SPACE SCIENCES LABORATORY

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A STUDY OF X-RAY EMISSION FROM GALACTIC AND EXTRAGALACTIC SOURCES WITH EMPHASIS ON SOFT AND ULTRA-SOFT WAVELENGTHS

Principle Investigator: Professor C. S. Bowye

Co-experimenters: Michael Lampton
R. G. Cruddace
Francesco Paresce

Covering the period: June 1, 1973 through May 31, 1974

August 1974

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I. INTRODUCTION

The flight of our rocket payload in February 1973, aboard GSFC Black Brant VC 21.016, ended catastrophically when the parachute failed, resulting in the destruction of the payload housing and half of the scientific instruments. During the reporting period June 1, 1973 to May 31, 1974, a new payload housing was built, repairs were made to our two new instruments, a soft X-ray background telescope and a 584 Å photometer equipped with a helium gas cell were built. This payload was launched successfully by a Black Brant VC, GSFC 21.017, at 23.11 MDT time on June 15, 1974, the primary objectives being X-ray scanning observations of the Coma and Virgo clusters, using two detectors, one equipped with a collimator of width 9.2 arc min (FWHM) and one designed for response to soft X-rays.

During this reporting period our ground-based astrophysical research, and analysis of the results of flight 21.016, continued. In the following we list articles published during the last year, of which members of the research group were authors or co-authors.

A Search for a Cosmological Component of the Soft X-Ray Background in the Direction of M31, Ap. J., 191, L117, 1974.

Soft X-Ray Observations of the Perseus Cluster, Submitted to Ap. J.

Soft X-Ray Spectroscopy of Three Extragalactic Sources. Submitted to Ap. J. (Letters).

Observation of X-Ray Emission From M31, Ap. J., 190, 285, 1974.

The Nature of Cyg X-3; A Prototype for Old Population Binary X-Ray Sources, Ap. J., 189, 331, 1974.

Observational Evidence That the Coma Cluster is not Bound by Ionized Intracluster Gas, Ap. J., 186, L119, 1973.

Limits on Ionized Intracluster Gas in Abell 2199, Ap. J., 191, L11, 1974.

Optical and X-Ray Observations of 3U 0614+09. Accepted for Publication in Ap. J. (Letters), 1974.

Effect of Gaunt Factors on Analysis of X-Ray Spectra: Viability of a Thermal Intergalactic Medium in the Coma Cluster, Ap. J., 184, 323, 1973.

On the Distance to Cygnus X-1, Ap. J. (Letters), 185, L113, 1973.

The Luminosity Function of Galactic X-Ray Sources: A Cut-off and a Standard Candle, Ap. J., 186, 91, 1973.

Photometry in the Cygnus X-1 Field, Astr. and Ap., 30, 467, 1974.

Limits on the Soft X-Ray and Extreme Ultraviolet Flux from RX Andromedae and U Geminorum, Submitted to Ap. J.

An Extreme Ultraviolet Survey of the North Galactic Polar Region, Accepted for Publication in Ap. J.

On the Opacity of the Interstellar Medium to Ultrasoft X-Rays and Extreme Ultraviolet Radiation, Ap. J., 187, 497, 1974.

Further Evidence for an Interstellar Source of Nighttime HeI, 584 Å Radiation, Ap. J., 188, L71, 1974.

An Observation of O^+ 834 Å Nightglow Emission, Geophysical Research Letters, 1, 109, 1974.

On the Distribution of He^+ in the Plasmasphere from Observations of Resonantly Scattered HeII, 304 Å Radiation, JGR, 79, 174, 1974.

Interplanetary Lyman-beta Emissions, Ap. J., 186, 1091, 1973.

Observations of HeI 584 Å Nighttime Radiation; Evidence for an Interplanetary Source of Neutral Helium, Ap. J., 187, 633, 1974.

Conjugate Excitation of Atomic Oxygen Emissions in the Far Ultraviolet, Accepted for publication in Astrophysics and Space Sciences.

Cosmic Far Ultraviolet Background, Nature, 247, 513, 1974.

The Ranicon: A Resistive Anode Image Converter for Soft X-ray and Vacuum Ultraviolet Wavelengths, Proceedings of the in depth Seminar on Instrumentation in Astronomy-II, SPIE, 1974.

An Extreme Ultraviolet Spectrometer for Space Research, Applied Optics, 13, 575, 1974.

The Ranicon: A Resistive Anode Image Converter, Rev. Sci. Inst., in press, 1974.

In the following we list talks given by members of our research group during the reporting period.

X-Ray and Far Ultraviolet Observations of the Perseus Cluster of Galaxies, P.A.S.P., 85, 530, 1973.

Viability of a Thermal Intergalactic Medium in the Coma Cluster, P.A.S.P., 85, 534, 1973.

On the Origin of the Soft Component of the Diffuse X-Ray Background, BAAS, 6, 331, 1974.

II. PAYLOAD CONFIGURATION AND FLIGHT PERFORMANCE

The payload for 21.017 is shown schematically in Figure 1. In addition to the two X-ray detectors, the soft X-ray background telescope and the HeI 584 Å photometer, the payload contained two 35 mm cameras whose function was to define the payload pointing attitude during flight. The payload was flown with the GSFC PCM telemetry system, contained in the nose-cone, and the Strap IV inertial guidance system, which we were using for the first time. Other changes included heavier separation springs, to prevent the booster catching up with the payload and possibly causing disorientation or damage, and a reefed parachute, designed to reduce the opening shock which probably caused the 21.016 recovery failure.

The experimental objectives were as follows:

(i) To scan the Coma and Virgo Clusters with fine spatial resolution, in order to measure structure in the X-ray sources.

(ii) To obtain measurements or improved upper limits of the soft X-ray spectra of the Coma and Virgo Clusters.

(iii) To measure the soft X-ray background flux during a 50° scan of the sky, using two detectors with 3° (FWHM) circular fields set 5° apart. By performing cross-correlation experiments with the results, it is hoped to set limits to the number density of discrete sources producing the galactic component of the soft X-ray background.

(iv) To search for soft X-rays from De Vaucouleurs 50, a dense group of galaxies.

(v) To set limits to the energy-dependence of the soft X-ray background spectrum, using an instrument employing a paraboidal grazing-incidence collector, a proportional counter, and a movable X-ray filter. The filter allows measurement of the flux in two well-defined energy bands.

(vi) To study the flux of solar 584 Å radiation resonantly scattered by neutral interstellar helium flowing through the solar system. Detailed measurements of this flux may be compared with theoretical models to derive properties of the local interstellar medium, in particular its temperature, which have yet to be well defined.

The requirements of the primary objective specified accurate pointing, to within 10 arc min, and smooth sky scans at a low rate, 1.5 arc min/sec. These were achievable only with the Strap IV system, which employs rate - integrating gyros and can update the guidance system using a startracker.

The payload was launched to a peak altitude of 188 km, above mean sea level, remaining for 205 sec above 140 km, the approximate lower limit for soft X-ray observations. These figures were a little lower than the planned values, a combination of excess mass resulting from spin balancing, slight underperformance by the solid-propellent motor, and a non-optimum launch angle caused by winds. De-spin and separation were achieved successfully, after which the ACS updated the guidance system in two axes, using sightings of Spica and Arcturus by the startracker.

Subsequently, slow scans of the Coma and Virgo clusters were made at the required rates, with initial set-up errors of 15' in roll and 13' in yaw for Coma, and 9' in roll and 16' in yaw for Virgo. The ACS may have performed better than these numbers indicate, as they probably contain systematic errors introduced by the alignment and camera film reading procedures. (See Section II.4)

Both X-ray detectors performed extremely well, but problems were encountered in the operation of the soft X-ray background telescope and the HeI 584 Å photometer. Both cameras performed well, and yielded star pictures which defined the astronomical scans precisely. The instruments will be discussed further in the following section.

Following the scientific observations and reentry of the payload into the atmosphere. the parachute was deployed successfully and lowered the payload to a remarkably soft landing.

III. THE SCIENTIFIC INSTRUMENTS

1. The X-Ray Detectors. The characteristics of the two X-ray detectors are summarized in the following table.

	XR-1	XR-2
Collimation	Two circular fields of view, 3° in diameter (FWHM), with centers 5° apart.	Etched-grid collimator containing 0.008" wide slots, defining a field view of 9.2' x 5° (FWHM)
Aperture	275 and 195 cm^2	390 cm^2
Window	Polypropylene, 70 $\mu g/cm^2$ Transmission: 0.85 at 44 Å 0.23 at 115 Å	Kimfol, 255 $\mu g/cm^2$ Transmission: 0.68 at 10 0.47 at 44

Counting Gas	Propane at 150 mm.	P-10 at 350 mm.

The dual-field collimator of XR-1 serves for cross-correlation background experiments, and also for simultaneous source and background measurements during observations of the Coma and Virgo Clusters. XR-1 has been designed to be effectively two detectors, in which alternate anode wires in the front layer are joined and view X-rays entering one 3° circular field, while the remaining front layer anode wires are joined and view X-ray entering the other field. As XR-1 was designed to fly with a very thin window, and the particle-induced background in X-ray detectors is known to climb steeply at low energies, it was decided to equip the collimator with magnets. The field in the collimator averages 70 guass, which with no particle reflection on the collimator walls should exclude electrons with energies below 47 keV. However, research at SSL and at the Lawrence Livermore Laboratory ('Electrons at Low Altitudes; a Difficult Background Problem for Soft X-ray Astronomy.' UCRL - 51470, October 24, 1973) has established a significant reflection of charged particles from metal walls. Therefore, allowing one electron bounce in the collimator, electrons with energies as low as 3 keV may reach the detector window.

Apart from these changes in collimator, the XR-1 and XR-2 detectors were similar to those flown in the 21.016 payload. Improvements in XR-1 included a new window design, and a propane heater system equipped with a temperature-sensing thermal control loop. The latter feature can accomodate substantial increases in propane flow-rate, caused for example by window tears or pinholes, which otherwise would drop the liquid supply pressure or flood the pressure regulator with liquid, resulting in regulator shut-down. These features have given us confidence in flying very thin windows, enabling us to fly at 70 μg/cm^2 window on 21.017, giving XR-1 a response to very soft X-rays. For example, the quantum efficiency of the detector is still 10% at 140 Å. Thinner windows could have been flown but below 70 μg/cm^2 the response of the detector to far and extreme ultraviolet radiation becomes significant. This has been established in the laboratory using monochromatic beams of 304, 584, 1216 and 1750 Å radiation.

XR-1 was flown in the fixed-gain mode, in which gas pressure and high voltage were set before flight, while XR-2 was flown in the gain feedback mode, in which counts from an internal Fe^{55} source are used to regulate the voltage. Both detectors were exposed during flight to external calibration sources, a Po^{210} source with an aluminum target (1.49 keV) for XR-1 and an Fe^{55} source (5.89 keV) for XR-2, for 10 sec before and 10 sec after the astronomical observations.

The pressure and voltage in XR-1 reached the preset values in flight, and varied by less than 1% and 0.5% respectively. The gas temperature was 7°C higher than measured in laboratory tests, contributing to a shift in gain of +15%. As a result the instrument dynamic range changed from the preset values of 0.04-2.5 keV to 0.03-2.1 keV. The gas pressure in XR-2 reached the expected value also, and varied by less than 3% during flight. The gas temperature was 10°C higher than expected also, and these temperature shifts in both counters appear to have been caused, at least in part, by heating of the rocket payload during ascent. The gain of XR-2 was 17% greater than the value set in the laboratory, the result of cosmic ray events recorded by the anode wire sensing the Fe^{55} 5.89 keV X-rays. The instrument dynamic range changed from the preset values of 0.07-9.0 keV to 0.08-10.5 keV. These shifts in dynamic range of XR-1 and XR-2 were well within the margins required by the scientific observations.

Examination of the telemetry records shows that the electronics unit on each detector (essentially the preamplifiers, coincidence logic circuits and the pulse-height analyzer) performed well, and that sensible accumulations of counts in each of the 64 PHA bins were transmitted by the telemetry to the ground station twice in each main TM frame (one frame lasts 0.0256 sec). Analysis of the data is proceeding.

2. SOFT X-RAY BACKGROUND TELESCOPE

This experiment was designed to look at the very soft X-ray background between 50 and 150 Å, to do photometry using a boron filter which has an absorption edge at 67 Å, and to measure the galactic latitude dependence of the intensity and spectrum at these wavelengths.

The telescope consists of a grazing incidence paraboloidal mirror (grazing angle 10 - 20°), a multiwire proportional counter at the focal plane, the boron filter, which is alternately flipped in and out of the beam by a stepper motor, a gas flow system, and an electronics box containing the preamplifier and stepper motor control circuits. The following table summarizes the instrument characteristics:

Collimator	8° FWHM circular field
Aperture	230 cm^2 (projected geometric area of paraboidal mirror).
Window	~ 0.8 micron polypropylene
Filter	Boron and VYNS (transmission = 0.35 at 68 Å)
Counting Gas	Propane, 100 mm.
Effective Area x Effective Solid Angle	~ 0.2 cm^2 -ster at 90 Å

The instrument did not perform as expected. A slight drop in gas pressure, caused by the gas regulator, produced a gain increase of about 60% in the proportional counter, which otherwise appeared to be functioning normally. However, the count rates seen in the primary astronomy channels of the counter were larger at the beginning of the flight by factors of 50 to 100 than the expected rates. The count rate fell gradually, and at the end of the flight was only 5 - 10 times the expected rate. It appears as though the increased count rate is due to external effects, as the count rate with the rocket doors closed was low and at the expected level. Further the insertion of the boron filter clearly modulated the count rate. Possible sources of these high count-rates, 304, 1216 and 1750 Å photons and low energy electrons, have been intensively investigated at SSL. The results revealed nothing which could have produced the high counting rate encountered during flight, although the sensitivity of the telescope to electrons bouncing off the mirrors was surprisingly high. To remedy this a magnetic "broom" will be used on the next flight, 21.031, and in addition, the counter and filter will be better shielded from electrons, stray light and solid particles by installing a thin metal shield around the instrument.

3. HeI 584 Å PHOTOMETER

A thin tin filter has been combined with a channel electron multiplier to make a photometer, which is sensitive in a band approximately 100 Å wide and including 584 Å. A 10 cm column of 300 °K helium, at a pressure somewhat less than 1 Torr, is confined between the tin filter and an aluminum filter, in order to absorb resonantly the 584 Å radiation backscattered by helium in the Earth's geocorona. Most of the flux of 584 Å from beyond the geocorona is sufficiently Doppler shifted not to be absorbed. Provision was made to fill and empty the column alternately during flight, thereby creating a periodically varying count rate and hence identifying positively doppler-shifted HeI radiation.

The experiment failed during flight when the helium pressure regulator supplied insufficient helium for resonant absorption. The failure was caused by operation at a regulator inlet pressure slightly above the range covered in the laboratory, and by an apparent slight change in regulator adjustment between final calibration and flight.

A fix is in process and the experiment will be reflown in 21.031.

4. CAMERAS AND INSTRUMENT POINTING SOLUTIONS

Star pictures are taken during flight once every 1.5 sec by a 35 mm Nikon camera, and once every 6.7 sec by a smaller 35 mm camera. The latter is a back-up camera, an armoured design capable of surviving re-entry malfunctions such as payload break-up and parachute failure. A window is provided in the upper door of our payload, so that failure of the door would still permit star pictures to be obtained by one camera.

Both cameras performed as expected, and the film from both has been read with an optical scanner at the Lawrence Berkeley Laboratory. The star position measurements are recorded on magnetic tape, which then is processed by a computer. The alignment of an optical flat, mounted on the camera, with respect to the ACS startracker is measured before and after flight, as are the alignments of similar flats mounted on the scientific instruments. The results for the Nikon camera show a discrepancy of 10 arc min between the position of the second update star, Arcturus, and the pointing position of the ACS startracker deduced from the camera record.

Most of this discrepancy may be explained in terms of the expected errors in the alignment measurements and in film reading, and therefore the Nikon camera solution is reliable. The ACS pointing errors summarized in Section I are based on this solution, and in so far as these errors show a systematic component in the same direction as the Arcturus discrepancy, the ACS would appear to have performed better than indicated in Section I.

The results for the armoured camera show a systematic error of about 1.5° with respect to the Nikon camera. This error has not been explained, and further alignment tests are necessary to improve the accuracy of the back-up camera.

Fig. 1 Payload for 21.017: Schematic Diagram