PHYSICAL PARAMETERS FOR SUBDWARF B STARS WITH COMPOSITE SPECTRA

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For many years, the evolutionary origins of subdwarf B stars remained a mystery. Observations of sdB stars with composite spectra and theoretical considerations suggested that binary star evolution should play a major role, but proof that a large fraction are binaries has taken a decade to establish. Whilst many sdB stars have recently been recognised to be in short-period binaries with unseen companions [8], we have focused on sdB stars in which the spectrum of the secondary can be seen [5]. We previously studied these systems by means of their flux distributions [1] and shown that the secondaries are probably main-sequence G stars. This result has been confirmed from analysis of their optical and near-infrared spectra [2].

The infrared triplet of ionized calcium was recognised as a good indicator of a late-type companion in composite sdB spectra [5] and is an excellent measure of cool star surface gravity. Our aim was to measure the effective temperatures, surface gravities, and surface helium abundances of the sdB stars in our sample, and the effective temperatures, surface gravities and radius ratios of their companions. This would enable us to identify the companions and estimate their masses.

Observations were obtained with the Isaac Newton and William Herschel Telescopes at the La Palma Observatory in 1997 and 1998. Spectra were obtained in the blue ($4000-4700$Å) and near-infrared ($8000-8800$Å) and mostly at a resolution $R \sim 5\,000$. The measurement of atmospheric parameters was achieved by finding the best-fit models within a model grid using χ^2 minimization. Model atmospheres and synthetic spectra for the sdB stars were computed using STERNE and SPECTRUM [6]. Cool star spectra were computed using Kurucz model atmospheres and SYNTHE [7]. χ^2 minimization was carried out using SFIT [6].

Full results are reported in [2]. We find that sdB stars in composite systems coincide in $T_{\rm eff}$ and $\log g$ with those of sdB stars with non-composite spectra both in our own sample and in independent samples. The cool companions are seen to be G stars on the main sequence. According to [3], such stars are produced by stable Roche Lobe overflow whilst the more massive star was close to the tip of the red-giant branch and are expected to have very long orbital periods.

It is well known that sdB stars typically have lower than normal surface helium abundances $y = n_{\rm He}/n_{\rm H}$ due to the downward diffusion of helium in the stellar atmosphere [9]. For all composite systems in our sample, we found $y \leq 0.01$. The majority of the remainder have $0.01 \leq y \leq 1.94$. It has been proposed [10] that sdB stars may be divided into three groups of helium stars, one of which we further subdivide:
– i) sdB stars with single spectra showing no radial velocity changes,
– ii) sdB stars with single spectra showing large velocity variations and periods of hours to days, a) having a low-mass main-sequence companion and b) having a white dwarf companion,
– iii) sdB stars with composite spectra showing small or no velocity variations and periods $\sim$ years.
Combining our measurements of y with previous measurements [8], we find that group (i) all have $y \geq 0.01$, group (ii) have $0.01 \leq y \leq 0.03$ and group (iii) all have $y \leq 0.01$. In order to explain this phenomenon we suggest that:
– i) single sdBs are formed from HeWD+HeWD mergers [4],[11] and have a smaller hydrogen reservoir than other sdBs, so y reaches some minimum even with diffusion.
– ii) for sdBs in short-period orbits, tidal perturbations occur at intervals shorter than the diffusion timescale (10^5 y) and so diffusion is disrupted.
– iii) sdBs in synchronous long-period orbits experience a much lower tidal disruption and diffusion is most effective at reducing surface helium.
The statistical basis for this hypothesis requires improvement. Its confirmation will be important for understanding sdB evolution.

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