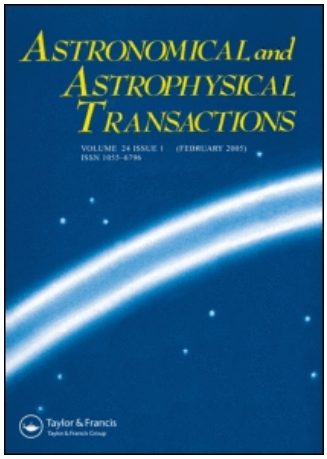

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SPOT TEMPERATURES IN BINARIES WITH TWO ACTIVE COMPONENTS: BY DRA AND ER VUL

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Evidence exists that both components of the two well-known binary systems BY Dra and ER Vul are active. Previously, modelling the observed spotted light curves of these binaries, spots were placed always on the primary component. We present a method to determine spot temperatures on the components of active binary stars separately. Using multicolour observations, results show that temperatures are different at different epochs. At some epochs hot spots were needed together with cool spots to fit the light and colour index curves. We try to explain these results using the different activity features present in the star at the same time.

KEY WORDS Starspots – stars: activity – late-type – imaging – stars: individual: BY Dra, ER Vul – binaries: close

1 INTRODUCTION AND METHOD

It is well known that among active close binaries there are systems formed by two active late-type stars. Spectroscopic observational data show this phenomenon on those systems where the luminosities of the components are similar, thus the light from the primary does not completely suppress the light come from the secondary. Such an example is AR Lac (Neff, 1992); using a spectral imaging technique areas of chromospherically active and inactive parts were mapped on its components. In the case of BY Dra Ca II H+K emission lines were observed in both stars (Bopp and Evans, 1973), and variable H_α emission on the secondary by Vogt (1980). Recent *IUE* spectra for BY Dra and ER Vul (Oláh *et al.*, 1995) show activity in all four stars of these two systems.

We developed a method to model starspots using photometric data on systems with two active components of similar luminosity. The method is described in detail in Kővári and Oláh (1996). Budding's (1977) equations and a grid search method were used to model the data. Only the spots' coordinates and sizes were the free parameters, assuming 1–1 spot on each component. The light loss caused by spots

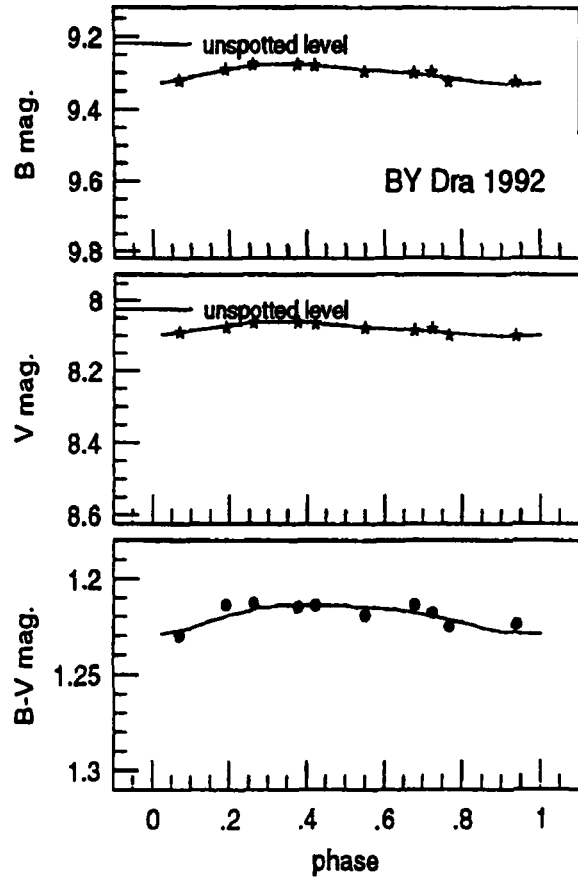

Figure 1 Modelled light and colour index curves for BY Dra from 1992 using spot temperatures and coordinates from Table 1.

was calculated separately for the components taking into account their luminosity ratio at different wavelengths. This ratio is about 2/3–1/3 in the case of BY Dra, whereas the luminosities of the components of ER Vul are nearly the same. The inclination of BY Dra is about 28° and of ER Vul it is 67°. Spot temperatures were determined using B and V observations of BY Dra, and V and I_C observations of ER Vul. A χ^2_C surface above the (ΔT_1; ΔT_2) plane was constructed where ΔT_1 and ΔT_2 denote the spot temperature difference to the photosphere on the primary and secondary components, respectively, and χ^2_C is the goodness of the fit of the colour index curve. To calculate the flux ratio at different spot temperatures, model atmospheres of Kurucz (1979) and Buser and Kurucz (1992) were used in the temperature range available, otherwise a black body approximation was supposed. Limb-darkening coefficients were taken from the tables of Van Hamme (1993).

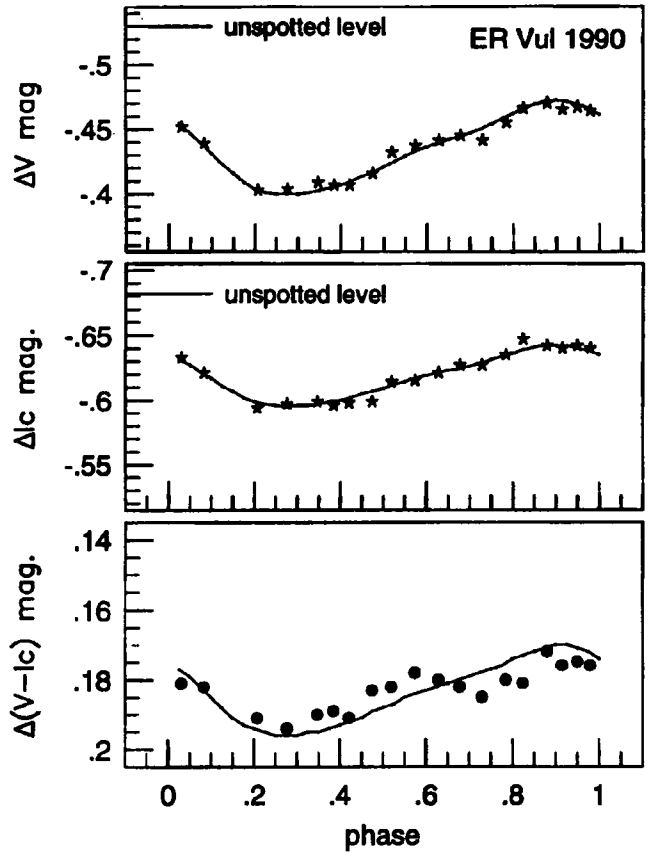

Figure 2 Modelled light and colour index curves for ER Vul from 1990 using spot temperatures and coordinates from Table 2.

2 RESULTS

The spot temperature results and spot coordinates are given in Tables 1 and 2 for BY Dra and ER Vul, respectively. Examples of light and colour index curve fits are displayed in Figure 1 for BY Dra and in Figure 2 for ER Vul.

Examining the tables the following results are found. In the case of BY Dra the spot temperatures seem to be quite homogeneous and well determined in the epoch studied, no acceptable alternative solutions were found in the χ^2_C sense. We present results for the years 1965, 1988 and 1992, when the system brightness was at minimum, medium and close to the maximum level, respectively. Only in the last case is a hot spot needed on the secondary to fit the colour index curve.

The situation is different in case of ER Vul. The best fits of the light curves are always those where a cool spot on the primary and a hot spot on the secondary are assumed. For the data from August and September 1991, slightly worse but still

Table 1. Derived $\Delta T(T_{star} - T_{spot})$ values and spot coordinates (in degrees) for the components of BY Dra from the $B - V$ colour index

Date	$\Delta T(K)$	*Longitude*	*Latitude*	*Radius*
		Spots on the primary		
1965	200	277	45	76.8
1988	200	262	46	69.5
1992	500	16	77	24.2
		Spots on the secondary		
1965	500	262	56	68.9
1988	200	263	49	66.9
1992	-300	90	22	26.8

Table 2. Derived $\Delta T(T_{star} - T_{spot})$ values and spot coordinates (in degrees) for the components of ER Vul from the $V - I_C$ colour index (alternative solutions are given below each other)

Date	$\Delta T(K)$	*Longitude*	*Latitude*	*Radius*
		Spots on the primary		
1990 Aug.	500	99	78	74.1
1991 Aug.	700	204	79	58.8
	500	272	68	47.0
1991 Sept.	1200	230	87	52.2
	1200	43	73	38.8
		Spots on the secondary		
1990 Aug.	-700	345	-1	17.3
1991 Aug.	-800	183	61	25.3
	200	80	55	53.0
1991 Sept.	-400	169	24	34.8
	300	267	22	49.7

acceptable solutions exist with cool spots on both components. Only additional information (e. g. spectroscopy) can solve this ambiguity. In September 1991 radio observations (Rucinski, 1992) and UV spectroscopy (Bradstreet *et al.*, 1993) made contemporaneously with the photometric data strongly suggest extended plage regions on the secondary component. This result is discussed in detail in Oláh *et al.* (1994 and 1995).

It seems likely that the secondaries of these systems, having later spectral types than the primaries, are more active as well. Our results appear to confirm this. Although the general light level change is much higher for BY Dra, the spot variability is much more stable than for ER Vul. The reason of this phenomenon is probably due to their different rotation periods, which is nearly 4 days for BY Dra and only about 16 hours for ER Vul. The separation between the components is also much greater among the BY Dra components. The faster rotation and closeness of the components of ER Vul may be the cause of its fast changing activity relative to BY Dra.

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