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The X-ray Modulation of Cygnus X-3

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SUMMARY

Results are presented of three ~ 40 d COS-B X-ray observations of Cyg X-3. The amplitude of the 4.8 h modulation is shown to vary more than proportional to the average source level. The shape of the light curve, though variable from cycle to cycle, is seen to be generally very stable when averaged over many cycles. During one four-week interval, however, a different mean light curve is observed. It is shown that the correlated behaviour of amplitude, average level and mean shape of the light curve can be explained in terms of an eclipsing binary surrounded by scattering gas, which becomes more transparent when the source intensity increases. In the highest quality part of the data, a variation is found in the phase of arrival of the minimum of the light curve, suggestive of a ~ 20 d periodicity. Apsidal motion of an orbit with e ~ 0.03 is suggested as a possible explanation of this effect.

Key-words: X-ray binaries- Cyg X-3 - eclipsing binaries

I. INTRODUCTION

The X-ray source Cyg X-3 is known to show a 4.8 h periodicity in infrared (Becklin et al., 1973), X-rays (Parsignault et al., 1972) and possibly at higher energies (Lamb et al., 1977, Danaher et al., 1980). Variability with longer periods has been claimed for the intensity (Holt et al., 1976; Holt et al., 1979) and for the 4.8h period (Molteni et al.,1980). The X-ray light curve has a stable asymmetry when averaged over months (Mason et al., 1976a) while some significant changes may occur that persist over weeks (van der Klis and Bonnet-Bidaud, 1981). The depth of modulation (amplitude/mean intensity) was claimed to be approximately constant (Parsignault et al., 1977).

The X-ray flux modulation has been proposed to be due to reflection from the campanion (Basko et al.; 1976), by matter between the two stars (Bignami et al.,1977) by scattering in a surrounding 'cocoon' (Milgrom, 1976) or by variable absorption in a stellar wind (Pringle, 1974; Davidsen and Ostriker, 1974). For the last two types of models simulations were performed which show that shape variations of the modulation can be induced by changes in the opacity (Hertz et al.; 1978) or in the orbital elements (Ghosh et al., 1980). In all cases, a detailed study of the modulation is required to determine the geometry of the system and the characteristics of the surrounding gas.

The data presented here allow a suitable survey of the X-ray modulation over more than hundred days of observations, and give an indication for period variations on a time scale of ~ 20 days.

II. OBSERVATIONS

The X-ray detector on board the ESA COS-B satellite is a 80 cm^2 proportional counter with a 2-12 keV energy band and a 10° FWHM field of view (see Boella et al.,1974). Data are recorded during a 25.4 s integration time every 102.4 s over the full 24h active part of the 36h satellite orbit. Background subtraction is performed using correlation formulae derived from pointings to empty fields (Bonnet-Bidaud and van der Klis, 1979).

Cyg X-3 has been in the field of view of the instrument on four occasions. During the first observation in 1976, the 4.8h modulation was detected (Bonnet-Bidaud et al.,1978), but the source intensity was low, and there was serious disturbance by charged particles. The source was observed again in 1977 and in 1978, in both cases for ~ 37 days. In these observations the pointing direction was chosen such, that Cyg X-1 was excluded from the field of view, and Cyg X-3 was observed at a geometrical efficiency of ~ 0.5. Some results on the phase and the mean intensity of the 4.8h modulation in these observations have already been published (Manzo et al.,1978; Molteni et al.,1980). Finally, in May-June 1980, COS-B observed Cyg X-3 for ~ 40 days at a geometrical efficiency of 94%. During this observation, Cyg X-1 was at the edge of the field of view.

Work on the mean light curve shape and on the long- term period behaviour in the 1980 observation was published earlier (van der Klis and Bonnet-Bidaud, 1981). In the present paper, we attempt to give a full account of the evolution of the intensity, amplitude, mean shape and phase of the 4.8h modulation during the ~ 114 days that COS-B observed Cyg X-3 from 1977 to 1980.

III. RESULTS AND ANALYSIS

a) Mean flux and amplitude of the light curve

The light curve of Cygnus X-3 is known to show considerable cycle - to - cycle variability (Mason 1976, Parsignault et al. 1977). Such a variability is present in all COS-B observations, and will be discussed elsewhere. In the present paper, only time scales of ~ 1 d or more are considered.

In order to determine the average behaviour of the mean flux and amplitude of the 4.8 hr modulation, a sinusoidal curve of the form $A_0 - A_1 . \cos (2 \pi (t-T_0)/P)$ was fitted to the ~ 5 cycles observed during each satellite orbit. The results for A_0 and A_1 are presented in fig. 1. Apart from fairly narrow intensity enhancements, the mean counting rate is relatively constant in the 1977 and 1978 observations, while it is steadily rising from 15 to 45 c/s in the 1980 observation (1 COS-B c/s ~ (2.3 to 2.7) $10^{-10} erg.cm^{-2} s^{-1}$ (2-12 keV) for the range of spectra given by Mason et al. (1976) and Becker et al.(1978)).

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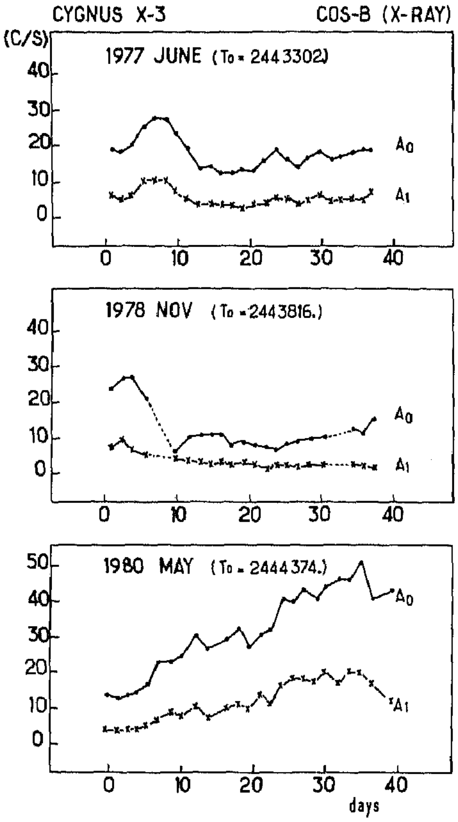

Fig 1: The mean counting rate A_0 and the amplitude A_1 of the 4.8h modulation as a function of time. Mean counting rate is after background subtraction and aspect correction. Each point is a mean value determined from about 5 cycles. Statistical error bars are smaller than the points. Lines between the points are drawn to show the trend of variation. A very strong correlation between A_1 and A_0 is visible.

These intensities are within the commonly observed range for Cygnus X-3 (Bradt et al., 1979). The intensity peaks in the first two observations have been related to a 34.1 d period (Molteni et al.1980). Extrapolating, a new intensity maximum would have been expected at JD (2444400.± 3.) in the last observation. The correlated behaviour of amplitude and intensity is evident from Fig.1. If we plot A_1 against A_0 however, it is clear that their relation is not linear (Fig.2a). Leach et al. 1975 found no correlation between intensity and the ratio A_1/A_0 in the 1970-73 Uhuru data; in the present observations, this ratio is significantly higher during the intensity peak in 1977 and in the second half of the 1980 observation, than at other times (Fig.2b). Such correlation is also suggested by the ANS data (Parsignault et al.,1977).

In the first part of the 1980 observation A_1/A_0 is quite consistent with the results of the 1977 and 1978 observations, and we can conclude that the contribution of Cyg X-1, if any was small. If it would have contributed appreciably to the counting rate in the second part (see Oda et al.,1980), the actual relation between A_1 and A_0 would be even more non-linear. For the calculations referring to the lines in Fig.2, see the discussion.

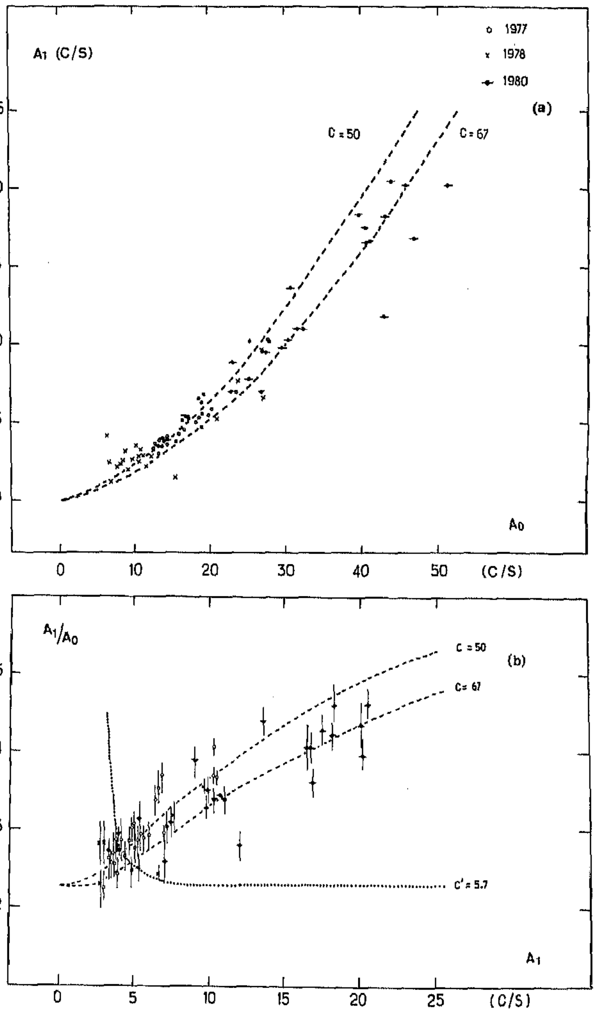

Fig. 2: a) The relation between the amplitude A_1 and the mean level A_0 of the 4.8h modulation determined from sinusoidal fits. Each point corresponds to ~1 day of data. Statistical errors are of the order of the size of the symbols. Notice that A_1 and A_0 are not linearly related, and that there is a good correspondence between the data obtained in 1977, '78 and '80.

b) The variable ratio A_1/A_0. Only points with a statistical error on A_1/A_0 of 0.03 or less were included in the plot. Typical error is 0.02. The curves represent the relation estimated from the two-component approximation in an eclipsing binary explained in the text, in the case that the effective optical depth of the gas is inversely proportionnal to the intrinsic X-ray luminosity (dashed curves), and in the case that it is directly proportionnal (dotted curve).

b) Shape of the light curve

It has been noted before (Mason et al.,1976a), that despite variability, the shape of the Cyg X-3 light curve is quite stable when averaged over many cycles. To investigate this for the present set of observations, the data were folded following the quadratic ephemeris given by van der Klis and Bonnet-Bidaud (1981). The individual light curves were normalized prior to folding according to the prescription: normalized flux = (flux - A_0)/A_1 to give the same weight to curves of different amplitude and mean flux.

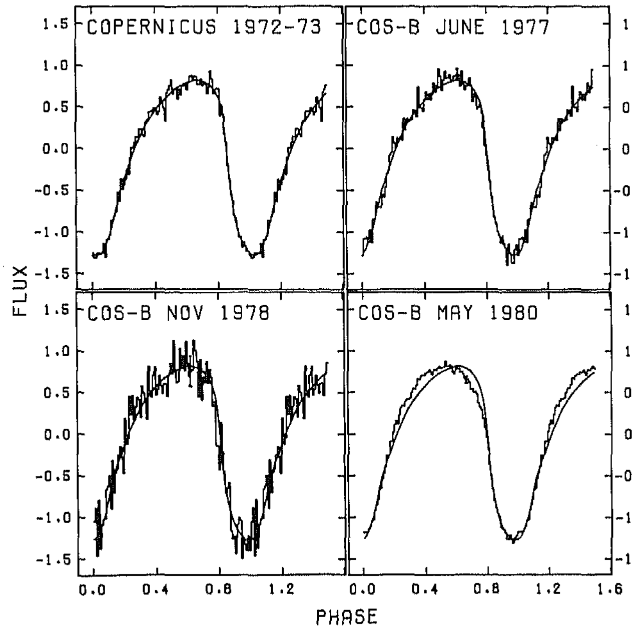

Fig.3:The mean light curve of Cyg X-3 sampled over 9years.The Copernicus data were adapted from Mason et al.(1976b).The COSB curves were obtained by folding in each case more than 5 weeks of data modulo the 4.8h period.The data were normalized according to the mean level and the amplitude of the modulation prior to folding.The ordinate is in arbitrary units. Typical error bars representing counting statistics and light curve variability are shown. The drawn curve in each figure is a smooth version of the Copernicus light curve.Notice the great similarity between the 1972'73 and the 1977, 1978 light curves, and the unexpected departure from the usual shape during 1980.

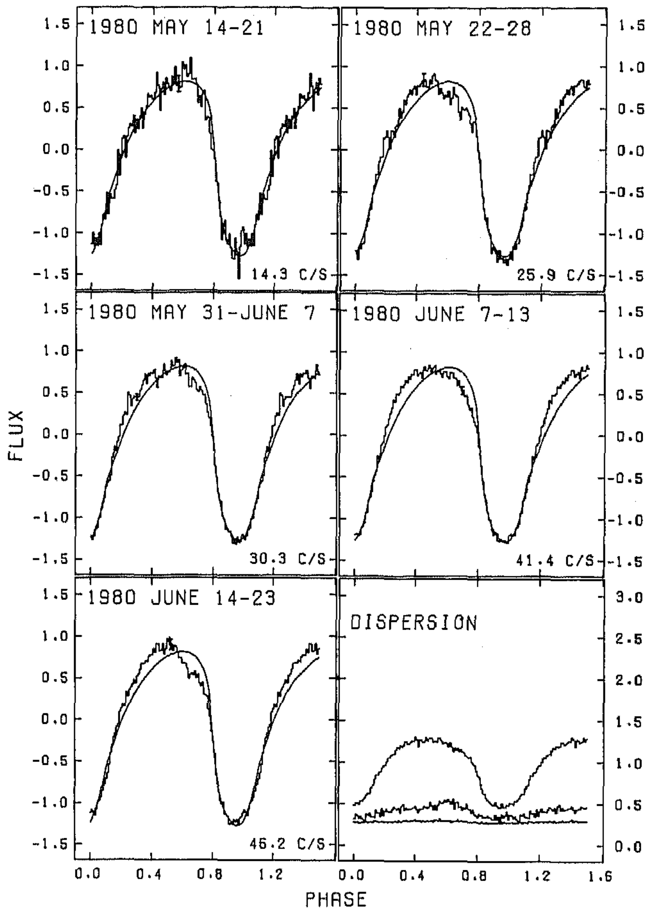

Fig.4:The 1980 observations decomposed into five one-week mean light curves.For folding and significance of the error bars, see fig.3. The mean counting rate is indicated in the figures.Drawn curves again represent the 'standard' shape derived from the '72'73 Copernicus observations.Notice the change in shape after the first week.The last figure gives the rms dispersion of the individual light curves around the 1980 mean curve(in the same unit as the curves themselves).The upper curve is the dispersion in the case that the signal is not normalized prior to folding;the dispersion is then dominated by A_1-A_0 variations.The lower curve is the dispersion expected from statistics The middle curve is the real dispersion observed in normalized light curves, due to statistical and shape variations.Notice that shape variability is apparently most important around phase 0.65,and nearly negligible around phase 0.

The numbers of 4.8h cycles that went into the average curves of 1977,1978, and 1980 were 116, 70 and 100 respectively. In Fig. 3 we show the results, together with the average light curve obtained by Mason et al.(1976b) during two years of Copernicus observations, plotted at the same scale for comparison; the reference line in each plot is a smoothed version of this Copernicus curve. The different noise levels of the curves are due to the differences in source intensity and position of the source in the field of view of the detector. The 1977 and 1978 curves are strikingly similar to each other and to the Copernicus curve obtained ~5 years earlier, while the light curve obtained in 1980 is quite different, with a more symmetric maximum. The shape of the minima is identical in all curves.

We next divided the data in ~ 1 week intervals and repeated the folding procedure. The curves obtained in this way for the 1977 and 1978 observations all had the same asymmetric shape, showing no significant differences from one week to the next. The five 1980 curves are displayed in Fig.4; they contain 21, 15, 25, 21 and 18 of the 4.8h cycles, respectively.

During the first week, when the intensity of the source was still low, the light curve has the same asymmetric shape as before. All four subsequent curves have the more symmetric maximum, with some fluctuations which could be attributed to residual cycle to cycle variability. Again, the minimum is very constant in shape. In the same Fig. (4.), we show the dispersion of the individual 4.8h cycles around the 1980 average curve, calculated as the rms of the fluctuations of the intensity in each phase bin. The upper curve represents the dispersion of the curves before they are normalized. This dispersion is mainly due to intensity variation. Taking out the effect of the variation of A_1 and A_0 by computing the dispersion of the normalized curves (middle curve), we still find a phase dependent result. The lower curve shows the dispersion expected on the basis of counting statistics. It is clear that the variability of the minimum is only slightly higher than expected from statistics, while intrinsic fluctuations are important from phase 0.2 to 0.8, and especially around phase 0.65. This result is at variance with that of Parsignault et al.(1977), who conclude to a constant relative rms fluctuation level, which is probably due to the better statistics in the present observations.

We looked for a correlation between the intensity and the degree of symmetry of the mean one-week light curves. We first aligned the different curves in phase using the method described below. The mean fluxes in two equal intervals around maximum (phase 0.2-0.5 and 0.5-0.8) and minimum (0.0-0.2 and 0.8-1.0) were then computed, and two coefficients measuring the asymmetry were formed by taking their relative differences. These coefficents will therefore be zero for a totally symmetric light curve and increase (in absolute value) with an increasing degree of asymmetry.

The results are shown in Fig. 5. While the lower part of the light curve is quite stable in asymmetry, the higher part becomes more symmetric for increasing intensity. Similar behaviour seems also to be suggested by previous observations (Mason et al.1976b). However, there is no exact correlation since the last part of the 1980 observations do not show significant changes in asymmetry in spite of a wide range of intensities.

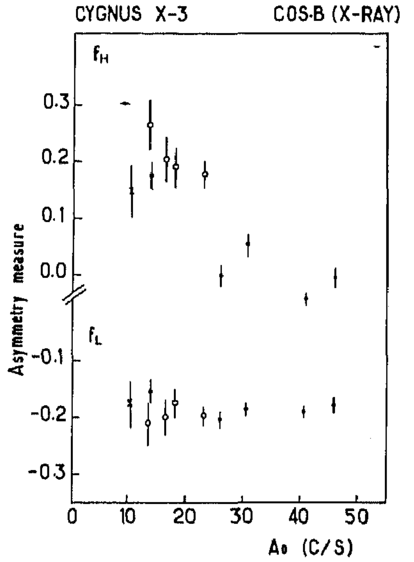

Fig.5:The 4.8h light curve asymmetry determined as indicated in the text for two different phase intervals around maximum f_h *and minimum* f_l, *as a function of the source mean intensity. Error bars are computed according to the dispersion of the individual light curves. Note the nearly constant value of* f_l *for the minimum, and the significant variation of the shape at maximum with intensity, varying from asymmetric to nearly symmetric*(f_h=0).

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c) Time of X-ray minimum

In the 1980 observations, the quality of the data allows us to determine the phase of X-ray minimum to an accuracy of ~ 3.10^{-3} cycles. Data obtained in each satellite orbit were folded according to the quadratic ephemeris given by van der Klis and Bonnet-Bidaud (1981). In view of the stability of the minimum, we determined a template curve in the restricted phase interval (0.8-1.2).

Phase shifts in the time of X-ray minimum were determined by fitting each folded curve, using a X^2 test, to a function A+B.f (φ + C), where f (φ) is the template curve representative of the minimum shape and C is the phase delay between the observed and predicted time of X-ray minimum. Figure 6 shows the results of this analysis. There are significant variations inside the ~ 40 days interval of observation. The changes in phase are suggestive of a sinusoidal periodic behaviour with a period ~ 20 days and an amplitude of ~ 2. 10^{-3} days. To evaluate the effect of changes in the shape of the light curve, we also determined the phases by fitting to a sine curve and to a template curve over the full cycle. The same kind of variation was found, but the periodic behaviour was less clear, as expected from the large variation in shape of the light curve around maximum. We analysed in the same way data obtained in 1977 and 1978. Variations of the same amplitude were seen in both cases, but the uncertainties, of the order of 0.01 cycles, prevent us to determine any regular changes, in spite of some indication of systematic effects (Molteni et al.,1980).

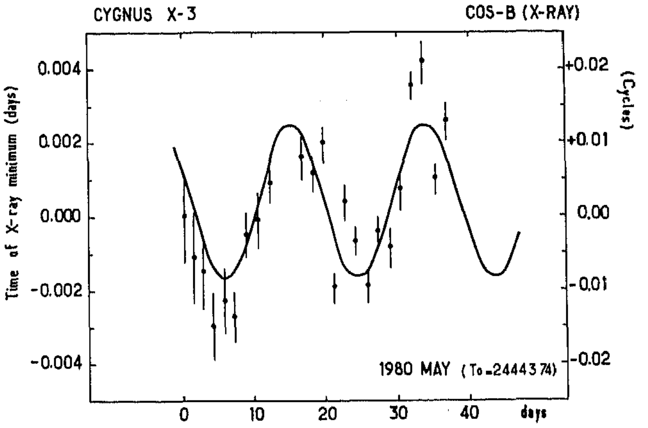

Fig.6: Variations of the heliocentric time of X-ray minimum in the COS-B 1980 observations. The shifts of the time of X-ray minimum were determined by fitting a template curve in the phase interval(0.8-1.2).Each point represents ∿5 binary cycles.Absolute scale is arbitrary. 1σ error bars are shown.Significant departure from a constant time delay suggestive of a sinusoidal variation is visible.Drawn curve is the best fit curve: $A\sin(2\pi(t-T_0)/P)$ *with* $A = (2.08\pm0.01)\ 10^{-3}d$, $P = (18.7\pm0.2)\ d$, *and* T_0=*JD(2444374.5±0.2).Comparaison between this figure and Fig.1 and 5 indicates that those phase variations are not related to the mean intensity changes nor to the changes in shape.*

We also searched for this periodicity in the published Copernicus phase measurements (Mason 1979). Again phase shifts of the same magnitude were present, but the distribution of the data makes it impossible to conclude about a similar periodic effect.

III. DISCUSSION

a) Period changes

Recent observations have revealed the existence of a continuous change in the 4.8h period of Cyg X-3 (Elsner et al.,1980; Lamb et al.,1979; Manzo et al.,1978). The value of the period derivative was refined after the 1980 COS-B observations to a best fit value of $\dot{P} \sim 1.2\ 10^{-9}$, but it was noted that a residual scatter around this trend still exists (van der Klis and Bonnet-Bidaud, 1981). The present observation shows that the period is also changing on a time scale of weeks in a way suggestive of periodicity (see Fig.6).

The amplitude of the T_{min} variations present in all three observations is $\delta T_{min} = 2.5\ 10^{-3}$ d. This number is of the same order as the phase scatter around the long term variation, which we can evaluate to be of the order of:

$\delta T_{min} = \pm \sigma \sqrt{X^2_\nu} = 3\ 10^{-3}$d, where σ is the mean uncertainty in T_{min} and X_ν^2 is the reduced X^2 of the long term best fit (van der Klis and Bonnet-Bidaud ,1981). Therefore it is likely that the short term variations are persistent over years.

The long term rate of change of the 4.8h period, $\dot{P}/P \sim +2\ 10^{-6} y^{-1}$ is similar to the orbital period changes observed in X-ray binaries. It can be explained by a change in the orbital parameters due to mass loss and/or mass transfer in the binary system, and is of the order of the rate of change of the mass (van den Heuvel and de Loore, 1974). It is clear from its magnitude and time scale, that the short term variation in P cannot be due to the same cause; this would imply a relative change of the angular momentum in the system of $\Delta J/J \sim 2\ 10^{-3}$.

Orbital motion has been proposed as the cause of the T_{min} variation in the 1977 and 1978 observations on the basis of an apparent 34d periodicity in the intensity, interpreted as a binary period in an eccentric orbit (Molteni et al.,1980).

The 1980 observations do not confirm the existence of such a periodicity in intensity or in the time of X-ray minimum. Also the phase modulation observed here does not show up in the intensity.

We propose that the observed periodic time shifts are due to apsidal motion, which, as noted by Milgrom and Pines (1978), would clearly establish the 4.8h period as orbital. An apsidal period of the order of 22y at an eccentricity of 0.5 was put forward by Elsner (1980) to explain part of the long term change in the 4.8h period and the apparent stability and asymmetric shape of the mean light curve.

Such a period is very constraining for the characteristics of the companion star and moreover the present observation shows the mean shape of the light curve to be quite variable.

The periodic term for the time delay of the X-ray minimum due to an apsidal motion of period P_{aps} is given to the first order of the eccentricity e by : $\Delta T_{min} = eP/_{\pi}.\cos(2\pi t/P_{aps})$ (Batten, 1973), i.e. the amplitude is proportional to eccentricity. The changes in T_{min} observed here are compatible with an eccentricity of e= 0.03 to 0.05.

The general equation for the ratio of orbital to apsidal period is (Batten, 1973):

$$P/P_{aps} = k.\,[m_x/m_*(15f + g) + g](r_*/a)^5$$

where m_x is the mass of the compact object, m_* and r_* the mass and radius of the companion, a the orbital separation and k the deformation parameter of the companion. f and g only depend on eccentricity and are of the order of unity for small eccentricity. (Relativistic effects and the compact star deformation have been neglected here). For $m_*/m_x = 0.3$, we have for a Roche lobe filling star : $r_*/a = 0.28$. The apsidal motion constant for a completely convective star is calculated as k = 0.14 (Kopal, 1959). For an excentricity e = 0.03 we then find an apsidal period of ~ 15 days, similar to the periodicity in Fig.6.

It appears therefore that the variation in the time of X-ray minima in Cyg X-3 can be well described in terms of an apparent short term period change due to an apsidal motion with a period of about 20 days, superposed to a continuous long term change on a time scale characteristic of the mass evolution of the binary system.

At the small eccentricity implied by the amplitude of the apsidal variation, we would not expect any visible periodic change of the shape of the light curve or of the intensity.

b) Light curve changes

Although the mean shape of the light curve of Cyg X-3 can be constant over very long periods, the shape for individual cycles varies considerably This makes it probable that the mean shape is associated with a dynamically stable large scale structure like the cocoon proposed by Milgrom (1976) or a stellar wind (Pringle, 1974), while the cycle to cycle variability is due to fluctuations in the opacity near the X-ray source or in its intrinsic luminosity. As noted by Milgrom and Pines (1978), an X-ray eclipse could then explain the lower short term variability around phase 0.0, as presently observed. The fact that the scattered and fluorescent radiation from the surrounding gas, responsible for the mean light curve, exhibits an asymmetric variation with phase, could be due to a highly eccentric orbit (Elsner et al.,1980), but this possibility is made improbable by the present work (see above). It could also be due to the light travel time in a large (10^{13} - 10^{14} cm) cocoon (Milgrom ,1976), or to a large scale asymmetry in the mass distribution.

In the 1980 observation, we see a transition to a more symmetric light curve and a greater modulation depth with increasing intensity. As noted before (van der Klis and Bonnet-Bidaud, 1981), in an eclipsing system this could be explained by assuming a decrease in the effective scattering optical depth τ_e of the gas around the system. This would raise the maximum with respect to the minimum and obliterate the asymmetric scattered light curve around maximum.

In a non-eclipsing system the modulation depth could be increased by raising τ_e, but in that case the dominant scattering would keep the light curve asymmetric.

Of the various model light curves published for Cygnus X-3 Pringle (1974) gives the transmitted flux in a stellar wind absorption model and Milgrom (1976) computes the flux scattered by a cocoon. The numerical simulations of Hertz et al.(1978), including Compton scattering, photo-ionization and fluorescence, result in sets of synthetic light curves for different values of τ_e for stellar wind and cocoon models.

We find that a simple two-component approximation, in which it is assumed that an X-ray photon is either scattered out or directly transmitted, can give a description of the relation between amplitude and mean level of the modulation which is well in acccordance with the Hertz et al. work. The effect of the approximation is found to be mainly to overestimate by roughly a factor of two the τ_e needed to explain a certain modulation depth. Thus take

$I_s = 1 - \exp(-\tau_e)$, and

$I_t \exp(-\tau_e)$,

where I_s is the secondary flux originating in the surrounding gas and I_t the flux that is directly transmitted. Describe the phase dependence of I_s and I_t, respectively by the functions f (φ) and g (φ) (assumed to be independent of τ_e), then the total flux is:

$$I_{tot}(\varphi) = [f(\varphi)(1-\exp(-\tau_e)) + g(\varphi)\exp(-\tau_e)]\,I_{int}$$

where I_{int} is the intrinsic source flux.

The observed quantities A_1 and A_0 can be computed from the values of I_{tot} at $\varphi = 0.0$ and 0.5.

The values for f at these phases were estimated from the Hertz et al. light curves at $\tau_e = 5$. In an eclipsing source, g= 0 at $\varphi = 0.0$; the value of g at $\varphi = 0.5$ depends on the eclipse width and the variation of optical depth with phase in the non-eclipsed part; it was assumed to be twice its phase average to allow for the phase dependence of the uneclipsed transmitted radiation, as visible in the Hertz et al. models for $\tau_e = 0.2$ and in the Pringle (1974) light curves.

In the present observation, we observe both the minimum and the maximum to rise when the modulation depth increases. Apparently, when τ_e drops, producing a deeper modulation and a more symmetric light curve, I_{int} rises simultaneously, which results in an increased scattered flux during eclipse. Indeed, Parsignault et al.(1977) observe an inverse correlation between equivalent column density and average intensity. We assume τ_e inversely proportional to I_{int} as a rough representation of the effect of increasing ionization of the gas at higher X-ray fluxes.

This simple picture gives a good description of the observed A_1-A_0 correlation. For example, a set of f and g values corresponding to the cocoon model with a companion radius of r_* /a= 0.4 results in an A_1-A_0 variation in agreement with the observed values (dashed lines in Fig. 2; two curves are given for two different values of the proportionality constant between τ_e and I_{int}^{-1}). The dotted line in Fig.2b shows the result for the same model assuming τ_e proportional to I_{int} (dominant electron scattering in a cold gas, see Holt et al.,(1979)). A constant A_1/A_0 would be obtained in Fig.2b if we assumed τ_e did not vary with I_{int}.

If we take into account the scaling factor of about two to the Hertz et al. models, it may be concluded that τ_e varies from ~ 2 to ~ 0.5 along the dashed lines in Fig.2. This implies a ten-fold decrease of the ratio of the asymmmetric scattered flux and the transmitted flux around maximum (from ~ 6 to ~ 0.6), consistent with a much more symmetric light curve, as observed. The decrease of τ_e for increasing 2-12 keV intensity would result in a softer spectrum at higher intensity, in accordance with spectral observations by Serlemitsos et al.,(1975).

CONCLUSION

The general long term stability of the mean shape of the 4.8h light curve indicates that this shape is connected to a stable feature of the Cyg X-3 system, e.g. surrounding gas in the form of a stellar wind or a 'cocoon'. It was shown that a change in the optical depth of this gas can explain the observed correlated changes in the shape of the light curve and in the intensity of the source.

Further observations are necessary to see if the apparent periodicity in the time of X-ray minimum is real and if it is uncorrelated to any periodic intensity variations. In that case, its interpretation as apsidal motion of a non-zero-eccentricity orbit would give information on the evolutionary status of Cyg X-3; the tidal circularization time of this short period binary could not be long (less than a few thousand years for a 0.4 $M_\odot$ red dwarf companion, (see Zahn,1977) which means that a violent event could have taken place in the system recently. This event may have been the collapse of a white dwarf to a neutron star in a cataclysmic variable progenitor system, which could result in a tightly bound compact X-ray binary with a period of a few hours (Van den Heuvel, 1977; Joss and Rappaport ,1979) with a pulsar as energy source (see Bignami et al.,1977).

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REFERENCES

Basko, M. , Sunyaev, R. and Titarchuk, L. 1976, Astron. Astrophys. 31, 249.

Batten, A., 1973, Binary and Multiple Systems of stars (Oxford-Pergamon Press)

Becker, R. , Robinson-Saba, J., Boldt, E., Holt, S., Pravdo, S., Serlemitsos, P., and Swank, J., 1978, Astrophys.J. Letters, 224, L 113.

Becklin, E., Hawkins, F., Mason, K., Matthews, K., Neugebauer, G., Packman, D., Sanford, P., Schupler, B., Stark, A. and Wynn-Williams, C. 1973, Astrophys.J. Letters, 192, L 119.

Bignami, G., Maraschi, L., and Treves, A., 1977, Astron.Astrophys. 55, 155.

Boella, G., Buccheri, R., Burger, J., Coffaro, P., Paul, J., 1974, Proc. 9th ESLAB Symp. ESRO SP-106, 345.

Bonnet-Bidaud, J.M.; Ilovaisky, S.A., Manzo, G.; Molteni,D. and Robba, R. 1978, Astron.Astrophys. 62, 275.

Bonnet-Bidaud, J.M., and Van der Klis, M. 1979, Astron. Astrophys. 73, 90.

Bradt,M., Doxsey, R., and Jernigan, J. 1979, Adv Sp Expl. vol.3

Danaher,S., Fegan, D., Porter, N., and Weekes, T., 1981, Nature, 289, 568.

Davidsen, A. and Ostriker, J., 1974, Astrophys. J. 189, 331.

Elsner, R.,Ghosh, P., Darbro, W., Weisskopf, M., Sutherland, P., and Grindlay, J., 1980, Astrophys.J. 239, 335.

Ghosh, P., Elsner, R., Weisskopf, M., and Sutherland, P. 1979, BAAS, vol.11, 794.

Hertz, P., Joss, P. and Rappaport, S. 1978, Astrophys.J. 224, 614.

Heuvel van den, E.P.J. and de Loore, C.; 1974, Nature Phys. Sci. 245, 117.

Heuvel van den, E.P.J., 1977, Ann.N.Y. Acad. Sci. 302,14

Holtd, S., Boldt,E., Serlemitsos, P., and Kaluzienski, L. 1976, Nature 260, 592.

Holt, S., Kaluzienski, L., Bolt, E., and Serlemitsos, P.,1979, Astrophys.J. 233, 344

Joss, P. and Rappaport, S., 1979, Astron.Astrophys. 71,217.

Klisvan der, M., and Bonnet-Bidaud, J.M., 1981, Astron. Astrophys. 95, L5.

Kopal, Z.,1959, Close binary systems (NY Wiley), Cha.II.

Lamb, R.C., Fichtel, C., Hartman, R., Kniffer, D., and Thompson, D., 1977, Astrophys.J.Letters, 212, L63.

Leach, R., Murray, S., Schreier, E., Tananbaum, H. and Ulmer, M. 1975, Astrophys.J. 199, 184.

Manzo, G., Molteni, D. and Robba, R., 1978, Astron. Astrophys. 70, 317.

Mason, K., Sanford, P., and Ives, J. 1976a, from X-ray binaries (Goddard), NASA SP-389, p255.

Mason, K., Becklin, E., Blankenship, L., Brown, R., Elias, J., Mjellming, R., Matthews, K., Murdin, P., Neugebauer,G., Sanford, P., and Willner, S. 1976b, Astrophys.J. 207,78.

Mason, K., and Sanford, P. 1979, Monthly Notices Roy. Astron.Soc. 189, 9p

Milgrom, M., 1976, Astron. Astrophys. 51, 215.

Milgrom, M., and Pines, D. 1978, Astrophys.J. 220,272.

Molteni, D., Rapisarda, M., Robba, R. and Scarsi, L. 1980 Astron. Astrophys. 87, 88

Oda, M., 1980, IAU Circ 3502

Parsignault, D., Gursky, H., Kellog, E., Matilsky, T., Murray, S., Schreier, E.; Tananbaum, H., Giacconi, R., and Brinckman, A. 1972, Nat.Phys.Soc.'239, 129.

Parsignault, D., Grindlay, J., Gursky, H. and Tucker, W. 1977, Astrophys.J. 218, 232.

Pringle, J., 1974, Nature, 247, 21.

Serlemitsos, S.P., Boldt, E., Holt, S.; Rothschild, R. and Saba, J. 1975, Astrophys.J. Letters 201, L9

Zahn, J.P., 1977, Astron. Astrophys., 57, 383.