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*Published in:*
ESA SP

# *686078*

UB Groningen
UvA Keur
Broerstraat 4
9700 AN Groningen

A078729882 ISN: 686078 RAPDOC (R) OPGEHAALD NCC/IBL

**Verzoeke te behandelen voor:** 09-06-2005 **Ingediend door:** 0004/9999
**Datum en tijd van indienen:** 26-05-2005 19:43 **Datum plaatsen:** 26-05-2005 19:43 **Type aanvrager:** UKB **I.D.:** UVA KEUR (UB GRONINGEN)

**PPN: 036734373**

Rolfe, E.

Heck, A. European IUE Conference : proceedings of the Third International Ultraviolet Explorer Conference, Madrid, Spain, 10-13 May 1982, co-sponsored by The European Space Agency (ESA), Consejo Superior de Investigaciones Cientificas (CSIC). (1982)Rolfe, E. (ed.) 1982 NoordwÅk ESA Scientific and Technical Publications ESA SP ; 176

**Gewenst:** **Electronisch leveren (LH=N)**

**Pagina's:**
259-260

**Opmerking:**
arno ID: 125062

**HAAFF** NN31010,176 beschikbaar

1. origineel gestuurd
2. fotokopie gestuurd
3. overige
4. nog niet aanwezig
5. niet aanwezig
6. niet beschikbaar
7. uitgeleend
8. wordt niet uitgeleend
9. bibliografisch onjuist
10. bij de binder

**Fakturen zenden aan:** Rijksuniversiteit Groningen
Bibliotheek, Uitleenbureau
Postbus 559
9700AN Groningen

# UV PHOTOMETRIC AND LINE-WIDTH VARIABILITY OF LMC X-4

M. van der Klis[1], G.Hammerschlag-Hensberge[1], J.M. Bonnet-Bidaud[2], S.A. Ilovaisky[3], M. Mouchet[4], W.M. Glencross[4], A.J. Willis[4], J.A. van Paradijs[1], E.J. Zuiderwijk[5] and C. Chevalier[3]

[1]Astronomical Institute, University of Amsterdam, Amsterdam, The Netherlands
[2]CEN-Saclay, Gif-sur-Yvette, France
[3]Observatoire de Paris-Meudon, Meudon, France
[4]Dep. of Physics and Astronomy, UCL, London, United Kingdom
[5]ESO, Garching bei München, Federal Republic of Germany

## ABSTRACT

Low-resolution IUE spectra of the massive X-ray binary LMC X-4 have been obtained between 1200 and 3200 Å at several epochs in August 1979 and April 1980. Comparison of these observations with theoretical light curves for an X-ray heated tidally distorted star indicate the existence of a disk around the compact star. The resonance doublets of N V, C IV and Si IV show marked changes with orbital phase, being particularly weak when the X-ray source is in front of the primary. These changes can be understood in terms of an anisotropic ionization structure in the expanding atmosphere of the primary caused by the presence of the X-ray source.

Keywords: X-ray sources, close binaries

## INTRODUCTION

LMC X-4 is a massive X-ray binary eclipsing with a period of 1.4 d (Li et al. 1978). Its optical counterpart is an O8 III-V star (Bradt et al. 1979), which shows ellipsoidal variations in the optical region from which the binary period was originally discovered (Chevalier and Ilovaisky 1977), and in the UV region (Bonnet-Bidaud et al. 1981). The X-rays exhibit an ON-OFF cycle of 30.5 d (Lang et al. 1981), which is found back as a variation in the amplitude of the optical light curve (Chevalier et al. 1981).

The analysis of the IUE data of LMC X-4, consisting of 16 low resolution spectra, was discussed in van der Klis et al. (1982); some of the results will be presented here.

## RESULTS

The most evident feature visible in the spectra obtained at different binary phases is the variability of the absorption lines due to the resonance doublets of N V, Si IV and C IV (see Fig. 1), which are predominantly formed in the circumstellar matter. These line variations are commonly explained in terms of ionization of the companion stellar wind by the X-ray flux (Hatchett and McCray 1977). The variation of the equivalent width of N V can be described adequately by a column density calculation assuming a conical boundary surface between the regions in the atmosphere in which N V respectively dominates and is ionized out of existence (dashed line in Fig. 2).

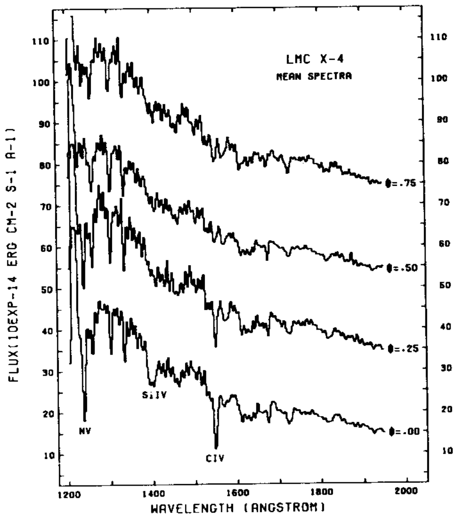


Fig. 1. Mean spectra of LMC X-4. Binary phases are indicated at right. Flux scale refers to $\emptyset$=0 spectrum; subsequent spectra were shifted 20 flux units for clarity.

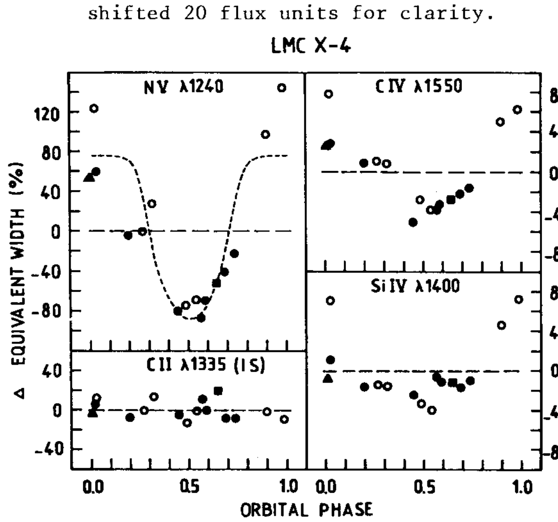


Fig. 2. Relative equivalent width variations. Symbols are as in Fig. 3.

It was not possible to explain the equivalent width variations of the other lines in a similar way: the variations have a smaller amplitude and a larger phase range than predicted.

Using the absolute flux information in the spectra, a clear variation was found in the depth of the UV light curve minimum at $\emptyset$=0.5 (X-ray source in front). As can be seen in Fig. 3, the data obtained in August 1979, corresponding to an X-ray ON-state in the 30.5 d cycle, show a much deeper minimum than those of April 1980 (X-rays OFF).

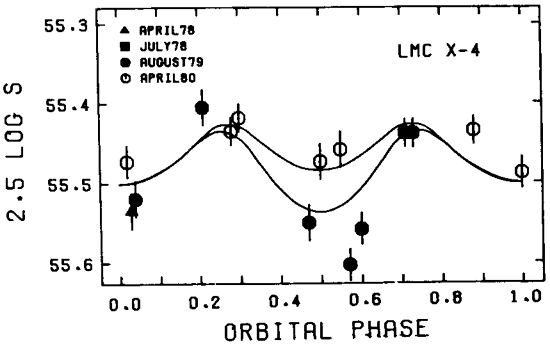


Fig. 3. UV light curve of LMC X-4. Points shown are the normalization constants of the best fit model spectra from Kurucz (1979). Data are plotted as magnitudes with 2 sigma error bars. Continuous lines represent synthetic light curves calculated according to Zuiderwijk et al. (1977), assuming the following system parameters: $M_x/M_{opt}$= 0.07, i=75°, a=$10^{12}$ cm, $L_{opt}$ = $5.10^{38}$ erg/s and $L_X$=0 (deepest at $\emptyset$=0.5) and $L_X$=1.2 $10^{38}$ erg/s.

Like in the case of the optical data (Chevalier et al. 1981), during the OFF state the light curve fits to a synthetic light curve corresponding to an $L_X$ of 1.2 $10^{38}$ erg/s (upper curve in Fig. 3). This suggests, that while we are shielded from the X-rays, the primary is not. Probably the precessing disk suggested by Lang et al. (1981) to explain the 30.5 d modulation is blocking the X-ray flux towards the earth without shadowing a large part of the primary surface.

During the OFF state, we would see the disk edge-on, but during the ON state it could show a considerable projected area. The anomalously deep minimum at $\emptyset$= 0.5 observed during the ON state could then be due to a partial eclipse of the primary by the disk. We calculate that, depending on the inclination, a disk precession angle of 12-25° could be sufficient to explain the observed effect.

Aknowledgements. MK and GHH aknowledge support by ZWO (ASTRON).

References: see van der Klis et al. 1982, Astron. Astrophys. 106, 339