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PERIOD ANALYSIS OF THE ECLIPSING BINARY DM DEL

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Abstract: The eclipsing binary system DM Del reveals changes of its orbital period. These variations could be described as a result of orbiting the eclipsing pair around a common center of mass with an unseen companion with the period about 33 years. Seven new minima observations were carried out by the authors.

DM Del (= GSC 01100-01710, $R.A. = 20^{\mathrm{h}}\ 39^{\mathrm{m}}\ 37.0^{\mathrm{s}}$, $Decl. = +14^{\circ}\ 25'\ 43''$, J2000.0, $V_{max} = 8.65$ mag, sp. A2V, according to Simbad database) is an eclipsing binary, which was discovered by Hoffmeister (1935), who also referred the system to be an Algol-type. The system was reclassified to β Lyrae type by Gudur et al. (1984), and the most recent detail analysis is that by Manimanis & Niarchos (2002), who presented the system to be of a semi-detached or near-contact W UMa-type. In this last paper the UBV photoelectric observations indicate also a presence of photospheric spots. On the other hand, the detailed period analysis of the system is still missing, despite the fact that the set of times-of-minima observations is quite large.

Our analysis of the minima times of DM Del is based on all available observations since 1929. Altogether there were collected 170 observations (listed in data.txt), seven of them were observed by the authors (see Table 1).

These new measurements were obtained by two observers and instruments. The first one was the 34-mm refractor at the Private observatory in Pohoří Jílové u Prahy, Czech Republic, using the G2/KAF-0402ME CCD camera and standard R filter by the specification by Bessell (1990), labelled [1] in Table 1. The second one was the 34-mm refractor at the Private observatory in Brno, using the SBIG ST-7XME CCD camera, and the same filter specification, labelled [2] in Table 1. The measurements were processed by the software C-Munipack[1], which is based on aperture photometry and using the standard DaoPhot routines. For determining the times of minima the Kwee-van Woerden method was used, Kwee & van Woerden (1956).

Table 1: The new minima timings of DM Del.

HJD	Error	Type	Filter	Observer
2454650.4987	0.0018	Sec	R	[1]
2454675.4143	0.0011	Prim	R	[1]
2454705.3992	0.0010	Sec	R	[1]
2454705.4021	0.0026	Sec	R	[2]
2454710.4669	0.0022	Sec	R	[1]
2454718.4946	0.0004	Prim	R	[2]
2454718.4947	0.0013	Prim	R	[1]

[1] see http://c-munipack.sourceforge.net/

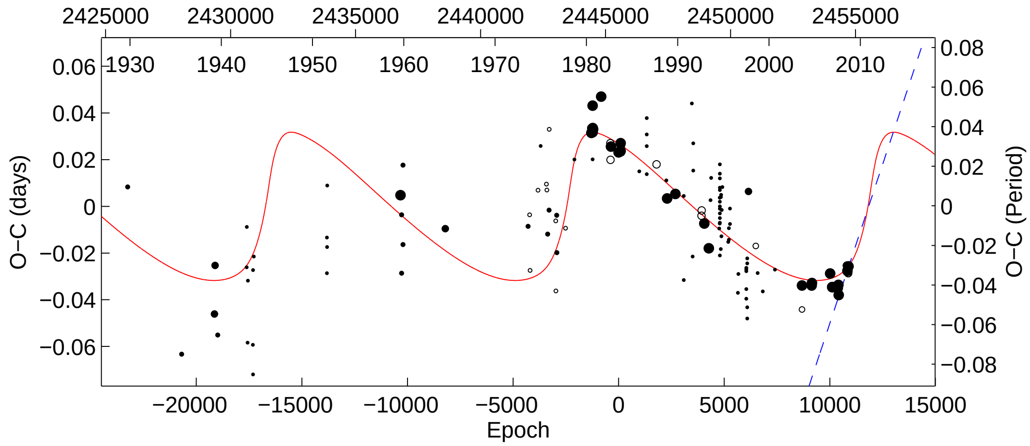

Figure 1: The $O - C$ diagram of DM Del. The dots represent the primary and the open circles the secondary minima, bigger the symbol, higher the weight. The red solid curve represents the predicted third-body variation, while the dashed blue line represents the linear ephemeris given in the text (Eq. 2, suitable for observations).

The period analysis results in new linear ephemeris of the star ($O - C = 0$ in Fig 1.)

$$\text{HJD Min I} = 24\,45523.4128 \;+\; 0\overset{\text{d}}{.}8446727 \cdot \text{E}. \qquad (1)$$
$$\pm 0.0043 \;\pm\; 0\overset{\text{d}}{.}0000006$$

On the other hand, these ephemerides are not very suitable for planning future observations. Due to this reason we also present another linear ephemerides of the star (see blue dashed line in Fig 1.), which tend to be more useful for observers in next few years:

$$\text{HJD Min I} = 24\,45523.090 + 0\overset{\text{d}}{.}84470 \cdot \text{E}. \qquad (2)$$

The minima observations reveal a periodic variation, which is clearly visible especially in the measurements after 1970. The most recent ones show that the linear ephemeris are inadequate for describing the behavior of the minima. We have applied the hypothesis of orbiting the system around the common center of mass with a third unseen companion, so-called light-time effect, see e.g. Irwin (1959). This approach was used in our programme, which is based on least-squares method and the simplex algorithm, see Kallrath & Linnell (1987). The variation with a period about 33 years is clearly visible from Fig.1. Especially the most recent data indicate that the periastron passage will occur in upcoming years (in 2011). The fit of the first cycle seems to be quite poor, but this is only due to insufficient coverage of the data and four observations from the early 1950's, which are only visual ones, therefore not very precise. All of the relevant parameters (the orbital period p_3, the periastron passage T_0, the semiamplitude of the effect A, the eccentricity e and the argument of periastron ω), which define the theoretical fit on Fig.1, are presented in Table 2.

The total mass of the system is questionable, because the spectroscopy of DM Del has not been performed yet. The first rough estimate of the total mass is that by Schneller (1960), who presented the value $M_{12} = 2.35\ \mathrm{M}_\odot$. On the other hand, Manimanis & Niarchos (2002) derived the masses of the individual components on the basis of the spectral types given by Hill et al. (1975), resulting in $M_1 = (2.51 \pm 0.28)\ \mathrm{M}_\odot$, $M_2 = (0.665 \pm 0.074)\ \mathrm{M}_\odot$. Because the system shows total eclipses (see e.g. Manimanis & Niarchos (2002) and Diethelm (1980)), one could also speculate about the accuracy of

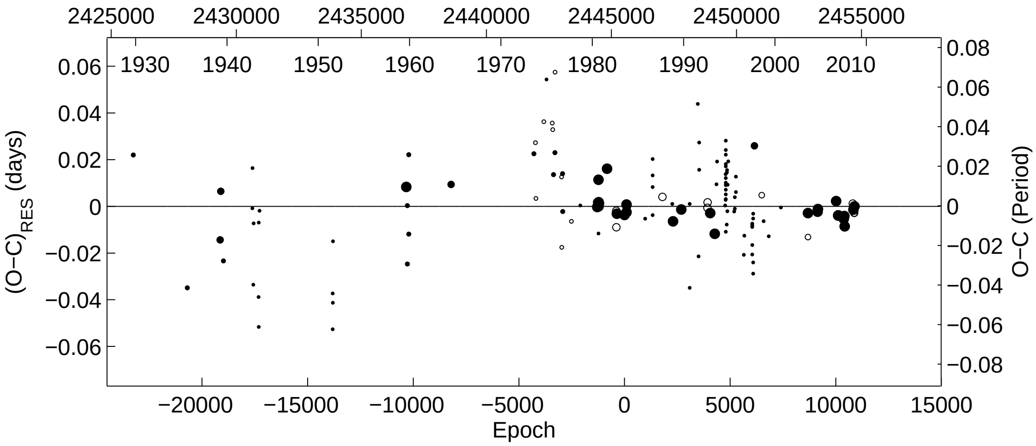

Figure 2: $O - C$ diagram of residuals.

these masses (see the discussion about the photometric masses in binaries showing total eclipses in Terrell & Wilson (2005).

From the total mass of the binary we are able to calculate the minimal mass of the third component from its mass function $f(M_3)$. Taking into account the range of values for the mass of the binary 2 $M_\odot < M_{12} <$ 3 $M_\odot$, the predicted minimal mass of the third body results in

$$2.0 \ M_\odot < M_{3,min} < 2.9 \ M_\odot.$$

This relatively high value indicates that the third component has approximately same mass as the binary itself. Assuming this component is located on the main sequence, it could be observable via a third light in light curve, but Manimanis & Niarchos (2002) have assumed that the value of the third light is zero. If this component is a single star, its light contribution would be so large, that the value of the third light could not be easily set to zero. Another explanation is that the component is also a binary with two rather equal components (spectral type around G), so its total contribution to the total luminosity would be smaller, about 30%. Such a third light would be also easily measurable, but one could ask how precise the observations by Manimanis & Niarchos (2002) are for such an analysis. As one can see from their solution, in some parts the light curve fit is not perfect for the presented data and one could speculate about a better fit with the non-zero third light. Taking into account also a light contribution of the third body, the light curve parameters would be different, mainly the inclination changes to the higher values. Therefore, another more detailed analysis is still needed. On the other hand, the presence of additional bodies is quite common among binaries. For example Pribulla & Rucinski (2006) and also Tokovinin et al. (2006) noted that about 60% of

Table 2: The parameters of the third body orbit of DM Del.

Parameter	Value
p_3 [yr]	33.1 ± 0.5
T_0 [HJD]	2443610 ± 100
A [d]	0.032 ± 0.004
e	0.8 ± 0.2
ω [deg]	12.4 ± 4.4
$f(M_3)$ [$M_\odot$]	0.62 ± 0.12
$M_{3,min}$ [$M_\odot$]	2.3 ± 0.8

binaries contain another components and Eggleton & Tokovinin (2008) presented that even 30% of triples contain another components.

From the parameters of the proposed third-body orbit one could also calculate an angular distance and a magnitude difference of this body for a prospective future interferometric detection. Using the value of distance 300 pc published by Shaw (1994), these result in angular separation about 60 mas and could be even brighter than the binary itself. On the other hand, if the third component is a binary, then the magnitude difference would be about 1 mag. Such a body could be therefore detectable with the modern stellar interferometers. No interferometric measurement has been obtained so far.

Regrettably, also no radial velocity study has been carried out, so the hypothesis could not be proved with nowadays data. Another detailed photometric or spectroscopic analysis is needed for the confirmation of our hypothesis by an independent method.

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