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from a Source in Crux\*

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CSR-P-71-57

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CENTER FOR SPACE RESEARCH  
MASSACHUSETTS INSTITUTE OF TECHNOLOGY



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ABSTRACT

On 1969 April 16 we carried out balloon X-ray observations from Australia (energies above 18 keV). We detected a strong X-ray flux in the range 18 to 36 keV from a source at  $\ell^{\text{II}} = 301 \pm 3^\circ$ ,  $b^{\text{II}} = -2 \pm 3^\circ$ . During our observations the X-ray flux flared up by about a factor of three. The flare lasted for a period of about one and a half hours. There is also some evidence for a flux change in less than 10 minutes. The average observed flux was about  $2 \text{ keV cm}^{-2} \text{ sec}^{-1}$ , which is at least a factor of seven higher than that observed about one month earlier on 1969 March 20 at which time no evidence for X-ray emission from this region of the sky was found by Lewin, McClintock and Smith. The average flux is about as high as that observed by Lewin, Clark and Smith on 1967 October 15 from a source at  $\ell^{\text{II}} = 304.8 \pm 1.5^\circ$ ,  $b^{\text{II}} = -1.5 \pm 2^\circ$ .

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During a balloon flight from Mildura, Australia, on 1969 April 16, we carried out X-ray observations of the region of the sky from which we had earlier observed a strong flux (Lewin, Clark and Smith, 1968b; 1968c). On 1969 March 20, one month before the presently reported observations, we did not detect any X-rays from this region (Lewin, McClintock and Smith, 1970). However, on 1969 April 16 we detected a flux about as strong as that detected on 1967 October 15.

We used our  $358\text{cm}^2$  NaI(Tl) scintillation detector surrounded by an anticoincidence jacket of plastic scintillator. The field of view had an angular width of  $13^\circ$  FWHM. A detailed description of the instrument is given elsewhere (Clark, Lewin and Smith, 1968). As a result of malfunctioning cutdown devices the instrument splashed down in the Tasman Sea after a ~16 hour float at altitudes above 130,000 ft. The telescope with the on-board data film washed up in New Zealand nine months later. A special processing technique which made the data on the film legible was developed by Kodak Research Laboratories. There is no ambiguity in the data; however, the quality of the film is poor; reading the data from the film cannot be automated and is consequently extremely time consuming. Therefore, although X-rays were detected in 7 energy channels in the energy range from 18 to ~105 keV, we have so far analyzed only the data obtained in a "sum channel" which groups the first three channels covering the energy range from ~18 to 36 keV.

During the observations described here between  $11^{\text{h}}10^{\text{m}}$  and  $15^{\text{h}}10^{\text{m}}$  U.T. the telescope axis was inclined  $29.5^\circ$  to

the vertical and was continuously rotated in azimuth with an average period of about 7 minutes. In-flight calibration every 20 minutes with an  $\text{Am}^{241}$  source demonstrated no change of any significance in the boundaries of the sum channel.

Background rates were determined by averaging data over 400 sec intervals, excluding those periods when obvious sources were in the field of view. The values thus obtained were used with linear interpolation to calculate the background counting rate at any desired instant. A correlation between the background counting rate and the azimuthal direction of the instrument was found; the counting rate was highest when the instrument was pointing toward the south-southeast and lowest when the instrument was pointing toward the north-northwest. Maximum differences from the average value were +2.5 percent and -1.5 percent. We have taken this azimuthal dependence of the background into account, although it had only a small effect on the results obtained.

The azimuth of the telescope axis was measured continuously by magnetometers which were calibrated in-flight by a sun sensor. The direction of the telescope axis could be determined within approximately  $1.5^\circ$ . The X-rays that we have detected

can be attributed to a single source whose maximum likelihood position is  $\ell^\pi = 301 \pm 3^\circ$ ,  $b^\pi = -2 \pm 3^\circ$ .

It seems likely that the flux reported here is due to the highly variable source at galactic longitude  $\ell^\pi \sim 301^\circ$ , which is described in the following paper (McClintock, Ricker

and Lewin, 1971). However, we cannot exclude the possibility that some or all of the flux comes from the highly variable source at galactic longitude  $\ell^{\text{II}} \sim 304^\circ$  which we first detected on 1967 October 15 (Lewin, Clark and Smith, 1968b; 1968c; Lewin, McClintock and Smith, 1970; see also following paper).

The accuracy in the determination of the galactic longitude of the X-ray source Cen XR-2, which is also variable, has recently been improved by Francey (1971) as a result of a re-analysis of the April 20, 1967 rocket data (Francey et al. 1967). He now reports a value of  $\ell^{\text{II}} = 310.2 \pm 1^\circ$ . If this determination is correct, we must conclude that the high-energy flux that we have detected in 1967 and 1969 (this paper) is not due to Cen XR-2, but is due to at least one new variable high-energy source. It is interesting to note that the AS&E group recently (1970 December 27) observed a source ( $F_1$ ) at galactic longitude  $303.7 \pm 0.5^\circ$ <sup>†</sup> (Giacconi et al., 1971).

We calculated the average flux from the source over 33 scans with a total effective exposure of  $\sim 2.3 \times 10^5 \text{ cm}^2 \text{ sec}$ . We obtained the average observed intensity in the energy channel 18 to 36 keV by taking into account the angular response function of the detector at each moment that data were recorded, and by correcting for atmospheric absorption.

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<sup>†</sup>We have estimated this galactic longitude from figure 4 of the AS&E paper.

We followed the procedure described in an earlier paper (Clark, Lewin and Smith, p.30, 1968). The results depend on the assumed form of the spectrum incident on the Earth's atmosphere. We have assumed here two forms of the energy spectrum: a power law of the form  $J(E)dE \propto E^{-\lambda}dE$  with  $\lambda \sim 1.5$  and an exponential of the form  $J(E)dE \propto e^{-E/kT}dE$  with  $kT \sim 5$  keV.

In Table 1 we list results of four balloon observations covering the region in Cen-Crux near the galactic plane. The results shown in the third column are calculated energy fluxes corrected to zero atmospheric thickness. In columns 4 and 5 we list the galactic coordinates of reported source positions derived under the assumption that only one source was predominantly responsible for the detected high-energy flux. We conclude that between 1969 March 20 and 1969 April 16 the flux in the 18 - 36 keV energy range from the source reported here equator in the vicinity of  $l^{\text{II}} \sim 300^\circ - 305^\circ$  increased by at least a factor of 7.

An analysis of each of the 33 scans over the source between  $11^{\text{h}}10^{\text{m}}$  and  $15^{\text{h}}10^{\text{m}}$  U.T. on April 16, 1969 was carried out using a method described in detail in an earlier paper (Lewin, Clark and Smith, 1968a). We have taken into account only the data for which the corresponding collimator-response function  $f$  (exposed fraction of sensitive crystal area) was greater than 0.30. Further, we have included only those 28 scans for which, under the above condition, the effective exposure time to the source was greater than  $\sim 10$  seconds.

Figure 1 shows the source intensity (18 - 36 keV) for these scans plotted versus Universal Time. The intensities have been corrected to an atmospheric thickness of  $3.50 \text{ g cm}^{-2}$  (average of line of sight to the source). The corrections were less than 10% for each scan.

The X-ray flux increased by at least a factor of three between  $13^{\text{h}}45^{\text{m}}$  and  $14^{\text{h}}30^{\text{m}}$  U.T. There seems to be some evidence that the flux thereafter decreased rapidly (in less than 10 minutes), increased again, and then decreased in a period of about 30 minutes. A  $\chi^2$  fit to a constant source intensity gave a value of 45 for the 28 points plotted.

#### Acknowledgements

A great many people have contributed to the success of these balloon observations. We believe that the most valuable contribution was made by Mr. J. C. Hodgson and Mr. W. R. Simpson who found the payload on Kaitaia beach in New Zealand. We also are very grateful to the police in Kaitaia, to the Director of the Oceanographic Institution in Wellington, to the Defense attaché in Wellington, Captain Hazlett, and to Lt. Col. St. George of the DIA in Washington who made it possible for the recovered payload and flight film to be returned to M.I.T. We are extremely grateful to Dr. Childers and Mssrs. Henn, Hahn, Swann, Passarell, and Olivares of Kodak Research Laboratories in Rochester, New York for developing a special technique that make the data on the

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Table 1

## High-Energy X-Rays from Centaurus =Crux

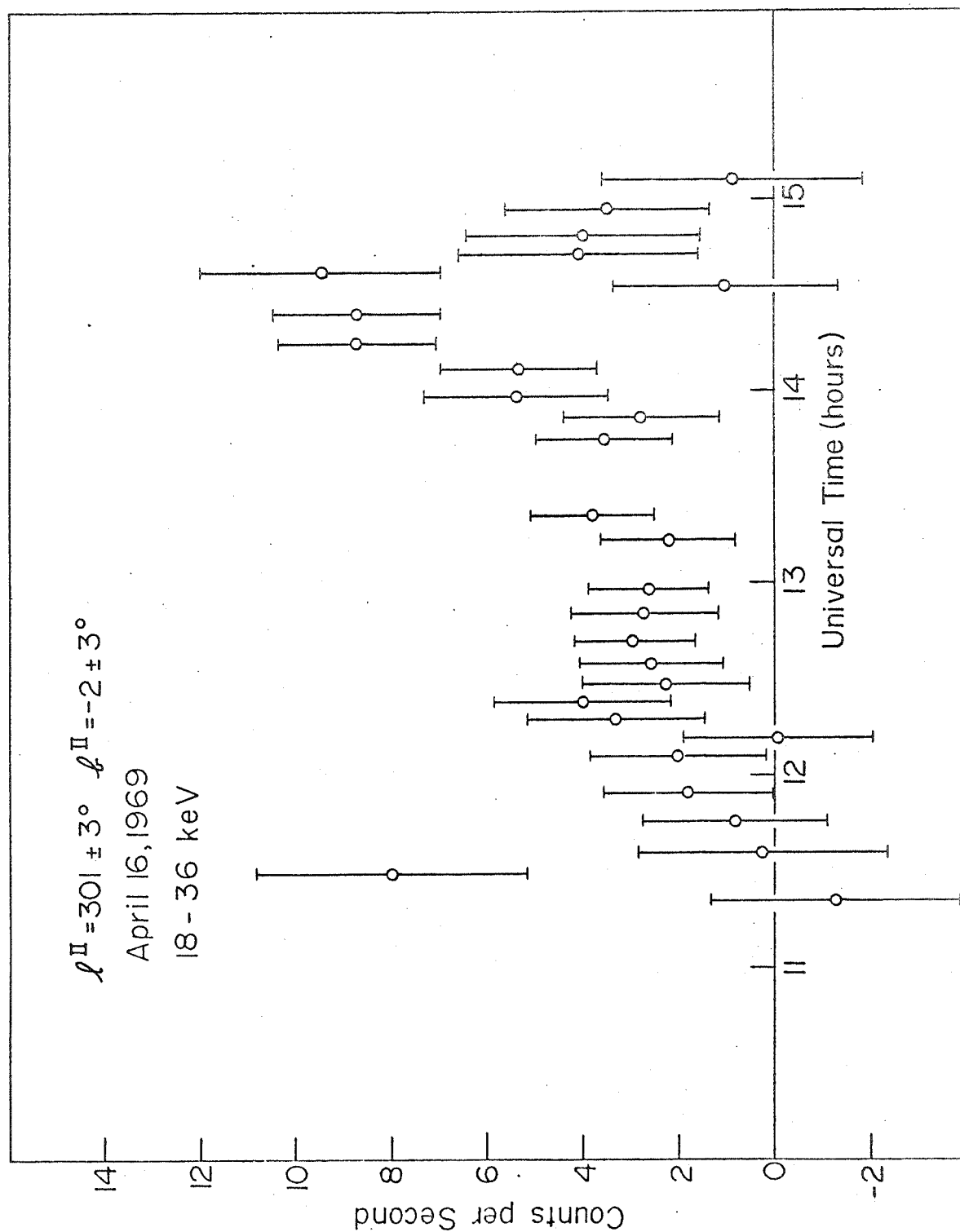
Observations made	Energy Channel (keV)	Energy flux* $10^{-2} \text{ keV cm}^{-2} \text{ sec}^{-1}$	$\ell$	$b$	Reference
Oct. 15, 1967	20-40	206 $\pm$ 19	304.8 $\pm$ 1.5 $^\circ$	-1.5 $\pm$ 2 $^\circ$	Lewin et al, 1968c
Oct. 24, 1967	20-42	133 $\pm$ 24	305 $\pm$ 3	-2 $\pm$ 3	Lewin et al, 1968c
March 20, 1969	18-38	<27 $^\dagger$			Lewin et al, 1970
April 16, 1969	18-36	$\left\{ \begin{array}{l} 190 \pm 18^\dagger \\ 325 \pm 30^\ddagger \end{array} \right.$	301 $\pm$ 3	-2 $\pm$ 3	this paper

\* corrected to zero atmospheric depth

+ assumed energy spectrum of a power law form with  $\lambda \sim 1.5$ .‡ assumed energy spectrum of an exponential form with  $k \sim 0.5$  keV.

Figure Caption

Figure 1: X-ray intensity (18 - 36 keV) from a source  
at  $\ell^{\text{II}} = 301 \pm 3^\circ$ ,  $b^{\text{II}} = -2 \pm 3^\circ$ , as observed  
on April 16, 1969. The intensities (counts  $\text{sec}^{-2} 358^{-1}$   
 $\text{cm}^{-2}$ ) for the 28 scans over the source have been cor-  
rected to an atmospheric thickness of  $3.50 \text{ g cm}^{-2}$ ;  
collimator response has been taken into account.



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