

SPECTRAL AND LOCATION MEASUREMENTS OF SEVERAL COSMIC X-RAY SOURCES
INCLUDING A VARIABLE SOURCE IN CENTAURUS*

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This paper reports the results of x-ray spectrum and location measurements of several cosmic x-ray sources made on 18 May 1967. Rocket-borne proportional counters were used. The x-ray spectra of Sco XR-1, Tau XR-1, and Lup XR-1 were measured, and the location of Vel XR-1, Lup XR-1, and a new source Cen XR-3 were determined. In addition, the x-ray spectrum and location of a variable source, Cen XR-2, were obtained.

On 18 May 1967 (UT) a rocket carrying two proportional counters was launched from Kauai, Hawaii, to determine the intensity and spectrum of the x rays from Sco XR-1 and Tau XR-1, with simultaneous visual observations of Sco XR-1. During the flight these two sources were successfully observed, and detailed results of the visual correlation investigation will be reported in a separate paper. In addition, x rays were detected from the direction of the constellations Vela, Centaurus, and Lupus.

The detector system used consisted of two Xe-CH₄ filled, beryllium-window (87-cm² area) proportional counters and was identical, except for collimation, to the system used and reported previously by the authors.¹ The rocket was fired essentially toward the zenith at 0616 UT, and spin stabilized at 5 rev/sec. The zenith pointed at 11^h15^m right ascension (R.A.) and +22° declination on the celestial sphere. Therefore, the detectors viewed the horizon throughout the flight. One detector *a* was collimated to 10° full width at half-transmission in azimuth and 30° full width at half-transmission in elevation. The second detector *b* was collimated to similar angles, but the collimator was rotated in such a way that a source above the normal to the detectors was detected earlier in the "b" detector by an amount of time proportional to the angle between the source and the normal to the detectors. Conversely, a source below the normal to the detectors was detected later in the "b" detector

by an amount of time proportional to the angle between the source and the normal to the detectors. By measuring the relative time of detection in each proportional counter, the location of a source could be determined to within 2° to 5°, depending on count rate and proximity of other sources.

Figure 1 shows all x rays detected while above the atmosphere as a function of azimuth. Location of the sources was accomplished by comparison of the data in Figs. 1(a) and 1(b).

The source in Vela has been observed previously by the authors.² Cen XR-2 agrees with the location of a source reported by Harries *et al.*³ Lup XR-1 has been observed by Friedman, Byram, and Chubb.⁴ Cen XR-3 has not been observed previously.

It is estimated that all sources except Cen XR-2 are within 5° of the locations given in Table I; Cen XR-2 is within 2.5°. Vela, Centaurus, and Lupus were previously scanned in a flight conducted by Grader *et al.*⁵ in 1965. None of these sources were observed during that flight. However, Cen XR-3, Lup XR-1, and Vel XR-1 are too weak to have been detected above background. Thus, no definite conclusion regarding the absence of these sources during the previous flight can be drawn. In the case of Cen XR-2, the situation is quite different. This source was clearly quite strong on 18 May 1967 and it was definitely absent on 28 October 1965. It can be concluded, therefore, that Cen XR-2 is a variable source.

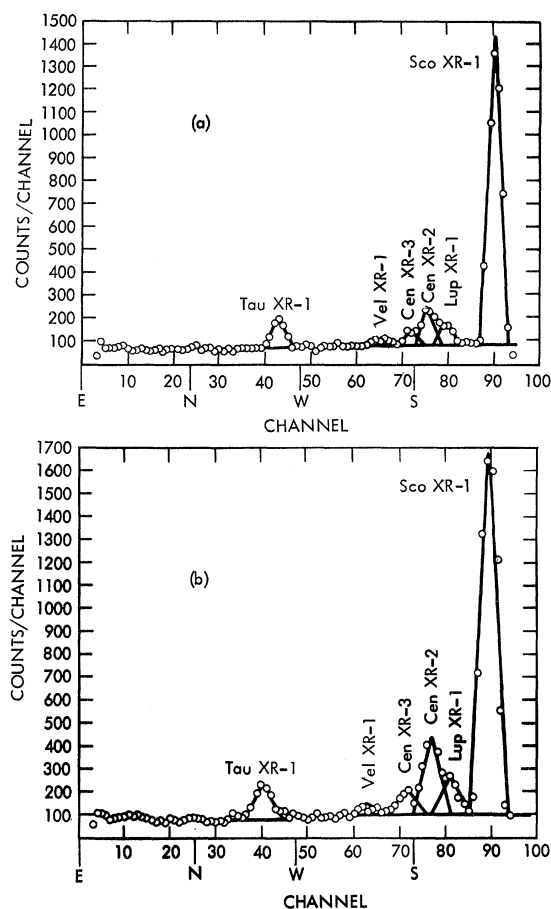


FIG. 1. (a) Total number of x rays of energy between 3.5 and 11.5 keV observed in the conventionally collimated detector *a* during the 240-sec period the rocket was above atmosphere. Each channel equals 3.75 deg of azimuth. (b) Same as (a), but the data were taken with the rotated collimator detector *b* between energies of 2.1 and 9.5 keV. Shifts in locations of the peaks are due to the position of sources above or below the detector normals.

Sufficient counts were accumulated from Tau XR-1, Sco XR-1, Cen XR-2, and Lup XR-1 to determine their spectra. All that can be said about Vel XR-1 and Cen XR-3 is that their spectra are "harder" than that of Cen XR-2. Figure 2 shows the spectra determined during this flight, and Table I summarizes all the results. The spectrum of Sco XR-1 agrees with that determined previously by the authors,⁶ but is lower in absolute intensity by a factor of 2. Cen XR-2 has a spectrum which agrees with that predicted for a thermal bremsstrahlung source at a temperature of 1.5 keV. This is consistent with the results obtained by Harries *et al.*³ Care should be taken in interpreting the Lup XR-1 spectrum since it may be contaminated by the source Nor XR-2. The difficulty is that the location given by Friedman, Byram, and Chubb⁴ has an uncertainty large enough to put the source above or below the x-ray horizon.

Cen XR-2 appears to be a source like Sco XR-1 but at a cooler temperature. Therefore, on the basis of extrapolating this x-ray intensity to the optical region, Cen XR-2 may look like a thirteenth magnitude, starlike object. This extrapolation procedure has been used successfully in the past to predict the visual magnitude of Sco XR-1⁷ and Cyg XR-2.^{2,8} In addition, the failure to detect this source by Grader *et al.*⁵ in 1965 indicates its intensity has increased more than a factor of 10. Therefore, plates of this area of the sky made during October 1965 should not show a visible object at the position of the x-ray source.

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Table I. Photon flux, intensity, and location of sources determined during 17 May 1967 flight.

Source	Energy interval (keV)	Photon flux (photons/cm ² sec)	Intensity (ergs/cm ² sec)	Temperature or spectral index	Location
Sco XR-1	2.1-16	36 ± 4	2.7 ± 0.3 × 10 ⁻⁷	5.8 × 10 ⁷ °K	Same as reported in Ref. 4
Tau XR-1	2.1-16	3.6 ± 0.6	3.1 ± 0.5 × 10 ⁻⁸	α = -0.9	Same as reported in Ref. 4
Vel XR-1	2.1-9.5	0.4 × counter efficiency			8 ^h 52 ^m R.A. -44° dec.
Cen XR-2	2.1-9.2	5.4 ± 0.7	2.8 ± 0.4 × 10 ⁻⁸	1.8 × 10 ⁷ °K	13 ^h 24 ^m R.A. -62° dec.
Cen XR-3	2.1-9.5	0.7 × counter efficiency			11 ^h 23 ^m R.A. -59° dec.
Lup XR-1	2.1-16	1.8 ± 0.4	1.8 ± 0.4 × 10 ⁻⁸	α = -0.9	14 ^h 59 ^m R.A. -52° dec.

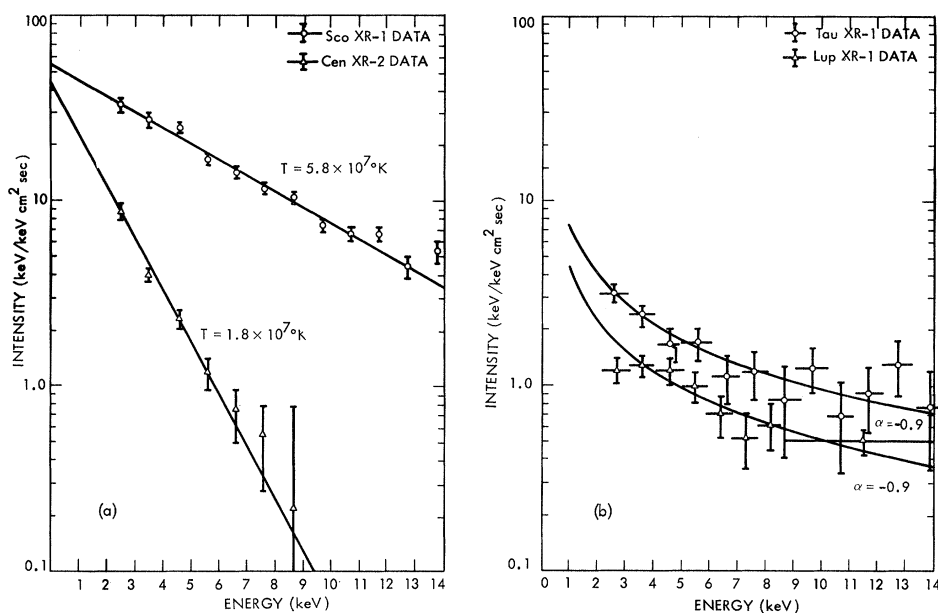


FIG. 2. Intensity of Sco XR-1, Tau XR-1, Cen XR-2, and Lup XR-1 as a function of x-ray energy determined from data taken during this flight. (a) Solid lines are calculated intensities for bremsstrahlung. (b) Solid lines are calculated intensities for synchrotron radiation.

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