THE MAY 1985 SUPEROUTBURST OF OY CARINAE: II. PHASE-RESOLVED IUE SPECTROSCOPY AND EXOSAT OBSERVATIONS

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ABSTRACT. We present ultraviolet and X-ray observations of the eclipsing SU UMa dwarf nova OY Car early in the decline from a superoutburst. From the UV emission line spectrum and lack of X-ray eclipse, we deduce the presence of an extended coronal region.

1. INTRODUCTION

This is the second of two papers covering the target of opportunity programme on the May 1985 superoutburst of OY Car, and will concentrate on the IUE and EXOSAT observations. Low resolution IUE spectra were obtained, phase-resolved on the orbital period of 91 minutes and within the 6 minute optical eclipse. On 2 May we obtained limited orbital phase coverage with 8 exposures, while on 5 May the 23 exposures gave good phase coverage, spanning a total of 9 orbital cycles. These are the first phase-resolved IUE observations of an eclipsing SU UMa system in superoutburst. Figure 1 of Paper I (Naylor et al 1986), shows the times of IUE observations relative to the superoutburst lightcurve. The IUE observations on 2 May are at least 3 days past maximum and the superhumps had been seen at least one day previously. Both IUE observations fall at beat phase zero. EXOSAT observations were obtained shortly following the IUE observations of 2 May, during those of 5 May and 6 days later.

2. IUE RESULTS

Figure 1 shows eclipse and non-eclipse SWP spectra on 5 May. The most striking property is the strong emission lines, uncharacteristic for a

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dwarf nova in outburst. These show some variability in strength with orbital phase, and CIV, SiIV, NV and Ly α have complex structure. The continuum is particularly weak in eclipse. The LWP spectra display only weak MgII emission and a weak continuum.

The lightcurve in the continuum band 1360±15Å (Figure 2b) has been folded on orbital phase (Figure 2a). There is a strong (90%) eclipse at orbital phase zero and apparently a smooth modulation throughout the orbit, peaking at phase 0.4 and dropping by ~50% by phase 0.9. We favour orbital modulation rather than secular decline, since the FES magnitude showed no systematic changes over the same period. The FES showed a rise near phase 0.9 indicative of the rise of the superhump. The LWP showed a distinct eclipse (45%) but no sign of decline at late orbital phases; in fact it even mimics the FES rise.

The CIV profile is asymmetric with the red wing much steeper than the blue wing and sometimes with two distinct peaks. A two-component model is a significantly better fit (Figure 3c) than a one-component model except during eclipse where the S/N is greatly reduced. Away from eclipse, the line can be parameterised by two gaussian components, separated by ~10Å (Figure 3a). The eclipse lines (fitted as a single component) lie near the rest wavelength. The FWHM (Figure 3b) of the blue component is distinctly wider (12Å) than either the red component (8Å) or the line during eclipse (10Å). The total flux in the CIV line (Figure 3d) shows an eclipse of about 45% and perhaps a smooth modulation. NV, SiIV and HeII show eclipses of 45%, 60% and >78% respectively and no other orbital modulation. Ly α shows distinct orbital modulation but no eclipse.

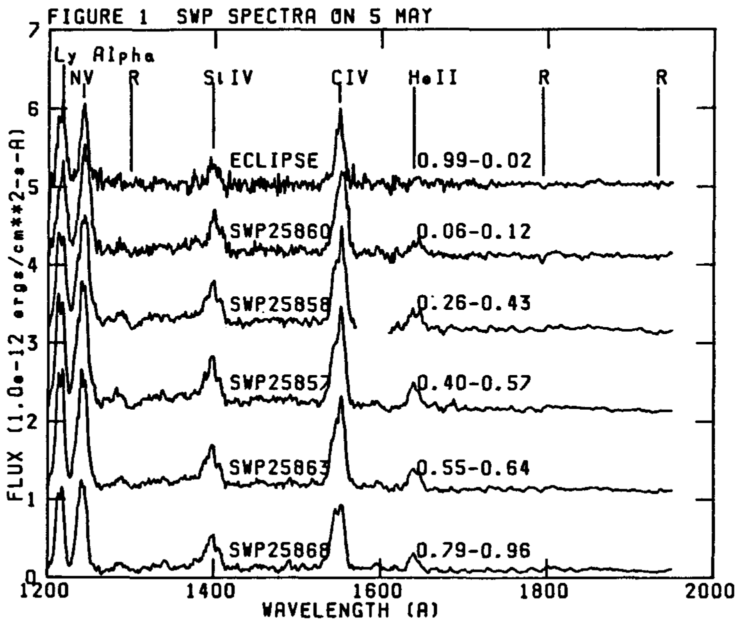

Figure 1. Typical out-of-eclipse and mean eclipse SWP spectra on 5 May with offset of 1×10^{-12} ergs/cm^2/s/Å.

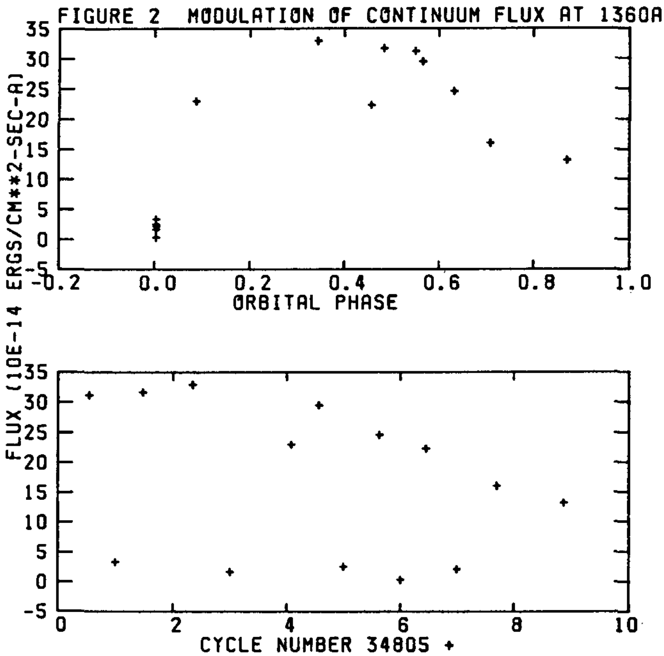

Figure 2. Modulation of continuum flux at 1360Å (bandwidth 30Å) a) folded on orbital phase. b) chronological order.

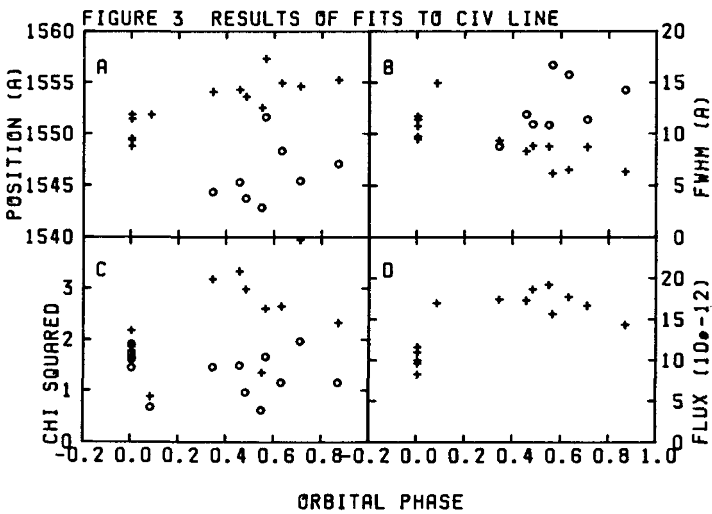

Figure 3. Profile fits to CIV line versus orbital phase. a) Position of individual components: blue (o), red (+). The points near eclipse are one component fits. b) As a) for FWHM. c) Reduced chi-squared for one (+) and two (o) component models. d) Total line flux.

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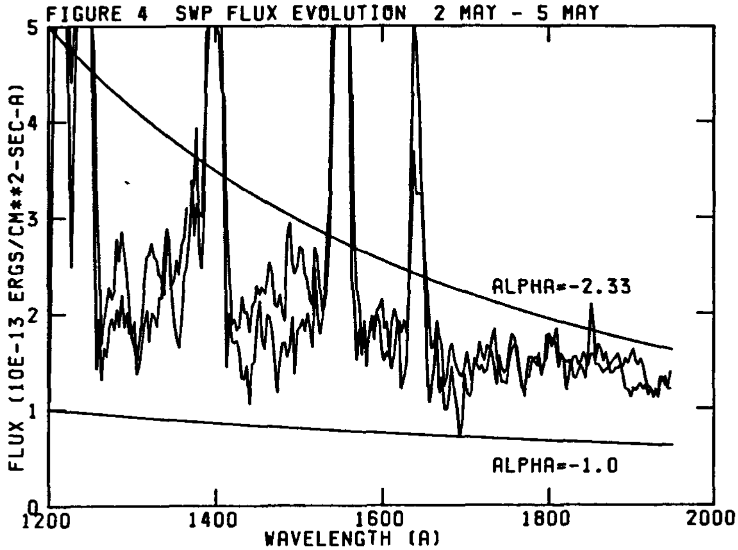

Figure 4. SWP flux evolution 2 May (lower) - 5 May (upper spectrum) in 3Å bins. Superposed lines are power laws with marked spectral indices.

Figure 4 compares the non-eclipse spectra on each day. The lower spectrum (2 May) is flatter than the upper spectrum (5 May), despite the fact that the FES magnitude is fainter during the second observation. On 2 May (5 May) the spectral index is -1.0 (-1.2) and with an SWP flux distribution similar to a star of spectral type A0 (B8) with a corresponding effective temperature of about 11,000K (13,000K).

2. EXOSAT RESULTS

Observations with the LE covered 5 eclipse times during the three runs. The count rates were highest on 3 May (about 10 cts/min in 3000-Lexan) and declined by a factor of three by 5 May, whereas the softness ratio (Al-Pa/3000-Lexan) stayed constant at 0.35. There was no obvious sign of eclipse at the predicted time, even in the 3000-Lexan run with highest S/N. No sign of longer term modulations or fast oscillations were revealed by Fourier analysis. We conclude that there is no X-ray eclipse or orbital modulation.

3. DISCUSSION

The absence of an X-ray eclipse indicates that the observed emitting region is extended and that we are not seeing the white dwarf and boundary layer emission. We can rule out an optically thick X-ray plasma using the count rates and softness ratio, whereas an X-ray emitting corona model may be compatible, with suitable choice of parameters. Using the Mewe et al (1985) calculation shows that a plasma at 10^6-10 K filling a volume comparable with the Roche lobe (radius= $\sim10^{10}$ cm) would have the observed softness ratio. The non-eclipse of Lyα and the partial eclipse of other emission lines support this coronal model.

The strong continuum eclipses are expected from a centrally condensed UV emitting accretion disc. The inwardly increasing temperature distribution would mean that a greater proportion of the SWP than LWP light emanates from the centre, leading to a deeper eclipse. The relative eclipse depths of the emission lines are correlated roughly inversely to the ionisation potentials. Non-spherical wind models by Drew & Verbunt (1985) may be able to produce the necessary outwardly increasing ionisation zones.

The CIV line profile is very similar to that of RW Tri (Cordova & Mason 1982), and we identify the red peak as a wind component with v~1000 km/s. It contrasts markedly with WX Hyi in superoutburst (Hassall et al 1983), in which the line profile is of a classical P Cygni type. WX Hydri is seen at a lower inclination (i~40 degrees) and the wind material is projected against the disc in the line of sight giving rise to the absorption wing. In the edge-on systems we see a broader complex component that is probably disc emission. Its narrowing in eclipse suggests that the higher velocity material is centrally condensed as in a disc, rather than from an outwardly accelerating wind.

The smooth continuum modulation peaking near phase 0.4 is definitely not the superhump (predicted phase 0). To cause modulation of an extended region (e.g. uneclipsed Lyα), the obscuring object must be large. The phase implies that it lies near the stream impact area or red component.

The flux distribution of OY Car is unusually cool for a dwarf nova in outburst, and it is unusual for gross changes in the UV distribution to occur so late in an outburst. Such changes in VW Hyi (Verbunt et al 1986) have only been seen on the rise and never on the decline. The X-ray flux, indicative of accretion rates at and near the white dwarf, is higher during the first IUE observation, implying that the UV-emitting inner disc is being obscured by a temporarily thickened outer disc, rather than undergoing drastic changes in temperature structure. This IUE observation coincided with peculiar optical/IR eclipse structure (Paper I).

4. CONCLUSIONS

The IUE observations show that the superhump is not a strong contributor to the UV flux during the eclipse. This is in accordance with the results of Paper I in which a large but cool (<10,000K) and uneclipsed source would not contribute significantly to the SWP flux.

The unusual appearance of OY Car is largely due to the high orbital inclination, which hides the white dwarf/boundary layer and inner disc from view. The projected disc area is small and high limb darkening results in much less UV continuum radiation than in most systems in outburst. Instead, it reveals to us the optically thin material that fills an extended volume around the system and gives rise to the emission lines and wind-like line profiles.

REFERENCES

F.A. Cordova, K.O. Mason, 1982. Astrophys. J. **260**, 716.
J.Drew, F. Verbunt, 1985. Mon. Not. R. astr. Soc. **213**, 191.
B.J.M. Hassall, J.E. Pringle, A. Schwarzenberg-Czerny, R.A. Wade, Mon. Not. R. astr. Soc. **203**, 865.
R. Mewe, E.H.B.M. Gronenschild, G.H.J. v.d. Oord, 1985. Astron. Astrophys. Suppl. Ser. **62**, 197.
T. Naylor et al 1986 (This Volume)
F. Verbunt, B.J.M. Hassall, J.E. Pringle, B. Warner, F. Marang, 1986 Submitted to Mon. Not. R. astr. Soc.
F. Wesemael, L.H. Auer, H.M. van Horn, M.P. Savedoff, 1980, Astrophys. J. Suppl. **43**, 159.

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