ANNUAL REPORT
of the
E. O. Hulburt Center for Space Research
Naval Research Laboratory
Washington, D. C.

CASE FILE COPY

to

The National Aeronautics and
Space Administration

for
Fiscal Year 1969

Herbert Friedman
Chief Scientist

1 July 1971

Encl (1) to NRL Ltr
7150-6:HF:jmw
SER: 9090
CONTENTS

II. The Hulburt Center Appointees................. v

III. Introduction...................................... vii

IV. New Discoveries and Highlights of 
    the Space Science Division...................... xi

V. Upper Air Physics Branch....................... 1

VI. Radio Astronomy Branch.......................... 13

VII. Rocket Spectroscopy Branch.................... 21

VIII. Publications and Talks....................... A1

IX. E. O. Hulburt Center for Space Research and 
    Lab. for Cosmic Ray Physics Joint Colloquia... B1
### THE HULBURT CENTER APPOINTEES

<table>
<thead>
<tr>
<th>APPOINTEE</th>
<th>PROJECT</th>
<th>STATUS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr. Stephen W. Kahler</td>
<td>Solar x-rays, theory of non-thermal solar x-ray phenomena</td>
<td>Papers on low energy impulsive x-ray bursts; investigation of physics of flare onsets. (J. F. Meekins)</td>
</tr>
<tr>
<td>Dr. Barry K. Moritz</td>
<td>Theory and behavior of solar corona; development of real-time interactive digital processing systems for OSO-7 and ATM data analysis.</td>
<td>Scientific consultant, OSO-7 and ATM data reduction teams.</td>
</tr>
<tr>
<td>Dr. Dianne K. Prinz</td>
<td>Lyman-α disk rocket experiment. Atmospheric ultraviolet airglow from satellite</td>
<td>Redesigned and built Lyman-α disk rocket experiment. Developed computer ray-tracing programs. Analyzed OGO-4 ultraviolet (Accepted permanent employment June 1971).</td>
</tr>
<tr>
<td>Dr. Seth Shulman</td>
<td>X-ray astronomy [ROCKET]</td>
<td>Papers on x-ray source variability and diffuse x-ray background. Experiment on Super-Chief to be launched October 1972.</td>
</tr>
</tbody>
</table>
INTRODUCTION

This year marks a quarter century since astronomical observations were first carried out in space through use of V-2 rockets brought to the United States in 1946. The V-2's were later superseded by the Aerobee, Viking, Rockoons and various two-stage combinations of small rockets and the Nike booster.

Although the solar spectrum was soon mapped from the ozone cutoff near 3000Å to the shortest x-ray wavelengths, full identification of x-ray and ultraviolet sources and the spectral influence of solar activity has required continuing effort.

Success in the solar program led naturally to efforts to probe the spectra of galactic and extragalactic objects. In the ultraviolet range from 1000 to 3000Å these culminated in identification of the Lyman bands of molecular hydrogen and the discovery of large stellar winds. But the greatest surprise was discovery of the enormous x-ray power radiated by a multitude of celestial objects. Thus, today's picture includes stellar objects which radiate a thousand times as much x-ray power as optical, supernova remnants which include the Crab pulsar, variable x-ray galaxies, and a background from soft x-rays to gamma rays which contains
the story of the hierarchical structure of the universe.

Within the current research program other studies are also yielding new insights. Among them are investigation of the infrared background and of the ultraviolet emissions of the celestial sphere. In radio astronomy the search for water vapor sources has been extended, very long baseline techniques have been further developed and the application of active and passive techniques in the study of sea state continues.

During this report year the Solrad X solar radiation monitoring satellite was launched, and the NASA orbiting solar observatory, OSO-7, was placed in orbit with major NRL instrumentation on board.

An ultraviolet lunar surface camera is scheduled for launch on the Apollo 16 spacecraft in March 1972.

Construction and delivery of the instruments for SKYLAB have progressed very well. Henceforth, full effort will be devoted to instrument test and integration, and astronaut training in preparation for launch in April 1973.

The High Energy Astrophysical Observatory experiment will enter its major construction phase next spring with considerable expansion in effort, and an OSO-EYE ultraviolet experiment to survey the Earth's
near environment is scheduled for launch in 1973.

The Division's contributions to technical publications, from August 1970 through October 1971, total 116. Of these 13 have appeared in books. To this list must be added three NRL Reports and 3 Ph.D. theses.

Seventy-five talks have been given.
NEW DISCOVERIES AND HIGHLIGHTS
OF THE SPACE SCIENCE PROGRAM

1. Observations of the Crab pulsar (with 33 millisecond period) reveal distinctive differences in time behavior between soft and hard x-rays. Those at 1-3 MeV are the most energetic pulsar emissions yet observed with certainty. (BALLOON)

2. γ-ray observations carried out from balloons show the presence of two high energy lines of atmospheric origin at 4.5 and 6.2 MeV.

3. X-ray emission from a slow (3.8 second) pulsar in the Crab has been observed. (BALLOON)

4. The morphology of the night helium ion glow at 304Å has been duplicated by theoretical calculation of the expected scattering of solar radiation from a model of the known helium ion distribution in the ionosphere.

5. Infrared rocket observations of the celestial glow within a few hours after sunset reveal a background much higher than the midnight intensity which may be as low as the postulated primordial background. (BLACK BRANT ROCKET)

6. X-ray observations of hot and cool solar flares reveal lines which have been identified with various states of highly ionized iron.
7. Very long baseline interferometry of H$_2$O radio sources was extended to longest baseline in wavelengths yet accomplished (USSR-USA, 7400 km, 547 million wavelengths) and interference fringes were detected.

8. High resolution (1.5) radio circular polarization measurements of H$_\alpha$ plages, flare regions and dark filaments show bi-polar magnetic fields in most cases and complex magnetic field in flare regions.

9. H$_2$O radio sources are shown by very long baseline interferometry to be aggregates of very small diameter sources (d < 5 A.U.), each associated with a doppler shifted line. No ordering in radial velocity and position is apparent.

10. Very long baseline interferometer experiments have been made at the low frequency of 120 MHz showing position coincidence of Crab Pulsar with compact low frequency source in Crab Nebula.

11. Seven new H$_2$O radio sources have been discovered in the southern hemisphere.

12. It has been shown that ocean oil slicks are detectable by passive microwave radiometry.

13. From rocket observation of the 1970 eclipse it has been shown that emissions from higher ionized states of silicon, aluminum and carbon extend to
10,000 km altitude, higher than explicable from conventional solar models.

14. Extreme ultraviolet solar limb spectra reveal many new lines of un-ionized silicon. The center-limb variation of continuum temperature across the sun has been re-verified. (AEROBEE)

15. Solar spectra in the range 170-600 Å reveal the presence of iron in the states corresponding to iron ionized from nine to thirteen times. (AEROBEE)

16. Highly ionized states of nickel, argon and calcium have been discovered in solar flare spectra. The observation of calcium seventeen times ionized implies a flare temperature of 8 million degrees as long as ten minutes after explosive phase of the flare.

17. Fluorescent behavior of the carbon monoxide molecule excited by the 1306 Å OI line has been analyzed in the laboratory from its ultraviolet spectrum.
I. New Results

γ and X-Ray Astronomy

A balloon-borne gamma-ray detector, launched by NRL from Palestine, Texas, on October 9 and 20, 1970, detected gamma radiation from the Crab Nebula pulsar NP 0532 in the energy region from 0.1-10 million electron volts (MeV). The detector was a thallium-activated sodium iodide crystal, 33 cm in diameter and 15.2 cm thick. A search for radiation from the Crab pulsar was made by comparing the excess counting rate in phase with the pulsar period, which was known to be 33.115 milliseconds (ms) during the period of observation.

Analysis of the data obtained from the balloon clearly showed emission in synchronism with the Crab pulsar CP 0532 in several spectral bands. The light curve obtained in the 100-400 keV band showed the greatest detail yet revealed in any X-ray measurement, and revealed a distinctly different time character than that observed at soft X-ray wavelengths or in the visible or radio portions of the spectrum. Strong pulsar emission was also observed in the 0.4-1.0 MeV range; emission was detectable from the 1-3 MeV band. These data are the highest energies of pulsar radiation yet detected with certainty.
Atmospheric γ-Ray Lines  (unpublished)

Analysis of the spectroscopic data obtained in three flights of the 13" x 6" Kurfess scintillator reveals the presence of two high energy γ-ray lines. The preliminary energies are 4.5 MeV and 6.2 MeV. The 4.5 MeV line might be the lowest transition of C\(^{12}\) resulting from cosmic ray reactions (p,n 2p) with N. The 6.2 MeV line might be the lowest transition of O\(^{16}\), resulting from cosmic ray reaction (p,py) with O.

Effect of Lead on Background Measured by Large Scintillator  (unpublished)

A knowledge of the factors contributing to background count is vital to the development of γ-ray astronomy. A study of the effect of passive high Z shielding on the count spectrum observed by the Kurfess scintillator was carried out by flying the sensor unshielded twice, and shielded once on all sides but the top with one-inch of lead. The lead caused a decrease in counts in the range above 2 MeV with the decrease at 6 MeV being a factor of 1.25. The lead caused an increase in counts in the 0.6-2 MeV range with the increase being a factor of 1.5 at 1.0 MeV. Both effects are believed to be the result of Compton scattering, which shifts photons to lower energy. Prompt particle-induced
X-rays and γ-rays were excluded from the count by a plastic anticoincidence shield.

Possible Discovery of an X-Ray Pulsar Associated with CP 0527 (unpublished)

Proportional counter data recorded in the 25–60 keV range during a balloon flight on October 17, 1970, were analyzed to extract the power spectrum for periods when the sensing system was directed at the Crab Nebula and at other portions of the sky. For the Crab an X-ray periodicity of 3.821 ± .015 seconds was observed, in addition to the 33 ms periodicity associated with pulsar CP 0532, as reported in 1970. The 3.821 second X-ray period is 2% slower than that of the radio pulsar CP 0527, which occurs in the same view-field. The possibility that both periods are manifestations of rotation of the same neutron star, with the period difference caused by the inertial frame drag of general relativity or some other effect has been considered speculatively, but inconclusively. The experimental result is considered marginal, but interesting.

Possible Observation of a Spectral Line Emission in the Cosmic Diffuse Background

Analysis of the pulse amplitude data obtained in rockets on 13 March 1969 and 28 February 1970,
showed the presence of a local excess in pulses at amplitudes corresponding to 6 to 7 keV of energy loss in the proportional counter. Attempts to explain these results in terms of instrumental effects failed, and the evidence was published for the presence of a line emission in the background spectrum. Such a result is very difficult to explain theoretically, since electrons interacting with iron atoms would produce line and background with a line/background ratio very much less than that observed. Initially, other X-ray observers disputed the results, but supportive data by others has been more recently obtained. The results nevertheless remain statistically marginal, and flights in the near future are planned to prove or disprove the observation.

Optical Geophysics and Solar Wind Studies:
Modeling of the Magnetoglow and Background

304 Å Emissions
A theoretical study was carried out of the resonant helium emission produced by scattering of sunlight by He⁺ ions distributed in the magnetosphere as indicated by satellite data. A morphological match to observations obtained on rocket NC 3.136 flown 13 October 1969 was obtained. The fit to the observations requires that part of the glow observed from
the rocket originates outside the magnetosphere, possibly due to He\(^+\) ions in the solar or interstellar wind.

A study of the location of the main equatorward arc of the aurora was carried out to determine whether the angle between the earth's magnetic dipole axis and the earth-sun line was important as regards the location of the oval. The analysis showed that this angle is not a major controlling parameter.

**Infrared Astronomy**

A rocket with far infrared photometers was flown from Wallops Island, and showed the presence of anomalous strong intensities of far IR glow. A comparison of NRL and Cornell University flights suggests that the local time of the flights affects the glow intensity observed. Flights flown shortly after sunset have shown high glow intensities; flights near midnight have shown lower intensities. The phenomenon is not understood, and confirming data are needed.

**Solar X-Ray Spectroscopy**

Analysis of flare spectra from OSO-6 has continued. The different behavior of lines in hot and cool flares has permitted sorting out of lines due to different stages of ionization in iron. As a result lines observed at 7.990, 8.233, 8.290, 8.317,
and 8.378 Å have been identified as transitions of Fe XXIV and a line at 8.307 has been identified as a transition of Fe XXXIII, in near agreement with calculations by R. D. Cowan. A comprehensive list of lines shortward of 8.49 Å was published.

SOLRAD

The SOLRAD X satellite was placed in operation as a solar XUV monitor and as a test of concepts for SOLRAD HI and HEAO A. Operation has been quite satisfactory with the result that solar monitoring with extended spectral coverage is now available.

Another year of solar monitoring by SOLRAD IX, in which all major solar events have been recorded, has been completed.

Electronic Imaging Program

Good progress has been made on a Mil Spec TV camera chain under NavShips' sponsorship. A range-gated TV system has been nearly completed but not fully tested. It awaits completion of the companion pulsed Nd laser by NEL before full testing can be implemented.

II. New Programs

The past year has seen a substantial shift in emphasis in the programs of the Upper Air Physics Branch from small projects and data reduction to the
preparation of equipment for large undertakings. These are: (1) The Lunar Surface UV Camera/Spectrograph, scheduled for flight on Apollo 16 in March 1972; (2) The SOLRAD HI two-satellite observatory, scheduled for launch to an orbit of 20 earth radii about December 1974; and (3) The LAXRAY Experiment (AXR-3), scheduled for launch aboard HEAO A about June 1975. Lesser, but still large, projects are the NRL XUV experiments, NNRL 114, scheduled for flight aboard SESP 72-1 about May 1972, the NRL XUV Solar Wind experiment, scheduled for flight aboard the NASA OSO-I spacecraft about December 1973, the DNA "Rocket Instrumentation Program," not yet scheduled for initial flight testing, and the Auroral IR Spectroscopy Study, scheduled for launch on a Black Brant 3 rocket about March 1972. An attempt to secure support for an Optical Geophysics and/or Astronomy Satellite, based on far UV imaging technology, has also been carried out during the year. A report on each of the firm programs follows.

Lunar Surface UV Camera/Spectrograph

The Lunar Surface UV Camera/Spectrograph is a Schmidt camera of 3-inch aperture, f/1.0, which uses electronographic, rather than photographic, recording. Two modes of operation are used with the camera on the lunar surface—direct imaging, and spectroscopy.
In the direct imaging mode, the camera will record in the range 1600 Å to 1050 Å or 1230 Å with two interchangeable corrector plates. In the spectrographic mode of operation, the camera views an objective grating, ahead of which is placed a photoengraved-grid collimator. The extreme spectral range will extend to 500 Å.

Objectives for the experiment include photography and spectral photography of geocoronal, airglow and auroral emissions, photography of patches of increased H in the solar wind, photographs of gaseous nebulae and other sources of UV emission outside the solar system, including likely extragalactic sources, and photographs of possible locally vented gas escaping from the lunar surface. Spectroscopic and photometric data on stellar emission is also expected. Instrument construction is proceeding on schedule.

**SOLRAD HI**

SOLRAD HI consists of a pair of spin-stabilized satellite observatories maintained at opposite sides of a 20 earth radius, low latitude circular orbit. The satellite sensors will monitor: solar X-ray and XUV radiation levels; ambient high energy particle fluxes; solar wind velocity, density, alpha-proton ratio, temperature and UV emissions; auroral X-ray fluxes; and earth albedo. A solar wind magnetic
field sensor and a solar X-ray polarimeter experiment are under consideration. Arrangements are to be made with AFCRL and Aerospace to provide the high energy particle sensing system, and with MIT to provide the main solar wind sensors. The primary objective of the satellite is to provide realtime space environmental data suitable for calculation of radio transmission attenuations and for prediction of communication disturbance conditions: radio fadeouts (SID), polar blackouts, and auroral absorption.

Work by all of the experimenters has been initiated; firm set of experiment designs is hoped for by Fall 1972.

**LAXRAY Experiment for HEAO A (AXR-3)**

The LAXRAY experiment for the NASA High Energy Astronomical Observatory (HEAO A) is a 1575 lb X-ray astronomy experiment designed to map the X-ray sky. It consists of a set of nine collimated X-ray proportional counters and one diffuse background module, supported by an auxiliary gas module and a central electronics module. The X-ray sensors are large area plastic window counters for the soft X-ray range, backed by scintillation counters to provide hard X-ray sensitivity. The counters view the sky mainly through 1° x 4° collimators, and scan the sky by means of a uniform 30-minute roll provided by the HEAO spacecraft.
The objective of the program is to provide a catalog of X-ray sources comparable to the 3C catalog of radio sources, giving locations, intensities, and spectral emission character of the observed X-ray objects. It is planned to have the experiment built by a contractor.

A small plastic window test counter has been flown on the SOLRAD X satellite and has operated properly.

SESP Experiment

The NRL SESP Experiment will provide data on the broadband spectral intensity of the XUV airglow and the intensity of earth X-rays originating in the aurora. The XUV sensors are sensitive from about 170 Å to about 1500 Å in several bands. The auroral X-ray sensor consists of a single proportional counter and a 4-channel pulse height analyser. The main motivation for flying the proportional counter is to obtain intensity and spectral information on auroral X-rays to judge their usefulness as auroral intensity indices, and to provide a basis for design of the SOLRAD HI auroral X-ray sensing system.

The experiments have been delivered to the spacecraft contractor for initial integration.
Rocket Instrumentation Program

The Rocket Instrumentation Program is a rocket experiment program undertaken in support of DNA needs. The program uses Code 7127 personnel, supported by Code 6612 personnel of the Nuclear Science Division. It is in a funded formative stage.

Auroral IR Spectroscopy Rocket

The Auroral IR Spectroscopy Experiment is an airglow emission study in the 5-60 micron range based on use of a liquid He-cooled Ebert-Fastie spectrometer. The spectrometer is being built by the Ray-Lee Corporation. The experiment is planned for flight in a Black Brant 5 rocket from Ft. Churchill in March 1972. Cryogenic problems and loss of ESD personnel assigned to the research team have threatened the flight schedule. The problem is partially supported by ARPA.
Very Long Baseline Interferometry

Two VLBI measurements of the 22 GHz \( \text{H}_2\text{O} \) sources were made: (1) between NRL, Green Bank, and Haystack with hydrogen masers, and (2) between Semeiz, U.S.S.R. and Haystack. A map of the W49 source region was made showing that the sources with sizes less than 0.0005 associated with individual lines are in different positions all within 1.5, but with no apparent relation between positions and radial velocities of the corresponding lines. For some lines the size limit is 0.0003 which corresponds to less than 5 A.U., i.e., less than the radius of Jupiter's orbit. Where the positions were separated by only a few fringes, high relative position accuracies of \( 10^{-4} \) arc seconds were obtained with hydrogen masers. The absolute position of the strongest component was measured to an accuracy of 1.5 \( \times 10^\circ \) where most of the error is systematic. This position for the water molecules agrees with that of the OH to within errors. Preliminary results indicate a precision of 10 to 15 meters in determining the position of the 85-foot antenna with respect to Haystack. For the Orion source, which is the closest to earth, some of the
components are partially resolved on the longer baselines; a source which was unresolved in June 1970 was partially resolved in February 1971 indicating a change in size from 0.4 to 1.5 A.U. A preliminary result for the USSR-USA baseline shows interference fringes on W49 at this baseline of 7400 km. The new Mark II VLBI system was used for the recent experiments.

A low frequency (120 MHz) VLBI experiment was done with Univ. of Maryland and NASA-Goddard between NRL and Green Bank to investigate the feasibility of VLBI at low frequencies and effects of the ionosphere. The phase stability of the interference fringes was excellent. The association of the compact source in the Crab Nebula with the Crab pulsar was confirmed through position coincidence, and flux densities measured for small diameter components of 10 other sources showing an increasing spectrum with frequency. Preliminary results of an experiment between NRL-Sugar Grove, Danville, Ill., and Owens Valley, Cal., indicate fringe detection over a 4000 km distance.

The potential for application of VLBI technology to navigation is being investigated, and a study of a moderate accuracy approach using a simple system measuring only fringe frequency on intense H2O sources
was evaluated theoretically. With a 6 foot antenna on the ship, navigation accuracies of 500 to 1000 meters are feasible at latitudes greater than ±30°. The main accuracy limitation is the knowledge of ship velocity. The accuracy can be increased by using hydrogen masers and time delay measurements with broader bandwidths.

22 GHz Water Molecule Radiation

Two searches for new H₂O sources using NRL radiometers in Australia discovered 7 new sources: the first by NRL personnel using a 29-foot NASA antenna; the second with scientists of the Australian CSIRO using the central 104 feet of the 210-foot Parkes radiotelescope. This increased the number of known celestial H₂O sources to 28.

One of the H₂O sources discovered at NRL in 1969 is associated with the variable star VY CMa, and for 2 years the H₂O emission remained stable. Between March and July 1971, the intensity decreased by a factor of 6. The possible association with characteristics of the star will be investigated. An extremely intense line in the spectrum of W49 has remained nearly constant for more than a year. Other extremely intense lines have varied rapidly.

Study of H₂O source time variations over 2 years
shows that some lines varied dramatically while others remained stable. The peak source intensity (any line) does not vary greatly in most cases. Only small variations in line frequency have been observed and are probably due to line blends. Since the H$_2$O and OH emission arise in the same general regions, and both are time variable and masers, an attempt has been made to associate their spectra and time variations without success.

**Searches for New Molecular Line Sources**

Line searches can be made more efficiently with the new radiometer system and more effort will be put into this area. Searches have been made at transition frequencies for C$_3$H$_4$, C$_3$H$_6$, HNO$_3$, OCS, CH$_3$CN, HCN, NH$_2$CN, CH$_3$CHO, HNCO, and NH$_2$HCO with varying degrees of effort so far without success.

**Solar Activity**

A radiometer-polarimeter at 9.5 mm was developed for studies of small diameter radio emission regions associated with regions of solar activity using the 1.6 resolution of the 85-foot. Good correlation is found with plage regions and between sense of circular polarization and the sense of magnetic field measured optically. Radio absorption is observed in H$_\alpha$ dark
filaments. The radio emission regions may give clues to the development of active regions, magnetic fields, and flare activity. Polarization structure of a minor flare region indicates a complex magnetic field.

Radio Source Characteristics

The variability of the radiation of quasars can be adequately fitted to the simple expanding cloud model in some cases but not others.

Polarization measurements of 10 sources at 9.5 mm gave intrinsic polarization and Faraday rotation.

Electronics

Initial problems in mounting and contacting Gallium Arsenide Schottky Barrier Diode chips produced in the cooperative program with the Electronics Division have been largely overcome. Initial tests show good characteristics at 30 GHz.

A new phase stable oscillator system for VLBI receivers has been designed and is under development.

The computer-controlled radiometer system was instrumented to perform the synchronous detection and integration of the signals to present a continuous oscilloscope display of the integration in the 50 channels, to calibrate and reduce the data on line, and to present the results on graphs, printouts, and punched tape.
The 18-26 GHz and 26-40 GHz spectral line radiometers were improved in performance.

Passive Remote Sensing of the Ocean

A dependence of the microwave brightness temperature of the sea on wind speed and sea state has been established arising from (1) the roughness of the water surface, and (2) the coverage of sea foam and white caps. The correlation of brightness with sea roughness increases with increasing observational frequency interpreted as a relative unimportance of roughness smaller than the radio wavelength. Enhancements of microwave brightness temperature > 100°K due to foam have been measured and found insensitive to polarization and angle of incidence. At high wind speeds effects of sea foam will dominate with the expected transition in the range of 30 to 40 knots.

A promising method for determining the thickness of oil slicks on water using passive microwave radiometry from airborne platforms was developed and tested. As the oil thickness increases through successive multiples of a quarter wavelength in oil, the brightness temperature passes through maxima and minima. By using two or more frequencies, ambiguities may be removed and the oil thickness determined.
Radar Remote Sensing of the Ocean

A theoretical investigation of satellite altimeter observations shows that the varying bias of the electromagnetic centroid relative to the geometric centroid due to different sea states must be determined. Measurements indicate the bias is about 5 percent of the significant wave height, and that sea state derived from radar measurements has a negative bias of only 6 percent of the significant wave height showing that sea state can be measured with short pulse radar.
ROCKET SPECTROSCOPY BRANCH

The following sections describe the accomplishment in each of the main areas of research emphasis in the Rocket Spectroscopy Branch.

OSO-7

On September 29, 1971 the seventh of NASA's series of Orbiting Solar Observatories was placed in orbit with the result that OSO-H became OSO-7. The pointed section carried two experiments prepared by NRL: A white light coronagraph covering the corona from 3 to 10 solar radii; an extreme ultraviolet coronagraph that recorded the range 171-630Å over and beyond the disk and with coverage decreasing to about 50% at about 5 solar radii. The objective of the pair of experiments is to relate changes occurring in the chromosphere and corona, as seen in the XUV, with changes in the solar wind as seen by the white light corona.

Both experiments are operating very well. They show striking day to day changes in both the white light and XUV coronas. The general changes are related to the magnetic field distribution over the sun and to the sectors in the magnetic field in space as observed by earth-orbiting satellites. The white light corona shows that the solar wind and the solar streamers are clearly related to the active regions seen in the XUV.

The white light coronagraph for the first time makes use of an SEC Vidicon operated in a digital mode to read and transmit images from a spacecraft to ground. The
image contains 256 x 256 picture elements. The corona is an object of very low light level. To detect the very low contrast features full use was made of the target storage capacity to obtain a high signal-to-noise ratio of 50 in each picture element. (The theoretical limit is 70 r.m.s.) In operation the SEC Vidicon is exposed for approximately 3 seconds to the sun's faint corona; on-board transfer of the target image to tape requires 44 minutes. The telemetered data are received at NRL by telephone line and reconstructed on a cathode ray tube. For the first time a polarizing plate has been used in the white light coronagraph in order to separate the F and K coronas. The white light instrument is operated in 3 to 5 successive orbits each day; in the normal mode one picture per orbit is obtained.

The XUV coronagraph is also operating very well, except for a reduction in sensitivity with time that is somewhat greater than expected. This is suspected to be caused by abnormal oxidation of thin film aluminum filters, used to exclude wavelengths from the visible to about 650Å. It appears that oxidation is occurring at an accelerated rate, owing to the presence of atomic oxygen in the atmosphere at spacecraft orbital altitudes. Nevertheless, excellent XUV images are being obtained. These show emission of XUV far beyond the sun's limb, extending to one solar radius with certainty, and probably to several radii. Research is planned to determine whether this is simply emission
from ions that are excited by collision or whether it is resonance scattering from photons emitted from the close-in corona.

The OSO-7 operation is extremely demanding of personnel and time. One or more members of the branch is required at the OSO Control Center at GSFC during certain periods each day to ensure that commands are sent and executed without error. It is possible for a command error to destroy the white light coronagraph.

The amount of data recorded from the two experiments is very great. Their volume causes a storage problem, and a manpower problem in processing and interpreting them in terms of the physical processes on the sun. The life of the spacecraft and experiments should be at least a year. At present the computerized data reproduction equipment is not completely operational, but is receiving maximum effort to prepare for the final data tapes when they do arrive.
SKYLAB:

The experiments being prepared by this branch for Skylab were described in the report for 1970. For ATM (the Apollo Telescope Mount) they are: the XUV spectroheliograph, S082A, the XUV high-resolving spectrograph, S-082B, and the television XUV system that forms part of S-082B. The two other experiments are S-020, a small grazing incidence XUV spectrograph, legally a "Corollary" experiment, but in fact included among the ATM solar experiments, and S-063, a Corollary experiment to photograph the twilight airglow and also the ultraviolet day airglow in an attempt to track ozone.

Construction and delivery of the instruments have progressed very well. We anticipate increasing demands upon our time during integration of the experiments in the Skylab, to train the astronauts, and incidentally ourselves in operating the mission after launch on April 30, 1973. From January 1973, four months prior to launch, until January 1974, conclusion of the third visitation, it will be necessary for a large group of scientists and engineers to take up continuous or at least intermittent residence at Houston, Texas, in order to control operation of the instruments. Inevitably these operations result in some reduction in the scientific productivity of the branch.

There are several continuing problems associated with Skylab. The ATM units, both prototype and flight, have been delivered, with the exception of the photographic
camera mechanisms. The latter are so intricate that more testing and debugging is required. A second problem on which progress has been made is the minimization of contamination, which can seriously affect the XUV instruments. NRL has designed and produced a Real Time Contamination Monitor consisting of a reflectometer that is placed in the test thermal vacuum chamber; it continuously measures the reflectance of a standard mirror for Lyman alpha radiation, 1216Å. Still another problem is the expected deterioration of the photographs during orbit through the proton flux over the South Atlantic anomaly, and as a result of high storage temperatures. All possible steps to minimize these effects have been taken. Nevertheless, it becomes absolutely necessary to calibrate the ATM instruments while in orbit. This is to be done by flying a series of calibration rockets which will use well-calibrated equipment to record exactly those solar features that are being recorded at the same time with the instrument in ATM. This rocket program is extremely complicated and expensive, but essential. It is not yet supported by NASA to the extent necessary to ensure complete success.

Another area of Skylab, and one where NRL has made perhaps the major input, is in programming the astronauts observing program. There are five institutions involved in ATM, and each has one or more instruments which serve several different purposes. To operate them all in such a way as to obtain the maximum and best results is a difficult problem, especially in view of other competition.
for astronaut time. It was finally decided to set up a series of observing programs each designed to acquire data bearing on a particular problem in solar physics. NRL has taken the major responsibility in coordinating the interests of the Principal Investigators. As a result, it appears that the ATM will be operated as a single large solar observatory with a series of separate but related purposes. Moreover, it appears probable that observatories all over the world will collaborate to observe special features of the sun simultaneously with observations from ATM. It is probable that each institution will receive a number of guests who will use the ATM data together with data they have obtained from ground during the mission.

NRL is in process of preparing for this data reduction effort. The most highly sophisticated computer-controlled microphotometer known to us has finally been delivered and is ready for assembly. It is intended to provide quickly on magnetic tape the readout of photographic images in accordance with a programmed scan. Following readout the data will be transformed by programs to calibrate them or weight them as desired.
ROCKETS:

To obtain solar XUV spectra one payload, a prototype ATM "B" instrument, was flown this year (in August 1971): it utilized an Aerobee-170 instead of a 150. As a result of a great improvement made in the ruling on the predisperser diffraction grating the spectra were free from scattered light. However, the NASA SPARCS II control system did not stabilize the instrument as well as the SPARCS I used on a previous flight. Analysis of these spectra has barely started. They will complement spectra obtained the previous year.

The so-called conglomerate payload, funded largely by NASA, is nearing completion for flight. This will contain a white light photographic coronagraph, a high resolution Lyman-alpha spectroheliograph, a repeat of the 1959 and 1960 Lyman-alpha profile photography to measure the hydrogen in the earth's atmosphere, and several other instruments.

Following this, it is not clear when funds will be available in sufficient quantity to prepare another rocket payload.

MAGNETOGRAPH:

Joint construction of the solar real-time vector magnetograph with the Marshall Space Flight Center is once again underway after a lapse caused by loss of funding. A technical difficulty was the de-bugging of the electronics associated with the SEC Vidicon. This work was transferred from EMR Sarasota, to EMR Princeton, and is now progressing satisfactorily. The equipment should be completed for
assembly and integration into the solar tower at Huntsville within six months.

LABORATORY WORK:

The most important work conducted in the extreme ultraviolet radiometry laboratory has been the study of diffraction gratings in order to ensure success of the ATM experiments. Two major problems have been resolved. The first was the excessive focused stray light produced by pre-disperser gratings being ruled by Bausch and Lomb. This was traced down to a variety of sources, and we have received at least one type of predisperser that is satisfactory. The second major problem was that the principal grating for the S-082B experiment was found to have deteriorated after one year to an extent that it was unusable. This was traced to the over-coating with aluminum of the gold replica. An intermetallic compound was gradually formed. After a year this destroyed the smoothness of the groove surfaces. The effect is related to the disease in electronic components called the "purple plague."

A sophisticated ray-tracing program has been produced for optical systems using more than one diffraction grating. It was found to be extremely useful, and has been applied to analysis of the performance of the S-082B ATM experiment. Consequently, anomalies in the behaviour of the spectrograph are understood and it became possible to arrive at optimum focus much more quickly. Although ray tracing has been in common use for complicated optical systems using lenses and mirrors, this has not been the case with diffraction
gratings for which little is available in the open literature. We believe that a major breakthrough in ray tracing was made in this work on diffraction gratings.

In the extreme ultraviolet spectroscopy laboratory, fluorescence of CO excited by the 1306 Å O I resonance line was investigated, because of its application to the earth's upper atmosphere and to planetary atmospheres. Work on the fine structure and perturbation analyses of the $A^3\Pi$ state, the lowest metastable state of CO, is approaching completion. The work is associated with the possible use of CO in UV lasers, and also with transitions that have been observed in atmospheres of other planets by satellites.

**DATA ANALYSIS:**

As mentioned in the introduction, data reduction of results from the space program has lagged owing to the urgency of ongoing programs. The results of the March 7, 1970 eclipse have been analyzed and it has been shown that emission from SiIII, AlIII, SiIV, and CIV actually extends to 10,000 km altitude in the solar atmosphere, much farther than can be explained on the basis of a homogeneous solar atmosphere. A model that explains the behaviour is proposed with cylindrical spicules, extending to 7000 km or more, each assumed to have a cool center sheathed by a transition zone extending to the interspicular corona.

Work has continued on analysis of the high resolution extreme ultraviolet limb spectra. Many new lines of SiI approaching the $3\,P$ limits, were discovered. The temperature in the continuum was also redetermined from the
center to limb variation in the range 1400-1790Å. The values from the 1970 flight are in agreement with those obtained in 1971, and also with the earlier data of NRL. Thus disagreement with intensity of the data reported by the Harvard College Observatory has not yet been resolved.

Work on the analysis of the solar spectrum in the range 171-630Å continues, based on the various grazing incidence spectra and also the flare spectrum of November 4, 1969. A number of important new identifications have been made, particularly in the spectra of Fe X, XI, XII, XIII, and XIV. In the flare, emission by Ni XVII and XVIII, Ar XV and XVI, and Ca XVII and XVIII have been discovered. The observation of CaXVIII implies that the flare plasma is still at a temperature of 8 million degrees from 6 to 10 minutes after the explosive phase of the flare.

SUMMARY:

The major success during this period has been completion of the experiments for OSO-H and their successful operation in orbit. Also successful was a rocket reflight of the ATM B instrument, resulting in solar spectra having negligible stray light. The third success was the delivery of the prototype and flight experiments for ATM, except for the camera mechanisms. A great deal of effort has been expended in the design of rocket-borne payloads required for calibration of the experiments in ATM, once they are placed in orbit. Unfortunately, support of this project by NASA is not sufficient. As a result of the great amount
of time spent on current and future experimental problems, and the difficulty in freeing personnel to work on theory and interpretation, publications in the area of space research have not been extensive. Extreme ultraviolet research in the laboratory, however, continues with publication at about the same level, in spite of limited funding.
APPENDIX A

SPACE SCIENCE DIVISION
and
E. O. HULBURT CENTER FOR SPACE RESEARCH

Publications and Talks
October 1970 - October 1971
Publications*

Friedman, Herbert
"Astronautics: Space Probes," 1971 Britannica
Yearbook of Science and the Future (William Benton,

Friedman, Herbert
"X-ray Background Radiation," presented at the
Pontifical Academy of Sciences, Vatican City,
April 1970; "Semaine d'Etude sur Les Noyaux des
Scientiarum Scripta Varia No. 35 (1971),
pp. 669-697.

Friedman, Herbert
"Priorities in Space Science and Applications,"
Statement by Herbert Friedman, The National
Space Program--Present and Future, a Compilation
of Papers prepared for the Subcommittee on NASA
Oversight of the Committee on Science and
Astronautics, U. S. House of Representatives,

Friedman, Herbert
Report of a Study on Space Science and Earth
Observations Priorities conducted by the Space
Science Board--National Research Council, chaired
by Herbert Friedman, Woods Hole, Massachusetts,
July-August 1970, published by the National

H. Friedman, T. A. Chubb, C. H. Mayer, R. Tousey

"Observatory Report: E. O. Hulburt Center for
Space Research, Naval Research Laboratory,"
Bull. Amer. Astron. Soc. 3, No. 1, Part II,

* Other co-authored papers appear in Code 7120 listing.
Papers to be published:

Friedman, Herbert

Friedman, H.

Friedman, Herbert

Friedman, H.
Invited Talks - H. Friedman


Publications:

Lepson, B.
"Entire Functions of Extreme Rates of Growth."

Lepson, B.

Noonan, J. W.

Noonan, J. W. and Thomas, D. K.

Papers to be published:

Lepson, B.
"Rates of Growth and Interpolation by Entire Functions with Non-negative Coefficients," Proceedings of the International Conference on Entire and Meromorphic Functions, Univ. of British Columbia, Vancouver, B.C., Canada, June 1971 (Invited Address).

Noonan, J. W.
"Boundary Behavior of Functions with Bounded Boundary Rotation," J. of Mathematical Analysis and Applications.

Noonan, J. W.

Noonan, J. W.
Papers to be published: (continued)

Noonan, J. W.
"On Close-to-Convex Functions of Order B."

Other Talks and Lectures:

Lepson, B.

Noonan, J. W.
Carruthers, G. R.

Henry, R. C.

Horan, D. M. and R. W. Kreplin

Meier, R. R. and D. K. Prinz

Tomblin, F. F. (Bellcomm, Inc.) and R. W. Kreplin

Weber, S. V., R. C. Henry and G. R. Carruthers
SPACE SCIENCE DIVISION
Upper Air Physics Branch (Code 7120)

Publications for 1971

Byram, E. T., T. A. Chubb, and H. Friedman
"Variability of X-Ray Emission from M-87,"

Byram, E. T., T. A. Chubb, and H. Friedman
"X-Rays from Centaurus A and the Far-Infrared Background Radiation: Reply to Ramaty."
Science 171, 500 (1971).

Carruthers, G. R.

Carruthers, G. R.

Carruthers, G. R.

Carruthers, G. R.

Carruthers, G. R.

Carruthers, G. R.

Carruthers, G. R., and T. L. Page

Buckley, J. L., H. W. Moos, and R. R. Meier
Carruthers, G. R.

Carruthers, G. R.

Doschek, G. A., J. F. Meekins, R. W. Kreplin, T. A. Chubb, and H. Friedman

Doschek, G. A., J. F. Meekins, R. W. Kreplin, T. A. Chubb, and H. Friedman

Doschek, G. A., J. F. Meekins, R. W. Kreplin, T. A. Chubb, and H. Friedman

Doschek, G. A.

Fritz, G. G., A. J. Davidsen, J. F. Meekins and H. Friedman

Publications for 1971 (Con't)

Henry, R. C., G. G. Fritz, J. F. Meekins, T. A. Chubb, and H. Friedman

Henry, R. C. and James E. Hesser

Hesser, J. E. and R. C. Henry

Hesser, J. E. and R. C. Henry

Horan, D. M. and R. W. Kreplin

Horan, D. M.

Johnson, C. Y., J. M. Young, and J. C. Holmes

Johnson, C. Y.

Johnson, C. Y.
Kahler, S. W. and R. W. Kreplin

Kahler, S. W.

Kahler, S. W., G. A. Doschek, J. F. Meekins, and D. M. Horan

Kurfess, J. D.

McNutt, D. P., K. Shivanandan, and P. D. Feldman

Meekins, J. F., G. G. Fritz, T. A. Chubb, and H. Friedman

Meier, R. R.

Meier, R. R. and C. S. Weller

Meier, R. R. and D. K. Prinz
Publications for 1971 (Con't)

Prinz, D. K. and R. R. Meier

Rottman, G. J., H. W. Moos, J. R. Barry, and R. C. Henry

Sadeh, D. S.

Schwentek, H., G. Hartmann, and R. W. Kreplin


Shulman, S. D., G. G. Fritz, J. F. Meekins, H. Friedman and M. Meidav

Smathers, H. W., D. S. Sadeh, and T. A. Chubb

Taylor, R. G.
Tinsley, B. A. and R. R. Meier  


Weller, C. W., R. R. Meier, and B. A. Tinsley  


Mange, P.  

A12
Holmes, J. C.  
"Use of Attitude Sensors to Determine the Motion of a Free Rotator". NRL Report 7194, 1971.

Meier, R. R., and P. Mange 
Talks 1970 (not included in 1970 Annual Report)

Carruthers, G.

Carruthers, G.

Carruthers, G.
"Optical Observations of Interstellar Molecules", presented at University of Maryland, Seminar on Interstellar Molecules, 5 October 1970.

Chubb, T. A., and Hicks, G. T.

Mange, P.
"OGO-4 Satellite Observations of the Far Ultraviolet in the Atmosphere from 100 to 10,000 km," presented at Space Physics Seminar, The University of Texas at Dallas, October 21, 1970.

Meier, R.
 Talks 1971 to date

Carruthers, G. R.

Carruthers, G. R.

Carruthers, G. R.

Chubb, T. A.

Chubb, T. A.
"X-Ray Astronomy - Recent Results from Rocket and Balloon Studies," American Physical Society Mtg., Wash., D. C., April 1971.


Doschek, G. A., J. F. Meekins, R. W. Kreplin, T. A. Chubb, and H. Friedman
Talks 1971 (Con't)

Doschek, G. A., J. F. Meekins, R. W. Kreplin, T. A. Chubb, and H. Friedman

Doschek, G. A.

Doschek, G. A., and J. F. Meekins

Johnson, C. Y.

Johnson, C. Y.

Johnson, C. Y.

Kahler, S. W., and R. W. Kreplin

Kurfess, J. D.
"Gamma-Ray Astronomy with Large Scintillation Detectors," AAS Division of High Energy Astrophysics - APS Division of Cosmic Physics, San Juan, Puerto Rico, December 1971.
Talks 1971 (Con't)

Meier, R. R., and C. S. Weller

Prinz, D. K., and R. R. Meier

Sadeh, D. S., M. Meidav, H. W. Smathers, T. A. Chubb, and H. Friedman

Shivanandan, K.

Shivanandan, K.

Shivanandan, K.
"Space Science at Naval Research Laboratory," Tata Institute of Fundamental Research, Bombay, India; National Physical Research Laboratory, Ahmedabad, India; University of Malaya, Kuala Lumpur, Malaysia; University of Singapore, Singapore, Malaysia; Rotary Club, Singapore, Malaysia; Teachers Training College, Jaffna, Ceylon; Scientific and Industrial Research, Columbo, Ceylon, June to July 1971.

Shulman, S. D.
Talks 1971 (Con't)

Taylor, R. G.

Taylor, R. G., and R. W. Kreplin

Weller, C. S., and R. R. Meier

Mange, P.
SPACE SCIENCE DIVISION

Code 7120

1971
AWARDS


NRL Research Publications Award, 1970


SPACE SCIENCE DIVISION
Radio Astronomy Branch (Code 7130)

Publications October 1, 1970 thru October 20, 1971


Hobbs, R. W. and Johnston, K. J.
"Observations of Seven Compact Sources in H II Regions at Wavelengths of 0.95, 1.65, and 2.73 Centimeters," Astrophys. J., 163, 299, January 1971.

Knowles, S. H. and Cheung, A. C.

Hollinger, J. P.

Shapiro, A., Yaplee, B. S., and Uliana, E. A.

Hammond, Donald L.

Hobbs, R. W. and Waak, J. A.

Hobbs, R. W. and Knapp, S. L.
Mayer, C. H. and McCullough, T. P.
"Microwave Radiation of Uranus and Neptune,"

Johnston, K. J., Knowles, S. H., Sullivan, W. T. III,
Moran, J. M., Burke, B. F., Lo, K. Y., Papa, D. C.,
Papadopoulos, G. D., Schwartz, P. R., Knight, C. A.,
Shapiro, I. I., and Welch, W. J.
"An Interferometer Map of the Water-Vapor Sources in W49,"

Sullivan, Woodruff T. III
"Variations in Frequency and Intensity of 1.35 Centimeter H₂O Emission Profiles in Galactic H II Regions,"

Johnston, K. J.
"Photoelectric Observations of UU Piscium,"

Yaplee, B. S., Shapiro, A., Hammond, D. L., Au, B. D., and Uliana, E. A.
"Nanosecond Radar Observations of the Ocean Surface from a Stable Platform,"

Hollinger, James P.
"Passive Microwave Measurements of Sea Surface Roughness,"

Sullivan, Woodruff T. III
"Microwave Radiation of Water Vapor in Galactic Sources," Doctoral Dissertation, University of Maryland, College Park, Maryland, July 1971.

Waak, John A. J.
Publications October 1, 1970 thru October 20, 1971 (cont'd.)

Johnston, K. J., Knowles, S. H., and Sullivan, W. T. III
"Observations of 1.35-Centimeter H\textsubscript{2}O Emission in
the Southern Hemisphere," Astrophys. J. (Letters),
167, L93, August 1971.

Hollinger, J. P.
"Passive Microwave Studies," Third Annual Earth
Resources Program Review, December 1-3, 1970,
Vol. III, Hydrology and Oceanography, p. 69-1,
1971.

Yaplee, B. S., Shapiro, A., Au, B. D., Hammond, D. L.,
and Uliana, E. A.
"Nanosecond Radar Observations of the Ocean
Surface from a Stable Platform," Third Annual
Earth Resources Program Review, December 1-3, 1970,
Vol. III, Hydrology and Oceanography, p. 68-1,
1971.

Hollinger, James P.
"Remote Passive Microwave Sensing of the Ocean
Surface," Proceedings of the Seventh International
Symposium on Remote Sensing of Environment,

Yaplee, B. S., Shapiro, A., Hammond, D. L., and
Uliana, E. A.
"Ocean Wave Height Measurements with a Nanosecond
Radar," Proceedings of the Seventh International
Symposium on Remote Sensing of Environment,
Talks October 1, 1970 thru October 20, 1971

Knowles, Stephen H.
"Very-Long-Baseline Interferometry of Water Sources," Seminar on Interstellar Molecules, Univ. of Maryland, College Park, Maryland, 2 November 1970.

Yaplee, B. S., Shapiro, A., Hammond, D. L., and Uliana, E. A.

Hollinger, James P.


Sullivan, W. T. III, NRL and Univ. of Md., and Kerr, F. J., Univ. of Md.

Johnston, Kenneth J.
Talks October 1, 1970 thru October 20, 1971 (cont'd.)

Clark, T. A., Donn, B., Jackson, W. M., NASA/GSFC; Sullivan, W. T., NRL; and Vandenberg, N., Univ. of Maryland
"Radio Search for H$_2$O Comet Bennett (1969i),"


Yaplee, B. S., NRL and Smith, S. L., NWL

Knowles, S. H. and Sullivan, W. T., III
"Interferometric and Single-Antenna Observations of the 1.35-Cm H$_2$O Transition in Galactic Sources," Radiophysics Division, CSIRO, Sydney, Australia, 23 April 1971.

Yaplee, B. S., Shapiro, A., Hammond, D. L., and Uliana, E. A.

Hollinger, James P.
Talks October 1, 1970 thru October 20, 1971 (cont'd)

Yaplee, B. S., Shapiro, A., Hammond, D. L., and Uliana, E. A.

Hollinger, James P.

Sullivan, W. T., III

Miller, Lee S., Brown, Gary S., RTI; and Hammond, Donald L., NRL

Schwartz, Philip R.

Johnston, K. J., NRL; Robinson, B. J., Caswell, J. L., and Batchelor, R. A., CSIRO, Sydney, Australia

Hollinger, James P.
Talks October 1, 1970 thru October 20, 1971 (cont'd)

Shapiro, A., Uliana, E. A., and Yaplee, B. S.
"Radar Pulse Shape Versus Ocean Wave Height,"
NOAA/NASA/NAVY Conference on Sea Surface
Topography from Space, Key Biscayne, Florida,
6-8 October 1971.
SPACE SCIENCE DIVISION
Rocket Spectroscopy Branch (Code 7140)

Publications - August 1970 through October 1971

Hunter, W. R. and Hass, G.

Hunter, W. R.

Tousey, R.

Tousey, R.

Tousey, R.

Winter, T. C., Jr. and VanHoosier, M. E.

Sandlin, G. D. and Widing, K. G.

Prinz, D. K. and Meier, R. R.

Howard, R.A., Vanderslice, J.T. and Tilford, S.G.

Brueckner, G.E., Bartoe, J.F., Nicolas, K.R. and Tousey, R.

Brueckner, G.
Code 7140

Publications - August 1970 through October 1971

Herzberg, G., Hugo, T. J., Tilford, S. G. and Simmons, J. D.

Moe, O. K., Brueckner, G. E. and Hagyard, M. J.

Benesch, W., Vanderslice, J. T. and Tilford, S. G.

Ginter, M. L. and Tilford, S. G.

Hunter, W. R., Osantowski, J. F. and Hass, G.
"Reflectance of Aluminum Overcoated with MgF_2 and LiF in the Wavelength Region from 1600 Å to 300 Å at Various Angles of Incidence," Applied Optics, 10, No. 4, 540-544, 1971.

Moritz, B. K. and VanHoosier, M. E.

Hunter, W. R., Mikes, T. L., Anstead, R. J. and Osantowski, J.F.

Howard, R. A.

Michels, D. J., Tilford, S. G. and Quinn, J. W.

Tilford, S. G.
Tilford, S. G. and Simmons, J. D.

Hunter, W. R., Cox, J. T. and Hass, G.

Pitz, E.

Widing, K. G., Sandlin, G. E. and Cowan, R. D.

Hunter, W. R., Cox, J. T., Hass, G. and Ramsey, J. B.

Tousey, R. and Koomen, M. J.

Brueckner, G. and Nicolas, K. R.

Tousey, R.
"High Resolution Solar XUV Observations," Space Research XII, (Accepted for publication) 1971.

Tilford, S. G. and Ginter, M. L.
"Electronic Spectra and Structure of the Hydrogen Halides: States Associated with the (σ^2 π^2) Cσ and (σ^2 π^2) Cσ Configurations of HCl and DCl," Journal of Molecular Spectroscopy (accepted for publication) 1971.

Tilford, S. G. and Simmons, J. D.
Code 7140

Publications - August 1970 through October 1971

Brown, C. M. and Ginter, M. L.
"Spectra and Structure of He2 Molecule, VI: Characteri-
ization of States Associated with 3p pi and 2s," Journal
of Molecular Spectroscopy (accepted for publication) 1971.

Ginter, M. L. and Brown, C. M.
"Dissociation Energies of X doublet sigma + u (He2+) and
A singlet sigma + u (H2)," Journal of Chemical Physics
(accepted for publication) 1971.

Ginter, M. L. and Tilford, S. G.
"Hopfield Continuum in High Orders Using an Argon Filter,"

Howard, R. A.
"Energy Levels of the Rotation Vibrator," Journal of

Tilford, S. G., Howard, R. A. and Ginter, M. L.
"Fluorescence of Carbon Monoxide Excited by the 1306Å
Oxygen Resonance Line," Journal of Chemical Physics,
(submitted for publication) 1971.

Bohlin, J. D., Koomen, M. J. and Tousey, R.
"Rocket-Coronagraph Photometry of the March 1970 Solar
Corona Between 3 and 8.5 R\(_S\)," Accepted for publication,
Talks - August 1970 through October 1971

Milone, E. F. and Schneider, W. P.

Tousey, R.

Ginter, M. L.

Hunter, W. R.

Tousey, R.
"XUV Television of a Solar Image from a Rocket," Symposium on The Processing of Telescopic Images, Laval University, Quebec, Canada, 1-2 October 1971.

Hutcheson, E. T., Cox, J.T., Hass, G. and Hunter, W. R.
"Monitoring the Thickness of Thin MgF2 and LiF Films on Al by Reflectance Measurements using the 1216Å Line of Hydrogen," 1971 Annual Meeting Optical Society of America, Ottawa, Canada, October, 1971.

Hunter, W. R., Mikes, T. L. and Hass, G.

Tousey, R.
SPAC...
APPENDIX B

E. O. Hulburt Center for Space Research
and
Laboratory for Cosmic Ray Physics

COLLOQUIA
E. O. Hulburt Center for Space Research
and
Laboratory for Cosmic Ray Physics

COLLOQUIA

20 August 1970
Prof. Yehuda Yeivin, Univ. of Tel Aviv and Goddard Institute for Space Studies
"MUON SPECTRA AND CHARGE RATIOS IN THE COSMIC RADIATION"

15 September 1970
Dr. Richard C. Henry, Johns Hopkins University and NRL
"RECENT RESULTS IN X-RAY AND ULTRAVIOLET ASTRONOMY"

8 October 1970
Prof. K. McCracken, Univ. of Adelaide, South Australia and Univ. of Texas at Dallas
"SOLAR COSMIC RAYS"

22 October 1970
Prof. Donat G. Wentzel, Univ. of Maryland, Astronomy Dept., College Park, Md.
"ACCELERATION AND HEATING OF THE INTERSTELLAR GAS BY COSMIC RAYS"

5 November 1970
"X-RAY EMISSION FROM SUPERNOVA REMNANTS"

12 November 1970
Prof. P. J. E. Peebles, Dept. of Physics, Princeton University, Princeton, New Jersey
"HOW DO GALAXIES FORM?"

3 December 1970
Dr. Seth D. Shulman, Research Associate, E.O. Hulburt Center for Space Research, NRL
"THE INTERSTELLAR MEDIUM: A HIGH RESOLUTION OPTICAL STUDY OF THE INTERSTELLAR LINE SPECTRUM OF ZETA OPHIUCHI"
11 December 1970
Prof. Livio Scarsi, Dept. of Physics, University of
Palermo, Palermo, Sicily, Italy
"GAMMA RAY OBSERVATIONS OF THE CRAB NEBULA PULSAR"

7 January 1971
Dr. R. Grant Athay, High Altitude Observatory,
Boulder, Colorado
"ENERGY BALANCE IN THE CHROMOSPHERE-CORONA TRANSITION
REGION"

14 January 1971
Dr. John H. Hoffman, Assoc. Professor, Atmospheric
and Space Sciences, The Univ. of Texas at Dallas,
Dallas, Texas
"COMPOSITION MEASUREMENTS OF THE POLAR IONOSPHERE--THE
POLAR WIND"

28 January 1971
Mr. Harry A. Taylor, Jr., Thermosphere and Exosphere
Branch, Goddard Space Flight Center, NASA, Greenbelt,
Maryland
"SOME RECENT RESULTS OF TOPSIDE ION COMPOSITION
MEASUREMENTS"

11 February 1971
Dr. Richard L. Blake, Dept. of Astronomy and Astro-
physics, University of Chicago, Chicago, Illinois
"K X-RAY TRANSITIONS IN MULTIPLY IONIZED ATOMS: SOLAR
AND LABORATORY"

18 February 1971
Dr. Joseph Silk, Berkeley Astronomy Department, Univ.
of California, Berkeley
"X-RAYS AND THE INTERSTELLAR MEDIUM"

25 February 1971
Prof. L. Woltjer, Dept. of Astronomy, Columbia Univ.,
New York
"QUASI-STEellar OBJECTS AND ACTIVE NUCLEI IN GALAXIES"

11 March 1971
Prof. S. Chandrasekhar, The Enrico Fermi Institute,
University of Chicago, Chicago, Ill.
"ON THE PROBLEM OF ROTATING STARS IN GENERAL
RELATIVITY"
18 March 1971
Dr. Chet B. Opal, Joint Inst. for Laboratory Astrophysics, University of Colorado, Boulder, Colorado
"SECONDARY ELECTRON SPECTRA FROM ATMOSPHERIC GASES WITH EMPHASIS ON THE AURORA"

1 April 1971
Mr. Patrick S. McIntosh, Space Disturbances Laboratory, Environmental Science Services Administration, Boulder, Colorado
"SUNSPOT EVOLUTION AND SOLAR FLARES"

29 April 1971
Dr. A. A. Penzias, Bell Telephone Laboratories, Inc., Holmdel, New Jersey
"MILLIMETER WAVE OBSERVATIONS OF INTERSTELLAR MOLECULES"

6 May 1971
Dr. Ray Weymann, Steward Observatory, University of Arizona, Tucson, Arizona
"CURRENT RESEARCH ON NUCLEI OF GALAXIES AT THE UNIVERSITY OF ARIZONA"

20 May 1971
Prof. Kinsey A. Anderson, Dept. of Physics, Univ. of California, Berkeley, California
"SOLAR FLARE X-RAY BURSTS"

27 May 1971
Dr. Frank Low, Lunar and Planetary Laboratory, Univ. of Arizona, Tucson, Arizona
"FAR INFRARED ASTRONOMY"

17 June 1971
Dr. Blair D. Savage, Washburn Observatory, Univ. of Wisconsin
"STUDIES OF THE INTERSTELLAR MEDIUM FROM OAO-2"

15 September 1971
Dr. Herbert Friedman, Supt., Space Science Division, NRL
"TWENTY-FIVE YEARS OF ROCKET ASTRONOMY AT NRL"

23 September 1971
Prof. J. H. Oort, Leiden Observatory, Leiden, Holland
"RADIO STRUCTURE OF GALAXIES"
7 October 1971
Prof. A. G. W. Cameron, Belfer Graduate School of Science, Yeshiva University, New York
"EVOLUTION OF THE GALAXY AND ABUNDANCE OF BLACK HOLES"

21 October 1971
Dr. Allen G. Blair, Los Alamos Scientific Laboratory, Los Alamos, New Mexico
"RECENT ROCKET OBSERVATIONS OF THE FAR INFRARED BACKGROUND"

4 November 1971
Prof. Edward P. Ney, School of Physics and Astronomy, University of Minnesota, Minneapolis, Minn.
"RECENT GROUND-BASED OBSERVATIONS IN INFRARED ASTRONOMY"

18 November 1971
Prof. William A. Fowler, Kellogg Laboratory, California Institute of Technology, Pasadena, California
"SYNTHESIS OF THE SUPERHEAVY NUCLEI"