Long-term photometric variations of the active RS Canum Venaticorum binaries DM Ursae Majoris and II Pegasi

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1. DM UMa

This is a single-lined spectroscopic binary with an orbital period of 7.492 days, and its visible component has a spectral type of K2 III–IV (Crampton et al. 1979) The first photometric light curve of DM UMa was obtained by Kimble et al. (1981) who found that the photometric period is approximately the same as the spectroscopic orbital period. We have been observing this object photometrically at Vainu Bappu Observatory using the 34cm reflector since 1980 obtaining a light curve every season.

Mohin & Raveendran (1992) have analyzed all the B and V light curves of DM UMa available during 1979–90 by means of a spot model which assumes that large discrete spots are responsible for the observed light variation. The method of least squares was employed to derive the best fit spot parameters. They have also reported that from 1984 onwards the brightness at light curve maximum has increased monotonically (by ~0.20 mag), whereas the amplitude of light variation has remained within a narrow range (0.16–0.23 mag) without any apparent trend. Their modeling has indicated a slow migration of spots towards the equator, and a gradual decrease of spot area during the corresponding period. They have also derived a mean spot temperature of 3400±60 K from the data obtained during ten observing seasons.

In Fig. 1 we have plotted the phase of light minima against the corresponding mean epoch of observation. Most of the data are taken from Mohin & Raveendran (1992, 1994). Based on the systematic migration with respect to the orbital phase, the phases of the light minima can be divided into five well defined separate groups. The minimum first observed in 1979 apparently migrated towards decreasing orbital phase and could be traced until 1982 (which we identify as group A). A second minimum which first appeared sometime in 1981 (group B) which again showed a similar migration could be traced until 1985. During 1986–87

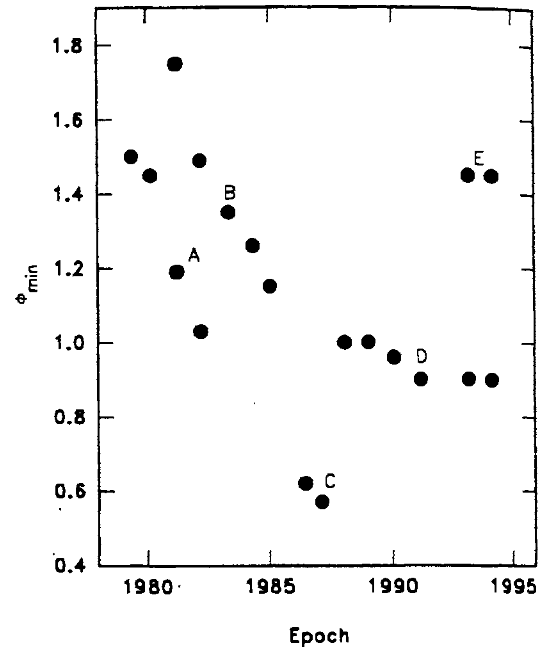

Figure 1: DM UMa: Plot of φ_{min} against the mean epoch.

there was a short-lived minimum (group C). The minima identified as group D had its origin sometime in 1988 and was in existence in 1994. During 1992–94 period there were two minima observed, one around $0.^{p}90$ and the other around $0.^{p}50$. The former minima seem to be an extension of group D whereas the latter seem to indicate the formation of a new spot group (group E).

It is interesting to see that all groups show migrations towards decreasing orbital phases. If the migration results from a difference between the photometric period and the orbital period, it implies that the latitudes at which spots form have a higher rotational velocity than the synchronously rotating latitudes, and if the equator is synchronized to the orbital motion then it also implies that spots are formed at higher latitudes and they rotate faster than the equator. This situation is very similar to that observed in the case of UX Ari (Vogt & Hatzes 1991; Raveendran & Mohin 1995). Such a scenario is contrary to what is observed in the sun where we find that the equator rotates faster than the higher latitudes.

We feel that we should have a fresh look at the interpretation of the migration of ϕ_{min}. Usually, we assume that the same spot or spot group is responsible for the minimum belonging to the same group identified from the phase migration. DM UMa has not so far shown a flat-topped light curve and frequently shows two well defined minima. Also it is clear from Fig. 2 that DM UMa exhibits a large variation in its brightness at light maximum. These factors indicate that spots are always present at more than one longitude, probably in several longitudes. The phase of light minimum indicates only the mean longitude of the dominant spot group and does not give any information on the longitudes of other spot groups. For example, if there are two spots which are close enough so that in the light curve they produce a single minimum, the phase minimum as derived from the light curve would not indicate the longitudes of neither spots, but the weighted mean of the longitudes. A change in phase of light minimum would be observed if another spot group becomes prominent at another longitude at a later time. And if this happens in a more systematic way such that the longitude of the predominant spot group changes in the same direction at least for a few consecutive seasons we would observe the migration of the phase of light minimum: we could be observing such a phenomenon in DM UMa and other spotted stars which show migration of ϕ_{min}.

From an analysis of the photometry available during 1979–84, Mohin et al. (1985) had put a lower limit of about four years for the lifetime of a spot group on the assumption that the same spot group is responsible for the observed migration of ϕ_{min}. Recently, based on the same assumption and using a more extensive data set, Mohin & Raveendran (1994) have reported that the lifetime of a spot or spot group can be as short as two years. In view of the new scenario mentioned above the life time of a spot group thus derived only refers to the period during which the spots at different longitudes become prominent in a systematic way. So we conclude that higher latitudes may not be rotating faster than the equator as implied by the migration of ϕ_{min} towards decreasing orbital phases. The observed migration may be due to spots present at different longitudes becoming more prominent in a systematic way; there is always some randomness associated with such a process because the migration of ϕ_{min} as seen from Fig. 1 is not very smooth. If it is so then the photometric period determined from the apparent migration of the light minimum is meaningless, and hence the inference that higher latitudes rotate faster than the equator is not valid.

Fig. 2 is a plot of ΔV_{max} and ΔV_{min} against the corresponding epoch of observations. It shows that both ΔV_{max} and ΔV_{min} show nearly similar trends in their behaviour; in general an increase in ΔV_{max} is followed by an increase in ΔV_{min} and a decrease in ΔV_{max} by a decrease in ΔV_{min}. Both ΔV_{max} and ΔV_{min} show

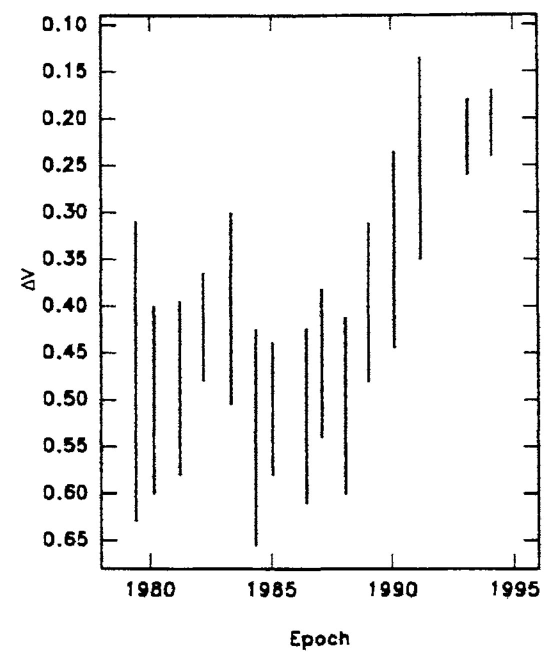

Figure 2: Long-term V variability of DM UMa. Vertical bars indicate the peak-to-peak amplitudes of the light curves.

a large range in magnitudes (about 0.30 mag), and a monotonic increase from 1984 onwards.

2. II Pegasi

II Peg is also a single-lined spectroscopic binary with a 6.724 day period, and its visible primary has been classified as K2 IV. Mohin & Raveendran (1993a) have analyzed the photometric data available during 1974-1991, and identified a total of six spot groups from the migration of the ϕ_{min} with life-times in the range two to seven years. Further they have modeled the light curve obtained during 1989–1990 season assuming that the light variation is caused by a single circular spot. The resulting spot parameters, though reproduce the observed B and V light curves reasonably well, indicate a substantial extension of the spot in the invisible hemisphere. Hence they have concluded that the approximation of a spot group by an equivalent circular spot is not possible.

In Fig. 3 we have plotted the brightness at light maximum V_{max} and minimum V_{min} against the corresponding amplitude. An inspection of Fig. 3 clearly reveals that at larger amplitudes the brightness at minimum decreases and the brightness at maximum increases. Observations of Chugainov (1976), however, do not

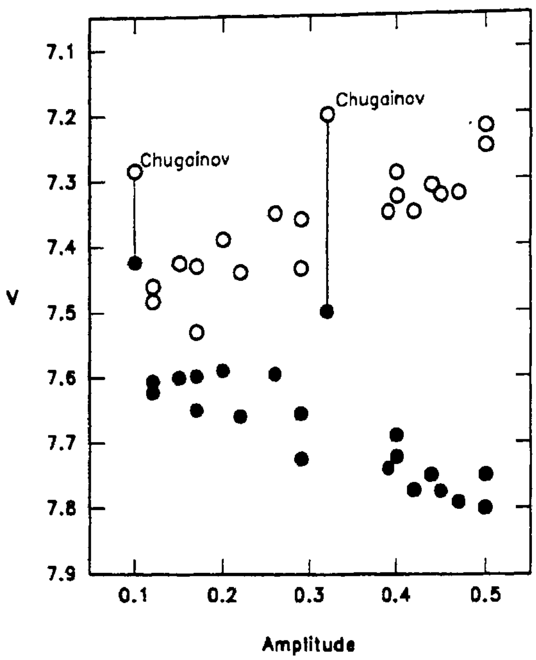

Figure 3: II Peg: Plot of the brightness at light maximum (open circles) and light minimum (filled circles) against the V amplitude.

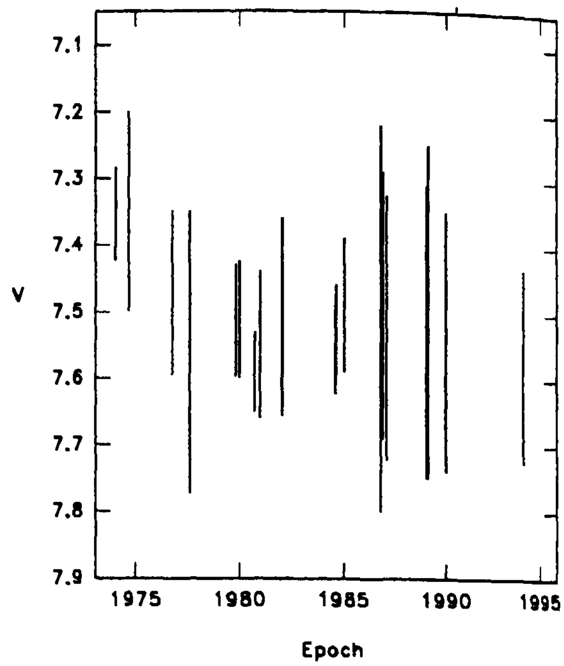

Figure 4: Long-term V variability of II Peg. The vertical bars indicate the peak-to-peak amplitudes of the light curves.

conform to this trend. As argued by Vogt (1981), it may possibly be due to a zero-point magnitude difference between Chugainov's and the others' photometry. The behaviour of II Peg, as seen in Fig. 3, is similar to that seen in the case of V711 Tau and UX Ari, two other active RS CVn stars (Mohin & Raveendran 1993; Raveendran & Mohin 1995).

We have plotted the values of V_{max} and V_{min} in Fig. 4 against the corresponding epoch of observations. If we exclude Chugainov's data it is clear from the figure that there is no long-term variation in the mean light level as expected from the behaviour seen in Fig. 3. However, the mean light level shows significant short-term fluctuations.

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