THE IUE OBSERVATIONS OF W UMA[†]

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Abstract. The low resolution, phase averaged SWP spectra reveal the trend of increased transition-region line intensities for higher temperatures of ion formation which was previously observed for other active systems. Two series of low resolution LWR spectra covering two full orbital periods have been used to check the photometric results from the ANS satellite and a good agreement is found for the 2200 Å band. Wavelength shifts and changes in the intensity of the blended Mg II emission feature are not inconsistent with the ANS result that the more massive component is the more active one in the W UMa system.

1. The SWP Spectra Region

Two low resolution, large aperture SWP spectra (Fig. 1) were obtained on April 4, 1980 by integrating the rather weak stellar signal during a few of the LWR camera read-out intervals (cf. next section). The exposures lasted effectively 140 and 85 minutes and covered the phase intervals 0.66-0.11 (SWP 8653) and 0.17-0.43 (SWP 8654). Therefore, the fluxes in Fig. 1 are phase averaged over considerable portions of the light curve. The phasing of our observations has been based on the light curve obtained with the FES detector and described by Rucinski et al. (1980). The tentative line identifications are marked on the figure. To convert the observed fluxes into the surface fluxes, we used the formulae given in Linsky and Ayres (1978). When compared with the solar data (Fig. 2) the emission line fluxes for lines originating in the transition region reveal the same trend as observed for other active stars and for other W UMa-type systems in particular (Dupree and Preston 1980), i.e. the trend of increased line intensity for higher temperatures of ion formation. This increase ranges between a factor of about 30 for the Si II lines up to about 250 for the Si IV

[†] Based on observations collected at the Villafranca Satellite Tracking Station of the European Space Agency.

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lines and can be interpreted by the relatively high proportion of closed magnetic tubes confining the high temperature plasma.

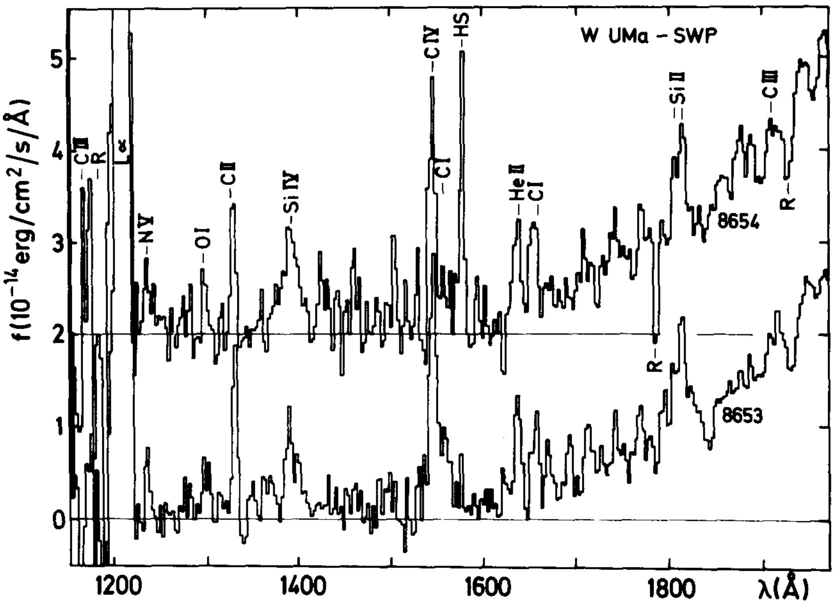

Figure 1. The SWP spectra of W UMa.

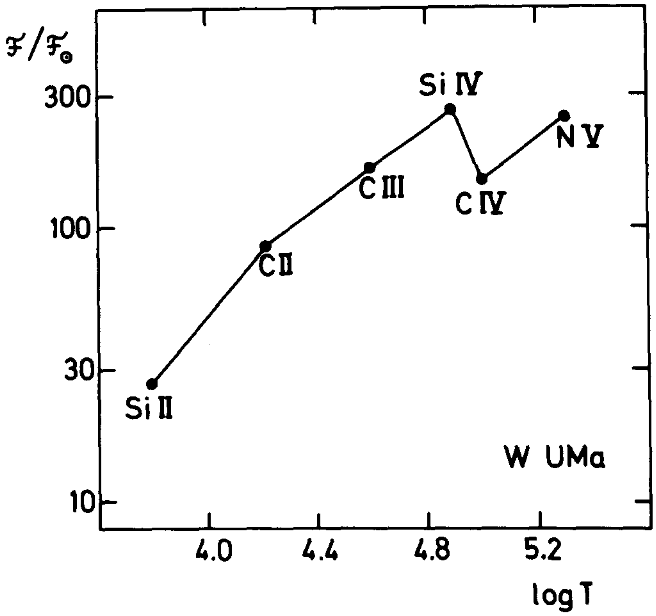

Figure 2. The surface line fluxes relative to the solar values versus the temperature of ion formation.

2. The LWR Spectral Region

Two series of low resolution, large aperture LWR spectra were obtained on April 3 and 4, 1980 during two consecutive European IUE shifts, i.e. shifts separated by 16 hours or, almost exactly, by two orbital periods of W UMa. Because of the modest dynamic range of the IUE cameras and the rapid fall-off of the continuum towards shorter wavelengths it was necessary to observe W UMa with different exposure times. Seven strongly exposed (25 minutes) images obtained during the first shift permitted analysis of the spectrum shortward of 2650 Å; ten images with exposures ranging between 5 to 10 minutes obtained during the second shift were used for the longward portion of the spectrum. Two representative spectra taken at orbital quadratures of W UMa are shown in Fig. 3; spectra at other phases are very similar in the general shape and intensities of spectral features.

The LWR spectra are dominated by broad blends of many Fe I and Fe II lines with especially prominent blends at 2400-2630 Å (Fe I, Fe II, Si I, Mg I) and close to the 2800 Å line of Mg II (Fe II, Cr II, Mg I, Mg II).

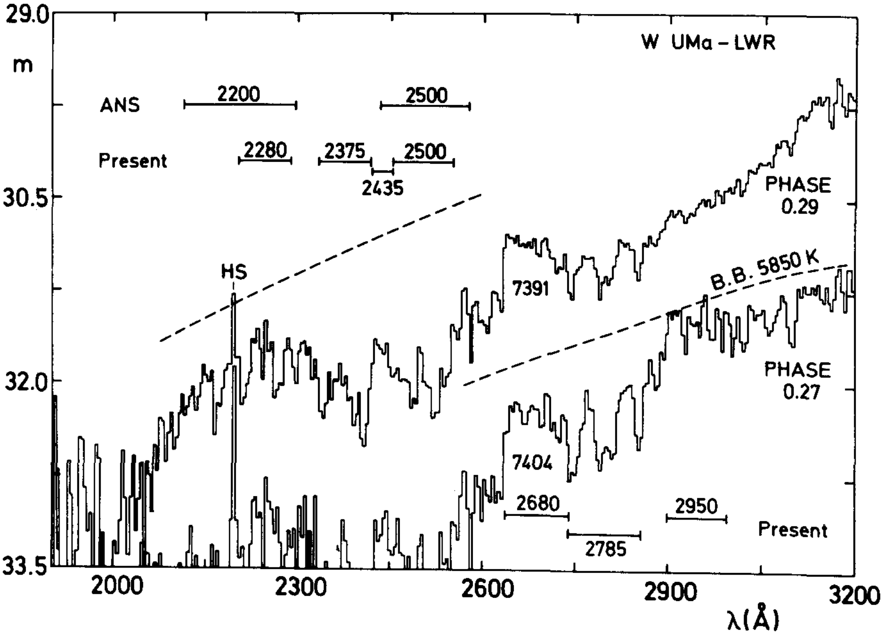

Figure 3. Two low resolution LWR spectra taken at phases close to orbital quadratures. The scale of stellar magnitudes (the ANS system) is appropriate for LWR 7391 (upper spectrum); the spectrum LWR 7404 is shifted down by 1.5 mag. Notice the overexposure of LWR 7391 extending from about 2650 to 3100 Å. A blackbody curve corresponding to the mean effective temperature of W UMa has been arbitrarily located in the vertical coordinate.

The behaviour of these blends could have some influence on the results obtained previously with the ANS satellite photometry by Eaton et al. (1980). They found that the gravity darkening must be rather small and that the dark spots on the more massive component are the only reasonable explanation for the W-type light curve. Their basic assumption was that the ANS spectral bands at 2200 and 2500 Å measured the photospheric continuum radiation and the ultraviolet-optical colours are good indicators of averaged effective temperatures. Locations of the almost rectangular ANS bandpasses relative to the spectrum (Fig. 3) suggest that the 2200 Å band was indeed a useful continuum indicator for W UMa whereas the 2500 Å falls into the choppy region what might explain, in addition to reasons listed by Eaton et al., the much worse definition of the ANS light curve at 2500 Å. Unfortunately the 2200 Å band contains a "hot-spot" at 2190 Å so that the simulated ANS fluxes (the IUE fluxes convolved with the ANS bandpasses) contain at least a 3% contribution (if one pixel is affected) from this blemish. The simulated ANS magnitudes at 2200 Å are presented in Fig. 4 together with the original ANS results.

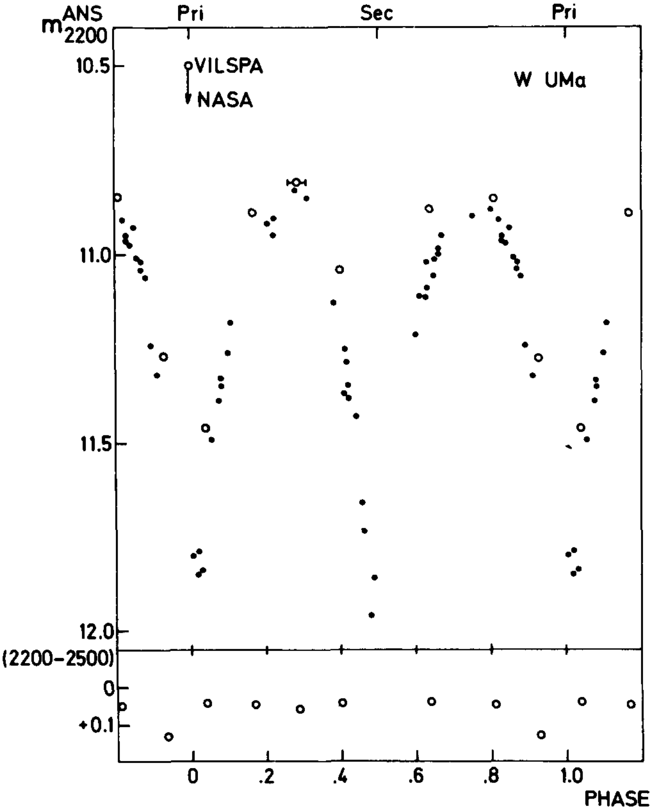

Figure 4. Comparison of the simulated ANS magnitudes for the 2200 Å bandpass (circles) with the original ANS data (dots).

The uncertainty of the calibration is shown by the arrow giving the change when the original Vilspa calibration used here (Bohlin et al., 1980a) is replaced by the new one adopted for the first time by NASA in May 1980 (Bohlin and Holm 1980b). Taking into account these instrumental uncertainties which together might reach 12%, the agreement is satisfactory.

In addition to the ANS bandpasses, we analysed also the phase dependence of the LWR spectrum in bands selected to represent the major low resolution features, as marked in Fig. 3. The obtained integral changes are very small, never exceeding 5-7%, i.e. rather close to errors of measurements; however, they do seem to be systematic, e.g. the absorption features at 2375 and 2500 Å become somewhat stronger at orbital quadratures (double cosine behaviour), whereas the triple blend contained in the 2785 Å band shows a weak single cosine dependence. This suggests that those spectral regions should be avoided in future continuum studies.

3. The Mg II Emission Line

The low resolution spectra reveal only a weak emission feature at the center of a broad absorption around 2800 Å. The emission peak shows small wavelength shifts resulting in variable blending with the steep branches of the surrounding absorption. The blending is phase dependent with indications of opposite in direction and largest shifts at quadratures (Fig. 5). The sense of shifts suggests that the more massive com-

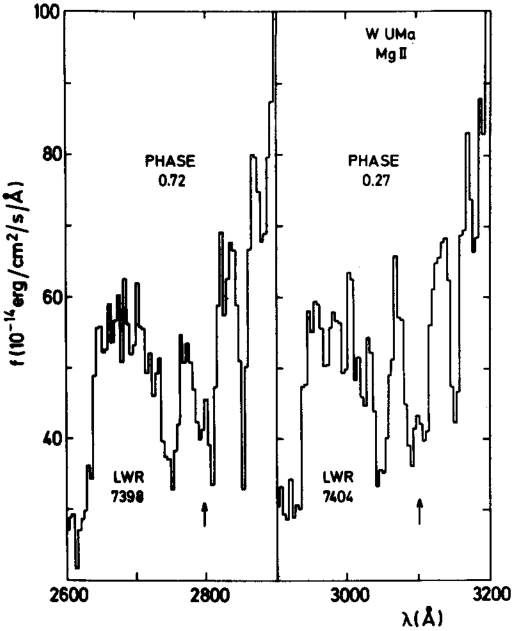

Figure 5. The region of LWR spectrum close to the Mg II line at two orbital quadratures of W UMa.

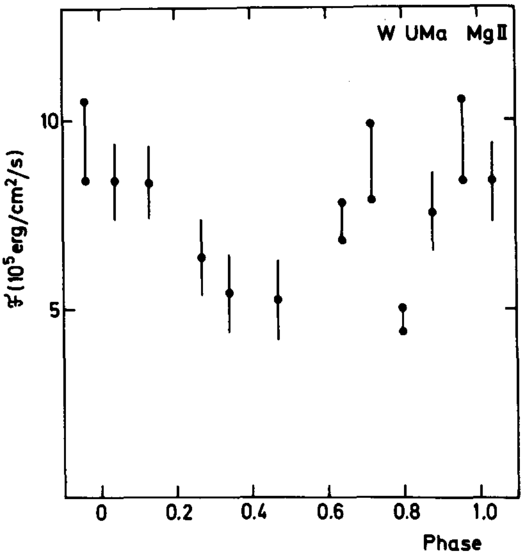

Figure 6. Approximate measure of the Mg II emission surface flux versus phase.

ponent contributes most of the Mg II emission but with the present resolution it remains an open question if this merely reflects the larger emitting area of this component or the stronger line flux indicating its elevated chromospheric activity.

To obtain a crude measure of the changes in intensity of the Mg II emission, the emission peaks have been integrated above the lowest points in the surrounding absorption. Such approximate fluxes have been converted to the surface fluxes and are shown in Fig. 6; the vertical bars in that figure represent estimates of errors due to the ambiguity in inclusion of individual pixels. As can be seen, the Mg II feature seems to reveal a broad minimum for phases when the primary (more massive) component is partially eclipsed indicating that indeed this component might be more chromospherically active of the two. Obviously, this result must be checked with the better observational material.

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