p-14

Final Technical Report for

THE JOINT NASA/GODDARD-UNIVERSITY OF MARYLAND RESEARCH PROGRAM IN CHARGED PARTICLE AND HIGH ENERGY PHOTON DETECTOR TECHNOLOGY

Under Grant NGR 21-002-316

F.M. Ipavich, Project Director

Submitted by

Department of Physics and Astronomy
University of Maryland
College Park, MD 20742

May 1990

The NASA Technical Officer for this grant is: Dr. F.C. Jones, Code 665, NASA, GSFC, Greenbelt, MD 20771.

(NASA-CR-180335) THE JOINT NASA/GODDARD-UNIVERSITY OF MARYLAND RESEARCH PROGRAM IN CHARGED PARTICLE AND HIGH ENERGY PHOTON DETECTOR TECHNOLOGY Final Report (Maryland Univ.) 14 p CSCL 03B G3/90

N91-10610

Unclas

0280463

INTRODUCTION

For more than a decade, individual research groups at the Goddard Space Flight Center and the University of Maryland have participated in experiments and observations that have led to the emergence of new disciplines. Having recognized at an early stage the critical importance of maintaining detector capabilities that utilize "state of the art" techniques, the two institutions formulated a joint program directed towards this end. Many phases of the cooperative effort directly involve faculty research associates and graduate students in the interpretation of data that is carried out at the Goddard Space Flight Center as well as on campus.

Detailed information on the research projects is available in the annual proposals submitted for this grant. The following are summaries of progress made during the period October 1988 to March 1989. A representative bibliography is also included.

SUMMARIES OF PROGRESS

UNIVERSITY OF MARYLAND

Space Physics Group

In studies of data from the AMPTE/CCE spacecraft CHEM experiment we have found that the ratio of solar wind to photospheric abundances decreased rather smoothly with the first ionization potential (FIP) of the ion with the low FIP ions being about a factor of two overabundant. Carbon and Hydrogen fit this trend particularly well. Since the overabundance of low FIP ions in our sample was a factor of two lower than for solar energetic particles (SEP), we suggest that the solar wind from coronal holes (about half of our time periods were during coronal hole flows) most closely resembled the photospheric abundances. We found that there is little if any change in the composition during the transport and acceleration of solar wind ions as they move from the magnetosheath to the plasmasheet.

We have analyzed several occurrences of field-aligned beams observed when CCE was upstream of the Earth's bow shock. The anomalously low He/H ratio (a factor ~40 less than in the simultaneously observed solar wind) is in excellent agreement with recent numerical models in which a portion of the solar wind is reflected and energized at the bow shock.

Also using CHEM data, we have examined in detail ring current intensity and composition changes during the main and recovery phases of the great geomagnetic storm that occurred in February 1986. O^+ was found to be the major ion during the maximum phase of the storm, whereas in all smaller storms H^+ was the most abundant ion. The rapid loss of that O^+ component charge via exchange explains the fast initial recovery in this and other great storms. The ring current energy content tracked Dst closely from storm maximum into recovery but did not track well during the complicated development phase. Near the storm maximum, we observed a local time ring current asymmetry. In the post-noon sector, the spectra showed a strong enhancement of O^+ and He^{++}, while in the pre-noon sector, the flux was consistent with adiabatic energization of the ion population injected earlier in the storm. We showed that this local time difference is consistent with a greatly enhanced electric field that brings a new population to the post-noon sector but not to the pre-noon sector.

Still using CHEM data, we have examined ring current characteristics in a survey of 20 magnetic storms ranging in size from -50 nT to -312 nT. It was found that storm size, as measured by the Dst index, has a very strong linear correlation with the measured ring current energy content; however, the constant of proportionality departs somewhat from that predicted by the Dessler-Parker-Sckopke linear theory. We found that the altitude of maximum ring current energy density correlated negatively with storm size, indicative of the stronger convection electric fields in large storms that drive the ring current ions close to the Earth. We measured the energy spectra of the ion species H^+, O^+, He^+, and He^{++} near storm maxima at all local times and interpreted the spectra in terms of a model of ion drift and loss. We found that the spectra predicted assuming a Voland-Stern electric field and charge exchange losses agreed well with observations in the post-noon sector, while in the pre-noon sector there were quantitative disagreements. These disagreements most likely result from inadequacies in the electric or magnetic field models used.

A study has been done of energetic (~ 30-130 keV/e) ion anisotropy characteristics in the Earth's magnetosheath region using data from the UMD/MPE experiment on ISEE-1. Analysis of the particle angular distributions has allowed us to deduce the speed and direction of the particle 'rest frame' as well as to determine the energy spectra and abundances of protons and alpha particles in this frame. These data have been compared with the expectations of the Fermi acceleration and the magnetospheric leakage models for the origin of this particle population.

We have analyzed the properties of ~30-130 keV/e protons and alpha particles upstream of six quasi-parallel interplanetary shocks that passed by the ISEE-3 spacecraft during 1978-1979. Our measurements were performed with the UMD/MPE ULECA sensor. We deduced the energetic particle diffusion coefficients, $\kappa_\parallel$, by calculating the difference between the bulk flow speed of the particles and their estimated scattering center speeds in the spacecraft frame, and relating this to the particle spatial intensity gradients upstream. This calculation yielded diffusion coefficients for each 2-min interval in the last ~15 minutes before shock passage, when the particle intensities were high.

Using observations carried out in interplanetary space over the period 1977-1982 using the MPE/UMD ULEWAT sensors on the ISEE-1 and ISEE-3 spacecraft, we have examined the composition of ~1 MeV/nuc heavy ions accelerated in interplanetary shock events, and compared them with the heavy ion abundances in solar particle events that preceded the shock. The average relative abundances for C, O, and Fe for the set of shock events used were found to be the same as in the preceding solar particle events, and also the same as in previously reported surveys of solar energetic particle composition. The Fe/O ratios in these events varied over a factor of 10, and it was found that the ratios in the shock associated particles are directly and very strongly correlated with those in the associated flare accelerated particle population. This high correlation, along with the observed spectral forms and flux increases seen at the shocks, suggest that these interplanetary shocks accelerated the particles by only a few hundred keV per nucleon.

Progress is being made in instrumentation using the Time-of-Flight systems developed at UMD, for experiments on future space missions (e.g., the GEOTAIL and WIND spacecraft of the ISTP programs).

GODDARD SPACE FLIGHT CENTER

High Energy Cosmic Ray Group

The first paper giving preliminary results on the antiproton to proton ratio is in press (Advances in Space Science, 1989). University of Maryland graduate student S. Stochaj has continued to be involved in all aspects of the

LEAP data analysis. The final run through the complete data set is currently in progress. Mr. Stochaj is preparing the LEAP time of flight system for use with the University of New Mexico Balloon Bourn Facility (BBMF). Two independent experiments, MASS (antiproton search and positron measurement) and HERO (light isotope measurements), will be flown as separate flights this summer. Mr. Stochaj will travel to New Mexico for the integration of the system and accompany the instrument to the remote launch facility in Prince Albert, Canada.

The analysis of the ALICE isotope experiment is progressing. Recalibration of the empirical scintillation maps has improved the charge resolution for iron from 0.21 charge units to 0.17 charge units. Empirical mapping of the Cherenkov detector to better than 0.5% with flight data has proved not to be possible. Therefore, preparations are under way to calibrate the Cherenkov detector at the Berkeley and Brookhaven accelerators in May and June, 1989. Dr. Joseph A. Esposito is leading the accelerator expeditions. The etching of the range stack, which is being performed at the Unviersity of Siegen, West Germany, nears completion. Iron events which have been identified within the stack have been used to align the stack coordinate system with the coordinate system of the drift chambers. For iron events, the electronic data can be correlated with tracks in the plastic range stack with 100% efficiency. Dr. Esposito visited the University of Siegen in December, 1988, and while there, assisted in the coordinate system alignment. The mass resolution for iron nuclei is presently 0.98 amu. The poor mass resolution is due to the present, 2% resolution Cherenkov detector map and will improve significantly when the new accelerator map is incorporated in the analysis.

Low Energy Cosmic Ray Group

J. Perko's collaboration with L. Burlaga has successfully extended the work published in Perko & Burlaga (J. Geophys. Res., 92, 6127-6131, 1987). This paper showed that using magnetic field compression measured by Voyager 2, one could demonstrate that the changes in high-energy, galactic cosmic-ray flux, also measured by Voyager 2, could be modeled during solar-cycle recovery by a spherically-symmetric, force-field approximation to the steady-state equation for solar modulation of cosmic rays. All parameters were held constant throughout the calculation save for the strength of the magnetic field relative to the local Parker value of the mean field. The 1987 paper ran the model from 1981 through 1984. With the arrival of new data, we now have a full seven years of successful modeling from 1982 to mid-1988. This includes not only the recovery phase of the previous cosmic-ray solar cycle, but the first eight months or so into the declining phase of the new cycle. We believe now that, as least in the ecliptic plane beyond about 10 AU, the transport of cosmic rays is dominated by large, compressed regions of magnetic field, regions created by the merger of numerous fast stream and transients originiating on the Sun. These results were reported at the December 1988 fall meeting of the AGU.

Also reported there were results by R. Ramaty and J. Perko that there is a plausible source to primary positrons in the galaxy which could account for the rise in intensity as one goes to lower energy in the spectrum measured at 1 AU. They could result from Co-56 decay in the aftermath of supervnova explosions. In any case, the background 0.511-MeV line reflects a sufficient source of positrons to account realistically for the ones we see. Our modulation arguments also showed that known sources of secondary positrons are unable to account for this low-energy excess.

We have continued the study of solar energetic particle events with particular emphasis on trying to disentangle the 'phases' or 'modes' of acceleration. We are in the process of a number of studies with two nearing completion.

One study involves the characterization of the particles and flares associated with type III radio bursts. These radio bursts are the archetypal signature of impulsive acceleration. We are able to show that flare duration is an important parameter for organizing the particle data. The presence of type II radio bursts seems also to organize the data suggesting that even in many impulsive events some shock acceleration is taking place.

The second study addresses particle accleration that takes place further away from the Sun viz. at interplanetary shocks. We have looked at the particles associated with a previously published list of schoks. This list is of special interest because it is of those shocks that have been associated with mass ejections. We show that the particle data can be organized by considering the properties of the mass ejections and those of the shocks.

Low Energy Gamma Ray Group

The Rapidly Moving Telescope (RMT) continues integration testing at the Goddard Optical Test Site. The telescope, CCD camera, and mirror mount hardware subsystems are completed. Work is progressing on implementing the 'automated' aspects of the total system and on the software to analyze the gigabytes of image information in real time. To date we have 45 hours of semi-automated 'stare mode' data. The RMT was designed to point to any position on the sky in less than one second and then track and image that target with one arcsecond angular resolution with a sensitivity of 14th magnitude and it has met those specs. It will be permanently installed at Kitt Peak with a companion all-sky instrument this summer. The scientific objective of the RMT is to identify and locate the optical counterpart flash to gamma ray bursts.

The spectral analysis software system for the BATSE experiment on the GRO satellite is being developed at a satisfactory pace. The complete system design has successfully passed the Critical Design Review and the coding of common subroutines is near completion. A model independent algorithm for spectral deconvolution has been developed and tested, and is currently being coded as an alternative to the traditional model dependent technique.

A number of searches for low energy counterparts to gamma-ray bursters have been completed, unfortunately, no candidates have been identified. Twenty four hours of VLA time located no radio counterparts inside ten small boxes. Two additional error boxes have been searched on the archival photograph collection at Harvard. The faint star in the 1901 OT error box was found not to vary in 12 days of observing.

Gamma-ray burst optical flashes are very rare, and the flashes from a variety of background sources are much more frequent. Hence, the background must be understood if GRB flashes are to be identified. However, the background is poorly understood. Recent studies at GSFC have identified three new major types of background flashes. The frequency of satellite glints was found both observationally and theoretically to be orders of magnitude greater than GRB flashes. Strong evidence was collected that normal field start will undergo large-amplitude short duration flashes with an average recurrence time of roughly once per century. A very low luminosity star (M-18, the fifth lowest known) was discovered along with a very large amplitude ($\Delta M > 9.5$!) flash.

High Energy Astrophysics Theory Group

R. Preece is continuing Ph.D. research with Dr. Harding in the study of 511 keV annihilation line emission from gamma-ray burst sources. Their model is a self-consistent numerical simulation consisting of exact quantum transition rates in strong magnetic fields, one photon pair production, and two photon pair annihilation. They have also separately studied respondant Compton scattering in strong magnetic fields.

J. Miller along with R. Ramaty have studied in detail the acceleration and subsequent transportation of relativistic electrons in impulsive solar flare events employing a realistic solar-flare magnetic loop model. They have subsequently calculated the time profiles and energy spectra of 0.3 to 120 MeV bremstrahlung emission. These results are in excellent agreement with corresponding observations made by the SMM gamma-ray spectrometer.

P. Giovanni, along with D. Kazanas, is studying the effects of neutrons produced in the vicinity of accreting compact sources. The presence of these particles can have both dynamical and spectral effects which are, in principle, observable. It is conjecture that the radiative signatures of these particles are already manifest in the spectra of radio bright quasars. Detailed models of neutron production and of their effects on the spectra of these objects are under development.

X-Ray Astronomy Group

This year the Goddard X-ray group has continued to be supported by University of Maryland graduate students and research associates. Dr. K. Arnaud joined the group as a research associate on September 1. His main concern is the preparation of the Guest Observer Facility, sited at GSFC, for the ROSATR mission, due to be launched early next year. He is also involved in aspects of the mission operations and data analysis of other prospective missions, including the BBXRT shuttle payload and the Japanese-US collaborative X-ray satellite, Astro-D. Keith's scientific interests lie mainly in clusters of galaxies. His most recent project comprises the comparison of X-ray data with radio observations of the Sunyaev-Zel'dovich effect for a number of clusters. This analysis is potentially a very powerful tool for determining the structure of clusters of galaxies and as an incidental benefit provides an estimate of Hubble's constant.

J. Lochner is in the final throes of his thesis under the supervision of Drs. J. Swank and E. Boldt (GSFC). He is working on the application of nonlinear dynamical techniques to the X-ray variability of the black hole candidate Cygnus X-1. Recent work has concentrated on the devlopment of shot models that reproduce the moments, power spectrum, and skewness of the Cyg X-1 variability. Fits to the 1/f power density spectrum yield limits on the range of the shot lengths, and fits to the phase portrait (a plot of intensity at a given time vs. intensity at a delayed time - give the shot rate, shot amplitude, and the contribution of the shots to the intensity. Lochner reported on some of his work at the January AAS meeting in Boston.

D. Christian has continued his Ph.D. thesis research on low mass X-ray (LMXB). He is working under the supervision of Drs. J. Swank (GSFC) and A. Wilson (UMD). His recent work has been to use the Einstein Observatory Solar State Spectrometer (SSS) and Monitor Proportional Counter (MPC) to investigate the X-ray spectra of LMXBs. He is also working with Dr. T. Kallman (GSFC) at constructing a self-consistent accretion disk corona model that can explain the emission lines observed using the SSS. This model is also being used to try and predict what will be seen in BBXRT observations of LMXBs.

K. Weaver has been working on Einstein Observatory SSS timing data under the tutelage of Drs. R. Mushotzky and R. Kelley. She has started by showing that clusters of galaxies are not variable in the SS data (a necessary control) and is now analyzing all the observations of active galactic nuclei. This data will be particularly valuable for looking at the short timescale variability of these sources.

BIBLIOGRAPHY

UNIVERSITY OF MARYLAND

Gloeckler, G. and J. Geiss, "The Abundances of Elements and Isotopes in the Solar Wind", Proc. of the Cosmic Abundances of Matter Symposium, AIP Conf. Proc. 183, 49-71, 1989.

Hamilton, D.C., G. Gloeckler, F.M. Ipavich, W. Stüdemann, B. Wilken and G. Kremser, "Ring Current Development During the Great Geomagnetic Storm of February 1986", J. Geophys. Res., 93, A12, 14343-14355, 1988.

Mason, G.M., C.K. Ng, B. Klecker and G. Green, "Impulsive Acceleration and Scatter-Free Transport of ~ 1 MeV per Nucleon Ions in ^{3}He-rich Solar Particle Events", Astrophys. J., 339, 529-544, 1989.

Richardson, I.G., C.J. Owen, S.W.H. Cowley, A.B. Galvin, T.R. Sanderson, M. Scholer, J.A. Slavin and R.D. Zwickl, "ISEE-3 Observations During the CDAW-8 Intervals: Case Studies of the Distant Geomagnetic Tail Covering a Wide Range of Geomagnetic Activity", J. Geophys. Res., in press, 1989.

Schindler, K., D.N. Baker, J. Birn, E.W. Hones, Jr., J. A. Slavin and A.B. Galvin, "Analysis of an Extended Period of Earthward Plasma Sheet Flow at ~ 220 R_E: CDAW-8", J. Geophys. Res., in press, 1989.

Slavin, J.A., D.N. Baker, J.D. Craven, R.C. Elphic, D.H. Fairfield, L.A. Frank, A.B. Galvin, W.J. Hughes, R.H. Manka, D.G. Mitchell, I.G. Richardson, T.R. Sanderson, D.J. Sibeck, E.J. Smith and R.D. Zwickl, "CDAW-8 Observations of Plasmoid Signatures in the Geomagnetic Tail: An Assessment", J. Geophys. Res., in press, 1989.

Tan, L.C., G.M. Mason, B. Klecker and D. Hovestadt, "Seed Population for ~ 1 MeV per Nucleon Heavy Ions Accelerated by Interplanetary Shocks", Astrophys. J., in press, 1989.

Tan, L.C., G.M. Mason, G. Gloeckler and F.M. Ipavich, "Energetic Particle Diffusion Coefficients Upstream of Quasi-Parallel Interplanetary Shocks", J. Geophys. Res., in press, 1989.

GODDARD SPACE FLIGHT CENTER

Esposito, J.A., R.E. Streitmatter, V.K. Balasubrahmanyan and J.F. Ormes, "Measurement of the Cosmic Ray Iron Spectrum Between 60 GeV/nuclon and 200 GeV/nucleon", submitted to Astrophys. J., 1989.

Esposito, J.A., R.E. Streitmatter, V.K. Balasubrahmanyan and J.F. Ormes, "Measurement of the Cosmic Ray Iron Spectrum above 60 GeV/n", AIP Conf. Proc., 183, 398, 1989.

Schaefer, B.E., "Flashes from Normal Stars", Astrophys. J., 337, 927, 1989.

Schaefer, B.E., "Model Independent Spectral Deconvolution", in Nuclear Spectroscopy of Astrophysical Sources, N. Gehrels and G. Share, eds., (New York: Am. Inst. Physics), 1988.

Schaefer, B.E., "A Slow-Rising Type II Supernova", Observatory, in press, 1989.

Schaefer, B.E., T. Cline, et al., "Gamma-Ray Burster Counterparts: Radio", Astrophys. J., 340, in press, 1989.

Schaefer, B.E., et al., "The Perseus Flasher and Satellite Glints", Astrophys. J., 320, 398, 1987.

Streitmatter, R.E., S.J. Stochaj, J.F. Ormes, R.L. Golden, S.A. Stephens, T. Bowen, A. Moats and J. Lloyd-Evans, "Experimental Limits on Low Energy Antiprotons in the Cosmic Radiation", Adv. Space Sci., in press, 1989.