ULTRAVIOLET STUDY OF V1341 CYG = CYG X-2. OBSERVATION OF AN ACCRETION DISK

L.Chiappetti[1], L.Maraschi[1,2], E.G.Tanzi[2] and A.Treves[1,2]
1) Istituto di Fisica dell'Università, Milano
2) Istituto di Fisica Cosmica, CNR, Milano

1. INTRODUCTION

Cyg X-2 belongs to the class of binary X-ray sources with a low mass companion. Although its optical identification with the variable star V1341 Cyg dates from 1967, a reliable determination of the binary period $P=9^d.843$ has been given only recently (Cowley et al, 1979 hereinafter CCH). The likely parameters of the system, taken from CCH, are reported in Table 1.

The absence of X-ray eclipses in most members of the low mass X-ray binaries (Joss and Rappaport 1979), which appeared puzzling for many years, is now generally interpreted as an indication of the existence of thick accretion disks, which screen off the X-ray emission when the inclination angle is close to 90° (Milgrom, 1978).

Ultraviolet observations are of particular importance for a direct study of the properties of the disk, the emission of which in the visible may be confused with that of the non collapsed secondary. The case of Cyg X-2, which is within the capability of the International Ultraviolet Explorer (I.U.E.), is therefore of great interest.

In this paper we discuss observations with I.U.E. in the range 1200-3000 A, with particular reference to the continuum. Some spectra have been already presented elsewhere (Maraschi et al, 1980).

2. OBSERVATIONS

All spectra examined here were obtained in the large aperture of the spectrometer on board I.U.E., in the low resolution mode ($\Delta\lambda \simeq 6$A). Epoch, exposure time and orbital phase as from the elements determined by CCH are given in Table 2 for each observation. The phase convention attributes phase 0 to periastron which very nearly corresponds to inferior conjunction of the X-ray source.

Integral fluxes in selected wavelength intervals are reported in

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Table 2. Variability of the ultraviolet emission is apparent. However the phase coverage is insufficient to detect unambiguously a phase modulation.

The short (1200-2000 A) and long (1900-3000 A) wavelength spectra obtained in succession on Dec 25, 1980, have been combined and are shown in Figure 1 (spectrum labelled $E_{B-V}=0.0$).

Several emission lines are apparent, the most prominent being N V (λ1240), Si IV (1400) and He II (λ1640). The line spectrum will be discussed in a forthcoming paper.

3. EXTINCTION OF THE SOURCE

In Fig.1 the combined spectrum of Dec.25 is dereddened with various values of E_{B-V}, using the mean galactic reddening curve by Seaton (1979). A good rectification of the 2200 A dip, which is clearly visible in the undereddened spectrum, is obtained for $0.4<E_{B-V}<0.5$. This corresponds to extinction values appreciably larger than that proposed by Lyuty and Syunayev(1976) on the basis of optical data.

4. A FIT TO THE ENERGY DISTRIBUTION

In Fig.3, the ultraviolet spectrum of Dec 25, 1980, dereddened for $A_V=1.5$, is reported, together with optical photometry taken from Kristian et al (1967); Peimbert et al (1968); Lyuty and Syunayev (1976). From Table 2 it appears that LWR 9572 corresponds to a low state of the source and therefore a match with optical photometry in low state seems reasonable, although in this source erratic variability dominates the phase modulation. A good fit to the resulting energy distribution is obtained with the sum of two black body components of $T_1 \simeq 7-9 \times 10^3$ °K and $T_2 \simeq 3-5 \times 10^4$ °K. The corresponding emitting areas and luminosities are $A_1 \simeq 3.3 \times 10^{24} cm^2$, $L_1 = 10^{36}$ erg/sec and $A_2 \simeq 3 \times 10^{22} cm^2$, $L_2 = 4.3 \times 10^{36}$ erg/s.

5. DISCUSSION

The dereddened UV spectrum indicates the presence of a contribution from a hot region of small area which is naturally interpreted as an X-ray heated accretion disk. The presence of this component was not apparent from our previous data due to the smaller wavelength range covered. The derived parameters of the disk are comparable to those given by Ziolkowsky and Paczynsky (1980) on the assumption that the disk should be thick enough to avoid a large heating effect on the primary, as suggested by the fact that the light curve in the V band is double peaked.

Assuming an average X-ray luminosity of $L_x = 6.4 \times 10^{37}$ erg/s we can directly estimate the solid angle subtended by the disk from the ratio of the disk luminosity $L_{disk} = L_2$ to L_x

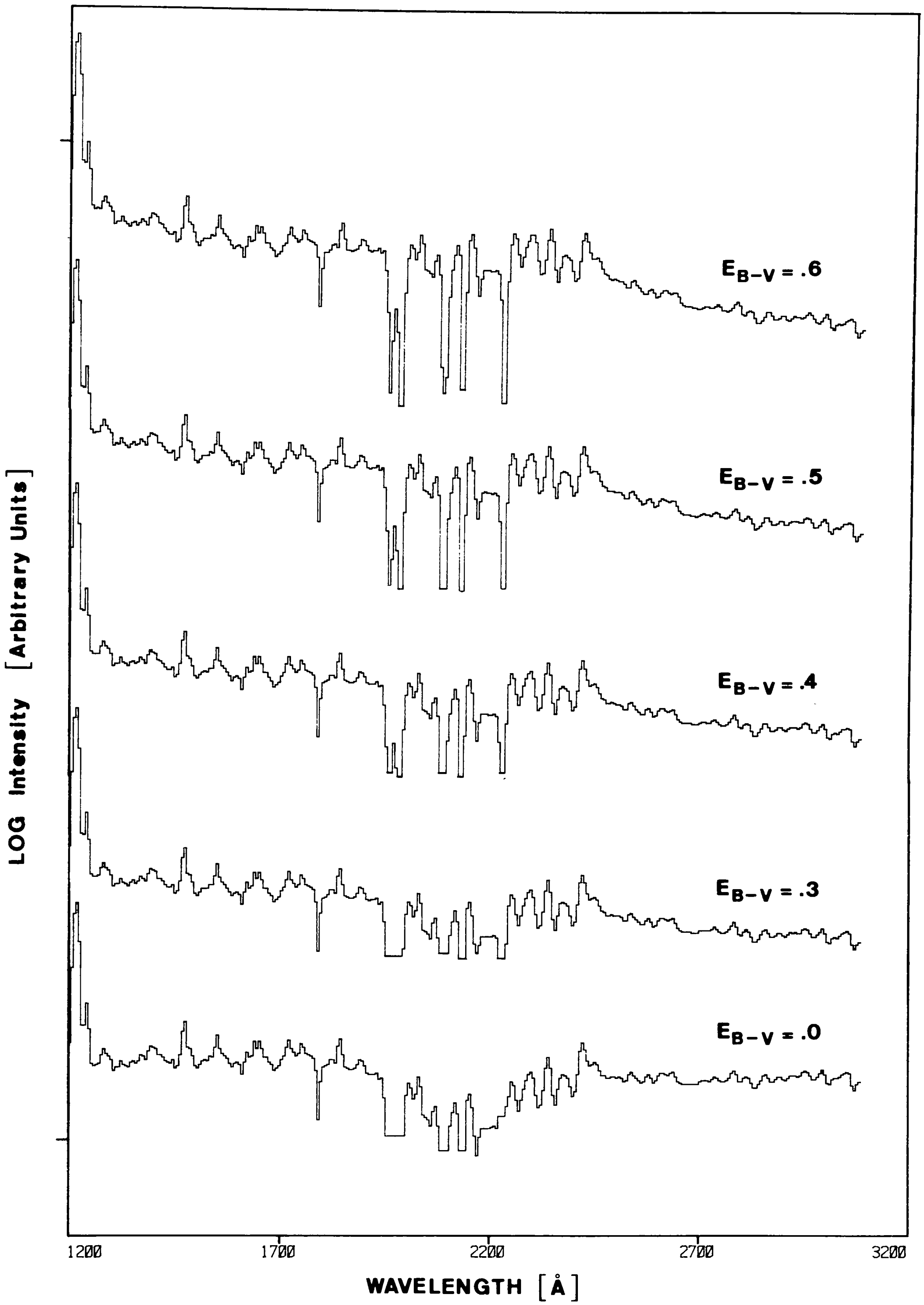

Fig. 1 - Combination of spectra SWP 10889 and LWR 9572 of Cyg X-2, de_ reddened with different values of E_{B-V}.

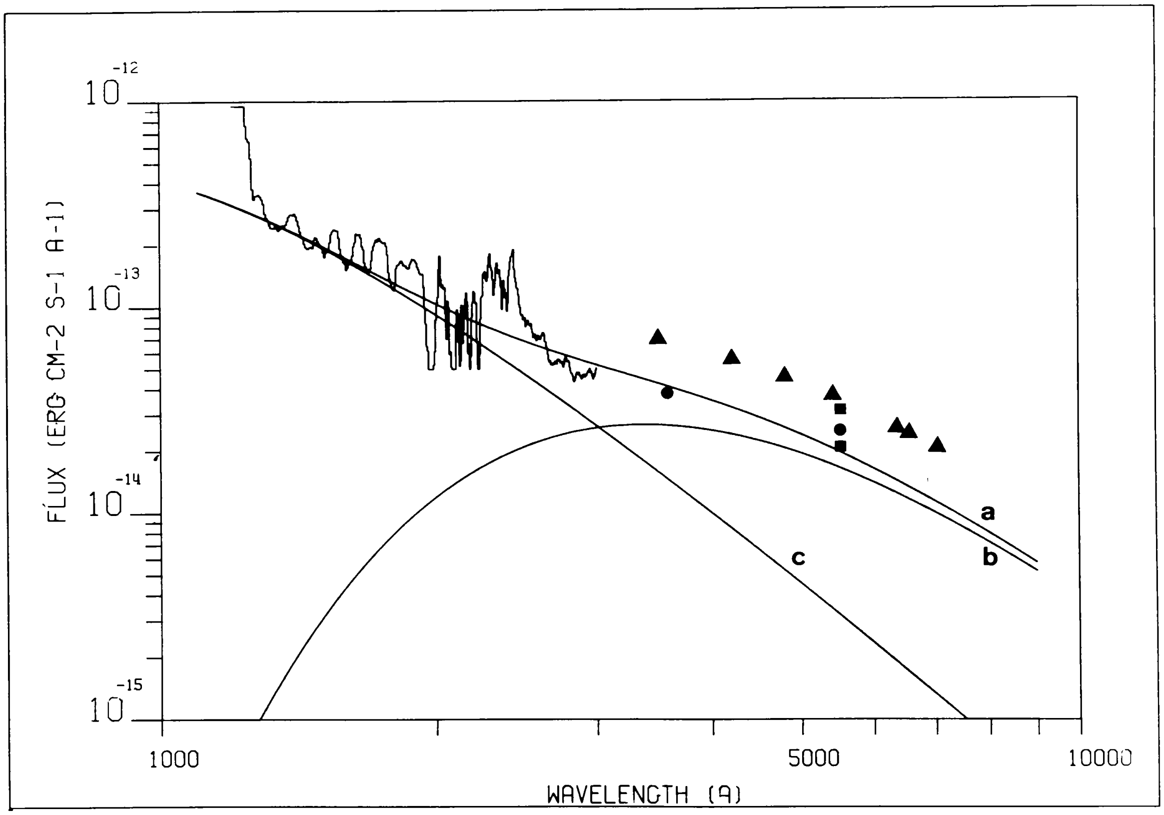

Fig. 2 - Energy distribution of Cyg X-2. Uultraviolet data are a smoothed combination of spectra SWP 10889 and LWR 9572 taken at phase 0. Filled triangles are from Peimbert et al. (1968); filled cilcles are from Lyutyi and Syunyaev (1976). Filled squares indicate the range of variation in the V band according to Kristian et al.(1967). Curve a is the sum of a black body with $T = 4 \times 10^{4}$ °K (curve b) and a black body with $T = 8.6 \times 10^{3}$ °K(curve c).

Table 1 - Relevant parameters of Cyg X-2 (after CCH)

Mass of the primary (M_{opt})	**0.7 $M_\odot$**
Mass of the secondary (M_x)	**1.6 $M_\odot$**
Inclination angle	**74°**
Radius of the primary (R)	**7.4 $R_\odot$**
Separation (D)	**26 $R_\odot$**
Distance	**7.9 kpc**
Bolometric luminosity	**∿ 100 $L_\odot$**
X ray luminosity	**∿ 1.6 x 10^{4} $L_\odot$**

Table 2 – Journal of observations of Cyg X-2 in the ultraviolet, and integral fluxes in selected wavelength intervals.

Image No.	Exp. time (min.)	Epoch (JD) 2444000 +	Phase	Integral fluxes (10^{-12} erg cm^{-2} s^{-1}) 1280-1320	1490-1530	1680-1720	1840-1880	2400-3000	Source of spectra
LWR 5816	90	159.104	.280					2.3	IUE Archives
SWP 6844	190	159.172	.287	.33	.26	.33	.24		Maraschi et al,1980
SWP 6877	180	162.206	.595	.18	.10	.16	.14		Maraschi et al,1980
LWR 7379	180	331.958	.840					3.4	IUE Archives
LWR 7380	205	332.041	.848					3.6	IUE Archives
LWR 7393	418	332.958	.941					2.0	IUE Archives
LWR 9572	150	598.841	.961					2.5	This paper
SWP 10889	440	599.050	.972	.26	.23	.24	.22		Tis paper

$$\Omega_{disk} = 4\pi \frac{L_2}{L_x} \simeq 1 \text{ sterad}$$

The corresponding angular thickness is $\phi = \Omega/2\pi = 0.16$ which is smaller than the angle subtended by the primary $\theta \simeq 2R/D = 0.54$. Therefore the primary would only be partially screened and the intercepted luminosity

$$L_{int} = \frac{L_x}{4\pi} \left(\frac{\pi R^2}{D^2} - \Omega_{disk} \frac{\theta}{2\pi}\right) = 2 \times 10^{36} \text{ erg s}^{-1}$$

would be of the same order of its intrinsic luminosity.

The heating effect should then dominate the ellipsoidal variations in contrast with the indication of the shape of the V light curve.

Two main uncertainties affect the estimate of Ω_{disk}. First, L_2 and L_x are not measured simultaneously. Secondly the disk spectrum may differ from a black body with high contributions shortward of 1200 A so that L_{disk} may be larger than L_2.

In conclusion the U.V. data yield evidence for the existence of a hot disk. Further extensive and simultaneous observations from the visible to the X-ray band are required in order to clarify the detailed structure of the system.

This work is based on I.U.E. observations collected at the ESA satellite tracking station at Villafranca del Castillo, Madrid, Spain.

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