P2

5

The 1975 May transition of Cygnus X-1

Lucio Chiappetti

Mullard Space Science Laboratory University College London, Holmbury St. Mary, Dorking, Surrey, UK. and Instituto di Fisica dell' Universita and Laboratory di Fisica Cosmica e Tecnologie, Relative del CNR, Milan, Italy.

We have known, since 1971, that the powerful X-ray source Cyg X-1 exhibits a bi-modal behaviour, sometimes in an active (HI) state (characterised by a steep complex spectrum) but usually in a quiet (LO) state (with a photon spectral index $\alpha \simeq 1.6$). A transition from the active to quiet state was observed in that year; other transitions occurred in 1975 April, May and September and 1976 February (Heise et al., 1975; Sanford et al., 1975; Holt et al., 1975, 1976).

The MSSL instrument (experiment C) on the Ariel 5 satellite observed Cyg X-1 during May 1975 (May 3rd to May 15th), for part of the HI state and the subsequent gradual recovery to the quiet state. These data, the only known spectral observations of moderate energy resolution made during a transition, are presented here.

The spectrum (see Figure 1) has at least two components. The low energy part is well approximated by a blackbody with kT $\sim$ 0.3 keV and (in the higher energy region) by a power law. The ratio of the luminosities of these two components agrees with the predictions of inverse Compton models (e.g. Sunyaev and Titarchuk, 1979; Liang, 1980). During the transition the spectral index of the power law component flattens from $\alpha \sim 2.8$ to $\alpha \sim 2.0$. A bump in the spectrum at $\sim$ 3 keV is possibly explained by a cut-off in the power law, but the data are also consistent with a continuation of the power law to the low energy region. If the cut-off hypothesis is accepted, the transition between HI and LO states is both the result of an increase of the blackbody temperature and a flattening of the power law (see Figure 2a). We note that the temperature increases before α drops. In the case of no assumed cut-off to the power law the temperature remains constant throughout the transition. Note also that the enhanced flux of the power law component, without spectral changes, is responsible for flares in the HI state. A very weak emission feature (<5σ above the continuum) is present between 6 and 7 keV. Due to its faintness, it has not been possible to determine its energy with sufficient precision to identify it with the 6.7 keV iron line.

An estimate of the electron temperature and the optical depth for Thomson scattering, by the electron cloud as it reprocesses the soft flux, has been attempted on the basis of recent theoretical calculations (Sunyaev and Titarchuk, 1979). In the HI state we find $kT_e \gtrsim 5$ keV, $\tau_0 \sim 5$ or $kT_e \lesssim 1$ keV $\tau_0 \sim 12$ respectively with and without a cut-off in the power law at 3 keV. In the LO state,

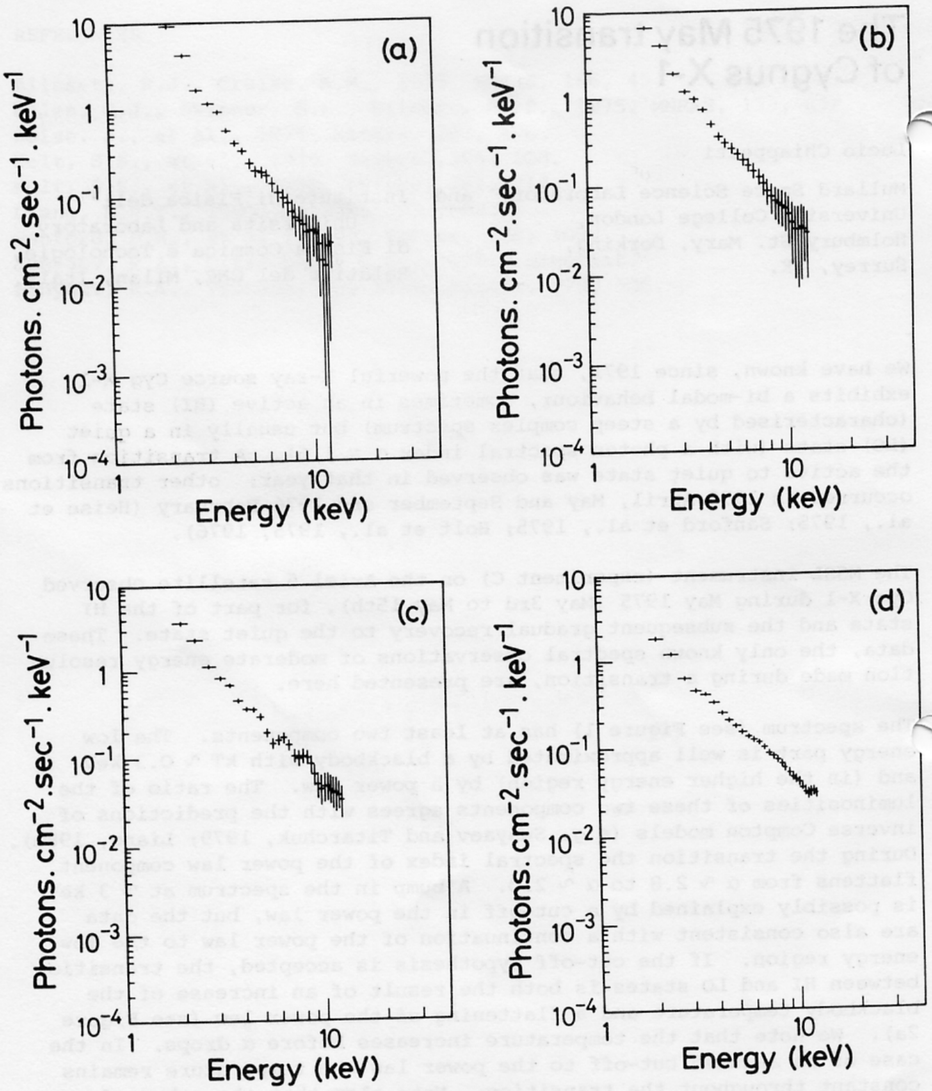

Figure 1: Some representative spectra of Cyg X-1, restored by the method of Blissett and Cruise (1979) (see also Blissett, these proceedings).

a) orbits 3064-3073 (combined)
b) orbit 3119
c) orbit 3153
d) orbits 3172-3219 (combined)

The variation between HI and LO state (from Figs. 1a to 1d) is clearly visible.

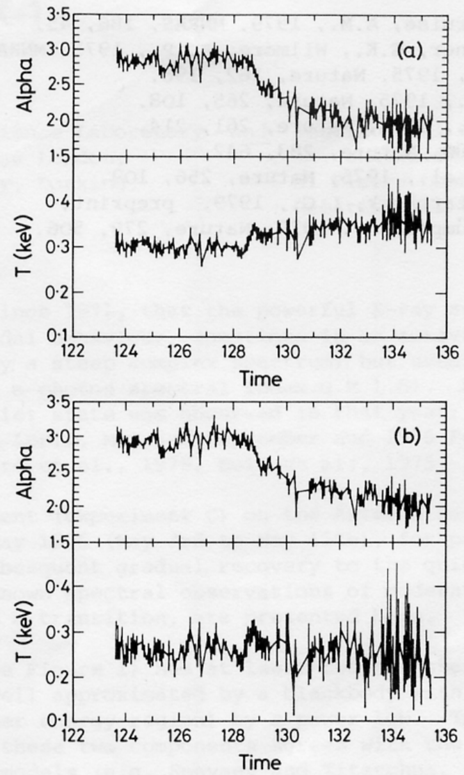

Figure 2: Photon spectral index and blackbody temperature versus time (days 1975), as obtained by a fit with cut-off at 3 keV for the power law component (Fig. 2a) and without cut-off (Fig. 2b). Errors shown are 3σ.

Sunyaev and Trümper (1979) find kT_e = 27 keV, $\tau_0 \sim 5$. In our last observation the recovery to the LO state was not yet complete ($\alpha \sim 2.0 \gtrsim 1.6$, the usual LO state value) the flux was also greater and the recovery was completed within the next month (Eyles et al., 1975). Since the formula which ties kT_e to the ratio of hard and soft luminosities has a singular behaviour around $\alpha = 2$, it was not possible to compute kT_e and τ_0 for the data from the less intense state. However a hint of an increase in kT_e is evident at the start of the transition.

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REFERENCES

Blissett, R.J., Cruise, A.M., 1979. MNRAS, 186, 45.
Eyles, C.J., Skinner, G.K., Wilmore, A. P., 1975. MNRAS, 173, 63P.
Heise, J., et al., 1975. Nature, 262, 196.
Holt, S.S., et al., 1975. Nature, 265, 108.
Holt, S.S., et al., 1976. Nature, 261, 214.
Liang, E.P.T., 1980. Nature, 283, 642.
Sanford, P.W., et al., 1975, Nature, 256, 109.
Sunyaev, R.A., Titarchuck, L.G., 1979. preprint.
Sunyaev, R.A., Trümper, J., 1979, Nature, 279, 506.