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# Infrared to UV energy distribution of the black hole candidate LMC X-3: Observation of the accretion disk

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INFRARED TO UV ENERGY DISTRIBUTION OF THE BLACK HOLE CANDIDATE LMC X-3 : OBSERVATION OF THE ACCRETION DISK *

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## INTRODUCTION

LMC X-3 is a binary X-ray source which most probably hosts a black hole /1,2/. Here we present a preliminary report on observations of the source in the IR, optical, and UV bands. The observations allow to evidentiate the presence of the accretion disk surrounding the black hole.

## OBSERVATIONS

LMC X-3 was observed in the 1200–3200 Å band with IUE in March 1986 and in January 1987. At the latter epoch coordinated observations in the optical and IR bands were made at the European Southern Observatory at La Silla, Chile. Details on the observations are reported in Table 1.

The IUE spectra were processed using the IHAP package developed at ESO. Regions corrupted by particle events and major flaws were recognized on the line by line extracted spectrum. In particular this led to the exclusion of the region between 1480–1640 Å for the 1986 spectrum (SWP27872). The 1987 far UV spectrum is reported in Fig.1. NV λ1240 Å and CIV λ1550 Å are apparent in emission with e.w. 17Å and 8Å respectively. The intensity of the latter is higher than that of the 1986 spectrum by a factor ~2. Two spectra were obtained in the optical (3800–8400 Å) on 1987 Jan 9,11 at the ESO 1.5-m telescope equipped with the Boller and Chivens spectrograph and Image Dissector Scanner (IDS). Standard reduction of data was performed including photometric calibration derived from the observations of several standard stars /3/ during the nights. The photometric accuracy of the spectrum taken on Jan 11 is better than 10%, while for that obtained on Jan 9 the accuracy is~ 30%. The V magnitude derived from the 1987 Jan spectra is V~16.7. Comparing with the photometry of van Paradijs *et al.* /4/, one recognizes that a high state of the source was observed.

Near infrared broad band photometry in the filters $J$ ($\lambda_{eff} = 12500$Å) ,$H$ ($\lambda_{eff} = 16500$Å), and $K$ ($\lambda_{eff} = 22000$Å) has been obtained on Jan 9, simultaneously with the optical data, at the ESO 3.6-m telescope equipped with InSb photometer. The magnitudes recorded in the photometric system in use at the ESO was $J = 16.9\pm0.2$, $H = 17.1\pm0.3$, $K = 16.4\pm0.3$. Conversion to flux density has been performed using the following zero magnitude values: $J = 3.14\times10^{-10}$, $H = 1.20\times10^{-10}$, $K = 4.17\times10^{-11}$ (erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$).

## THE SPECTRUM OF THE NON-COLLAPSED COMPONENT

Our observations of 1986 and 1987 are summarized in Fig. 2. As discussed in Treves *et al.* /5/ the UV emission in 1986 is most probably dominated by the non-collapsed (secondary) star which, according to van Paradijs *et al.* /4/ is a 17.5 mag star of spectral class B3V /1/. A Kurucz /6/ model atmosphere for a B3V star normalized at V=12.5 and corrected for a Galactic reddening of $A_v^G = 0.20$ (21 cm) substantially exceeds the flux observed at UV wavelengths. This, besides confirming that in this state the UV emission

* Based on ultraviolet observations with the International Ultraviolet Explorer collected at the ESA Satellite Tracking Station, Villafranca, Spain, and on optical-IR observations obtained at the European Southern Observatory, La Silla, Chile.

From the projected emission area, assuming for the disk radius $R_x$ that of the Roche lobe of the collapsed component we can derive the inclination angle. The assumed V magnitude and reddening, together with the adopted temperature yields a mass of the secondary $\sim 2.3 M_\odot$ /10/. The corresponding $R_x$ is $6.5 R_\odot$ /4/ which yields an inclination angle close to 55°.

The mass of the primary, *i.e.* the black hole, for the inclination given above would be $M \sim 7.2 M_\odot$ and the bolometric luminosity of the disk $L_{bol} = 3.3 \times 10^{36}$ erg s$^{-1}$.

Further information on the accretion disk can be derived from the overall energy distribution. This is reported in Fig. 2 combining IR, optical, UV data of Jan 87, with the X-ray spectrum obtained in Dec 84 with the EXOSAT satellite /9/. The total X-ray luminosity (0.1–9 keV) was estimated to be $L_X(0.3-9keV) = 3 \times 10^{38}$ erg s$^{-1}$, 100 times the luminosity of the disk in the optical–UV range. Assuming that this ratio correspond to the solid angle subtended by the disk, one finds a disk angular width $\theta \sim 1°$.

On the other hand the secondary should have a radius $r \sim 3.7 R_\odot$ and subtend an angle $\theta \sim 15°$, which would allow a substantial heating by the X-ray source, contrary to the presence of two even maxima in the optical light curve /11/. Although the ratio $F_{opt} / F_x$ derives from non-simultaneous observations, the optical state at the epoch of the X-ray observations corresponded to a $V$ magnitude $\sim 17$ /4/, a weaker state than that of Jan. 1987. Therefore the discrepancy is even more severe and requires other explanations. One possibility is that the X-ray emission may be non isotropic and mostly directed perpendicularly to the disk. A non-axisymmetric disk can be also considered, with a broader outer rim in the direction of the secondary, a situation rather common in X-ray binaries.

**Table 1**

| Instrument | Spectral range (Å) | Spectrum Identifier | Obs. Date | Obs. Phase | Exposure (min.) | Flux (erg cm$^{-2}$ s$^{-1}$ Å$^{-1}$) |
|---|---|---|---|---|---|---|
| IUE | 2000–3200 | LWP 7753 | 86 Mar 7 UT 04:15 | 0.85 | 385 | $F_{(2550)} = 1.6 \times 10^{-15}$ |
| IUE | 1700–1950 | SWP 27872 | 86 Mar 8 UT 05:56 | 0.47 | 281 | $F_{(1740)} = 3.94 \times 10^{-15}$ |
| IUE | 1200–1950 | SWP 30059 | 87 Jan 9 UT 08:09 | 0.61 | 395 | $F_{(1740)} = 6.50 \times 10^{-15}$ |
| IUE | 2000–3200 | LWP 9942 | 87 Jan 16 UT 07:42 | 0.71 | 183 | $F_{(2550)} = 3.37 \times 10^{-15}$ |
| 1.5m ESO BC + IDS | 3850–8250 | — | 87 Jan 11 UT 04:00 | 0.69 | 48 | $F_{(5500)} = 8.20 \times 10^{-16}$ |
| 3.6m ESO + INSb | — | — | 87 Jan 8 UT 03:40 | 0.92 | — | $J = 16.9 \pm 0.2$<br>$H = 17.1 \pm 0.3$<br>$K = 16.4 \pm 0.3$ |

*References*


/1/ Cowley, A.P., Crampton, D., Hutchings, J.B., Remillard, R., Penfold, J.E., *Ap. J.*, **272**, 118 (1981).

/2/ Paczynski, B., *Ap. J.*, **273**, L81, 1983

/3/ Stone, R.P.S., *Ap. J.*, **218**, 767, 1977

/4/ van Paradijs, J., van der Klis, M., Augusteijn, T., Charles, P., Corbet, R.H.D., Ilovaisky, S., Maraschi, L., Motch, C., Pakull, M., Smale, A.P., Treves, A., van Amerongen, S., *Astr. Ap. in press*, 1987

/5/ Treves, A., Belloni, T., Chiappetti, L., Cristiani, S., Falomo, R., Maraschi, L., Tanzi, E.G., van der Klis, M, *ESA SP*, **263**, 451, 1986

/6/ Kurucz, R.L., *Ap. J. Suppl. Ser.*, **40**, 1, 1979

/7/ Seaton, M.J., *M.N.R.A.S.*, **187**, 73p, 1979

/8/ Fitzpatrick, E.L., *Astr. J.*, **92**, 1068, 1986.

/9/ Treves, A., Belloni, T., Chiappetti, L., Maraschi, L., Stella, L., Tanzi, E.G., van der Klis, M., *Ap. J. in press*, 1988

/10/ Popper, D.M., *Ann. Rev. Astr. Ap.*, **18**, 115, 1980

/11/ van der Klis, M., Clausen, J.V., Jensen, K., Tjemkes, S., van Paradijs, J., *Astr. Ap.*, **151**, 322, 1985

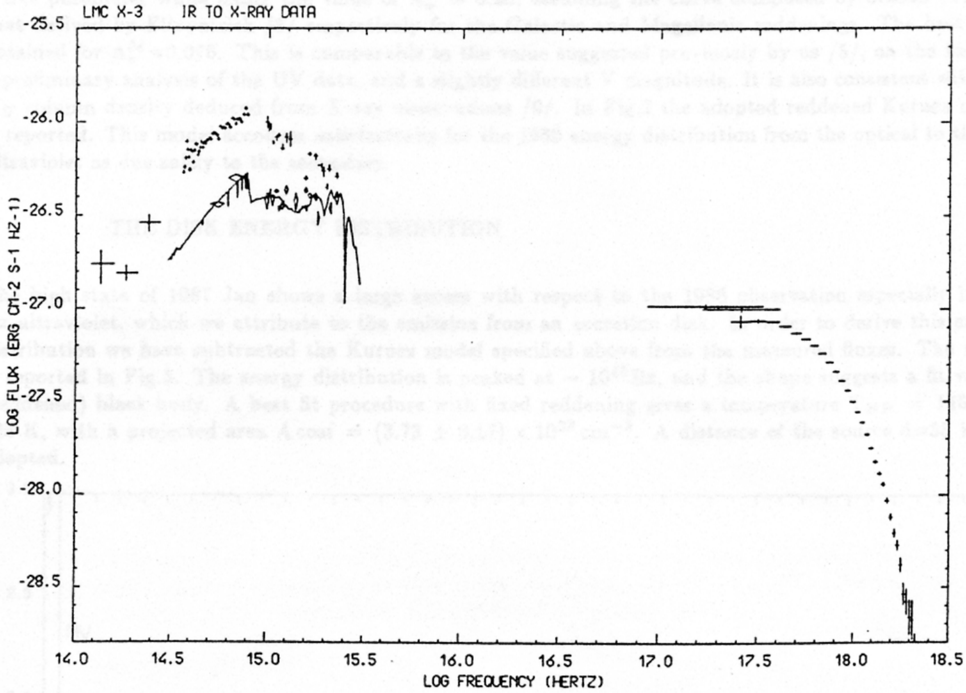


**Fig.2** Overall energy distribution of LMC X-3. The X-ray derive from 1984 Dec observations with EXOSAT.

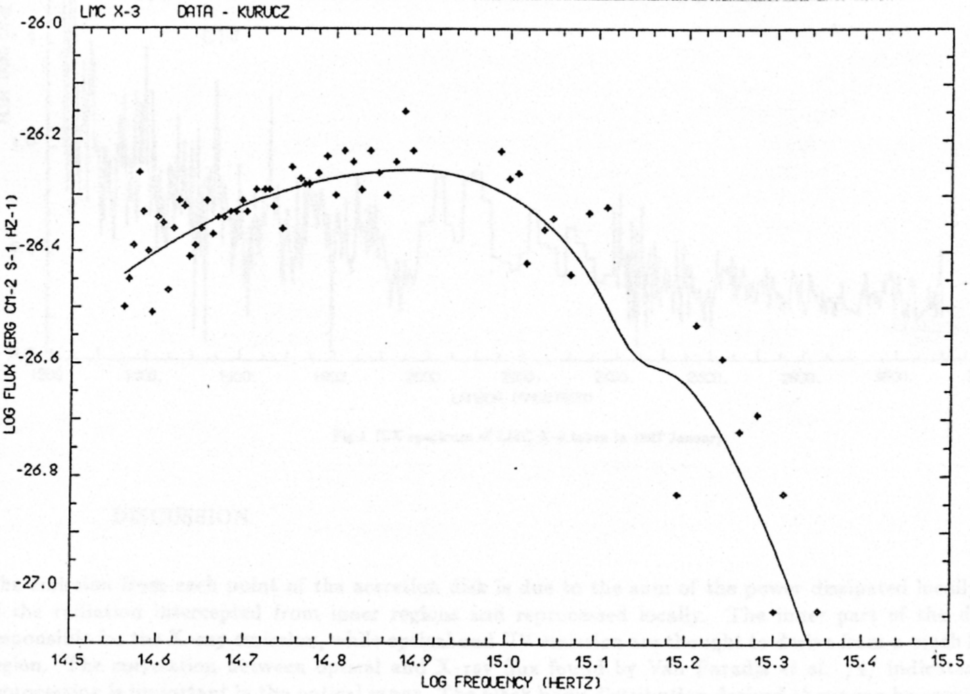


**Fig.3** Energy distribution of the accretion disk. The points represent the difference between tha Jan 87 high state and the Kurucz model for Mar 86. The continuum is a reddened blackbody.

of other components of the system is negligible, suggests a presence of a sizeable reddening $A_v^M$ within the LMC. A Kurucz model with T=19000 K, normalized at V=17.5 was fitted to the data considering $A_v^M$ as a free parameter while fixing the value of $A_v^G = 0.20$, assuming the curve computed by Seaton /7/ and that derived by Fitzpatrick /8/ respectively for the Galactic and Magellanic reddenings. The best fit is obtained for $A_v^M$=0.076. This is comparable to the value suggested previously by us /5/, on the basis of a preliminary analysis of the UV data, and a slightly different V magnitude. It is also consistent with the $N_H$ column density deduced from X-ray observations /9/. In Fig.2 the adopted reddened Kurucz model is reported. This model accounts satisfactorily for the 1986 energy distribution from the optical to the far ultraviolet as due solely to the secondary.

## THE DISK ENERGY DISTRIBUTION

The high state of 1987 Jan shows a large excess with respect to the 1986 observation especially in the far ultraviolet, which we attribute to the emission from an accretion disk. In order to derive this energy distribution we have subtracted the Kurucz model specified above from the measured fluxes. The result is reported in Fig.3. The energy distribution is peaked at $\sim 10^{15}$Hz, and the shape suggests a fit with a (reddened) black body. A best fit procedure with fixed reddening gives a temperature $T_{BB} = 14585 \pm 225$ K, with a projected area $A \cos i = (3.73 \pm 0.17) \times 10^{23}\,\mathrm{cm}^{-2}$. A distance of the source d=55 kpc is adopted.

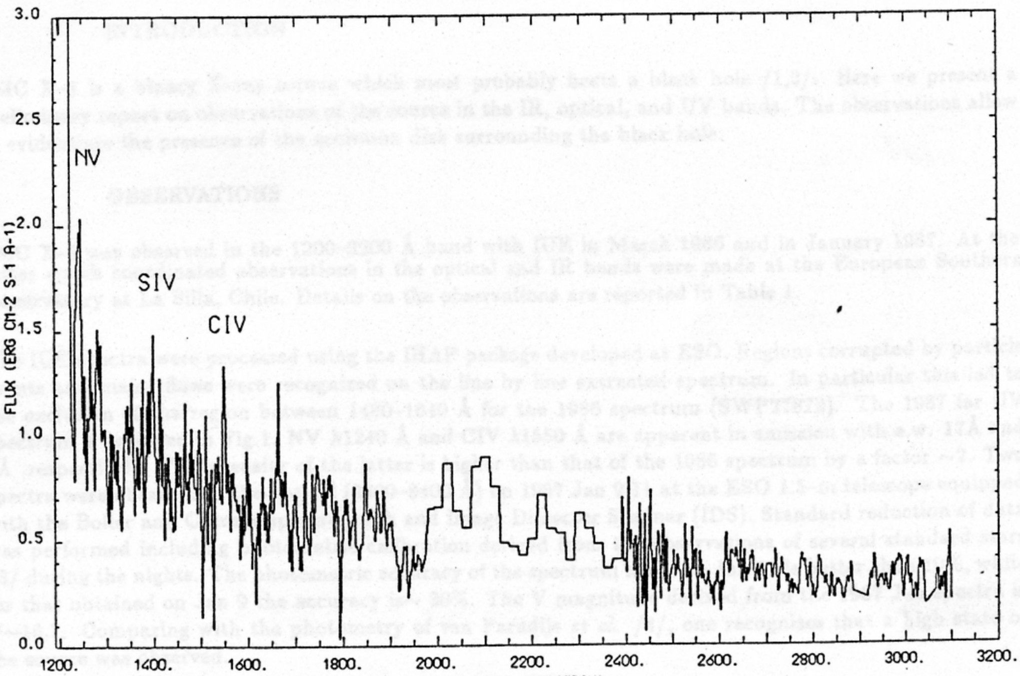


**Fig.1 IUE spectrum of LMC X-3 taken in 1987 January.**

## DISCUSSION

The emission from each point of the accretion disk is due to the sum of the power dissipated locally and of the radiation intercepted from inner regions and reprocessed locally. The inner part of the disk is responsible for the X-ray emission, while optical and UV emission are thought to derive from a much larger region. The correlation between optical and X-ray flux found by Van Paradjs *et al.* /4/ indicates that reprocessing is important in the optical range. The black body distribution derived above can be considered to approximately represent the reprocessed emission.