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NEW DISCOVERIES IN SPACE SCIENCE AT NRL DURING THE PAST YEAR

The Space Science Division program has had substantial successes in all elements of its flight program during the past year.

The following is a list of some of the more noteworthy results:

1. The mean number density of atoms between earth and Tau XR-1 (The Crab Nebula) was determined to be 0.55 atoms cm^{-3}, assuming normal cosmic abundance. (AEROBEE)

2. The above study also placed limits on the ratios Ne/He and O/He and showed that observations were compatible with normal cosmic abundances, but incompatible with any oxygen excess of a factor of 3. (AEROBEE)

3. A new study of the diffuse, soft x-ray background at high galactic latitude again found evidence that the flux of photon energy <1 keV is greater than an extrapolation of the flux curve observed between 1-10 keV, and showed for the first time with certainty that the excess is due to x-rays and not to electrons or other effects. (AEROBEE)

4. Discovery of H_2 in the column path between earth and ξ Persei, observed in absorption in the 1000 - 1120 A region with an electronographic camera. (AEROBEE)

5. A slow scan study of the extragalactic source Cen A, revealed a low x-ray intensity which can be explained if the infrared background glow is not hotter than ~3 °K. (AEROBEE)

6. Far UV electronographic recording was used in star field photography for the first time. (AEROBEE)

7. Calcium K line photometry of A stars in the Southern Hemisphere has confirmed an earlier finding that the abundance of Ca (and presumably other metals) varies about a factor of 2 in typical field population I stars.

8. The observed dimness of geocoronal glow over the polar caps has been interpreted as the effect of a reduction in Hydrogen by virtue of its ionization ($H + O^+ \rightarrow H^+ + O$), supersonic acceleration, and loss from the earth in the outward flow of the polar wind. (OGO-4)

9. A 1304 A OI glow was discovered, which occurs in post-sunset or pre-dawn periods when the portion of earth magnetically conjugate to the observing point is sunlit at approximately the 200 Km level. (OGO-4)

10. Discovery of the magnetoglow of He II 304 A in the night sky. The portion of the magnetosphere below the plasmapause is glowing with resonantly scattered 304 A photons and the magnetospheric structure can, in principle, be studied by 304 A photography. (AEROBEE)

11. Solar flare plasmas have been found to have a characteristic time history pattern. Characteristically the temperature peaks first, next the x-ray radiation output, and finally the emission measure. (SOLRAD)

12. Solar spectra (1170 - 1800 A) were photographed at 8″, 24″, 40″, and 5′ inside the photospheric limit, the profiles of H I Lyman-α; the OI ($3p - {}^3S^6$) resonance triplet 1302, 5, 6; Si II, C II and Al II showing solar reversals of greatest depth close to the limb.

UPPER AIR PHYSICS BRANCH

X-Ray Astronomy Program

Since the last report x-ray observations of both discrete objects and of the diffuse background of space have continued, using the Aerobee rocket as carrier vehicle. The highlight of the effort was the discovery of the x-ray pulsar in the Crab Nebula and the measurement of its x-ray light curve. The x-ray light curve was found to be remarkably similar to the light curve observed in the visible, except that a higher fraction of x-ray emission occurs during the secondary pulse. The secondary pulse is also seen to start earlier than its optical counterpart. The integrated x-ray output of the pulsar was found to be equal to 6% of the total x-ray output of the Crab Nebula.

X-ray studies of the Crab Nebula were carried out with special emphasis being given to the soft x-ray portion of the spectrum, where the absorbed fluxes provide a measure of the column density of interstellar material. Using a combination of proportional counter pulse amplitude spectroscopy and two color photometry based on the transmission properties of Mylar and Teflon windows, the mean number density of atoms between earth and Tau XR-1 was determined to be 0.55 atoms cm^{-3}, assuming normal cosmic abundance. Some of the absorption, however, may be due to He within the source. The study also placed limits on the ratios Ne/He and O/He and showed that observations were compatible with normal cosmic abundances but incompatible with an oxygen excess of a factor of 3. A photon spectrum fitting an

emission law in the 1-10 keV region of:

$$n\ (E)\ dE = 9.27\ E^{-2.0\pm.1}\ dE$$

was indicated by the results.

A new study of the diffuse soft x-ray background at high galactic latitude was performed with the same counter assembly. This second study again found evidence that the diffuse soft x-ray flux of photon energy < 1 keV is greater than an extrapolation of the flux curve observed between 1-10 keV, and showed for the first time with certainty that the excess is genuinely due to x-rays and not to electrons or other effects. The excess flux is explainable either in terms of an increase in the background spectral index toward lower energy, or in terms of an added thermal component, perhaps emission from a hot intergalactic medium. This study indicated that a gas temperature of $\sim$ 4 million degrees would have to be assumed for this thermal component instead of the $\sim$ 1 million degree temperature, or less, reported previously. The higher temperature is required, because the new study shows that an excess soft x-ray flux exists throughout the spectrum below 1 keV.

Two slow scan studies of extragalactic sources were carried out, the first being a study of Cen A, the second of M-87 and 3C273. The scan of Cen A resulted in positive indication of emission from the northern radio lobe and the optical center, but at only a 2σ statistical level. The relatively low intensity measured places limits on possible models of the emitting relativistic plasma and on the infrared background glow, which is subject to Compton scattering by the plasma. The low x-ray intensity is more easily explained if

the infrared background glow is not hotter than ~ 3° K. The 1969 scan of M-87 resulted in a signal 11σ above background, and defined the position of the x-ray source to be the same as that of the optical galaxy within an error box of ~ ±0.5 deg. The spectrum was found to be soft, fitting a law:

$$n(E)\,dE = 0.15\,E^{-3.0}\,dE$$

The scan of 3C273 resulted in a positive signal but again only at a 2σ level.

Infrared Studies

A mapping survey of a portion of the sky near Orion using a liquid-helium-cooled telescope and four band-sensitive detectors covering the spectral range 10-1000 microns was attempted from a Black Brant VB rocket. The study did not contribute reliable astronomical results mainly because of interference problems associated with dust-like scatterers passing by the telescope view-field.

Ultraviolet-Astronomy Studies

Stellar spectroscopy and star field photography were both pursued using electronographic camera techniques. The highlight of the program was the discovery of substantial amounts of H_2 in the column path between earth and ξ Persei. The molecular hydrogen was observed in absorption in the spectral region 1000-1120 A by means of the vibrational transitions of the Lyman resonance series ($B^1\Sigma_u \leftarrow X^1\Sigma_g$), and bands (0,0) through (7,0) were observed. An H_2 column density of 1.3×10^{20} cm^{-2} was deduced from a comparison with laboratory absorption spectra.

The atomic H column density as deduced from the equivalent width of the Lyman-α line at 1216 A was 4.2×10^{20} cm^{-2}. The presence of molecular hydrogen absorption bands in the spectrum of ξ Per and its lack in the absorption spectrum of other bright stars thus far studied is believed a result of the presence of a dust cloud in the column path to ξ Per. ξ Per is strongly reddened showing a color excess E (B-V) = 0.33.

A spectral study of Orion stars was carried out in 1969, which provided a spectrum of the star θ Orionis. The spectrum showed an interstellar Lyman-α absorption line with an equivalent width of 16 $\pm$ 4 A, corresponding to an H column density of 5×10^{20} atoms cm^{-2}, which is about one-fifth of the column density which had been deduced from an interpretation of 21 cm absorption data. The radio data agrees with the ultraviolet data, however, if an atomic hydrogen spin temperature of 20 °K, rather than 100 °K, is used in interpreting the radio results. Far UV photometer data was also obtained for θ Orionis, which indicates that it is much brighter in the far UV than would be the case for an inverse wavelength reddening law. Instead it appears that the color excess observed in the far UV is almost the same as in the visible. One possible explanation for the anomalous behavior of θ Orionis is that the fine grains that contribute most to absorption in the far UV from most stars have been lost from the dust cloud surrounding θ^1C Ori.

Also in 1969 far UV electronographic recording was used in star field photography for the first time. Photographs were taken of the Orion region using a Schmidt camera with CaF_2 corrector. The most striking feature was the absence of

any recorded signal from α Orionis, which illustrates how completely the extended atmosphere of a red supergiant degrades the spectrum of a high energy producing object. Also conspicuous by its absence is Barnard's Loop Nebula. The lack of any visibility of Barnard's Loop suggests that nebular emission is much less in the 1230-2100 A spectra region than in the 2200-3200 A near-ultraviolet region, probably due to differences in the absorption or scattering properties of interstellar grains in these two wavelength regions.

Visible and Near-Visible Astronomy

Calcium K line photometry of A stars in the Southern Hemisphere has confirmed an earlier finding that the abundance of calcium (and presumably other metals) varies about a factor of two in typical field population I stars. Observation of six clusters of stars, however, showed that in at least one (NGC 6475) the range of metal abundance is much less, perhaps within ±20%, which is within the limit of sensitivity of the observing method. This suggests that in at least some cases, clusters are born out of clouds much more homogeneous in composition than the general run of material in the galactic plane.

A low-light-level television has also been used in combination with etalon Hα filters to study Hα from the Jupiter disk. With an initial filter assembly evidence for emission variations was found in 1969. The 1970 results have been uncertain, with steady Jovian emission having been observed on two good nights and variable disk emission having been observed during one night. The etalon filters are now rotated during the orthicon image integration period to provide improved field uniformity.

Aurora, Airglow, and Geocorona

Two low-light-level image-orthicon television systems are in use in Norway in a cooperative research effort with the University of Oslo. The systems have been used to photograph the aurora. Single station observations were obtained of one flaming aurora, which occurred at unusually high invariant latitude. Assuming a 110 km altitude for the lower border the apparent velocity up the magnetic field lines was determined for the rising curtains of light. The emission was found to be explainable in terms of the velocity dispersion of electrons with the electrons accelerated in bunches at the magnetic equator.

Earth auroral studies have continued using OGO-4 data. The aurora is seen by downward looking photometers on both day and night crossings of the auroral oval, with the midday aurora being on the average 40% as intense as the midnight aurora. Proton-rich aurora are distinguishable from electron-rich aurora and occur poleward during the late afternoon and early evening hours. At increasing K_p, the aurora both intensifies and moves to lower latitude. The aurora as observed in molecular N_2 emission does not cover the polar cap, but exists as one or several broad arcs around the auroral oval. At invariant latitude greater than 80° and at times near geomagnetic midnight the sky is about as dark in N_2 emission as at temperature latitudes; hence, astronomical work may be possible above the auroral zone.

As noted in the previous report, radiative transport theory, including multiple scattering, has been applied to explain the observed Lyman-alpha airglow caused predominantly by the scattering of solar photons around the earth in the optically thick hydrogen geocorona. These analytic techniques have been used to show that a

non-terrestrial Balmer-alpha background of some 3 to 4 rayleighs must be present in addition to the airglow. Moreover, correlation of Lyman-alpha intensities observed from beyond the geocorona by OGO-III with solar activity suggests the presence of an atomic hydrogen component in space which is scattering solar radiation and is distinct from the geocorona. Monthly variations of 30% in the geocoronal glow itself provide evidence for the variability of the solar flux at the center of the Lyman-alpha line. The observed dimness of geocoronal glow over the polar caps has been interpreted as the effect of a reduction in hydrogen by virtue of its ionization, supersonic acceleration, and loss from the earth in the outward flow of the polar wind.

Another glow phenomena discovered is a 1304 A OI glow which occurs in post-sunset or pre-dawn periods when the portion of earth magnetically conjugate to the observing point is sunlit at the ~ 200 km level. When the solar zenith angle of the conjugate point is 90°, the typical intensity observed for the post-sunset or pre-dawn condition is ~ 50 rayleighs.

Helium Magnetoglow

A second study of the night glows responsible for maintaining E and lower F region ionization showed that He II radiation at 304 A is incident on the night sky. A mapping of the 304 A brightness under conditions such that the sun was depressed 44° below the horizon at an azimuth of 293° indicated that an intensity maximum of 7 rayleighs occurred to the southwest at an azimuth

of 248°, indicating a concentration of He^+ ions toward the equatorial plane. The data imply that the portion of the magnetosphere below the plasmapause is glowing with resonantly scattered 304 A photons, and that the magnetospheric structure can, in principle, be studied by 304 A photography. We call this glow phenomenon the magnetoglow. It is analogous to the Lyman-α glow of the geocorona, except that, since the He^+ scatterers are charged, they must distribute themselves in conformity with the magnetic structure of the earth. He^+ glow regions can be expected to be found around other planetary objects. On the sun high density coronal structures are seen in magnetoglow radiation from high ionization states of iron, magnesium, and other elements.

Solar Monitoring, Solar X-Ray Spectroscopy, Study of Solar Events

Throughout the period covered by this report, the x-ray output of the sun has been monitored from the SOLRAD 9 satellite, with the result that no major solar activity events (i.e., events lasting longer than about 20 minutes) have escaped notice. Lists of the events and intensity plots are published in the ESSA Research Laboratories' publication, "Solar Geophysical Data," obtainable through World Data Center A, Upper Atmosphere Geophysics, ESSA, Boulder, Colorado 80302. Individual events have been studied both by using x-ray photometer data and by using Bragg crystal spectrometer plots of their .5 - ~13 A emission spectrum. It has been found possible to interpret the emission character of all events studied in terms of the thermal emission of hot plasmas. Observations at the shorter wavelengths tend to emphasize the hotter portions of the plasma. Plasma electron temperatures are

deduced from the intensity ratio $\lambda\lambda$ 0.5 - 3 A/$\lambda\lambda$ 1 - 8 A, which provides basically an x-ray continuum temperature. Plasma electron temperatures are also derived using line intensity ratios, working usually with resonance lines of one and two electron ions of the same element. More specifically for the case of silicon, electron temperature is derived from the line ratio R_{Si} observed for the transitions

Si XIV ($1s\ ^1S$-$2p\ ^2P$) / Si XIII ($1s^2\ ^1S$ - $1s2p\ ^1P$).

Temperatures calculated from sulphur and calcium line ratios are slightly higher than those calculated for silicon. The temperatures calculated from line ratios are in general agreement with those calculated from the x-ray continuum using the band sensitive photometers, provided the mean observations wavelengths are in the same region of the spectrum.

A flare classification system based on plasma temperatures was developed: Cool flares, Te < 10^7 K; medium flares, 10^7 K < Te < 2 x 10^7 K; hot flares, 2 x 10^7 K < Te < 3 x 10^7 K; superhot flares, Te > 3 x 10^7 K. Most sizable x-ray events are medium flares; most small events are cool flares; hot flares are very rare; and superhot flares are yet to be seen.

Flare plasmas have been found to have a characteristic time history pattern. The flare plasma is characterized by electron temperature, emission measure ($\int n_e^2 dV$) and x-ray radiation output. Characteristically in a flare the temperature peaks first, next the x-ray radiation output, and finally the emission measure; in other words the emission measure continues to grow during the early bright stages of flare formation. Often the emission measure stays almost constant during the late stages of the

flare in which case the emission of the flare appears to merge into that of the corona as the plasma cools.

Identification of most of the bright x-ray lines from the flare plasma has been made in terms of: (1) Lyman series lines of ions with single electrons, (2) allowed, forbidden, and intercombination lines of ions with 2 electrons, (3) K-x-ray lines (inner shell transitions or satellite lines) from ions with 3, 4, 5, etc. electrons. Iron ions emit mostly K-x-ray lines in medium temperature flares. Emission lines from Mg, Aℓ, Si, S, Ar, Ca, and Fe are dominant in the spectrum shortward of 8.5 A.

Study of line ratio changes and of continuum edges was found to be instructive as regards the behavior of hot plasmas. It was discovered that the prominence of certain Ca and Fe satellite lines and the existence of certain continuum edges could best be explained by dielectronic recombination involving excitation of K shell electrons. This K shell dielectronic recombination occurs with or without L electrons being present. The high intensity of satellite line emission is difficult to understand in terms of present dielectronic recombination theory.

Water Vapor Line Emission Sources

Studies of the interstellar water vapor line emission at a wavelength of 1.35 cm were initiated in January 1969, using the 85-foot reflector at the Maryland Point Observatory. These studies made with 2.3-arc minute angular resolution and 4-kHz spectral resolution showed the water vapor emission regions to have small angular diameters and high intensities and brightness temperatures, their spectra to be made up of narrow, doppler-shifted lines spread over a wide velocity range--for W49 at least 300 km/sec--which are extremely variable on very short time scales (weeks) implying very small sizes, and showed the radiation of some line features to be significantly linearly polarized but in no case circularly polarized. Five new sources were found. The extremes of variability are observed in the W49 source spectrum where narrow line features have been observed to grow to flux densities of about 10^{-21} watts m^{-2} Hz^{-1} (antenna temperatures of about 6000 °K) and disappear in a month or two. The long-term observations show that in addition to the intensity variations, the line features are variable in halfwidth and velocity as well. Velocity shifts of 1.5 km/sec have been observed, but as yet no system or periodicity is evident. The line-width variations are usually inversely coupled with intensity variations. The polarization of the radiation in some line features of the Orion source varies from 10 percent to 40 percent and is correlated with the intensity variations of the polarized features.

Very long baseline interferometer investigations of the water vapor sources have shown that the most intense lines are emitted by regions which are unresolved at the longest interferometer baseline used so far, 3600 km, putting limits on their angular sizes of less than about 0.0004 arc seconds and on their apparent physical sizes in some cases of approximately 6 astronomical units. The small diameter sources associated with line features at different radial velocities are spread over a small angular extent. These observations are being extended to longer baselines, additional sources, and greater precision to determine positions.

2-cm Formaldehyde Line

The $2_{12} \rightarrow 2_{11}$ rotational transition of interstellar formaldehyde was first observed in August 1969 using the 85-foot reflector at Maryland Point, and has been the subject of more recent intensive investigation using a cooled parametric amplifier. The line has been observed in absorption in the directions of Sgr B2, Sgr A, and W51. The radial velocities of the 2-cm lines agree with those observed for the 6-cm line of formaldehyde at NRAO except for the Sgr A region where the maximum of the 2-cm absorption is displaced 3' south of the continuum peak in agreement with the ammonia cloud rather than the 6-cm formaldehyde cloud which is symmetric about Sgr A. The displacement of the Sgr A 2-cm formaldehyde absorption from the 6-cm absorption in both angular distribution and Doppler velocity suggests that the main absorption at 2 cm and at 6 cm is in different regions. The energy levels of the 2-cm and 6-cm transitions are connected by transitions at 2-mm wavelength and are expected to be in equilibrium with the 3° isotropic background radiation flux at the 2-mm wavelength. Comparison of the observations at 2-cm

and 6-cm for the W51 region imply a flux at 2-mm which corresponds to a temperature in the range 2 to 5 °K and present investigations will result in more accurate estimates of the isotropic radiation flux at 2-mm wavelength.

Ammonia Line Emission Regions

The 2.′1 angular resolution of the 85-foot reflector has been used to investigate the distribution of density, velocity, and excitation of the ammonia molecules in the galaxy. The investigation was extended to other regions with the aid of a parametric amplifier. The measurements of the (1,1), (2,2), and (3,3) ammonia inversion spectrum in the Sgr B2 cloud show that the ammonia is distributed irregularly over a region 8′ x 14′ in size and varies considerably over this region in velocity and states of excitation. Maximum column densities are near 10^{16} cm^{-2} and the velocities vary ±15 km/sec about an average of 50 km/sec with apparent turbulent velocities of several kilometers per second. The kinetic temperatures of the gas are mainly in the range of 20 to 100 °K. Relative intensities of the inversion in the (1,1), (2,2), and (3,3) states were found not to correspond to equilibrium conditions in some parts of the cloud.

The ammonia cloud near Sgr A centered about 4′ south and 1′ west of the galactic center was mapped in the (1,1) and (3,3) radiation and to some extent in the (2,2) radiation. The mean radial velocity within the cloud varies from 40 km/sec to 0 km/sec and the linewidth is about 35 km/sec. There is a significant difference between the size and position of the ammonia cloud and the OH and 6-cm formaldehyde clouds which are of larger angular extent and symmetrical about Sgr A, although the formaldehyde

observed in the 2-cm transition is similar in position and angular extent to the ammonia.

Searches were made for ammonia radiation for a variety of possible sources outside the galactic center region with negative results.

Radio Sources

In January 1969 a very long baseline interferometer experiment was initiated at 121 MHz between the Maryland Point Observatory and the NRAO Green Bank Observatory. The fringe visibilities of several extragalactic sources and of two pulsars were measured. The Crab Nebula pulsar appears to agree in position with the small diameter continuum source.

The periodic observations of variable radio sources at 1.65-cm wavelength have been extended to include eight sources--3C 84, 3C 273, 3C 379, and 3C 354.3 observed previously, and 3C 120, 3C 345, 3C 446, and VRO 42.22.01. The observations at 9.5-mm wavelength have been less frequent because of apparatus failures. Outstanding short term variability was observed for VRO 42.22.01 which doubled in intensity in two month's time at 9.5-mm with a corresponding 50 percent increase at 1.65 cm.

The pulse arrival times of five pulsars were observed over a year using the 150-foot Sugar Grove reflector at 405 MHz. The residuals of the arrival times masked the annual relativistic effect, but the periods, rates of change of periods, and positions of the pulsars were determined.

The spectra of an additional eleven sources were extended to 1.65-cm wavelength and eight of these to 9.5-mm wavelength using the 85-foot reflector.

Measurements of the linear polarization of 135 extragalactic sources at 25.5-cm wavelength made with the NRAO 300-foot reflector were reduced. The observed degree of polarization of the source radiation shows the same statistical dependence on galactic coordinates as was observed previously at 21-cm wavelength and interpreted as evidence for depolarization of the source radiation by small scale irregularities of magnetic field or electron distribution in the interstellar medium. The position angles of the plane of polarization at other wavelengths are being analyzed together with data at other wavelengths to determine the overall Faraday rotation in the interstellar medium and study the large scale magnetic field and electron distributions in the galaxy.

Seven compact sources in ionized hydrogen regions were observed at 9.5-mm, 1.65-cm, and 2.73-cm wavelengths using the 85-foot reflector. The measurements show the flux spectra to be flat with no evidence for dense concentrations which become optically thin in this wavelength range. Three planetary nebulae were observed at the same three wavelengths. The radio source near NGC 6857 is extended and has the spectrum to be expected from a composite thermal source.

Lunar Occultations

Five lunar occultations of the galactic center region were observed in the 21-cm line of neutral hydrogen using the 84-foot reflector with an effective angular resolution of 2′ and a spectral

resolution of 4 kHz (0.85 km/sec). No significant small angular structure is apparent in either the narrow feature at +6 km/sec or the general absorption extending from +15 to -15 km/sec.

Planets

The radio emission of Uranus and Neptune was measured at three wavelengths, 1.65 cm, 2.7 cm, and 6 cm using the 85-foot reflector for the two shortwer wavelengths and the NRAO 140-foot reflector at the 6-cm wavelength. The radio brightness temperatures of both planets at all three wavelengths are near 200 °K confirming the high brightness temperature at 2-cm wavelength previously observed by NRAO and extending the spectra to the 6-cm wavelength. Accurately calibrated complementary measurements of Mars and Jupiter at the 1.65-cm and 2.7-cm wavelengths both provide accurate points on the spectra of these planets and add confidence to the calibrations of the Uranus and Neptune observations.

Accurate, self-consistent, long-term observations of the radio emission of Venus over more than one complete phase cycle have been made at 2.7-cm wavelength using the 85-foot reflector and a broad band radiometer. The measurements show an rms scatter of 9 °K around a mean brightness temperature of 613 °K indicating no significant variation with the phase of solar illumination.

Skylab

During the period since the 1st NRL Observatory Report the Apollo Telescope Mount (ATM) project of the NASA has moved forward and has been combined with the Orbital Workshop (OWS) to form what is expected to be the first manned space station, now called Skylab I. A large part of the effort of the Rocket Spectroscopy Branch continues to be devoted to the preparation of instrumentation for Skylab, now planned for launch in late 1972. The major experiments are solar, and form a part of ATM. In brief, the first is S082A, an XUV photographic spectroheliograph producing a spectrum of monochromatic, overlapping solar images, covering the range 150 to 650 A. The solar image diameter is 18.5 mm, or 26 A measured in terms of dispersion. The spatial resolution is expected to lie in the range 1 to 5 arc sec, depending on exposure time, wavelength, and other parameters. The second instrument, S082B, is an XUV spectrograph that will produce photographic spectra with high spectral and spatial resolution over the range 970 to 3940 A. The slit can be positioned by the astronaut on any solar feature, as viewed by a closed-loop H-α, white light, or XUV TV system. The spatial resolution provided by the slit is 2 x 60 arc sec; the spectral resolution is slit-width limited to 0.08 A in the short wavelength range, 970 - 1970 A, and twice this in the first order image that covers 1940 - 3940 A. As part of this experiment a second instrument is being provided that will produce in real-time a solar image in the band 170 -500 A

having about 20 arc sec spatial resolution, for the astronaut's use in selecting regions for observing with the spectrograph. Scaled-down versions of this instrument, of approximately half size have been constructed and flown in rockets; the results will be described in a later section.

The S082A and B experiments are part of ATM, and are automatically kept pointed to ± 2.5 arc sec in yaw and pitch, as directed by the astronaut. Also included in Skylab, but in the workshop area are many other experiments. Of these S020 and S063 are being prepared by the Rocket Spectroscopy Branch.

Experiment S020 is a small, grazing incidence photographic spectrograph, designed to record the spectrum of the entire sun in the ranges 10 A to 100 A and 20 A to 200 A with 0.04 and 0.8 A resolution, respectively. Originally constructed for flight in an early Apollo mission and to be attached to the Scientific Hatch airlock, it was removed from the program when the hatch airlock became unavailable as a result of the fire. The experiment is now approved for flight in the Skylab workshop, making use of the new scientific airlock that is approximately co-aligned with ATM. The advantage gained by this instrument is that exposures can be made that are as much as 20 times longer than is possible with rockets; therefore an order of magnitude more XUV and solar emission lines should be recorded than have been discovered from rockets, or with lower-resolving photoelectric scanning grating and Bragg crystal spectrometers.

Experiment S063 is a second experiment that suffered work stoppage as a result of the fire. It is a continuation and

extension of the night airglow photography carried out by NRL on Gemini flights IX, XI, and XII. It is currently planned for flight in Skylab. One part of the experiment is to record the sunlit earth's atmosphere above and into the ozone layer by photography in the ultraviolet at wavelengths inside and just outside the region where ozone absorbs. A second camera will make photographs simultaneously in the visible to determine the radiation reflected from clouds and terrain below the ozonosphere. The ultraviolet pictures should be of interest because of the differing depths of sunlight penetration in the several spectral bands to be used and because ozone clouds may be revealed. The second experiment involves the use of the same cameras, but with different filters and observing conditions. They will be used to photograph the horizon atmospheric glow at twilight. The wavelengths, as currently planned, are N_2^+ + 3914 A and the Herzberg O_2 2600 A continuum.

Orbiting Solar Observatory

The OSO-F experiment was launched successfully on 22 January 1969 and became the fifth NASA Orbiting Solar Observatory, OSO-5. A spectroheliograph in the pointed section utilizes two concave gratings to form solar images that are scanned by six channel-photomultipliers when the spacecraft is in its raster-scan mode. The disk images observed are at λ284 A (Fe XV), λ304 A (He II), λ335 A (Fe XVI), λ465 A (Ne VII), λ499 A (Si XII) and λ1216 A (HI). The raster measures 38 by 41 arc minutes, is made up of 1,920 elements, and yields a spatial resolution of approximately 1 x 1 arc minute. All sensors have given good data except the

one for λ284 A, where scattered light overpowered the very weak disk signal. After three months of operation, sensitivity of the detectors was still high, although decreased by nearly an order of magnitude, presumably because of loss of efficiency of the grating. After 18 months of operation the outputs of all detectors except for He II λ304 A degraded to low levels because of photomultiplier fatigue. The quality of spectroheliograms reproduced from the λ304 A data, however is still high. The experiment is expected to operate until September 30, 1970 completing its 9,288th orbit, and then may be shut down for economy reasons.

A system has been developed to produce spectroheliogram pictures from the satellite data. The telemetry data is processed by computer, formatted, and stored on magnetic tape. The tape is then read into a buffered logic system which controls an oscilloscope. The scope traces the 40 raster lines of 48 words each plus 2 extra lines of coded information. A photograph of the scope reproduces the raster scan of the sun. A special design technique was employed in producing the picture-forming elements in the proper aspect ratio to reproduce the sun's disk from a rectangular array of numbers.

Most of the data in final form have been received from NASA and will be used to reconstruct the various spectroheliograms for inclusion in an Atlas covering the lifetime of the experiment. Special flare events will also be shown in detail in the form of movies composed of the images recorded at a rate of approximately once every 10 minutes.

Preparation of the double experiment for OSO-H is nearing completion, with flight currently scheduled for April 1971. The two experiments will record the sun's corona alternately in white light and in the XUV band 171 - 500 A. The purpose is to look for changes of all kinds in both the white light electron-scattered corona, and the XUV corona that is produced by resonance lines emitted by highly stripped ions, especially iron. Relations between changes in the two coronas will be searched for. The white light coronagraph is optically similar to the instrument flown in rockets (see below) covering the range 2.8 - 9 $R_\odot$; however, the image will be recorded with an SEC Vidicon, which will integrate the low intensity until the time for readout into the tape recorder, with subsequent transmission to the ground. A spatial resolution of 1.25 arc min is expected. The XUV coronagraph will observe the corona overlying the solar disc and out to one solar radius beyond the limb, using a single channel-photomultiplier capable of 20 arc second resolution. Partial coverage of the corona from 2 $R_\odot$ to 5 $R_\odot$ will be provided by three other channel-photomultipliers. This instrument utilizes the raster scan mode of the spacecraft in alternation with the point mode required by the white light coronagraph. Planning is underway for computer-driven imaging systems to reconstruct both white light and XUV coronal images as has been done for OSO-5 data.

The Solar Corona

Photography of the outer white light corona (3 to 9 solar radii) with externally occulted rocket coronagraphs has continued.

Photographs have been made at intervals of approximately six months since 1965 under a NASA-funded program. The latest observations not previously reported here, occurred on April 16 and 17, 1969. An interval of one day was chosen to record short term changes in the corona. A similar coronagraph was flown on 7 March 1970 to make corona photographs which could be compared with other observations of the total solar eclipse which occurred that day. Streamers to approximately 9 solar radii were recorded in all flights. The one-day interval produced surprisingly large changes in the streamer pattern. These changes, although partly ascribable to rigid rotation of streamers with the sun, showed great changes of an intrinsic nature, including disappearance of some streamers and the birth of others. Many streamers evidently arose from features on the front or rear of the solar disk, rather than from limb features alone, and were actually foreshortened beams projected toward or away from the observer. The streamers were always straight, and in fact no curved streamers between 3 and 9 solar radii have been recorded during the program regardless of the degree of foreshortening. Thus, there has been no evidence of "garden hose" spiral produced by solar rotation, nor of influence on the streamers by the solar magnetic field pattern observed in the photosphere.

All rocket coronagraph instrument packages contained an XUV heliograph to photograph the solar disk and corona in the band 170 - 550 A. Resolution of 10 to 15 arc sec was obtained for short exposures. In longer exposures, coronal emission was recorded to approximately one solar radius beyond the limb but with less resolution. No structure corresponding to white-light

streamers was found. The XUV corona, as recorded above the limb on 7 May 1970, matched qualitatively the Fe XIV 5303 A corona photographed by the University of Hawaii, as would be expected.

The complete explanation of the XUV corona is uncertain. Thomson scattering of the solar disk radiation cannot be an important mechanism because the coronal emission is far too intense relative to emission from the disk. Collisional excitation of ions (particularly Fe) by the coronal free electrons may be important but the observed lack of streamers provides no confirmation. It is likely that the XUV corona is caused by resonance as well as collisional excitation and that its unexpectedly high intensity is associated with the high abundance of Fe ions in the corona.

An XUV Spectrum of a Flare

As supporting research for the ATM experiments, a large XUV spectroheliograph was constructed for flight in a SPARCS-Stabilized Aerobee-150 rocket. One objective was to launch during a flare, in order to obtain data concerning the morphology and spectrum of a flare in the spectral range 171 - 650 A. After much waiting, the rocket was launched at 2029 UT, November 4, 1969, during an importance 2 N flare, located 13° from the limb. The flare image was recorded in about 300 emission lines. In excited lines between Mg 368 A and Fe XVI 335-361 A the flare showed only as a small intense featureless nucleus 6 arc sec in diameter with enhanced diffuse emission in the nearby corona. For the lower chromospheric lines, Ne VII 465 A - He I 584 A, fine bright structures within the plage accompanied the flare nucleus, as was the case in H-α,

and there was little or no emission in the corona. Associated with the line spectrum of the flare were many regions of continuum emission. Because of their high resolution, 3 - 5 arc sec, the spectroheliograms show great detail of many kinds; e.g., the chromospheric network, prominences, plages, spicules, and the limb. Conspicuous is the gradual disappearance of the chromospheric network and of most of the fine structure within plages as recorded in lines that originate at higher and higher altitudes above the photosphere.

The Sun's XUV Flash Spectrum

An Aerobee-170 rocket was flown from Wallops Island into the total solar eclipse on 7 March 1970 in order to record the sun's XUV flash and coronal spectra. The rocket carried four Wadsworth mounting spectroheliographs to photograph the ultraviolet spectrum of the sun during entrance into the umbra of the eclipse at an altitude of 162 km. The wavelength ranges covered were 150 - 440 A (8.3 A/mm); 725 - 1060 A (8.3 A/mm); 1216 A (1.2 A/mm); 1400 - 1965 A (9.4 A/mm).

A newly developed guidance system provided an absolute pointing accuracy of ±1 arc minute in pitch and yaw and ±0.5 degrees in roll angle. The stability of the system was better than ±2.5 arc seconds. The guidance system also started the camera sequence at the moment when the rocket saw a 5 arc second wide photospheric crescent. The pointing system worked as anticipated; all four cameras began sequencing at 5 arc seconds from totality. However, because of a malfunction of the parachute recovery system, the payload sank 115 km off the Virginia coast in 1,900 meters of water. It was recovered on 22 March 1970 by the U.S. Navy Supervisor of Salvage. The spectra of the middle-UV camera

(1400 - 1965 A) were developed successfully, but everything else was destroyed by strong electrolysis.

A preliminary analysis shows that the strong lines of Si II, Aℓ II, Fe II can be seen up to 500 km above the photosphere; Aℓ III, Si III, approximately 7,000 km; He II, O III, approximately 9,500 km; and C IV 13,000 km. Many new weak lines which cannot be seen in the older NRL disc chromospheric spectra were present in the flash spectrum.

XUV Limb Spectra

A high spatial (2 x 60 arc sec) and spectral (0.05A) resolution XUV spectrograph covering the range 1170 - 1800 A was flown successfully in an Aerobee-150 rocket on 13 August 1970. The instrument was a half-size prototype for ATM experiment S082B. Spectra were photographed at four positions; 8", 24", 40" and 5' inside the photospheric limb. The profiles of HI Ly-α; the O I ($^3P - {}^3S^0$), resonance triplet 1302, 5, 6; Si II, C II and Aℓ II show solar reversals of greatest depth close to the limb. On first inspection, no other lines are self-reversed, but show profiles varying from the instrumental limit 0.05 A, to several tenths of an Angstrom. From these spectra it will be possible to derive center to limb data for a large number of lines and also continua that arise from the region extending from the outer photosphere, across the temperature minimum, and well up into the chromosphere.

Reduction of Solar Data

Wavelength measurement of all rocket spectra prior to 1970 photographed in the spectral range 1200 A - 2100 A has been

completed and identification of lines is continuing. This work has provided a starting point for the analysis of the March 1970 eclipse spectra photographed in the same spectral range, and for the much higher resolution limb spectra photographed on 13 August 1970.

Wavelength measurement and identification of solar emission lines photographed at grazing incidence in the 163 - 425 A region using both slit and slitless techniques has largely been completed, and the results are being prepared for publication. Approximately 400 emission lines were measured in this region, of which approximately 50 - 70% could be identified. Lines from about 50 ions are identified.

A determination of the intensity distribution in the solar UV continuum between 1450 and 2100 A has been published.

The temperature near 1650 A, which is crucial to the solar model in the region of the temperature minimum, was determined to be 4670 $\pm$ 100 °K, a value considerably higher than reported by another experimental group. A re-investigation of the carbon arc light source used to standardize the NRL spectra supports the higher value and leaves the question unresolved.

Work on the Atlas for the range 2100 - 3000 A is continuing, with derivation of the detailed curve of intensity distribution at ~0.03 A resolution nearing completion.

Magnetograph

The Real Time Solar Vector Magnetograph, being constructed in a joint program with the Marshall Space Flight Center is nearing completion. Using Fe I, 5250 A, a 0.13 A bandpass birefringent filter, polarization optics, an SEC-Vidicon and a Univac 1108

computer, two dimensional images will be obtained showing all four Stokes parameters within 1 minute of real time, and with a spatial resolution of 1 arc sec, if atmospheric conditions permit. Progress has been made in the interpretation of the Zeeman effect for λ5250, taking into account a TiO molecular line blend, and the continuum suppression within sunspot umbras by weak molecular lines.

Laboratory Work

The investigation of the optical properties of reflecting aluminum films overcoated with MgF_2 or LiF at wavelengths less than 1000 A has been completed. Reflectance spectra were obtained to wavelengths as short as 300 A for a number of dielectric thicknesses. For the most part, these reflectors have a lower reflectance than either Pt or Ir below 1000 A. However, they can be used to wavelengths as short as 500 A if a loss of speed by a factor of two or less can be tolerated.

Studies of contamination of optical materials and surfaces by simulated space environments have been completed. A real-time contamination monitor for use in vacuum chambers has been constructed for the ATM project. This monitors the reflectance of a mirror for H-Lyα, 1216 A.

Reflectance spectra of evaporated Rh films, deposited at various substrate temperatures, have been measured and the optical constants, n and k, have been obtained from these spectra. The location of the $N_{II, III}$ soft x-ray edge at 269 A is apparent from the sudden increase in the extinction coefficient that occurs between 261 A and 270 A. However, there is no evidence of the N_I

edge at 156 A even though the measurements extend to 150 A. The loss function has been computed and shows two distinct maxima, at 375 A and 1410 A. The reflectance of Rh differs from that of Pt and Ir in that there is a broad minimum at 1300 A. Calculations indicate that thin Rh films deposited on MgF_2 or LiF substrates will be useful as broadband transmitting filters over the wavelength range from the substrate cut-off to wavelengths of about 1600 - 1800 A, depending on the thickness of the Rh film.

A study of the optical properties of glass and fused quartz has been started and measurements completed from 150 A to 584 A.

Investigations of methods of preventing or retarding the formation of pinholes in thin, unbacked aluminum films is being done by Sigmatron, Incorporated, under contract to NRL, because of the use of such films in XUV instrumentation for long-time space missions. Two approaches are being used: (1) deliberate adulteration of the aluminum with Si during evaporation; and (2) encapsulation of the pure Al films with evaporated SiO, thus forming an SiO-Al-SiO sandwich. Measurements show that these two processes cause no degradation in the transmittance of the filter, and do appear to help prevent pinholes when the filter is subjected to a rapid aging process.

Development is underway to establish a method of monitoring, at 1216 A, the thickness of the MgF_2 layer that is used for over-coating fresh aluminum films to produce the highly reflecting Al - MgF_2 mirrors that show 80-85% reflectance at 1216 A.

The investigation of the high resolution spectrum of doubly and triply ionized nitrogen below 500 A has been completed. One hundred-eight-nine new terms have been classified and four hundred seven previously unreported spectral lines in these spectra have been assigned. Preliminary analyses of "Fano-type" resonances have been completed for several auto-ionized levels in the spectrum of each species. Examples of two transitions from the same auto-ionized level to different lower states have been observed to exhibit unlike resonance profiles. This is the first detailed examination of asymmetrical type profiles in an emission spectrum produced in the laboratory.

Isotope studies of the high resolution vacuum ultraviolet absorprtion spectrum of the carbon monoxide molecule have led to the correction or confirmation of the vibrational numberings for the valence states of this molecule. A complete summary of the CO absorption spectrum from 1800 to 1070 A has been completed and complete R-K-R potential curves have been calculated for each of the states $X\ ^1\Sigma^+$, $A\ ^1\Pi$, $a\ ^3\Pi$, $a'\ ^1\Sigma^+$, $e\ ^3\Sigma^-$, $I\ ^1\Sigma^-$, $d\ ^3\Delta_i$, $D\ ^1\Delta$, $b\ ^3\Sigma^+$, $B\ ^1\Sigma^+$, $j\ ^3\Sigma^+$, $C\ ^1\Sigma^+$, $c\ ^3\Pi$, and $E\ ^1\Pi$.

High resolution absorption spectra have been observed and characterized from the two lowest $\pi^3\sigma$ electronic configurations in the hydrogen halides. In addition, states from the lowest $\pi^3\pi$ configuration of hydrogen and deuterium bromide have been characterized and work is continuing on the analysis of the similar and higher configurations in the other hydrides.

The analysis of the spectra of the O_2^{18} Schumann-Runge band system is almost complete. The O_2^{16} system has also been re-investigated above v' = 6. From these new analyses, improved R-K-R potential curves have been calculated.

Observed auroral measurements have been reported which indicate an increase in the apparent vibrational temperature of molecular nitrogen proportional to the intensity increase of the 6300 A oxygen red line. A new long-path-length high temperature vacuum furnace has been obtained and experiments have been initiated on species containing hydrogen, carbon, and oxygen which are expected to be present in the solar and stellar atmosphere.

THE HULBURT CENTER APPOINTEES

APPOINTEE	PARENT INSTITUTION	PROJECT	STATUS
Dr. George A. Doschek	Univ. of Pittsburgh	Theory of x-ray flare spectra, planning for OSO-I	Papers in press include discussion of dielectronic recombination. (will accept permanent appointment at NRL December 70.)
Dr. Paul D. Feldman	Johns Hopkins	Solar infrared astronomy, 10-500μ.	Aerobee NF 3.193 launched 24 January 1970. (Dr. D. P. McNutt)
Dr. Richard C. Henry	Johns Hopkins	Celestial x-ray sources, UV airglow studies; Blue Scout Jr. + pointing control, Aerobee.	Aerobee NB 3.210 launched 13 March 1969; Blue Scout Jr. scheduled for launch 23 Nov. 1970. Numerous papers.
Dr. Stephen W. Kahler	Univ. of Calif., Berkeley	Solar x-rays, laboratory x-ray studies	Papers on fundamental mechanism of solar flare x-ray emission. (J. F. Meekins)
Dr. James D. Kurfess	Rice University	Celestial gamma-ray spectroscopy, x-ray balloon experiments. Balloons.	Balloon experiment scheduled for launch October 1970. (Dr. T. A. Chubb)
Dr. Barry K. Moritz	Univ. of Maryland	Theory and behavior of solar corona	Scientific Consultant, OSO-H instrument design and theory team, launch early 1971. (Dr. R. Tousey)
Dr. Dianne K. Prinz	Univ. of Maryland	Solar Lyman-alpha instrument interpretation of far UV airglow data.	Papers: Atmospheric N_2, O Emission in far UV, etc.
Dr. Seth Shulman	Columbia Univ.	X-ray astronomy, particle physics	Experiment on Super-Chief, to be launched 21 Oct. 1970.

APPENDIX A

PUBLICATIONS AND TALKS

Space Science Division
and
E. O. Hulburt Center for Space Research

June 1969 - September 1970

SPACE SCIENCE DIVISION
Code 7100

Publications,* June 1969 through September 1970:

Friedman, H.
"Cosmic X-ray Observations," Proceedings of Discussion Meeting on Cosmic X-ray Astronomy, The Royal Society, London, November 1968, Proc. Roy. Soc. 313, 301-315 (1969).

Friedman, H., Chubb, T. A., Tousey, R., and Mayer, C. M.
"Observatory Report: E. O. Hulburt Center for Space Research," Bull. Astron. Soc. 1, 220 (1969).

Friedman, H.
"Space Age Astronomy," United Press International, August 1969.

Friedman, H.
"Objectives of Science in Space," The Christian Science Monitor, 26 September 1969.

Friedman, Herbert
"X-ray Astronomy," Advances in X-ray Analysis, Vol. 13, Proceedings 17th Annual Conference on Applications of X-ray Analysis, August 1969, ed. B. L. Henke, J. B. Newkirk and G. R. Mallett (Plenum Press, New York 1970), pp. 289-312.

Friedman, Herbert
"Pulsars," Astronautics & Aeronautics 8, No. 4, 22 (1970).

Friedman, H. and Johnson, F. S.
"A Decade of Discovery," Transactions AGU 51, 4 (1970), reprinted from Chapter 3, "Physics of the Earth in Space/A Program of Research: 1968-1975, Space Science Board, NAS-NRC, August 1968.

Friedman, H.
"Observations of Solar Ionizing Radiations and Their Significance for the Eclipse-Ionosphere," Proceedings on Solar Eclipses and the Ionosphere, Lagonissi, Greece 1969, Solar Eclipses and the Ionosphere (Plenum Press, 1970), pp. 93-114.

* Other coauthored papers appear in Code 7120 listing.

Publications, Code 7100 (Continued)

Friedman, Herbert
"Astronautics: Space-oriented Satellites," 1970 Britannica Yearbook of Science and the Future, pp. 112-116.

Papers to be published:

Friedman, Herbert
"Astronautics: Space Probes," 1971 Britannica Yearbook of Science and the Future (In Press).

Friedman, Herbert
"X-ray Background Radiation," Proceedings of the Semaine d'Etude on Nuclei of Galaxies, Pontifical Academy of Sciences, Vatican City, April 1970 (In Press).

Friedman, H.
"Space Programs and the Public Viewpoint: Science in Space," Aeronautics & Space Engineering & Manufacturing Meeting, Los Angeles, October 1969.

Friedman, H.
"X-ray Sources, Astronomical," Encyclopaedia Britannica (In Press).

Code 7100
H. Friedman

Invited Talks and Lectures, July 1969 through September 1970

1. Space Programs and the Public Viewpoint: I. Science in Space," Aeronautics & Space Engineering & Manufacturing Meeting, Los Angeles, 8 October 1969.

2. "The Violent Universe," Alfred P. Sloan Lectures, Howard University, Washington, D. C., 29 October 1969.

3. "X-ray Astronomy," Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, Massachusetts, 25 November 1969.

4. "X-ray Pulsations from NP 0532," 131st Meeting of the American Astronomical Society, New York, 9 December 1969.

5. "Celestial X-ray Sources," Annual Meeting of the American Association for the Advancement of Science, Boston, 29 December 1969.

6. "X-ray Stars, Galaxies and Background Radiation," General Electric Space Center, Valley Forge, Pennsylvania, 31 March 1970.

7. "X-ray Background Radiation," Semaine d'Etude on "Nuclei of Galaxies," Pontifical Academy of Sciences, Vatican City, Rome, 13-19 April 1970.

8. "X-rays of Extragalactic Origin," Spring Meeting, American Physical Society, Washington, D.C., 1 May 1970.

9. "The Violent Universe," United States Naval Academy, Annapolis Maryland, 1 May 1970.

10. "X-ray and Gamma Ray Astronomy," 11th International Space Science Symposium, Leningrad, USSR, 20-29 May 1970.

Code 7120

Publications for 1969 (not included in 1969 report)

Carruthers, G. R.
"On the Far Ultraviolet Interstellar Extinction Law in the Orion Nebula Region," Ap. J. 157, L113, 1969.

Carruthers, G. R.
"Far Ultraviolet Photometry of Orion Stars," Astrophys. and Space Sci. 5, 387, 1969.

Carruthers, G. R.
"Observation of the Lyman-Alpha Interstellar Absorption Line in Theta Orionis," Ap. J. 156, L97, 1969.

Carruthers, G. R.
"Magnetically Focused Electronographic Image Converters for Space Astronomy Applications," Applied Optics 8, 633, 1969.

Feldman, P., and D. P. McNutt
"Far Infrared Nightglow Emission from Atomic Oxygen," J. Geophys. Res. 74, 4791, 1969.

Feldman, P. and D. P. McNutt
"A Rocket-borne Liquid Helium-cooled Infrared Telescope. II. Photoconductive Detectors," Applied Optics 8, 2205, 1969..

Hoffman, J. H., C. Y. Johnson, J. C. Holmes, and J. M. Young
"Daytime Midlatitude Ion Composition Measurements," J. Geophys. Res. 74, 6281, 1969.

Hoffman, John H.
"Ion Mass Spectrometer on Explorer XXXI Satellite," Proc. of IEEE 57, 1063, 1969.

Hunter, J. H.
"Hα Auroral Activity on Jupiter," Nature 223, 388,. 1969.

Kreplin, R. W.
"Solar X-rays--Developing Background for Comprehensive Theory," Astronautics & Aeronautics, pp. 58-65, December 1969.

Publications for 1969 (Cont'd.)

Mange, P. and H. Friedman
"IQSY Data Review, Space Research: Introduction," Annals of the IQSY, Vol. 6, Paper 12 (M.I.T. Press, Cambridge, Mass. and London, England, 1969), pp. 225-226.

McNutt, D., K. Shivanandan, and P. D. Feldman
"A Rocket-borne Liquid Helium-cooled Infrared Telescope. I.: Dewar and Optics," Applied Optics 8, 2199, 1969.

Meekins, J. F., R. C. Henry, G. Fritz, H. Friedman, and E. T. Byram
"X-ray Spectra of Several Discrete Cosmic Sources," Astrophys. J. 157, 197, 1969.

Meier, R. R.
"Balmer-Alpha and Lyman-Beta in the Hydrogen Geocorona," J. Geophys. Res. 74, 3561, 1969.

Meier, R. R.
"Temporal Variations of Solar Lyman-α," J. Geophys. Res. 74, 6487, 1969.

H. Friedman and R. W. Kreplin
"X-ray Emission Events Preceding the Proton Flare of 7 July 1966," Proc. IQSY/COSPAR Symposium on Results of the IQSY, London 1967, Annals of the IQSY, Vol. 3, Gen. Ed. A. C. Stickland (M.I.T. Press, Cambridge, Mass. and London, 1969), pp. 144-153.

H. Friedman and R. W. Kreplin
"X-ray Emission from the Proton Flare of 7 July 1966," ibid., pp. 202-203.

H. Friedman and R. W. Kreplin
"The Slowly Varying Component of Solar X-ray Emission in the Period 1-15 July 1966," ibid., pp. 78-81.

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Publications for 1970

Byram, E. T., T. A. Chubb and H. Friedman
"X-ray Survey of Centaurus A," Science 169, 366, 1970.

Carruthers, G. R:
"Atomic and Molecular Hydrogen in Interstellar Space," Space Sci. Rev., 10, 459, 1970.

Carruthers, G. R.
"Rocket Observation of Interstellar Molecular Hydrogen," Astrophys. J. 161, L81, 1970.

Carruthers, G. R.
"Far-Ultraviolet Intensities of Orion Stars," Ultraviolet Stellar Spectra and Related Ground-Based Observations, ed. by L. Houziaux and H. E. Butler (D. Reidel, Dordrecht-Holland, 1970) p. 100.

Chubb, T. A. and G. T. Hicks
"Observations of the Aurora in the Far Ultraviolet from OGO-4," J. Geophys. Res. 75, 1290, 1970.

Doschek, G. and J. F. Meekins
"The Helium-Like Calcium, Silicon, and Sulfur Lines During the Decay of a Large Flare," Solar Physics 13, 220, 1970.

Henry, R. C., G. Fritz, J. F. Meekins, H. Friedman and E. T. Byram
"Intensity of the Solar X-ray Background Flux: Reply to Bowyer and Field," Nature 225, 362, 1970.

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"Equatorial Aurora/Airglow in the Far Ultraviolet," J. Geophys. Res. 75, 6233, 1970.

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Horan, D., R. G. Taylor, and R. W. Kreplin
"Solar X-Ray Emission; October 26, 1968-November 4, 1968," Upper Atmosphere Geophysics Report UAG-8, Part II, March 1970

Horan, D. and R. W. Kreplin
"Solar X-Ray Emission on November 18, 1968," Upper Atmosphere Geophysics Report UAG-9, April 1970.

Horan, D. M.
"Coronal Electron Temperatures Associated with Solar Flares," Ph.D. Dissertation, The Catholic University of America, April 1970. (Ann Arbor Michigan, University Microfilms, 70-22133).

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Kreplin, R. W., D. M. Horan, and B. D. Osecky
"Solar X-Ray Data from SOLRAD 9, in the form of hourly average, monthly flare lists, and daily plots," published in Solar Geophysical Data, ESSA Research Laboratories, IER-FB-293 (January 1969) through SGD-311 (July 1970); 19 sets of data).

Kreplin, R. W.
"The Solar Cycle Variation of Soft X-Ray Emission," Annales de Geophysique, 26, 1970, pp. 567-574.

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"Flare X-Ray and Radio Wave Emission," Space Research X -(North-Holland Publishing Co. Amsterdam, 1970), pp. 920-927.

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"Far Ultraviolet Photography of Orion: Interstellar Dust," Science (In Press).

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"OGO-III Observations of the Lyman-Alpha Intensity and the Hydrogen Concentration Beyond 5 Earth Radii," J. Geophys. Res., 75, 1837 (1970).

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"Recombination Edges Observed in Solar X-Ray Spectra," Solar Physics, 13, 213 (1970).

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"Observations of Lyman-α and the Atomic Hydrogen Distribution in the Thermosphere and Exosphere," Space Research X (North-Holland Publishing Co., Amsterdam, 1970), pp. 572-581.

Meier, R. R. and P. Mange
"Geocoronal Hydrogen: An Analysis of the Lyman-Alpha Airglow from OGO-4," Planet. and Space Science, 18, 803 (1970).

Shivanandan, K.
"Infrared Astronomy," Proc. of Erice Summer School in Cosmic Physics, Feb. 1970.

Shivanandan, K.
"Far Infrared Cosmic Background," Proc. of the Symposium on Submillimeter Waves, June 1970.

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Shivanandan, K.
"Cosmic Background Measurements in the Far Infrared," Ph.D. Dissertation, The Catholic University of America, May 1970. (Ann Arbor, Michigan, University Microfilms).

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"Photomultiplier Yield of a Channel Electron Multiplier in the 304-1493A Wavelength Range," Applied Optics, 9, 505, (1970).

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NRL Reports (1969)

Fritz, G., R. C. Henry, J. F. Meekins, T. A. Chubb, and H. Friedman
"X-Ray Pulsar in the Crab Nebula," Report of NRL Progress June 1969.

Horan, D. M., A. T. McClinton, Jr. and R. W. Kreplin
"Solar X-Ray Emission During the Flight of Apollo 8, Dec. 21, 1968 - Dec. 27, 1968"
NRL Report 6917, June 13, 1969.

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"Using Solar X-Rays as Indicators of Solar Flare Activity," NRL Report 6884, March 27, 1969.

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Barton, G. G.
"The Harkers Island Experiment," NRL Report 7054. A Comparison of Four Night Optical Surveillance Devices under Natural Marine Conditions. (1970)

Johnson, C. Y., J. M. Young, J. C. Holmes
"Magnetoglow - A New Geophysical Resource," Report of NRL Progress, August 1970.

Kaufmann, P., J. A. de Freitas Pacheco, and J. P. Sudana, MacKenzie University and R. W. Kreplin, NRL
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Kreplin, R. W.
"Solar Cycle Variation of Soft X-Ray Emission," Report of NRL Progress, pp. 8-17, February 1970.

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Carruthers, G.
"Far Ultraviolet Intensities of Orion Stars," presented at IAU Symp. #36, "Ultraviolet Stellar Spectra and Related Ground-Based Observations," Lunteren, The Netherlands, June 26, 1969, (Proceedings to be Published).

Chubb, T. A.
"Equatorial Emissions in the Far Ultraviolet," presented as part of panel discussion at AGU meeting, San Francisco, Dec. 1969.

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"Soft X-Ray Spectral Studies of Flare Plasmas," G. A. Doschek, J. F. Meekins, and H. Friedman, Orbiting Solar Observatories Workshop, JILA, 4-15 August, 1969, Boulder, Colorado, (Univ. of Colorado).

Doschek, G. A., J. F. Meekins, and H. Friedman
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"Far Ultraviolet Wide Angle Electronographic Photography of the Orion Region," by R. C. Henry and G. R. Carruthers, American Astronomical Society, New York, December 1969.

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Johnson, C. Y.
"Ionospheric Hodgepodge Unraveled," NRL-RESA Lecture, Washington, D. C., 4 November 1969.

Kahler, Stephen and Robert W. Kreplin
"The X-ray Event of June 9, 1968, National Fall Meeting, American Geophysical Union, San Francisco, 15-18 December 1969.

Kurfess, J. D.
"Hard X-ray Sources: Crab Nebula and M-87," Cornell University, Ithaca, New York, 13 March 1969.

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Talks 1970 to date

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"Microchannel Intensifier Vidicon for Far UV Imaging," Symposium on Astronomical Use of Television-Type Image Sensors, Princeton University, May, 1970. (Proceedings to be published).

Chubb, T. A.
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Talks 1970 (Continued)

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SPACE SCIENCE DIVISION

Code 7120

Talks 1970 (Continued)

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"Extreme Ultraviolet Radiation in the Night Sky," AGU, Washington, D. C. April, 1970.

Meier, R. R.
"The Far Ultraviolet Airglow," Washington-Baltimore Colloquium on Atomic and Molecular Collision, Washington, D. C., February, 1970.

McNutt, D. P.
"Rocket Infrared Astronomy, Cornell University, Ithaca, New York, April, 1970

Kreplin, R. W.
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Talks - June 1969 through August 1970 continued

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"A Photographic Spectrum of a Flare in the XUV," ABSTRACT, Solar Terrestrial Physics 1970 International Symposium, Ieningrad, USSR, May 1970.

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"Observations of the Sun in the Extreme Ultraviolet," The Royal Society of London, England, Discussion Meeting on Solar Studies, 21-22 April 1970.

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"The NRL Observing Program," ABSTRACT, NRL Air Force Training Seminar, 22 April 1970.

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"Observation of Starck - Effect in a Far UV Flare Spectrum," ABSTRACT, 14th General Assembly of IAU, University of Sussex, England, 18-27 August 1970.

APPENDIX B

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

COLLOQUIA

2 September 1969
Prof. W. J. G. Beynon, University of Wales
"Magnetic Storms and Tropospheric Winds"

19 September 1969
Prof. J. A. Roberts, University of Toronto
"Interstellar Scintillations"

24 September 1969
Prof. O. E. H. Rydbeck, Chalmers Inst. of Technology, Gothenburg, Sweden
"New Sources of Galactic OH Emission"

3 October 1969
Mr. Roger Thomas, University of Michigan
"Flare-Associated Solar Soft X-Ray Bursts"

16 October 1969
Dr. John N. Bahcall, School of Natural Sciences, Princeton, N.J. (leave of absence from Calif. Inst. of Tech.)
"Solar Neutrinos"

23 October 1969
Prof. E. N. Parker, University of Chicago
"The Origin of Magnetic Fields in the Astrophysical Universe"

30 October 1969
Dr. E. Bauer, Inst. for Defense Analysis, Arlington, Va.
"Energy Balance and Energy Transfer in the Lower Thermosphere"

13 November 1969
Prof. Carl Sagan, Cornell University
"Recent Studies of the Planet Venus"

20 November 1969
Dr. K. I. Kellerman, National Radio Astronomy Observatory, Greenbank, W. Va.
"Compact Radio Sources in Galaxies and Quasars"

4 December 1969
Prof. R. H. Dicke, Princeton University
"The Solar Oblateness, Its Significance"

8 December 1969
Dr. James E. Felten, Inst. of Theoretical Astronomy, Univ. of Cambridge, England
"Observations and Theories of the Jet in Galaxy M87"

17 December 1969
Dr. Richard C. Henry, Johns Hopkins University, Balt., Md. & NRL
"Interstellar Grains"

18 December 1969
Dr. B. Zuckerman, University of Maryland
"Observations of Polyatomic Interstellar Molecules"

15 January 1970
Dr. Glenn M. Frye, Case-Western Reserve University, Cleveland, Ohio
"Recent Developments in Gamma Ray Astronomy"

22 January 1970
Prof. Kenneth Greisen, Cornell University, Ithaca, New York
"Origin of the Background Gamma Radiation"

5 February 1970
Dr. Charles Barth, University of Colorado
"Mariner Measurements of Lyman-Alpha Emissions from the Earth, Venus, Mars and the Galaxy"

19 February 1970
Prof. W. G. Fastie, Johns Hopkins University
"Ultraviolet Studies of Planetary Atmospheres"

26 February 1970
Mr. Kenneth Frost, Goddard Space Flight Center, Greenbelt, Md.
"Hard Solar X-Ray Observations from the Fifth Orbiting Solar Observatory"

5 March 1970
Dr. Gleb Wataghin, Dir., Inst. of Physics, University of Turin, Italy
"On a Model of the Expanding Universe"

12 March 1970
Prof. A. Dalgarno, Harvard College Observatory, Cambridge, Mass.
"Atomic Processes in the Interstellar Medium"

19 March 1970
Dr. Karl G. Henize, (NASA Astronaut), Manned Spacecraft Center, Houston, Texas
"The Future of Astronomy in Manned Space Flight"

2 April 1970
Dr. Carl Fichtel, Goddard Space Flight Ctr, Greenbelt, Md.
"Solar Cosmic Rays"

24 April 1970
Dr. Oved Shisha, Aerospace Research Laboratories, Wright-Patterson Air Force Base
"Rearrangements of Numerical Sequences and Their Geometric Interpretation"

24 April 1970
Dr. J. David Bohlin, Mt. Wilson and Palomar Observatories, California Inst. of Technology, Pasadena, Calif.
"Structure and Evolution of Coronal Streamers"

17 June 1970
Prof. Charles H. Townes, University of California
"Recent Work on the Nature of Interstellar Matter"

25 June 1970
Prof. Yash Pal, Tata Inst. of Fundamental Research,
Bombay, India
"Perspectives in High Energy Particle Astronomy"

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
E. O. Hulburt Center for Space Research, NRL
"Recent Results in X-Ray and Ultraviolet Astronomy"

8 October 1970
Prof. K. McCracken, University of Adelaide, South Australia
and University of Texas at Dallas
"Solar Cosmic Rays"