SDSS J122339.61-005631.1: a short period eclipsing binary with a white dwarf component

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Introduction

When the most massive star of a binary system evolves off the main sequence (MS), it may fill its Roche lobe (in ~25% of the cases) and initiate a dynamically unstable mass transfer to the companion star (Willems & Kolb 2004). As a consequence of this mass transfer, a Common-Envelope (CE) is formed containing the core of the star in the giant branch (or asymptotic giant branch) and the companion star (Ivanova et al. 2013). Frictional forces inside this envelope cause a rapid decrease (~10^3 years) of the binary separation.
Due to the redistribution of angular momentum and orbital energy during the CE phase, the system finally ejects the envelope. The resulting system is a hot Sub Dwarf/White Dwarf plus MS star (SD/WD-MS), and is referred as a Post-Common-Envelope-Binary (PCEB). These systems have typical orbital periods between 2 hours and 2 days, although the great majority of them are closer to the lower boundary. In recent years, the number of eclipsing binaries with a white dwarf component has increased, mainly due to large surveys such as the Sloan Digital Sky Survey (SDSS; York et al., 2000) and the Catalina Sky Survey (CSS; Drake et al., 2009).

SDSS J122339.61-005631.1 (hereafter SDSS J1223-0056) was identified as a binary system by Raymond et al. (2003), who analyzed spectra obtained from the SDSS searching for pre-cataclysmic variables. SDSS J1223-0056 was included in the largest and most homogeneous catalogue of spectroscopically confirmed WD+MS Binaries, presented by Rebassa-Mansergas et al. (2007, 2010, 2012a). They, using data from the SDSS, determined its stellar parameters (see Table 1). Parsons et al. (2013), who searched eclipsing PCEBs combining WD+MS from this catalogue with the CSS light curves, determined the orbital ephemeris of the system (Table 1). The left panel in Figure 1, shows a scale sketch of SDSS J1223-0056 while in the right panel, it can be seen the Spectral Energy Distribution (SED) of the binary system. In this contribution, we report a new analysis of this binary system.

Table 1

Mass WD [M_{Sun}]	0.45 ± 0.06
Teff WD [K]	11565 ± 59
Radii WD [R_{Sun}]	0.01549 ± 0.00107
Spectral type WD	DA
Spectral type MS star	M6
Orbital Period [h]	2.1618720 ± 0.0000003
T_0 [MJD]	55707.0169865(72)

Table 1: Stellar parameters of SDSS J1223-0056 determined by Rebassa-Mansergas et al. (2010) and the orbital ephemeris of the system estimated by Parsons et al. (2013).

Figure 1

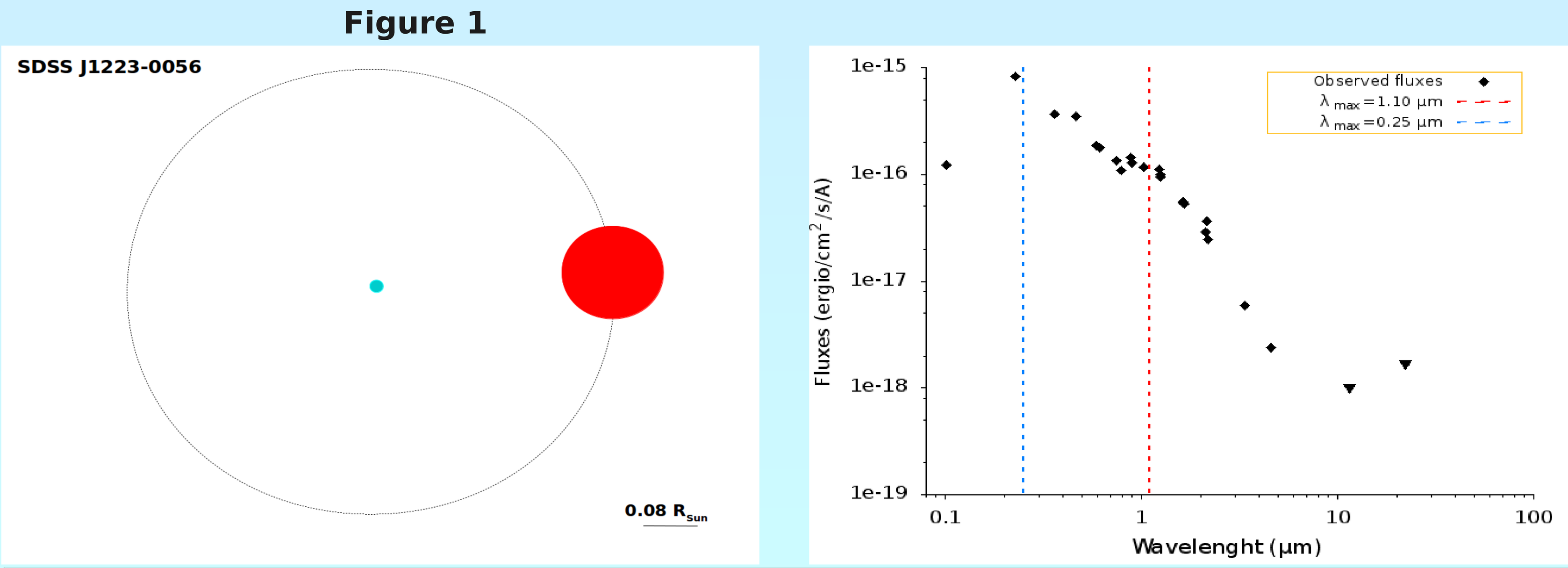

***Figure 1*: (Left panel)** Scale sketch of SDSS J1223-0056, using the stellar parameters determined by Rebassa-Mansergas et al. (2010). The WD is represented with a light blue circle and the MS star with a red circle.
(Right panel) Spectral Energy Distribution (SED) of SDSS J1223-0056. The observed fluxes (black diamonds and triangles) were obtained through VOSA (VO Sed Analyzer). The black triangles, correspond to upper limits. The dashed lines show where are the maximum emission of radiation from the blackbody of the white dwarf (blue) and the MS star (red).

Light Curves

We present new optical photometry of SDSS J1223-0056, obtained the night of March 8, 2016 with CCD Roper 2048B, attached to the 2.15 m Jorge Sahade telescope at Complejo Astronómico El Leoncito (CASLEO, Argentina). The field covered by this CCD is 5.1'x5.1' (Figure 2). During the observation, Johnson R filter was used and the exposure time was 5 min, with a dead-time between exposures of ~30 s. The images obtained were processed using standard IRAF tasks. To obtain instrumental magnitudes with aperture photometry, we used an algorithm called FOTOMCC (Petrucci et al. 2013, 2015), a quasi-automatic pipeline which use the DAOPHOT package, from the IRAF environment.
We complemented ours observations with the CSS light curves. The light curves obtained are presented in Figure 3. In the top panel, we show the differential light curve obtained in CASLEO. Although it was possible to detect an eclipse, SDSS J1223-0056 is a partially eclipsing system and the eclipse only lasts a few minutes (Parsons et al. 2013, Pyrzas et al. 2015) so for future observations we plan to reduce the exposure time to improve the cadence of observations. In the bottom panel, we present the light curve from CSS, where the exposure time was between 5-40 s.

Figure 2

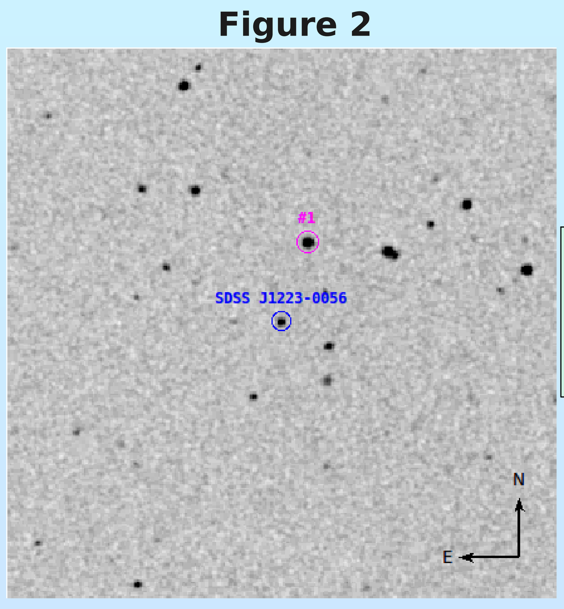

Figure 2: The field covered by the CCD roper 2048B, attached to the 2.15 m Jorge Sahade telescope at CASLEO. In blue and magenta are indicated SDSS J1223-0056 and the comparison star, respectively.

Figure 3

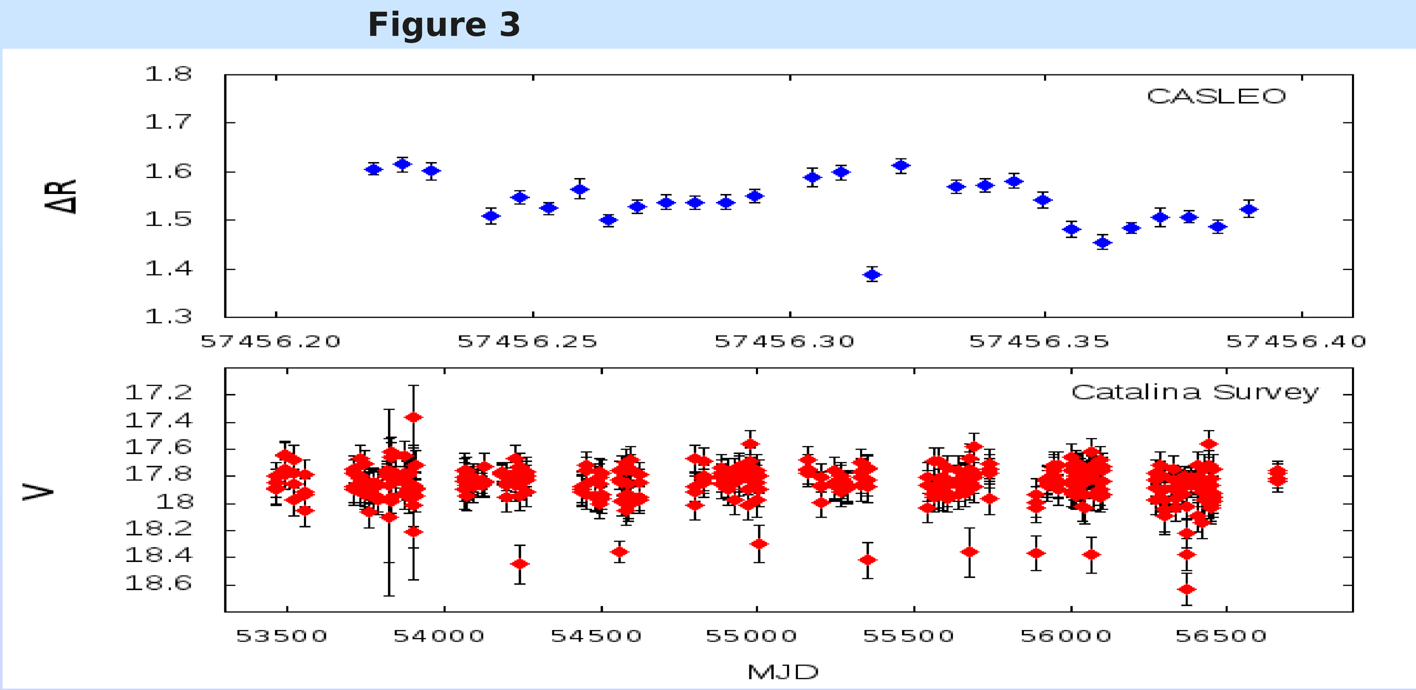

***Figure 3*: (Top panel)** Light curve of SDSS J1223-0056 obtained in CASLEO. **(Bottom panel)** Light curves of SDSS J1223-0056, from CSS database.

Ephemeris and O-C diagram

Measuring the times of mid-eclipse from the 9 eclipses in Figure 3 and the 9 mid-eclipse times presented in the Madelon Bours thesis, we determined the orbital ephemeris of the system. The linear ephemeris obtained for SDSS J1223-0056, was calculated using a linear least-squares approach to minimize the residuals:

$$T = T_0 + P_{orb} E$$

where P_{orb} is the orbital period of the binary in days, T_0 is the time at which the cycle number E=0, and T is the time of a given orbital cycle E.

We used O-C diagrams to get a more precise ephemeris and search for deviations from a constant orbital period. The O-C diagram is a plot showing the observed times of an event (O) minus those calculated according to an adopted ephemeris (C), as a function of time. Figure 4, shows a plot of the O-C diagram obtained. We did not detect any significant periodicity in the O-C values. As it can be seen, there are 2 points that are outside to the standard deviation of the sample, so we decided to re-calculate ephemeris discarding the indicated points. Therefore, the best linear ephemeris obtained is:

$$T\ [MJD] = 55707.0141(46) + 0.09007811(49)\ E$$

where the numbers in brackets indicate the error on the last two digits. We did not detect any significant periodicity in the O-C values.

Figure 4

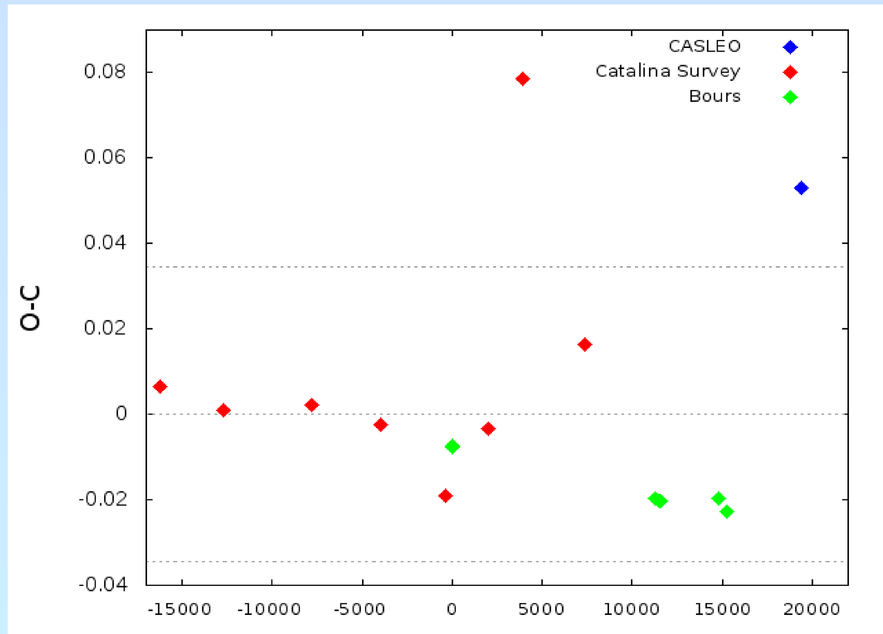

Figure 4: Observed-Calculated (O-C) versus Cycle. Dashed lines indicate ±3σ. CASLEO, CSS, and Bours data of SDSS J1223-0056 are shown as blue, red and green diamonds, respectively.

Synthetic light curve obtained with the W-D code

We generated a synthetic light curve with the LC subroutine of the Wilson-Devinney (W-D) code (Wilson & Devinney 1971), using the stellar parameters of Table 2. We obtained a light curve (Top panel of Figure 5) that is quite similar to that presented by Pyrzas et al. (2015), showed in the Bottom panel of Figure 5. They used the high-speed camera ULTRACAM mounted on ESO's 3.5 m New Technology Telescope (NTT) at La Silla. Data were obtained in the Sloan u′, g′, and r′ bands.

We plan to continue the systematic monitoring of SDSS J1223-0056, covering several orbital periods. This will allow us to derive a well covered light curve to adjust with the DC subroutine of the W-D code. The parameters listed in Tables 1 & 2 should provide a good starting solution to be refined with the DC subroutine.

Table 2

T_{WD} [K]	11565
$T_{MS-star}$ [K]	2600
R_{WD}[R_{Sun}]	0.06
$R_{MS-star}$ [R_{Sun}]	0.1
q	0.44
e	0
***i* [°]**	83.9
Orbital Period [day]	0.0901
s-m axis [R_{Sun}]	0.733

Table 2: Stellar parameters used to generate the synthetic light curve of SDSS J1223-0056, with the LC subroutine of the W-D code.

Figure 5

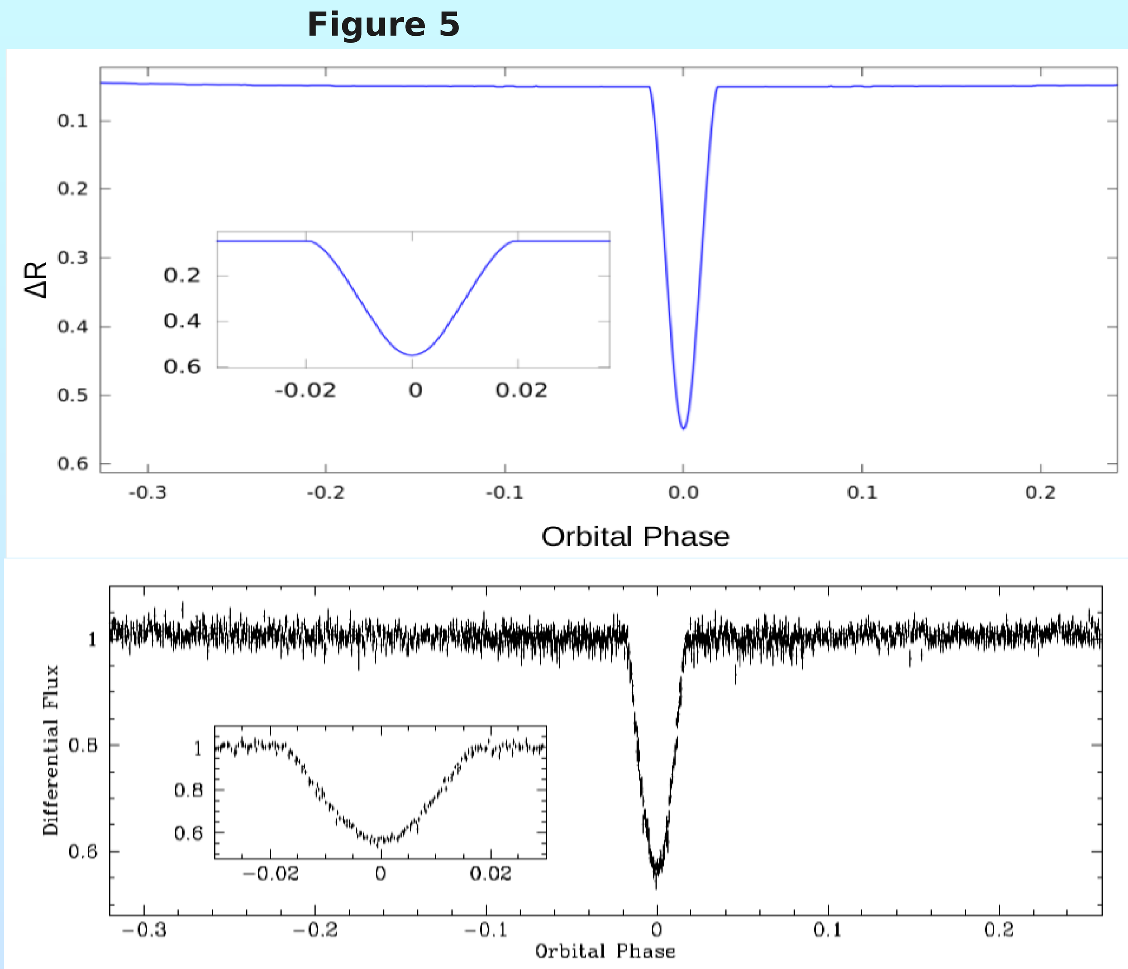

***Figure 5*: (Top panel)** synthetic light curve with the W-D code, using the parameters listed in Table 2. Inset panel: a zoom around the eclipse.
(Bottom panel) g' filter light curve of SDSS J1223-0056 obtained by Pyrzas et al. (2015).

Conclusions

In this contribution, we present new optical photometry of SDSS J1223-0056, obtained in CASLEO. We complemented our observations with the CSS light curves. Measuring the times of mid-eclipse from CASLEO and CSS and the 9 mid-eclipse times presented in the Madelon Bours thesis, we determined the orbital ephemeris of the system. In the O-C diagram (Figure 4), 2 points are outside to the standard deviation of the sample, so we decided to re-calculate ephemeris discarding the indicated points. We did not detect any significant periodicity in the O-C values.

Finally, we generated a synthetic light curve with the W-D code, quite similar to that presented by Pyrzas et al. (2015), show in the bottom panel of Figure 5. We plan to continue the systematic monitoring of SDSS J1223-0056, covering several orbital periods. This will allow us to derive a well covered light curve to adjust with the DC subroutine of the W-D code. The parameters listed in Tables 1 & 2 should provide a good starting solution to be refined with the DC subroutine.

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