Baltic Astronomy, vol. 15, 187–190, 2006.

SUBDWARF B BINARIES IN THE EDINBURGH-CAPE SURVEY

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Received 2005 July 1

Abstract. We give an update of the results of a campaign to obtain orbital solutions of subdwarf B stars from the Edinburgh-Cape survey (Stobie et al. 1997). To date we have obtained blue spectra of 40 subdwarf B stars from the Edinburgh-Cape catalogue using the grating spectrograph at the 1.9 m Radcliffe telescope at the South African Astronomical Observatory. We find that 17 out of these 40 are certain binaries with a few other objects showing radial velocity variations of small amplitude. The binary fraction found in our sample, after correcting for our binary detection efficiency, is 48%. We have secured the orbital parameters for 4 of the 17 systems and narrowed down the orbits of another 7 to a small range of periods.

Out of the four subdwarf B binaries for which we have determined the orbital solution, three have orbital periods that, according to population synthesis studies by Han et al. (2003), suggest they have been formed via a common envelope ejection channel. The masses of the companions, assuming a canonical mass of $0.5\,M_{\odot}$ for the subdwarf B star, suggest that they are probably white dwarfs. We observed the shortest period binary (3 h) of the three, to search for indications of modulation in the lightcurve due to irradiation of the companion by the subdwarf B star. No indications of reflection effect were found confirming that the companion is indeed a white dwarf. The fourth system with measured orbital parameters shows an orbital period that could correspond to a subdwarf B binary formed either via the common envelope ejection channel or the stable Roche Lobe overflow channel.

The aim of the this study: to obtain an independent, statistically significant sample of subdwarf B binaries, with solved orbits, based purely upon the Edinburgh-Cape survey to avoid the uncertain biases of the Palomar-Green and other surveys, is underway.

Key words: subdwarfs – binaries: close – binaries: spectrospcopic

1. THE BINARY FRACTION OF SUBDWARF B STARS

Maxted et al. (2001) find that 69±9% of the subdwarf B (sdB) stars in their observed sample are in binary systems. Napiwotzki et al. (2004) find a binary fraction of 40% in their SPY (Supernova type Ia Progenitor Survey) sample.

Radial velocity measurements of a sample of 40 sdBs from the Edinburgh-Cape (EC) survey yield 17 certain spectroscopic binaries. Radial velocities were measured by fitting a model line profile to Hβ and Hγ simultaneously (Morales-Rueda et al. 2004). To determine the true binary fraction in our sample we need to compute our detection efficiency, i.e., the probability of detecting (or not detecting) a binary at a certain orbital period due to the sampling of the data and the accuracy of the radial velocity measurements. These probabilities were calculated in a similar way to those by Maxted et al. (2001) and are shown in Fig. 1 (solid line). For comparison we are also plotting in Fig. 1 the observed orbital period distribution (dashed line) and the theoretical distribution, considering both the common envelope (CE) ejection and the Roche lobe overflow (RLOF) channels (dash-dotted line) and only the CE ejection channel (dotted line). These distributions will be discussed again in Section 3. We find that for orbital periods up to 1 day our average detection efficiency is 87% which gives a binary fraction for our sample of 49±8%. The observed distribution peaks at $\log_{10} P = -0.1$ and the theoretical distribution (only considering binaries formed through the CE ejection channel) peaks at $\log_{10} P = 0.6$ where the detection efficiency is 90% in which case the binary fraction of our sample is 47±8%. We find that this number agrees better with the binary fraction found by Napiwotzki et al. (2004) than with that found by Maxted et al. (2001).

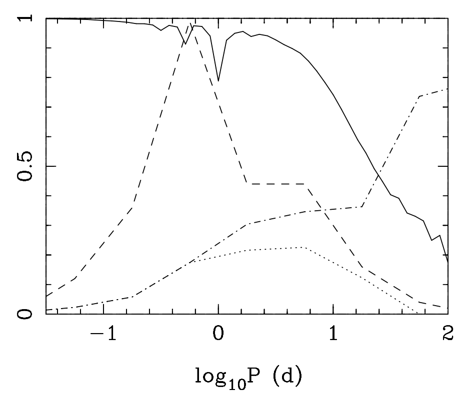

Fig. 1. Detection efficiency as a function of orbital period.

Napiwotzki et al. (2004) suggested that this discrepancy in binary fraction could be due to the fact that the SPY sdB sample belongs mainly to the thick disk and the halo, whereas the PG sample studied by Maxted et al. (2001) comes from the thin disk. In the case of our EC sample, we expect most of the sdBs to belong to the thin disk population which indicates that the reason for the discrepancy in binary fraction is due to something else, probably to low number statistics.

It is also worth noticing how our detection probability decreases with longer period systems (less than 50% above 25 days). A longer time baseline is one of the requirements to increase our sensitivity in this period range.

2. ORBITAL SOLUTIONS

We find the orbital solutions for four of the systems observed, EC 00404−4429, EC 02200−2338, EC 12327−1338 and EC 12408−1427. The orbital solutions for EC 00404−4429 and EC 02200−2338 were already presented by Morales-Rueda et al. (2005) and are given in parenthesis in the following paragraphs. The orbital solutions for EC 12327−1338 and EC 12408−1427 are given in Table 1.

EC 00404−4429 ($P = 0.12834(4)$ d, $M_2(\text{min}) = 0.32\ M_\odot$). Its orbital period places it in the group of sdB binaries formed via the CE ejection channel (see right panel of Fig. 2). The minimum mass of the companion, assuming the canonical mass of $0.5\,M_\odot$ for the sdB, indicates that the companion is probably a white dwarf. We have looked for indications of a reflection effect on the companion of this system as it is the shortest period binary of our sample and found no significant reflection effect. This confirms that the companion is a white dwarf. The system must have formed therefore via the second CE ejection channel (Han et al. 2003)

EC 02200−2338 ($P = 0.8022(7)$ d, $M_2(\text{min}) = 0.39\ M_\odot$) & **EC 12327−1338**. Their orbital periods place them in the group of sdB binaries formed via the CE ejection channel. The minimum masses of the companions, assuming the canonical mass for the sdB star, indicate that the companions are probably white dwarfs.

EC 12408−1427. The orbital period of this sdB binary is consistent with the binary having been formed either via the CE ejection channel or via the RLOF channel. The minimum mass of the companion is compatible with both a white dwarf or a main sequence star.

Table 1. Orbital solution for two sdB binaries. γ is the systemic velocity, K is the radial velocity semiamplitude, and the 1 and 10 percent rows give the probability that the true period lies further than 1 and 10 per cent (respectively) from the given value. The numbers given are the $\log_{10}$ of the probabilities.

	EC 12327-1338	EC 12408-1427
Period (d)	0.363221(1)	0.90243(1)
HJD_0 (d)	2452728.153(1)	2452732.068(5)
γ (km s^{-1})	-6.44 ± 1.74	-52.02 ± 1.19
K (km s^{-1})	124.30 ± 2.55	58.90 ± 1.55
$M_2(\text{min})$ ($M_\odot$)	0.38	0.21
χ^2_{reduced}	1.9	0.8
2nd best alias (d)	0.369281(1)	9.493(1)
$\Delta\chi^2$	33	38
n	15	29
1 percent	−7.34	−6.89
10 percent	−11.58	−6.96
Systematic error (km s^{-1})	2	2

3. ORBITAL PERIOD DISTRIBUTION

Theory predicts that most sdB stars should be in long period binaries (Han et al. 2003). They would have formed via a stable Roche Lobe overflow channel (dashed line in right panel of Fig. 2) and have main sequence companions. This long period population is missing from the observations shown in the left panel of Fig. 2. At present only two long period sdBs candidates are known. This is probably caused by biases in the observed sample: (1) early type companions will swamp the light of the sdB star, (2) long period binaries will show smaller amplitude radial velocities thus higher resolution spectra is needed to find them,

(3) longer time baselines are required to measure periods of a few hundred days.

Biases numbers 2 and 3 affect directly the binary detection efficiency curves presented in Section 1. This explains the differences between the observed and the predicted orbital period distributions at long orbital periods.

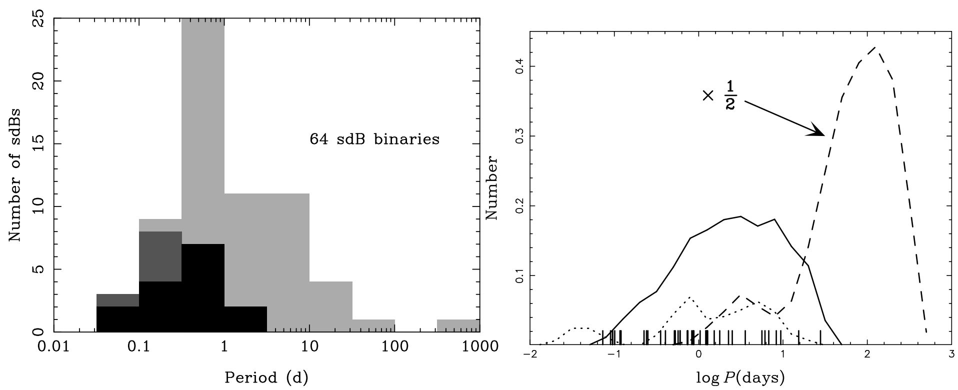

Fig. 2. Left panel: Observed orbital period distribution of sdB binaries. Light grey: unknown companion type, dark grey: main-sequence companions, black: white dwarf companions. Right panel: theoretical orbital period distribution taken from Han et al. (2003). Dotted line: CE channel sdBs with white dwarf companions, solid line: CE channel sdBs with main-sequence companions, dashed line: stable Roche Lobe overflow channel sdBs with main-sequence companions.

With 40 EC sdBs observed and 17 binaries found, this study is well on its way. More observations are required to obtain the statistically significant sample, based only on EC sdBs, that we seek.

ACKNOWLEDGMENTS. This paper uses observations made at the South African Astronomical Observatory (SAAO). LMR is supported by NWO-VIDI grant 639.042.201 to P. J. Groot. The authors would like to thank the Leids Kerkhoven-Bosscha Fonds for providing funding to attend this meeting.

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