SDSS121258.25–012310.1: a new eclipsing post common envelope binary

A Nebot Gómez-Morán¹, A D Schwope¹, M R Schreiber² and B T Gänscike³

¹ Astrophysikalisches Institut Potsdam, An der Sternwarte 16, D-14482 Potsdam
² Departamento de Física y Astronomía, Universidad de Valparaíso , Avenida Gran Bretana 1111, Valparaíso, Chile
³ Department of Physics, University of Warwick, Coventry, CV4 7AL, UK
E-mail: angm@aip.de

Abstract. From optical photometry we show that SDSS121258.25–012310.1 is a new eclipsing post common envelope binary with an orbital period of $\sim 8.06$ hours and eclipse length of 23 minutes. From spectroscopic follow up observations we measured the semi-amplitude of the radial velocity for the secondary star, $K_2 = 181 \pm 3$ km s$^{-1}$. By fitting the optical SDSS spectrum we constrained the stellar parameters. The white dwarf temperature is $17700 \pm 300$ K, its surface gravity $\log g = 7.53 \pm 0.2$, the spectral type of the secondary star is M4 $\pm 1$ and the distance to the system $d = 230 \pm 20$ parsec. Masses are estimated to be in the range $0.25 - 0.38$ M$_\odot$ for the red dwarf and $0.33 - 0.48$ M$_\odot$ for the white dwarf. We finally discuss the evolutionary state of the system.

1. Introduction
Most of the stars in the Galaxy are born in binary or multiple star systems, and some of them will interact at some point of their lives. If the orbital separation of the initial binary is small enough as the more massive star evolves mass transfer occurs and, if the rate at which it happens is high, it may engulf its companion, entering a common envelope (CE) phase. The stars start a spiral-in process, the envelope is not co-rotating with the binary and friction within the common envelope leads to a shrinkage of the binary separation and angular momentum and energy are extracted from the orbit, eventually expelling the CE. Once the CE is expelled the binary can be formed by a remnant of the more massive star, i.e. a white dwarf, and a main sequence star, perhaps surrounded by the ejected material. These are the so called post common envelope binaries (PCEB) and further evolution, mainly driven by angular momentum loss due to gravitational radiation and magnetic braking, can bring the system into semi-contact, where the secondary star fills in its Roche lobe and mass transfer occurs again but in a stable way, forming a cataclysmic variable (Paczyński 1976; Iben & Livio 1993).

There are theories for the CE phase, but this phase is still poorly understood and even more, there is a lack of observational constraints (Schreiber & Gänscicke 2003). Eclipsing binaries are of most relevance as we can derive stellar parameters with highest accuracy. Recently the number of known eclipsing PCEBs is increasing (Nebot et al. 2008; Pyrzas et al. 2008). Our serendipitous discovery of a new eclipsing PCEB, SDSSJ121258.25–012310.1 (henceforth SDSS1212–0123), in
our ongoing search for PCEBs (Schreiber et al. 2008; Rebassa et al. 2007; 2008), triggered further observations.

2. Eclipse ephemeris from optical photometry
We observed SDSS1212–0123 over 11 nights using two different telescopes, the IAC80 (OT, Spain) and the 70 cm telescope of the Astrophysikalisches Institut Potsdam (Babelsberg, Germany) in three different bands. Differential magnitudes were obtained with respect to the star SDSSJ121302.39–012343.5. The light curve is presented in Fig. 1, the deeper eclipse in the V band represents the fact that the white dwarf is being occulted by its companion. We measured the eclipse length, 23 ± 1 minutes, and determined the ephemeris of eclipse center to $HJD_{\text{mid}} = 2454104.7086(2) + 0.3358706(5) \times E$, where numbers in parenthesis indicate the 1σ uncertainty in the last digits.

3. Spectroscopic follow up observations
Spectroscopic follow up observations were obtained for SDSS1212–0123 in the period May 16-19, 2007, with the LDSS3 imaging spectrophotograph at the Magellan Clay telescope. We measured the radial velocities from the NaI absorption doublet (8183.27Å, 8194.81Å) present in the spectrum of SDSS1212–0123 and originating from the secondary star. The radial velocity semi-amplitude was obtained from a least-squares fit of a sine function, $v_r = \gamma_2 + K_2 \sin \left( \frac{2\pi(t - t_0)}{P} \right)$, to the observed radial velocity measurements. Orbital period, $P$, and epoch of mid eclipse, $t_0$, were determined photometrically and were kept fixed. We find the systemic velocity $\gamma_2 = 17 \pm 3 \text{ km s}^{-1}$ and $K_2 = 181 \pm 3 \text{ km s}^{-1}$ (see Fig.2).

4. Decomposition of the SDSS spectrum
From the optical SDSS spectrum we determined the stellar parameters of SDSS1212–0123 following the procedure described in Rebassa et al. (2007). We determine the spectral type of the secondary star by fitting the spectrum (Fig. 3, black line) to composite spectra made of M-dwarfs and white dwarfs templates (Fig. 3, dotted line). We subtract the best dM and we fit the white dwarf to modeled atmospheres of white dwarfs on a $T_{\text{eff}}$–$\log g$ grid, getting two results, a ‘cold’ and a ‘hot’ solution (Fig. 4, upper panel). To discern we fit the overall continuum plus lines (Fig. 4, bottom panel).
The spectral type of the secondary was determined to be M4 ± 1 implying a distance $d_{\text{sec}} = 320 \pm 95$ pc, mass range of the secondary $M_{\text{sec}} = 0.255 - 0.380$ $M_\odot$ and radius range $R_{\text{sec}} = 0.258 - 0.391$ $R_\odot$, using Rebassa et al. (2007) spectral type-mass and spectral type-radius empirical relations respectively. The best fit was found for $T_{\text{eff}} = 17700 \pm 300$ K and $\log g = 7.53\pm0.05$ (implying a white dwarf mass $M_{\text{wd}} = 0.39\pm0.02$ $M_\odot$, and $R_{\text{wd}} = 0.018\pm0.001$ $R_\odot$). All the quoted errors are purely statistical, the true uncertainty of the white dwarf spectral parameters is clearly larger than suggested by the derived numbers. We estimate the systematic uncertainty of our log $g$ determination to be of the order of 0.2 dex, which results in rather large ranges of possible values for the mass and the radius of the primary, i.e. $M_{\text{wd}} = 0.33 - 0.48$ $M_\odot$ and $R_{\text{wd}} = 0.015 - 0.021$ $R_\odot$. The derived distance to the white dwarf is $d_{\text{wd}} = 226 \pm 8$ pc (assuming the statistical error only). The two distance estimates differ, $d_{\text{sec}}$ being larger than $d_{\text{wd}}$, but in agreement within the errors, taking into account systematic errors we obtain $d_{\text{wd}} = 230 \pm 20$ pc as the distance to the system.

5. Evolutionary state

Following Schreiber & Gänssicke (2003) we predicted the post common envelope evolution of SDSS1212–0123. From the mass and the temperature of the primary we estimated the cooling age to be $6.8 \times 10^7$ years, using the cooling tracks from Wood (1995) (see Fig. 5). From the derived mass of the secondary we conclude that the only mechanism reducing the orbit of the binary is gravitational radiation (magnetic braking gets disrupted when the secondary star becomes completely convective, $\sim 0.3$ $M_\odot$). SDSS1212–0123 left the CE phase with an orbital period of about 8 hours and, according to its cooling age, SDSS1212–0123 has passed only a small fraction of its PCEB lifetime. The system appears to be different to the progenitors of the current CV population as the calculated PCEB lifetime exceeds the Hubble time. SDSS1212–0123 will become a CV within or slightly above the orbital period gap.
Figure 5. Upper panel: We derived a cooling age for SDSS1212–0123 of $\sim 7 \times 10^7$ years by interpolating the cooling tracks of Wood (1995). Bottom panel: We reconstructed the evolution of SDSS1212–0123 finding that it has only lived a small fraction of its PCEB lifetime, it will take $\sim 1.8 \times 10^{10}$ years until SDSS1212–0123 will become a CV.

6. Conclusions
From optical photometry we conclude SDSS1212–0123 is a eclipsing PCEB with an orbital period of 0.336 days and an eclipse length of 23 min. From spectroscopic follow-up observations we have derived a systemic velocity of $17 \pm 3$ km/s and a semi-amplitude of the radial velocity of $181 \pm 3$ km/s. From the SDSS spectrum we derived $T_{\text{eff}} = 17700 \pm 300$ K, log $g = 7.53 \pm 0.2$ and a secondary spectral type M4$\pm1$ and a distance to the system of $230 \pm 20$ parsecs. We estimated $M_{\text{sec}} = 0.25 - 0.38$ M$_{\odot}$ and $M_{\text{wd}} = 0.33 - 0.48$ M$_{\odot}$ from the eclipse length, using the mass function and an empirical mass radius relation for main sequence stars. We have reconstructed and predicted the post CE evolution of SDSS1212–0123, finding that SDSS1212–0123 at the end of the CE phase had a very similar orbital period. The only mechanism involved in shrinking the orbital period is and has been gravitational radiation. As the PCEB lifetime of SDSS1212–0123 exceeds the Hubble time we conclude that it is not representative of the progenitors of the current CV population.

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