Discovery of the strongly eccentric, short-period binary nature of the B-type system HD 313926 by the MOST satellite

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ABSTRACT

The MOST photometric space mission discovered an eclipsing binary among its guide stars in 2006 June which combines a relatively large eccentricity $e = 0.20$ with an orbital period of only 2.27 d. HD 313926 appears to consist of two early-type stars of spectral type B3–B7. It has the largest eccentricity among known early-type binaries with periods less than 3.5 d. Despite the large components indicated by its spectral type and light curve model, and its short period, the orbit of HD 313926 has not yet circularized so it is probably very young, even compared with other young B stars.

Key words: binaries: eclipsing – stars: evolution – stars: individual: HD 313926.

1 INTRODUCTION

Tidal dissipation is known to lead to circularization of close binary star orbits. In hot (radiative equilibrium) stars, the dominant dissipative mechanism is thought to be dynamical tides. Its efficiency is expected to show a very strong dependence on the relative size of the stars, with a time-scale $t_{\text{diss}} \propto (r/a)^{-3/2}$ ($r$ is the radius and $a$ is the mean separation of the components), even stronger than for cool (convective equilibrium) stars, $t_{\text{diss}} \propto (r/a)^{-8}$ (Zahn 1975, 1977, 2005). However, coefficients in the two proportionality differ by many orders of magnitude, with the latter efficiency being much higher than the former. Therefore, as pointed out in a review by Zahn (1992), a low-mass, cool secondary component can contribute most of the dissipation so that the range of possibilities here is very wide.

The main tool in studies of orbit circularization is the period–eccentricity distribution and its evolution with time. A whole meeting (Duquennoy & Mayor 1992), jokingly referred to by its editors as ‘The $e - \log P$ Workshop’, was devoted to this subject. Twelve years after that meeting, a focused workshop (Claret, Gimenez & Zahn 2005) discussed apparent limitations of the current theories which point at the need for additional, more efficient dissipation mechanisms in addition to those included in the classic theory of Zahn. The discovery of a short-period eccentric binary by the MOST space mission adds an observation to an interesting region of $e - \log P$ parameter space.

2 MOST OBSERVATIONS

MOST (Microvariability & Oscillations of STars) is a microsatellite housing a 15-cm telescope which feeds a CCD photometer through a single custom broad-band optical filter (350–700 nm). The pre-launch characteristics of the mission are described by Walker et al. (2003) and the initial post-launch performance by Matthews et al. (2004). MOST is in a Sun-synchronous polar orbit (820-km altitude) from which it can monitor some stars for as long as 2 months without interruption. The instrument was designed to obtain highly precise photometry of bright stars through Fabry imaging. Since launch, its
Figure 1. The MOST photometry of HD 313926 in 2-min bins, phased to a period of 2.270 38 d. The solid curve is the best fit from our light-curve synthesis model.

Figure 2. The phased ASAS light curve of HD 313926 for the 2003 season (JD 245 2743–245 2952).

Capabilities have been expanded to obtain photometry of the guide stars used to orient the spacecraft, with the same time coverage as the primary science target.

Table 1. Information from the literature about HD 313926. Mean standard errors are given in parentheses.

| Parameter                     | Data                  |
|-------------------------------|-----------------------|
| Designations                  | HD 313926             |
|                               | CPD–21° 6659          |
|                               | GSC 06276–01849       |
| Position (J2000)              | α = 18°09′07″93, δ = −21°28′24″8 |
| Galactic coordinates (°)      | l = 9.12, b = −0.85   |
| Photometry (Tycho-1)          | B − V = 0.372         |
| Photometry (Tycho-2)          | V_T = 10.602 (0.062)  |
|                               | B_T = 11.059 (0.062)  |
|                               | B − V = 0.388         |
| Data from SIMBAD             | V = 10.7, spectral type: B9 |
| Parallax (Tycho-1)            | π = 90.455(0) mas     |
| Proper motion (Tycho-2)       | PM_Ra = 0.8 (2.8) mas yr⁻¹ |
|                               | PM_Dec = −1.6 (2.9) mas yr⁻¹ |

Table 2. Eclipse timing for HD 313926 (A = ASAS, M = MOST).

| JD (primary) | E   | O–C (d) | JD (secondary) | Secondary phase | Source |
|--------------|-----|---------|----------------|-----------------|--------|
| 245 2054.066 | −810 | +0.002  | 245 2054.920   | 0.377           | A 2001 |
| 245 2362.828 | −674 | −0.007  | 245 2363.695   | 0.379           | A 2002 |
| 245 2846.432 | −461 | +0.006  | 245 2847.300   | 0.385           | A 2003 |
| 245 3893.071 | 0   | 0       | 245 3893.912   | 0.370           | M 2006 |

is nearby, without any reddening, then the colour corresponds to approximately F3 V. Therefore the published spectral type of B9 requires verification.

3 THE BINARY EPHEMERIS

It is clear from Fig. 1 that HD 313926 is an eccentric binary, with the secondary eclipse at phase 0.38 relative to the primary eclipse at phase 0.00.

HD 313926 had been observed photometrically by the ASAS (All-Sky Automated Survey) photometric survey (Pojmański & Maciejewski 2005; Paczyński et al. 2006), but the large displacement of the secondary eclipse went unnoticed in this survey. The available V-band ASAS observations (482 in number) were collected during five consecutive seasons between 2001 June and 2004 July. Typical data are shown in Fig. 2, from the 2003 season. Note the difference in phase coverage of the ground-based data spanning 209 d compared with that of the MOST data in Fig. 1 collected over only 23 d. The depths of the eclipses are different in Figs 1 and 2 because of the differences in the filters used for the respective photometric measurements.

The ASAS photometry permits determination of three seasonal moments of primary eclipses and, as a result, an improvement of the primary eclipse timing solely from the MOST data (Table 2). We determine from the MOST and ASAS data an ephemeris of

\[
\text{Min } I = 245 3893.071(15) + 2.270 38(22) \times E,
\]

where the errors in the last significant digits are given in parentheses. There is no clear indication of any apsidal motion in the secondary eclipse times from the ASAS and MOST data.

4 LIGHT CURVE SYNTHESIS

In the MOST measurements, the primary eclipse is about 0.45 mag deep and the secondary eclipse about 0.25 mag deep. Both eclipses
prominent peaks occur at the MOST plane as does not show any variability beyond instrumental effects due to model. Fig. 3 shows the Fourier amplitude spectrum. The spectrum reproduces the observed light curve quite well. In particular, the elliptical orbit causes a stronger ellipsoidal distortion of the components with radii of about 4.150 km s
−1 for mid-B stars like those inferred to be in HD 313926 (~150 km s
−1 for mid-F stars). However, the overall solution will still not be extremely accurate because of the partial eclipses.

5 SPECTROSCOPY OF HD 313926

A few classification-resolution spectra of HD 313926 were obtained with the 1.88-m telescope of the David Dunlap Observatory (DDO), at a mean wavelength of 4200 Å, covering the region 3900–4650 Å with a resolution of about 1.2 Å. Because the star is visible from DDO at an elevation of only 25° above the southern horizon, over the very bright Toronto sky, the spectra are of relatively low quality with a strongly attenuated blue part and with a large noise due to the bright background subtraction. Our classification must be considered very preliminary, to be confirmed from a spectrograph in the southern hemisphere.

We have been able to confirm the early type of the components from the presence of the He I lines λ4387 and 4471. The range of admissible spectral types is B3 to B7, which is even earlier than given by SIMBAD. Therefore the binary appears to consist of massive, large stars, and the large B − V colour must be due to the interstellar reddening.

A simple reality check on the size of the components, from Kepler’s Third Law and the geometrical elements in Table 3, as well as the main-sequence mass–radius relation, suggests components with radii of about 4−6 R⊙ and masses of 10−15 M⊙. These ranges are consistent with spectral types of B2 to B5.

A thorough radial velocity (RV) study of HD 313926 would be useful. This calls for a 1.5−2-m class telescope in the southern hemisphere with a spectrograph of resolving power $R \sim 10,000$. Such a study would provide masses and absolute dimensions, permitting a full characterization of the system. Based on the MOST light curve, the RV semi-amplitudes are expected to be of the order of $K_1 \simeq K_2 \simeq 250 \text{ km s}^{-1}$ for mid-B stars like those inferred to be in HD 313926 (~150 km s$^{-1}$ for mid-F stars). However, the overall solution will still not be extremely accurate because of the partial eclipses.

6 THE LARGE ORBITAL ECCENTRICITY OF HD 313926 IN PERSPECTIVE

Close binaries with similarly short periods and large eccentricities do exist, but for periods around 2 d, systems earlier than A0 have eccentricities typically below $e \simeq 0.15$. In Fig. 4, we show the distribution of measured values of $e$ versus orbital period $P$ for periods less than 5 d based on data from the most recent version of the Hégédûs, Gimenéz & Claret (2005) catalogue. The figure suggests that the upper envelope for early-type stars may be flatter than that for spectral types later than A0; for late spectral types of the same orbital
period, stars are smaller and the tidal dissipation correspondingly weaker. HD 313926, of spectral type B3–B7, lies near the extreme limit of eccentricity, compared to 22 other studied early-type stars with periods less than 3.5 d (of which 16 have $e < 0.1$).

In summary, HD 313926 defines a new position of the upper envelope for eccentricities of early-type stars at short orbital periods. Although all early-type stars are young, this pair of stars may be very young compared with the other youngsters. Unfortunately, we have no idea what was its initial eccentricity, to judge how much the orbit may have evolved in a short time. With the current preliminary geometrical parameters, we also cannot predict how long the circularization process for HD 313926 would take. The system definitely requires further attention in efforts to estimate the circularization rates in massive, early-type stars.

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