X-RAY ABSORPTION IN CIRCINUS X-1 IN THE LOW STATE

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ABSTRACT

We report observations of Cir X-1 with the Ariel 5 spectrometer, showing that the hydrogen column density in the low state is comparable to that observed in the high state. The implications of this fact for the models of the source are discussed.

1. INTRODUCTION

Circinus X-1 was discovered by Margon et al. (1971). A point radio source associated with it was found by Clark et al. (1975), who suggested the system to be a runaway ejected from a nearby SNR. Whelan et al. (1977) identified the optical counterpart as a highly reddened 20 mag star. A common 16.6 d periodicity was discovered in the X-ray Kaluziensky et al 1976), radio (Whelan et al. 1977) and IR bands (Glass 1978). The X-ray light curve is highly asymmetric and characterized by a sharp drop at phase 0. Mention of "extended low states" in the literature occurs before the discovery of the periodicity. We carefully searched the literature, finding that all observations are consistent with the 16.6 d modulation. The peak intensity could however be highly variable. Throughout this paper we mean as "low state" the low part of the 16.6 d cycle.

2. OBSERVATIONS AND RESULTS

Circinus X-1 was observed by Ariel 5 MSSL Experiment C on 1975 February, 1976 February, 1976 September, 1977 April. All observations, with the possible exception of the last one, were taken during the low part of the 16.6 d cycle.

Some of the observations are in time mode where a 64 sec resolution (with no spectral information) is attained. Time mode data were analyzed for periods up to 100 min, with negative results. The variability of the

Space Science Reviews **30** (1981) 389–393. 0038–6308/81/0303–0389 $00.75.

source is contained within 5-10% of the mean value of the count rate.

Most observations are in quadrant mode, where spectral information is available on an energy range between 2-10 or 3-30 KeV according to the gain used. Background was subtracted with the standard Ariel V quadrant mode procedure (see e.g. Sanford and Ives, 1976). Contributions of other sources in the field of view was estimated, with particular regard to the nearby SNR 4U1510-59. These contaminations are practically negligible in the lower energy channels, so we can be confident that what we observe there is really Cir X-1 in its low state. Some spectra (restored with the direct deconvolution method by Blissett and Cruise, 1979) are shown in Fig.1.

Raw spectra were also fitted by a least square technique to a power law spectral form. In some cases the χ^2 was improved by the inclusion of a weak line at ∿7 KeV. The photon spectral index ranges between 2.3 and 3.2 and is usually around 2.6. The flatter spectra are obtained in the groups of orbits where contamination by harder sources is possible. No large low energy cut-off is apparent. The hydrogen column density can be estimated to be $\sim 2\ 10^{22} cm^{-2}$. No significant correlation between spectral shape and intensity exists.

3. DISCUSSION

Our result that the slope, and particularly the low energy cut-off, in the low state are completely similar to those observed in the high state is relevant for an understanding of Cir X-1.

The current model for Cir X-1 (Murdin et al.1980) assumes that: the optical/IR source in the system is a massive supergiant; the compact companion (X-ray source) is in an eccentric orbit; the absorption along the line of sight is variable and the variation is due to the motion of the X-ray source in the stellar wind of the primary.

Within the frame of the current model the low states are explained by an increase of absorption, up to a column density of $2.5\ 10^{24} cm^{-2}$. This implies a cut-off at 12 KeV, which is only inferred from the result of Coe et al (1976), by combining Ariel 5 ST (26-1200 KeV) observations with an upper limit by the Ariel 5 RMC and with a point taken three years previously by OSO 7, and contrasts with our results.

We modified the current model to take account of the accretion rate onto the compact object. The X-ray luminosity is a function of r, the distance from the primary.

$$L_x(r) \propto \dot{M}_{accr}(r)\ e^{-\tau(r)}$$

$\tau(r)$ is given by Murdin et al.(1980), while $\dot{M}_{accr}(r)$ is computed assuming an inverse square density law for the wind. The theoretical light curve shapes (see Fig.2) are different, more peaked than those of Murdin et al.

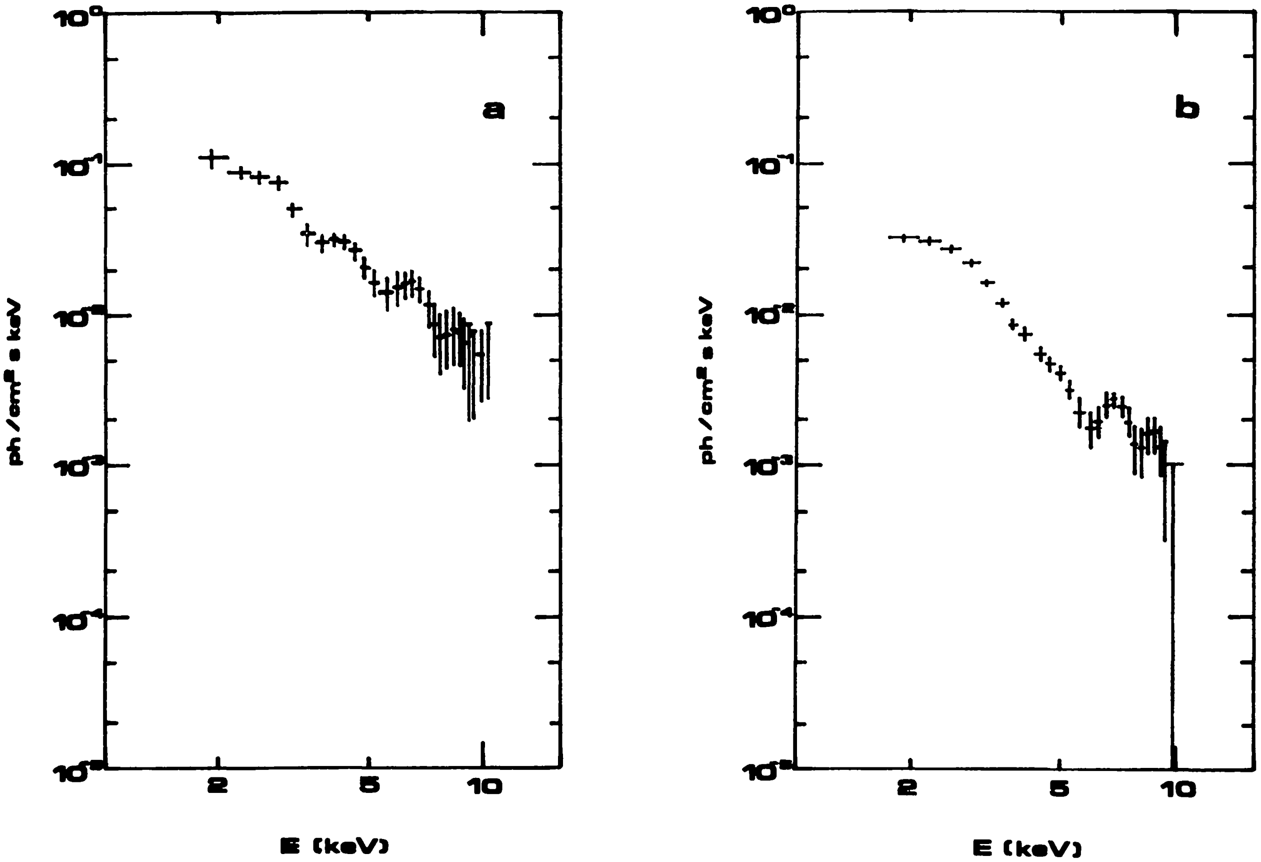

Fig.1 : Spectra of Cir X-1 restored with the method of Blissett and Cruise (1979). a) combination of 10 orbits (February 5-6, 1976) b) combination of 15 orbits (February 7-8, 1976).

(1980), who assume $\dot{M}_{accr}$ to be constant. We note that the asimmetry of the light curve is due to $\tau(r)$, while $\dot{M}_{accr}(r)$ is simmetric with respect to the line of apsides.

If we use the same eccentricity of Murdin et al (1980) e=0.7 we cannot use $\tau_o=5$ (τ_o is the optical depth at the surface of the star), since this implies $N_H \sim 2.5\ 10^{24} cm^{-2}$ contrary to our results. Our value of N_H implies $\tau_o \sim 0.05$: with such a value the absorption effect is almost negligible and the light curve modulation is due only to $\dot{M}_{accr}(r)$, therefore simmetric, contrary to all observational results. We are thus led to change some of the parameters. We tentatively suggest a lower eccentricity ($e \sim 0.5$). In this case we can use $\tau_o=0.5$ (which gives a significant modulation) : since in this case at periastron the compact object is not grazing the primary the observed X-ray cut-off can be lower than that corresponding to the column density at the surface of the primary.

Inclination cannot be very different from 90°. The model is quite insensitive to the values of the masses and radii of the components. We

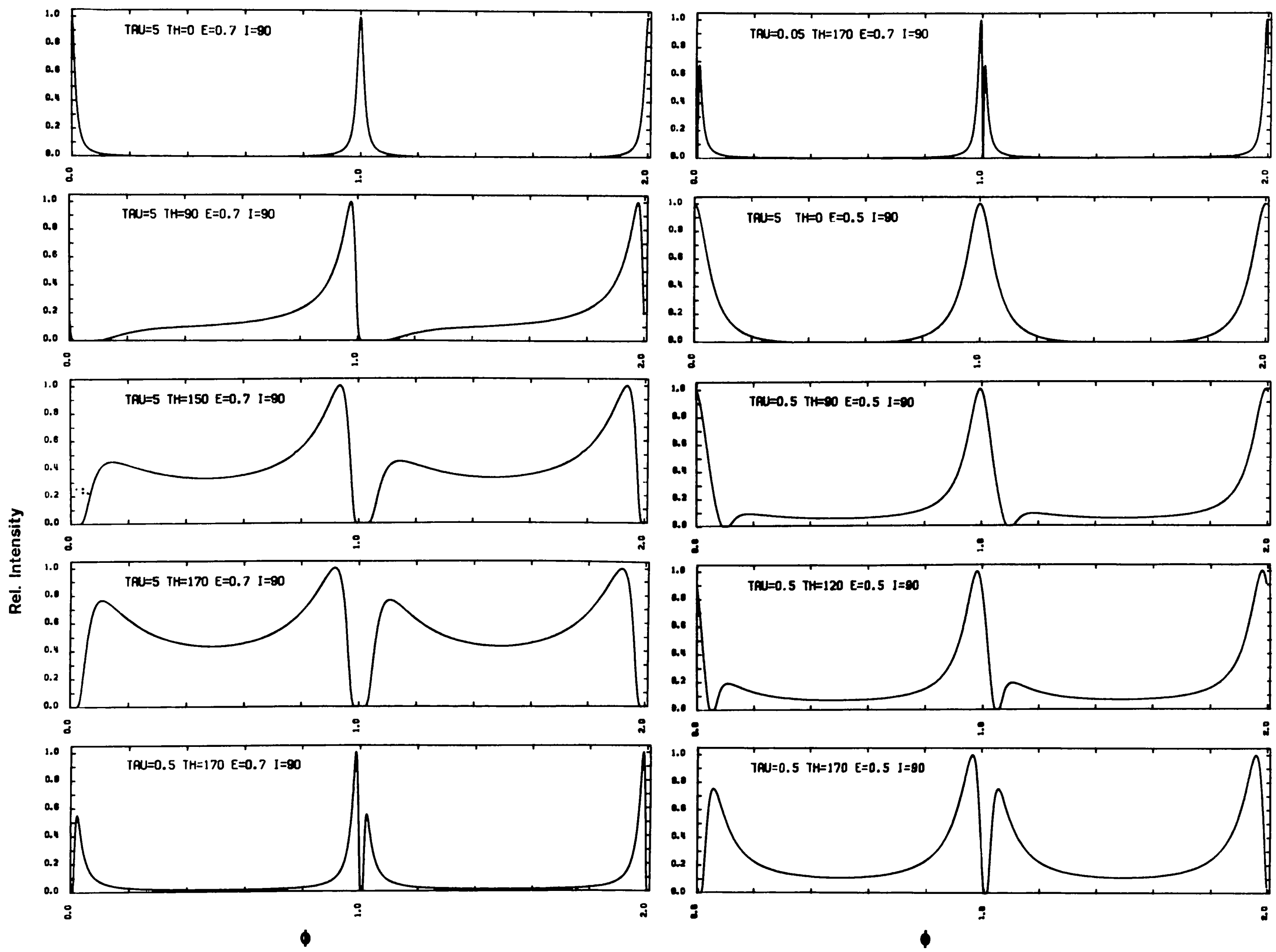

Fig. 2 : Theoretical light curves for Cir X-1. For each curve the following parameters are given : optical depth at the surface of the star, angle between the major axis of the orbit and the line of sight, eccentricity, inclination.

used throughout our calculations $M = 20\ M_\odot$, $R = 20R_\odot$ and $M_x = 1\ M_\odot$. Since the nature of the primary is still uncertain (see e.g. Nicolson et al. 1980) those values should be considered rather orbitrary.

We note that in every case the modulation of high energy X-rays should be due only to the variation of $\dot{M}_{accr}(r)$. We predict a sharp peak centred at phase ϕ. Its width should be related to the eccentricity of the orbit (being broader at lower eccentricities).

REFERENCES

Blissett, R.J., Cruise, A.M., 1979, Mon.Not.R.Astr.Soc. 186, 45
Clark,D.H., Parkinson, J.H., Caswell, J.L., 1975, Nature 254, 674
Coe,M.J., Engel,A.R., Quenby,J.J., 1976, Nature, 262, 563
Glass,I.S., 1978, Mon.Not.R.Astr.Soc. 183, 335
Kaluziensky,L.J. et al, 1976, Astrophys.J., 208, L71
Margon, B. et al., 1971, Astrophys.J., 169, L23
Murdin, P. et al., 1980, Astron.Astrophys. 87, 292
Nicolson,G.D., Feast,M.W., Glass,I.S., 1980, Mon.Not.R.Astr.Soc.191, 293
Sanford,P.W., Ives,J.C., 1976, Proc.R.Soc.Lond., A350, 491
Whelan,J.A.J.et al, 1977, Mon.Not.R.Astr.Soc. 181, 259