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OBSERVATIONS OF OUTSIDE-ECLIPSE BRIGHTNESS VARIATIONS OF CM Dra

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CM Dra is a spotted eclipsing binary star with a period of 1.27 days. Strassmeier et al. (1993) reckoned this star among the BY Dra type variables and included it in their catalogue of chromospherically active binary stars. The BY Dra stars and their cousins, the RS CVn stars, often show brightness variations caused by star spots. Such variations in CM Dra were observed by Lacy (1977). These variations proved to be sine wave with an amplitude of about 0.02 mag. Probably, because of their low amplitude these variations were not described in the literature after 1977. In the present paper we report results regarding the outside-eclipse brightness variations of CM Dra from our observations obtained at Kourovka observatory of the Ural State University during 1996–97.

Some particular characteristics of CM Dra, mainly small sizes of the components (their total surface area is about 12% of the solar value (see Lacy 1977, for all system elements)) make this star suitable in order to search for extrasolar planets by means of differential photometry. However, such a task needs a large amount of observations. To obtain sufficient observational coverage, the "TEP" (Transits of Extrasolar Planets) network was formed with the participation of several observatories (Deeg et al. 1998, Doyle et al. 2000). At Kourovka observatory we performed the CM Dra observations as a part of the TEP network observations. We used the 70 cm telescope and the two-star photometer (Kozhevnikov & Zakharova 2000). The observations were made through a standard R filter. The total duration of our observations obtained during 43 nights is 155 hours.

Besides the main goal of these observations, i.e. detecting of transits of planets orbiting in the plane of binary components, we decided to construct a composite lightcurve of CM Dra in order to derive some orbital elements of the system. It seemed to be not a very simple task because the differential lightcurves showed slow airmass-related changes from differential extinction due to the large colour difference between CM Dra and the comparison star. These slopes of the differential lightcurves in the TEP network observations were removed by subtraction of a polynomial fit to the off-eclipse lightcurves (Deeg et al. 1998). In order to construct the composite lightcurve, using the data obtained at Kourovka observatory, we decided not to remove the slopes of the individual lightcurves, hoping that they would be averaged owing to the large amount of the observations (155 hours). Besides the extinction, the slopes can contain brightness variations caused by star spots if they are present on the binary components. These brightness variations have to occur over approximately the same time-scale as the extinction since the period of CM Dra's components is very likely locked to the binary period of 1.27 days. CM Dra is a very old system (see, for example, Viti et al. 1997), and its components have to be completely in synchronous rotation. Thus, having not removed the slopes of the individual lightcurves, we could detect outside-eclipse brightness variations of CM Dra. Unfortunately, during almost two years of our observations the instrumental colour system underwent little changes that resulted in the average differential magnitudes somewhat different for different observing seasones. These average differential magnitudes were previously subtracted from the individual lightcurves belonging to the different observing seasons.

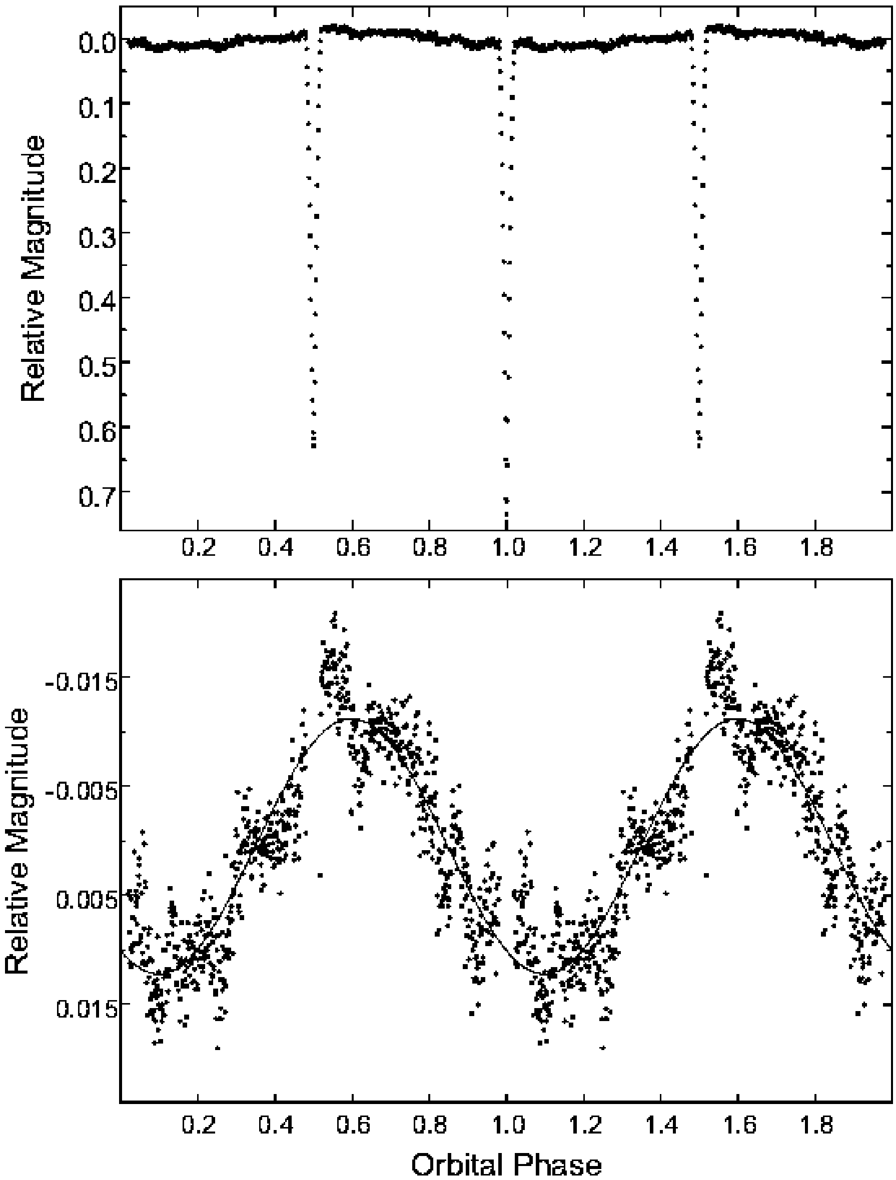

Figure 1. Composite lightcurve of CM Dra. The lower frame shows an expanded view of the outside-eclipse variations. The solid curve is the best-fitting sine wave. Two periods are shown for the sake of clarity

The composite lightcurve obtained by averaging all our observations of CM Dra is shown in Fig. 1. We used 856 bins per phase. The duration of the phase bins equals the exposure time (128 seconds). Each point is the average magnitude of 4–6 individual measurements obtained in different nights. The outside-eclipse brightness variations with an amplitude of about 0.02 mag are clearly visible in this lightcurve. As mentioned above, similar sinusoidal variations of the off-eclipse lightcurve of CM Dra with the same amplitude were found by Lacy (1977). However, there is a remarkable distinction between the results obtained by Lacy in 1976 and our results. The phase of maximum brightness that was obtained twenty years prior to our observations was 0.28, whereas the phase of maximum brightness in our observations is 0.60. The difference is approximately equal to one third of the orbital period.

Since our observations cover almost two years, we tried to find the difference of the phases of maximum brightness between 1996 and 1997. In order to make this, we constructed two composite lightcurves, using the data of 1996 and 1997 separately. Then we found the phases of maximum brightness, using sine wave fits to these lightcurves. Unfortunately, as seen in Fig. 1, the points around the sine wave are not distributed smoothly. In order to obtain more realistic values of formal errors from least squares technique, we averaged points of the lightcurves in 0.02 phase bins. Then sine waves were fitted to these lightcurves consisting of 50 points. The results with their rms errors are given in Table 1. As follows from Table 1, the difference of the phases of maximum brightness for the two years only slightly exceeds the triple interval of the rms errors, and we cannot draw a conclusion about the appreciable change of the phases of maximum brightness between 1996 and 1997. On the contrary, we can conclude that these phases can change significantly within one decade or more (as follows from the comparison of our observations and the observations made by Lacy (1977)).

Table 1. The information about the best-fitting sine waves

time interval	number of nights	duration (hours)	semiamplitude (magnitude)	phase of maximum
1996 April–October	22	68	0.010 ± 0.002	0.517 ± 0.023
1997 April–October	21	87	0.013 ± 0.001	0.635 ± 0.009
all the data	43	155	0.012 ± 0.001	0.597 ± 0.008

Brightness variations of the BY Dra and RS CVn stars are usually considered to be the effect of star spots that covered appreciable parts of the surfaces of one or both components of the system. The strong resemblance of the shapes and amplitudes of such variations in CM Dra that were observed in 1976 (see Fig. 5 of Lacy 1977) and in 1996–97 seems amazing and may mean that these brightness variations are caused by the same feature, namely, a spotted region on the star.

As seen in Fig. 1, the brightness variations in CM Dra have a smooth shape without a flat top or bottom. As noted by Lacy (1977), such a shape of brightness variations may mean that the spotted area is located very close to the rotational pole of one of the stars, since otherwise it would be out of view at some point in the orbit. Another hint that the spotted area in CM Dra is located close to the rotational pole may be the low amplitude of the brightness variations. As far as one can see in the data given by Strassmeier et al. (1993) in the catalogue of chromospherically active binary stars, brightness variations due to star spots in the BY Dra stars have usually greater amplitudes than in CM Dra and can reach several tenth of a magnitude. If the spotted area in CM Dra is similar to the spotted areas in most of the BY Dra stars, then by assuming the location of the star spot almost strictly on the rotational pole one can easily account for the small amplitude of the brightness variations due to a slightly nonsymmetric shape of the star spot. Also the change of the phases of maximum brightness between 1976 and 1996–97 can be explained, supposing a little change in shape or asymmetry of this large polar star spot after 1976.

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