X-ray Gas Scintillation Spectrometer Experiment

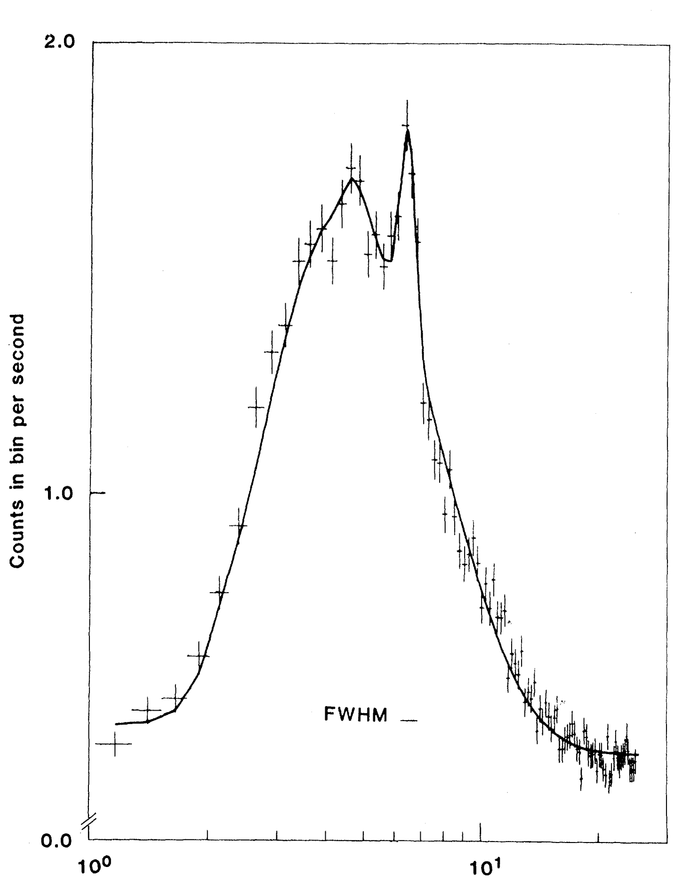
Abstract. *The payload complement on Spacelab 1 included a spectrometer for observations of the brighter cosmic x-ray sources. The primary scientific objective was to study the detailed spectral features of cosmic x-ray sources and their associated temporal variations over a wide energy range from about 2 to 80 kiloelectron volts. The instrument, based on the gas scintillation proportional counter, had a geometrical area of some 180 square centimeters with an energy resolution of about 9 percent at 7 kiloelectron volts. The results presented here show new results from two galactic binary x-ray sources, Cygnus X-3 and Centaurus X-3, and from the Perseus cluster of galaxies. The excellent energy resolution of the instrument permits line features to be identified in these sources with unprecedented quality.*

The payload complement on Spacelab 1 included a gas scintillation proportional counter for cosmic x-ray spectroscopy. This broadband medium-energy instrument has provided new information on the spectra of strong x-ray sources at energies above ~2 keV. The novel type of detector has an energy resolution at least a factor of 2 better than that of the classical proportional counter used in the past over a similar energy range. Such an improvement in energy resolution allows emission and absorption lines to be resolved from the underlying continuum emission. The observation of lines from highly ionized heavy elements and the determination of such parameters as line strength, width, and energy will provide information on the temperature, elemental abundance, and electron density in the hot plasma generally associated with cosmic x-ray sources.

The x-ray spectrometer. The flight instrument consisted of two units, the detector assembly and the digital electronics box. In the integrated payload both of these units were located on the European Bridge Assembly. This was a pallet-mounted structure located directly behind the Spacelab module and essentially consisted of a flat plate (cold plate) suspended across the pallet. The detector assembly was mounted on top of this, looking vertically upward with respect to the shuttle body. Its viewing axis was closely aligned with that of experiment 1NS005, a far-ultraviolet telescope (*1*), to enable simultaneous observations to be made. The digital electronics box was mounted on the underside of the cold plate. The principal characteristics of the Spacelab 1 x-ray spectrometer are summarized in (*2*). A more detailed description of the instrument can be found in (*3*).

Preliminary results. The x-ray spectrometer was controlled during flight from the Payload Operations Control Center (POCC) at NASA–Johnson Space Center. The POCC received all the payload data and maintained voice and command contact with the spacecraft. The results presented in this report are based on data collected at the POCC in near-real time, using the experimenter-provided computer system.

The experiment was switched on



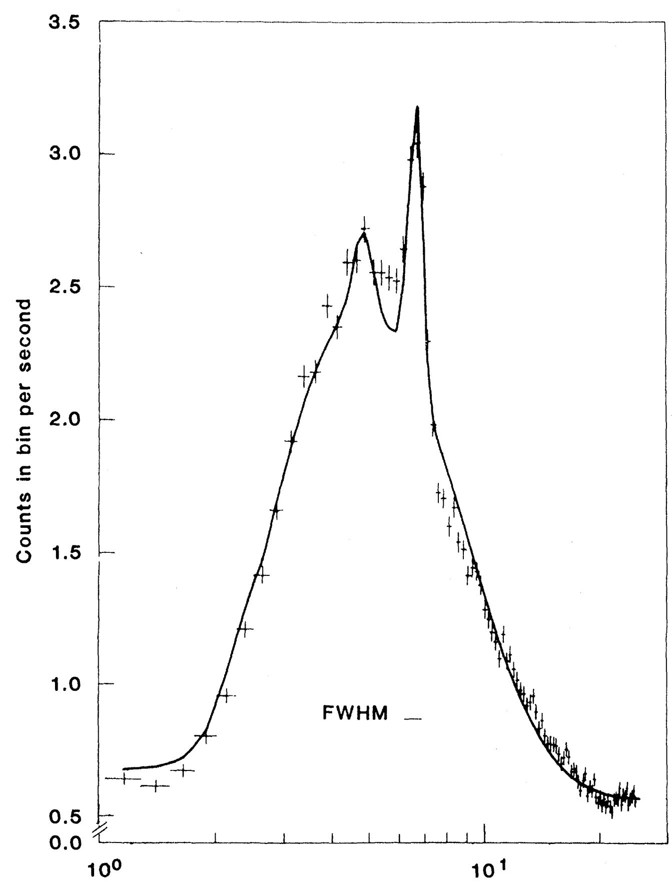


Fig. 1 (left). Quick-look energy spectrum of the galactic binary x-ray source Cygnus X-3 at an orbital phase of 0.032. Fig. 2 (right). Quick look energy spectrum of the galactic binary x-ray source Cygnus X-3 at an orbital phase of 0.65.

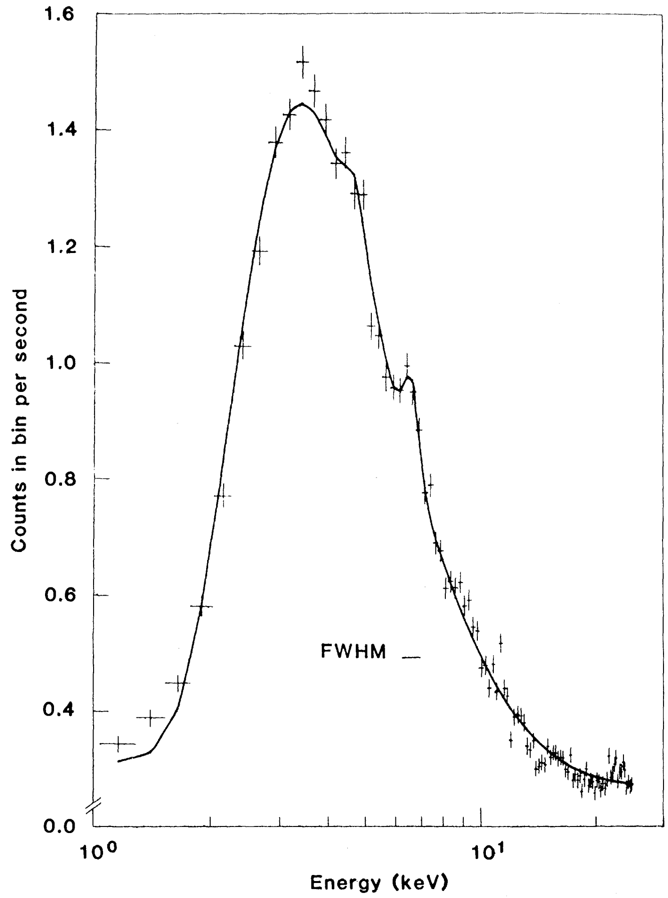


Fig. 3. Quick-look energy spectrum of the Perseus cluster of galaxies.

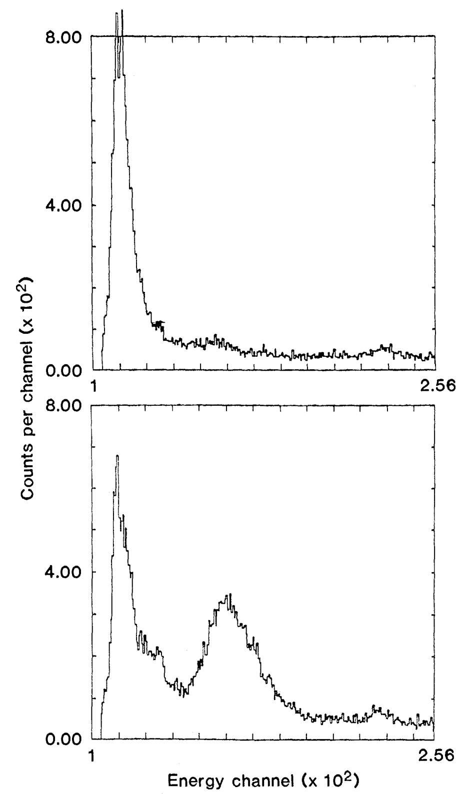


Fig. 4. Two quick-look energy spectra (0 to 30 keV) of the galactic binary x-ray source Centaurus X-3 taken 15 minutes apart, demonstrating the spectral variability of the source.

shortly after Spacelab activation and switched off only when the payload bay was looking toward the sun. The observing target sequence during the mission and the on-target times, are given in Table 1. During the cold test of the experiment, a systematic background scan was undertaken. Preliminary results show a flat background spectrum and a quite low absolute flux of approximately 0.4 event sec^{-1} keV^{-1} in the energy range 2 to 10 keV whenever the latitude was below ±30° and outside the South Atlantic Anomaly.

Interesting data were recorded from Cygnus X-3, a galactic x-ray binary source. This source shows intensity variations with a period of 4.8 hours, implying binary motion in a very compact system. Figures 1 and 2 show the raw quick-look data at two different orbital phases, 0.032 and 0.65. The solid line in Figs. 1 and 2 represents a fit to the data taking into account the background, the instrument response characteristics, and a blackbody spectrum for the continuum radiation. In addition two lines are present which have been tentatively identified at approximately 4.7 and 6.4 keV. The first line is present in all observations, including those of the Crab, and may be explained as a detector feature due to the absorbing xenon gas. The second line, at 6.4 keV, could be interpreted as iron fluorescence radiation. It will be interesting to see how much the line-to-continuum flux ratio changes with orbital phase. The peak position appears to be constant with time.

Figure 3 shows the data from the 200-minute observation of the Perseus cluster of galaxies. The continuum flux is fitted by using an exponential thermal model. The observation of ionized iron line emission at 6.7 keV implies that thermal emission from a hot intracluster gas (10^8 K) is the physical source of the x-ray flux. Figure 4 shows energy spectra (0 to 30 keV) of the galactic binary source Centaurus X-3. The two raw spectra, with integration times of several minutes, were taken about 15 minutes apart and demonstrate the significant spectral variability of this source.

Table 1. Observing target sequence during the mission and times on target in minutes.

Target	Time (minutes)
Cygnus X-2	21
4U1636-53	17
Hercules X-1	19
Coma	25
Cygnus X-3	27
Perseus	18
Cygnus X-1	17
Cassiopeia A	21
Cygnus X-1	19
Perseus	200
Cygnus X-1	30
Crab	16
Centaurus X-3	29
Cygnus X-2	40
Vela X-1	29

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References and Notes

1. See J. Bixler *et al.*, *Science* **225**, 184 (1984).
2. The principal characteristics of the Spacelab 1 x-ray spectrometer are as follows: collimator field of view (movable +8° to −7°), 4.5° full width at half-maximum (FWHM); peak collimator transparency, 90 percent; nominal energy range, 2 to 40 keV; available energy range, 2 to 80 keV; number of channels per energy range, 500; background rejection efficiency (2 to 10 keV), 97 percent; background rejection efficiency (10 to 20 keV), 96 percent; x-ray acceptance efficiency A_x, 80 percent; background after rejection (2 to 10 keV), 0.4 count sec^{-1} keV^{-1}; background after rejection (10 to 20 keV), 0.5 count sec^{-1} keV^{-1}; total geometric area for photoabsorption of x-rays (includes collimator peak transparency and A_x), 183 cm^2; energy resolution (FWHM) (E < 25 keV), $27/E(keV)^{1/2}$ percent; K escape fraction above 34.5 keV, 58 percent; L escape fraction above 4.5 keV, 2 percent.
3. R. D. Andresen *et al.*, *Adv. Space Res.* **2** (No. 4), 281 (1983).

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Very-Wide-Field Ultraviolet Sky Survey

Abstract. *Very-wide-field photographs of the sky were taken on Spacelab 1 at 1650, 1930, and 2530 angstroms with a limiting magnitude of 9.3 at 1930 angstroms. A 1.2 by 2.4 kiloparsec ultraviolet extension of the Shapley wing of the Small Magellanic Cloud is seen in some of the photographs.*

Astronomical observation of very extended phenomena, such as the zodiacal light, the Milky Way as a whole, or the extragalactic sky background, requires very wide fields of view. With very large fields it is possible to compare the brightness of the extended source with the limit brightness of the sky background on the same exposure. Ground-based observations with very-wide-field, high-luminosity cameras have proved useful in the detection of galactic nebulae of large angular diameter and faint surface brightness (*1*). At ultraviolet wavelengths a wide field (80° by 120°) in the northern Milky Way was photographed at 2650 Å (*2*), but most ultraviolet space observations have been performed with scanning techniques, which have the disadvantage that it is necessary to deal with the difficulty of image reconstruction.

Experiment 1ES022 on Spacelab 1 was designed to carry out a deep, large-scale imaging survey of a large portion of the celestial sphere at ultraviolet wavelengths. The main objective of this survey was to obtain new information (photometric, morphological, and spectrographic) on the large-scale distribution of (i) stellar ultraviolet radiation in the Milky Way and the nearest galaxies, (ii) scattering dust clouds in and above the galactic plane, and (iii) sunlight scattered by interplanetary dust (zodiacal light). The survey was also expected to be useful in the detection of ultraviolet stars and starlike objects.

Instrument. The very-wide-field camera (VWFC) devised for the Spacelab 1 mission has been described (*3*). In the photometric mode, an all-reflection *f*/1.9 Schmidt camera refocuses the image of the sky from a hyperbolic primary mirror onto the photocathode of a 40-mm, proximity-focused ITT intensifier. The overall useful field is 66° in diameter and the angular resolution is 5 arc minutes, a value compatible with the guiding performance of the orbiter. Three interference filters can be placed across the entrance pupil of the Schmidt camera. They are centered at 1650, 1930, and 2530 Å with bandwidths at half-maximum of 400, 250, and 250 Å, respectively.

By using a holographic grating in place of the filters, the camera may be operated as a large-field (14° by 6′) nebular spectrograph (spectrographic mode). The observed spectral range extends from 1400 to 2900 Å with a spectral resolving power of 700 at 1900 Å.

Observations. The VWFC was mounted in the Spacelab scientific air lock. It was operated during the nights of revolutions 84 to 91, 94 to 96, and 98. Each sequence of exposures was initiated by the crew and completed automatically under computer control. The whole program for the 28 November launch was achieved nominally. A total of 48 exposures were obtained for ten astronomical targets. Six additional exposures on the earth airglow were made during revolution 105.

Because of the delayed launch date, only about 40 percent of the original VWFC scientific program was achieved. The delayed program did not permit observation of the zodiacal light and considerably shortened the orbital night durations.

Most of the photographs obtained during the Spacelab 1 mission suffer from a high level of sky background. The main contributor to this background is stray

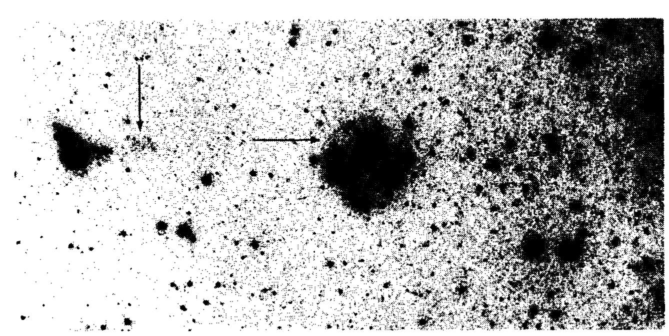

Fig. 1. (Left) Positive print of a 66° field, 300-second exposure taken by the very-wide-field camera at 1930 Å. The field is centered on the Large Magellanic Cloud (LMC). The Milky Way is on the right and the Small Magellanic Cloud (SMC) is on the left. Below the SMC is the very bright star α Eridani. This picture shows on the right side of the SMC a 1° by 2° region of faint emission, pointing toward the LMC, which is interpreted as a large cloud of hot stars in the interconnecting bridge of matter between the SMC and the LMC. (Right) Negative enlargement of the central part of the upper photograph showing the two Magellanic Clouds and the ultraviolet extension of the Shapley wing of the SMC (vertical arrow). Note also in the upper left part of the LMC a very thin arc-shaped feature (horizontal arrow) previously observed at 2000 Å by the Marseilles-Geneva balloon-borne telescope (*11*).