- ⁴ Gudzenko, L. I., Ozernoi, L. M., and Chertoprud, V. E., *Soviet Astronomy—AJ*, **12**, 392 (1968).
- ⁵ Gudzenko, L. I., Ozernoi, L. M., and Chertoprud, V. E., *Nature*, **215**, 605 (1967).
- ⁶ Ozernoi, L. M., and Chertoprud, V. E., *Soviet Astronomy—AJ*, **10**, 15 (1966).
- ⁷ Terrell, J., and Olsen, K. H., *Astrophys. J.*, **161**, 399 (1970).
- ⁸ Kunkel, W. E., *Astron. J.*, **72**, 1341 (1967).
- ⁹ Manwell, T., and Simon, M., *Nature*, **212**, 1224 (1966).
- ¹⁰ Manwell, T., and Simon, M., *Nature*, **217**, 938 (1968).
- ¹¹ Smith, H. J., in *Quasi-Stellar Sources and Gravitational Collapse* (edit. by Robinson, I., Schild, A., and Schucking, E. L.) (University of Chicago Press, 1965).
- ¹² Jurkevich, I., *Astrophys. J. Lett.*, **172**, L29 (1972).

Anomalous Minima in Cen X-3

SCHREIER *et al.*¹ have presented convincing evidence that the highly variable pulsing X-ray source Cen X-3 is a member of a binary system. The UHURU satellite observations have shown that the intensity of the source varies with a 2.09 day period, and the short term pulsations show a periodically varying Doppler shift also compatible with this period to a high degree of accuracy. But a curious feature of the UHURU observations is that on several occasions the source remained at intensity minimum during periods when maxima were predicted. This anomalous behaviour must be explained before a detailed model can be formulated for Cen X-3. As pointed out by Schreier *et al.*, the fact that the suggested optical counterpart of Cyg X-1 is a spectroscopic binary increases the importance of understanding the X-ray binary phenomenon.

Here we report an observation made with a rocket-borne argon-methane proportional counter equipped with a 'Mylar' window and sensitive to X-rays in the 0.2 to 10 keV band. The scan track and instrumentation of the flight have been reported in detail elsewhere^{2,3}. During a scan of the galactic plane, the $3^\circ \times 12^\circ$ FWHM collimated detector passed directly over the location of Cen X-3 ($\alpha = 11$ h 19.0 m, $\delta = -60^\circ 19.2'$, 1950.0; ref. 1) at a roll rate of 1° per second. The location of the scan track in this part of the flight has been fixed accurately by observations of galactic sources whose positions are well known, and also by attitude control system (ACS) performance data. The altitude of the payload during the transit of Cen X-3 was 133 km, making corrections for atmospheric absorption negligible.

The count rate of the detector during the 3.08 s period centred on the transit was $71.8 \text{ counts s}^{-1}$ in the 1–10 keV band, compared with a background count rate of $72.4 \text{ counts s}^{-1}$. This background was determined from 39.5 s of high-latitude observations which excluded the positions of all known X-ray sources. From these data we may set a 2σ upper limit on the intensity of Cen X-3 at the time of our observation at $4.7 \times 10^{-10} \text{ erg cm}^{-2} \text{ s}^{-1}$ (1–10 keV). This upper limit has been derived from the observed count rate using the Cen X-3 spectrum presented by Giacconi *et al.*⁴, although it is not highly sensitive to spectral shape. As the binary period has been derived with great accuracy from the satellite data, and the time of transit of Cen X-3 through our detector is known to us to within a few seconds from ACS data, we may with some confidence extrapolate back to the time of our flight, June 14, 1969. The centre of the low intensity state from satellite data is J.D. $(2441132.083 \pm 0.001) \pm n(2.08712 \pm 0.00004)$. The UHURU observations also indicate that the intensity minima, maxima and transition periods last 0.488 ± 0.012 , 1.529 ± 0.012 , and 0.035 ± 0.007 days, respectively. Cen X-3 transited our detector at J.D. 2440387.414. Thus we calculate that our observation occurred 0.154 ± 0.015 day into a maximum period, well within the high intensity interval. The uncertainty has been calculated by permitting the maximum stated error in both the period and epoch to accumulate in the most unfavourable sense.

The intensity reported by UHURU for Cen X-3 during these maximum periods corresponds to $(2.6\text{--}4.5) \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1}$ in the 1–10 keV band, as compared with a low intensity value of ≈ 0.1 of this figure. Thus we have apparently observed a flux upper limit compatible with the low intensity period, but during a predicted interval of high intensity.

We have compared our intensity estimates of nonvariable sources also observed in this detector with those made by UHURU. For example, our flux determination for 3C 273 (refs. 2 and 5) agrees excellently with that of the satellite⁶. Thus we consider systematic errors in detector calibration or background subtraction unlikely. We therefore conclude that we have observed behaviour similar to that occasionally seen by UHURU, that is, an extended minimum of X-ray flux. It is tempting to postulate that the period of the proposed X-ray binary system has been incorrectly set or that true periodicity is not present, and that this discrepancy has been accentuated by the long time baseline provided by a comparison of our observations with those of UHURU. But the fact that Schreier *et al.* have never recorded a period of maximum intensity during an expected minimum, the converse of the effect reported here, makes this explanation highly unlikely. Thus we conclude that the anomalous effect is intrinsic to the source, and has now been identified at least intermittently over a 2.5 year period.

Schreier *et al.*¹ have already postulated that a variation in the radius of the envelope of the central object may account for small fluctuations in the duration of the transition state. Occasional larger variations in envelope radius would be compatible with both our data and those of UHURU and may account for the anomalous X-ray minima. A drastic envelope expansion causing immersion of a binary companion has previously been proposed to explain the cessation of eclipses in the CV Ser system⁷.

This effect may aid greatly in the optical identification of the Cen X-3 system. If the anomalous minima do occur when the X-ray source is enveloped by a shell of material, the spectrum of the optical counterpart may well change rapidly and dramatically at these times. This may prove to be the only unambiguous way of identifying the system optically, because, as pointed out by Schreier *et al.*, there is no reason to expect long or short period photometric variation from the central object. A recently suggested candidate for the optical counterpart of Cen X-3 (ref. 8) in fact shows emission line variation on a time scale of days.

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- ¹ Schreier, E., Levinson, R., Gursky, H., Kellogg, E., Tananbaum, H., and Giacconi, R., *Astrophys. J. Lett.*, **172**, L79 (1972).
- ² Bowyer, C. S., Lampton, M., Mack, J., and deMendonca, F., *Astrophys. J. Lett.*, **161**, L1 (1970).
- ³ Cruddace, R., Bowyer, S., Lampton, M., Mack, J., and Margon, B., *Astrophys. J.* (in the press).
- ⁴ Giacconi, R., Gursky, H., Kellogg, E., Schreier, E., and Tananbaum, H., *Astrophys. J. Lett.*, **167**, L67 (1971).
- ⁵ Margon, B., Bowyer, S., and Lampton, M., *Astrophys. J.* (in the press).
- ⁶ Kellogg, E., Gursky, H., Leong, C., Schreier, E., Tananbaum, H., and Giacconi, R., *Astrophys. J. Lett.*, **165**, L49 (1971).
- ⁷ Kuhl, L. V., and Schweizer, F., *Astrophys. J. Lett.*, **160**, L185 (1970).
- ⁸ Margon, B., and Wray, J. D., *Astrophys. J. Lett.* (in the press).