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Spectral analysis of the 1975 May transition of Cygnus X-1

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Summary. X-ray spectra from *Ariel V* of the 1975 May active (HI) state and the subsequent transition of Cyg X-1 are examined. The presence of a blackbody soft component ($kT \sim 0.3$ keV) in the spectrum is revealed. During the transition the spectral index of the hard, power-law component decreases from 2.8 to 2.0. The possibility of a simultaneous variation of the blackbody temperature is discussed. A weak emission feature may be present at 6–7 keV. The data are found to be in general agreement with the predictions of inverse Compton models for Cyg X-1. An estimate of the electron temperature and the optical thickness for Thomson scattering of the emitting region is attempted on the basis of recent theoretical calculations.

1 Introduction

Cyg X-1 is one of the most luminous and best known X-ray sources in the sky. It was discovered by Bowyer *et al.* (1965). HDE 226868 was identified as the optical counterpart by Murdin & Webster (1971). Webster & Murdin (1972) and Bolton (1972) first proposed that a black hole could be responsible for the X-ray emission.

Cyg X-1 has been studied from radio to gamma rays; in the IR, visible and UV bands it is dominated by the normal star. Because of the interstellar absorption the X-ray spectrum below 0.5 keV has not yet been observed.

Review papers on Cyg X-1 have been published by Oda (1977) and Eardley *et al.* (1978) for X-ray observations (in the former paper a detailed review of short term variability is also included). Bahcall (1978) and Conti (1978) have described optical studies.

We have known since 1971 that Cyg X-1 exhibits a bimodal behaviour in the X-ray emission; in that year for the first time a transition between a high and a low state was observed (Tananbaum *et al.* 1972). The transitions reported since that date are listed in Table 1. A tentative reconstruction of the behaviour of the source prior to 1971 is given in Sanford

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Table 1. Summary of the observed transitions of Cyg X-1.

Date	Transition	Band	Source/notes
1971 March–April	HI–LO	X 2–20 keV Radio	Tananbaum *et al.* (1972) Braes & Miley (1971) Hjellming *et al.* (1971)
1975 April	LO–HI	X 2.5–19 keV X 1–7 keV X 3–6 keV	Rao *et al.* (1976)* Heise *et al.* (1975) Holt *et al.* (1975)
1975 May	HI–LO	X 1.5–15 keV X 26–1200 keV X 3–7 keV Radio	Paper I, this work Coe *et al.* (1976) Eyles *et al.* (1975) Hjellming *et al.* (1975)†
1975 September	‡	X 1–30 keV	Primini (1975)
1975 November	LO–HI	X 3–6 keV X 25–150 keV X 15–250 keV	Holt *et al.* (1976) Sommer *et al.* (1976) Dolan *et al.* (1979)
1976 February	HI–LO	X 3–6 keV Radio	Holt *et al.* (1976) Braes & Miley (1976)
1980 May–June	LO–HI	X 1–12 keV	Oda (1980a)
1980 June–July	HI–LO	X 1–12 keV	Oda (1980b)
1980 November	‡	X 1–12 keV	Oda (1980b)

* Immediately preceding transition.
† Radio flux increased in HI state; non-flat radio spectrum.
‡ Short duration flux enhancement.

et al. (1975; hereafter Paper I). Useful information about the variability before 1970 can be found in the review by Dolan (1971). The most usual state of Cyg X-1 is the LO one, which can last years, while the duration of the HI states is of the order of months (or less) (see e.g. Holt *et al.* 1979). The LO state is characterized by a flatter spectrum (photon spectral index ~1.6), a lower flux at low X-ray energies (2–6 keV) and an increased flux both at high X-ray energies (> 10 keV) and in the radio band. On the other hand the HI state shows a steeper spectrum, with evidence of a break at 5–10 keV, increased X-ray flux at low energies, low hard X-ray and radio flux.

The present paper deals with the 1975 May downward transition. The 1975 April–May state was in many respects different from the only other HI states observed (1971 and late 1975): its duration was shorter, the radio flux did not decrease, but on the contrary increased to the highest values ever observed, and the shape of the radio spectrum changed (Hjellming, Gibson & Owen 1975). The X-ray observations by the *Ariel V* experiments (see Table 1) provide a complete coverage of the whole HI state. The All-Sky-Monitor observed the upward transition (Holt *et al.* 1975), then the satellite was re-oriented to put Cyg X-1 in the field of view of the other experiments. The observations reported in this paper were obtained by the MSSL Collimated Proportional Counter (experiment C). A preliminary analysis has already been published in Paper I. Cyg X-1 went out of the field of view of experiment C when the downward transition was almost complete, but remained in the field of view of the Rotation Modulation Collimator (experiment A) till the end of the decrease (Eyles, Skinner & Willmore 1975).

The observations of experiment C discussed in this paper are unique, for the moderate spectral resolution of the instrument allows a detailed study of the variations of the spectrum. These, together with the *Uhuru* observations of Tananbaum *et al.* (1972) are the only available spectral data during a transition of Cyg X-1 in the 2–10 keV band, where the variations are more significant.

2 Observations and data analysis

Ariel V experiment C (Sanford & Ives 1976) observed Cyg X-1 from 1975 day 123.6 (May 3) to day 135.4 (May 15). The observations cover part of the transient HI state, the subsequent sharp drop in intensity and part of a more gradual decrease, which continued for about one month, as from *Ariel V* experiment A observations (Eyles *et al.* 1975). The actual number of available orbits is 143. The time resolution of the data is one orbital period of the satellite (90 min). The detector energy range was 1.4–12 keV for high gain observations and 2.6–25 keV for low gain orbits, of which there were only few and which are not discussed in the following. Data are distributed in 32 nearly equal width energy channels. The instrument was operated in quadrant mode. Since the instrument axis is offset from the spin axis pointing direction, and the field of view is divided into four quadrants, it is possible to subtract the diffuse background by fitting the observed counts in each quadrant to a linear function of the effective area of the quadrants (more details of the analysis technique can be found in Pollard 1980).

2.1 THE LIGHT CURVE

Fig. 1 shows the light curve (source and background) for all 1975 May high gain observations of Cyg X-1. The background was remarkably constant. The data are plotted at the mid-time of each orbit.

The first two days of observations are characterized by large flares. The maximum to minimum ratio is 1.5 or greater. We note that the more intense the flare, the deeper is the following minimum. The following two days are characterized by irregular activity (maximum to minimum ratio for the small outbursts is ~1.3), superimposed on a constant or very slightly decreasing flux. A major decrease in intensity occurs in the following two days, apparently in two steps, each preceded by a flare (max/min ~ 1.7), with the result of halving the count rate. For the remainder of the time a regular decrease, interrupted only by small events, is observed. The return to the LO state at the end of the decrease was observed by

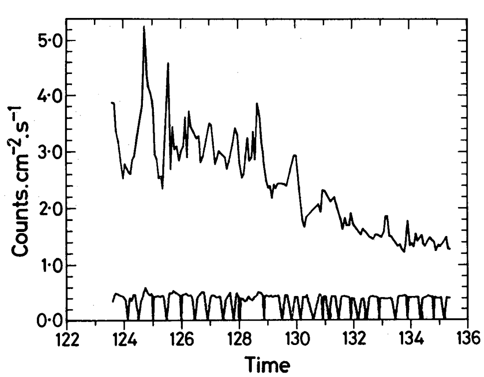

Figure 1. *Ariel V* experiment C X-ray light curve of Cyg X-1 during the transition of 1975 May. Time is in days 1975. Only high gain orbits were used for the production of the intensity (upper) curve. Orbits which were not shown in the upper curve are given in the background (lower) curve with zero flux.

experiment A (Eyles *et al.* 1975). We can compare the X-ray flux during the 1975 May Cyg X-1 observations with that observed by experiment C in 1974 November when Cyg X-1 was in a LO state. The flux in the 1975 May HI state is generally 4–5 times (and up to 8–9 times during flares) that of 1974 November. At the end of the observations the flux is only twice the 1974 November one.

2.2 THE SPECTRUM

To examine in detail the spectral behaviour of Cyg X-1 during the transition, individual PHA channel light curves were constructed. The flux in each channel was normalized to that over the total energy range of the detector (see Fig. 1) and averaged over the length of the observation. Fig. 2 shows the percentage deviation from this average for each orbit. The curves for channels 1–5 (~1.3–3 keV) indicate a sharp drop of the flux followed by a more gradual decrease. The decrease, still apparent in channel 6, can barely be detected in channel 7. From channel 8 upwards (in energy) a reverse trend can be seen, the more apparent the higher the PHA channel number. This can be noted also for the last channels, despite the large fluctuations in the flux values. We have executed the same analysis after applying the Blissett & Cruise (1979) spectral restoration technique to the data. This technique enables removal of the detector resolution broadening effects. Similar results are obtained, though the curves for PHA channels 5 and 6 are almost flat (while they still show a decrease in the raw data) and some evidence of an upward transition is already seen in channel 7.

The general conclusion is that a 'pivot energy' exists below which the transition from HI to LO state is seen as a decrease in flux, while at higher energies there is an increase. The difference between 'pre' and 'post' flux values is greater, the farther the channel is from the pivot energy. The existence of a pivot energy in the spectrum of Cyg X-1 was already known but its position was not known with great accuracy. On the basis of the raw and restored data analysis we locate the pivot energy at ~3 keV.

We have used the curves in Fig. 2 to study the spectral behaviour during flares. Because of the normalization, a flare shows up in these curves only if it is associated with a spectral variation. The major peaks in the HI state part of the light curve in Fig. 1 are clearly apparent in negative (i.e. as dips) in the curves for channels 2–5. They are not visible in channel

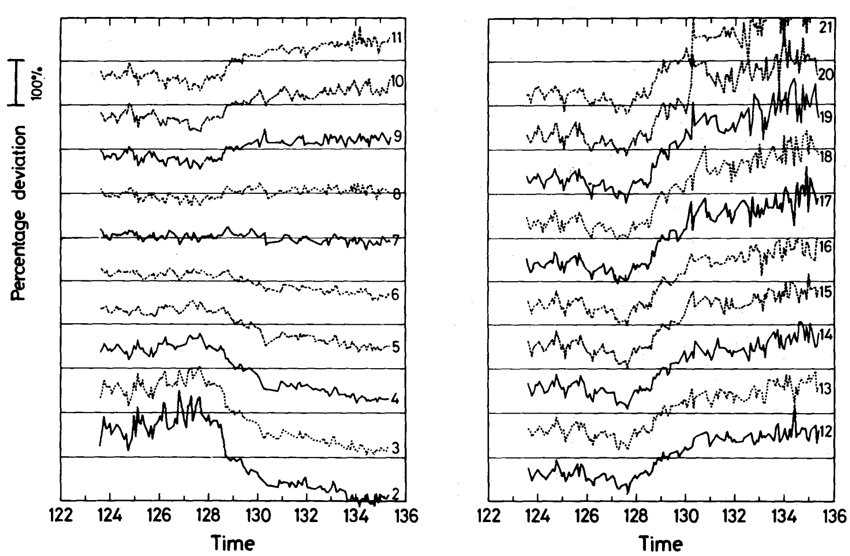

Figure 2. Percentage deviation from the average flux in each PHA channel, normalized to the total flux. Only channels 2–21 are shown. In each graph the horizontal lines indicate 0 per cent deviation. For clarity each curve is displaced by 100 per cent with respect to the preceding one.

6, and the largest of them can perhaps be discerned as positive in the following channels. This seems an indication of a spectral hardening during the larger flares (contrary to the general spectral softening in the HI state) and allows us to distinguish those few events from the less drastic enhancements which are not associated with a spectral variation.

A more quantitative spectral analysis is now required. In a first approximation, similar to that adopted in Paper I, one can fit the spectra with a single power law. Since the energy range of experiment C is not particularly suitable for the study of interstellar absorption, the hydrogen column density was fixed at $3.0 \times 10^{21}\,\mathrm{cm}^{-2}$, the usual value obtained from X-ray measurements (e.g. Gorenstein 1976; Priedhorsky *et al.* 1979). We find the best fit spectral index is sometimes greater than 3 in the HI state and gradually decreases to 2 towards the LO state. The quality of the fit is unsatisfactory, and this is reflected in the high χ^2 values. This is completely insensitive to large variations of the hydrogen column density and the results are essentially an indication that the actual spectrum deviates strongly from a single power law. In the LO state a better χ^2 indicates a spectrum closer to a power law.

To investigate the deviation from a power law spectrum in more detail, the data were examined after applying the Blissett & Cruise (1979) direct deconvolution technique, which does not require any assumption on the spectral form.

The overall shape of the restored spectra exhibits a turnover in the first 2–3 channels (these are unreliable because of the poor detector efficiency at those energies and are not shown in the figures), a steep portion below 3 keV, a bump between 3–5 keV, a break at 5 keV, where a flatter tail begins. A reasonable hypothesis is that we are dealing with a two component spectrum and the bump is due to superposition in an energy range where they are comparable. Representative restored spectra are shown in Fig. 3.

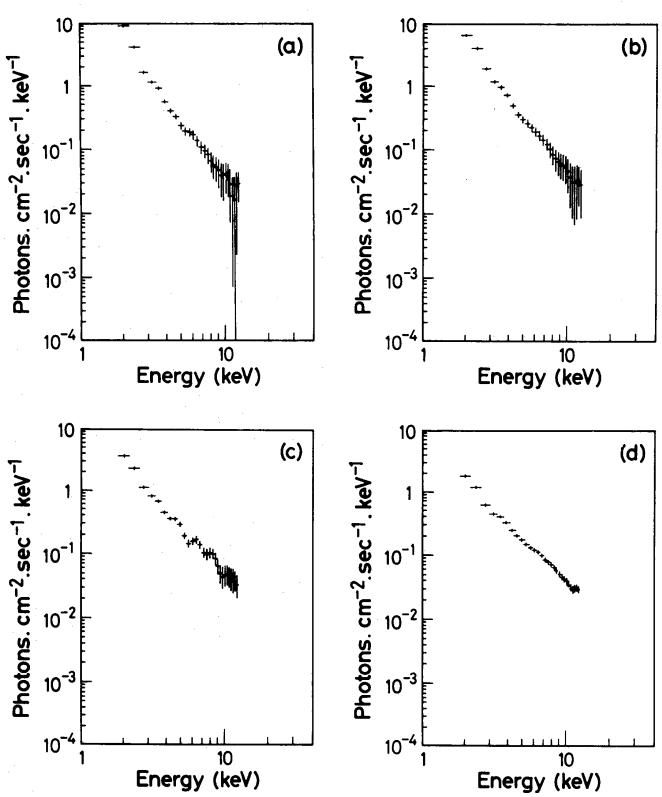

Figure 3. Most representative spectra of Cyg X-1, restored with the Blissett & Cruise (1979) technique: (a) combination of eight orbits (UT days 125.1–125.8); (b) one orbit (UT day 128.8); (c) one orbit (UT day 131.0); (d) combination of 30 orbits (UT days 132.3–135.4). The variation between HI and LO state occurs in the sequence (a) to (d). (c) shows the possible 6.7 keV line with the side-lobe effect described by Kahn & Blissett (1980).

Table 2. Quality of spectral fits. The total number of high gain orbits is 129; the percentage of them for which the χ^2 exceeds a given value is given.

Spectral form: Low energy	High energy	Cut-off	Percentage of orbits with $\chi^2 > 10$ / $\chi^2 > 5$ / $\chi^2 > 3$
Single power law			46.5 69.0 74.4
Bremsstrahlung	Power law	3 keV	7.0 24.8 49.6
Modified blackbody	Power law	no	3.9 12.4 31.0
Modified blackbody	Power law	3 keV	3.1 15.5 39.5
Blackbody	Power law	no	3.9 13.2 29.5
Blackbody	P.l. + line	3 keV	1.6 6.9 20.9

Unfortunately it is not easy to fit the restored spectra because of the large errors at high energies (the de-broadening gives an apparent increase in the errors, because they are not independent) and spurious fluctuations are introduced by the sidelobes of the response function (see Kahn & Blissett 1980).

A two component fit to the raw spectra was then carried out with different combinations of spectral forms, using a least squares fitting model for non-linear functions as described in Bevington (1969). The hydrogen column density was fixed at $N_H = 7 \times 10^{21}\ \text{cm}^{-2}$, the value implied by the visual extinction. A smaller measured value of N_H than expected from the N_H–A_V relation has been suggested as evidence of the presence of a soft component in the spectrum of Cyg X-1 (Gorenstein 1976; Priedhorsky *et al.* 1979). As an indication of the quality of the fit we take the total number of orbits for which the χ^2 exceeds a fixed value. Table 2 summarizes our results. It can be clearly seen that a two component fit is much more satisfactory than a single power law fit.

The fit with a bremsstrahlung spectrum (with energy dependent Gaunt factor) as the low energy component gives χ^2 values slightly but regularly above those of the other fits and seems less satisfactory. The quality of the remaining fits is similar and it is not possible to discriminate between them. The modified blackbody has the following form

$$\frac{dN}{dE} = \frac{1}{D^2} \frac{E^{1/2}}{(kT)^{3/2}} \frac{\exp(-E/kT)}{[1-\exp(-E/kT)]^{1/2}}, \tag{1}$$

where D is the distance of the source in cm (Lightman, Shapiro & Rees 1978). With the exception of a larger normalization factor and of the slightly higher temperature, the results are very similar to those for the normal blackbody. Since no preference can be given to one or other form, and the modified blackbody is a rather unusual spectrum, in the remainder of the paper only the blackbody + power law model will be discussed.

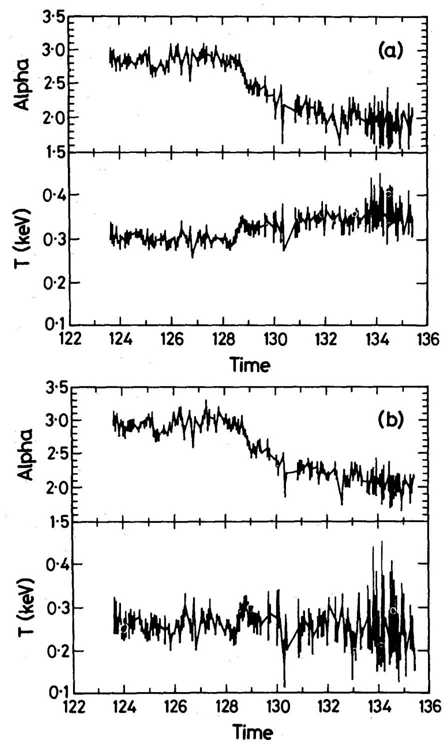

Figure 4. Photon spectral index and blackbody temperature versus time, as obtained by fitting with a cut-off at 3 keV (a) and without cut-off (b). Errors are 3 σ.

Two additional possibilities were accounted for. In the first the power law extends over the whole energy range and the blackbody simply adds on at low energies. In the second the power law is assumed to vanish below 3 keV (case marked '3 keV cut-off' in Table 2), where the blackbody is dominating. This assumption is quite arbitrary, an *ad hoc* expedient to separate out the soft component. It can only be a rough approximation of the true emitted spectrum where the transition between soft component and high energy power law tail should be more gradual. The introduction of the cut-off at 3 keV is suggested primarily by the opposite trends shown below and above 3 keV in the single PHA channel light curves (See Fig. 2). Fig. 4 shows the behaviour of the power law photon index and of the blackbody temperature for the no cut-off and 3 keV cut-off cases. The observation of a rise in the blackbody temperature simultaneously with a decrease of the power law spectral index is strictly dependent on the assumption of the existence of the cut-off. On the basis of the χ^2 alone we cannot rule out or favour the model with a constant blackbody temperature. In Fig. 4(a) we note that the rise in temperature happens before the decrease of the spectral index, which could be expected if the hard component is due to reprocessing of the soft X-ray flux. An event with a temperature rise is present also in the no cut-off case (Fig. 4b), at the same time when the increase of temperature begins in the 3 keV cut-off case.

Residuals have been computed for the observed and the fitted spectra in both cut-off cases. They are shown in Fig. 5 as a percentage of the fitted counts. Similar features are present for all orbits about channels 7–8 and 15–16. We believe they are real for their repetitivity, even if the residuals are less than 10 per cent above or below the fit and generally consistent with non-zero values only at 1–2 σ. The deviation about channels 7–8 could be associated with the hump at 3 keV. In fact a positive residual is present for the no cut-off fit (which does not take into account a similar feature) while a negative residual is present for the 3 keV cut-off fit (the rough form of cut-off used in the fit can lead to an overestimate of the feature).

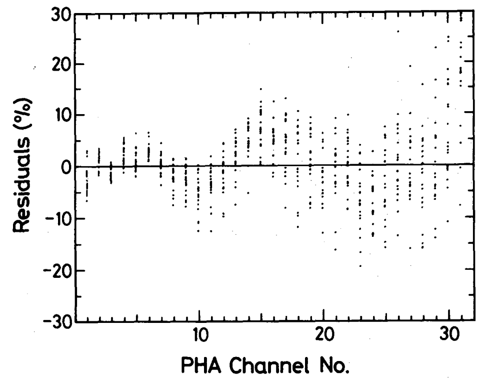

Figure 5. Percentage residuals versus channel number. Only a limited number of HI state orbits is shown. The assumed continuum is the best fit in the 3 keV cut-off case.

A positive residual is also always present at channels 15–16 (approx. 7 keV). A feature can be seen at that energy in most of the high and low gain restored spectra. This could be explained by the presence of an iron line at 6.7 keV. Since the excess above the continuum is only a few per cent, the attempts to fit the spectrum including a line meet many difficulties. We have combined groups of about 10 high gain orbits and fitted a spectrum by varying the spectral index, the blackbody temperature, the line intensity (in count $cm^{-2} s^{-1}$) and width. In the no cutoff case the data are not compatible with the presence of a line, or, when the line is fitted, the χ^2 is not improved. In the 3 keV cut-off case the introduction of the line causes a definite improvement of the χ^2: the line appears to be located at 6.2 keV (with an intensity of 0.02 count $cm^{-2} s^{-1}$). No reliable values of the line width are obtained.

3 Discussion

General consensus is that the high energy spectrum of Cyg X-1 arises from Comptonization (see Liang 1980) of a primary soft source. While a standard cool accretion disc cannot be the origin of the hard X-ray spectrum, this is possible in a modified disc. Models have been proposed where the outer, cooler part of a large disc is the soft source and the hot central part is responsible for the Comptonization (Thorne & Price 1975; Shapiro, Lightman & Eardley 1976); other models use a cool disc with a hot corona (Liang & Price, 1977; Bisnovatyi-Kogan & Blinnikov 1976) or a disc with supersonic turbulence (Pacheco & Steiner 1976). Unfortunately there is no clear evidence of a large disc in Cyg X-1 (see, however, Kemp 1980). Since the mass transfer between the primary star and the compact companion is probably fed by a stellar wind and Roche-lobe overflow (Conti 1978; Petterson 1978), only a small 'marginal' disc can perhaps be formed (Shapiro & Lightman 1976). Also, spherical accretion has been considered by Meszaros (1975) as a possible mechanism: cyclotron radiation in an equipartition magnetic field could be the source of the soft X-rays, at least in the less luminous states (Eardley & Lightman 1976).

According to theoretical calculations (Shapiro *et al.* 1976; Sunyaev & Titarchuk 1980) the shape of the secondary X-ray spectrum is independent of the nature of the source. Also in the case of a thermal distribution of electrons a power law spectrum is obtained, which steepens at very high energy (where the photons no longer gain energy from the electrons, see e.g. Sunyaev & Trumper 1979). The origin of the soft component has not been clarified, even if its existence was predicted (Gorenstein 1976; Sanford 1974). The present work shows clearly that such a component exists when the source is in the high state, while it seems to fade away towards the low state. Since the soft source is expected to be optically thick, its approximation with a blackbody is justified. We are aware that the spectrum is probably the sum of the contributions of different regions with different temperatures (Shapiro *et al.* 1976). Nevertheless the use of more complex spectral forms is not justified by our data, which cover only part of the Wien portion of the spectrum.

The delay between the rise of the blackbody temperature and the decrease of the spectral index at the start of the transition (see Section 2.2, Fig. 4) suggests that the transition is triggered by a variation in the soft (primary) component (which is reasonable in the framework of the inverse Compton model). This delay cannot be the result of a variation in the primary component and its subsequent effect on the secondary: the time-scale for such an effect is much shorter (see e.g. Priedhorsky *et al.* 1979). What we observe could be the gradual accumulation of a number of independent variations. We note that the time-scale of the major intensity decrease on days 127.8–129.8 is consistent with the time-scale for reversal of the rotation sense of a marginal disc (Shapiro & Lightman 1976) if the density variation causing the transition is $d\rho/\rho \sim 3.5$ per cent. Also the radius of the emitting region (~ square root of the blackbody best fit normalization factor) is consistent with the same model. The decrease of such normalization factor towards the LO state then indicates a shrinking or disappearance of the disc.

From our fits we can compute the luminosity of the two spectral components. The soft X-ray luminosity is given by $L_s = 4\pi\sigma f(r) T_s^4$, where the normalization factor obtained from the fit is $f(r) = r^2$ for spherical geometry and $f(r) = 0.5r^2$ in the case of a disc. The hard X-ray luminosity has been calculated as the integral of the power law between 3 keV (or 1 keV for the no cut-off case) and 200 keV. This introduces two approximations, one due to the deviation from a power law at high energies (see Sunyaev & Trumper 1979) and the other one due to the uncertainty in the location and shape of the low energy cut-off. The distance of the source has been taken to be 2.5 kpc. If we assume that the power law is cut off at 3 keV, we obtain $L_h \sim 10^{37}$ erg s^{-1}, $L_s \sim 1.4 \times 10^{38}$ erg s^{-1} in the HI state and $L_h = L_s \sim 2 \times 10^{37}$ erg s^{-1} for the part of the light curve when the intensity starts to decrease (see Fig. 1). The absence of a cut off would double L_h in the HI state, so that both L_h and L_s decrease with the transition. What is important is the ratio L_h/L_s which, in the 3 keV cut-off, is ~ 0.1 in the HI state and ~ 1 the rest of the time. This is qualitatively in agreement with the inverse Compton model, which predicts the overall luminosity to be dominated by the soft (primary) component on the occasions when the high energy spectrum is steep. The power law spectral index is related to the Comptonization parameter by

$$\gamma = n^2 + 3n = \frac{\pi^2}{3} \frac{m_e c^2}{kT_e(\tau_0 + 2/3)^2}, \tag{2}$$

where n is the energy spectral index, T_e the electron temperature and τ_0 the electron scattering optical thickness of the cloud responsible for the Comptonization (some authors use a Comptonization parameter $y = \gamma/4$). From the above formula it is, however, not possible to obtain separately T_e and τ_0. In an attempt to obtain them, we used formula (11) of Sunyaev & Trumper (1979), which gives the ratio

$$\frac{L_h}{L_s} = \left(1 + 2.9 \frac{kT_e}{\langle h\nu_{\rm soft}\rangle}\right)^{1-n}. \tag{3}$$

It has been pointed out subsequently (Sunyaev, private communication) that the formula is an approximation valid in the range $0.3 < n < 0.7$. We note nevertheless that for $n \sim 1$ (our LO state data) we obtain a luminosity ratio very close to unity, in exact agreement with equation (3). If we use the same formula also for $n > 1$ (our HI state data) in the 3 keV cut-off case we obtain an electron temperature of ~ 5 keV with an indication of a rise during the downward transition. τ_0 is generally about 5. For the no cut-off case the electron temperature is much lower (~ 1 keV) and τ_0 higher ($\sim 12-13$). The error on T_e is $\gtrsim 25$ per cent, if we consider only the propagation of errors on the fitted parameters. The uncertainty in the shape of the low energy cut-off can be responsible for a further 10 per cent error.

Formulae for the luminosity ratio in the range $n > 1$ are given by Sunyaev & Titarchuk (1980; their formula 18) and Liang (1980; his formula 1) but in both cases they do not allow a separate determination of T_e and τ_0, since in this range of spectral indexes the luminosity ratio is a function only of the Comptonization parameter. This means that the soft component is scarcely affected by the Comptonization. In both cases the computed luminosity ratio has a higher value than we measure, and L_h is larger than L_s already for $n \sim 1.5$. The discrepancy between observations and predictions is due to the high value of L_s we obtain from the best fit parameters. However we infer the blackbody contribution from observations in a very narrow band of the Wien tail and so the determination of the luminosity should be regarded with caution (but see similar results in Heise *et al.* 1975).

Sunyaev & Titarchuk (1980) give a formula for the luminosity ratio in the case $n \sim 1$ which is function only of the ratio $kT_e/\langle h\nu \rangle$ (where the average energy of the soft photons can be obtained from the blackbody temperature). Unfortunately it is not clear whether the definitions of the luminosity in their paper are the same as ours (moreover the formulae for the luminosity ratio require $kT_e \gg \langle h\nu_{soft} \rangle$, which may not be consistent with the situation we observe). Assuming they use similar definitions of luminosity, the electron temperature can be evaluated as $kT_e \sim 2$ keV ($\tau_0 \sim 12$).

In every case with the larger uncertainties both in observations and theory (the models are for very simple geometry of the electron cloud) for the HI state we obtain an electron temperature of about one order of magnitude lower than that reported by Sunyaev & Trumper (1979) for the normal LO state ($kT_e \sim 27$ keV, $\tau_0 \sim 5$), which is not unreasonable in the framework of the inverse Compton model. We stress nevertheless that, since the nature of the soft component is not completely understood, our results should be regarded as an order of magnitude estimate. Another method for the determination of the electron temperature requires knowledge of the energy of the high energy spectral break which occurs when the photons no longer gain energy from the electrons. In a first approximation this occurs at $\sim 3kT_e$ (for more detailed discussion under particular model conditions, see Sunyaev & Titarchuk 1980). Since our data extend to about 15 keV without apparent high energy cut-off, a lower limit of ~ 5 keV, marginally consistent with our previous results, is suggested for kT_e. However the spectrum in the HI state is known to extend without major breaks to higher energies (see the simultaneous observations of Coe, Engel & Quenby 1976). Additional high quality observations of the soft and hard parts of the Cyg X-1 spectrum are needed to produce a better understanding of this still puzzling object.

4 Conclusion

We have examined the spectrum of Cyg X-1 during the 1975 May HI state and part of the following transition to the LO state. The spectrum shows two components. The soft component is well approximated by a blackbody with $kT_s \sim 0.3$ keV and the hard component by a power law with photon index decreasing from 2.8 to less than 2 during the transition. The ratio of the hard to soft luminosities agrees with the predictions of the inverse Compton model. Fitting the soft component spectrum becomes more difficult as the source intensity decreases towards the LO state. A bump in the spectrum at ~ 3 keV is tentatively explained as due to a cut-off in the power law. If our interpretation is correct, the transition between HI and LO states consists of both an increase in the backbody temperature and a flattening of the power law part of the spectrum. The latter effect could, however, be sufficient to explain the observations. We note that only an enhancement of flux of the power law component, without spectral changes, is responsible for the flares in the HI state. A very weak emission feature (< 5 per cent above the continuum) is present between 6 and 7 keV. The parameters of the electron cloud reprocessing the soft X-ray flux cannot be obtained precisely, due to uncertainties in both theory and observations; we can nevertheless estimate the electron temperature in the HI state to be about one order of magnitude lower than in the LO state.

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