1. Introduction

It is now generally accepted that the subluminous B (sdB) stars can be identified with models for Extreme Horizontal Branch (EHB) stars burning He in their core, but with a very tiny inert hydrogen envelope (Heber, 1986). An EHB star bears great resemblance to a helium main-sequence star of half a solar mass and its further evolution should proceed similarly (i.e. directly to the white dwarf graveyard) as confirmed by evolutionary calculations (Dorman et al. 1993). How stars evolve to the EHB configuration is controversial. The problem is how the mass loss mechanism in the progenitor manages to remove all but a tiny fraction of the hydrogen envelope at precisely the same time as the He core has attained the minimum mass ($\approx 0.5M_\odot$) required for the He flash.

There is growing evidence that close binary evolution is an important if not the dominant formation path of sdB stars (Maxted et al. 2001a, Heber et al. 2002). SdB stars can result from stable Roche lobe overflow or common envelope ejection models (Han et al. 2002). The companions are either low mass main sequence stars or white dwarfs. SdB stars may also result from the merger of two He white dwarfs (Webbink, 1984).

2. Masses of sdB stars

According to evolution theory the mass of an sdB star is fixed by the core mass of the giant progenitor at the core helium flash ($\approx 0.46 \ldots 0.48 M_\odot$). The envelope ($< 0.02 M_\odot$) does not contribute to the total mass significantly. Therefore half a solar mass is generally assumed to be the appropriate mass of an sdB star. A binary system containing an sdB star may offer the opportunity to measure the mass of sdB star using Keplers third law.
from light and radial velocity curves. A direct solution for the masses of both components is possible for systems which are eclipsing and for which both radial velocity curves can be measured. Although many subluminous B stars in binaries are known, no such system has yet been found.

Today orbital periods have been determined for 38 sdB stars (Morales-Rueda et al. 2002 and references cited therein). In all cases the companions are invisible. For thirteen systems the companions have been identified as white dwarfs and only in five systems as low mass main sequence stars. Atmospheric parameters are available for 36 of them and are consistent with the predictions of evolutionary EHB models (Fig. 1a). Eclipses have been reported only for three of them: HW Vir, PG 1336-018 and HS 0705+6700. In all three cases the companions are low mass main sequence stars. Hence the mass function and the inclination angle can be determined. However, the masses of both components can be derived if the gravity of the sdB stars can be determined accurately from spectroscopy. The analysis of the light and radial velocity curve combined with the spectroscopic gravity measurement results in sdB masses of $0.54 \, M_\odot$ (HW Vir), $0.5 \, M_\odot$ (PG 1336-018) and $0.48 \, M_\odot$ (HS 0705+6700) close to the canonical value of half a solar mass (see Drechsel et al. 2001).

Even in the case of a non-eclipsing system we may be able to determine the mass. If the system is sufficiently close, the rotation of the sdB star will be tidally locked to the orbit. The projected rotational velocity can be measured from high quality spectral line profiles and therefore the inclination angle can be derived. For HS 0705+6700 the inclination derived form $v \sin i$ is consistent with that derived from the light curve analysis. The method has also been applied successfully to the non-eclipsing system PG 1017–086 (Maxted et al. 2001b).

3. HD 188112

HD 188112 is a bright (V=10.2) nearby sdB star. Its distance is well determined by a parallax measurement of the HIPPARCOS satellite to be $d=81^{+13}_{-11}$pc. The spectral analysis is based on high resolution (0.1Å) optical spectra taken at the ESO 1.5m equipped with the FEROS spectrograph. Atmospheric parameters are derived by matching the observed by synthetic spectra calculated from LTE model atmospheres. The results are $T_{\text{eff}}=19300\pm500$ K, $\log g = 5.51\pm0.1$ and a helium content of only He/H $= 5\times10^{-5}$. These parameters are unusual for an sdB and place the star it below the zero age Horizontal Branch (see Fig. 1a). It cannot have evolved off the EHB either, since the evolution of the EHB stars leads to increasing temperatures and lower gravities than observed for HD 188112 (see Fig. 1a).

Combining the atmospheric parameters with the parallax measurement
the mass of HD 188112 can be derived to be $M = 0.23^{+0.15}_{-0.09} \, M_\odot$, far below the canonical sdB mass. Therefore HD 188112 cannot be a core helium burning star. Such a low mass object, however, can be formed in a close binary system when the progenitor star fills its Roche lobe on the first giant branch (RGB) well before the core mass has increased to the critical mass for the core helium flash. The star will then evolve to become a helium core white dwarf. The evolution of such post-RGB stars has been calculated by Driebe et al. (1998) and evolutionary tracks for different masses are shown in Fig. 1. The position of HD 188112 in the $(T_{\text{eff}}, \log g)$-diagram is bracketed by the evolutionary tracks for $M=0.195 \, M_\odot$ and $M=0.234 \, M_\odot$; interpolation gives $0.22 \, M_\odot$, in perfect agreement with the parallax based mass estimate. The evolutionary time since departure from the RGB is of the order $10^8$ years according to the models of Driebe et al. (1998).

If HD 188112 resulted from close binary evolution, the companion should be detectable from the spectral energy distribution or from radial velocity variations. The optical spectrum does not show any hint for a second spectrum. Combining optical photometry with UV fluxes measured by the IUE satellite and NIR fluxes from the 2MASS catalog we can construct the spectral energy distribution. The latter is well matched by the sdB model flux distribution. Hence there is no evidence for light from the companion. However, HD 188112 was indeed found to be radial velocity variable.
August 2002 we measured the radial velocity curve with the FEROS spectrograph at the ESO 1.5m telescope. The preliminary analysis reveals a period of 0.6066 days and an half amplitude of $K=188.4\text{km/s}$ (Heber et al., in prep.). From the mass function we derive a lower limit to the companion mass of $0.72 M_\odot$. Hence the companion cannot be a main sequence star but must be a compact object, most likely a white dwarf, but we cannot rule out a neutron star companion. The mass of the sdB is rather low for a helium core white dwarf. Such low mass white dwarfs, however, have been observed as companions to neutron stars. The projected rotational velocity will be determined to constrain the inclination angle and, therefore, improve the estimate for the lower limit to the companion mass. A measurement of its light curve would also be very valuable.

4. Progenitors of helium core white dwarfs

HD 188112 was found to be a bona-fide progenitor of a helium core white dwarf. Only few other candidates are known, e.g. HZ 22 (Schönberner 1978), EGB 5 (Karl et al. these proceedings) and AA Dor (Rauch, 2000). Unlike HD 188112 these stars lie above the EHB in the $(T_{\text{eff}}, \log g)$-plane as can be seen from Fig. 1a for AA Dor. Hence their position can also be matched by post-EHB tracks. Alternatively, the position of AA Dor can be compared to post-RGB evolutionary tracks (Fig. 1b). Hence in the absence of a mass determination its evolutionary status cannot be assigned uniquely.

AA Dor is an eclipsing single lined binary consisting of a hot sdOB star ($T_{\text{eff}}=42000\text{K}, \log g=5.2$) and a low mass main sequence star or brown dwarf (Rauch, 2000). From the comparison to post-RGB tracks (Fig. 1b) one can read of the mass as $0.33 M_\odot$. However, this result is not consistent with the mass function and light curve (see Fig. 17 of Rauch, 2000).

HD 188112 remains the most compelling case of a progenitor for a helium core white dwarf.

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