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Search for X-Rays from the Large and Small Magellanic Clouds

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Two high energy x-ray sky surveys were carried out in balloon flights from Mildura, Australia, on October 15 and 24, 1967. We observed a 30% decrease in the high energy x-ray intensity of Cen XR-2 between the two balloon observations. We also placed upper limits on the high energy x-ray intensities from the Large and Small Magellanic Clouds that are less than 1/12 and 1/8 of the intensity from Tau X-1, respectively.

Results on Cen XR-2 from the October 15th flight have been published elsewhere (Lewin et al, 1968a). In this paper we discuss the results from the October 24th flight. We used four NaI(Tl) scintillation detectors with a total sensitive area of 368 cm^2 and an anticoincident jacket of plastic scintillator. The field of view had an angular width of 17.5° FWHM. The instrument was suspended from the balloon with its axis inclined at 40° from the vertical, and it was rotated continuously with an average period of about 8 minutes. The pulses were analyzed in 7 channels covering the energy range from 20 to 110 keV. In-flight calibration every 20 minutes with an Am^{241} source demonstrated that no change of any significance occurred in the channel boundaries. We determined the background rates by averaging over 400 sec intervals, excluding those periods when obvious sources were in the field of view. The azimuth of the telescope axis was measured continuously by magnetometers which were calibrated in flight by reference to a sunsensor. The direction of the telescope axis was determined within an uncertainty radius of approximately 2° at every instant throughout the flight. A more detailed description of the instruments and matters of analysis is given elsewhere (Clark et al, 1968; Lewin et al, 1968a).

We derived the spectrum and intensity of the Centaurus source from only those data recorded when the axis of the detector was within 12° of the source. The total effective exposure accumulated under this condition in 19 scans over the source was $1.6 \times 10^5 cm^2 sec$. Taking into account the angular response function of the detector at each moment as the data was recorded, and correcting for small variations in the atmospheric attenuation due to altitude variations (2.17 to 2.19 mm Hg), we obtained the average observed rate above background in each of the 7 channels at the average balloon altitude. These data were converted into the estimated values for the energy intensity (keV/keV cm^2sec) shown in figure 1 using the atmospheric attenuation and the response function of the scintillation detector. Figure 1 also shows our results obtained 10 days earlier on October 15, 1967 when we achieved an exposure of $3.3 \times 10^5 cm^2 sec$ in 35 scans over the source. The spectral data derived from the last positive rocket observation on May 18, 1967 (Chodil, et al, 1967) are also shown in the figure.

Table 1 gives the spectral data on both the October 15 and the October 24, 1967 flight. Columns 1 and 3 show the energy channel settings, columns 2 and 4 show the calculated energy intensity corrected to zero atmospheric thickness. The ratios of the intensities as observed during the two flights are given in column 5. Lumping the data from 20 to 52 keV, 52 to ~107 keV, and 20 to ~107 keV, we find ratios of 1.53±0.25, 1.17±0.29, and 1.38±0.19, respectively. Thus we conclude that the intensity decreased by approximately 30% between October 15, 1967 and October 24, 1967.

When first observed in April 1967, by Francey, et al, Cen XR-2 was nearly as bright as Sco X-1. Its intensity decreased by an order of magnitude and the spectrum form changed significantly in a period of six weeks (Francey et al, 1967; Cooke et al, 1967; Chodil et al, 1967). Seventeen days before our October 15th observation, on September 28, 1967, the region was scanned by LRL (Chodil, et al, 1968) and no source at the position of Cen XR-2 was observed. The high energy x-ray flux on October 15, 1967 from 20 to 52 keV and 52 to 105 keV was ~4 x 10^{-9} and ~2.7 x 10^{-9} ergs/cm^{2}sec, respectively. This is about half the flux observed in the same energy interval from Tau X-1 (Peterson et al, 1968; Lewin et al, 1968c).

The measured rate of change in the energy intensity from 20 to 52 keV is 35±17% in 9.8 days. Extrapolations back in time (based only on our October 15th and October 24th observations) to May 18, 1967, assuming either an exponential or a power law time decay function lead to high values that do not match the rocket results from May 18, 1967 (see fig. 1). We therefore conclude that the rate of change as measured by us is either accidentally high or, which seems more likely, the high energy x-ray flux originated at a later time than the low energy x-ray flux. This would eliminate the possibility that the high energy spectrum has a more permanent character and is older in origin than the recent nova-like x-ray outburst. Manley (1968) has suggested that the high energy x-ray spectrum arises from an expanding shell whose shock front accelerates, generating increasing temperatures as it propagates into the interstellar material around the Centaurus source. This suggestion is worked out in more detail in the following paper.

An analysis similar to the one described elsewhere (Lewin et al, 1968b) for the 19 scans over the source on October 24, 1967 between $21^h\ 05^m$ and $23^h\ 20^m$ U.T. showed no evidence of short term intensity variations.

From the October 15 and 24 flight data we have found the maximum likelihood positions of the Cen XR-2 source to be $\alpha = 196^{\circ}\!.5 \pm 3^{\circ}$, $\delta = -64^{\circ} \pm 2^{\circ}$* and $\alpha = 197^{\circ} \pm 6^{\circ}$, $\delta = -64^{\circ}\!.5 \pm 3^{\circ}$, respectively.

In order to compare our observations with the rocket observation of Chodil et al (1968) made 17 days before our October 15th flight, we have extrapolated the high energy spectrum to lower energies and find values for the energy intensity on October 15, 1967 between 2 and 5 keV of $\sim 1.8 \times 10^{-9}$ ergs/cm^{2}sec and $\sim 6.4 \times 10^{-9}$ ergs/cm^{2}sec for an assumed exponential (kT=20 keV) and a power law ($\alpha = 1.2$) spectrum form, respectively (see fig. 1). Similar, though somewhat lower values, can be inferred from the

*This position (revised) differs somewhat from the position $\alpha = 197^{\circ}\!.2 \pm 3^{\circ}$, $\delta = -62^{\circ} \pm 1^{\circ}\!.5$ as reported earlier by us (Lewin et al, 1968a)

October 24th results. An upper limit on the energy flux (2-5 keV) of $\sim 3 \times 10^{-9}$ ergs/cm²sec was reported as a result of the rocket observation on September 28, 1967 (Chodil et al, 1968). We therefore conclude that the energy flux (2-5 keV) on September 28, 1967 was most likely $(2\pm1) \times 10^{-9}$ ergs/cm²sec. The actual flux could have been significantly lower on this date if the spectra as observed by us bent over towards lower energies, or if Cen XR-2, or a source within a few degrees from Cen XR-2, increased its x-ray flux significantly between September 28 and October 15, 1967.

If an exponential function is forced to fit the above result and all previous fluxes (2-5 keV) reported for Cen XR-2 its constant τ is about 45 days. A value of $\tau \sim 25$ days was obtained by Harries et al (1967) from the April and May 1967 data only. Manley (1968) considers that a power law time decay of the energy intensity for Cen XR-2 is a more plausable assumption. If such a law of the form $t^{-\alpha}$ is forced to fit the available low energy data (2-5 keV) including the one derived here for September 28, 1967, then the values for α vary from ~ 2 to ~ 6 under various assumptions regarding the moment of the origin of the intense x-ray emission which must lie between October 28, 1965 and April 4, 1967. Values for α of 2.3, 2.9, 4.4 and 6.2 were calculated, assuming that the x-ray outburst originated on March 1, 1966, July 1, 1966, November 1, 1966 and March 1, 1967, respectively.

No evidence was found of discrete sources in the directions of the Large and Small Magellanic Clouds. The upper limits on the x-ray energy flux between 20 and 52 keV from the Large and Small Magellanic Clouds are ~0.6 x 10^{-9} ergs/cm^2sec and ~1.2 x 10^{-9} ergs/cm^2sec, respectively, assuming a spectrum like that of Tau X-1. The upper limits in the 52 to ~110 keV energy range for both Clouds are ~10^{-9} ergs/cm^2sec. The above upper limit on the Large Magellanic Cloud is a factor of three below the only other reported upper limit (Seward and Toor, 1967) in the energy range above 20 keV.

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TABLE 1.

October 15, 1967		October 24, 1967		
Energy channel settings (keV)	Energy intensity* keV/keV cm^2 sec	Energy channel settings (keV)	Energy intensity* keV/keV cm^2 sec	Flux ratios $\frac{\text{Oct. 15}}{\text{Oct. 25}}$
20-30	13.8±1.7	20-31	7.8±2.2	1.8±0.5
30-41	6.8±0.7	31-42	4.3±1.0	1.6±0.4
41-52	5.0±0.6	42-52	3.7±1.0	1.3±0.4
52-63	3.2±0.7	52-64	2.8±0.9	1.1±0.4
63-74	3.9±0.8	64-75	3.0±1.3	1.3±0.6
74-90	3.6±0.8	75-92	3.3±1.3	1.1±0.5
90-105	3.6±1.2	92-110	1.3±1.7	2.8±3.8

*Corrected to zero atmospheric thickness.

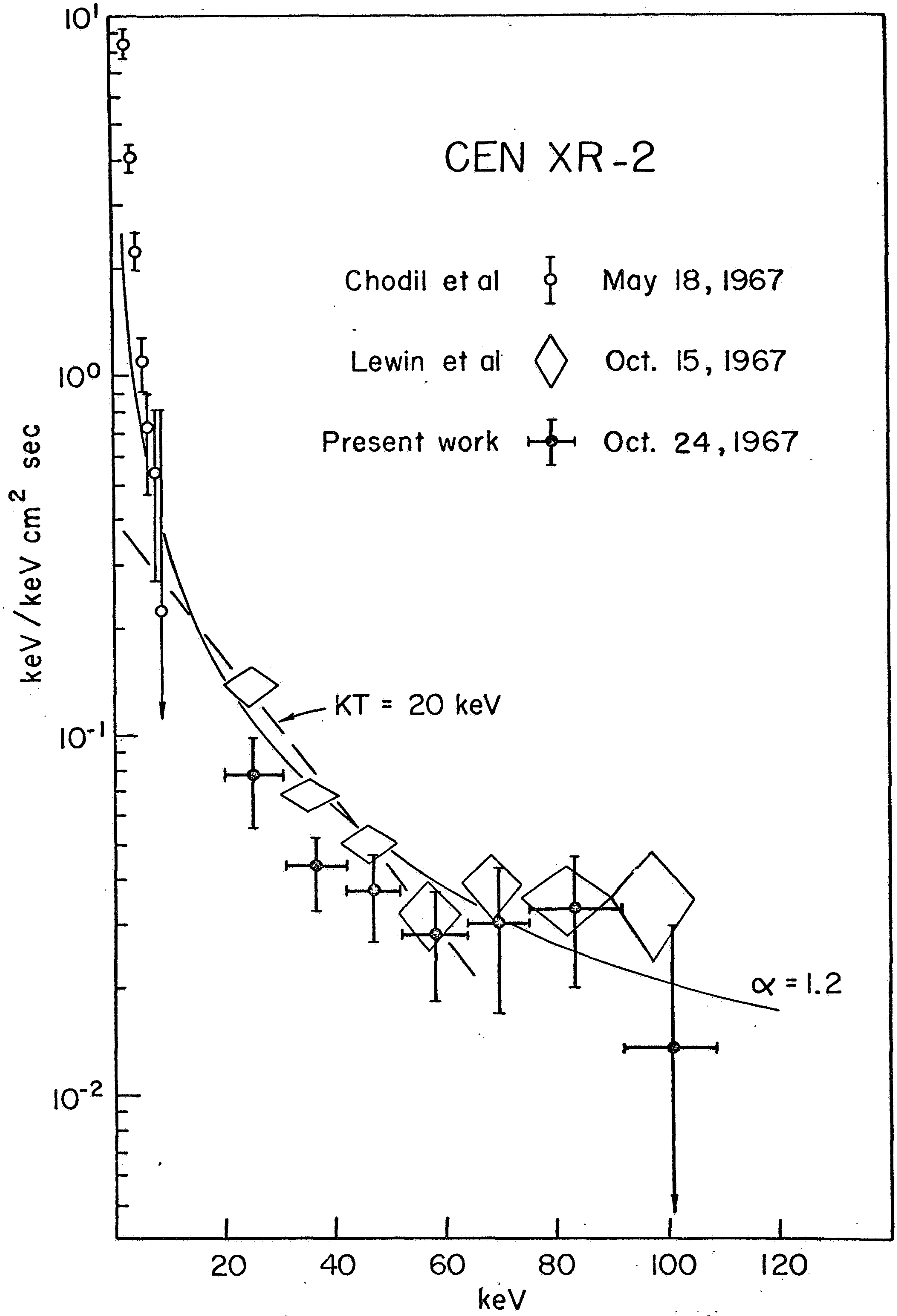

Fig. 1. - Spectra from Cen XR-2

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