IUE OBSERVATIONS OF BY DRACONIS

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ABSTRACT

Phased IUE observations of BY Draconis show no significant modulation of the prominent SWP emission lines over one rotation period. However, a marginally significant anticorrelation of the MgII flux, and the flux in the LWR 'continuum', with the V light curve is observed, and is interpreted as due to 'plage' type areas over the photospheric spots. Two SWP spectra show sporadic enhancements of the emission lines as has been seen in other IUE spectra of flares.

Observations, which were made over the period 2–5 October 1981 included some seven SWP spectra and thirteen LWR spectra, all of low resolution, and exposed in the large aperture. Two of the SWP spectra: SWP 15162 and SWP 15169 contained two separate exposures made at opposite ends of the large aperture. The two spectra found in each case were sufficiently well separated on the image that it was possible to extract them independently. All of the spectra have been extracted using the IUEEDR package on STARLINK devised by J.R. Giddings of University College London. (Giddings 1983)

2. THE SWP SPECTRA

Following the extraction of the SWP spectra the positions of the five strongest emission lines have been examined for possible wavelength shifts and a mean value determined for each spectrum. The mean correction to the wavelength scale, which never exceeded 1.5 Å and was generally less than 1 Å, was then applied to all wavelengths on that spectrum. Following this correction the spectra were mapped onto a 1 Å grid and were binned in the wavelength intervals associated with each emission line to determine the integrated flux in the lines.

In Figure 1 we plot the observed fluxes in several of the prominent SWP lines as a function of phase together with the optical light curve determined in June - October 1981 by Rodono et al (1983). We may remark immediately that, contrary to what might be expected, there is no significant correlation, or anti-correlation, of the emission line fluxes with the optical light curves. There are several possible causes for this lack of correspondence.

1) The light curve at that time had a small amplitude (ΔV ~ .1 mag) and therefore any modulation of the SWP emission lines may be correspondingly reduced to such a level that they would be undetectable with IUE.

2) The plage-type regions, which on the solar model would be expected to be associated with the spot or spots on BY Dra, may be much more uniformly distributed over its surface than the photospheric spot thereby reducing any modulation caused by

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1. INTRODUCTION

The BY Draconis group of variable stars are late type (K-M) dwarfs which show quasi-sinusoidal photometric variations of small amplitude. These variations are now commonly attributed to the presence of spots on the stellar surface which modulate the visible light as the star rotates. Most, but not all, BY Draconis variables are relatively close binaries, and often the binary orbital period is equal to the rotation period; that is, the component stars are gravitationally 'locked'.

A series of IUE observations of BY Draconis were planned as part of an international collaborative programme on star systems which are believed to contain spotty stars; namely the RSCVn and BY Draconis groups of variables.

On the solar analogy it would be expected that the large photospheric spots believed to be responsible for the optical variation would be accompanied by extensive active regions in the 'chromospheres' of these stars. The object of this programme is to study the modulation of the strong chromospheric and transition region lines over one cycle of the optical light curve.

rotation. This seems a reasonable explanation in view of the relatively high level of excitation of the emission lines at all phases (10-50 times Quiet Sun values).

3) Any rotational modulation of the emission lines that might in fact exist is swamped by short-term erratic changes due to weak flares or similar local heating mechanisms. This view gains some credence when the fluxes observed in the two closely spaced double spectra, SWP 15162 and SWP 15169, are compared. For these images two spectra with ∆t ∼ 60 min were exposed at opposite ends of the large aperture. Whereas the lower excitation lines of O I and C II differed by about 3% between the two double exposures, the higher excitation emission lines of NV, C IV, Si IV and He II differed by about 18%. This suggests that micro-flares or other local heating which show up in the higher excitation lines may indeed mask any rotational modulation.

Most of the SWP emission line but particularly C IV and C II show a dramatic increase in two spectra, SWP 15156 and SWP 15172. We suggest that these enhancements which are of the order of 50% over the mean values are probably the result of flares on BY Dra. Unfortunately no optical coverage was available at this time to confirm the nature of these events but their similarity to other flares detected on IUE spectra (Butler et al. 1981, Bromage et al. 1983) would suggest that this interpretation is correct. On the more dramatic flares observed by IUE a 'continuum' has been seen in the SWP or LWR regions of the spectrum. The presence of an enhanced 'continuum' in SWP 15156 and 15172 has been demonstrated by integrating the flux in three wavelength intervals which do not contain any prominent emission lines: 1345-1381 Å, 1414-1530 Å and 1684-1785 Å.

The results show a total integrated flux over these intervals of 119 x 10^14 ergs/cm^2/s in SWP 15172 and of 89 x 10^14 ergs/cm^2/s in SWP 15156 as compared to 69 x 10^14 ergs/cm^2/s in the average of the remaining 5 spectra. It is quite likely that this does not represent a true continuum but rather an enhancement of a host of weak emission lines.

In Figure 2 we show the observed IUE spectra for SWP 15156 and SWP 15172 together with the mean of all the remaining SWP spectra.

3. THE LWR SPECTRA

The same techniques have been used in the extraction of the LWR spectra as were employed for the SWP spectra. Only two prominent features are conspicuous in this spectral region: the Mg II h and k emission lines and the groups of Fe II lines which occur near 2620 Å. However, as both of these features are affected to some extent by background 'continuum' emission we have binned the spectra in wavelength intervals chosen for their lack of obvious lines and their suitability for correcting the Mg II lines (λ ~ 2800 Å) and the Fe II band (λ ~ 2620 Å) for background.

We have plotted as a function of phase the fluxes in the Mg II h and k and Fe II (2620) groups of lines, both corrected for background. The Fe II strength appears to be totally uncorrelated with phase and only a slight tendency for a wave like
Fig. 2  The observed fluxes in units of $10^{-14}$ ergs/cm$^2$/s for the two SWP spectra showing flares and the mean non-flare spectrum.
variation can be seen in MgII. If present in MgII this tendency would appear to be approximately anti-correlated with the optical light curve suggestive of plage regions associated with the photospheric spot. Also in Figure 1 we plot the total flux in the four 'continuum' regions. Here again there appears to be marginal evidence for a modulation in the same sense as for the MgII variation. The fact that this 'continuum' flux is anti-correlated with the optical light curve suggests that we are measuring the combined effect of many unresolved emission lines rather than true continuum radiation.

4. THE FLARES RECORDED ON SWP 15156 AND SWP 15172

In Figure 3 we plot the log of the ratio of the fluxes of the prominent SWP emission lines to Quiet Sun fluxes for the two spectra on which we believe we may have recorded flares and also the mean non-flare spectrum. All three cases show an increasing enhancement of the surface flux over Quiet Sun values as log $T_e$ increases but with a dip at log $T_e \approx 4.8$ corresponding to SiIV. The general trend of increasing surface flux with temperature implies that, not only is there considerably more material at higher temperatures in the atmosphere of BY Dra compared to the Quiet Sun, but also, that the relative amount of material is increasing with temperature (and height). However this overall trend appears to be temporarily reversed for the material emitting the SiIV line.

In Figure 3(b) we plot the log of the ratio of the fluxes in the strong emission lines in SWP 15156 and SWP 15172 to the average non-flare values. This diagram shows several interesting effects.

1) That more material is heated into the temperature range $4 < \log T_e < 4.8$ in the SWP 15172 flare than in the SWP 15156 flare.

2) That the SWP 15156 flare contains more material at $10^5$ K, compared to the SWP 15172 flare, but less at $2.4 \times 10^5$ K.

Giampapa (1983), commenting on similar differences in the relatively few published IUE spectra of flares, has proposed that there may be two different types of flares, (a) the more common solar type which shows intensity enhancements for spectral lines originating at $10^4 - 10^7$ K, and (b) another type which is confined to the lower atmosphere, i.e. below $10^5$ K.

5. REFERENCES


