SPECTRALLY RESOLVED MAPS OF OPTICALLY THICK ACCRETION DISKS

R. BAPTISTA[1,2], K. HORNE[2], I. HUBENY[3], K. LONG[1],
C. W. MAUCHE[4], R. G. M. RUTTEN[5], R. A. WADE [6]
1. Space Telescope Science Institute, USA
2. University of St. Andrews, Scotland, UK
3. Goddard Space Flight Center, USA
4. Lawrence Livermore Nat. Lab., USA
5. Royal Greenwich Observatory, Tenerife, Canary Islands
6. Pennsylvania State University, USA

Abstract. We report first results of the HST/FOS time-resolved, low-resolution spectroscopy of the eclipsing cataclysmic variable UX UMa, including multi-wavelength mapping of its accretion disk in the ultraviolet region.

1. Introduction

The *Faint Object Spectrograph* on HST was used to monitor the nova-like UX UMa during eclipse. The basic aim of the project is to use eclipse mapping techniques to derive the structure of an optically thick accretion disk and to test our models of accretion disk atmospheres and chromospheres by comparison with spatially-resolved disk spectra.

2. Observations and data analysis

Time-resolved spectroscopy centered on eclipses of UX UMa was obtained with HST/FOS in 1994 August (G160L, 1100...2500 Å) and 1994 November (PRISM, 1600...8500 Å) at a time resolution of 5.3 s, in a total of 4 data sets and 3122 spectra.

The G160L out-of-eclipse spectrum (Fig. 1) shows prominent emission lines (C III λ1176, Lyα, N V λ1240, Si IV λ1400, C IV λ1550) as well as many absorption features and possibly broad absorption bands, particularly near 1900 Å and 2400 Å. He II λ1640 appears as a weak emission line. At mid-eclipse the continuum flux is reduced by a factor of ~ 3, while the emission

A. Evans and J. H. Wood (eds.), Cataclysmic Variables and Related Objects, 17–20.

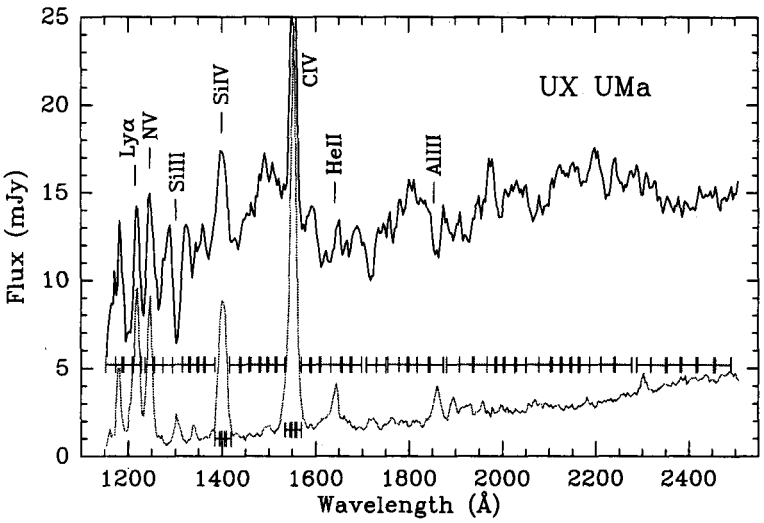

Figure 1. Average out-of-eclipse (dark) and mid-eclipse (light) spectra of UX UMa. Horizontal bars indicate the passbands used to extract eclipse light curves.

lines are much less deeply eclipsed and some of the lines that are seen in absorption in the out-of-eclipse spectra appear in emission. UV continuum light curves show significant flickering activity outside of eclipse, relatively much stronger than observed in the optical range. The eclipses are deep and steep in the continuum with an asymmetry in their egress portion, however no clear evidence of a compact bright spot is seen.

The calibrated spectra were divided into 59 (G160L) and 36 (PRISM) passbands (15...30 Å wide in the continuum and $\sim$ 3000 $\mathrm{km\,s^{-1}}$ in the emission lines) and light curves were constructed for each one. Fig. 2 shows average light curves at selected passbands. Maximum entropy eclipse mapping techniques (Horne 1985; Baptista & Steiner 1993) were used to solve for a map of the disk brightness distribution and for the flux of an additional uneclipsed component in each band (Fig. 2).

3. Results

Spatially resolved disk spectra of the 1994 August data (G160L) show that the inner disk in the UV is characterized by a blue continuum filled with absorption lines and bands, which change to emission with increasing disk radius (Fig. 3). The spectrum of the infalling gas stream, compared with the disk spectrum at the same distance from disk center, shows pronounced emission lines of C II λ1336, N IV+Fe II λ1488, Fe II λ2367, and possibly a blend of Si I lines at 1977...2015 Å. The spectrum of the uneclipsed

https://doi.org/10.1017/S0252921100038082 Published online by Cambridge University Press

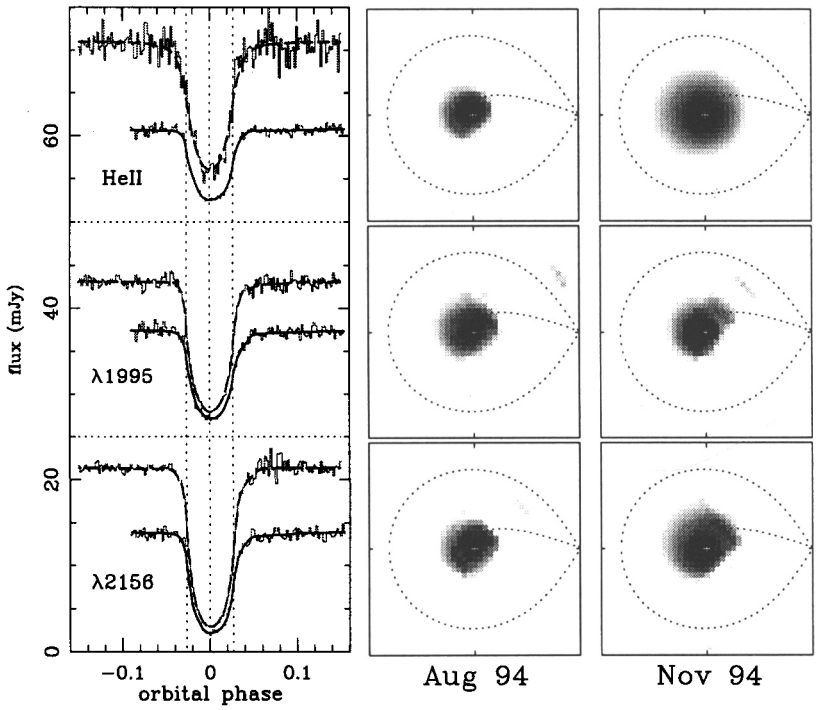

Figure 2. Left: Eclipse light curves (light gray) and fitted models [solid (Aug) and dashed (Nov) lines] for selected passbands. Right: eclipse maps in logarithmic grayscale. Dotted curves show the projection of the primary Roche lobe onto the orbital plane; the secondary star is to the right of each panel and the stars rotate counter-clockwise.

component shows strong emission lines of Lyα, N V λ1240, Si IV λ1400, and C IV λ1550, a weak He II λ1640 component, and a continuum rising towards longer wavelengths.

UX UMa was brighter (by up to 50% at 2000...3000 Å) in 1994 November than in 1994 August. Quasi-periodic oscillations (QPOs) of period 20...30 s are easily seen in the 1994 November light curves. The comparison of the 1994 August and November eclipse maps shows a significant ($\gtrsim$ 50%) increase in brightness in the inner disk regions at the later epoch.

The radial temperature profiles of the August continuum maps are well described by a steady-state disk model ($\dot{M} = 10^{-8.4\pm0.3}\ \mathrm{M}_\odot\,\mathrm{yr}^{-1}$), while the November maps give an excellent fit to a steady disk model of $\dot{M} = 10^{-8.2\pm0.3}\ \mathrm{M}_\odot\,\mathrm{yr}^{-1}$, indicating an increase in the mass accretion rate compatible with the observed increase in brightness. Since the UX UMa disk seems to be in a high-viscosity state in both cases, this result suggests variations in the mass transfer rate from the companion star of considerable magnitude ($\gtrsim$ 50%).

https://doi.org/10.1017/S0252921100038082 Published online by Cambridge University Press

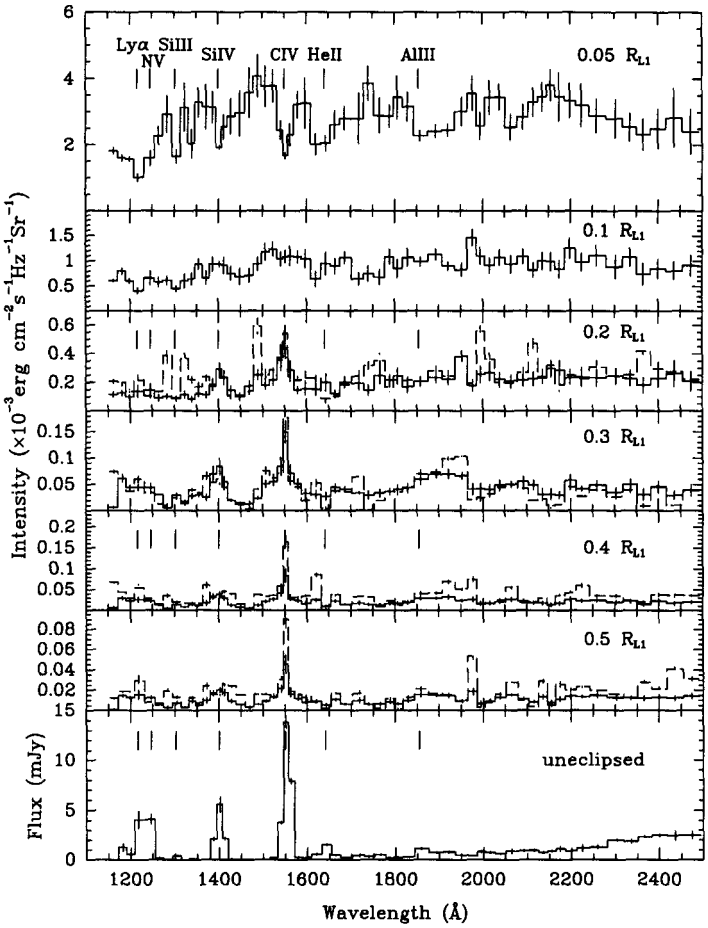

Figure 3. Spatially resolved disk spectra of UX UMa. The spectra were computed for a set of concentric annular sections (labeled values in units of the distance from disk center to the inner Lagrangian point). The spectra of the disk section containing the gas stream are shown as dashed lines.

Further analysis will extend the eclipse mapping study up to 8500 Å, study and map the flickering and QPOs, and model the spatially-resolved disk spectra with state-of-the-art disk atmosphere models.

Acknowledgment. This work was supported by NASA grant GO-5488 from the STScI (which is operated by AURA under NASA contract NAS5-26555).

References

Baptista, R., Steiner, J.E., 1993, A&A, **277**, 331
Horne, K., 1985, MNRAS, **213**, 129