Abstract. We report preliminary \textit{VRI} differential photometric and spectroscopic results for KBS 13, a recently discovered non-eclipsing sdB+dM system. Radial velocity measurements indicate an orbital period of 0.2923 ± 0.0004 days with a semi-amplitude velocity of 22.82 ± 0.23 \, km \, s\,^{-1}. This suggests the smallest secondary minimum mass yet found. We discuss the distribution of orbital periods and secondary minimum masses for other similar systems.

1. Introduction

SdB and dM binaries are fairly rare (Green et al. 2005), even though it is photometrically straightforward to detect an M dwarf secondary by its ‘reflection effect’ for orbital periods less than a day or two. Still, even though the peak in the orbital period histogram is close to one day, there are about 20 to 30 times as many known post-common envelope sdB+white dwarf binaries as there are sdB+dM binaries. The latter are particularly interesting because they will eventually evolve into cataclysmic variables (CV). Understanding the pre-CV evolution may shed additional light on, for example, the CV period gap.

KBS 13 was selected from a list of blue objects in the fields of the Kepler mission. D. Sing’s spectroscopic survey (priv. communication) of Kepler Blue Stars (KBS) identified it as an sdB. Exploratory lightcurves for several KBS sdB candidates in November 2005 showed a reflection effect for KBS 13. Its 2MASS colors constrain the main sequence companion to be no brighter than a mid-M dwarf. Follow-up photometry in May and September 2006 confirmed the reflection effect, and showed that KBS 13 does not eclipse.
2. Spectroscopic Results

We obtained optical high-resolution echelle spectra with the 2.7 m and the Hobby-Eberly telescope (HET) at the McDonald Observatory. Radial velocities (RV’s) were calculated by comparing the measured wavelengths of all clearly identified metal lines with laboratory values. The 1 $\sigma$ error values are about 1 km s$^{-1}$. Fig. 1 shows the $\chi^2$ minimization over a range of periods, while the bottom panel shows the phased RV curve.

A zero metallicity NLTE model grid was fitted to the Balmer and Helium lines of low-resolution spectra obtained at the Steward 2.3-m telescope to derive $T_{\text{eff}}$, log $g$ and log $N$(He)/$N$(H). Table 1 summarizes the derived system parameters.

3. Photometric Results

More extensive observations in the $VRI$ band covering the orbit of KBS 13 were carried out in 20–25 June 2007 using the Mont4K CCD on the Steward
Observatory 1.55-m telescope. By alternating the filters, lightcurves in two different bands were obtained each night, relative to multiple reference stars of comparable magnitude and color to KBS 13.

We attempted to derive the orbital period from the combined 2006 and 2007 photometry. Unfortunately, due to the large observing gap, the Lomb-Scargle period search routine failed to give a unique solution. Therefore, we folded the lightcurves with the orbital period and ephemeris derived from spectroscopy. In Fig. 2, we show the phased $VRI$ lightcurves; the amplitude variations are $\Delta I = 0.066$ mag, $\Delta R = 0.048$ mag and $\Delta V = 0.035$ mag, respectively.

4. Similar Systems

Of the eight previously known sdB+dM binaries, PG 1017-086 (Maxted et al. 2002), HS 0705+6700 (Drechsel et al. 2001), PG 1336-018 (Kilkenny et al. 1998), HS 2231+2441 (Østensen et al. 2007), HW Vir (Wood & Saffer 1999), HS 2333+3927 (Heber et al. 2004), PG 1329+159 (Green et al. 2004) and PG 1438-029 (Green et al. 2005), five have orbital periods under 3.0 h (shorter than all but two of the more than 50 known sdB+WD binaries) and typical secondary masses of 0.10–0.15 $M_\odot$. A sixth has a period of 4.1 h and a minimum mass of 0.18 $M_\odot$. The remaining two sdB+dM systems have periods of 6.0 and 8.2 h, and low velocity semi-amplitudes of 38 and 32 km s$^{-1}$, respectively, which imply surprisingly small minimum masses of 0.07 $M_\odot$ for both secondaries.

KBS 13 is only the third known sdB+dM binary with an orbital period longer than 4.5 h. Its secondary has the smallest minimum mass found so far, $\sim 0.046$ $M_\odot$. Although the inclination is not yet known, it cannot be very low for any of these systems or we would not be able to see the reflection effects as strongly as we do. The distribution of orbital period vs $M_{2,\text{min}}$ for all known sdB+dM binaries (Fig. 3) shows no correlation; in fact, the systems with the longest periods have the smallest minimum masses. This is unexpected, since common envelope theory indicates that lower mass secondaries would need to
Figure 3. The distribution orbital period vs secondary minimum mass for sdB+dM binaries. Eclipsing and non-eclipsing systems are marked by triangles and solid circles, respectively.

spiral in much closer in order to eject the envelope. Therefore, longer period systems should be the ones with higher mass secondaries.

5. Outlook

The VRI lightcurves will be analyzed simultaneously with the MORO code (Drechsel et al. 1995). This program is primarily based on the Wilson-Devinney logistical approach but the underlying model is a modified Roche model that has taken into account the radiative interaction between the components of hot, close binaries. Commonly, difficulties arise when the system is degenerate in mass ratio and shows no eclipse (i.e. low inclination). We hope that further constraints on the free parameters will give us a unique set of system parameters for KBS 13.

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