Subdwarf B Binaries from the Edinburgh–Cape Survey

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Abstract. We present the first results of a campaign to obtain orbital solutions of subdwarf B (sdB) stars from the Edinburgh-Cape survey. We have obtained blue spectra of 35 sdBs, 20 of which have been observed in more than two epochs. 15 out of the 35 are certain binaries with a few other objects showing radial velocity variations with small amplitude, possibly long period sdB binaries. We have secured the orbital parameters for 2 of the 15 systems and narrowed down the orbits of another one to a small range of periods. These preliminary results only use data taken up to December 2003.

1. Introduction

In March 2002 we started a campaign to obtain orbital solutions of 100 subdwarf B (sdB) binaries from the Edinburgh-Cape (EC) survey (Stobie et al. 1997). This work was intended as the Southern Hemisphere counterpart of that undertaken by Maxted et al. (2001) and Morales-Rueda et al. (2003). In their work Morales-Rueda et al. (2003) select their targets from two main sources, the Palomar-Green (PG) and the Kitt Peak-Downes (KPD) catalogues. The PG catalogue is biased against targets that show a Ca II H-line (as these were taken out of the catalogue), and thus, against sdB binaries with main sequence companions. On the other hand the EC survey does not show these biases, as the object selection is based on colours only, and is ideal to obtain an “unbiased” sample of sdB binaries that can then be compared with binary evolution theories (Han et al. 2003). We should mention that some bias might still remain as in the cases where the main sequence star was somewhat brighter than the sdB star (i.e. combined colour redder than $U - B = -0.4$), the binary would have been classified probably as a late A star and would have been taken out of the catalogue.

2. Observations, Data Reduction and Period Determination

The spectra were obtained with the grating spectrograph plus the SITe CCD at the 1.9 m Radcliffe telescope at the SAAO. Grating 4, with 1200 grooves
per mm was used to obtain spectra covering H\(\beta\) and H\(\gamma\) with a dispersion of 0.5 Å/pix and a resolution of less than 1 Å at 4600 Å. The spectra were reduced according to standard procedures. The Balmer lines were fitted with a model line profile consisting of three Gaussians to measure their radial velocities. These were then fitted with functions consisting of a sinusoidal plus a constant with 4 free parameters, i.e. the constant, the semiamplitude of the sinusoidal, the period and the zero point. A value of the \(\chi^2\) of each fit was obtained for each combination of parameters and a periodogram of the form shown in the right hand panels of Figs. 1, 2 and 3, obtained for each system. We considered that the orbital period of the binary was determined when the difference in \(\chi^2\) between the first and second alias was larger than 20. We calculated the probability that the true orbital period lies further than 1 and 10 per cent from our chosen period and present these values in Table 1 together with the orbital solution for each system. For details on the data reduction, period determination and probability calculations see Morales-Rueda et al. (2003).

3. Results: Orbital Parameters for Three New sdB Binaries

We find the orbital solutions for two systems EC00404−4429 and EC02200−2338. These are presented in Table 1 and in Figs. 1 and 2 respectively. For another system, EC12327−1338, we find that the orbital period lies around 0.36 d but the number of observations is not enough to obtain an accurate orbital period.

Figure 1. **EC00404−4429**: Left panel: radial velocity curve solution fitted to the data measurements. Right panel: periodogram showing the favoured period and the closest aliases.

4. Discussion

Their orbital periods place EC00404−4429, EC02200−2338 and EC12327−1338 in the group of sdB binaries formed via the common envelope (CE) ejection channel (see fig. 10 of Han et al. 2003). The minimum mass of the companion, calculated assuming the canonical mass of 0.5 \(M_\odot\) for the sdB, indicates that the companions are probably white dwarfs, thus these binaries have probably formed through the second CE path (Han et al. 2003).
Table 1. Orbital solutions for three sdB binaries from the EC survey. In the case of EC12327−1338 a range of parameters is given as there are 13 aliases in a small range of periods. Δχ² is the difference in χ² between the 1st and 2nd aliases. n is the number of radial velocities used for the orbit determination. The rows labelled as 1 and 10 per cent give the probabilities that the true period lies further than 1 and 10 per cent from our favoured value. Numbers given are the log₁₀ of the probabilities. The last row gives the systematic uncertainty that has been added in quadrature to the raw error to give a χ² that lies above the 2.5 per cent probability in the χ² distribution. This systematic uncertainty accounts for unaccounted sources of error like slit-filling, intrinsic variability of the star etc. Numbers marked with a * have been calculated for the lowest χ² alias, P = 0.36397(4) d.

|                  | EC00404−4429 | EC02200−2338 | EC12327−1338 |
|------------------|--------------|--------------|--------------|
| Period [d]       | 0.12834(4)   | 0.8022(7)    | 0.3628 - 0.3674 |
| HJD₀ [d]         | 2452895.4418(4) | 2452896.029(4) |
| γ [km s⁻¹]       | 32.97 ± 2.94 | 20.74 ± 2.29 | -7.43 - -4.06 |
| K [km s⁻¹]       | 152.8 ± 3.4  | 96.35 ± 1.43 | 119.8 - 124.3 |
| M₂min [M☉]       | 0.32         | 0.39         | 0.38*         |
| χ²/reduced       | 1.3          | 0.42         | 1.6-3.6       |
| 2nd best alias [d]| 0.11350(3)  | 0.3038(1)    |
| Δχ²              | 73           | 61           |
| n                | 9            | 10           | 13            |
| 1 per cent       | -15.18       | -11.35       | -3.47*        |
| 10 per cent      | -15.18       | -11.35       | -10.81*       |
| Systematic error | 2            | 2            | 2             |

Figure 2. EC02200−2338: Same as in Fig.1

We have added the orbital periods of these three new systems to the orbital period distribution of sdBs known, Fig. 4. The most interesting features of this distribution are the excess of binaries at orbital periods around 1 d and that the very long period systems (tens and hundreds of days) are starting to appear in the sample. The comparison of the observed distribution with theoretical predictions (Han et al. 2003) is invaluable to determine, among other important evolutionary unknowns, plausible values for the CE ejection efficiency.
Figure 3. **EC12327−1338**: Same as in Fig.1. The data have been folded using the orbit solution with smaller $\chi^2$. The periodogram shows many aliases comprised in the range given in Table 1.

Figure 4. Orbital period distribution for the sdB binaries known. The figure is an update of Morales-Rueda et al. (2003) and Morales-Rueda et al. (2004).

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