PROBLEMS WITH SPOTS

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Many cool late-type stars show a peculiar type of variability called BY Dra (in dwarfs) or RS CVn (in subgiants and giants). The general interpretation of this phenomenon is in terms of very large-scale photospheric spots, analogous to sunspots. A non-uniform distribution of such dark spots on the surface of a rotating star produces the quasi-sinusoidal light curves seen in these objects. Changes in the phase, amplitude and shape of the light curves, on time scales which are sometimes as short as a few rotations, can be understood in terms of the growth and decay of individual spots.

Confidence that the cool-spot model is the correct one is reinforced by several lines of evidence. All spotted stars are rapid rotators, an observation which indicates the dependence of the phenomenon on strong dynamo magnetic field generation. All exhibit strong chromospheric and coronal emission. Colour changes accompanying the modulation of optical light generally indicate a cooler mean temperature at light minimum and this is reinforced by the observation of spectroscopic changes, also consistent with the presence of a greater concentration of cool areas at light minimum.

The problem which I wish to address here is that of determining the unspotted surface brightness of these stars and its implications for our understanding of the spot phenomenon and the nature of cool stars in general. The difficulty arises in the first instance because, when a BY Dra or RS CVn star is observed over several seasons, the light curve maximum is seen to vary (Figure 1). If at any time we were to observe the unspotted stellar surface, then this should be the maximum brightness observed at any epoch. A single observation of a given star’s light curve will not give an assured determination of this quantity. The star which I have studied most intensively over the years is the RS CVn star, II Peg. V light curve maxima for this star have ranged from at least 7.18 to 7.45 (Figure 1). The value 7.18 was observed only once (Chugainov 1976) and is generally, although not universally, adopted, in the absence of other evidence, as the unspotted V magnitude.

Modelling of the optical light curves gives some indication of the spot coverage needed to account for the observed modulation. In the case of the largest amplitude light curve yet observed this amounts to a spot coverage of at least 16% of the star’s surface, the latter in the case that the unspotted magnitude is that observed (Byrne and Marang 1987). If the unspotted magnitude is $V \sim 7.18$ then this surface coverage increases to $\sim 25 - 30\%$. Furthermore, observations of this star since 1974 indicate that this is a typical situation rather than some rare occurrence. Since the redder visual optical photometric bands are close to the peak of the radiated output of II Peg, this represents a substantial reduction over a long period of time in the star’s bolometric luminosity.

The problem we face is explaining what happens to this missing luminosity. Recent bolometric observations of the Sun suggest that the radiation deficit in sunspots is not redistributed to the surrounding regions of the atmosphere (Willson et al. 1981). Similarly, there is no evidence from stellar lightcurves that this is so. Recent theoretical calculations,
however, indicate that it is possible for stars of this sort to store very large amounts of energy at the base of their convection zone (Spruit 1981) and to release it on a time scale of many thousands of years.

Figure 1. Light curves for the RS CVn star II Peg in late 1974 (circles) and late 1986 (squares). A \((V-I)_K\) colour curve for 1986 is also given.

References


