Physical parameters for subdwarf B stars with composite spectra

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Abstract

Intermediate-resolution spectra have been obtained for a number of subdwarf B stars having both single and composite spectra. Physical parameters have been determined for the sdB stars and, in composite-spectrum systems, their cool companions. For these binaries, we have developed a method which uses the blue-optical spectrum to determine the effective temperatures of both stars, the surface gravity of the hot stars and the radius ratio of the system. The surface gravity of the cool star is measured using the infrared calcium triplet. The surface gravities of these cool companions identify them as main-sequence stars with masses in the range $0.8-1.2M_\odot$. There is evidence that the composite-spectrum sdBs are more helium-poor than single-spectrum sdBs.

Introduction

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 be a major contributor, but proof that a large fraction are binaries has taken a decade to establish. Whilst others have recently identified many sdB stars in short-period binaries with unseen companions, we have focused on those sdB stars in which the spectrum of the secondary can be seen. We previously studied these systems by means of their flux distributions (Aznar Cuadrado & Jeffery 2001) and shown that the secondaries are probably main-sequence G stars. In this study, published recently in full by Aznar Cuadrado & Jeffery (2002), we report an analysis of their optical and near-infrared spectra.

Observations

Observations were obtained at the Isaac Newton and William Herschel Telescopes at the La Palma Observatory in 1997 and 1998. Spectra were obtained in the blue ($\lambda \sim 4000-4700$Å) and near-infrared ($\lambda \sim 8000-8800$Å) and mostly at a resolution $R \sim 5\,000$. All spectra were reduced using standard procedures.

Spectral Analysis

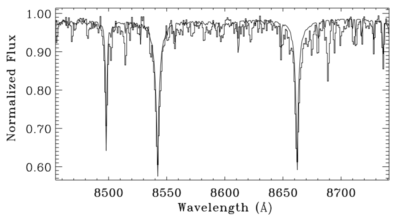

Figure 1. Normalized red spectrum of the composite PG 2110+127 around the infrared calcium triplet (histogram) together with the best fit model spectrum (polyline).

The infrared triplet of ionized calcium was recognised as a good indicator of a late-type companion in composite sdB spectra by Jeffery & Pollacco (1998) and is an excellent measure of cool star surface gravity. Our aim was to the measure the effective temperatures, surface gravities, surface helium abundances and radius ratios of the sdB stars and their companions in our sample. This was achieved by finding the best-fit model spectra within a model grid using χ^2 minimization. Model atmospheres and synthetic spectra for the sdB stars were computed using STERNE and SPECTRUM (Jeffery et al. 2001). Cool star spectra were computed using Kurucz model atmospheres and SYNTHE (Kurucz 1993). The χ^2 minimization was carried out using SFIT. One result is shown in Figs. 1 and 2.

Table 1. Results for composite sdB stars

Star	$T_{\rm eff:1}$	$\log g_1$	y_1	$T_{\rm eff:2}$	$\log g_2$	R_2/R_1
PG 0110+262	21 000	5.17	<0.01	5 250	4.53	3.2
PG 0749+658	25 400	5.70	<0.01	5 000	4.58	3.5
PG 1104+243	32 850	5.40	0.01	6 400	4.30	5.9
PG 1701+359	32 500	5.75	<0.01	6 000	4.60	2.7
PG 1718+519	29 000	6.00	<0.01	5 200	4.55	4.8
PG 2110+127	26 500	5.20	<0.01	5 400	4.40	4.7
PG 2135+045	28 400	4.80	<0.01	5 000	4.40	3.1
PG 2148+095	30 000	4.90	<0.01	5 700	4.40	3.0

Composite sdB stars

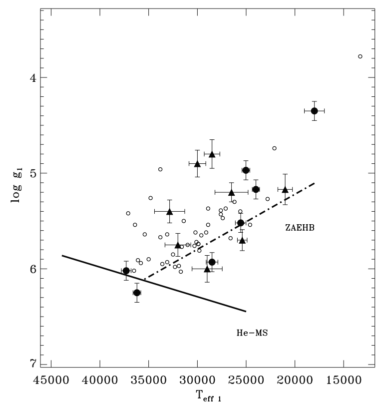

Figure 3. Position of single (filled circles) and composite sdB stars (filled triangles) in the ($\log g_1$–$T_{\rm eff:1}$) diagram. Open circles represent the position of an homogeneous (Maxted et al. 2001).

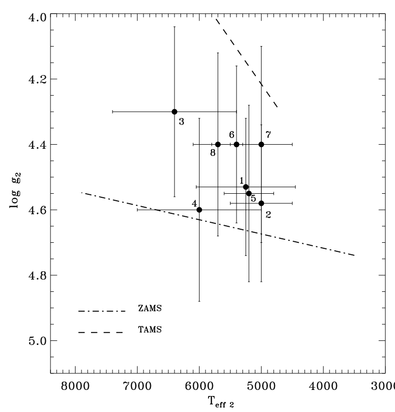

Figure 4. Position of cool companions to composite sdB stars in the ($\log g_2$–$T_{\rm eff:2}$) diagram. Labels refer to sequential number in Table 1.

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 (Fig. 3). The cool companions are seen to be G stars on the main sequence (Fig. 4).

Helium Abundances

We also measured the surface helium abundance $y = n_{\rm He}/n_{\rm H}$ for both composite and single sdB stars in our sample. For all composite systems, $y \lesssim 0.01$. For other sdBs, the majority have $0.01 \lesssim y \lesssim 1.94$. Following Saffer et al. (2001) we consider three groups of helium stars, one of which we subdivide;

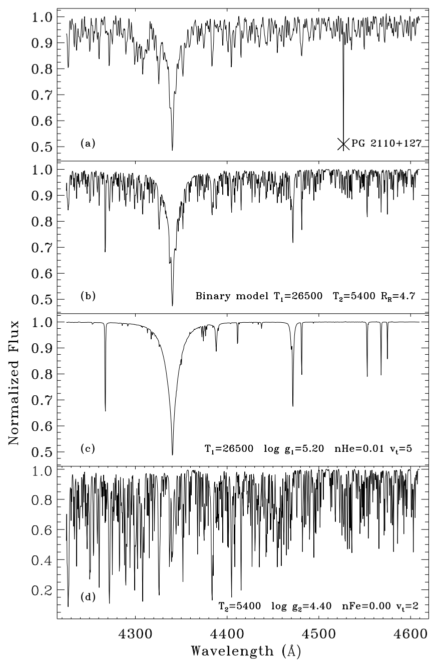

Figure 2. Normalized blue spectrum of the composite PG 2110+127 (a) together with the best fit composite model spectrum (b) formed by adding models with (c) and (d) with a radius ratio R_2/R_1=4.7. Model spectra have been velocity shifted and degraded to match the observations. × marks a CCD defect.

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,
iia) as above having a low-mass mains-sequence companion,
iib) as above having a white dwarf companion,
iii) sdB stars with composite spectra showing small or no velocity variations and periods ∼ years.

Together with the results of Maxted et al. (2001), our measurements show that group (i) all have $y \geq 0.01$, group (ii) have $0.01 \lesssim y \lesssim 0.03$ and group (iii) all have $y \lesssim 0.01$.

We suggest that the y measurements may be explained for each group as follows:
i) single sdBs are formed from HeWD+HeWD mergers (Iben 1990, Saio & Jeffery 2000) 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 low tidal disruption and diffusion is most effective at reducing surface helium.

sdBs with $y \to \infty$ (negligible hydrogen) are considered in a separate poster (Ahmad et al. 2002).

References

Ahmad A., Jeffery C.S., Woolf V.M. 2002, this conference

Aznar Cuadrado R., & Jeffery C.S. 2001, A&A, 368, 994

Aznar Cuadrado R., & Jeffery C.S. 2002, A&A, 385, 131

Iben I., Jr. 1990, ApJ, 353, 215

Jeffery C.S., & Pollacco D. 1998, MNRAS, 298, 179

Maxted P.F.L., Heber U., Marsh T.R., & North R.C. 2001, MNRAS, 326, 1391

Saffer R.A., Green E.M., Bowers T.P. 2002, 12th European Conf. on White Dwarfs, ASP Conf Ser., 226

Saio H., Jeffery C.S. 2000, MNRAS, 313, 671