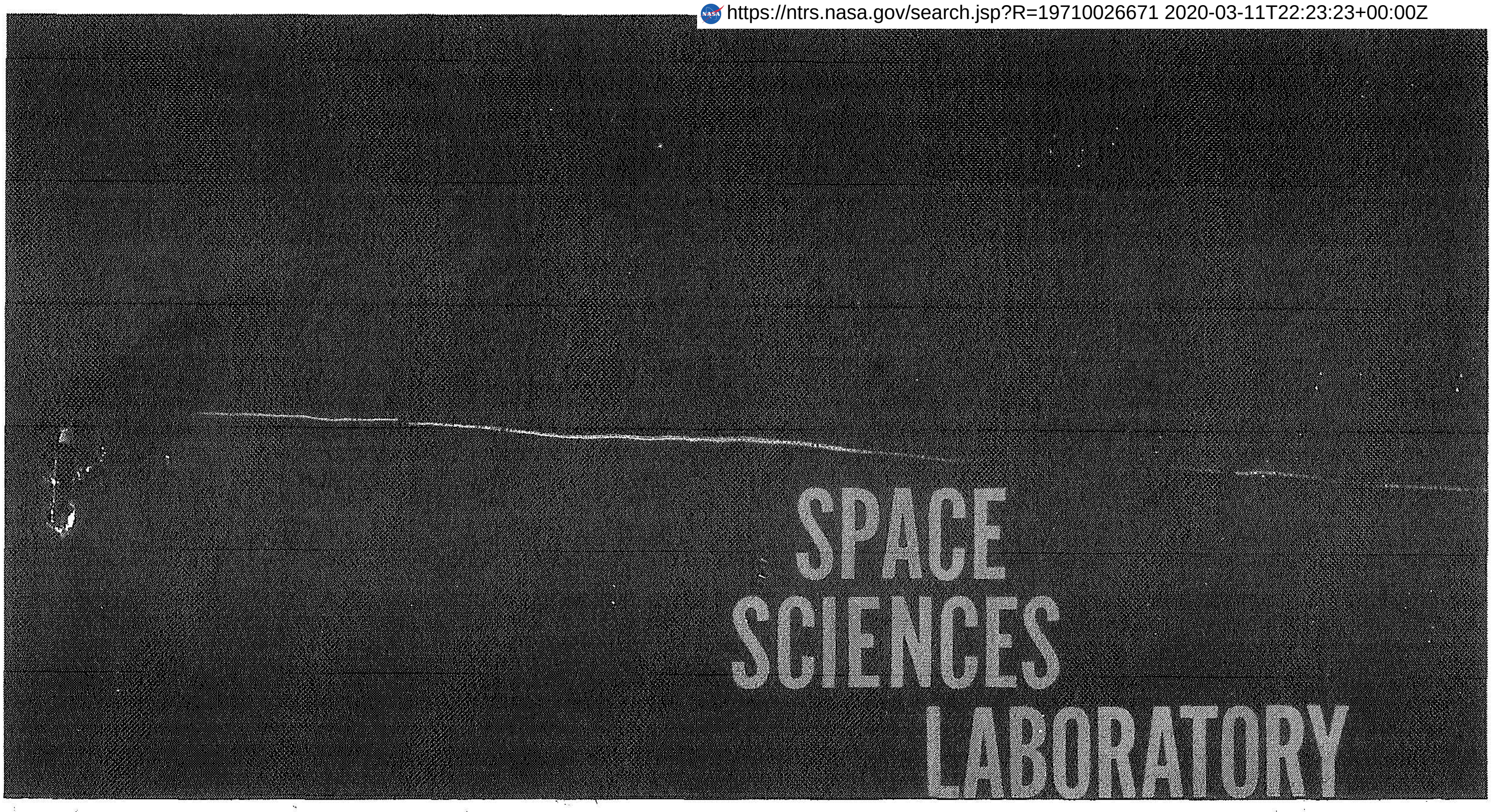

A PULSING X-RAY SOURCE IN CIRCINUS

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Abstract: A pulsing x-ray source with period 685 ± 30 ms has been observed in Circinus. Approximately 10% of the 1 to 10 keV x-ray emission of the source is contained in these pulses. A spectrum of the source is presented, and may be fit by a thermal bremsstrahlung emission mechanism with $T = 3.5 \times 10^7$ °K, or by a black body at $T = 1.1 \times 10^7$ °K, both subject to heavy absorption.

The observation reported in this letter was made from an Aerobee 150 rocket launched from Natal, Brazil, on June 14, 1969. Data were obtained by two argon-methane proportional counters equipped with mylar windows. Extragalactic observations from this flight, together with a description of the instrumentation and method of spectral data analysis, have been reported previously (Bowyer et al. 1970; Lampton et al. 1971). A complete description of galactic source observations made on the flight is in preparation (Cruddace et al. 1971).

During a scan of the Norma-Lupus-Circinus region, a well-isolated source was observed in both counters. The two detectors were collimated differently, one with a 3° × 12° FWHM fan beam, the other with a 1.°6 FWHM pencil beam. A comparison of the count rate of the source as observed by each detector in combination with the time lag between peak count rates permitted the source to be located with reference to the scan track to an accuracy of 0.°5. The location of the scan track was established by comparing our x-ray source observations with that of known sources. The source is located at $\ell^{II} = 321.°4 \pm 0.°9$, $b^{II} = -0.°5 \pm 2°$ ($\alpha = 15^h\ 14^m$, $\delta = -57°\ 49'$, 1950.0) within the constellation Circinus and is hereafter referred to as Circinus XR-1.

The data presented here are taken from the fan beam detector, whose 308 count s^{-1} average background-corrected count rate substantially exceeded that of the pencil beam detector. The sampling period of our telemetry was 128 ms. The power spectrum of 64 successive count rate accumulations, which represent the entire 8.2 s transit of Cir XR-1, was calculated using the method described by Lampton et al. (1970). Figure 1 is a plot of this power spectrum. The peak at 1.46 ± 0.06 Hz (685 ± 30 ms) is statistically significant. The corresponding probability of a random fluctuation reaching this power level anywhere in the observed spectrum is 8.36%. The fractional modulation, which we define as the ratio of half-amplitude to the mean background-corrected count rate, is 10 ± 2%. As a check against possible systematic error, we have similarily analyzed the count rate from four other galactic sources observed during this flight. No other obviously periodic variations were observed.

In Figure 2 we present the photon spectrum of Cir XR-1. These data represent 6.53 s of observation centered on the transit of the source through the fan beam detector. Each point is corrected for counter efficiency, resolution, and background. Three different model photon distributions were fit to the data in the manner described by Lampton et al. (1971).

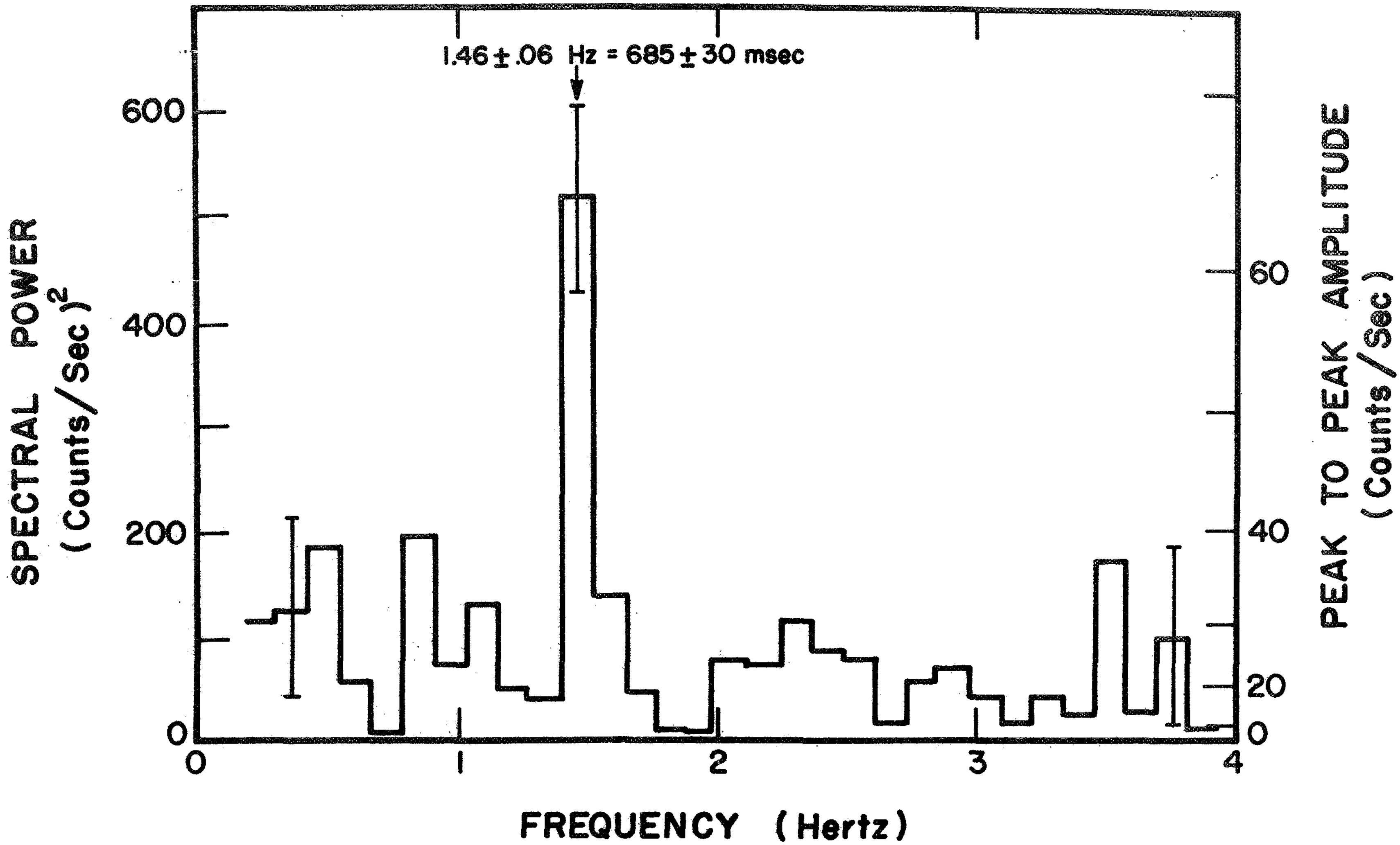

Figure 1. Power spectrum of Circinus XR-1.

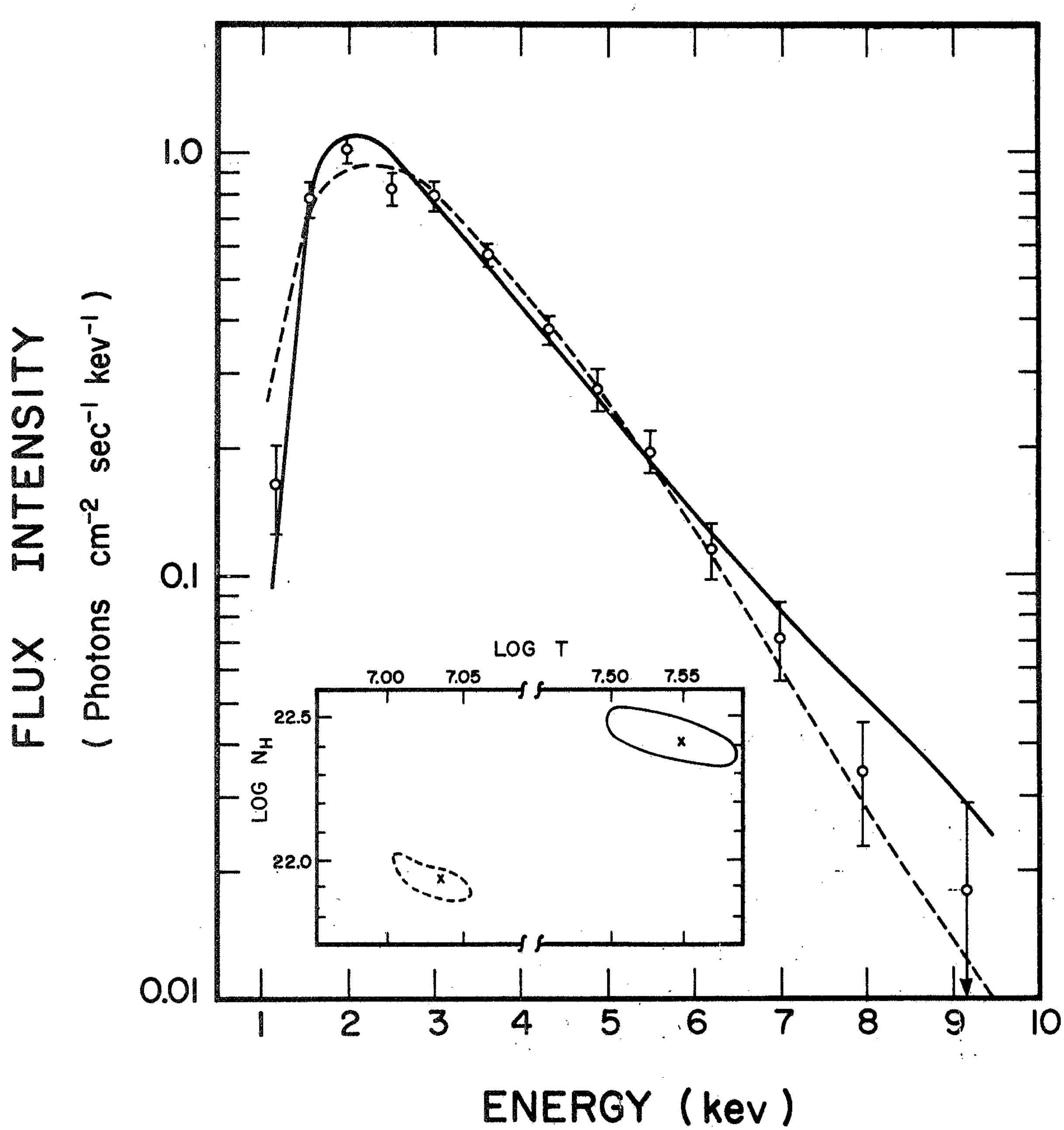

Figure 2. Photon spectrum of Circinus XR-1. Solid line: best bremsstrahlung fit; broken line: best black body fit. Error bars are ±1 σ statistical errors. Inset: contours of constant probability for the two models.

The results are shown in Table 1. It is clear that the bremsstrahlung and black body models are compatible with the observations, while the power law is not. The 1 to 10 keV intensity of the source is 9.46 ± 0.56 keV cm^{-2} s^{-1} or 2.85 ± 0.17 photons cm^{-2} s^{-1} (errors quoted are statistical only). Figure 2 also presents contours of constant probability for the bremsstrahlung and black body models. The contours shown are those where the confidence of the least-squares fit drops to $e^{-\frac{1}{2}} = 0.606$ of the peak value.

Table 1. Spectral analysis of Circinus XR-1.

Model	T or n	N_H (cm^{-2})	Confidence (%)
Bremsstrahlung	3.5×10^7 °K	2.5×10^{22}	18.4
Black Body	1.1×10^7 °K	0.8×10^{22}	33.4
Power Law	2.925	3.5×10^{22}	0.1

Cir XR-1 resembles two previously reported pulsing x-ray sources, Tau XR-1 and Cyg XR-1, in that it has a fairly small fraction of the total counts in pulsed form; it is similar to the one other reported x-ray pulsar, Cen XR-3 (Giacconi et al. 1971b), in that Cir XR-1 has a thermal spectrum. All four objects thus far observed have extremely low galactic latitudes. Tau XR-1 is known to be at a distance of 2.02 kpc and shows little photoelectric absorption. An upper limit of about 1 kpc can be placed on the distance to Cyg XR-1 based on the turnover in its spectrum (Gursky et al. 1971). Both Cen XR-3 and Cir XR-1 are heavily absorbed.

For Cir XR-1, 21 cm emission measurements give a total column density $N_H = 1.4 \times 10^{22}$ cm^{-2} (McGee et al. 1966). This is close to the number deduced from absorption in the x-ray spectrum and suggests that the source is quite distant.

The Milne catalog of galactic non-thermal radio sources (Milne 1970) lists three sources — designated MSH 15-52A, MSH 15-52B, and Kes 24 — within the error box of Cir XR-1. Although the radio pulsar MP1530 lies near Cir XR-1, its position falls 4.°9 from the center of our error box, and is probably not associated with the source.

Due to uncertainties in latitude determinations of Uhuru satellite observations (Giacconi et al. 1971a), the source in Lupus tentatively reported by Giacconi et al. (1971b) as exhibiting x-ray pulsation may in fact be Cir XR-1, since the longitude of the two sources is virtually identical.

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References

Bowyer, C. S., Lampton, M., Mack, J., and deMendonca, F. 1970, *Ap. J. Letters*, **161**, L1.

Cruddace, R. G., Mack, J. E., Lampton, M., Bowyer, C. S., and Margon, B. 1971, (in preparation).

Giacconi, R., Kellogg, E., Gorenstein, P., Gursky, H., and Tananbaum, H. 1971a, *Ap. J. Letters*, **165**, L27.

Giacconi, R., Gursky, H., Kellogg, E., Schreier, E., and Tananbaum, H. 1971b, *Ap. J. Letters*, **167**, L67.

Gursky, H., Gorenstein, P., Kerr, F. J., and Grayzeck, E. J. 1971, *Ap. J. Letters*, **167**, L15.

Lampton, M., Bowyer, C. S., and Harrington, S. 1970, *Ap. J.*, **162**, 181.

Lampton, M., Bowyer, S., Mack, J. E., and Margon, B. 1971, *Ap. J. Letters*, **168** (in press).

McGee, R. X., Milton, J. A., and Wolfe, W. 1966, *Australian J. Phys.*, Suppl. **1**.

Milne, D. K. 1970, *Australian J. Phys.*, **23**, 425.