) Studying by means of observations on magnetic fields and particles made simultaneously inside a magnetic cloud and throughout the terrestrial magnetosphere the interaction of magnetic clouds with the Earth. We believe we have made a number of advances to each of these areas. On each we have published or are about to publish a number of contributions. We also have a number of ideas how to advance the work further.

I am also actively involved in studies (data and theory) on reconnection at the Earth's dayside magnetopause. This is a collaborative effort with several colleagues at universities and research institutions in England, Scotland, Austria and Russia. We recently studied the relationship between the so-called quasi-steady reconnection and flux transfer events. These have for many years been studied separately and the observational signatures (accelerated plasma flows at the magnetopause, on the one hand, and characteristic variations in the magnetic field, on the other) considered as mutually exclusive. Thus arose the myth that reconnection at the magnetopause is sometimes steady in time (and then we have quasi-steady reconnection) and sometimes bursty and impulsive (and then we have flux transfer events).

We have sought over the last few years to show that this is an artificial subdivision, or, at least, it is a conclusion not warranted by the data. We generalized Petschek's (1964) classic reconnection model, which in the form presented by Levy et al. has formed the backbone of analyses of high speed flows, to include a time dependent reconnection rate. We then find that time dependent Petschek-type reconnection can give both signatures at the same time. We further argue that no observation has yet been done at the magnetopause from

which one could unambiguously infer the reconnection rate, whether steady or otherwise. We have reported on this work in a number of papers. In the near future this point of view will be defended in an article in the EOS journal meant for a wide spectrum of readers. I am interested in introducing these ideas of reconnection, and the model which has been developed, to the study of some phenomena observed in the interplanetary medium and in connection with magnetic clouds,

One of my main interests over the last few years has been the signatures of magnetopause processes at ionospheric heights. With my English colleagues I did some work aimed at distinguishing the ionospheric signatures of pressure pulses of solar wind origin from those due to reconnection. Recently I wrote a review article with my colleague Dr Mervyn Freeman summarising the large volume of work done in this area over the last 5 years or so. My interest in ionospheric phenomena has now shifted to observations of enhanced flows in the nightside auroral zone, which occur during substorm activity in the geomagnetic tail. It turns out that these flow bursts occur with a periodicity of about 1 h, when reconnection in the magnetotail continues uninterrupted. In our study of the substorm activity attending the passage of a magnetic cloud, we found a similar periodicity of the occurrence of substorm onsets themselves.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Michael J TEAGUE Task Number: 5000-911

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Responsible for operations of US STEP (Solar-Terrestrial Energy Program) Coordination Office (USSCO) including M. Teague as US Coordinator and V. Papitashvili as Visiting Scientist under terms of the Stanley Shuman Fellowship.

Responsible for organization of 1992 US STEP Symposium / 5th COSPAR Colloquium; Chair of Organizing Committee and Convener of Program Committee. In August 1992 approximately 300 scientists from 29 countries will convene at JHU/APL to present 111 oral papers and 250 poster papers in 7 science sessions over a 5 day period. Responsible for: definition of science program, all logistics functions, financial support for 55 scientists

Responsible for science editing and generation of the monthly STEP Newsletter - STEP International. This is a 16 page newsletter with a distribution of 4000 to 32 countries. Responsible for planning newsletter, solicitation and collection of articles and science editing; authored 8 articles in last 12 months.

Responsible for operations of US STEP Situation Center which maintains on-line STEP file of 5000 participants, maintains STEP E-Mail file and coordinates worldwide campaigns and documents same.

Member of STEP Steering Committee, GEM Data Committee, IACG WG2, leader of STEP Project 6.3 and 6.4 and member of STEP WG 6. Member of GEM and CFAR Steering Committees



**Describe any Significant Recognition of your work:** (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Establishment of Russian Coordination office, acquisition of data from  
former Soviet Union, STEP symposium and the acquisition of  
support funds for visiting scientists STEP Newsletter.

**Honors or Awards Received:**

**Papers Published or Accepted for Publication:** (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

1.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Vladimir Papitachvili Task Number: 5000911

General Description of Your Research Activities: (Include a Paragraph on each Activity).

STEP International Newsletter: to promoting to publish articles from Russian STEP projects; editing current issues; gathering articles from world-wide community

Coordination of STEP Projects between Russia and US communities: 1) pilot digitization project with IZMIRAN for STEP Project 6.4: 1-minute geomagnetic data - 3 years/station have been digitized.

Preparation of the 1992 STEP Symposium: Abstract volume has been prepared and published in May all staff for Symposium are ready in August.

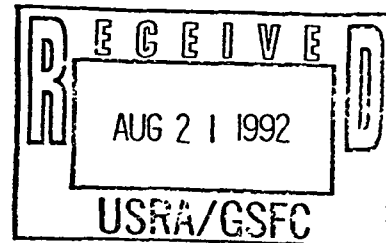
Satellite Situation Center: preparation of maps with ground-based support of STEP Projects

Project 6.4: preparation of 1-min geomagnetic data base, and development of corresponding software

Attending of scientific conferences and workshops: May 16-20 - Ottawa, STPW, June-July: CEDAR and GEM Meetings in Colorado.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Thomas H. Morgan Task Number: 69012

General Description of Your Research Activities: (Include a Paragraph on each Activity).

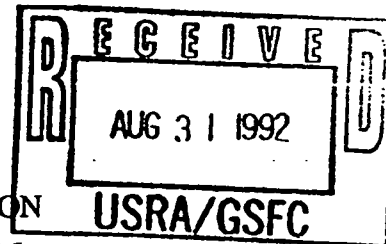
A MERCURY

Observations on the emission from Na and K in the exosphere of Mercury obtained in December 1990 during a period of intense solar activity have been reduced. The Na and K emissions do not show a strong spatial correlation. The Na emission shows frequent concentrations towards the polar regions and is time variable. The peak of the potassium emission tends to be fixed from day to day during this period. A simple explanation for this phenomenon is that the surface expression of the relatively incompatible element K is more variable than that of Na. A preliminary report of this work will be given at the Munich meeting of the Division of Planetary Science and a publication is being prepared.

There are two broad classes of explanation for the apparent concentrations of Na and K. External ones and internal ones. External ones include photon stimulated desorption and sputtering while internal processes might include diffusion and porous flows (the regolith and megaregolith are highly fractured structures). Both photon simulated desorption and diffusion have been considered this year (see publication list). The conclusion of this work to this point is that diffusion is likely not a major source process for Na and K in the atmosphere of Mercury unless the temperatures at shallow depths are much larger than presently supposed, that the crust of Mercury must be more sodic than previously thought (more like that of the Earth), and that a very likely explanation for the loci of K concentrations is simply that the composition of the crust of mercury may show regional variations.

B. MOON

The origin of the Na exosphere of the Moon appears to be well established—impact vaporization. The distribution of the Na is less well known, but observations by a number of observers (Potter and Morgan 1988, Potter and Morgan, 1991; Mendillo et al. 1991) clearly show that the exosphere is quite extended and may possess a tail. The gas-surface interaction is a matter of intense debate (Morgan and Shemansky 1991 and Sprague et al., 1992). Within this debate are three important observational issues: 1. Delineating the global (three dimensional) distribution of Na. 2. Detecting (or setting limits on) any velocity shifts which would indicate flow into and along the tail from sunward portion of the atmosphere/corona (which would show that a large percentage of the particles are not returning to the surface). 3. Determining the precise distribution of Na with respect to altitude above the equatorial terminator when the Sun is at local zenith. Accordingly, three separate observational programs have been initiated this year. The data is still being reduced.



UNIVERSITY SPACE RESEARCH ASSOCIATION  
 GODDARD VISITING SCIENTIST PROGRAM  
 EMPLOYEE SUMMARUY OF ACCOMPLISHMENTS  
 (for the year ending 9/30/92)

Employee Name: Tian-Sen Huang

Task Number: 690-13

General Description of Your Research Activities:

Finished research work:

- (1) A new version of paper: "Neptune's Magnetosphere in the OTD Magnetic Field Frame" by T. S. Huang, E. C. Sittler and T. J. Birmingham. This work has been extended in order to relate closely to Voyager observations and give more calculations which will be useful in the further work on Neptune's magnetosphere.
- (2) The paper "Configuration of Convecting Plasma in a Line Dipole Field" by T. S. Huang and T. J. Birmingham. In this work we first developed a self-consistent dynamical description in analytic form for a convecting plasma. We also investigated the interchange instability in the convecting plasma, and predicted the regions in Earth's magnetosphere which is unstable against the interchange instability.

(Above two papers will be submitted to *J. Geophys. Res.* soon.)

- (3) The derivation of density and pressure distributions for a convecting anisotropic plasma resulted from a localized boundary in line dipole field.
- (4) The derivations of electric current distribution in the aforementioned plasma and the new strict magnetosphere-ionosphere coupling equation. The effects of coupling between magnetosphere and ionosphere, which leads to modification in the electric field distribution, is included.

(Both items (3) and (4) are in collaboration with Dr. Birmingham.)

Ongoing research work:

- (1) Complete the computational work for the subjects mentioned in items (3) and (4) of finished research work, and write up for publications.
- (2) A new subject about the effects of magnetospheric plasma on the ionosphere and atmosphere in collaborate with Dr. T.W. Hill at Department of Space Physics and Astronomy, Rice University.

Describe any Significant Recognition of Your Work:

During the past two years (Jan. 1990 — June 1992)

(1) The paper "Types of Planetary Tori" by T. S. Huang and G. L. Siscoe (*Icarus* 70, pp366–378, 1987) has been cited four times by D. M. Hunter (*Icarus* 1990), J. D. Richardson and A. Eviatar and M. L. Delitsky (*Geophys. Res. Lett.*, 1990), R. L. McNutt (*Rev. of Geophys.*, 1991), and F. Bagenal (*Annu. Rev. of Earth and Planet. Sci.*, 1992).

(2) The paper "Centrifugal Field Line Breaking: an Upper Limit to Io Mass Injection" by T. S. Huang and G. L. Siscoe (*Ap J.*, 312, pp475–483, 1987) has been cited twice by R. L. McNutt (*Rev. of Geophys.*, 1991), and F. Bagenal (*Annu. Rev. of Earth and Planet. Sci.*, 1992).

(3) The paper "Corotation Lag Limit on Mass-loss Rate From Io" by T. S. Huang and G. L. Siscoe, (*Ap J.*, 319, 1003–1009, 1987) has been cited three times by A. Eviatar (*J. Atmos. and Terr. Phys.*, 1990), R. L. McNutt (*Rev. of Geophys.*, 1991), and F. Bagenal (*Annu. Rev. of Earth and Planet. Sci.*, 1992).

(4) The paper "Motion of Charged Particles in Planetary Magnetospheres with Nonelectromagnetic Forces" by T. S. Huang, T. W. Hill, and R. A. Wolf (*J. Geophys. Res.*, 93, pp5513–5523, 1988) has been cited four times by R. L. McNutt (*Rev. of Geophys.*, 1991), M. Fujimoto and A. Nishida (*J. Geophys. Res.*, 1990), T. S. Huang, R. A. Wolf, and T. W. Hill (*J. Geophys. Res.*, 1990), T. S. Huang and T. W. Hill (*J. Geophys. Res.*, 1991).

(5) The paper "Corotation Lag of the Jovian Atmosphere, Ionosphere and Magnetosphere" by T. S. Huang and T. W. Hill (*J. Geophys. Res.*, 94, pp3761–3765, 1989) has been cited twice by R. L. McNutt (*Rev. of Geophys.*, 1991), and R. Prange and M. Elkhamsi (*J. Geophys. Res.*, 1992).

(6) The paper "Interchange Instability of the Earth's Plasmapause" by T. S. Huang, R. A. Wolf, and T. W. Hill (*J. Geophys. Res.*, 95, pp17187–17198, 1990) has been cited once by T. S. Huang and T. W. Hill (*J. Geophys. Res.*, 1992).

(7) The paper "Drift Wave Instability in the Io Plasma Torus" by T. S. Huang and T. W. Hill (*J. Geophys. Res.*, 96, pp14075–14083, 1991) has been cited once by Y. S. Yang, R. A. Wolf, R. W. Spiro and A. J. Dessler (*Geophys. Res. Lett.*, 1992).

Honors or Awards received:

Non

Paper Published or Accepted for Publication:

T. S. Huang and T. J. Birmingham, The Polarization Electric Field and Its Effects in an Anisotropic Magnetospheric Plasma, *J. Geophys. Res.*, **97**, pp1511–1519, 1992.

Papers Submitted but not yet Accepted for Publication:

T. S. Huang, Upwelling Plasma Flux in the Convection and Its Effects on the Solar Magnetic Field, submitted to *Ap. J.*, in 1991.

Papers Presented at Scientific Meetings:

*Invited Papers:*

“The Dynamic Properties of Convecting Plasma in a Line Dipole Field” invited by chairman D. H. Wang to give talk in the meeting of International Symposium on Space Science to be held in Xiamen, China, during October 20 – 24, 1992.

*Contributed Papers:*

(1) “The Polarization Electric Field and Its Effects in an Anisotropic Rotating Magnetospheric Plasma” by T. S. Huang and T. J. Birmingham presented in *AGU 1991 Fall Meeting*, December 9 – 13, 1991, San Francisco.

(2) “The Configuration of Convecting Plasma in a Line Dipole Field” by T. S. Huang and T. J. Birmingham presented in *AGU 1992 Spring Meeting*, May 12 – 16, 1992, Montreal, Canada.

*Colloquia, Seminars, and Special Lectures:*

Talk titled “Particle Motion and Configuration of Convecting Plasma in a Line Dipole Field” was given in Brown-Bag Seminar of Laboratory for Extraterrestrial Physics on November 15, 1991.

The same talk given in USRA Council Meeting, April, 1992.

Community Service:

(1) Refereed one proposal for NASA Headquarters which is in response to NRA-91-OSSA-10.

(2) Refereed one paper for *Journal of Geophysical Research* — the subject regards to the criterion for interchange instability

(3) Refereed one proposal for National Science Foundation, GEO/ATM/Magnetosphere Physics, 1992.

(4) Refereed one paper for journal *Planetary and Space Science* — the subject is about the plasma transport in the Jovian magnetosphere.

University Collaborations:

(1) In collaboration with Dr. T. W. Hill at Dept. Of Space Physics and Astronomy, Rice University, we are studying the effects of Ether's magnetospheric convection on the motions of ionosphere and atmosphere. The early work we developed for a special problem in the Jovian magnetosphere is extended to the terrestrial magnetosphere-ionosphere-atmosphere system. The work will give a first globe estimate for the velocities of neutral wind and ion drift in Earth's ionosphere and atmosphere.

(2) In collaboration with Dr. R. S. Selesnick, Institute of California Technology, on the subject of "Couple between Coriolis Force with Convection Motion in the Planetary Magnetospheres".

Other Collaborative Activities:

non

Supply any Additional Information You Feel Would Be Useful in Evaluating Your Research Work:

In August 1992 as Principal Investigator I have submitted two proposals:

“The Plasma Configuration of Neptune’s Magnetosphere”

“Particle Motion and Plasma Configuration in the OTD magnetospheres”

(Dr. R. E Hartle is Co-Investigator) to NASA Headquarters in response to NRA-91-OSSA-9 and NRA-92-OSSA-10.

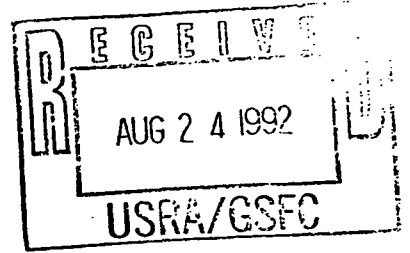
In addition, as a Co-Investigator I participated the proposal of Hong-Yee Chiu, “Differential Rotation of the Sun”, submitted to NASA Headquarters in response to NRA-92-OSSA-10.



690-014 5↓

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Susan Hoban Task Number: 690-014

General Description of Your Research Activities: (Include a Paragraph on each Activity).

I have continued my work in the area of infrared spectroscopy of cometary parent molecules. A search for the infrared signature of formaldehyde in several recent comets was published in the February issue of Icarus. I am currently involved in the reduction and analysis of 4-μm spectra of comet Levy in which we are searching for molecular emissions. This work is done in collaboration with M. Mumma and D. Reuter (Code 690 and 693, GSFC).

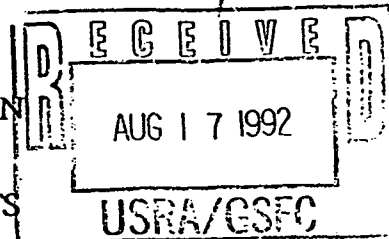
The first image of a comet in the light of the 3.4-μm organic feature was published in the February issue of Icarus as part of a collaboration with J. Klavetter of the University of Maryland. I am involved in the reduction and analysis of narrowband CCD images of comet P/Brorsen-Metcalf, in collaboration with M. A'Hearn at the University of Maryland. We are investigating the variations in spatial structure of the OH and CN comae of this comet.

I have begun a project of reduction and analysis of infrared images of Mars and Venus obtained last year with D. Gezari's (Code 685) 5-18 micron array camera. This work is done in collaboration with M. Mumma, F. Espenak (Code 690 and 693), D. Gezari and F. Varosi (Code 685).

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Elizabeth Roettger Task Number: 690-014A

General Description of Your Research Activities: (Include a Paragraph on each Activity).

I evaluated the possibility of detecting a set of cometary parent molecules with low- and medium-resolution instruments on available telescopes, ruling out some combinations and determining required conditions for other combinations. Results were used in several proposals (both for observing time and for funding). We wrote proposals to the Planetary Atmospheres program (comets and Mars), and two cycles of proposals for using the CHELL instrument on the IRTF (also comets and Mars). A target-of-opportunity proposal to observe comet Shoemaker-Levy using the CSHELL instrument was granted time. We developed the means for optimizing the search for water emission lines, observed the comet July 21-23, and began reducing the data.

I am reducing a survey spectrum of comet Halley taken from the KAO. This spectrum shows 15 to 20 emission lines of water. I developed programs to look for laboratory-detected lines of water, evaluate the intensity, and test for statistical significance. I am learning (and documenting) how to use an available program and computer system to model the Earth's atmospheric transmission. I am modifying my programs to test, statistically, the results of varying model parameters to match a lunar spectrum, and will apply the answers to the Halley spectrum. The line fluxes thus obtained should permit analysis of the excitation state of the water molecules. I expect this to be an iterative process, with more details added each time. The programs can then be used on other spectra from the same observing program. I have submitted an abstract of this work for the AAS/DPS meeting in October.

In April, there was some doubt about being able to continue in my position as Research Associate. To insure that continued funding would not be an immediate problem, I arranged to alter my task to work part of the time (average of 1-2 days per week) with Dr. Jurgen Rahe on projects for NASA Headquarters. This arrangement commenced in June, with the understanding that funding would be available up to one year. I work primarily on projects related to education. I am coordinating two projects with JPL: the JPL summer school and a related International Conference. I have worked on the announcements and programs, participant lists, invited speakers/lecturers and letters of invitation, protocol, and coordination between JPL and HQ. I am organizing the Education Research Program (supplemental to Planetary Astronomy/Planetary Atmospheres grants) as well as the Computational Upgrade Supplements. I was part of the Planetary Astronomy Review Panel, 4-6 August 1992.

Together with Dr. Susan Hoban, I developed a plan for producing an Astronomy Sourcebook for area elementary school teachers. In cooperation with Dr. Donald Jennings and Dr. Dennis Reuter, we developed and submitted two proposals to allow us to carry out the project.

670-015

Michael L. Goodman  
SPOF/ISTP/GGS  
NASA/Goddard  
Code 695  
Planetary Magnetospheres Branch  
(301)286-3497

10/27/92

USRA NASA Contract Number:NAS 530442

Ms. Denise Dunn  
Administrative Assistant  
USRA Visiting Scientist Program  
Mail Code 610.3  
NASA/Goddard Space Flight Center

Subject: Technical Report for 7/1/92-9/30/92, and  
Planned activities for 10/1/92-12/31/92

Dear Ms. Dunn,

My activities are divided into two categories; operations within the SPOF, and research. My activities within each of these categories are as follows.

OPERATIONS:

I have installed the SPOF ORACLE database on three of the four SPOF workstations. I am in the process of setting up SQL\*Net TCP/IP to connect the databases on the several workstations. Over the next two months I will begin design and SQL code development for the long term science plan which will be stored in the database.

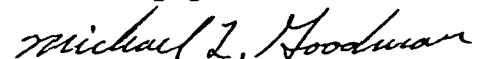
I will be installing the PV-WAVE graphics language package on the remaining three workstations.

RESEARCH:

Alex Klimas, Bill Farrell, Adolfo Vinas, and I have submitted a Director's Discretionary Fund Proposal, "A Faster and More Accurate Plasma Simulation Method", to design, develop, test, and apply extensions of our present Vlasov simulation method to include multi-species and higher dimensional electromagnetic phenomena.

I have been continuing with the development of an MHD equilibrium model which includes classical resistivity, thermal conductivity, viscosity, and thermoelectric effects.

Sincerely yours,

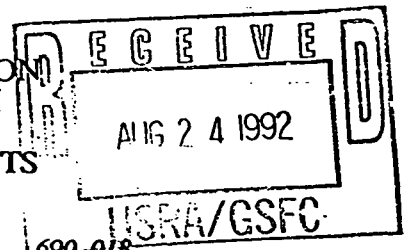


Michael L. Goodman

640-018

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
 GODDARD VISITING SCIENTIST PROGRAM  
 EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
 (for the year ending 9/30/92)



Employee Name: Harri E. Laakso

Task Number: 690-018

General Description of Your Research Activities: (Include a Paragraph on each Activity).

*After joining to USRA in April 1992, Dr. Laakso has started the following research activities:*

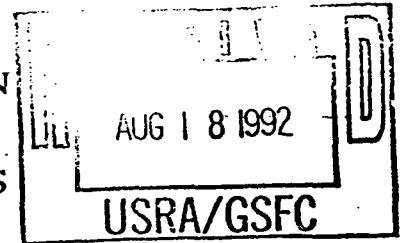
*On double probe theory, the main issue is the errors induced by spatial variations of the electron density and temperature. We have found that in some occasion reasonable gradients of these parameters may lead to large spurious electric fields if the probes are assumed to be at the same floating potential. The largest errors occur at negative floating potentials. The magnitude of the error is directly proportional to the electron temperature.*

*On cometary plasma physics, we have investigated some current layers detected in the vicinity of comet Halley. Near these current layers relatively strong dust density variations were observed. The main issue of this study is the dust-plasma interaction and its possible consequences. For instance at a dust envelope a mass density gradient across the envelope may, in some conditions, result in a hydromagnetic discontinuity. For instance, tangential discontinuities or slow shocks could be possible mechanisms to produce such magnetic signatures as observed by us. In another case we found some evidence that dust grains may occasionally give a contribution to the plasma flow stagnation in the inner coma.*

*On magnetospheric physics we have surveyed possible research fields for the CRRES electric field and magnetic field data base. This spacecraft offers good opportunities to make research on various topics of auroral physics, low-frequency waves and plasmaspheric processes. We have made some research in the first two topics.*

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: YOSIO E. SHIMABUKURO Task Number: 900-001A

General Description of Your Research Activities: (Include a Paragraph on each Activity).

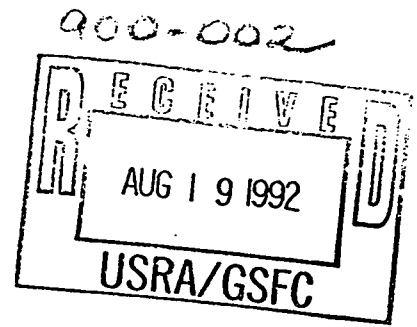
Since January 1992, I have been in the Biospheric Sciences Branch working with the GIMMS (Global Inventory Mapping and Monitoring) Group under the coordination of Dr. Compton J. Tucker. Currently, I am a CO-Investigator in the Interdisciplinary Project entitled "Long term monitoring of the Amazon ecosystems through the Eos: from patterns to processes" responsible for HIRIS and MODIS analysis for vegetation assessment.

During the last year, I have been involved with remote sensing activities in several projects for vegetation studies. In Brazil, I was involved in a project in cooperation with the Brazilian Agency for Agricultural Research to develop methodology using AVHRR/NOAA vegetation index and TM/Landsat images for savanna region. Also, I was involved in a project to develop methodology of using multisensor approach (AVHRR and TM) and GIS techniques for monitoring vegetation in the Amazon region. I have participated in the Remote Sensing Master Science Program of INPE as the committee member and adviser.

Here, at Goddard, I have been working with several remote sensing data such as TM, AVHRR and AVIRIS, in different study sites in collaboration with Biospheric Sciences Branch scientists. We have been analyzing the multitemporal AVHRR GAC data for the investigation of the vegetation phenology. For this study, we are using data from August 1981 to June 1991 over Brazil, analyzing the vegetation cover of Amazon, savanna, "caatinga" and transition regions. The mixture problem is other research activity that I have been involved in this period. A linear relation is used to represent the spectral mixture of targets within the resolution element (pixel) of the remote sensing systems. The algorithms to estimate the

components proportion within the pixels are the Constrained Least Squares (CLS) and Weighted Least Squares (WLS) methods developed at Colorado State University as part of my Ph. D. dissertation. These methods were implemented in the GIMMS Laboratory and I have applied to several remote sensing data (AVIRIS, TM and AVHRR) over different study sites.

The results of these research activities have been presented in the remote sensing meetings and published or submitted to the remote sensing journals.



Universities Space Research Association  
Goddard Visiting Scientist Program

Employee Summary of Accomplishments

Jeff Dozier — Task No. 5000-092

(for year ending 9/30/92)

GENERAL DESCRIPTION OF RESEARCH ACTIVITIES

During this year I served as the Project Scientist for the Earth Observing System (EOS). This was my final year in a two-year appointment.

Accomplishments this year include:

1. Formulation of NASA GSFC's science response to various external reviews, especially the National Academy of Science's review of EOSDIS. Discussions with Academy in February 1992.
2. Guiding selection of instruments for the EOS platforms. My presentations to the Payload Panel last October, to the EOS IWG meeting in July, and a planned presentation to the Payload Panel in September begin down-selection of the payloads in response to budgetary guidance from Congress.
3. Designing and articulating science strategy for EOS, including use of data sets available before the 1998 launch.
4. Service on the Source Evaluation Board for the EOSDIS Core System contract from the beginning of the year until the end of April, 1992.
5. Attendance at science team meetings and guidance to investigators.  
item Presentation of papers about EOS at professional meetings, educational institutions, and corporations.

6. Discussions with John Klineberg and Lennard Fisk about EOS budgets and restructuring.
7. Discussions with Japanese colleagues on plans for EOS.
8. Guidance of video presentation on EOS (scheduled to be released "soon").
9. Discussions with Senator Gore about possible value of classified assets in study of global change.
10. Interviews with Popular Science for article about EOS and global change (published June 1992).
11. Discussions with Museum of Science, Boston, about remote sensing display, March 1992.
12. Discussions with DoE officials about use of remote sensing for environmental restoration of DoE sites, March and May 1992.
13. Service on NSF proposal review panel on Continental Hydrologic Processes.
14. Service on NOAA panel to review use of operational satellite data in global change research.
15. Service on NASA panel to evaluate applications for Global Change Fellowships.
16. Participation in GSFC plans for IV&V (Independent Verification and Validation) contract.
17. Participation in Office of Technology Assessment workshop on future of remote sensing, April 1992.
18. Service as member of Landsat Science Working Group, May and July 1992.
19. Co-chair of Topographic Science Working Group.
20. Chair of EOS Science Executive Committee.

#### RECOGNITION OF WORK

1. Editor, *Geophysical Research Letters*.
2. Associate Editor, special volume of *Annals of Glaciology* on remote sensing of snow and ice.



## HONORS OR AWARDS

1. Elected Fellow, American Geophysical Union, "for innovative contributions to remote sensing of snow and ice in alpine environments, snow hydrology, and snow chemistry."  
(Selection is based on an individual attaining acknowledged eminence in a branch of geophysics. The number of Fellows selected annually is limited to no more than 0.1% of the AGU membership.)
2. Distinguished Visiting Scientist, Jet Propulsion Laboratory.

## PAPERS PUBLISHED OR ACCEPTED

### *Journal Articles*

1. Dozier, J., Opportunities to improve hydrologic data, *Reviews of Geophysics*, in press.
2. Dozier, J., Planned EOS observations of the land, ocean, and atmosphere, *Atmospheric Research*, in press.
3. Dozier, J. and Moore, B., EOS: science and policy priorities for remote sensing technology, *Geotimes*, 37(6), 12–15, 1992.
4. Moore, B., Dozier, J., Abbott, M. R., Butler, D. M., Schimel, D., and Schoeberl, M. R., The restructured Earth Observing System: instrument recommendations, *Eos, Transactions, American Geophysical Union*, 72(46), 505, 510, 516, 1991.

### *Books or Chapters in Books*

1. Dozier, J., The EOS Data and Information System (EOSDIS), in *TERRA-1: Understanding the Terrestrial Environment, the Role of Earth Observations from Space*, edited by Mather, P. M., pp. 163–173, Taylor and Francis, London, 1992.
2. Dozier, J., Gjessing, Y. T., Johannes, A. J., and Morris, E. M., Chemical processes in snow—where should we go?, in *Seasonal Snowpacks: Processes of Compositional Change*, edited by Davies, T. D., Tranter, M., and Jones, H. G., NATO ASI Series G: Ecological Sciences, Vol. 28, pp. 457–460, Springer-Verlag, Berlin, 1991.

3. Dozier, J. and Williams, M. W., Hydrology and hydrochemistry of alpine basins, in *Geophysics News 1991*, edited by Knopman, D. and Morse, S. A., pp. 24-25, American Geophysical Union, Washington, 1991.
4. National Research Council, Computer Science and Telecommunications Board, *Computing the Future: A Broader Agenda for Computer Science and Engineering*, National Academy Press, Washington, D.C., 1992.
5. Singh, R. P., Tabbagh, A., Gower, J. F. R., Smith, W. L., MacDonald, A. E., Manton, M. J., Pailleux, J., Tsuchiya, K., and J. Dozier, editors, *Remote Sensing of the Earth's Surface and Atmosphere*, Advances in Space Research, vol. 12, no. 7, Pergamon, Oxford, 1992.

#### *Conference Proceedings or Other Publications*

1. Emery, W. and Dozier, J., One-stop shopping for Earth sciences data, *Space News* 3(22), 19, 1992.
2. Rott, H., Davis, R. E., and Dozier, J., Polarimetric and multifrequency SAR signatures of wet snow, in *IGARSS '92*, pp. 1657-1662, IEEE No. 92CH3041-1, Piscataway, NJ, Institute of Electrical and Electronics Engineers.
3. Shi, J. and Dozier, J., Radar backscattering response to wet snow, in *IGARSS '92*, pp. 927-929.
4. Wan, Z. and Dozier, J., Effects of temperature-dependent molecular absorption coefficients on the thermal infrared remote sensing of the Earth surface, in *IGARSS '92*, pp. 1242-1247.

#### INVITED PAPERS PRESENTED AT SCIENTIFIC MEETINGS

1. Papers on remote sensing of snow and snow accumulation at American Geophysical Union, San Francisco, December 1991.
2. Paper on EOSDIS at AAAS (American Association for the Advancement of Science) Meeting, Chicago, February 1992.
3. Paper on EOS at AAS (American Aeronautical Society) Meeting, Keystone, February 1992.

4. Paper on advanced data and information systems, High Speed Computing Conference, Gleneden Beach, OR, May 1992.
5. Paper on data base issues in EOSDIS, SIGMOD conference, San Diego, June 1992.
6. Paper on planned EOS observations of land, ocean, and atmospheres at International Radiation Symposium, Tallinn, Estonia, August 1992.
7. Paper on EOS payloads, International Geographical Congress, August 1992.
8. Paper on temperature measurement from space, COSPAR, Washington, September 1992.
9. Paper on EOS instruments, COSPAR, Washington, September 1992.
10. Paper on advanced data and information systems, NOAA/Mitre workshop on Terabyte Data Bases, September 1992.

#### COLLOQUIA, SEMINARS, AND SPECIAL LECTURES

1. Lectures on EOSDIS and advanced data and information systems, NATO Advanced Studies Institute, Glucksburg, Germany, October 1991.
2. Presentation on Sequoia 2000 at press conference, University of California, Berkeley, October 1991.
3. Lecture on EOS, University of Maryland, October 1991.
4. Lecture on remote sensing of snow and ice, NASA Goddard Earth Science Seminar, November 1991.
5. Lecture on EOS at University of Colorado, November 1991.
6. Five interactive television presentations on EOS via WorldNet (U.S.I.A.) to worldwide audiences, December 1991 through February 1992.
7. Lecture on data systems at DEC Global Change Seminar, December 1991.
8. Lecture on EOS at NASDA (Japan's NASA), December 1991.
9. Lecture on EOS at Louisiana Space Symposium, January 1992.

10. Lecture on EOS at University of California, Santa Barbara, April and June 1992.
11. Taught course on numerical modeling with Dr. Warren Wiscombe (GSFC) at North Carolina Supercomputer Center, May 1992.
12. Lecture on advanced data and information systems, Stanford University, May 1992.
13. Introductory lecture and lecture on EOS, NASA/JPL/UCSD summer school on Earth systems science, June 1992.
14. Presentation on EOSDIS at Illinois Supercomputer Center, July 1992.
15. Lecture on advanced data and information systems, Institute for Defense Analysis, August 1992.

#### COMMUNITY SERVICE

1. American Association of Avalanche Professionals, member of Education Committee.
2. American Geophysical Union, Information Technology Committee.
3. American Geophysical Union, Executive Committee, Hydrology Section.
4. American Geophysical Union, Snow, Ice and Permafrost Committee.
5. International Commission for Snow and Ice, U.S. Correspondent.
6. NASA, Chairman of Science Advisory Panel for EOS Data and Information.
7. National Academy of Sciences, member of Committee to Assess the Scope and Direction of Computer Science and Technology.
8. NASA, Chairman of Topography Working Group.

#### UNIVERSITY COLLABORATIONS

1. Principal Investigator, University of California, Santa Barbara: NASA Grant on *Hydrology, Hydrochemical Modeling, and Remote Sensing in Seasonally Snow-Covered Alpine Drainage Basins.*

2. Co-Principal Investigator with Dr. Michael Stonebraker, University of California System, grant from Digital Equipment Corporation on *Sequoia 2000: Large Capacity Object Servers for Global Change Research*.
3. Co-Principal Investigator with Dr. Helmut Rott, University of Innsbruck, on NASA grants, *Radar Investigations of Snow and Glaciers in Alpine Terrain*.
4. Co-Investigator with Dr. William Emery, University of Colorado, on NASA grant, *A Land-Surface Testbed for EOSDIS*.
5. Chairman of the following Ph.D. committees at the University of California, Santa Barbara:

Kelly Elder	Ph.D. candidate
Richard Kattelman	Ph.D. candidate
Anne Nolin	Ph.D. candidate
Jiancheng Shi	finished Ph.D. December 1991
6. Member of the following Ph.D. committees at the University of California, Santa Barbara:

Yong Wang	finished Ph.D. June 1992
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#### GOVERNMENT LABORATORY COLLABORATIONS

Co-Investigator with Dr. Robert E. Davis, U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, NH on *Electromagnetic Properties of Snow*.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS

(for the year ending 9/30/92)

Employee name: Shrinivas Moorthi

Task Number: 5000-103

General Description of Your Research Activities: (Include a Paragraph on each Activity).

a) *Semi-Lagrangian modeling*

1) Adiabatic formulation

I have significantly improved the computer code of the adiabatic version of the semi-Lagrangian semi-implicit (SLSI) atmospheric general circulation model (GCM) which was successfully developed in the previous year in collaboration with Dr. J. R. Bates of NASA and Dr. R. W. Higgins of USRA. This has resulted in significantly less core requirements and improved efficiency. A paper discussing the results from this model has been accepted for publication in the Monthly Weather review. A paper that discusses the direct elliptic equation solver used in this model is also accepted for publication in the Monthly Weather Review.

I also investigated the accuracy of the semi-Lagrangian, Eulerian finite-difference methods applied to one dimensional Burger equation with a known analytical solution.

2) Diabatic formulation

I have now completed a first version of the SLSI GCM with full physics. I have designed the computer code of the model following closely the other GCM (ARIES GCM) I have been working on. Therefore, for the first version of the SLSI GCM, I basically borrowed the physics package I developed for ARIES GCM in collaboration with Dr. Max Suarez. Thus the current version of SLSI GCM includes the Relaxed Arakawa Schubert cumulus parameterization, Harshvardhan radiation, a scheme for large scale precipitation, and a simple boundary layer parameterization. The physics at the moment is treated in a time-split manner. In the future, we hope to treat it in semi-Lagrangian manner. I have been able to run the SLSI GCM, with a horizontal resolution of 2X2.5 degree latitude/longitude resolution with 16 equally spaced layers in the vertical, for more than one full simulated year. The results turned out to be extremely

encouraging and the simulation of both winter and summer turned out to be very reasonable. I have just restructured the model code to enable automatic initialization using the digital filter technique. This initialization procedure involves a backward adiabatic integration followed by a forward diabatic integration. Then the time series from the forward integration is filtered using a digital filter to provide the initialized field from which forecast is performed. Due to this automation of the initialization, it is very easy to experiment with different initial states at different resolutions and parameter values.

We have just submitted a three year proposal to NASA for further development of the SLSI methods and I am a co-investigator on this proposal.

b) *Work related to ARIES GCM.*

I have continued to improve the Relaxed Arakawa Schubert (RAS) cumulus parameterization by including the cumulus friction and redesigning the computer code. The current version of the RAS code is very efficient and produces very reasonable results. I have developed a fully "plug-compatible" version of this parameterization. Therefore, it can be easily used any model of the atmosphere. It is already being used in the SLSI GCM and the GEOS-1 GCM at Goddard, in addition to the ARIES GCM. I have received requests for RAS code from the North Carolina State University, the State University of New York, Albany and expect more requests in the future. I am also planning to improve RAS by including some downdraft formulation.

I have successfully incorporated the digital filtering initialization in a version of the ARIES model with options to run adiabatic/diabatic backward/forward modes. I plan to perform some forecast experiments with this model and also compare RAS with the original Arakawa-Schubert parameterization.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper or coded reference and the number of citations for each).

- o Inclusion of the Relaxed Arakawa Schubert (RAS) cumulus parameterization scheme in the GEOS-1 GCM at Goddard.
- o Requests by researchers from the North Carolina State University and the State University of New York, Albany for the computer code of RAS.

Honors or Awards Received:

none

Papers published or accepted for publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

- (1) Moorthi, S. and M.J. Suarez, 1992: Relaxed Arakawa-Schubert: A parameterization of moist convection for general circulation models. *Monthly Weather Review*, **120**, 978-1002.
- (2) Bates, J. R., S. Moorthi, and R.W. Higgins 1992: A global multi-level atmospheric model using a vector semi-Lagrangian scheme. Part I: Adiabatic formulation. (Accepted for publication in the *Monthly Weather Review*)
- (3) Moorthi, S. and R. W. Higgins, 1992: Application of fast Fourier transforms to the direct solution of a class of 2-D elliptic equations on the sphere (accepted for publication in the *Monthly Weather Review*)



Papers Submitted but not yet Accepted for Publication: (please include full title, co-authors [with affiliations], publication, and submission date).

- (1) Schubert, S., M. Suarez, C.K. Park, and S. Moorthi, 1992: GCM simulations of intraseasonal variability in the Pacific/North American region. (submitted to the *Journal of the Atmospheric Sciences*)
- (2) Li, Y., I. M. Navon, S. Moorthi and R. W. Higgins, 1992: The 2-D semi-implicit semi-Lagrangian global model: direct solver and adjoint model development, (submitted to the *Monthly Weather Review*).

Papers Presented at Scientific Meetings:

*Invited papers:* (Include title of talk, meeting name, date, and any special meeting role, e.g. session chair, rapporteur).

none

*Contributed papers:* (Include title, meeting, and date)

- (1) Bates, J. R., S. Moorthi, and R.W. Higgins 1991: Integration of a global multilevel model using a finite-difference vector semi-Lagrangian scheme. Preprint volume, 9th AMS Conference on Numerical Weather Prediction, October 14-18, 1991, Denver, Colorado.
- (2) Moorthi, S. and M.J. Suarez, 1991: Relaxed Arakawa-Schubert: A parameterization of moist convection for general circulation models. Preprint volume, 9th AMS Conference on Numerical Weather Prediction, October 14-18, 1991, Denver, Colorado.
- (3) Schubert, S., M. Suarez, C.K. Park, and S. Moorthi, 1991: Mechanisms of Low frequency variability in the atmosphere and a GCM. Preprint volume, 5th AMS Conference on Climate variations, October 14-18, 1991, Denver, Colorado.
- (4) Bates, J. R., S. Moorthi, and R.W. Higgins 1992: Development of a semi-Lagrangian global atmospheric model. Second International Conference on Modeling of Global Climate Change and Variability, Hamburg, Germany, Sept. 7-11.

*Colloquia Seminars, and Special Lectures: (Provide title, date, and place)*

- a) Presented a talk on " Moist Convective Parameterization at GLA" on July 12, 1992 to the NASA review of the Data Assimilation Office
- b) Gave an informal presentation on some recent results from the one year integration of semi-Lagrangian GCM with full physics at NMC in June, 1992

Community Service: (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.)

- a) Reviewer of manuscripts submitted to the Journal of the Atmospheric Sciences
- b) Reviewer of proposals submitted to the NSF (in early part of 1991)
- c) Developed a "Plug-Compatible" version of the Relaxed-Arakawa-Schubert parameterization and made it available to the research community

University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant//contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

- (1) Continuing collaboration with Professor I. M. Navon of Supercomputer Computations Research Institute of Florida State University to develop an adjoint model of the semi-Lagrangian GCM. This collaboration has already resulted in a FSU technical report and a manuscript has been submitted to the Monthly Weather Review for publication.

Other Collaborative Activities: (Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s))

Continuing collaboration with the Development Division of National Meteorological Center on the development/use of the semi-Lagrangian GCM.

Supply any Additional Information you Feel Would be Useful in evaluating your performance:

- o I am a co-investigator on a NASA proposal to develop a semi-Lagrangian GCM.
- o I am also a co-investigator on a NASA proposal on physical parameterization with Dr. Mark Helfand as PI.
- o Principal architect of the SLSI GCM code.
- o An author on the following technical memorandums:
  - (1) Li, Y., I. M. Navon, S. Moorthi, R. W. Higgins, 1991: The 2-D semi-implicit semi-Lagrangian global model: direct solver, vectorization and adjoint model development. Rep # FSU-SCRI-91-158, The Florida State University, FL 32306.
  - (2) Moorthi, S. and R. W. Higgins, 1992: A fast direct solver for 2D elliptic equations on the sphere *NASA Technical Memorandum #104567*, May, 1992, pp39.

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910-007

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

RECEIVED	
SEP 22 1992	
USRA/GSFC	

Employee Name: Chung-Hsiung Sui Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

For the year ending 9/30/92, my research activities in the USRA-Goddard visiting scientist program continue to involve in two projects: the joint TRMM project with Bill Lau, W. K. Tao and M. L. Wu (Tropical Rainfall and Convective Systems and Their Influence on Global Climate), and joint TOGA-COARE project with Bill Lau (Cumulus and dynamic modelling). Major research goals are i) to understand the hydrological cycle of western Pacific cloud clusters using the Goddard Cumulus Ensemble (GCE) model; ii) to understand the processes maintaining the coupled ocean-atmosphere system over the warm pool region. We have produced three papers: one has been accepted for publication, one is submitted and the one is to be submitted by the end of October, 1992.

I was invited by School of Ocean and Earth Science and Technology, University Hawaii at Manoa to give a seminar on February 27, 1992. The title of the seminar is "On the climatic equilibrium of the ocean-atmosphere system in the tropical Pacific".

I and W. K. Tao were invited by NCAR to attend the Cloud Ensemble Modeling Workshop held in Boulder, CO, during the period of July 9-10, 1992. Three CEM modeling groups from GFDL, NCAR and GSFC decided to collaborate on the study of convective-radiative equilibrium using CEMs.

Starting 8/1/92, I took a leave without pay from USRA to visit Center for Climate System Research, University of Tokyo for the following six months. During this period, major research work will still follow my research interest as stated above with a particular emphasis on the study of cloud feedback mechanism in the climate system using the Goddard CEM.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Dr. Vikram M. Mehta Task Number: 910-007

General Description of Your Research Activities: (Include a Paragraph on each Activity).

### Programmatic activities

In task 910-007, Dr. K.-M. Lau (code 913) and I are analyzing the global hydrologic cycle (GHC) and its variability using observational and model data.

Last year, we analyzed a series of one-year integrations of an atmospheric general circulation model (GCM) developed at Goddard. The main scientific finding of last year's work was that large-scale droughts and floods can occur entirely due to the natural variability of the atmosphere-biosphere system. Earlier this year, we submitted a paper containing the above work for publication in the Journal of Geophysical Research. We have continued to study the GHC using GCMs. Recently, I have completed analysis of rainfall in a GCM developed at Geophysical Fluid Dynamics Laboratory (GFDL) of NOAA. We find that the annual cycle of rainfall and rainfall variability at time scales of a few weeks are well-simulated by the GFDL GCM. We are now analyzing other components (evaporation and moisture transport) of the GHC. We are also comparing the details of the GHC over various regions of the world in the GFDL GCM and observations. We are developing a paper based on the recent work.

### Independent research

I have continued to work on understanding and modelling climate variability at time scales of 10-20 years. Using a simple yet fairly realistic model of the coupled ocean-atmosphere system, I showed that decadal climate variability can occur as a result of ocean-atmosphere interaction. A paper containing the above work was published in the April 1992 issue of the Journal of Climate. I am now modelling the effects of ocean boundaries on decadal coupled ocean-atmosphere oscillations. In collaboration with Dr. Amita Mehta (code 910.4), I am modelling the effects of nonlinearities and external forcings on decadal coupled ocean-atmosphere oscillations. Two papers based on the above work will be presented by me and Dr. Amita Mehta in the Second International Conference on Modelling of Global Climate Change and Variability to be held in Hamburg during 7-11 September.

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## Contributed presentations at scientific conferences

Mehta, V.M.: Interdecadal variability of Atlantic Ocean meridional circulations in a linear, coupled ocean-atmosphere model. *Annual Meeting of the Atlantic Climate Change Program*, Miami, March 9-11, 1992.

Mehta, V.M., and K.-M. Lau: Relationship between zonally-symmetric and zonally-asymmetric intraseasonal oscillations. *Fifth Conference on Climate Variations*, American Meteorological Society, Denver, Oct. 14-18, 1991.

Mehta, V.M., K.-M. Lau, and Y.C. Sud: Low-frequency variability of the global hydrological cycle in an atmospheric general circulation-biosphere model. *Fifth Conference on Climate Variations*, American Meteorological Society, Denver, Oct. 14-18, 1991.

Mehta, V.M., and A. Barcilon: A model of low-frequency, zonally-symmetric modes of the ocean-atmosphere system. *Eighth Conference on Atmospheric and Oceanic Waves and Stability*, American Meteorological Society, Denver, Oct. 14-18, 1991.

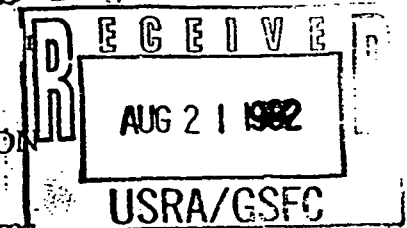
Mehta, V.M.: Interannual to interdecadal variability of meridional circulations in a linear, coupled ocean-atmosphere model. To be presented at the *Second International Conference on Modelling of Global Climate Change and variability*, Hamburg, Germany, 7-11 September 1992.

Lau, K.-M., V.M. Mehta, M. Fiorino, and Y.C. Sud: Rainfall variability in general circulation models: An intercomparison. To be presented at the *Second International Conference on Modelling of Global Climate Change and variability*, Hamburg, Germany, 7-11 September 1992.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Li-Peng

Task Number: 5000-108

General Description of Your Research Activities: (Include a Paragraph on each Activity).

The following aspects of tropical-extratropical interactions were investigated on the basis of the coupled modes between tropical convection and 200mb streamfunction, as found in the previous year:

**1. The reproducibility of the previously found coupled modes.**

Data sets were subdivided into subsets and coupled modes were obtained for the subsets to test the robustness of the modes. It was found that the leading modes were reproducible from the subsets without much change.

**2. The physical nature of the coupled tropical-extratropical modes.**

The 3-dimensional structure of the coupled modes was obtained by the method of composition based on the associated time series. A barotropic extratropical structure suggests that the mode derive its energy from a tropical source, while a baroclinic extratropical structure suggests that the mode is likely developed within the extratropical region.

**3. Implications on the propagation of atmospheric wave-activities.**

Barotropic fluxes of vorticity were computed using wind data for each of the significant coupled modes. The characteristic of the fluxes varies greatly with the modes.

**4. Seasonal variations of the coupled mode.**

Seasonal stratified data were used to study the seasonal effects on the coupled modes. Since the energy exchanges between the tropics and extratropics depend upon the meridional profile of mean zonal winds, those modes with strong intraseasonal oscillations were found to have considerable seasonal variations.

**5. Frequency dependence of the coupled modes.**

The associated time series of most of the coupled modes were analyzed using conventional and 'singular' spectral analysis, and were found as containing multiple time scales from intraseasonal to interannual. The strongest amplitudes were generally found to be interannual.

**6. The possibility of rotating the coupled modes to achieve better understanding.**

Since many of the found coupled modes are associated with multiple spatial and time scales, decomposition is desirable for easier understanding. It is a standard practice in empirical orthogonal analysis and factor analysis to rotate the obtained eigenvectors or factor loadings to achieve physical understanding. Our new approach was to try a similar procedure on the modes obtained by singular value decomposition(SVD). The results were not satisfactory because the maximization of coupling under SVD could not be held any more.

**7. Regional aspects of tropical-extratropical coupling.**

were studied. Modes of two different nature were found. A paper of this work is scheduled to be presented at the International Conference on East Asia and Western Pacific Meteorology and Climate.

**8. Numerical simulation of the coupled modes.**

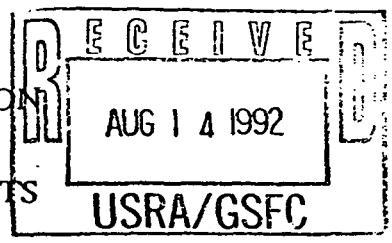
Barotropic atmospheric models were used to investigate the dynamic mechanism responsible for the coupled tropical-extratropical modes, and, in particular, to find out how well the anomalous tropical divergence fields, derived from the modes of the outgoing longwave radiation anomalies, can be used as forcing in a barotropic atmospheric model to reproduce the corresponding 200mb streamfunction modes. The results of the model simulation shew that the general features of the simulated patterns were comparable to the corresponding patterns of 200mb streamfunction, but the simulated positions of the centers always shifted westward considerably.

A paper based on parts of the above work is to be submitted to the Journal of Climate shortly.





UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: JOAN ROSENFELD Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

I continued my research into the radiative effects of polar stratospheric clouds (PSCs), investigating their potential impact on Antarctic stratospheric temperatures. Based on time-marching calculations of radiatively determined temperatures, I found that the small heating effect (0.1-0.2 deg/day) of the PSCs can translate into a temperature difference of 5 to 10 degrees. I submitted a paper to Geophysical Research Letters on this work.

I participated in AASE II (Airborne Arctic Stratospheric Expedition II). I supervised calculations of daily, Northern Hemispheric radiative heating rates, for each day of the AASE.

I participated in the Stratospheric Models & Measurements Intercomparison. My assignment was to discuss and intercompare the heating rates and circulations used in the participating two-dimensional photochemical models.

I carried out some calculations of radiatively determined temperatures with varying amounts of CO2 in order to see how much of the lower mesospheric temperature trend (roughly -0.1% per year) can be explained by increasing atmospheric CO2. The results indicated that only about half of the trend can be explained by changing CO2. A manuscript is in preparation on this work.

I significantly revised the proposal that I had submitted to NASA Headquarters last year, entitled "A Modeling Proposal for Stratospheric Photolysis Rates," and resubmitted it.

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Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Numer of citations in the 1991 Annual Science Citations Index for papers on which I am the first author:

- 1987, "Computation of Stratospheric Diabatic Circulation..." (6)
- 1988, "Antarctic Springtime Ozone Depletion..." (1)
- 1990, "Radiative Heating Rates During the Airborne..." (1)
- 1991, "A Simple Parameterization..." (3)

I was an invited reviewer in 1991 for the WMO/UNEP Scientific Assessment of Ozone Depletion

Honors or Awards Received:

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Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

"Ozone, Absorption and Emission of Radiation," J. E. Rosenfield, in Encyclopedia of Earth System Science, Academic Press, Vol. 3, p.525-530, 1992.

"Radiative Effects of Polar Stratospheric Clouds During the Airborne Antarctic Ozone Experiment and the Airborne Arctic Stratospheric Expedition," J. E. Rosenfield, J. Geophys. Res., 97, 7841-7858, 1992.

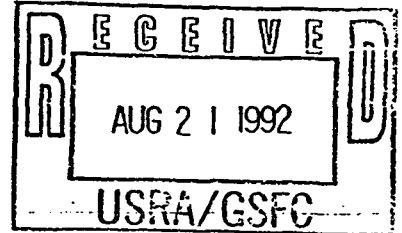
"The Structure of the Polar Vortex," M. R. Schoeberl, L. R. Lait, P. A. Newman, and J. E. Rosenfield, J. Geophys. Res., 97, 7859-7882, 1992.

"The Stratospheric Warming of January 1989: Results from the STRATAN Data Assimilation System," S. D. Steenrod, R. B. Rood, D. J. Lamich, J. E. Rosenfield, and R. C. Govindaraju, Monthly Weather Review, 120, 221-229, 1992.

"Residual Circulations Calculated from Satellite Data: Their Relations to Observed Temperature and Ozone Distributions," M. A. Geller, E. R. Nash, M. F. Wu, and J. E. Rosenfield, J. Atm. Sci., 49, 1127-1137, 1992.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Kenneth E. Pickering Task Number: 5000-115

General Description of Your Research Activities: (Include a Paragraph on each Activity).

(1) Simulating the effects of deep convective events on free tropospheric ozone production

Squall line type convective events have been simulated with the 2-D Goddard Cumulus Ensemble Model (Scala and Tao in Code 912). I have used the resulting wind fields to transport measured trace gases that are critical for photochemical ozone production. I then use particular profiles from the resulting trace gas distributions in a 1-D photochemical model to estimate the effects of the convective storm on ozone production during the first 24 hours following the event. I submitted a paper to JGR concerning effects on ozone production of urban plume entrainment into deep convection. This paper was accepted and is currently in press. I have also been preparing for the simulation of two additional squall line events.

(2) Simulating the effects of deep convective events during STEP on upper tropospheric ozone production

Following a procedure similar to that described above, I have simulated the effects of deep convective events during the Stratospheric-Tropospheric Exchange Project (STEP) on tropical upper tropospheric ozone production rates. I found that production of  $\text{NO}_x$  from lightning has a much greater effect on ozone production in the experimental region than does convective transport of ozone precursor gases. A paper has been prepared for JGR on these simulations and will be submitted before September 30. I have also provided guidance to an M.S.-level programmer for analyses of STEP aircraft measurements. These analyses have been completed.

(3) NASA/GTE/TRACE-A Experiment

I am a Co-I for participation in a field mission under the NASA Global Tropospheric Experiment entitled, TRACE-A (Transport and Atmospheric Chemistry Near the Equator-Atlantic). I have been conducting planning and preparatory activities over the last year. These activities have included participation in planning meetings with other project personnel, making arrangements for particular meteorological measurements during the experiment, and continual close contacts with the Mission Scientist and Mission Meteorologist regarding details of the upcoming flights. I will be participating in the field (in Brazil) for two weeks, from 26 August to 9 September 1992. This experiment will investigate the atmospheric chemistry and general circulation over the South Atlantic region from Brazil to Southern Africa.

(4) Pre-TRACE-A Ozone/Fires Trajectory Analysis

Air trajectory analyses have been conducted to link TOMS total ozone maxima over the South Atlantic with biomass fire counts for Africa using 1989 data. I conceptualized this project and have been providing guidance to an M.S.-level atmospheric scientist doing the bulk of this work. Backward trajectories were run from the TOMS maxima for two case studies and strong linkages between biomass fires and remotely-sensed ozone were found. I submitted a paper (which has been accepted) including these preliminary results for the Proceedings of the 1992 Quadrennial Ozone Symposium. Trajectory intercomparisons, using different meteorological input fields have also been conducted.

First Author:

Pickering, K. E., J. R. Scala, A. M. Thompson, W.-K. Tao, J. Simpson, A regional estimate of convective transport of CO from biomass burning, Geophys. Res. Lett., 19, 289-292, 1992.

Pickering, K. E., A. M. Thompson, J. R. Scala, W.-K. Tao, J. Simpson, Ozone production potential following convective redistribution of biomass burning emissions, J. Atmos. Chem., 14, 297-313, 1992.

Pickering, K. E., A. M. Thompson, J. R. Scala, W.-K. Tao, R. R. Dickerson, and J. Simpson, Free tropospheric ozone production following entrainment of urban plumes into deep convection, J. Geophys. Res., in press, 1992.

Pickering, K. E., A. M. Thompson, D. P. McNamara, M. R. Schoeberl, L. R. Lait, P. A. Newman, C. O. Justice, and J. D. Kendall, A trajectory modeling investigation of the biomass burning - tropical ozone relationship, Proceedings of the 1992 Quadrennial Ozone Symposium, in press, 1992.

Co-author:

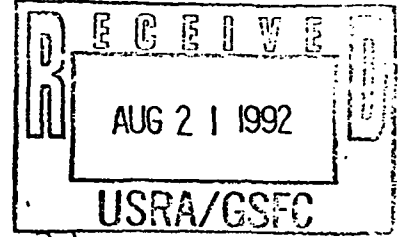
Tao, W.-K., J. Simpson, C.-H. Sui, B. Ferrier, S. Lang, J. Scala, M.-D. Chou, K. Pickering, Heating, moisture and water budgets of tropical and midlatitude squall lines: Comparisons and sensitivity to longwave radiation, J. Atmos. Sci., in press, 1992.

Luke, W. T., R. R. Dickerson, W. F. Ryan, K. E. Pickering, L. J. Nunnermacker, Tropospheric chemistry over the Great Plains of the United States 2: Trace gas profiles and distributions, J. Geophys. Res., in press, 1992.

Thompson, A. M., K. E. Pickering, D. P. McNamara, Effect of marine stratocumulus on TOMS ozone in the tropical eastern Atlantic, Proceedings 1992 Quadrennial Ozone Symposium, in press, 1992.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Leslie Robert Lait Task Number: 910-032

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Most of the past year was spent working on the second-Airborne Arctic Stratospheric Expedition field mission (AASE-II). Beginning in October 1991 and continuing until March 1992, two to three weeks of every month were spent in Bangor, Maine, the site of the mission. This campaign involved researchers from NASA, NOAA, Harvard University, the University of California at Irvine, the National Center for Atmospheric Research, the University of Denver, and the Smithsonian Institution; its purpose was to use aircraft-borne instruments to examine the evolution of stratospheric chemistry in the environs of the polar vortex during the course of the winter, with particular emphasis on ozone depletion chemistry. I was responsible for setting up the data system used by the group from Goddard Space Flight Center. This involved system configuration, helping create programs to bring data files into the system automatically, writing data display programs for use by GSFC and collaborating researchers, setting up an automatic data mailer system for use by fellow investigators, and keeping the data system operational during the entire mission.

Analysis of the data taken during this mission, as well as re-analysis of previous missions' data, has begun. The main approach taken in my research is to incorporate these data into the constituent reconstruction technique, which uses potential vorticity and potential temperature as conserved coordinates to create composite pictures of the distribution of trace constituents. Unfortunately, the frequency of aircraft flights during the mission was curtailed, making it impossible to apply the reconstruction technique in the field in real time as planned. However, with the addition of data acquired after the mission from ozonesondes and the UARS satellite, the outlook for achieving results is promising.

My computer duties over this past year included setting up new computer workstations and incorporating them into our data system, as well as creating the capability of making computer animated video tapes of our data. I also helped draw up specifications for the procurement of mass storage devices our branch is purchasing. In addition, the portable data format designed last year was refined, and a document has been written up describing it.

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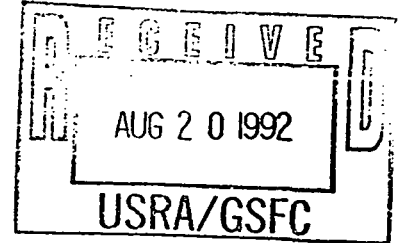
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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Stephen C. Bloom

Task Number: 5000-136

General Description of Research Activities:

1. Development of an improved methodology for simulating observation errors for use in OSSE's involving LAWS data. OSSE's (Observing System Simulation Experiments) are an important tool for the evaluation of the potential impact of a new observing system in assimilation/forecast situations. This has been my primary research focus over the past year. Accomplishments to date: 1) the development of a useful diagnostic procedure to assess an OSSE's ability to simulate the statistics of conventional data (which is quite useful for calibration purposes), 2) the development of code to modify the "Nature" used in an OSSE so that the simulated rawinsonde height data will have assimilation statistics comparable to real data. Currently, the code to modify the Nature run is in the testing stage; I estimate that tests of the impact of this procedure will be undertaken by the end of this fiscal year, or early in the next. If the modification procedure for simulated rawinsonde heights has an ameliorative impact on the simulation system, then this process will be extended to other types of simulated data (eg. simulated satellite temperature retrievals, and rawinsonde winds).
2. Surface Wind Directional Assignment/Assimilation. This has been a continuing project of R. Atlas and mine; my main interest in the near term with this work is the completion of testing of the General Balance Method (GBM) of assigning directions to SSM/I wind speed data. The priority of this project was lowered while awaiting the development of a 'frozen' assimilation system by the Data Assimilation Office (DAO). I plan to begin testing the application of median filtering methods to results from a GBM sometime during the first quarter of the next fiscal year. There is an ambiguity in direction assignment inherent in the GBM approach, which can lead to noisy surface wind fields. This is very analogous to the 'dealiasing' problem that has been encountered before with SEASAT data here at GLA. I anticipate that the median filter approach has the potential to extract the meteorological signal from the noisy (small scale) structures that current result from the application of GBM.
3. Development/Implementation of Optimal Interpolation (OI) Techniques at GLA. Currently, my work in this area is largely of a consultational nature; I interact with members of the DAO on development issues related to the OI analysis system. I have played a major role in the development of a significant feature of the current data assimilation system - Incremental Analysis Updating (IAU) - and I anticipate that I will be similarly involved in the preparation, with other members of DAO, on the publications which shall ensue from this work. I also plan to work with both the DAO and the Satellite Data Utilization Office on a project to modify IAU system to account properly for the asynoptic nature of certain data types (especially satellite retrievals).
4. Simulation Experiments Using Spatially Correlated Errors. I am involved with a number of projects which will use a methodology of generating spatially correlated random fields from known correlation functions: (i) testing the procedures which estimate the GCM forecast error statistics, using a test correlation function; (ii) Monte-Carlo estimates of short-term forecast error growth. The first project involves a relatively straightforward application of parts of the machinery described in point (1) above. The second project is part of a longer-term collaboration of mine with S. Schubert of DAO involving issues concerning short-term error growth in the GLA assimilation system.

Papers Accepted for Publication:

Atlas, R. , R.N. Hoffman and S.C. Bloom, 1992: Surface Wind Vectors Over the Oceans. to Appear in Global Change Atlas.

Papers Submitted:

Schemm, J., S. Schubert, J. Terry, S. Bloom and Y. Sud, 1992: Estimates of Monthly Mean Soil Moisture for 1979-1989. NASA/GSFC Tech. Memo.

Papers Presented at Scientific Meetings:

*Contributed Papers:*

"A Scheme to Incorporate Analysis Increments Gradually in the GLA Assimilation System," S.C. Bloom, L.L. Takacs and E. Brin, *9th Conference on Numerical Weather Prediction*, Denver, CO, October 14-18, 1991.

"Assimilation of Satellite Surface Wind Speed Data and Its Impact on NWP," S.C. Bloom and R. Atlas, *9th Conference on Numerical Weather Prediction*, Denver, CO, October 14-18, 1991.



N.B. -

**Surface Wind Velocity Over the Oceans**

This is  
a Chapter

R. Atlas, R. N. Hoffman<sup>1</sup> and S. C. Bloom<sup>2</sup>

in a Book -

Laboratory for Atmospheres  
NASA Goddard Space Flight Center  
Greenbelt, MD 20771

(No  
Abstract)

**1. Introduction**

Consistent oceanic surface wind data of high quality and high temporal and spatial resolution are required to understand and predict the large scale air-sea interactions which are thought to significantly influence both the atmosphere and ocean. Such observations are needed to provide initial data and verification data for numerical weather prediction models, drive ocean models and surface wave models, calculate surface fluxes of heat, moisture and momentum, and construct ~~surface climatologies~~.

Surface wind stress provides the most important forcing of the ocean circulation, while the fluxes of heat, moisture and momentum across the air-sea boundary are important factors in the formation, movement, and modification of water masses and the intensification of storms near coasts and over the open oceans. In addition, air-sea interaction plays a major role in theories of ENSO and the 50-day oscillation, as well as in the initiation and maintenance of heat waves and drought and other persistent anomalies.

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1 Atmospheric and Environmental Research Inc., Cambridge, MA 02139  
2 Universities Space Research Association

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Dr. R. Wayne Higgins

Task Number: 910-037

General Description of Your Research Activities: (Include a Paragraph on each Activity).

We (with Ray Bates and Shrinivas Moorthi) completed development of the adiabatic version of a global multilevel atmospheric model using a vector semi-Lagrangian finite difference scheme (Bates *et al.*, 1992). The model uses a Lorenz grid in the vertical and a C-grid in the horizontal. The momentum equation was discretized in vector form to avoid problems near the poles. The 3-D model was reduced to a set of 2-D elliptic equations, whose solution was found by means of an efficient direct solver (Moorthi and Higgins, 1992a,b). The solver was made efficient by vectorizing over longitudinal wavenumber and by using a vectorized fast Fourier transform routine. We thoroughly tested the performance of the scheme by integrating it for various time periods starting from initialized states derived from real data. A resolution of 16 levels in the vertical was used with various horizontal resolutions. Integrations with timesteps of 10 min, 30 min and 1 hour were compared. This work was presented at the Ninth Conference on Numerical Weather Prediction in Denver, Colorado.

During this year we also developed the first version of the diabatic model (Moorthi *et al.*, 1993). The physics package was borrowed from a version of the ARIES model of Suarez and Moorthi. In addition, the Relaxed Arakawa Schubert convection scheme has been improved and the initialization package (which involves a digital filter) has been automated. We completed several extended integrations of the model including a particularly successful one year integration (the only "climate" integration of a semi-Lagrangian model that has been reported anywhere in the world). Thus it appears that this model may be suitable both for numerical weather prediction and climate studies. The results from the one year integration are being presented at the Second International Conference on Modeling of Global Climate Change and Variability in Hamburg, Germany. A proposal for continuation of this work at GSFC under the NASA Global Modeling and Data Assimilation Program, Earth Science and Applications Division has been submitted (P.I.: Dr. J.R. Bates). Currently, we are testing the diabatic version of our model in short term forecast mode (ten day forecasts). In addition, a comparison of our model and the Eulerian GCM used in the Data Assimilation Office (DAO) is underway. Some theoretical considerations concerning the advection schemes used in these models suggest that the semi-Lagrangian model will give more accurate results and will perform well for large Courant numbers.

Recently, we opened up a dialogue between the National Meteorological Center (with Dr. Eugenia Kalnay), the National Center for Atmospheric Research (with Dr. Dave Williamson) and ourselves concerning a three way comparison of models from the respective centers. If the comparison proves favorable for the semi-Lagrangian model, then it has the potential to replace the operational spectral model at NMC. Our collaboration with Drs. Michael Navon and Yong Lee of Florida State University, concerning the development of an adjoint of the semi-Lagrangian model, is continuing.

We (with Siegfried Schubert) completed our study of low-frequency synoptic eddy activity in a model (ARIES GCM of Suarez and Moorthi) and observations (Higgins and Schubert, 1992). In this study we focused on: 1) a comparison of the time mean eddy

forcing of the zonal wind in the model and observations, 2) the dominant components of the transient eddy forcing in the storm track regions, 3) the hemispheric distribution of the eddy forcing and 4) the importance of baroclinic wave packets in explaining the distribution of the eddy forcing. A preliminary version of this work was presented at the Fifth Conference on Climate Variations in Denver, Colorado. A more complete version of this work is being presented at the Seventeenth Annual Climate Diagnostics Workshop in Norman, Oklahoma. As part of the Data assimilation Offices' annual RTOP Review, I presented a talk entitled "Model and Observational Diagnostic Studies: Role of the Synoptic Eddies" in which the the results from Higgins and Schubert (1992) were discussed.

We (with Siegfried Schubert) have begun a series of studies to diagnose the "climate characteristics" of data sets produced in the DAO with particular emphasis on the structure of the synoptic-scale (wavelengths ~ 1000-3000 km) eddies and their connection to the large-scale flow. The objectives of this research are to evaluate the quality of the data sets via intercomparisons with data sets from other centers and to provide feedback from these studies into the modelling and analysis efforts of the DAO. The topics we are currently investigating include 1) Studies of the coupling between planetary waves and the zonal wind, 2) An examination of the "zonality" of the storm tracks in DAO models and in observations, and 3) Low-Frequency synoptic-eddy activity in DAO model simulations. This work involves a lot of postprocessing of very large data sets from our GCM simulations. We also have plans to begin a study of the Goddard Earth Observing System (GEOS) model bias using a DAO 5 year analysis, once the analysis is available.

Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Over the last decade it has become generally recognized that the semi-Lagrangian approach is a significant advance in the numerical formulation of global atmospheric models; several centers, including the European Center for Medium Range Weather Forecasting (ECMWF) have operational semi-Lagrangian models in place or are in the process of converting to such models. Currently, the Development Division of the National Meteorological Center is considering whether to convert from their operational spectral model to a semi-Lagrangian model. To help them decide, we (Drs. Bates, Higgins, and Moorthi) are collaborating with Dr. Eugenia Kalnay \* (and associates) and Dr. Dave Williamson\*\* on a three way model intercomparison. If the comparison proves favorable for our model, then it has the potential to replace the operational spectral model at NMC.

\* National Meteorological Center  
Camp Springs, MD

\*\* National Center for Atmospheric Research  
Boulder, CO

Honors or Awards Received:

Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

#### Refereed Journals

Higgins R. W.\* and S. D. Schubert\*\*, 1992: Low-frequency synoptic eddy activity in the Pacific storm track, (accepted in *J. Atmos. Sci.* ).

Moorthi S.\* and R. W. Higgins\*, 1992: Application of fast Fourier transforms to the direct solution of a class of 2-D separable elliptic equations on the sphere, (accepted in *Mon. Wea. Rev.*).

Bates J.R.\*\*, S. Moorthi\* and R.W. Higgins\*, 1992: A global multilevel atmospheric model using a vector semi-Lagrangian finite difference scheme. Part I: Adiabatic Formulation, (accepted in *Mon. Wea. Rev.*).

\* Universities Space Research Association, NASA/GSFC, Greenbelt, MD. 20771

\*\* NASA/GSFC, Greenbelt, MD 20771

#### Technical Reports

Moorthi S.\* and R. W. Higgins\*, 1992: A fast direct solver for a class of two-dimensional separable elliptic equations on the sphere. *NASA Tech. Mem.*, 104567.

Li, Y.\*\*, I.M. Navon\*\*, S. Moorthi\* and R.W. Higgins\*, 1991: The 2-D semi-implicit semi-Lagrangian global model: direct solver vectorization and adjoint model development. *Supercomputer Computations Research Institute Report FSU - SCRI-91-158*, Florida State University, Tallahassee, FL.

\* Universities Space Research Association, NASA/GSFC, Greenbelt, MD. 20771

\*\* Supercomputer Computations Research Institute, Florida State University, Tallahassee, FL.

#### Proceedings Volumes

Higgins R. W.\* and S.D. Schubert\*\*, 1991: Influence of synoptic eddies on low-frequency intraseasonal variability in the Pacific storm track. Proc. of the Fifth Conference on Climate Variations, Denver, CO., Oct. 14 -18, pp 416-419.

Bates J.R.\*\* , S. Moorthi\* and R.W. Higgins\* , 1991: Integration of a global multilevel model using a vector semi-Lagrangian finite difference scheme. Proc. of the Ninth Conference on Numerical Weather Prediction, Denver, CO., Oct. 14 - 18, pp 280-282.

\* Universities Space Research Association, NASA/GSFC, Greenbelt, MD. 20771

\*\* NASA/GSFC, Greenbelt, MD 20771

Papers Submitted but not yet Accepted for Publication: (please include full title, co-authors [with affiliations], publication, and submission date).

Li, Y.\*\* , I. M. Navon\*\* , S. Moorthi\* , and R.W. Higgins\* , 1992: The 2-D semi-implicit semi-Lagrangian global model: direct solver and adjoint model development, (submitted to *Mon. Wea. Rev.*)

\* Universities Space Research Association, NASA/GSFC, Greenbelt, MD. 20771

\*\* Supercomputer Computations Research Institute, Florida State University, Tallahassee, Fl.

Papers Presented at Scientific Meetings:

*Invited Papers* : (Include title of talk, meeting name, date, and any special meeting role, e.g. session chair, rapporteur).

*Contributed Papers* : (Include title, meeting, and date)

Higgins R. W. and S.D. Schubert, 1991: Influence of synoptic eddies on low-frequency intraseasonal variability in the Pacific storm track. Fifth Annual Conference on Climate Variations, Denver, CO., Oct. 14 -18.

Bates J.R., S. Moorthi and R.W. Higgins, 1991: Integration of a global multilevel model using a vector semi-Lagrangian finite difference scheme. Ninth Conference on Numerical Weather Prediction, Denver, CO., Oct. 14 - 18.

Higgins R. W. and S.D. Schubert, 1992: Low-frequency synoptic eddy activity in the Pacific storm track. Seventeenth Annual Climate Diagnostics Workshop, Norman, Oklahoma, Oct 19 - 23.

Bates J.R., S. Moorthi and R.W. Higgins, 1992: Development of a semi-Lagrangian global atmospheric model. Second International Conference on Modeling of Global Climate Change and Variability, Hamburg, Germany, Sept. 7 - 11.

*Colloquia, Seminars, and Special Lectures* : (Provide title, date, and place)

*Model and Observational Diagnostic Studies:  
Role of Synoptic Eddies*

July 13, 1992

NASA/GSFC, Building 21, Room 183  
Greenbelt, MD 20771

(Presented as part of the Data Assimilation Offices' annual program review)

Community Service: (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.)

University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborators (s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

*Collaborative Research Projects* :

We (with Drs. Bates and Moorthi) continue our collaboration with Professor I.M. Navon\* and Dr. Yong Li\* on the development of an adjoint of the 3-D adiabatic version of the semi-Lagrangian semi-implicit model of Bates, Moorthi and Higgins. We provided a version of the model code along with necessary documentation for its implementation. So far this collaboration has produced a Technical Report and a paper which has been submitted to Monthly Weather Review (see the Publications list above). In June we met with Drs. Navon and Li here at Goddard to discuss recent progress on this work.

\*Florida State University  
Tallahassee, FL 32306-4052

We (with Drs. Bates and Moorthi) are collaborating with Professor Achi Brandt\*, Professor Stephen McCormick\*\* and Dr. John Ruge\*\* to develop a more advanced version of the adiabatic semi-Lagrangian model involving, in part, the solution of nonlinear elliptic equations at each time step, for which we shall use multigrid methods. To carry out this work, we proposed a collaborative project between the meteorological modeling team (Bates, Moorthi, Higgins) at Goddard and the team of multigrid experts (McCormick, Brandt, Ruge) at Ecodynamics Research Associates, Inc. The proposal entitled "Development of a Semi-Lagrangian Atmospheric General Circulation Model " (Ray Bates, P.I.) has been submitted to the NASA Global Climate Modeling and Data Assimilation Program, Earth Science and Applications Division. The proposed GCM should become an important component of the data assimilation system being planned by NASA in relation to EOS. In mid July we met with the multigrid team here at Goddard to plan the details of this project.

\* Dept. of Applied Math and Computer Science  
Weizmann Institute of Science  
Rehovot, Israel

\*\* Ecodynamics Research Associates, Inc.  
Campus Box 170  
P.O. Box 173364  
Denver, CO 80217-3364

Other Collaborative Activities: Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator (s)

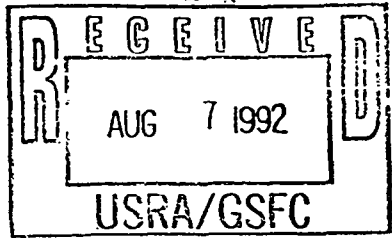
As mentioned above, the Semi-Lagrangian Research Group at NASA/GSFC (Drs. Bates, Higgins, and Moorthi) is collaborating with Dr. Eugenia Kalnay \* (and associates) and Dr. Dave Williamson\*\* on a three way model intercomparison. We are providing a version of our semi-Lagrangian model along with necessary documentation. Several meetings have been held at NMC to discuss the technical details of this project.

\* National Meteorological Center  
Camp Springs, MD

\*\* National Center for Atmospheric Research  
Boulder, CO

Supply any Additional Information you Feel Would be Useful in evaluating your performance:

910-038 E ↓



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Michael S. Fox-Rabinovitz Task Number: 910-038

General Description of Your Research Activities: (Include a Paragraph on each Activity).

1. Development of diabatic dynamic initialization (DDI)
  - Testing DDI within the GLA 4-D Data Assimilation System (extending to 10 mb)
  - Application of DDI to the stratospheric data assimilation system (extending to 0.1 mb), and testing the technique in climate assimilation mode.
  - Comparison of DDI with normal mode initialization
2. Participation in the GLA model development
  - Testing the 46-layer stratosphere-troposphere model (Oct. 91-Dec. 91)
  - Comparison of the A-grid and C-grid models (Oct. 91-Dec. 91)
  - Experiments on the cold polar bias problem (Oct. 91-Dec. 91)
  - Development of a spherical harmonics filter
  - Experiments on the role of ocean forcing in an atmospheric GCM (Oct. 91-Dec. 91)
3. Numerical experiments on consistent horizontal and vertical resolution for atmospheric models and observing systems
4. Numerical analysis of computational dispersion properties of vertical staggered grids for atmospheric and ocean models.
5. Numerical analysis of irregular and stretched grids.



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NUMERICAL EXPERIMENTS ON CONSISTENT HORIZONTAL AND VERTICAL  
RESOLUTION FOR ATMOSPHERIC MODELS AND OBSERVING SYSTEMS

Michael S. Fox-Rabinovitz<sup>1</sup>  
Laboratory for Atmospheres  
NASA/Goddard Space Flight Center  
Greenbelt, MD 20771, USA

and

Richard S. Lindzen  
Center for Meteorology and Physical Oceanography  
Massachusetts Institute of Technology  
Cambridge, MA 02139, USA

(Revised version submitted to Monthly Weather Review)

April 1992

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<sup>1</sup> Universities Space Research Association

Corresponding author address: Dr. M. S. Fox-Rabinovitz, Code 910.3, Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD 20771

## ABSTRACT

Simple numerical experiments are performed in order to determine the effects of inconsistent combinations of horizontal and vertical resolution in both atmospheric models and observing systems. In both cases, we find that inconsistent spatial resolution is associated with enhanced noise generation.

A rather fine horizontal resolution in a satellite data observing system seems to be excessive when combined with the usually available relatively coarse vertical resolution. Using different strength horizontal filters, adjusted in such a way as to render the effective horizontal resolution more consistent with vertical resolution for the observing system, may result in improvement of the analysis accuracy. However, the increase of vertical resolution for a satellite data observing system is desirable. For the conventional data observing system with better vertically resolved data, the results are different in that little or no horizontal filtering is needed to make spatial resolution more consistent for the system.

The obtained experimental estimates of consistent vertical and effective horizontal resolution are in a general agreement with consistent resolution estimates previously derived theoretically by the authors.

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N93-18719

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DIABATIC DYNAMIC INITIALIZATION

Michael S. Fox-Rabinovitz<sup>1</sup>

and

Brian D. Gross<sup>2</sup>

Laboratory for Atmospheres  
NASA/Goddard Space Flight Center  
Greenbelt, MD 20771, USA

(Revised version submitted to Monthly Weather Review)

June 1992

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<sup>1</sup> Universities Space Research Association

<sup>2</sup> Present affiliation: AOS Program, Princeton University

Corresponding author address: Dr. Michael S. Fox-Rabinovitz, Code 910.3, Laboratory for Atmospheres, NASA/Goddard Space Flight Center, Greenbelt, MD 20771.

## ABSTRACT

A generalized dynamical adjustment procedure has been applied to a diabatic model to produce balanced initial conditions. Namely, backward adiabatic model integration is followed by forward diabatic model integration, with a high frequency (low pass) filter in the form of the Euler-backward time differencing scheme being applied throughout the whole integration.

As a result of the application of such a diabatic dynamic initialization procedure within the GLA 4-D data assimilation system, the following properties of forecasts from initialized fields are achieved right from the beginning of the usual forecast integration: 1) the forecast tendencies (and fields) are free of any noise due to imbalance in initial conditions, and 2) the shocks related to an initial imbalance between model physics and dynamics, and especially the substantial initial imbalance of precipitation and evaporation fields, or the initial spin-up effect, are practically removed.

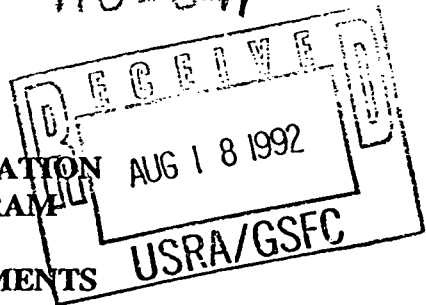
Diabatic dynamic initialization has been compared with implicit nonlinear normal mode initialization, and found to be superior in removing the initial spin-up effect, and also in improving the tropical structure.

The diabatic dynamic initialization procedure has been successfully tested for the GLA system with the use of all conventional data and the GLA satellite data retrievals. It allows a smooth data insertion without any shocks or imbalances, which is highly desirable for efficient functioning of 4-D data assimilation systems.

The developed initialization procedure is computationally efficient and in principle easily applicable to different forecast models.

910-041

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee: DR. MICHAEL FIORINO (covering the period 10/1/91 - 9/30/92)

General Description of Research Activities: (Include a paragraph on each activity)

*10-year GCM Climate Simulation with Observed Forcing*

I ported the enhanced surface processes version of the GLA GCM to the CRAY 2 at Lawrence Livermore National Laboratory as part of a DOE-sponsored Atmospheric Model Intercomparison Project (AMIP) and began the 10-year integration. The objective of the AMIP is to determine whether GCMs can simulate observed atmospheric interseasonal climatic events, such as El Nino, given specified SST, solar radiation and sea ice forcing fields and how the simulation varies with model configuration. There will be 30+ GCM groups world-wide participating and the solutions will be stored in a common digital data base. Dr. Lau and I have initiated a diagnostic subproject within the AMIP to examine the hydrologic cycle in more detail. We will also participate in a tropical variability subproject where I will concentrate on low-level circulation activity in the tropics.

*Computational Climate Variability*

The climate of an atmospheric GCM integration is defined through time averages of the solution. While high-frequency events or the "weather" in the model solution are known to be chaotic (very slight changes in the initial conditions grow rapidly and lead to uncorrelated solutions after a period of 10-20 days); it has generally been accepted that the long-term statistics would not depend how the weather evolves. Performing the 10-year AMIP integration on a Cray 2 presented a unique opportunity to determine the validity of this notion. Data are identical at the binary level on the GSFC Cray Y-MP and the LLNL Cray 2, the compilers are functionally identical, but given identical initial and boundary conditions and identical source code, the actual model executable will be different and produce slightly different solutions. Preliminary results from 3 years of the 10-year AMIP integration on both supercomputers revealed a much larger-than-expected dependence on the details of the computation.

### ***Data Compression***

The computational power of supercomputers is growing faster than the ability to store and manage the large volumes of data which result from numerically-intensive GCM integrations. Thus, the analysis of the simulated climate from a GCM simulation will become more limited by the ability to manipulate large data volumes than by computer processing power. I have applied data compression technology to build a storage/access procedure specifically for GCM solutions that will allow more efficient analysis of model data. This scheme will decrease the disk storage used by the current system by a factor of 4 and will make it possible to store an entire 10-year run on several DAT tapes and to make the data available to other researchers at GSFC and universities.

### ***GCM Validation and Verification***

I am building a comprehensive system to validate and verify long-term climate simulations of GCMs. There are two components of the system: 1) verification data and access procedures and; 2) analysis and display. I have assembled a variety of verification data sets of the general circulation and hydrologic cycle and are stored using my data compression procedure. Analysis and display is based on the Grid Analysis and Display System (GrADS) of the Center for Ocean Land Atmosphere interactions (COLA) at the University of Maryland.

### ***EOS Hydrologic Processes and Climate (HPC) Interdisciplinary Project Management Support***

I am assisting Dr. Lau in managing his EOS HPC project and have prepared and update a three-year research plan for each of the 12 tasks. These plans and a project directory have been distributed to all participants as a means of fostering communication and data exchange. I am also a member of the project data base and processing team and I serve as a liaison to EOSDIS.

**Describe any Significant Recognition of Your Work:** (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each)

N/A

**Honors or Awards Received:**

N/A

**Papers Published or Accepted for Publication:** (Please include complete bibliographic

citations(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstracts to this worksheet)

"An Evaluation of the Real-time Tropical Cyclone Forecast Skill of the Navy Operational Global Atmospheric Prediction System in the Western North Pacific"

Michael Fiorino; James S. Goerss, Naval Oceanographic and Atmospheric Research Laboratory, Atmospheric Directorate, Monterey, California; Jack J. Jensen, Commanding Officer, Fleet Numerical Oceanography Center Monterey, California, Edward J. Harrison, Jr., ARC Professional Services Group, Inc., Landover, Maryland; *Weather and Forecasting*; September, 1991

ABSTRACT

We have evaluated the meteorological quality and operational utility of the Navy Operational Global Atmospheric Prediction System (NOGAPS) in forecasting tropical cyclones and have shown that the model can provide useful predictions of motion and formation on a real-time basis in the western North Pacific. The evaluation was conducted during the 1990 operational testing of a procedure to improve the initial analysis or specification of tropical cyclones (TCs) in NOGAPS by the U.S. Navy Fleet Numerical Oceanography Center (FNOC). The NOGAPS TC analysis procedure generates synthetic TC observations based on operational vortex data (e.g., location and maximum surface wind speed) and then adds the observations to the observational data base with flags to force their assimilation. Results from the first year of testing were favorable, despite intermittent application of the procedure.

The meteorological characteristics of the NOGAPS tropical cyclone predictions were evaluated by examining the formation of low-level cyclone circulation systems in the tropics and vortex structure in the NOGAPS analysis and verifying 72-h forecasts. We found analyzed circulations in the vicinity of developing TCs for nearly all cyclones during the operational test period. This finding implies that the model is "primed" for assimilating the synthetic observations and may be accurately simulating the large-scale environments favorable to TC formation. The analyzed TC circulations had greater-than-observed horizontal extent due coarse grid spacing ( $\Delta x \sim 160$  km) in the global model; however, the vortices, in general, were vertically stacked and maintained during the forecast by realistic amounts of thermodynamic forcing from the cumulus parameterization. Despite the large size of the NOGAPS TC vortices, the track forecasts were not overly biased with regards to track or speed. The operational utility of the NOGAPS track forecasts was analyzed through a comparison with the real-time runs of a baseline climatology-persistence aid and with the best dynamical model used by the Joint Typhoon Warning Center, Guam. To insure a realistic comparison of the forecasts and to improve the appearance of the global model tracks, a post-processing adjustment procedure was employed that accounts for the observed initial motion and position. The adjusted NOGAPS track forecasts showed equitable skill to the baseline aid and the dynamical model. In fact, NOGAPS successfully predicted unusual equatorward turns for several straight-running cyclones. Overall, we judge the adjusted NOGAPS track forecasts as competitive with other

aids used by the operational forecasters at JTWC and suggest that global models may make important contributions to improving TC forecasting in the future.

Papers Submitted, but not yet Accepted for Publication: (Please include full title, coauthors (with affiliations), publication and submission date):

N/A

Papers Presented at Scientific Meetings:

*Invited Papers:* (Include title of talk, meeting name, date and any special meeting role, e.g., session chair, rapporteur)

N/A

*Contributed Papers:* (Include title, meeting and date)

"AMIP Progress and Plans"; Annual AMIP meeting; Berkeley CA; 21 February 1992

*Colloquia, Seminars and Special Lectures:* (Provide title, date and place)

"Unforced Chaos in an atmospheric general circulation model"; 16 June 1992; Naval Research Laboratory, Monterey, CA

"Unforced Chaos in an atmospheric general circulation model"; 17 June 1992; Lawrence Livermore National Laboratory, Livermore, CA

"An evaluation of the tropical cyclone forecasting skill of the U.S. Navy's NOGAPS global spectral model in the western North Pacific; 2 September, 1992; Japan Meteorological Agency, Tokyo, Japan

"Computationally-induced Noise in the Climate of an Atmospheric General Circulation Model"; 3 September, 1992; Meteorological Research Institute, Tsukuba, Japan

"An evaluation of the tropical cyclone forecasting skill of the U.S. Navy's NOGAPS global spectral model in the western North Pacific; 4 September, 1992; University of Tokyo, Tokyo, Japan

"Computer-induced variability in the climate of an atmospheric general circulation model"; 24 September; Climate Analysis Center, Camp Springs, MD

Community Service: (e.g., offices in professional societies, lectures to community or educational groups, consultation, etc.)



Special Projects Officer, Naval Oceanography Reserve Activity 0966, assisting the staff of the Oceanography of the Navy in the preparation of a Department of Defense position paper on the Global Change Data Information System; completed 17 days of active duty for training at Naval Oceanography Command Facility, Yokosuka Japan to perform typhoon training and to brief the Commander, U.S. Seventh Fleet on typhoons affecting his area of responsibility (western North and South Pacific, Indian Ocean and the Persian Gulf); attended a symposium on the affects of the environment in coastal warfare in Monterey, CA.

**University Collaborations:** Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here)

**Professor Eric Wood, Department of Civil Engineering, Princeton University:** We are jointly evaluating the effect of land surface hydrologic parameterization on the climate of the Geophysical Fluid Dynamics Laboratory GCM. A paper on our research will be presented at the 73rd AMS annual meeting in January, 1993 and two manuscripts are now in preparation.

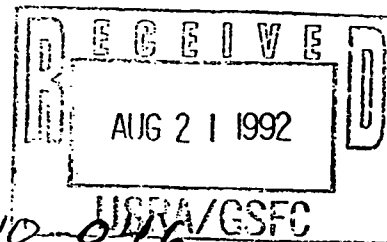
**Professor William Gray, Department of Atmospheric Science, Colorado State University:** I have corresponded with Dr. Gray regarding the relationship between higher-frequency tropical circulation activity, including tropical cyclones, and low-frequency oscillations in the tropics. He is pursuing similar issues and has expressed an interest in working with the solutions which will be produced for the 10-year AMIP GCM run. I am also working with one of his Ph.D. students on the association of Sahalian rainfall and tropical cyclone climatology in the Atlantic.

**Other Collaborative Activities:** Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborators(s)

N/A

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: James Gleason Task Number: 910-046

General Description of Your Research Activities: (Include a Paragraph on each Activity).

The major accomplishment of this past year has been the development and implementation of a correction algorithm for the correction of the Nimbus-7 SBUV ozone data. The SBUV data record now extends from November 1978 to June of 1990. The SBUV instrument was launched on Nimbus-7 in November 1978. SBUV functioned from launch to February 1987, when an instrument malfunction developed. The optical chopper wheel lost synchronization with the counting electronics. The instrument continues to operate, but the data quality was unknown. If the data record could be extended it would have several benefits. The ozone trends calculated from this data set are more significant with a longer data record. The extension of the data record through June of 1990 insures that a complete solar cycle is included in the data record. Solar effects on the ozone data can be subtle, and having a complete solar cycle enables you to remove the solar cycle effects from the ozone record. The successors to the SBUV instruments have been launched on the NOAA polar orbiters. The NOAA 11 SBUV-2 instrument started its data record in January 1989. We now have 18 months of overlap that we can compare these two instruments. The NOAA 11 instrument is beginning to fail and its successor NOAA 13 will be launched in January 1993. We can now create a continuous ozone data record of total column ozone and ozone profile from November 1978 through the lifetime of NOAA 13 and its successors. The overlap of the SBUV with the NOAA 11 SBUV allows us to use NOAA 11 as a transfer between SBUV and NOAA 13 SBUV-2. We can do this because the data overlap between the NOAA 11 SBUV-2 and the Nimbus 7 SBUV instrument is now 18 months instead of no overlap at all. A complete analysis of the SBUV data set is now in progress. A description of the method is being published in a conference proceedings and is also being written up for publication in the Journal of Geophysical Research. Additional papers on the analysis of the SBUV ozone record are currently being written.

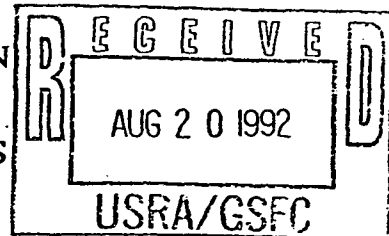
I wrote a grant proposal under NRA-92-OSSA-04 to continue the analysis of the reprocessed SBUV data set. This would involve the extensive intercomparison of the SBUV instrument with external data sources to determine if the correction method has introduced a bias in the SBUV data record.

I am a co-investigator on a successful Goddard Directors Discretionary Fund (DDF) proposal. We proposed the development of a lightweight limb viewing ozone sounder. I am collaborating with Dave Glenar, Code 715 on the optical development. I am also doing the radiative transfer calculations to determine the expected signal levels for a limb viewing instrument.

I have been involved in the review of the new TOMS instruments that are currently being built for our branch by Perkin Elmer Instruments. I traveled to the science review in February and I have been involved in the planning of the calibration of the TOMS instruments here at Goddard.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Name                                   Amita Y. Mehta  
Address                                Code 910.4, Satellite Data Utilization Office  
  Phone : 286-1446  
Task Numbers                         5000/147 and 727

**General Description of Research Activities  
during September 1991 - September 1992.**

My scientific research activity during the last year includes the following projects.

**1. *Calculations of Outgoing Longwave Radiation and Downward Longwave Flux at the Earth's Surface***

I am working on this project in affiliation with Dr. Joel Susskind and his group (Code 910.4). I have developed an algorithm to calculate outgoing longwave radiation (OLR) as a function of the earth's surface temperature, atmospheric temperature, water vapor, ozone, cloud-amount and cloud-top distributions.

Currently, I am developing an algorithm to calculate downward longwave flux (DLF) at the earth's surface as a function of the atmospheric thermal, water vapor and ozone distributions. To include the effect of clouds on the DLF, cloud-amount, cloud-top and cloud-base distributions are essential. Global distributions of cloud-top and cloud-amount can be obtained from the satellite measurements with reasonable accuracy. Cloud-base information however, is difficult to obtain. I am examining sensitivity of DLF to clouds using a medium band spectral resolution radiative transfer model with a wide range of hypothetical cloud distributions. The final DLF algorithm will include a simple scheme of assigning cloud-base height as a function of satellite-derived cloud-top height, and moisture profile.

The OLR algorithm is being used as a part of the atmospheric parameter retrieval scheme developed by Dr. Susskind's group. The DLF algorithm will also be included in the scheme in the coming months. I will complete the DLF algorithm by the end of October, 1992. Dr. Susskind is planning to generate a long term record of the atmospheric parameters including OLR and DLF based on satellite measurements of infrared and microwave radiances. My primary interest is to analyze variability of OLR and DLF, since they are very important components of the radiation budget of the earth-atmosphere system.

## **2. *Shortwave and Longwave Radiative Transfer Parameterization Models***

Since February 1992, I have been working with Dr. Chou and Dr. Suarez (Code 913). Under this project I compared two different sets of longwave and shortwave radiative transfer parameterization models in terms of their accuracy of calculations. From October onwards, I will continue to work with Dr. Chou on the improvement of radiative transfer parameterizations -- including parameterizations of cloud and aerosol effects -- to be used in ARIES atmospheric general-circulation models (GCM) developed by Dr. Suarez. Under this project a number of experiments will be carried out using the ARIES GCM to examine climate sensitivity to the radiative processes.

## **3. *Calculation of Precipitation Index from Satellite Measurements***

I am interested in observational analysis of low frequency atmospheric variability in the tropics, especially related to the Asian monsoon. I have calculated precipitation index over the Indian Ocean and western Pacific Ocean during the summer season of 1988 using INSAT geostationary satellite's infrared window measurements. To understand the variability of the hydrological cycle over the monsoon region, I am also examining moisture divergence using objective analysis data set from European Center for Medium Range Weather Forecasting.

A short paper about this work is under preparation and has been accepted for presentation during the Fourth Symposium on Global Change Studies to be held in January, 1993.

## **4. *Ongoing Projects***

During last year I also started the following projects but have not been able to pursue continuously-

-As a continuation of my Ph. D. work, I developed a one-dimensional radiative-convective model. I want to examine effect of clouds on equilibrium temperature profiles and radiative damping time.

-I have carried out preliminary analysis of satellite-derived global precipitation (retrieved by Dr. Susskind's group from satellite-based infrared and microwave measurements ) for the year 1979.

Papers Submitted but not yet Accepted for Publication: (please include full title, co-authors [with affiliations], publication, and submission date).

Mehta A. V. and E. A. Smith\*, 1992 : Intraseasonal variability of infrared cooling rates over the Asian monsoon Region - Part I: Observational Estimates. submitted to - Journal of the Atmospheric Sciences, July 1992.

\*Professor Eric A. Smith  
Department of Meteorology  
The Florida State University  
Tallahassee, FL 32306

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Papers Presented at Scientific Meetings:

*Invited papers:* (Include title of talk, meeting name, date, and any special meeting role, e.g. session chair, rapporteur).

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*Contributed Papers:* (Include title, meeting, and date)

Intraseasonal variability of infrared cooling rates over the Asian monsoon region based on INSAT measurements. Presented at The 6<sup>th</sup> conference on Satellite Meteorology and Oceanography, Atlanta, GA, on January 8, 1992.

Infrared Forcing and Feedback on Intraseasonal Time Scales during the Asian Summer Monsoon. Presented at The 5<sup>th</sup> conference on Climate Variations Denver, CO, on October 17, 1991.



**Other Collaborative Activities:** Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

I am working with Dr. Vikram Mehta of code 913, Climate and Radiation Branch, GSFC/NASA. Dr. Vikram Mehta has developed a climate model containing a two-layer ocean and a two-level atmosphere. I have developed simple parameterizations for large scale and convective scale moist processes for the two-level atmospheric model. We are examining the influence of latent heating and external forcing on the natural variability of the modeled climate system.

I will be presenting this work at the '2<sup>nd</sup> International Conference on Modeling of Global Climate Change and Variability.' in Hamburg, Germany on September 8, 1992.

**Supply any Additional Information you Feel Would be Useful in evaluating your performance:**

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I am one of the co-investigators on a proposal submitted by Dr. M. D. Chou (Principal Investigator) of Code 913, Climate and Radiation Branch.

Title of the Proposal      Development of Radiation Parameterizations for Atmospheric Models and Studies of their Impacts on Climate Simulations

Submitted to                The Earth Science and Application Division,  
NASA

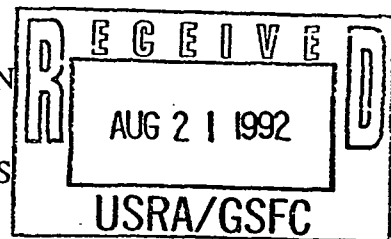
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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Joanna Joiner Noll Task Number: 5000-147

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My main research activity has been the development and implementation  
of an algorithm to retrieve climate parameters using AIRS/AMSU (a proposed  
infrared/microwave radiometer). I have made several significant contributions  
in this area: (1) I simulated combined AIRS/AMSU retrievals of temperature,  
water vapor, and ozone profiles (2) I developed and implemented a cloud  
filtering algorithm and showed that the retrievals did not degrade with  
increased cloudiness (3) I improved the algorithm by using a single value  
decomposition approach (4) I have added the capability of recovering the  
surface emissivity as a function of frequency. (5) I have investigated the  
effect of instrument noise on the retrieval accuracy (6) I have studied  
the effects of channel and variable selection on the retrieval accuracy and  
have optimized the retrieval algorithm to give improved results.

I have also continued research related to my doctoral dissertation.

I presented the results of my work at a conference and published a journal  
article. I have also continued to collaborate with Paul Steffes  
on research related to the microwave spectra of planetary atmospheres. I  
have also refereed journal articles related to my background in the remote  
sensing of planetary atmospheres.

I am using my expertise in non-linear inversion techniques in other  
areas. I have begun collaborating with Joe Otterman on inverting measurements  
of grass and soil infrared emission to obtain grass temperatures.



Describe any Significant Recognition of your work: (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

My research on the AIRS/AMSU retrieval algorithm was highlighted in the current issue of "The Earth Observer" (Vol.4, No.3) in a report of the AIRS Science Team Meeting. The discussion of the retrieval algorithm was described as "the high point of the meeting" and the prototype algorithm of the "team headed by Joel Susskind" (team consists of Joel Susskind and myself) presented results which were "considered very respectable." See copy of enclosed article.

Honors or Awards Received:

Papers Published or Accepted for Publication: (please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

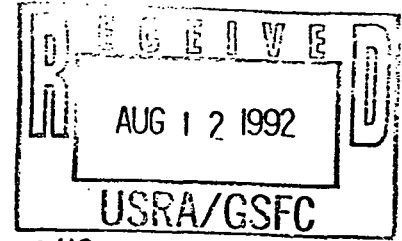
Joiner, J., Steffes, P.S., and Noll K.S. (1992). Search for Sulfur ( $H_2S$ ) on Jupiter at Millimeter Wavelengths. IEEE Trans. Microwave Theory Tech. Vol.40 No.6

Susskind, J., Joiner, J., and Chahine, M.T. (1992). Determination of Temperature and Moisture Profiles in a Cloudy Atmosphere Using AIRS/AMSU. In High Spectral Resolution Infrared Remote Sensing for Earth's Weather and Climate Studies, accepted.

Cheruy, F., Susskind, J., Scott, N.A., Chedin, A., Joiner, J. (1992)... GLA and LMD Approaches to the processing of AIRS and IASI Observations. In High Spectral Resolution Infrared Remote Sensing for Earth's Weather and Climate Studies, accepted.

910-049 E↑

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: George J. Huffman Task Number: 910-049

General Description of Your Research Activities: (Include a Paragraph on each Activity).

The primary focus of my research is global estimates of precipitation using passive microwave data recorded by satellite sensors in conjunction with other data sources. Passive microwave data have a fairly strong physical connection to precipitation, but they are only available from polar-orbiting platforms. To make up for the lack of continuous time and space coverage, we are experimenting with blending in infrared data recorded by geosynchronous-orbit satellites. Infrared wavelengths have a weaker physical connection, but the geosynchronous platform allows continuous coverage. I have lead responsibility for acquiring and evaluating data sets, implementing the system to generate precipitation estimates, and evaluating the results. I am also involved in validating and improving the "Goddard Scattering Algorithm" that provides estimates from the microwave data. One major goal of the project is to assemble a quasi-operational system for inferring rainfall from the best available information. When the Tropical Rainfall Measurement Mission satellite is launched we expect that the methodology developed here to be directly applicable, even though the particular algorithms and data sources will likely change.

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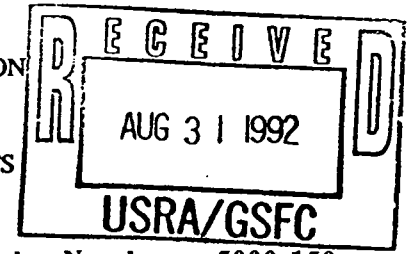
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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Chung-Kyu Park

Task Number: 5000-150

General Description of Your Research Activities:

- (1) Low-frequency waves in the atmosphere:  
The climate dynamics of general circulations in relation to the interaction between the tropical circulation and extratropical waves has been investigated. The general circulation models are utilized to examine low-frequency variability and predictability of the global circulation. My diagnostic studies have had a profound impact on our understanding of the 30-60 day oscillation and provided guidance for improving simulations of tropical low-frequency variations in general circulation models.
- (2) The GEOS GCM diagnostics:  
My data analysis techniques and graphical displays have provided a significant contribution to the development of the GEOS GCM, and are currently being implemented as a standard diagnostic package for the GEOS GCM.

Describe any significant recognition of your work:

- Schubert, S.D., C-K. Park, R.W.Higgins, S.Moorthi, and M.Suarez, 1990: An atlas of ECMWF analyses (1980-87), Part I - first moment quantities. NASA Technical Memorandum 100762, 360pp.  
=> This technical report has been cited extensively in the Holton's textbook, Introduction to Dynamic Meteorology, 3rd edition, 1992, which is the most popular textbook in meteorology. In his textbook, most of the climatology patterns are adopted from this technical report.
- Park, C-K., D.M.Straus, and K-M.Lau, 1990: An evaluation of the structure of tropical intraseasonal oscillations in three general circulation models. J. Meteor. Society of Japan, 68, 403-417.  
=> This paper has been cited by Slingo, J.M. and R.A.Madden, 1992, Q. J. Roy. Meteor. Society, Cited reference 62.

Papers published or accepted for publication:

- (1) Kung, E.C., W. Min, J. Susskind, and C-K. Park, 1992: An analysis of simulated summer blocking episodes. Q. J. Royal Meteor. Soc., 118, 351-363.
- (2) Park, C-K., and S.D. Schubert, 1992: Remotely-forced intraseasonal oscillations over the tropical Atlantic. J. Atmos. Sci., 49, October.
- (3) Schubert, S.D., M Suarez, C-K. Park, and S. Moorthi, 1992: Intraseasonal variability in the Pacific/North American region: a comparison of observations and a GCM. accepted to J. Atmos. Sci.
- (4) Schubert, S.D. C.-Y. Wu, J.Zero, J.-K. Schemm, C-K. Park, and M Suarez, 1992: Monthly means of selected climate variables for 1985-89. NASA Technical Memorandum 104565, 360pp.

Papers presented at scientific meetings:

**Invited papers:**

**Tropical connections of extratropical low-frequency oscillations, Autumn Workshop, The Korean Federation of Science and Technology Societies (October 8-12, 1992)**

**Contributed papers:**

**Park, C-K., and S.D. Schubert, October 1991: Remotely forced intraseasonal oscillations in the tropical Atlantic convection. Fifth Conference on Climate Variation, Denver Colorado.**

Colloquia, seminars, and special lectures:

**Invited speaker to**

- (1) Department of Marine, Earth and Atmospheric Sciences, North Carolina State University, April 1992**
- (2) Department of Meteorology, University of Maryland, May 1992**
- (3) Department of Atmospheric Sciences, Pusan National University, Summer special lecture July-August 1992, Pusa, Korea**
- (4) Autumn Workshop, The Korean Federation of Science and Technology Societies, October 8-12, 1992, Seoul, Korea**

University collaborations:

**Research collaborations with University of Missouri (see recent publications with Kung)**

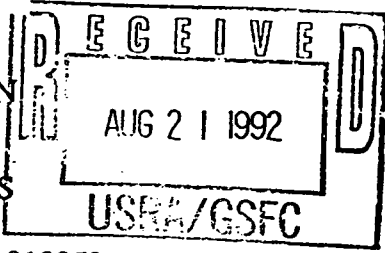
**Research collaboration with Department of Marine, Earth, and Atmospheric Sciences and**

**Department of Statistics, North Carolina State University (this is a recent development)**

Additional information:

- (1) Reviewer of research proposals for the National Science Foundation, Atmospheric Sciences Division, Climate Dynamics program (1989-1992)**
- (2) Reviewer of research proposals for the NASA Global Change Research Fellowship program (1991-1992)**
- (3) Co-Investigator of GSFC/NASA research proposal (1993-1995):  
The transition seasons and short-term climate variability**

910-052 E



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Hye-Yeong Chun Task Number: 910052

General Description of Your Research Activities: (Include a Paragraph on each Activity).

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\_\_\_\_\_ 1. The long-lasting large amplitude mesoscale wave events are investigated using the  
\_\_\_\_\_ solitary wave theory. The numerical method to obtain wave solution has been improved by  
\_\_\_\_\_ automatically determining a critical level. The wave phase speed by the solitary wave  
\_\_\_\_\_ solution is well matched with the observed one, while the calculated horizontal wavelength  
\_\_\_\_\_ is too small compared to the observed one. The possibility of the gravity wave generation  
\_\_\_\_\_ by the convection or the initiation of convection by gravity wave, and their interaction are  
\_\_\_\_\_ investigated using the two-dimensional cloud model. The cloud model is initialized with  
\_\_\_\_\_ the solitary wave solution.

\_\_\_\_\_ 2. A weakly nonlinear response of the stably stratified atmosphere to a thermal forcing  
\_\_\_\_\_ in a uniform ambient wind has been investigated.

\_\_\_\_\_ 3. A theoretical study of stratospheric gravity wave generated by deep convection is  
\_\_\_\_\_ investigated. The role of a critical level on the wave propagation and the amplification is  
\_\_\_\_\_ examined.

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## Effects of Diabatic Cooling in a Shear Flow with a Critical Level

YUH-LANG LIN AND HYE-YEONG CHUN

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(Manuscript received 9 July 1990, in final form 12 February 1991)

### ABSTRACT

The response of a two-dimensional, stably stratified shear flow to diabatic cooling, which represents the evaporative cooling of falling precipitation in the subcloud layer, is examined using both a linear analytical theory and a nonlinear numerical model. The ambient wind is allowed to reverse its direction at a certain height and the cooling is specified from the surface to a height below the wind reversal level.

From a scale analysis of the governing equations, a nonlinearity factor of the thermally induced finite-amplitude wave,  $gQ_0/(c_p T_0 U_0^2 N)$ , is found. From a scale analysis of the linear system, it is shown that the wind shear can modify the condition in which the upstream propagation of the density current is opposed by the ambient wind. When the shear and the basic wind are of opposite sign, small basic wind is enough to prevent the upstream propagation of the density current. This is because part of the cooling is used to compensate the positive vorticity associated with the positive wind shear. Therefore, the effective cooling rate, or the speed of the density current, becomes smaller than that in the uniform wind case.

In the nonlinear numerical simulations, it is found that the response of the atmosphere to a steady cooling in a shear flow may be categorized as either a *stationary cold pool* or a *density current*, depending upon the strength of the effective cooling. For a strong shear flow, the cold pool is stationary with respect to the upstream flow because most of the cooling is used to compensate the positive vorticity associated with the positive wind shear. In this case, the response is similar to the linear steady-state case. For a weak shear flow, the cold pool is able to propagate upstream because the effective cooling, which increases with time, is strong enough to push the outflow against the basic wind. From the comparison of linear and nonlinear numerical model simulations, it is found that the nonlinearity appears to reduce the wave disturbance below the critical height and above the cooling top, while it tends to strengthen the density current or cold pool near the surface.

### 1. Introduction

The cold air outflow produced by the evaporation of falling precipitation in the subcloud layer has been regarded as one of the important mechanisms for convective storm dynamics. Many observational and numerical studies have indicated that the cold air outflow from thunderstorms can trigger and maintain convective storms (e.g., Charba 1974; Mitchell and Hovermale 1977; Matthews 1981; Thorpe et al. 1982; Seitter 1986; Droegemeier and Wilhelmson 1987). The leading edge of the outflow, called a gust front, tends to lift air parcels ahead of it and generate deep convection under favorable conditions.

Environmental wind shear is a crucial dynamic factor that can either enhance or suppress deep convection. Vertical wind shear has long been observed as an important factor in the convective storm dynamics (Newton 1950; Newton and Newton 1959; Pastushkov 1975; Ogura and Liou 1980). Effects of vertical wind shear and rain-produced cold pools on the maintenance

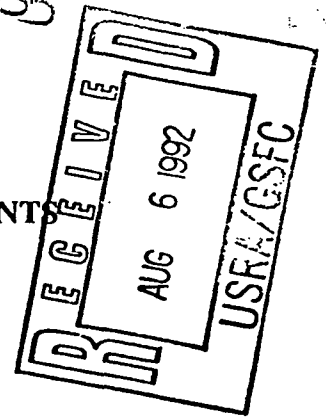
and generation of long-lived convective systems have been a main research topic in the numerical modeling studies (e.g., Thorpe et al. 1982; Weisman and Klemp 1982; Rotunno et al. 1988; Weisman et al. 1988; Fovell and Ogura 1989). Thorpe et al. (1982) proposed that a strong low-level wind shear can prevent outflow from moving away from convective cells, thus, providing a favorable condition for long-lived convective systems. Rotunno et al. (1988) suggested that when the cold pool is balanced by the wind shear, the circulation induced by a cold pool trying to spread downshear is opposed by the wind shear and a deep penetration may take place. Fovell and Ogura (1989) showed that in multicellular storms wind shear is linearly proportional to the density current speed for a large value of wind shear. In studies pursuing the dynamical similarity between a laboratory-produced density current and a thunderstorm outflow, the vertical shear of the basic flow has been ignored. Recently, Droegemeier and Wilhelmson (1985a,b) investigated the effects of vertical wind shear on convective cloud formation using a three-dimensional numerical model. They found that the vertical wind shear controls characteristics of the cloud forming along an outflow collision line.

In theoretical studies, the evaporative cooling in the subcloud layer associated with the thunderstorm

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USRA/GVSP EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
YEAR ENDING SEPTEMBER 30, 1992

Dr. John R. Scala      Task # 910-055



**General Description of Research Activities**

The overall objective of my research is to investigate the transport dynamics associated with squall-type mesoscale convective systems. This objective is accomplished by combining meteorological data from several data acquisition systems (surface, aircraft, and remotely based) with the results of the Goddard Cumulus Ensemble (GCE) model. Cloud-scale motion and transport structure is determined from model-calculated air parcel trajectories, and applied to an evaluation of the effect of convection on the vertical redistribution of important trace gases.

The investigation utilizes a case by case analysis of large data sets obtained from major field experiments. The event of interest is specifically described by field observations and sampling. A portion of my research time is spent selecting suitable convective events from successful field programs for study. The selection process is based on my personal field participation, and collaboration with other investigators. The observations are used to initialize, and verify the simulation. Model-generated cloud fields reveal the dynamic character of the simulated convection, and permit comparison with published studies.

Currently, I am using a two-dimensional version of the GCE. I work closely with Dr. W.-K. Tao who has also developed a three-dimensional version of the model. In an effort to augment the interpretation our results, and their visual presentation, we have produced several two- and three-dimensional color animations of the convective redistribution of specific trace gases. This unique approach enables a more detailed representation of cloud-scale motion, specifically how the convection transports moisture, heat, and momentum through the troposphere.

The use of conservative tracers details the transport behavior while providing a method for diagnosing the post-storm convective redistribution which has been shown to be important in the production/destruction of ozone. A significant portion of my research effort is spent in collaboration with Drs. Pickering and Thompson (GSFC) who utilize the model results to interpret the chemical consequences of trace gas redistribution by convection.

Additional research activities include collaboration with other investigators at several institutions, the presentation of results (at conferences, and in the refereed literature), and participation in the planning of future field experiments.

### **Significant Recognition**

I would suggest that selection by the editor of a refereed journal to review a submitted manuscript is both an honor, and a recognition of the quality of one's work. I was honored in this manner when I was selected by the editors of the *Journal of Applied Meteorology* and the *Journal of Geophysical Research-Atmospheres* to be a reviewer.

In addition, I was selected to participate in a recent workshop at GSFC for the purpose of formulating research objectives for a proposed cloud-chemistry field experiment.

### **Publications**

Pickering, K.E., A. M. Thompson, J. R. Scala, W.-K. Tao, and J. Simpson, 1992: Ozone production potential following convective redistribution of biomass burning emissions. *J. Atmos. Chem.*, **14**, 297-313.

Pickering, K.E., J. R. Scala, W.-K. Tao, and J. Simpson, 1992: A regional estimate of convective transport of CO from biomass burning. *Geophys. Res. Letters.*, **19**, 289-292.

Pickering, K.E., A. M. Thompson, J. R. Scala, W.-K. Tao, R. R. Dickerson, and J. Simpson, 1992: Free tropospheric ozone production following entrainment of urban plumes into deep convection. *J. Geophys. Res.*, in press.

Tao, W.-K., J. Simpson, C.-H. Sui, B. Ferrier, S. Lang, J. Scala, M.-D. Chou, and K. Pickering, 1992: Heating, moisture and water budgets of tropical and midlatitude squall lines: Comparisons and sensitivity to longwave radiation. *J. Atmos Sci.*, in press.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee: Todd P. Mitchell

Task Number: 910-056

General Description of Research Activities:

My time has been spent working on the documentation and interpretation of historical records of summertime surface temperature and precipitation for the contiguous United States. This effort is a continuation of previous work in which the dominant patterns of covariability between these two fields were documented using the singular value decomposition (SVD) technique.

One part of my present effort has been to develop an extension of this technique that relaxes the spatial orthogonality constraint of SVD. For the present problem, the implementation of this extension has led to higher order modes which look more physically reasonable than those from standard SVD analysis. The development of this extension has required an extensive review of the theory of factor analysis and orthogonal rotations. It is believed that this extension will be of wide use in the analysis of geophysical data fields.

The results of this analysis have been interpreted in terms of the importance of variations in soil moisture in producing the observed surface temperature anomalies during observed drought-heat wave episodes. This analysis was also augmented by documenting the atmospheric circulation patterns during months of extreme drought-heat wave conditions and also during months characterized by cool-wet conditions. A paper describing these results is being written and will be submitted by the end of September, 1992.

In June I gave an invited lecture on this research at the Joint Institute for the Study of the Atmosphere and Ocean at the University of Washington in Seattle, Washington.

As an independent research activity, I have prepared and submitted a grant proposal with Prof. Warren Blier of UCLA to study variations of California precipitation. This proposal was submitted to the NOAA Office of Global Programs. This work was pursued during evenings and weekends. The expertise gained from this study complements the study of summertime precipitation variability.

Papers Presented at Scientific Meetings:

*Special Lectures:*

"Droughts, droughts, and the analysis of the covariability of multiple fields." Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Seattle, WA. June 1992.

University Collaborations:

As an independent research activity, and pursued on evenings and weekends, I have collaborated with Prof. Warren Blier of the Department of Atmospheric Sciences, University of California Los Angeles. This work has involved preparing a paper for submission on the variations of California precipitation on the monthly and seasonal time scale. We have also prepared and submitted a grant proposal to the NOAA Office of Global Programs to pursue this work in the future.

Additional information:

I have reviewed two papers for the *Journal of Climate* during this period.

**UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM**

**EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)**

**Employee Name : Ranga B. Myneni  
Task Number: 920-002**

**GENERAL DESCRIPTION OF YOUR RESEARCH ACTIVITIES**

- [1] **Synergistic Use of Optical and Microwave Data in Agrometeorological Applications :** Optical and microwave data can be synergistically used to infer land surface properties. Optical data can potentially provide information about surface and air temperatures, precipitable water vapor, cloud top temperature and its water content. This information can be utilized to correct microwave data for atmospheric effects. Vegetation canopy reflectance at red and near-infrared wavelengths can be used to correct for vegetation effect on microwave emissivities at low frequencies for estimating soil moisture. Optical data can also be used to estimate surface albedo, radiation absorption by vegetation canopies and their photosynthetic efficiencies. These points are illustrated with theoretical analyses and by application to satellite data. The basic physical mechanisms operative at the various wavelengths are also discussed.
- [2] **Atmospheric Effects in the Remote Sensing of Surface Albedo and Radiation Absorption by Vegetation Canopies :** A one-dimensional turbid medium model of a vegetation canopy that includes specular reflection and the hot spot effect is used to calculate surface bidirectional reflectance factors (BRFs), albedo, absorbed solar and photosynthetically active radiation and, canopy photosynthetic efficiency. Simulated surface BRF distribution is then used as the lower boundary condition of the atmospheric radiative transfer problem. A horizontally homogeneous cloudless midlatitude continental atmosphere with both molecular and aerosol loading is assumed throughout. The dynamics of surface and planetary albedo are examined for varying surface and atmospheric parameters. The relationship between planetary and surface albedo and its sensitivity to problem parameters is investigated. An algorithm for the estimation of surface albedo is outlined and the magnitude of errors incurred is discussed. An effort is made to relate canopy radiation absorption to top-of-the-atmosphere spectral vegetation indices and the sensitivity of these relationships to problem parameters is evaluated.
- [3] **Atmospheric Effects and Spectral Vegetation Indices :** A vegetation / atmosphere radiative transfer method is employed to study atmospheric effects in spectral vegetation indices. A one-dimensional turbid medium model of a vegetation canopy that includes specular reflection and the hot spot effect is used to calculate canopy bidirectional reflectance factors. These are then used to specify the lower boundary condition of the atmospheric radiative transfer problem. A horizontally homogeneous cloudless midlatitude continental atmosphere with both molecular and aerosol loading is assumed throughout. The canopy and atmospheric radiative transfer equations are

numerically solved by the discrete ordinates method. A total of 13 discrete wavelengths in the solar spectrum outside the absorption bands of major atmospheric constituents were considered in this study. Spectral and angular distribution of surface radiances above the canopy and atmosphere were evaluated for different solar zenith angles and leaf area indices. The most frequently used spectral vegetation index NDVI and variants introduced recently to correct for atmospheric and soil brightness effects (ARVI, SAVI and SARVI) were calculated to investigate the extent of atmospheric distortion. The nature of the relationship between top-of-the-atmosphere and top-of-the-canopy spectral vegetation indices is studied and its sensitivity to various problem parameters is assessed.

- [4] **Simulation of Space Measurements of Vegetation Canopy Bidirectional Reflectance Factors** : A method for simulating remote measurements of vegetation canopy bidirectional reflectance factors (BRFs) from satellite-borne sensors is presented. The atmospheric radiative transfer problem is numerically solved with the lower boundary condition parameterized through vegetation canopy BRFs obtained from a numerical solution of the canopy radiative transfer equation. A horizontally homogeneous cloudless continental atmosphere with both molecular and aerosol loading is assumed. The one-dimensional turbid medium model of a vegetation canopy complete with specular reflection from the leaf surface and the hot spot effect is used to evaluate canopy BRFs. The magnitude of atmospheric effects in the principal plane at red and near-infrared wavelengths for two sun positions and increasing aerosol optical depths is evaluated. The net atmospheric effect is positive (negative) at the red (near-infrared) wavelength due to strong scattering (absorption) in the atmosphere. It appears that the hot spot of a dense vegetation canopy can be detected by satellite-borne devices at visible wavelengths. The influence of problem parameters on the anisotropy correction factors ( $g$ ) used to convert broad band radiances to fluxes in radiant energy budget studies is studied. The  $g$ -factors are greater than unity in the forward scattering directions where the actual radiance is less than the mean radiance. The smallest  $g$ -factors are encountered in directions about the retro-solar direction. These increase with aerosol optical depth depending on the wavelength and solar zenith angle.

**DESCRIBE ANY SIGNIFICANT RECOGNITION OF YOUR WORK**

[1] The following is a list of citations during July 91 – June 92 (Source : Science Citation Index)

- 1 Myneni – RB – 1985 – Agr – Forest – Meteorol – V33 – P323
- 1 Myneni – RB – 1985 – Agr – Forest – Meteorol – V34 – P3
- 1 Myneni – RB – 1986 – Agr – Forest – Meteorol – V37 – P189
- 1 Myneni – RB – 1987 – Agr – Forest – Meteorol – V39 – P1
- 3 Myneni – RB – 1988 – J – QUANT – SPECTROSC – RA – V40 – P165
- 1 Myneni – RB – 1988 – Agr – Forest – Meteorol – V42 – P1
- 1 Myneni – RB – 1988 – Agr – Forest – Meteorol – V42 – P87
- 1 Myneni – RB – 1988 – Agr – Forest – Meteorol – V42 – P101
- 8 Myneni – RB – 1989 – Agr – Forest – Meteorol – V45 – P1
- 7 Myneni – RB – 1990 – T – THEORY – STAT – PHYS – V19 – P205
- 1 Myneni – RB – 1991 – IN – PRESS – J – QUANT – SPE
- 1 Myneni – RB – 1991 – Agr – Forest – Meteorol – V55 – P232
- 1 Myneni – RB – 1991 – IN – PRESS – REMOTE – SENS
- 1 Myneni – RB – 1991 – J – QUANT – SPECTROSC – RA – V46 – P259
- 3 Myneni – RB – 1992 – PHOTON – VEGETATION – IN

#### PAPERS PUBLISHED IN PEER-REVIEWED JOURNALS

- [1] Myneni, R. B., Asrar, G. and Hall, F. G., 1992. A three dimensional radiative transfer method for optical remote sensing of vegetated land surfaces. *Remote Sens. Environ.*, 41: 105-121.
- [2] Myneni, R.B., Asrar, G., Tanre, D. and Choudhury, B. J., 1992. Remote sensing of solar radiation absorbed and reflected by vegetated land surfaces. *IEEE Trans. Geosc. Remote Sens.* 30: 302-314.
- [3] Myneni, R. B. and Asrar, G., 1991. Photon interaction cross sections for aggregations of finite dimensional leaves. *Remote Sens. Environ.*, 37: 219-224.
- [4] Myneni, R. B. and Ganapol, B. D., 1991. A simplified formulation of photon transport in leaf canopies with finite dimensional scatterers. *J. Quant. Spectroscop. Radiat. Transfer*, 46: 135-140.
- [5] Myneni, R.B., Marshak, A.L. and Knyazikhin, Yu., 1991. Transport theory for leaf canopies with finite dimensional scattering centers. *J. Quant. Spectroscop. Radiat. Transfer*, 46: 259-280.
- [6] Asrar, G., Myneni, R. B. and Choudhury, B. J., 1992. Spatial heterogeneity in vegetation canopies and absorbed photosynthetically active radiation: A modeling study. *Remote Sens. Environ.*, 41: 85-103.
- [7] Ganapol, B. D. and Myneni, R. B., 1992. The  $F_N$  method for the one-angle radiative transfer equation applied to plant canopies. *Remote Sens. Environ.*, 39: 213-231.
- [8] Knyazikhin, Y. V., Marshak, A. L. and Myneni, R. B., 1992. Interaction of photons in a canopy of finite dimensional leaves. *Remote Sens. Environ.*, 39: 61-74.

#### PAPERS ACCEPTED FOR PUBLICATION IN PEER-REVIEWED JOURNALS

- [1] Myneni, R. B., Ganapol, B. D. and Asrar, G., 1991. Remote sensing of vegetation canopy photosynthetic and stomatal conductance efficiencies. *Remote Sens. Environ.* (accepted for publication in April 1992).
- [2] Ganapol, B. D. and Myneni, R. B., 1991. Chandrasekhar's method applied to the radiative transfer equation in plant canopies. *J. Quant. Spectroscop. Radiat. Transfer.* (accepted for publication in March 1992).

## PAPERS SUBMITTED FOR PUBLICATION IN PEER-REVIEWED JOURNALS

- [1] Myneni, R. B. and Choudhury, B. J., 1992. Synergistic use of optical and microwave data in agrometeorological applications. *Adv. Space Res.* (submitted in August 1992).
- [2] Myneni, R. B. and Asrar, G., 1992. Atmospheric effects and spectral vegetation indices. *Remote Sens. Environ.* (submitted in June 1992).
- [3] Myneni, R. B., Impens, I. and Asrar, G. 1992. Simulation of space measurements of vegetation canopy bidirectional reflectance factors. *Remote Sens. Revs.* (submitted in March 1992).
- [4] Asrar, G. and Myneni, R. B., 1992. Atmospheric effects in the remote sensing of surface albedo and radiation absorption by vegetation canopies. *Remote Sens. Revs.* (submitted in August 1992).
- [5] Knyazikhin, Y, Marshak, A. L., Schulze, D. and Myneni, R. B., 1992. Optimization of solar radiation input in forest canopy as a tool for planting pattern of trees. *Trans. Theory and Stat. Phys.* (submitted in March of 1992).

## PAPERS PRESENTED AT SCIENTIFIC MEETINGS

### [A] Invited Papers/Talks

- [1] A plenary talk *Synergistic Use of Optical and Microwave Data in Agrometeorological Applications* will be given at XXIX COSPAR PLENARY MEETING of the WORLD SPACE CONGRESS to held in Washington, D.C., from August 28th to September 9, 1992. This invited talk will also be published in *Advances in Space Research* after a peer-review.
- [2] I was invited to present *Modelling and Utility of Space Measurements of Vegetation Canopy Bidirectional Reflection Functions* at the International Radiation Symposium (IRS92) held in Tallinn, Estonia, 3-8 August, 1992. I could not attend these meetings for personal reasons but plan to submit a manuscript.

### [B] Contributed Papers

- [1] I gave a talk *Simulation of Space Measurements of Vegetation Canopy BRDF* at the International Geoscience and Remote Sensing Symposium held in Houston, Texas, 26-29 May, 1992.

### [C] Colloquia, Seminars, and Special Lectures

- [1] As a NFWO (Belgian National Science Foundation) visiting professor at the University of Antwerp (Nov 91 to Feb 92) I gave several seminars and assisted graduate students in the Laboratory for Plant Ecology. The general theme was *Remote Sensing of Vegetated Land Surface Parameters*.



## UNIVERSITY COLLABORATIONS

- [1] I was a visiting professor at the University of Antwerp (Belgium) for four months (Nov 1991 through Feb 1992). This visit was partly funded by the Belgian National Science Foundation.
- [2] I am assisting a PhD student, Jeff Privette, of the Univ. of Colorado, who is a summer student at GSFC. Jeff is a student in the Department of Aerospace Engineering Sciences and is working towards his degree under Prof. Bill Emery.
- [2] I hosted Dr. Oker-Blom of the University of Helsinki, Finland, during the month of March for a week. We discussed our respective research activities and are collaborating on radiative transfer models for needle canopies.

## ADDITIONAL INFORMATION

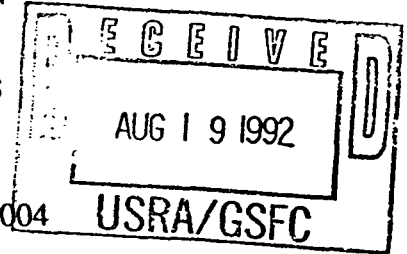
- [1] I am the Co-PI of a proposal titled *Radiative Transfer Calculations for Optical Remote sensing of Vegetated Land Surfaces*. This proposal is funded by NASA Headquarters through the Remote Sensing Science program from March of 1990 till FY93.
- [2] I am the Co-PI of a proposal titled *Remote Sensing of Radiant Energy Interactions and Physiological Functioning of Boreal Ecosystems* submitted for funding under the BOREAS program of NASA HQ. Funding decision is expected in Nov 92.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Name: Gregg Bluth

Task Number: 920-004

General Description of Research Activities

Our TOMS SO<sub>2</sub> working group (myself, Lou Walter, Charlie Schnetzler, Scott Doiron, and Arlin Krueger) changed slightly this year; Scott moved to GISS in March. Since that time I took over the day-to-day functions of responding to information requests and examining eruption reports that Scott had been doing. This cut into my research time quite a bit, especially when we had reports of eruptions (e.g., Mount Spurr, Alaska in June). We have finally hired someone to take Scott's position (Courtney Scott, excuse the name confusion), but she is only working one day a week until at least September. My main research goals this past year have been to complete our inventory of TOMS data for publication, and find ways to validate our measurements. During the course of this work I have continued to look at the data from Mount Pinatubo's eruption in 1991. I'm using the TOMS data in a slightly different way to look at longer, year-long trends of sulfur dioxide dispersion - normally we can only observe a discernable SO<sub>2</sub> cloud on the order of days or weeks. I'll be presenting the results of this work at the American Geophysical Union meeting in December. While going over our eruption inventory I also looked in more detail at an eruption in 1982, Mount Galunggung in Indonesia. Galunggung was the first volcanic eruption to have affected commercial aircraft. I discovered about 25 separate eruptions of the volcano over four month's time. During these eruptions a different instrument was used to measure outgassed SO<sub>2</sub>, so I was able to make some comparisons of the two techniques (see included abstract). With regards to completing the TOMS inventory one of the major obstacles has been overcome: that of standardizing just how we measure and define an eruption cloud. Depending on latitude, season, eruption size, local weather conditions, current instrument conditions, and investigator there were many possible interpretations of the extent and size of an erupted SO<sub>2</sub> cloud, which made it difficult to make intercomparisons of our data. I am now able to use virtually the same method to evaluate each eruption. We are also cataloguing each eruption and storing images and processed data as part of a project with the Earth Observing System team.

My other research involves the effects of chemical weathering of rocks and soils on long-term global climate. I have continued working with Elissa Levine (Biospheric Sciences Branch) to refine a computer model of soil generation based on rock type and climate on million-year time scales. In March I spent some time in Hawaii surveying catchment areas for basin analyses. Throughout the year I have also worked on implementing some of my work on paleogeologies and rock weathering rates into chemical cycling and climate models (details in the Collaboration sections).

Papers Published:

- Bluth, G.J.S., S.D. Doiron, A.J. Krueger, L.S. Walter and C.C. Schnetzler (1992) Global tracking of the SO<sub>2</sub> clouds from the June, 1991 Mount Pinatubo Eruptions. *Geophysical Research Letters*, **19**, 151-154.
- Doiron, Scott D., Gregg J.S. Bluth, Charles C. Schnetzler, Arlin J. Krueger, and Louis S. Walter (1991) Transport of Cerro Hudson SO<sub>2</sub> clouds. *EOS Transactions AGU*, **72**, 489-498.
- Krueger, Arlin J., Scott Doiron, Gregg Bluth, Louis Walter, and Charles Schnetzler, Volcanic hazard detection with TOMS. First International Symposium on Volcanic Ash and Aviation Safety, Seattle, WA, July 8-12, 1991, in press.

All at NASA/Goddard Space Flight Center

Papers Submitted but not yet Accepted for Publication:

- Bluth, G.J.S.<sup>1</sup>, S. D. Doiron<sup>2</sup>, C.C. Schnetzler<sup>1</sup>, T.J. Casadevall<sup>3</sup>, A.J. Krueger<sup>1</sup> and L.S. Walter<sup>1</sup>, Outgassed Sulfur dioxide from the 1982-1983 eruptions of Galunggung, Java. Submitted to *Journal of Volcanology and Geothermal Research*, September, 1991.

<sup>1</sup>NASA/Goddard Space Flight Center

<sup>2</sup>Hughes STX Corporation, Goddard Institute for Space Studies, NY

<sup>3</sup>US Geological Survey, Denver, CO

Papers Presented at Scientific Meetings:

*Contributed Papers (speaker underlined)*

- Kump, L.R., G.J.S. Bluth, M. Gibbs, and E.J. Barron (1992) The role of paleogeology in CO<sub>2</sub>-induced climate change. International Geologic Congress August 25-28, 1992, Japan.
- Bluth, G.J.S., S.D. Doiron, C.C. Schnetzler, A.J. Krueger, and L.S. Walter (1992) Trends of SO<sub>2</sub> production by explosive volcanism. AGU Chapman Conference on Climate, Volcanism, and Global Change, March 23-27, 1992, Hilo, Hawaii.
- Krueger, A.J., C.C. Schnetzler, L.S. Walter, S.D. Doiron, and G.J.S. Bluth (1992) On the fate of volcanic sulfur dioxide clouds. AGU Chapman Conference on Climate, Volcanism, and Global Change, March 23-27, 1992, Hilo, Hawaii.

- Bluth, G.J.S., S.D. Doiron, C.C. Schnetzler, A.J. Krueger, and L.S. Walter (1991)  
Volcanic output of SO<sub>2</sub> during explosive eruptions: an evaluation of 13 years of TOMS observations. American Geophysical Union meeting December 9-13, 1991, San Francisco, CA.
- Krueger, A.J., L. Walter, C.Schnetzler, G. Bluth, and S. Doiron (1991) The sulfur dioxide content of the June 1991 eruptions of Mt. Pinatubo. American Geophysical Union meeting December 9-13, 1991, San Francisco, CA.
- Doiron, S.D., G.J.S. Bluth, A.J. Krueger, C.C. Schnetzler, and L.S. Walter (1991)  
Circumpolar transport of the Cerro Hudson sulfur dioxide clouds. American Geophysical Union meeting December 9-13, 1991, San Francisco, CA.
- Kump, Lee R. and Gregg J.S. Bluth (1991) Erosional area/age curves for the Phanerozoic: implications for sediment recycling and preferential preservation. Geological Society of America meeting October 28-31, 1991, San Diego, CA.

*Papers Submitted but not yet Presented*

- Bluth, G.J.S., A. J. Krueger, S.D. Doiron, C.J. Scott, L.S. Walter, and C.C. Schnetzler (1992) Dispersion of SO<sub>2</sub> clouds: a comparison of Mt. Pinatubo and El Chichon eruptions using TOMS data. American Geophysical Union meeting December 7-11, 1991, San Francisco, CA.
- Bluth, G.J.S., A. J. Krueger, C.J. Scott, L.S. Walter, and C.C. Schnetzler (1992) SO<sub>2</sub> Cloud Tracking from the June 27 Eruption of Mount Spurr, Alaska. American Geophysical Union meeting December 7-11, 1991, San Francisco, CA.

*Colloquia, Seminars and Special Lectures*

Talk at University of Maryland, October 4, 1991: "Can 100 Million Years of Earth's History be Described with Boxes and Arrows?" Seminar sponsored by the Department of Geology.

Guest lecture, Physical Geology class, University of Maryland, October 17, 1991: "Seafloor Hot Springs".

Guest lecture, Physical Geology class, University of Maryland, November 14, 1991: "Climatic Change".

I gave a talk at the Branch 921/926 Science Seminar Series, entitled "TOMS SO<sub>2</sub> and SiO<sub>2</sub> studies in Hawaii", on May 5, 1992.

*Community Service*

Talk at the Goddard Visitor Center, October 27, 1991: "Tracking of a 4,000 Mile Long Volcanic Cloud from Space"

Two talks at Edmund Burke School (grades 7-12), Northwest D.C., November 13, 1991: "Deep Sea Research" (9th grade Earth Sciences class); "Volcanic Emissions Research at Goddard (advanced placement Chemistry class).

On February 11, 1992, I gave a short talk entitled "Climate models and predictions" and participated in a panel discussion of environmental issues at the University of Maryland Student Union.

University Collaborations:

In the Spring, 1992 I taught a course "Climate and Climate Change" in the Geology Department at the University of Maryland. This was a course I designed which looked at climate change from a variety of disciplines such as geology, geography,

biology meteorology, etc. The department thought well enough of my efforts to ask me back again next year, and also gave me the appointment of Visiting Assistant Professor.

I am working with Dr. Lee Kump at The Pennsylvania State University on global models of weathering and paleogeological investigations. At various times throughout the year I have been working with one of his students, Mark Gibbs, to help him with methods and computer programs used in analyzing paleolithologic data.

I have been working this year with Dr. Lisa Sloan, currently with University of Michigan, on implementing paleogeologic data for specific time periods - see note about George Moore below.

Other Collaborative Activities:

I met with George Moore (Chevron Research, La Habre, CA) and Lisa Sloan at the Fall AGU meeting in San Francisco. We are interested in using my weathering rate results and paleogeology with his and Lisa's determinations of paleoclimates and George's models of paleogeographies to study source regions for fossil fuels in the Late Jurassic (~150 mya).

I accepted an invitation to join the International Association of Volcanism and Chemistry of the Earth's Atmosphere (IAVCEI) task group on "Volcanism and the Earth's Atmosphere". This group is composed of 14 formal members (including myself) and 16 corresponding members from Universities, government agencies and research laboratories from around the world. The purpose of the group is to consolidate a database on volcanic eruptions for the past 10,000 years with the focus on the past 200 years. The group will serve as somewhat of a clearing house of information.

As a result of a meeting with Peter Mougini-Mark at the Chapman conference in Hawaii last March, I was asked to be member of the Earth Observing System (EOS) task team for the TOMS data. On July 23-24, I attended the EOS Plume meeting held at Goddard. I gave a presentation of our recent work using TOMS data.

Supply any Additional Information:

From July 6-24 I was mentor to Eleni Roumel under the National Space Club Scholars program. She worked on a project with me using information from Dr. Tom Simkin of the Smithsonian Institution global Volcanism Program. She looked for satellite evidence of a large eruption of Fernandina caldera, Galapagos, discovered by Simkin in the field. The only clues he could give us was that the eruption occurred sometime between late 1980 and early 1982. Eleni and I searched through the TOMS

database, and were able to confirm that no large emissions of sulfur dioxide had accompanied the eruption.

I reviewed two manuscripts for publication in Geophysical Research Letters. The first was "Identification of the Mount Hudson Volcanic Cloud over SE Australia", by I.J. Barton, A.J. Prata, I.G. Watterson and S.A. Young. The second was "Observations of an Anomalous Aerosol Extinction Mode by SAGE II Following the Eruption of Mt. Pinatubo", by L.W. Thomason.

Because of the timing of this report, it's hard to know what to include in this year's work. I am submitting a proposal to NASA headquarters in response to a "Dear Colleague" letter. The general topic is understanding the role of sulfate and other aerosols in the troposphere. The proposal is due October 1, 1992 so it will certainly fall into this year's work load.

"Explosive volcanic contribution of sulfur dioxide to the troposphere", submitted with Dr. A.J. Krueger (Code 660) as coprincipal investigator (Geodynamics Branch, GSFC).

920-007

EJ

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GODDARD VISITING SCIENTIST PROGRAM

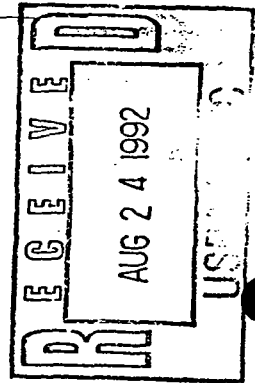
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: HELENA GUERTLER Task Number: 920-007

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Research on the database to be used in evaluating the Gravity-Field Model of Mars continued during this period. Propulsion and orbital data has been compiled, and a Supplement to the Database has been created marking radio science and telecommunications performance. Additional resource material has been provided by Frank Lemoine from the Colorado Center for Astrodynamics Research.

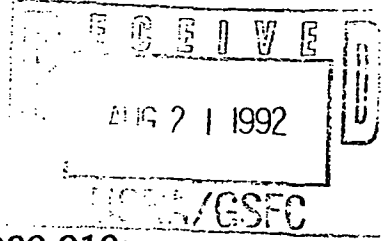
Contingent upon proper computer tools, the author hopes to condense the database into computer-readable form.



Lined area for additional research activities, currently blank.

920-010 EV

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GODDARD VISITING SCIENTIST PROGRAM



EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Dr. Alan Nelson Task Number: #920-010:

General Description of Your Research Activities: (Include a Paragraph on each Activity).

I was hired, beginning January 27, as Information Scientist for the BOREAS (BOReal Ecosystem-Atmosphere Study) project. BOREAS is a multi-disciplinary field and remote-sensing project that will be jointly implemented by the United States and Canada. So far, my activities have centered on these main issues:

1) Visits to the primary BOREAS study sites (Prince Albert National Park, Saskatchewan and Thompson, Manitoba) and preparation of intensive-study site descriptions. (Described on page 5)

2) Review of proposals submitted to BOREAS and assembling a cohesive, project plan assembled from the proposal "pieces". (Described on page 5).

3) Development of the hardware/software configurations necessary to establish the BOREAS Information System (BORIS). (Described below)

4) Development of a network of automated meteorological stations (AMS) that will collect reference meteorological and radiation measurements in, near and between the major BOREAS study sites. (Described below)

3) Preparing hardware/software configurations for BORIS meant first learning what was already available, what had been ordered before I arrived, and piecing together what else is needed. The current plan is to use a soon-to-arrive VAX 6410 for the production image processing, and to use an existent VAX station as a database server using ORACLE. Peripherals for the 6410 (tape drives, disks, are currently being assessed and orders need to be placed next week. Version 7 of ORACLE for the VAX station is budgeted and has been promised for several months. A programmer for the PC environment was hired in June and has a good start on the formatting software to be distributed to the BOREAS principal investigators in December.

4) Two AMS stations built by NCAR were in place before I arrived at GSFC. Original plans were for NASA to hire local support personnel to maintain these stations. With the difficulty in transferring funds from the U.S. to Canada, that plan was dropped. On top of other cost overruns, maintenance by NCAR proved to be too costly and too unreliable. I have checked out Saskatchewan Research Council (SRC) as an alternative for supplying AMSs and for providing timely maintenance. My conversations with Canadian researchers who have worked with SRC, and my visit to SRC in Saskatoon have all led to the conclusion that SRC would not only be acceptable as a means of maintaining the AMS network, but also as a local source of highly technical expertise and equipment (machine shop, chemistry labs, communications).



*Colloquia, Seminars, and Special Lectures: (Provide title, date, and place)*

I attended the ISLSCP America Workshop held in Columbia, MD, June 23-26, 1992.

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Community Service: (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.)

I have attended several meetings of a small group in Code 920 (Laboratory for Terrestrial Physics) interested in a community outreach program. The discussions so far have leaned toward programs in the educational setting. Some of our potential activities will be informational and directed at all grades and abilities. Some of us would also like to work with advanced high school students and have them work on projects at GSFC. I think that BORIS could constructively use and educate such a student in our data-processing activities. I will continue to pursue these activities as time allows.

I also sang second tenor in the University of Maryland Chorus in a performance of Handel's Messiah performed on period instruments at Kennedy Center...I was the tenor soloist (for seven measures, chorus member for the rest of the concert) for the same group in a concert at Second Presbyterian Church.

University Collaborations: Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

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Other Collaborative Activities: Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

1) In June, I was part of a 30-member team that visited a total of nine intensive-study sites in Canada. We visited the sites to pinpoint the location for construction of flux-measurement towers (which will be the focal point for many research activities); accurately characterize species composition, soil characteristics and forest parameters (tree ages, density, height, etc.) at pre-selected representative locations near the tower locations; and to broadly characterize the extent of canopy closure on two 300-meter transects and a 500-meter transect radiating out from the flux tower locations. There were two sets of field teams deployed each day. I was part of one transect team and had each day's measurements ready to display for each evening-meeting discussion on the suitability of each site. The graphs of canopy closure proved valuable in determining the general homogeneity of the stand and the length of homogeneous stretches available for good flux measurements.

2) Much of the month of July was consumed by the selection of the BOREAS puzzle pieces. Along with other members of the BOREAS Executive Committee (BEC) (Piers Sellers and Forrest Hall, GSFC; and three Canadians: Mike Apps, Forestry Canada; Josef Čihlar, Canadian Centre for Remote Sensing; Barry Goodison, Atmospheric Environment Service) I participated as an *ex officio* member of the peer-review panel which reviewed all 224 submitted proposals in five days of marathon meetings. The review panel presented us with approximately 20 "definitely-in" proposals and 15 "definitely-out" proposals, thereby leaving almost 190 "acceptable" proposals. The next 10 days were consumed by picking, evaluating, rejecting, re-evaluating and carving out a cohesive set of proposals and pieces of proposals. The complete project scenario was presented to the BOREAS overview committee (representatives of U.S. and Canadian funding agencies) and was well-received.

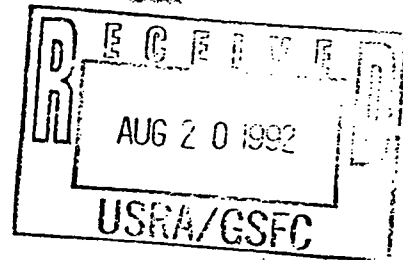
Supply any Additional Information you Feel Would be Useful in evaluating your performance:

I have attached draft copies of documentation for the BORIS communication system. These documents have been prepared under my direction by Patrick Agbu of the former PLDS crew (now officially part of the Goddard DAAC). These are documents to be sent out to new users as we bring them on line.

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UNIVERSITIES SPACE RESEARCH ASSOCIATION  
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EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Dr. Manohar Marebhojane Task Number: 5000-302

General Description of Your Research Activities: (Include a Paragraph on each Activity).

**Vector Quantization (VQ) based Image Compression on Massively Parallel Systems :**

Massively parallel VQ based image compression algorithms were developed and implemented on 16384 processor SIMD machine, MasPar. The compression technique that was developed is called Progressive VQ in which the given multispectral data is decomposed into browse and residual data. The residual data is further decomposed into approximate and full detail. This decomposition can be carried out recursively until desired number of levels are obtained. This enables the data distribution across computer networks economically. Further, decoding the VQ compressed images is a table lookup process which can be performed reasonably fast on any sequential machine thus ensuring the computational burdens are not passed on to the users.

**Subband Coding**

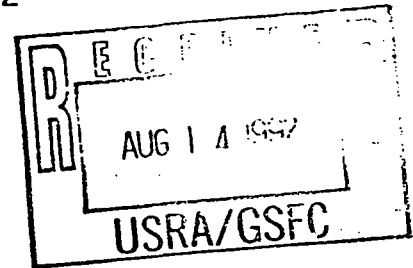
Subband coding is an effective compression technique that decomposes the given image data into multiple data sets based on recursive division of frequency into octaves. The essential components of this technique are pair of filters called Quadrature Mirror Filters (QMF) that are used to band splitting into two halves: low frequency and high frequency. After splitting (by a process called convolution) the images are decimated and the low frequency component is further decomposed into low and high frequency components. This can be recursively performed on low frequency until required size (16-64 smaller) is obtained. This scheme is very suitable for progressive transmission.

**Wavelet Compression**

Wavelet Transforms is similar to windowed Fourier Transform in which the basis functions are derived from a mother wavelet which is not necessarily based on Sine Cosine terms. The mother wavelet is usually compactly supported having one or two oscillations. The other basis functions of the complete orthonormal set can be derived by translation and dilation of the mother wavelet. These basis functions can be used to compress image data efficiently since the wavelet functions have localization property in both time as well as frequency. The computational frame work is same as the subband coding except that the lowpass filter is based on different criterion in the Fourier domain. The work in this direction is to explore the use of wavelet for image compression and evaluate these results with those obtained by QMFs.

USRA / GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
for the year ending September, 1992

MAKOTO SATAKE  
Task Number: 930-008



General Description of Research Activities

Since March 4, 1991, I have been visiting at the Space Data and Computing Division (code 936) of the NASA/GSFC, with Dr. Daesoo Han as my task originator, on leave from Communications Research Laboratory (CRL), Japan. My task at GSFC is related to the Tropical Rainfall Measuring Mission (TRMM) project. I have worked on two main subjects relating TRMM : the TRMM Science Data and Information System (TSDIS) and radar rainfall measurements. TSDIS is being developed by the TRMM Data System Team (code 936) led by Dr.Han. Studies on radar rainfall measurements relating to TRMM have been made by several scientists in the Laboratory for Atmosphere (code 910) and the Laboratory for Hydrospheric Processes (code 970). The TRMM satellite is scheduled for launch in 1997. It is worth noting that TRMM is a joint project between the US and Japan and that the precipitation radar, which is the most ambitious instrument to be boarded on TRMM, is being developed by NASDA (National Space Development Agency of Japan) in cooperation with CRL. I assume that after I return to CRL, Japan, my experience visiting at GSFC will be useful to contribute not only to developing the data system of Japan but to accomplishment of the TRMM project .

Following are descriptions of my activities in each of the two main subjects.

*(1) Development of the TRMM Science Data and Information System (TSDIS):*

The TSDIS team, with its manager Dr.Han, is engaged in that development. Although I have been working with the team, I had had little knowledge and experience on data system development so that I had to learn about it from the ABCs. Meetings, handouts and some reading helped me to learn about the data system along with TSDIS's concept, design, and development strategy.

Since development of the TRMM Ground Truth Data Processing System (GTDPS) which would be a part of TSDIS was started in May, 1991, I had taken a part in it. We studied, as a model of the GTDPS, a predecessor system which had been operated by the TRMM Ground Truth (GT) team of code 910.1. About five months later the GTDPS development was discontinued due to a change of the project . The study, however, resulted in a report and was very useful to me.

Developing a prototype of TSDIS was started in the end of 1991 in order to obtain users' feedback on the system requirements and to identify risks of the TSDIS development. For that purpose the data system team needs to get inputs from the TRMM Science Team Members (that is, the users), such as their requirements for TSDIS, algorithms to process the science data and sample data for the test. So we started regular meetings in which the scientists (users) and the system developers could communicate with each other. Being close to the user side of the radar group, I am intending to be a contact point between the scientists and the system developers.

*(2) Radar rainfall measurements :*

My study on radar rainfall measurements has been made with the TRMM GT team (Dr.D.Short of code 913, Mr.D.Wolff and his colleagues of code 910.1) regarding surface radar and raingage data, and with the TRMM radar team (Drs.R.Meneghini and T.Iguchi of code 975) regarding airborne radar data.

First I studied the GT data system being operated by the GT team to learn how to process surface (ground-based) radar data and raingage data which had been collected as TRMM GT data. With the system I then processed data from the Patrick Air Force Base Radar, one of the GT sites, and raingage data in its vicinity during the CaPE (Convection and Precipitation Electrification) experiment which was held in summer of 1991 in Florida. The CaPE experiment data was interesting to us, not only because those data had not been examined yet, but because there were concurrent rain measurements by some other surface radars and several airborne platforms. Having got airborne radar data obtained at the same time with NASA/CRL radar boarded on the T-39 aircraft, we identified a rainfall event observed simultaneously with those surface radar, raingage and airborne radar, to make a comparison of the data. I presented the result at a remote sensing conference (described below).

I am expanding this comparison to develop an algorithm to get rainfall parameters from space-borne rain radars (e.g., TRMM radar).

Papers Presented at Scientific Meetings:

*Contributed Paper.*

M.Satake, D.A.Short and T.Iguchi; "A Comparison of Airborne and Ground-Based Radar Observations with Rain Gages During the CaPE Experiments," 1992 International Geoscience and Remote Sensing Symposium (IGARSS-92), pp.1731-1733, Houston, Texas, May 26 to 29, 1992.

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**A COMPARISON OF AIRBORNE AND GROUND-BASED RADAR OBSERVATIONS  
WITH RAIN GAGES DURING THE CAPE EXPERIMENT**

**Makoto Satake\*, David A. Short and Toshio Iguchi\***

NASA/Goddard Space Flight Center  
Greenbelt, Maryland 20771, USA

**ABSTRACT**

The vicinity of Kennedy Space Center, Florida, where the primary ground truth site of the TRMM (Tropical Rainfall Measuring Mission) ground truth program is located, was the focal point of the multi-agency CaPE (Convection and Precipitation/Electrification) experiment in July and August, 1991. In addition to several specialized radars, local coverage was provided by the C-band (5 cm) radar at Patrick Air Force Base, Florida. Point measurements of rain rate were provided by tipping bucket rain gage networks. Besides these ground-based activities, airborne radar measurements with X- and Ka-band nadir-looking radars on board an aircraft were also recorded. A unique combination data set of airborne radar observations with ground-based observations was obtained in the summer convective rain regime of central Florida. We present a comparison of these data intending a preliminary validation. A convective rain event was observed simultaneously by all three instrument types on the evening of July 27, 1991. The high resolution aircraft radar was flown over convective cells with tops exceeding 10 km and observed reflectivities of 40 to 50 dBZ at 4 to 5 km altitude, while the low resolution surface radar observed 35 to 55 dBZ echoes and a rain gage indicated maximum surface rain rates exceeding 100 mm/hr. The height profile of reflectivity measured with the airborne radar show an attenuation of 6.5 dB/km (two way) for X-band, corresponding to a rainfall rate of 95 mm/hr.

**INTRODUCTION**

Future space-borne radars, such as the one to be flown in conjunction with NASA's Tropical Rainfall Measuring Mission (TRMM), are the most promising method to monitor global rainfall. At the present time, prototypes of future space-borne systems are being tested aboard aircraft. At the same time, methods of validating such airborne and space-borne radar observations with ground-based observations are under development.

Ground-based radar and rain gage observations are being collected at numerous tropical sites as part of the TRMM ground truth program [1]. The primary ground truth site, in the vicinity of Kennedy Space Center, was the focal point of the multi-agency sponsored CaPE (Convection and Precipitation/Electrification) experiment in July and August, 1991 [2]. In addition to several specialized radars such as CP-2 radar of NCAR (National Center for Atmospheric Research), local coverage was provided by the C-band (5 cm) radar at

Patrick Air Force Base, Florida. Point measurements of rainfall rates were provided by tipping bucket rain gage networks (operated by NASA and several of Florida's Water Management Districts). Besides these ground-based activities, airborne radar measurements with X- and Ka-band nadir-looking radars on board the NASA T-39 aircraft were also collected. A unique combination data set of airborne radar observations with ground-based observations was obtained in the summer convective rain regime of central Florida.

We present a comparison of these data intending a preliminary validation of the airborne radar. Because of the highly variable nature of tropical convection, opportunities for direct comparison of point (rain gage), line (aircraft) and area (surface radar) sensors are rare. In this paper we describe a convective rain event that was observed simultaneously by all three instrument types on the evening of July 27, 1991.

**SENSOR DESCRIPTION**

**SURFACE RADAR**

Patrick Air Force Base (PAFB) radar is routinely operated by NASA/Kennedy Space Center, mainly for monitoring hazardous weather for launches and flights. The C-band (5cm) pulse radar with 2.2° beam width was operated in CAPPI scan mode every 5 minutes during the CaPE.

**AIRCRAFT RADAR**

The airborne radar, which was originally developed at CRL, Japan, is a dual frequency (X- and Ka-band) radar with dual polarization reception capability. It was flown on board the NASA T-39 aircraft over convective cells with tops exceeding 10 km in the CaPE by the NASA/GSFC team.

**RAIN GAGES**

Rain gage data from a network of tipping bucket type gages, which record the time of each 0.01 inch tip to the nearest second, was provided by the St. John's River Water Management District.

**OBSERVATION**

In Fig.1, the T-39 flightpath at 22:30 to 22:45 (UTC) of July 27, 1991 is shown with the location of the PAFB radar and its 3km CAPPI image (reflectivity shown in grayscale) at 22:39 (UTC). Three areas of rain cells can be seen westward of the radar from 40 km range and further. Since the PAFB radar is located on the central east coast of the Florida peninsula, all of the rain cells were over land. We concentrated on the southwestern cell which we concluded to be a convective one from observations. The aircraft executed a closed-loop right-hand turn at a roll angle of -26°, passing over an intense convective cell about 50 km southwest of the radar.

\*visiting Scientists from the Communications Research Laboratory (CRL), Japan through the Universities Space Research Association (USRA).

**T-39 Flightpath  
July 27, 1991  
22:30 - 22:45 UTC**

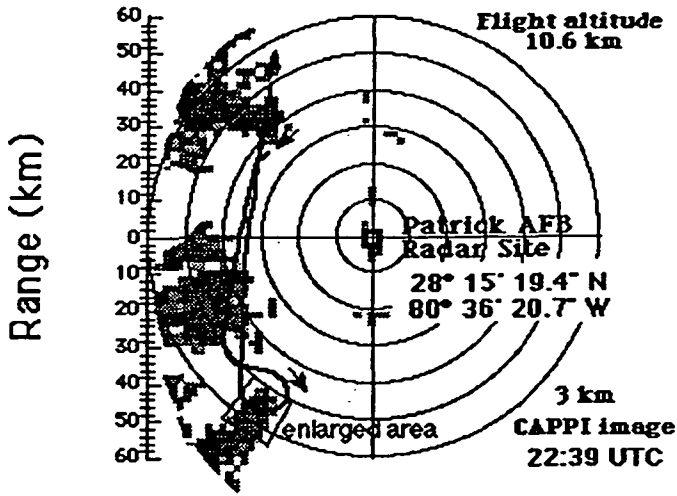


Fig.1 Airborne radar flightpath and PAFB radar CAPPI (3km) image at 22:39 of July 27, 1991.

In Fig. 2 an enlargement of the area over the southwestern cell is depicted in a rectilinear azimuth-range coordinate, overlaid with locations of the rain gage and the T-39 flightpath. The surface radar reflectivities were recorded at 1° azimuth by 2km range resolution using a single pulse measurement. High reflectivities over 50 dBZ can be seen near the flightpath. However, it should be noted that the radar reflectivities, without pulse averaging, might be very noisy and that the radar image and the flight were not exactly concurrent.

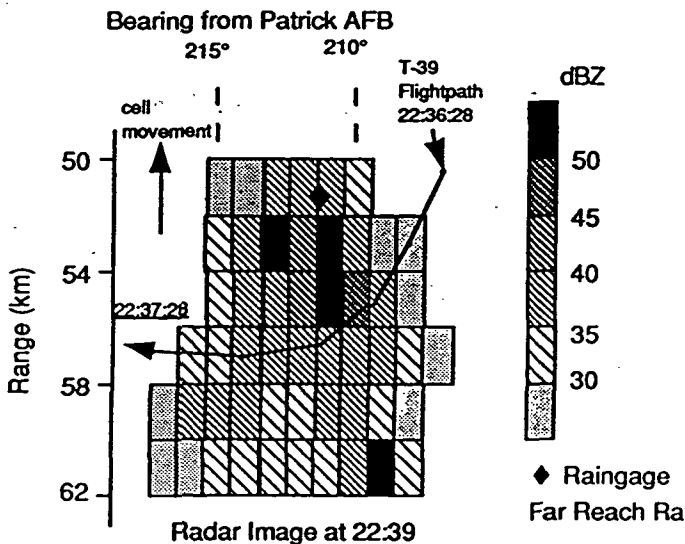


Fig.2 Enlarged surface radar image of a convection rainfall, along with airborne radar flightpath and rain gage location.

Rainfall rates observed with the rain gage at 22:30 to 23:00 (UTC) are shown in Fig.3. The rain started after 22:40 with 40 to 80 mm/hr and rather heavy rain over 100 mm/hr was observed from 22:45 to 22:50.

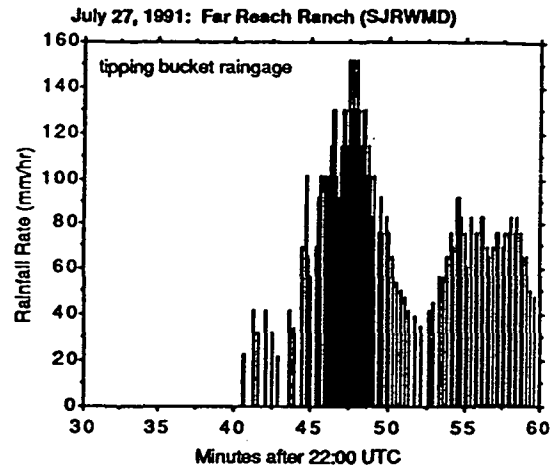


Fig.3 The rain gage rainfall rate, at 211.5° azimuth, 51.5km range from PAFB radar.

Fig.4 shows reflectivities observed by the airborne X-band radar in height-time coordinate. Due to the roll angle of the turning aircraft (~26°), it can be regarded as a tilted vertical cross section in the rain cell (setting the radar altitude to height zero). In the core of the cell at 4 to 5 km altitude, high reflectivities over 50 dBZ can be seen.

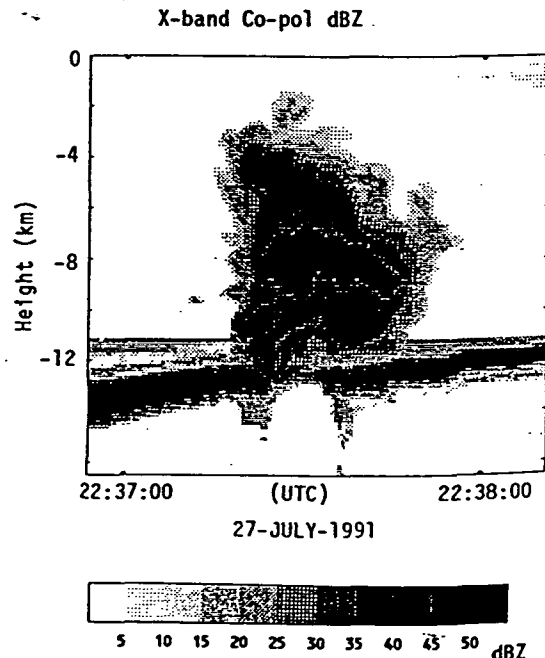


Fig.4 Vertical cross section (tilted) of reflectivities observed with airborne (X-band) radar.

Fig.5 shows altitude profiles of X-band and Ka-band reflectivities, and the linear depolarized ratio (LDR) of X-band, in the middle of the rain cell (setting the land surface to altitude zero).

Dual Frequency Radar, T-39, CaPE, 27-July-92, 22:37

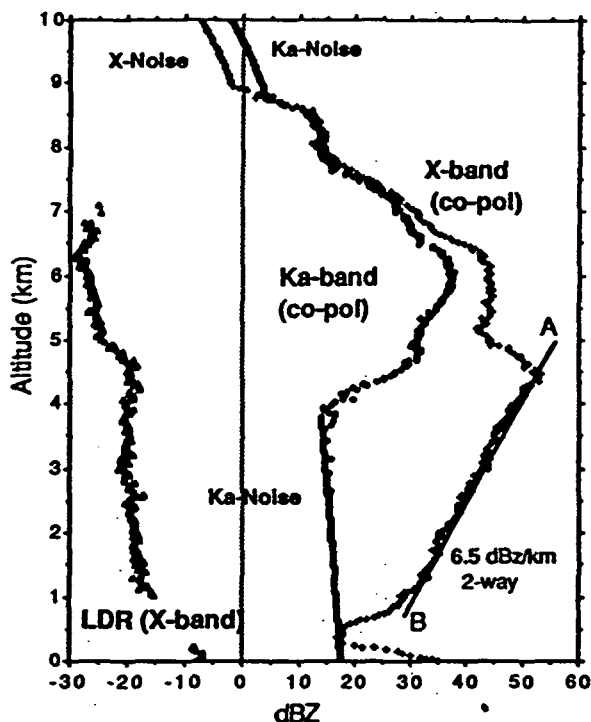


Fig.5 Altitude - reflectivity profiles observed with airborne radar in the middle of the rain cell.

#### DISCUSSION

Peak reflectivities of the convective cell were around 50 dBZ both in the C-band surface radar (Fig.2) and in the X-band aircraft radar (Fig.4), and peak rainfall rates measured with the rain gage were over 100 mm/hr. These values seem to be reasonable for measurements of a rain cell, considering the differences of observed space (field of view) and observed time period. The sequence of observed time of the peak values from the airborne radar, the surface radar and the rain gage is consistent, assuming movement of the rain cell toward the northeast (shown in Fig.2 as an arrow) which was determined from successive images of the surface radar.

In Fig.5, in the range from 1 to 4 km, a linear slope of X-band reflectivity, 6.5 dBZ/km (two-way) (line A-B) suggests an attenuation due to a layer of constant rainfall rate. As the one-way attenuation coefficient of X-band can be estimated by  $0.012 R^{1.23}$  (dB/km) [3], 3.25 dB/km gives the rainfall rate,

$$R (X \text{ -att, 1-4km}) = 95 \text{ mm/hr.}$$

Note in Fig. 5 that the Ka-band and X-band reflectivities at the top of the storm are almost equal, consistent with Rayleigh scattering by small particles. After a few km penetration the Ka-band signal begins to decrease rapidly, apparently due to attenuation, falling to the noise level near 4 km. Although the LDR signal shows an increase around 4.5 km, near the 0°C level outside the cloud, the LDR signature does not clearly indicate a concentrated melting level with abundant aspherical particles, as was observed in stratiform precipitation areas [4].

#### SUMMARY

A preliminary validation of airborne radar observations during the CaPE experiment has shown consistent relations between reflectivities measured by the airborne radar and an operational surface radar. In addition, surface rainfall rates in excess of 100 mm/hr were observed for several minutes by a rain gage, within a convective cell where the airborne radar attenuation inferred a rainfall rate of 95 mm/hr.

Pulse averaged reflectivity data from the operational surface radar will provide better opportunities for general validation. Data from the CP-2 radar (NCAR), a dual frequency dual-polarization surface radar, will soon be available for more detailed case studies.

A more complete examination of the observations needs to examine probability distributions of echo intensities observed by the airborne radar and along flightpaths by the ground-based radars, as well as rain rate distributions observed by rain gages in the vicinity of the flightpaths at the time of the flights. Such statistical comparison methods require a kind of homogeneity assumption that may be satisfied in tropical convection.

#### ACKNOWLEDGEMENT

Our thanks to O.Thiele, D.Wolff, B.Fisher and D.Makofski of the TRMM Ground Truth Team of NASA/GSFC for processing the surface data. The rain gage data were provided through the good offices of Mr.W.Osburn of the St.John's River Water Management District.

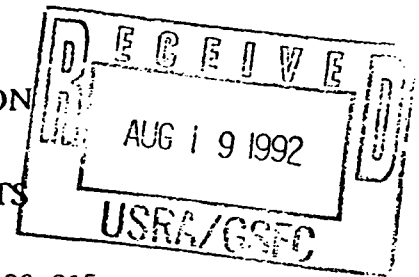
#### REFERENCES

- [1] J.Simpson (edit.), "Report of the science steering group : TRMM (Tropical Rainfall Measuring Mission)," NASA/GSFC, 1988.
- [2] G.B.Foote (edit.), "Scientific overview and operations plan for the Convective and Precipitation/Electrification (CaPE) experiment," NCAR, 1991.
- [3] F.T.Ulaby, R.K.Moore and A.F.Fung, "MICROWAVE REMOTE SENSING: active and passive," Artech House, MA, 1981, vol.1, p321.
- [4] T. Iguchi, R. Meneghini and H. Kumagai, "Radar depolarization signatures of rain in cumulus clouds measured with a dual-frequency air-borne radar," IGARSS'92, this volume.



450-015 SV

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM  
EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Kevin Olson Task Number: 930-015

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My research is focused on development of a gravitational N-body code to study the dynamics of galaxy-galaxy interactions. To do this, a tree code (Barnes and Hut 1986) is used. In this code the particles are placed in grids of varying size. Each grid has a cell size  $1/2$  the size of the upper level grid. The total mass and the center of mass of each grid cell at each level are computed and stored. Also, at the lowest grid level a pointer from the grid location to the particles it contains and the number of particles it contains is also stored. To find the force on any one particle, neighboring cells at the lowest level are looked at first. If the quantity  $(\text{cell size}/r)$  (where  $r$  is the distance from the particle to the center of mass to the cell)  $< 1$ , the force due to that cell (treating it as a point mass) is added to the force on that particle. If  $(\text{cell size}/r) > 1$  the forces due to all particles in that cell are added to the force on the particle under consideration. This is repeated for all particles. Once this is completed, the algorithm goes to the next level (with a cell size twice the size of the previous level) and the nearest cells are searched. The decision to resolve is the same as described above except that a cell is resolved into sub cells rather than into individual particles. In this way a particle sees its nearest neighbors to a high degree of resolution and the mass distribution at larger distances to an increasingly coarse resolution. The scientific question I wish to address by developing the above code is that of the instabilities produced in galaxies when they pass near another galaxy and the effect this has on the interstellar medium of the galaxies. Recent work by other researchers (Noguchi 1988, Gerin, Combes and Athanassoula 1990) has shown that a bar can be induced to form when galaxies interact. However, the number of simulations carried out to date is small and the available parameter space is sparsely sampled. Also, these simulations are two dimensional. With the code I have developed I hope to run a large number of cases to investigate if bars are indeed a common outcome of galaxy-galaxy interactions and under what conditions they form. The code I have developed is fully three dimensional and things such as inclination of the orbit of the galaxies relative to their disks, mass of the perturber, and mass distribution within the galaxy, will be investigated.

This research has the additional goal of testing out new, parallel programming environments. Toward this end I have developed the above described code using APPL (Application Portable Parallel Library) developed by Angela Quealy at NASA/Lewis and run it across a distributed network of IRIS/Indigo workstations here at Goddard. APPL consists of a set of primitives (callable from either fortran or c codes) for message passing between processes and computing global sums and products across all processes. APPL has been written for a number of different parallel architectures such as Intel iPSC/860, Intel Delta, Alliant FX/80 and distributed networks of IBM RS6000, SUN or IRIS workstations.

Performance of the code is good. Using 6 processors and 16,000 bodies, I have achieved similar performance to that obtained using a Cyber 205 vectorizing supercomputer. Barnes (1988) achieves performance of  $\sim 35$  seconds to do one time step, while my code using APPL achieves  $\sim 30$  seconds to do one time step with the same number of particles. Through experimentation, it has been found that around 4-5 processors, communications in the network become important and increasing the number of processors doesn't do much good. The developers of APPL have communicated to me similar results.

Among the machines APPL has been developed for are the Intel iPSC/860 (128, 40 Mhz processors, 8 Mbytes of memory each ) and the Intel Touchstone Delta (513, 40 Mhz processors, 16 Mbytes each). NASA/Ames has a iPSC/860 and is currently soliciting proposals to use it. I have submitted a proposal for time on this machine and obtained some. Also, I have obtained time to use the Intel Delta machine at Caltech. Experiments in using APPL on these machines is presently in progress. This will be a good test of the portability of APPL codes. Should this prove successful, APPL will provide a convenient way of developing parallel codes, ie. one could develop and debug the code using a distributed network of workstations and then port it to a larger machine with dedicated communications for production runs.

I have also begun preliminary work on developing a Hydrodynamics/Magnetohydrodynamics code known as SPH (smooth particle hydrodynamics). In this algorithm a continuous fluid is modeled as a set of particles. The particles each carry with them average values of the local physical quantities (eg. temperature, pressure, and density). Toward this end I have developed a one dimensional SPH code which models the interaction of two opposing streams of gas as well as the shock tube problem.

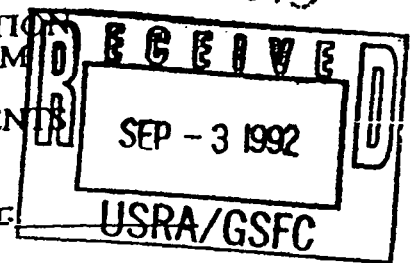
Since, in SPH, the gas is modeled as set of particles, it should be relatively easy to combine this with the above mentioned gravitational N-Body code. This has been done by several researchers (Hernquist and Katz 1989). Such codes have been shown to be useful for astrophysical applications where gravity is important (eg. cloud-cloud collisions and galaxy interactions). However, such codes have not been shown to be of good use for a wide array of problems. I plan to investigate this and possibly improve the code by developing it in such a way that it takes advantage of parallel processing. Olson and Kwan (1990) found that a large number of collisions between interstellar clouds are produced by a galaxy-galaxy interaction. They also found that these collisions are of a high relative velocity. They hypothesized that any observed burst of star formation which is triggered by the interaction of two galaxies may be related to these high energy cloud-cloud collisions. By using SPH I hope to model, in greater detail, the collision of two interstellar clouds.

## 1 References

- Barnes, J., 1988, ApJ, 331, 699
- Barnes, J., & Hut, P., 1986, Nature, 324, 446
- Gerin, M., Combes, F., & Athanassoula, E., 1990, A&A, 230, 37
- Hernquist, L. & Katz, N., 1989, ApJS, 70, 419
- Noguchi, M., 1988, A&A, 203, 259
- Olson, K. M., & Kwan, J., 1990, ApJ, 349, 480

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: Dr. Anil Deane Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

General area of research is in turbulence, MHD, magnetoconvection, computational fluid dynamics and parallel supercomputing.

Compressible MHD: Currently an MHD code of S. Zalesak and D. Spicer (Code 930) has been modified to include gravity, viscous and thermal diffusion, and slip-free walls. The code is geared to solve the compressible magneto-convection problem. The presence of boundaries makes the specification of high order "fluxes" (required for the method of FCT) a delicate issue. Even nominally correct procedures can lead to instabilities along the boundaries. Flux forms that are fourth-order accurate that alleviate this problem have been derived<sup>1</sup>. A parallel version of the code has been developed for running on the Intel Delta parallel supercomputer located at Caltech. In this code the domain is decomposed into a number of zones, each of which lays on a single processor of the 520 node machine. The individual zones communicate through message passing routines via a layer of "ghost points" which mark the boundary of each zone. Results of this work are being prepared for publication<sup>2</sup>

1. "High-Order Flux Forms for Boundaries," with S. Zalesak, Internal Report (in preparation).
2. "Compressible Magnetoconvection," with S. Zalesak and D. Spicer (in preparation).

Turbulence Analysis: Newly available techniques such as Karhunen-Loeve analysis and multi-fractal analysis (in which I have made several contributions in the past), and Wavelet analysis (I guided a summer student in this) are being applied to computations of various turbulent flows.

Turbulence Modeling: High Reynolds number flows can require a prescription for the behavior of unresolved scales. Initiating a research effort into models that are applicable to MHD.

Wake Instabilities: The wake of a bluff body provides a laboratory for the study of nonlinear interactions. Work continues (albeit slowly!) on this problem along with collaborators from Princeton University<sup>3</sup>

3. "Flow Past a Circular Cylinder: Dynamics and Symmetry," with I. Kevrekidis, G. Karniadakis and S. Orszag (in preparation).

Parts of the above efforts have been included in two proposals mentioned later.

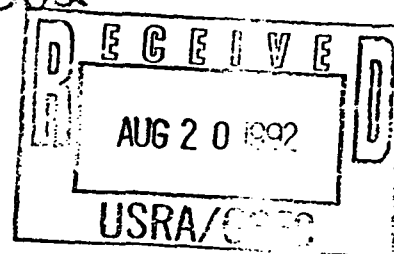
**Other Collaborative Activities:** Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

1. Contributed to the writing and named 0.2 WY consultant on \$2.3 Million Grand Challenge proposal titled "A Grand Challenge Proposal to Develop Accurate, Time-Dependent Simulations of the Coupled Magnetosphere-Solar Wind System," Dr. M. Goldstein, PI, Code 692.
  2. Contributed to the writing and named 0.1 WY consultant on \$1.2 Million Space Physics Theory Program (SPTP) proposal "The Role of Turbulence in Heliospheric Plasmas," Dr. M. Goldstein, PI, Code 692.
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**Supply any Additional Information you Feel Would be Useful in evaluating your performance:**

1. Direction of VSEP student Christopher Mitchell research on "Wavelet Analysis of Turbulence Data."
2. Attended meeting on Parallel CFD at Rutgers University, April 92.
3. Participated in All-NASA video conference on parallel architectures, March 92.
4. Attended NASA Ames video lecture on Adaptive Grid Refinement, Aug 92.
5. Attendance of two-week lecture series by P. Colella and S. Zalesak on High-Order Godunov schemes and Modern Shock-Capturing methods.
6. Participate in weekly Computational Techniques meetings.
7. Refereed papers for scientific journals (2 for Physics of Fluids A and 1 for Journal of Computational Physics.)
8. Reviewed proposals for NASA SBIR on massively parallel supercomputing.

710-008



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Toshio Iguchi Task Number: 5000-702

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My activities here are three-fold.

My major research activity is to conduct air-borne radar measurements of rainfall and to analyze the data. The air-borne radar measurements were successfully carried out and many valuable data were collected during the CaPE experiment in Florida in July, 1991. After the experiment, I calibrated the radar and started analyzing the data. Some of the results were presented at IGARSS meeting in Texas in May 1992. The data analysis also includes the comparisons of different algorithms for rain-profile retrievals. This is important for the implementation of the best algorithm for TRMM radar data processing.

We decided that the CRL's (Communications Research Laboratory, my home affiliation) air-borne radar which we used for the measurement of rain from aircraft for the past 7 years will be reconfigured as a ground based radar and be installed at Wallops Island. Currently, I am collaborating with Mr. Meneghini on this task.

Another research activity on which I am working is the maintenance and calibration of the millimeter-wave (82 and 245 GHz) link system on the Wallops island. The system was damaged (presumably by lightning strike) last fall. The problems were identified and the mixer for 82 GHz channel and the log-amplifier were replaced this spring. The system is now operational and has yielded useful data.

My third activity is to participate in the TRMM science studies. This task includes participating in TRMM meetings, addressing issues concerning TRMM data products, and serving as a liaison between the US and Japanese teams.

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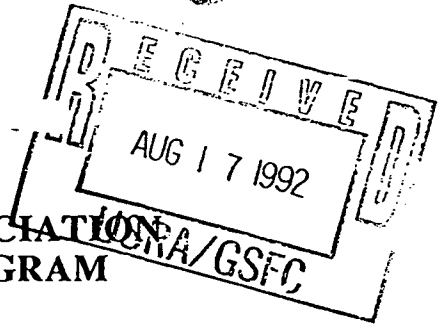
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970-006

EV



**UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM**

**EMPLOYEE SUMMARY OF ACCOMPLISHMENTS**  
(for the year ending 9/30/92)

Employee Name: Chaing Chen

Task Number: 5000-706

**General Description of Your Research Activities:** (Include a Paragraph on each Activity).

During the past year, efforts had been concentrated on the study of gravity currents propagating in stably stratified shear flows. Originally, this research was motivated by a desire to extend the vorticity matching theory described by Rotunno, Klemp and Weisman (1988) for gravity currents propagating in a neutrally stratified shear flow to an atmosphere with stratification. However, during the course of study we encountered unanticipatedly strange upstream effects, in the form of upstream propagating columnar modes and internal bores, ahead of the gravity current. In order to gain greater insight into the understanding of these effects, numerous sensitivity experiments using Dr. Chen's nonhydrostatic model were conducted with the gravity current replaced by an obstacle to understand what might be the governing parameters for the upstream effects. The writing of a paper regarding this subject was completed and the paper was submitted to the Journal of the Atmospheric Sciences.

At the beginning of the FY92, Dr. Chen has been successfully migrating all the model files from IBM-VM and VAX-MV5 to Silicon Graphics workstations. He also reconfigured the workstations as the front-end computer for the CRAY supercomputer. Therefore, the model can be either integrated at the local workstation or at the remote supercomputer. In addition, in order to digest model data more efficiently Dr. Chen also made arrangements such that all model data are processed at local workstation to produce images and hard copy plots.

Dr. Chen also assisted Dr. Koch to study frontal merging process and hydraulic jumps over Appalachian Mountains using Dr. Chen's nonhydrostatic model. As a result, a paper was written and presented at the Fifth Conference on Mesoscale Processes.

One of the major accomplishments during the past year was the successful development of a hydrostatic model. The purpose is in an attempt to understand the source of errors in the calculation of pressure gradient force over a steeply sloped terrain using hydrostatic equation. The writing of a Note for Monthly Weather Review to address this problem is in progress.

Another major achievement was the adoption of Dr. Tao's cloud microphysical routines into Dr. Chen's model system and the upgrade of the model from a 2D to a 3D model. These modeling activities were a part of efforts to develop a next generation nonhydrostatic mesoscale model to study scale interaction processes occurred in a mesoscale environment.

**Describe any Significant Recognition of your work:** (You may wish to include the total number of citations to each of your publications as reported in a recent Science Citation Index. Give the title of the paper, or coded reference, and the number of citations for each).

Chen, CH. and H. D. Orville, 1980: Effects of Mesoscale Convergence on Cloud Convection. *J. Appl. Meteor.*, 19, 256-274.

HUNG RJ	INT J	REMOT	12	831	91
HUNG RJ	INT J	REMOT	12	863	91
HUSTON MW	J APPL MET		30	1389	91
MCCUMBER M	J APPL MET		30	985	91
TAO WK	M WEATH RE		119	2699	91

Chen, C. and W. R. Cotton, 1983: A One-Dimensional Simulation of the Stratocumulus-Capped Mixed Layer. *Boundary Layer Meteor.*, 25, 289-321.

ENGER L	J APPL MET	39	157	91
NICHOLLS ME	M WEATH RE	119	298	91

Chen, C. and W. R. Cotton, 1987: The Physics of the Marine Stratocumulus-Capped Mixed Layer. *J. Atmos. Sci.*, 44, 2951-2977.

HYMSFIE AJ	J ATMOS SCI	48	493	91
RAUBER RM	J ATMOS SCI	48	1005	91
SLINGO A	J GEO RES-A	96	5341	91
SLINGO JM	Q J R METEO	117	333	91

**Honors or Awards Received:**

**Papers Published or Accepted for Publication:** (Please include complete bibliographic citation(s) with all co-author names/affiliations, in the order in which they appear in the journal, and attach abstract(s) to this worksheet).

Chen, C., 1991: A Nested-Grid, Non-Hydrostatic, Elastic Model using a Terrain-Following Coordinate Transformation: The radiative-nesting boundary conditions. *Mon. Wea. Rev.*, 119, 2852-2869.

Keating, G. M., C. Chen, 1993: Extensions to the CIRA Reference Models for Middle Atmosphere Ozone. *Adv. Space Res.*, Vol. 13, No. 1, pp. (1)45-(1)54.

Keating, G. M., C. Chen, 1991: Middle Atmosphere Change through Solar Forcing. *Adv. Space Res.*, Vol. 11, No. 3, pp. (3)9-(3)20.

**Papers Submitted but not yet Accepted for Publication:** (Please include full title, coauthors [with affiliations], publication, and submission date).

Chen, C., J. W. Rottman, and S. E. Koch, 1992: Numerical Simulations of Gravity Currents in Stably Stratified Shear Flows. Submitted to J. Atmos. Sci. on July 16, 1992.

**Papers Presented at Scientific Meetings:**

Invited papers: (Include title of talk, meeting name, date, and any special meeting role, e.g., session chair, rapporteur).

Contributed Papers: (Include title, meeting, and date)

Chen, C., J. W. Rottman, and S. E. Koch, 1992: Numerical Simulations of Gravity Currents in Stratified Shear Flows. Preprints, Fifth Conference on Mesoscale Processes (Atlanta, GA), Amer. Meteor. Soc., Boston, 241-245.

Koch, S. E., C. Chen, and P. J. Kocin, 1992: The Role of Scale Contraction Processes in the Formation of a Severe Frontal Rainband. Preprints, Fifth Conference on Mesoscale Processes (Atlanta, GA), Amer. Meteor. Soc., Boston, 186-191.

Chen, C., 1991: A Nested-Grid, Non-Hydrostatic, Elastic Model using a Terrain-Following Coordinate Transformation: The radiative-nesting boundary conditions. Preprints, Ninth Conference on Numerical Weather Prediction (Denver, CO), Amer. Meteor. Soc., Boston, 293-296.

Colloquia, Seminars, and Special Lectures: (Provide title, date, and place)



**Community Service:** (e.g. Offices in professional societies, lectures to community or educational groups, consultation, etc.)

**University Collaborations:** Briefly describe activities. Provide name and affiliation of research collaborator(s), courses taught, books written or contributions made to edited books, grant/contract proposals submitted or funded, technical reports prepared, visits made, students mentored, etc. (Co-authored research papers listed above need not be repeated here).

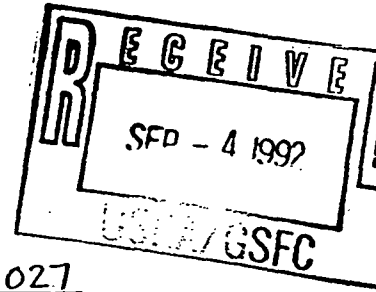
**Other Collaborative Activities:** Briefly describe activities (as described above) with other (non-university) research groups. Provide name and affiliation of collaborator(s)

**Supply and Additional Information you Feel Would be Useful in evaluating your performance:**

Dr. Chen has taken a lead position to develop a nonhydrostatic mesoscale model. He has for several years been developing a two-dimensional nonhydrostatic, elastic, nested grid model with terrain-following coordinate transformation. Presently, this model has been used to study the propagating of gravity currents in stably stratified shear flow and the merging of gravity currents over the actual Appalachian Mountains. Recently, this model has been upgraded from a 2D to a 3D model. The goal is to evolve the model toward mesoscale regime by integrating modules derived from the existing modeling system, such as GMASS and GCE models.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)



Employee Name: V. MOHAN KARYAMPUDI Task Number: 610-027

General Description of Your Research Activities: (Include a Paragraph on each Activity).

Dr. Karyampudi performed additional GEMPAK analyses on the observational case study of the 13-14 April 1986 severe weather case and wrote two journal articles (respectively entitled as "The influence of the Rocky Mountains in the 13-14 April 1986 severe weather outbreak. Part I: Formation of a mesoscale tropopause fold and its relationship to severe weather and dust storms" and "The influence of the Rocky Mountains in the 13-14 April 1986 severe weather outbreak. Part II: Generation of an undular bore and its role in triggering a squall line") which were submitted to the *Monthly Weather Review*. This joint work resulted from collaboration with researchers both at Goddard (e.g., Drs. Steven Koch and James Rottman) and at Universities (e.g., Dr. Michael Kaplan at N. C. State University and Dr. Julio Bacmeister at Johns Hopkins University). These papers are presently under revision.

Joint collaborative work with Dr. Michael Kaplan (of N. C. State University) resulted in two other papers (respectively entitled "Meso-beta scale numerical simulations of terrain drag-induced along-stream circulations. Part I: Midtropospheric frontogenesis" and "Meso-beta scale numerical simulations of terrain drag-induced along-stream circulations. Part II: Concentration of potential vorticity within dryline bulges"). These papers were accepted for publication in *Meteorology and Atmospheric Physics* journal.

Dr. Karyampudi participated in the STORM-FEST field experiment (a multi agency field campaign) conducted over the high plains during the period 12-27 February 1992. He assisted the NASA field experiment scientists in the flight planning of the NASA-ER2 aircraft for data collection. Another reason for his participation in this experiment is his interest to closely observe the severe weather events resembling those of the detailed case study (13-14 April 1986) that he analyzed.

Dr. Karyampudi supervised the numerical modeling study of 3-4 January 1989 ERICA case carried out by Dr. John Manobianco as well as the data preparation for the 9-11 September 1988 Hurricane Florence case carried out by Mr. Horn Shin. Dr. Karyampudi also incorporated Kuo et al's technique for enhancing the initial moisture field using the satellite-derived precipitable water.

Dr. Karyampudi is involved in studying the development of rainbands generated by conditional symmetric instability using 2-D hydrostatic and non-hydrostatic model simulations. He not only supervised the overall progress of the project but also contributed to the benchmark simulations of symmetric instability rainbands carried out by Dr. Jong-Jin Baik.

770-020

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Brad S. Ferrier

Task Number: 920-005

General description of your research activities:

During the past year ending on 30 September 1992, the double-moment four-class ice (4ICE) microphysical parameterization that I developed for the Goddard Cumulus Ensemble (GCE) model has been substantially improved by: (1) incorporating two ice multiplication processes and improving the parameterization of ice nucleation; (2) improving the accuracy of rapid accretion processes by reformulating the finite-difference form of the collection kernel; (3) calculating from thermodynamic principles the freezing rates of liquid water collected on ice, rather than assuming instantaneous freezing of the collected water as in other schemes; (4) substantially modifying the method of transferring the number concentrations of particles between hydrometeor classes by preserving the mean spectral properties of the particle distributions rather than maintaining strict conservation of particle number concentrations (especially important in order to simulate accurately the reflectivity structure of convective and stratiform clouds); and (5) constraining the numerical advection in order to prevent decoupling of the different particle moments, such as grid points where there is positive hydrometeor mixing ratios and zero number concentrations (an improved advection scheme will soon be tested that should help solve this decoupling problem). These extensive changes to the 4ICE scheme solved the following problems encountered this past year in simulations of a GATE squall line: (1) modeled radar reflectivities in the convective cores were 10-15 dBZ higher than observed; (2) the reflectivity maxima within the simulated convection were located above the freezing level, whereas the strongest reflectivities were always observed below the freezing level; and (3) the spatial distribution of radar reflectivity in the trailing stratiform precipitation region differed substantially between the simulations and the observations.

I am currently writing a paper describing the 4ICE scheme, and I will soon start on a second paper showing how well his scheme simulates the radar and microphysical structure of an intense midlatitude-continental (COHMEX, COoperative Huntsville Meteorological EXperiment) squall line and a weaker tropical-maritime (GATE, GARP Atlantic Tropical Experiment) squall line. Unlike in any of the other microphysical parameterizations, the radar structures of convective systems in vastly different environments are simulated well using the 4ICE scheme without the need for tuning a variety of adjustable coefficients.

A series of sensitivity simulations of the same TAMEX squall line as studied by Dr. Tao (Tao et al., 1991) were performed using different microphysical schemes, including my 4ICE parameterization. Depending upon the parameterization, the simulated squall line either became upshear-tilted and was long lived or remained downshear-tilted and gradually decayed (this result was also described in the Tao et al. paper). The observed squall line tilted upshear and was long lived. I found that the 4ICE scheme was more sensitive to the initial conditions, such that stronger initial cool-pool forcing produced sustained, upshear systems and weaker cool pools resulted in decaying, downshear storms. Storms tilted upshear rapidly in simulations where large ice fell slowly (e.g., graupel in the Rutledge and Hobbs, 1984 scheme) because of (1) reduced hydrometeor loading and decreased subsidence warming in the downdrafts, (2) more of the ice was advected rearward by the storm-relative winds at mid levels, and (3) less precipitation fell into newly developing updrafts. The upshear tilt of storms either did not occur or was delayed in simulations where higher fallspeeds were assumed for the large ice (e.g., hail in Lin et al., 1983 and frozen drops in 4ICE). In the annual Laboratory review, I had documented a sequence of events associated with the transition from downshear to upshear storm development, in which the rear inflow jet rapidly descended into the leading convective line and the gust front temperatures dropped abruptly as the storm tilted upshear. I plan on writing a short paper describing the results of this work sometime in the fall.

I have also been involved in the following activities this past year: (1) presented a paper and preprint at the 5th Mesoscale Conference; (2) sent a preprint to the 11th Conference on Clouds and Precipitation, and I am working with Dr. John Scala in our cloud modeling group on simulating a North Dakota squall line for the 3rd Cloud Modeling Workshop; (3) collaborated with Dr. Joanne Simpson and Drs. Tom Keenan and Greg Holland on a combined observational and modeling study of island thunderstorms over Northern Australia (mentioned further in the next section), and I am currently working with Drs. Keenan and Simpson on a subsequent study of these interesting convective systems; (4) corresponded and provided guidance to Dr. Robert Pasken, who is visiting our Branch this summer as part of the JOVE program, on analysis of Doppler radar data from the TOGA radar of a monsoon system and a monsoon-break squall line over Darwin; (5) attended a one week workshop to learn the shipborne radar system for the upcoming TOGA COARE (I will be the radar PI on one of the ships); (6) worked closely with Dr. Tao in addressing reviewers' comments of his paper on comparing the water budgets of different convective systems, which has been subsequently approved for publication.

Describe any significant recognition of your work:

The one-dimensional time-dependent cloud model that I developed is currently being used elsewhere at (1) the University of Washington, (2) Colorado State University, (3) the University of Wisconsin, (4) Texas A&M University, and (5) soon will be used at the Bureau of Meteorology Research Centre (BMRC) in Melbourne, Australia. The title of the paper describing the cloud model is "One-dimensional time-dependent modeling of GATE cumulonimbus convection."

I have received very positive comments when my new 4ICE microphysical scheme was presented recently at the 25th International Radar Conference in Paris and at the 5th Mesoscale Conference in Atlanta. Because I am currently writing several articles that describe my scheme and its encouraging performance in being able to simulate accurately vastly different convective storms, I hope to receive more recognition of my recent work in the future.

Papers published or accepted for publication:

Simpson, J.<sup>1</sup>, T. D. Keenan<sup>2</sup>, B. Ferrier<sup>3</sup>, R. H. Simpson<sup>4</sup> and G. Holland<sup>2</sup>, 1992: Cumulus mergers in the maritime continent region. Meteorology and Atmospheric Physics, (accepted)<sup>3</sup>.

Tao, W.-K.<sup>1</sup>, J. Simpson<sup>1</sup>, C.-H. Sui<sup>3</sup>, B. Ferrier<sup>3</sup>, S. Lang<sup>5</sup>, J. Scala<sup>3</sup>, M.-D. Chou<sup>1</sup> and K. Pickering<sup>3</sup>, 1992: Heating, moisture and water budgets of tropical and midlatitude squall lines: Comparisons and sensitivity to longwave radiation. J. Atmos. Sci., (accepted).

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<sup>1</sup>Goddard Space Flight Center, NASA, Greenbelt, MD

<sup>2</sup>Bureau of Meteorology Research Centre, Melbourne, Australia

<sup>3</sup>Universities Space Research Association, Goddard Space Flight Center, NASA, Greenbelt, MD

<sup>4</sup>Simpson Weather Associates, Charlottesville, VA

<sup>5</sup>Science Systems and Applications Inc.

## CUMULUS MERGERS IN THE MARITIME CONTINENT REGION

*Joanne Simpson<sup>1</sup>, Thomas D. Keenan<sup>2</sup>, Brad Ferrier<sup>3</sup>,  
R.H. Simpson<sup>4</sup> and Greg J. Holland<sup>2</sup>*

### ABSTRACT

We examine a family of tall (up to 20 km) cumulonimbus complexes that develop almost daily over an adjacent pair of flat islands in the Maritime Continent region north of Darwin, Australia and are locally known as "Hectors". Nine cases observed by a rawinsonde network, surface observations (including radiation and soil measurements), the TRMM/TOGA radar, and one day of aircraft photography are used to analyse the development, rainfall, surface energy budgets, and vertical structure of these convective systems.

The systems undergo convective merging which is similar to that observed in previous Florida studies and is multiplicative in terms of rainfall. About 90% of the total rainfall comes from the merged systems, which comprise less than 10% of convective systems, and this has implications for the manner in which tropical rainfall is parameterised in larger-scale numerical models. By comparison to the West Indies, GATE and Florida, the Hector environment contains a weaker basic flow, with less vertical shear. The main thermodynamic difference is that the Darwin area has an unstable upper troposphere and very high tropopause. Numerical modelling results support earlier observations of updrafts in excess of  $30 \text{ ms}^{-1}$  in this region, but show that only modest convective drafts are experienced below the freezing level (5 km).

The surface fluxes over the islands are estimated from a Monash University study to be mainly in latent form from evapotranspiration, with a Bowen ratio only slightly larger than that commonly observed over oceans. These surface fluxes are crucial to the development of

## ABSTRACT

A two-dimensional, time-dependent and non-hydrostatic numerical cloud model is used to estimate the heating ( $Q_1$ ), moisture ( $Q_2$ ) and water budgets in the convective and stratiform regions for a tropical and a midlatitude squall line (EMEX and PRE-STORM). The model is anelastic and includes a parameterized three-class ice-phase microphysical scheme and longwave radiative transfer processes. A quantitative estimate of the impact of the longwave radiative cooling on the total surface precipitation as well as on the development and structure of these two squall lines is presented.

It was found that the vertical eddy moisture fluxes are a major contribution to the model-derived  $Q_2$  budgets in both squall cases. A distinct mid-level minimum in the  $Q_2$  profile for the EMEX case is due to vertical eddy transport in the convective region. On the other hand, the contribution to the  $Q_1$  budget by the cloud scale fluxes is minor for the EMEX case. In contrast, the vertical eddy heat flux is relatively important for the PRE-STORM case due to the stronger vertical velocities present in the PRE-STORM convective cells. It was found that the convective region plays an important role in the generation of stratiform rainfall in the both cases. Although the EMEX case has more stratiform rainfall than its PRE-STORM counterpart, the relative contribution to the stratiform water budget made by the horizontal transfer of hydrometeors from the convective region is less. But the transfer of condensate from the convective region became relatively less important with time in the stratiform water budget of the PRE-STORM system as it developed from its initial stage, such that the relative contribution to the stratiform water budget made by the horizontal transfer of hydrometeors from the convective region is similar at the mature stages of both systems.



Papers submitted but not yet accepted for publication:

"A double-moment multi-phase four-class ice scheme. Part I: Model Description" to be submitted in September to J. Atmos. Sci. by Brad S. Ferrier (USRA).

"A double-moment multi-phase four-class ice scheme. Part I: Simulations of convective storms in different large-scale environments" to be submitted in October to J. Atmos. Sci. by Brad S. Ferrier (USRA), Wei-Kuo Tao and Joanne Simpson (Severe Storms Branch, Code 912, NASA/GSFC).

"Sensitivity of TAMEX squall simulations to feedbacks between dynamics and microphysics", which is likely to be submitted in November to Atmospheric Research by Brad S. Ferrier (USRA), Wei-Kuo Tao and Joanne Simpson (Severe Storms Branch, Code 912, NASA/GSFC).

Papers presented at scientific meetings:

*Contributed papers:*

"Sensitivity of TAMEX squall simulations to microphysical schemes and initial conditions" at the 11th Conference on Clouds and Precipitation in August 1992.

"Assessment of the feedback effects between radiation and ice microphysics associated with mesoscale convective systems in different environments" at the 5th Mesoscale Conference in January 1992.

"Radar and microphysical characteristics of convective storms simulated from a numerical model using a new microphysical parameterization" at the 25th International Conference on Radar Meteorology in June 1991.

"Comparison of numerically-simulated microphysical characteristics of convective storms with multiparameter radar observations during COHMEX" at the 25th International Conference on Radar Meteorology in June 1991.

*Colloquia, seminars, and special lectures:*

"Ice microphysics in the GCE model" presented at the annual Code 910 Laboratory Review in early June.

Community service:

I am a member of the Severe Storms Branch's (code 912) hardware committee, which meets once every two to three months to address issues regarding computer hardware needs of the branch.

University collaborations:

Collaborations continue with all of the institutions summarized in the section regarding significant recognition of work. In addition, a collaborative effort with Prof. Robert Pasken of St. Louis University on analyzing Doppler radar data of different types of Darwin convective storms will continue into fiscal year 1993. Potential collaborations with Dr. Chen at Penn State and/or Dr. Yefim Kogan at Univ. of Oklahoma are planned, where their explicit microphysical parameterizations will be used to improve the 4ICE bulk scheme. Collaborations with Prof. Robert Houze and several of his colleagues at the Univ. of Washington on combined observational and numerical modeling studies of convective systems studied during the 1991 CAPE (Convective and Precipitation Electrification) experiment over Florida are anticipated in the future.

Other collaborative activities:

Close collaboration continues with Dr. Tom Keenan of BMRC on the study of island thunderstorms over northern Australia. In addition, I am involved in plans for an experiment over the islands north of Darwin called MCTEX (Maritime Continent Thunderstorm EXperiment), which is to be carried out in 1994 and 1997. I am also working with Drs. Andy Heymsfield and Wei-Kuo Tao on using aircraft observations of ice in different storms to test and improve the microphysical parameterization in the GCE model. I also supplied model output from simulations using my 4ICE scheme of a midlatitude squall line, a subtropical storm, and a tropical squall line to Dr. Man-Li Wu for testing and development of retrieval algorithms. I have also been working with Dr. John Scala in our cloud modeling group on simulating convective storms from the North Dakota Thunderstorm Project.

Supply any additional information you feel would be useful in evaluating your performance:

I have had to overcome numerous, unforeseen obstacles in improving the 4ICE microphysical parameterization, as described at the beginning of this form. It took me nearly seven months of development of the 4ICE scheme in order to produce a satisfactory parameterization that can simulate convective storms in widely varying conditions. It was also necessary to perform substantial diagnostics and testing of the 4ICE scheme for nearly three months in order to understand the puzzling results of the TAMEX simulations. Although these factors have delayed me from writing the results of my work for almost a year, I am finally in the process of writing several manuscripts which I expect to submit within the next few months. I have also identified areas where bulk microphysical schemes need further improvements. Addressing these issues will require the use of explicit microphysical parameterizations, airborne microphysical observations, conventional and multi-parameter radar data, and multi-frequency passive microwave observations. In my opinion, my understanding of cloud modeling and microphysics, radar and passive-microwave remote sensing, aircraft observational techniques, and mesoscale processes, as well as my experiences in field projects (Pre-STORM, DUNDEE, and in the upcoming TOGA COARE) affords me the opportunity to assist in the development and improvement of the modeling efforts of the Severe Storms Branch's cloud modeling group.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Jong-Jin Baik Task Number: 970-021

General Description of Your Research Activities: (Include a Paragraph on each Activity).

1. Explicit water-ice phase microphysics has been incorporated in the two dimensional hydrostatic mesoscale model. The model, called 4.0 version of 2D GMASS, is capable of simulating cold-frontal rainbands, which is initialized with the analytic solutions to the semigeostrophic frontogenesis model. The role of ice-phase microphysics and the impacts of including both cumulus parameterization and explicit microphysics on the simulated cold-frontal rainbands are examined.

2. An axisymmetric tropical cyclone model was used to investigate impacts of including both cumulus parameterization and explicit microphysics on the storm development. Also, the role of inertial stability on the rapid intensification of the storm was studied through numerical model simulation.

3. Observational aspects of tropical cyclone intensity change with special emphasis on upper level eddy angular momentum fluxes were examined using three-year data set over the north Atlantic ocean. The scale-controlled objective analysis technique was employed to combine all the available data to give 1° by 1° gridded data set.

4. A weakly nonlinear theory for thermally induced waves is proposed. The theory contains analytic solutions to the weakly nonlinear response of a stably stratified atmosphere to thermal forcing in a uniform basic state wind.

5. The NRL / NCSU model was used to study the rainfall characteristics (orographic-convective nature) during the Indian southwest monsoon. The FGGE data and the nonlinear normal mode initialization technique were employed to provide initial conditions for the model integration.

6. A newly found evidence for sun-climate relation using the satellite and global surface temperature data was proposed. The satellite data consists of the 13-year measurement of solar irradiance and the global surface temperature data come from the data compiled by GISS group.

UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Narinder Chauhan  
Task number: 970-022

**General description of Your Research activities:**

1. Modeling and its Application : Microwave models are being developed to study the backscatter signatures from vegetation. The models are based on discrete scatter approach and use distorted Born approximation. The procedure for modeling usually involves two steps. The first step is the formulation of a microwave model for a general case of vegetation. Here, the vegetation is treated as a mixture of simple dielectric scatterers and scattering cross-section of each of the dielectric scatterers is computed. The general case can then be specialized for a particular vegetation species and thus the modeling can be extended to a) natural environment such as grass, bushes, etc. b) agricultural crops such as corn, soybeans, alfa alfa, etc. c) forested areas having hemlock, pine, spruce trees, etc. The active remote sensing models can be extended to obtain brightness temperature (passive case). In either case the models are tested against the experimental data obtained from both active and passive devices.

The multi polarization and multi frequency remotely sensed data in conjunction with microwave models can be used to retrieve ground truth parameters. Development and testing of inversion algorithms is in progress. The estimation of soil water content is one of the most important parameters of interest to hydrology. The modeling process allows the estimation of the above ground vegetation, thus the retrieval of the water contents of soil can be done with a reasonable accuracy. The estimation can be further improved by using both active and passive data in synergism with one another. The passive data show a large dynamic range in brightness temperature to the changes in soil moisture whereas the active data is very sensitive to plant architecture. These properties of active and passive sensors are being used in developing techniques for the retrieval of parameters.

2. Sensor Development: Work is also in progress for redesigning and upgrading the radar system. The L-band antennas are mounted on the boom of a new cherry-picker truck. The old system that powered the antennas has been replaced with HP8719A network analyzer. The L-band radar system was recently used in

experiments at Oklahoma (MACHYDRO II) and Boise. Initial results from the L-band radar show a great promise for retrieving hydrological parameters. Further work to include a C-band along with the existing L-band is continuing on the radar system.

3. SAR Image Processing: A PCI based image processing system on silicon graphic terminals was installed in our branch. This system is being used to develop and implement software for the calibration of AIRSAR data from JPL. During the past few months, a calibration program POLCAL has been tested and implemented on the new system. Some of the old data from MACHYDRO I experiment in Pennsylvania has been externally calibrated by using the corner reflectors and the results were presented at this year International Conference on Geoscience and Remote Sensing.

**Papers Published or Accepted for Publication:**

"A microwave scattering model for layered vegetation"

M.A. Karam and A.K. Fung (Electrical Engineering Department, University of Texas at Arlington, Arlington, Texas)

R.H. Lang (Department of Electrical Engineering and Computer Science, George Washington University, Washington D.C.)

N.S. Chauhan (Laboratory for Hydrospheric Processes, Code 974, NASA/Goddard Space Flight Center, Greenbelt, MD.)

IEEE Trans. for Geosci. & Remote Sensing, (in press), 1992.

(Please see the abstract attached)

**Papers Presented at Scientific Meetings:**

**Invited Papers, Session Chair, Rapporteur etc.:**

I chaired IEEE Session-FP-F, Remote Sensing in Hydrology-SAR, at International Geoscience and Remote Sensing Symposium 1992, Houston, Texas (IGARSS'92).

**Contributed papers:**

1. "L-band radar scattering from grass", N. Chauhan, P.O'Neill, D. LeVine, R. Lang and N. Khadr, Proceedings of IGARSS'92, Houston, Texas.

2. "Synergistic use of active and passive microwave in soil moisture estimation", P.O'Neill, N. Chauhan, T. Jackson and S. Saatchi, Proceedings of IGARSS'92, Houston, Texas.

3. "Modeling of SAR returns from a red pine stand", R. Lang, O. Kilic, N. Chauhan and J. Ranson, Proceedings of IGARSS'92, Houston, Texas.

4. "An approach to mapping soil moisture with multi frequency polarimetric SAR data", K.S. Rao, N. Chauhan, W.L. Teng, J.R. Wang and E.T. Engman, International Symposium on Photogrammetry Remote Sensing, Washington D.C. 1992.

**Special Lecture:**

A site review by Remote Sensing Program managers from NASA headquarters was held in February, 1992. I shared RTOP talk with P. O'Neill at GSFC/NASA.

### **University Collaborations:**

1. MACHYDRO II experiment at Oklahoma: A two week multisensor experiment was conducted at Chickasha, Oklahoma (June 8-20, 1992). Professor Roger Lang from George Washington University (GWU) Washington D.C. provided the HP8719A network analyzer that was used to drive Goddard's radar system (antennas). Ground truth and canopy geometry measurements were also made jointly by the Goddard teams and members from GWU. Prior to the experiment, Narinder Chauhan made frequent visits to GWU for the development of on-line data acquisition system for the radar.

2. The collaboration on microwave modeling with the George Washington University ( Roger Lang and others in his group) and the University of Texas at Arlington has been continuing as evidenced from the published work.

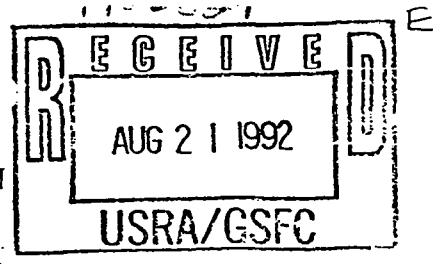
### **Other Collaborative activities:**

1. Jon Ranson, Code 923, GSFC/NASA: Radar modeling of forested areas is progressing well with Jon Ranson's group. A joint proposal on BOREAS project has already been submitted in the spring of 1992. Also a paper entitled "Radar Modeling of Red Pine Trees" written jointly with Jon Ranson is in the process of being submitted.

2. Mark Seyfried, United States Department of Agriculture (USDA), at Boise, Idaho: A joint radar experiment was conducted at Reynolds Creek near Boise to determine the effect of sagebrushes and soil moisture at L-band radar returns. The Goddard radar was taken to Boise for the experiment.

3. Thomas Jackson, United States Department of Agriculture (USDA), Beltsville, MD: The synergistic use of active and passive sensors for soil moisture estimation is in progress. A paper was presented at the last IGARSS'92 symposium. We also worked with Thomas Jackson during the MACHYDRO II experiment in Oklahoma.

4. David LeVine, Code 975, GSFC/NASA: David LeVine's ESTAR (passive radiometer) flew over the fields where the L-band radar data was being collected in the MACHYDRO II experiment. A joint work involving active and passive sensors will be performed by using modeling and experimental results. Previous work involving PBMR and AIRSAR data from MACHYDRO I (from Pennsylvania) is in the process of submission for publication.



UNIVERSITIES SPACE RESEARCH ASSOCIATION  
GODDARD VISITING SCIENTIST PROGRAM

EMPLOYEE SUMMARY OF ACCOMPLISHMENTS  
(for the year ending 9/30/92)

Employee Name: Anthony Daniel Kowalski Task Number: \_\_\_\_\_

General Description of Your Research Activities: (Include a Paragraph on each Activity).

My primary research activity is concerned with the development of algorithms and corresponding programs for high performance numerical modeling of coupled ocean - atmosphere circulation. These algorithms must be scalable to run on future massively parallel machines containing thousands of processors and capable of teraFLOP performance. This involves spatial and/or functional decomposition of algorithms along with corresponding data dependency analysis.

My research also requires an in-depth knowledge, and participation in the development of, the analytic physical models and appropriate numerical solution methods. The high performance algorithms must not only be speedy but must also adequately represent the physical processes involved as well as provide accurate numerical solutions to the chosen model.

The research also involves a detailed performance analysis of different parallel machine architectures. Machine details like, for example, the presence of instruction and data cache, vector processing units, pipelined instruction hardware, and interprocessor communication architecture can greatly affect algorithm performance.

Since my employment with USRA, I've been working on each of these activities. I've acquired, through a successful mini-proposal, computer time on the Touchstone Delta parallel computer at NASA/JPL and I've been conducting performance and algorithm experiments on that machine and the CRAY Y-MP at NASA/GSFC. In addition, I'm reviewing the current ocean and atmosphere models in preparation for parallel algorithm development.



## A Robot System Planner and Automatic Code Generator for Enzyme Kinetics Assays

### ABSTRACT

Programs that generate other programs (i.e. code generators) are becoming more prevalent in the software products we use. The most common being any computer language compiler which maps a high level program into a machine level equivalent. The trend is to incorporate more "domain-specific" knowledge into code generators in order to increase the complexity, quality and quantity of code that can be automatically generated. These knowledge-based system techniques were used to develop a code generator at Sterling Winthrop Pharmaceutical Research. The system automatically translates a high level specification of an enzyme kinetics assay into code that directs a laboratory scale robot and its auxiliary devices to perform the assay. It is an integral part of a larger system developed for the purpose of putting into the hands of the bench chemist the capability of developing a completely new automated chemical assay in a matter of minutes.

