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NSV 12223: A NEW W UMa ECLIPSING BINARY

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Strohmeier (1958) discovered the variability of NSV 12223 (= BV 238 = GSC 4456 1244) on photographic plates taken from 1932 to 1939. He mentioned variations going from magnitude 12.0 to 12.5 (photographic) and a probable eclipsing type. The star is situated in Draco at $19^h34^m31^s$; $+74°03'$ (J2000).

Vandenbroere (2000) published the results of period searches made on her 151 first visual estimates of the star in a Note Circulaire of GEOS. She was not yet able to discriminate in favour of the actual period between the peaks of the periodogram and she called upon CCD measurements.

P. Van Cauteren obtained 195 V and 26 B CCD measurements of the star at his private observatory using a 0.40-m telescope. He used an ST7E camera and the MIRA Aperture Photometry software (produced by Axiom Research Inc.). GSC 4456 1751 was used as comparison star and GSC 4457 16 was the check star. The observations were left in the instrumental system. A PDM search on the V measurements showed that the orbital period of NSV 12223 is around 0.350376 d and that the star is an EW-type eclipsing binary with minima slightly different in depth (see Fig. 1). The amplitudes of the light variations in V are of 0.51 mag between the deeper minimum and its preceding maximum, and of 0.43 mag between the two other extrema. The EW type is in perfect agreement with the differential $B-V$ indices which are nearly constant except for a very slight reddening during the two minima.

A. Pigulski analyzed the light curve of NSV 12223 obtained from the CCD observations made by P. Van Cauteren. The V data were phased with a rough value of the period and used with the Wilson-Devinney (WD) code (Wilson & Devinney 1971) to get a synthetic light curve which reproduces well the observations. In the next step, this synthetic light curve was fitted separately to the data carried out on each of the three nights of observations. During the fit, the time of minimum was derived as the only parameter. The results of the fit are shown in Fig. 1. This procedure, taking into account all the points in the light curve, allows to derive the time of minimum light even when there are no observations at minimum at all. So, three times of primary minima could be derived.

To these three times of primary minima, we could add ten instants determined from the visual estimates of J. Vandenbroere (see Table 1). The relative weights for the three CCD times of minimum were calculated according to the inverse square of their r.m.s. errors and were rescaled to be a few times larger than those derived from visual data. A linear regression of all times of minimum gives the following ephemeris (the number in parentheses denotes the r.m.s. error of the last digit):

$$\mathrm{T_{min}\,I} = \mathrm{HJD}\,2451470.159(2) + 0.350374(2) \times E, \tag{1}$$

where E is the number of cycles elapsed from the initial epoch.

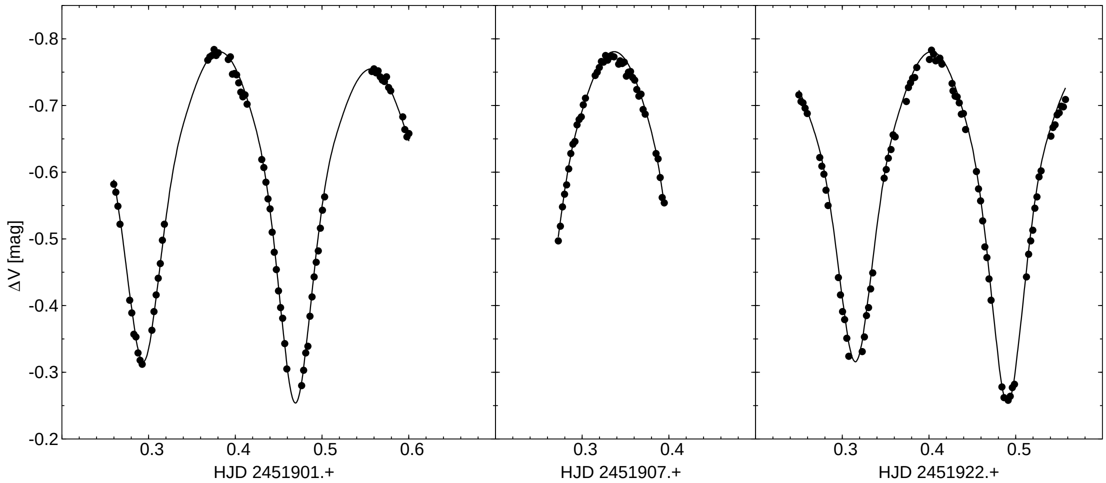

Figure 1. Differential (with respect to GSC 4456 1751) CCD V measurements of NSV 12223 (dots) with synthetic light curve (solid line) fitted to derive the times of minimum for the three nights.

Table 1. Times of minimum light of NSV 12223

Observer	Type of photometry	Time of minimum HJD 2400000.+	Weight	Epoch E	O − C [d]
VBR	visual	51470.332(5)	1	0.5	−0.002
VBR	visual	51757.462(5)	1	820.0	−0.003
VBR	visual	51762.376(5)	1	834.0	+0.006
VBR	visual	51769.381(5)	1	854.0	+0.003
VBR	visual	51779.536(5)	1	883.0	−0.003
VBR	visual	51798.453(5)	1	937.0	−0.006
PVC	CCD	51901.4691(6)	8	1231.0	+0.0003
PVC	CCD	51907.4245(11)	2	1248.0	−0.0007
PVC	CCD	51922.4904(9)	4	1291.0	−0.0008
VBR	visual	52136.397(5)	1	1901.5	+0.003
VBR	visual	52145.500(5)	1	1927.5	−0.004
VBR	visual	52146.379(5)	1	1930.0	−0.001
VBR	visual	52167.401(5)	1	1990.0	−0.001

VBR = J. Vandenbroere, PVC = P. Van Cauteren. HJD is given with an estimated accuracy of the last digit(s).

In order to obtain the parameters of the binary system with the WD code, the CCD data (both in B and V) were first phased with the new value of the orbital period (Eq. (1)). In the case of NSV 12223, we have B and V light curves and we suspect that the system is a contact binary. In Fig. 1, we can see that the maxima are not equal (O'Connell effect).

This means that there is a spot (or spots) on the side surface of one of the stars. Because we have only 26 B CCD measurements, it is rather impossible to adjust accurately the four parameters of a spot. Therefore, it was assumed that the spot resides in star 1 (that one which is eclipsed near phase 0, at primary, deeper eclipse). By trial and error, we found roughly the latitude (90°), longitude (310°) and the angular radius (25°) of the spot. The only spot parameter adjusted was the temperature factor.

Furthermore, gravity darkenings (0.32), bolometric albedos (0.5), and limb darkening coefficients have been taken from tables of Van Hamme (1993). The average temperature of star 1, which is roughly correlated to the orbital period, was assumed to be $T_1 =$ 5500 K.

The following parameters of NSV 12223 were next iterated:

- phase shift, ϕ,
- orbital inclination, i,
- average surface temperature of star 2, T_2,
- surface potential, $\Omega = \Omega_1 = \Omega_2$,
- relative monochromatic luminosity for star 1, L_1,
- temperature factor for the spot.

For a contact binary, it is practically the mass ratio $q = M_2/M_1$ which determines the geometry of the system. The best solution is found by checking the changes of the weighted sum of squares of residuals as a function of the assumed mass ratio q (see Fig. 2). We can see that in a wide range of q (between 0.7 and 1.8) all fits give practically the same residuals and therefore are equally good. This means that we cannot accurately determine the mass ratio, and thus say which star is bigger. This is the consequence of the fact that the eclipses are partial.

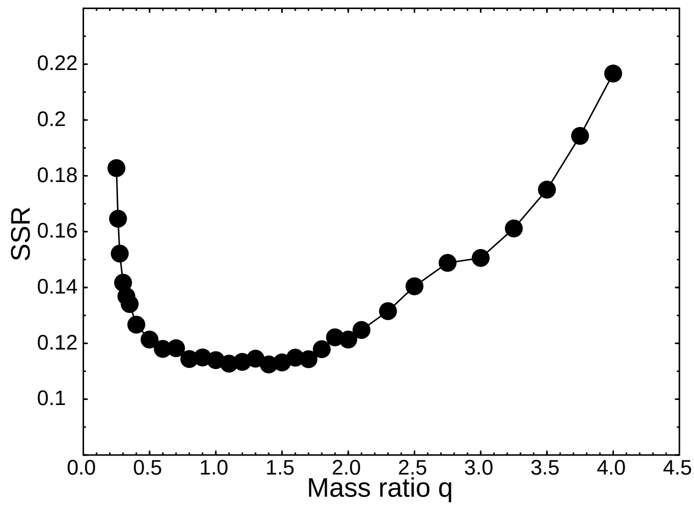

Figure 2. The weighted sum of squares of the residuals (SSR) taken from the best fit, plotted against the assumed value of the mass ratio, q.

Nevertheless, it appears that some parameters which were iterated do not change considerably in the best solutions for $0.7 < q < 1.8$. First of all, the inclination angle, i, equals to $72\overset{\circ}{.}0 \pm 0\overset{\circ}{.}5$, and the average surface temperature of star 2, T_2, is lower by about 110 ± 10 K in comparison with T_1. Finally, the overfill factor equals to about 5–7%, depending on q. This is quite typical for W UMa systems. In Fig. 3 we show one of the best solutions, that with $q = 1.4$. The standard deviation of the residuals from the fit is 0.0097 mag for B and 0.0082 mag for V-filter observations.

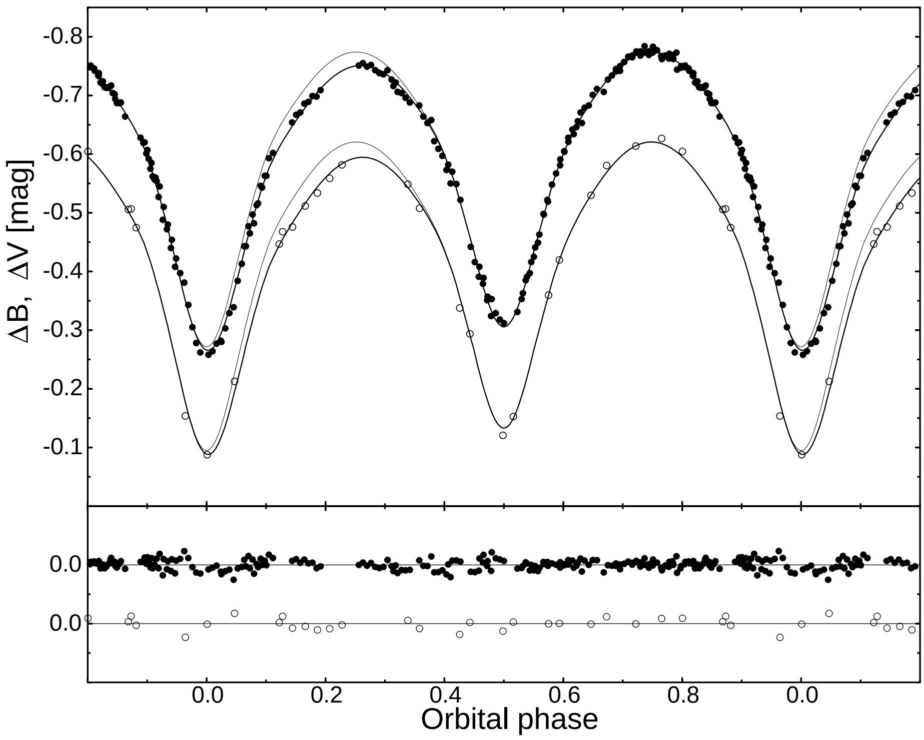

Figure 3. The differential light curve of NSV 12223 in B (circles) and V (dots) filter compared to the best fit with $q = 1.4$ (continuous line). The light curves shown with thin lines are those if there were no spot. Lower panel shows the residuals from the fit (the ordinate is in scale).

Concluding, NSV 12223 is a contact binary of the W UMa type with orbital period given by Eq. (1). The eclipses are partial. The inclination of the system is $72^\circ\!.0 \pm 0^\circ\!.5$. Mass ratio is in the range between 0.7 and 1.8. There is a spot at the surface of one of the stars resulting in a small O'Connell effect. Moreover, star 2 is cooler than star 1 by about 110 K.

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