SPACE SCIENCES LABORATORY

NASA CR 115906 N71-15491

Summary and Current Status Report

STUDY OF X-RAY EMISSION FROM SELECTED REGIONS OF THE SOUTHERN HEMISPHERE SKY

Supported by
NASA Grant NGR 05-003-278

Principal Investigator:
Professor C. Stuart Bowyer

January 1, 1971

Space Sciences Laboratory Series 11 Issue 90

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I. LIST OF PUBLICATIONS BASED ON WORK SUPPORTED BY THIS GRANT

Journal Articles

"Simultaneous Radio and Optical Measurements of Sco XR-1," M. Lampton, S. Bowyer, W. J. Welch, and G. Grasdalen (submitted to *Ap. J. Letters*).

"Feedback Control of Proportional Counter Gain," M. Lampton (submitted to *Rev. Scientific Instr.*; will appear in January 1971).

"X-Ray Scattering From Grains in the Direction of the Crab Pulsar and Sco XR-1," S. Bowyer, M. Lampton, and J. Mack, *Nature 225,* 1125, 1970.

"Far U.V. Photometer for Space Research," S. Bowyer, F. Paresce, M. Lampton, and J. Mack, *Planetary and Space Science 18,* 835, 1970.

"A Search for Rapid Optical Oscillations in Sco XR-1," M. Lampton, S. Bowyer, and S. Harrington, *Ap. J. 162,* 181, 1970.

"Detection of X-Ray Emission from 3C273 and NGC 5128," S. Bowyer, M. Lampton, J. Mack, and F. Mendonca, *Ap. J. Letters 161,* L1, 1970.

"Temperature and Emission Measure Profiles of Two Solar X-Ray Flares," S. Kahler, R. Kreplin, J. Meekins, and S. Bowyer, *Ap. J. 162,* 293, 1970.

"Intensity of the Soft X-Ray Background Flux," S. Bowyer and G. B. Field, *Nature 223,* 573, 1969.

"Upper Limits to the 304 and 584 Å Night Helium Glow, S. Bowyer, P. M. Livingston, and R. D. Price, *J. Geophys. Res. 73,* 1107, 1968.

"Detection of an Anisotropic Soft X-Ray Background Flux," S. Bowyer, G. B. Field, and J. Mack, *Nature 217,* 32, 1968.

Abstracts

"Measurements of Extreme Ultraviolet Radiation from Cosmic Sources: Instrumentation and Preliminary Results," F. Paresce, M. Lampton, and S. Bowyer, *Publications Astronomical Society of the Pacific 82,* 1037, 1970.

"Rocket Observations of Extreme Ultraviolet Radiations in the Night Airglow," F. Paresce, S. Kumar, M. Lampton, and S. Bowyer, *Trans. Am. Geophys. Union 11,* 1970.

"First Observations of HeI 584 Å and HeII 304 Å Dayglow Radiations," S. Kumar, F. Paresce, M. Lampton, and S. Bowyer, *Trans. Am. Geophys. Union 11,* 1970.

"On the Possible Existence of a Dense Intergalactic Medium," S. Bowyer and G. B. Field, *Bulletin of the American Astronomical Society 1,* 2, 1969.

"Helium as a Major Constituent of the Jovian Atmosphere," S. Bowyer, M. Lampton, and F. Paresce, *Bulletin of the American Astronomical Society 1,* 2, 1969.

"The Attempt to Detect the Earth's Geocoronal Helium Emissions; Past Results and Future Prospects," S. Bowyer, J. Mack, and F. Paresce, *Trans. Am. Geophys. Union 49,* 731, 1968.

II. SUMMARY OF WORK CARRIED OUT IN 1970

Analysis of the x-ray data obtained from two payloads flown in 1969 from Natal, Brazil, was continued. Strong evidence was found for x-ray emission from three extra-galactic objects: M87, 3C273, and NGC 5128 (Cen A). X-ray emission from M87 had been observed previously by several groups and the detection of x-rays from 3C273 had been previously reported at the 1 σ confidence level. The flux detected on the flight for 3C273 was compatible with this previous measurement within the statistical limitations of the two experiments.

The x-ray data from Cen A were found to fit best a point source coincident with the optical galaxy. An upper limit to the size of this source is 1.5°. No emission was detected from the extended radio halo. The observed x-ray flux of this object fell below the extrapolated core radio spectrum.

Work continued in the extreme ultraviolet region of the spectrum (100 to 1000 Å), including development of laboratory equipment as well as flight experiments. An extremely promising source was developed for use in the laboratory calibration system. The source is a continuous discharge device which provides intense line emission over a wide range of wavelengths to below 200 Å.

Two extreme ultraviolet photometers covering the wavelength ranges 200-800 Å and 200-500 Å were flown on an Aerobee sounding rocket launched from White Sands Missile Range, New Mexico, at 0955 MST on June 15, 1970. The XUV dayglow radiations measured by these photometers have been identified as resonantly scattered He I 584 Å and He II 304 Å. Observations were made in the altitude range of 90 to 185 km. At the peak altitude, the He I 584 Å intensity from the zenith was found to be 210 ± 70 rayleighs, while the He II 304 Å intensity was found to be 9.5 ± 3.1 rayleighs. The altitude profile as well as the absolute intensities can be grossly accounted for on the basis of resonant scattering of solar radiation from terrestrial helium in combination with atmospheric attenuation.

Four photometers covering the wavelength ranges 200-500 Å, 200-800 Å, 700-1100 Å, and 1050-1500 Å were flown on a Nike-Tomahawk sounding rocket launched from Thumba, India, on March 10, 1970, at 0205 IST. A preliminary analysis of the data obtained has been carried out and the results are interpreted as the product of solar radiation resonantly scattered by hydrogen and helium in the earth's geocorona. Altitude profiles of the 304 He II, 584 He I, and 1216 H I fluxes have been obtained and are in reasonable agreement with theoretical predictions.

A study was made on the transparency of the interstellar medium to XUV radiation. It was concluded that, although the medium was indeed quite absorbing at these wavelengths, the extent of this absorption had been overemphasized in previous studies and there is at least some expectation that limited astronomical observations at XUV wavelengths can be made. An instrument was developed suitable for a search for XUV objects in the night sky and was flown as a piggyback experiment on an Aerobee rocket. A signal substantially above background was observed which may be an XUV source.

A number of ground-based studies were carried out in an attempt to understand the x-ray source Sco XR-1. The Crossley 36-inch telescope at Lick Observatory was used in combination with a high-speed data system to search for oscillations in the optical output of this object. Power spectra were obtained for frequencies between 0.002 and 500 Hz, which cover the observed range of pulsar frequencies and the predicted range of fundamental radial-mode vibrations of white dwarfs and neutron stars. No persistent oscillations were detected at these frequencies.

An attempt was made to determine the relation between the longer-term optical variations and the possible variation of the radio output of this object. Radio data were obtained using the NASA 210-ft radio antenna at Goldstone, and simultaneous optical observations were made with the Crossley telescope. A radio flare was observed as well as a slower variation in the radio output of this object. From a comparison of the optical and radio data it was clear that on any given night there was no apparent correlation between the optical and radio intensity; specifically, the radio flare observed was neither accompanied nor preceded by an optical flare. Nightly averages of both the optical and radio brightness were computed to search for possible longer term correlations of the data, but no obvious correlation was apparent. These data suggest that energy is not promptly supplied to the radio envelope from the central x-ray object.

III. WORK IN PROGRESS

Work in progress can be broken into two major categories: 1) instrumental development and 2) analysis of data obtained on previous flights and from results of laboratory work. In the area of instrument development we have been concentrating our efforts on soft x-ray detectors. A more complete account of this work is provided in a forthcoming proposal and will not be repeated here. In regard to the analysis of data already in hand from flight and laboratory work, we believe we will have useful results in the following areas:

a) The possible detection of an XUV source.

A detailed analysis of data from our previous flight leads us to believe that we may have detected a source radiating primarily in the 170 to 600 Å band.

b) A laboratory source for XUV radiation.

We have developed a simple, compact source of XUV radiation which provides a stable long-lifetime source of line emission at wavelengths from 270 to 1200 Å. This source provides a number of distinct advantages over XUV sources currently employed.

c) XUV absorption by the interstellar medium.

We have carried out a study which leads us to believe that the interstellar medium may be much more transparent than heretofore believed.

d) Existence of an intercluster gas in a cluster of galaxies.

We believe we have data which indicate the presence of an intercluster gas in a well known cluster of galaxies.

e) Source Spectrum Data Analysis.

A number of projects underway require a sophisticated data analysis program for full realization. This is especially important at soft x-ray energies where instrumental broadening becomes pronounced. A considerable effort has been made to greatly increase the sophistication of the computer program employed to derive source spectra from flight proportional counter data. The flight data are a convolution of the true x-ray source mechanism, absorption by the interstellar medium and by the residual overhead atmosphere, all in combination with the quantum efficiency of the detector and detector broadening effects. The program developed solves the integral equation

$$G = A \int dY \int \eta(E)\tau(E)e^{-N\sigma(E)}F(E)R(E)dE$$

where:

- G is the observed spectrum in counts/cm^2 sec keV
- η is the detector efficiency
- τ is terrestrial atmosphere absorption
- N is the column density of the interstellar medium
- σ is the x-ray cross section of the interstellar medium
- F is the intrinsic source spectrum
- R is the instrumental broadening function
- Y is the energy channel of the detector
- A is a fitting factor dependent upon the source distance and strength.

The program operates by assuming a form for F(E), computing the integral, and varying free parameters until the best fit with observations is obtained. The free parameters are generally N, the column density of the interstellar medium in the line of sight, and T, the source temperature. Four basic forms for the the source function F(E) are computed:

1) Thermal Bremsstrahlung, exponential approximation
2) Thermal Brensstrahlung, Elwert approximation
3) Power Law (synchrotron)
4) Black Body.

The output of the program consists of a comparison of the goodness of fit of each of the four types of source functions against the experimental data for a wide variety of values of N and T. This permits a determination of the most probable source mechanism and also the most likely values of N and T associated with this mechanism.

f) X-ray source locations and spectra in the Southern sky.

We have determined the location of the sources we observed in the Southern sky on our last flight. We have only to analyze the spectral results obtained for these sources with the aid of the above program.

g) Spectra of extragalactic objects.

We have some spectral results on M-87. These data have only to be processed with the aid of the above program to provide useful results.

IV. FINANCIAL STATUS

Our primary source of funding for this work has been NASA Grant NGR 05-003-278. The funds in this grant were exhausted approximately six months ago; however, it was unnecessary to request additional funding at that time because of various stopgap funds we were able to obtain (primarily from Manned Spacecraft Center in Houston). These funds will be fully expended by March 1, 1971.