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SPECTRAL ANALYSIS OF sdB-He STARS FROM THE SDSS

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Abstract. We present spectral classification and physical parameters of a sample of "helium-rich" sdB-He stars from spectra obtained from the SDSS archive. The spectral classification was carried out using an automated neural network, and the physical parameters were derived using LTE model atmospheres. The results indicate that most of these stars are not typical He-sdB stars but rather are normal sdB stars with slight helium enrichment. This is most likely a result of the use of a different definition of "helium-rich" in the initial SDSS classification to that used more widely in the field.

Key words: stars: chemically peculiar – early-type, subdwarfs, fundamental parameters

1. INTRODUCTION

Subluminous B stars form the dominant population of faint blue stars in our Galaxy down to a limiting magnitude of $B \approx 16$ mag. These so-called subdwarf B (sdB) stars are thought to be low-mass core helium burning stars with a thin hydrogen envelope. The surfaces of sdB stars are predominantly helium-deficient due to diffusion and gravitational settling. However, a small number have extremely helium-rich atmospheres. The evolution of these "helium-rich subdwarf B" (He-sdB) stars has recently been the subject of much debate involving both single and binary star evolution.

Only a very small fraction (∼5%) of sdB stars identified in previous surveys of faint blue stars like the Palomar Green survey (Green et al. 1986) and the Edinburgh Cape survey (Kilkenny et al. 1997) are helium-rich. A small number of stars discovered amongst the many thousand hot subdwarfs in the recent Quasar survey – the Sloan Digital Sky Survey (SDSS) have been reported to show strong helium lines and labelled 'sdB-He' (Harris et al. 2003).

In this study we used an artificial neural network (ANN) to classify spectra of sdB-He stars from the SDSS and to derive fundamental atmospheric parameters. The aim was to determine whether sdB-He stars are similar to He-sdB stars. This would increase the number of known helium-rich subdwarfs for further studies.

2. DATA MINING

Where available, reduced spectra were manually extracted from the SDSS Data Release server using coordinates listed in Harris et al. (2003). The spectra were then normalized using the continuum provided in the fits file. The normalized spectra were then classified and parameterised. It should be noted that the spectra analysed here are moderate resolution (∼3 Å) and have a typical signal-to-noise (S/N) ratio of ∼40.

3. CLASSIFICATION

We have classified the SDSS sdB-He sample onto the MK-like system defined by Drilling et al. (2000). As the hot subdwarfs do not fall within the scope of the original MK system, Drilling et al. (2000) have extended and refined the earlier work of Drilling (1996) and Jeffery et al. (1997) to construct a three-dimensional MK-like classification scale for these stars.

This scale is based upon a sample of spectra from a number of sources, covering the wavelength region 4050–4900 Å at a resolution of 2.5 Å. It defines a spectral type running from sdO1 to sdA, analogous to MK spectral classes, and uses luminosity classes IV–VIII, where most hot subdwarfs have a luminosity class ∼VII. A helium class has been introduced, which runs from 'He0' to 'He40', based on H, He I and He II line strengths.

Table 1. Classifications of the SDSS sdB-He sample as determined by the ANN. Error estimates are ∼2 subtypes for spectral type, ∼1 subclass for luminosity, and ∼4 subclasses for the helium class.

Name [SDSS J+]	n_{He}	ANN classification
09 40 44.08+00 47 59	0.16	sdB0 VIII:He23
11 38 40.69−00 35 31	0.01	sdB3 V:He1
12 43 46.38+00 25 34	0.05	sdB1 V:He23
12 54 10.86−01 04 08	0.01	sdB3 III:He5
13 17 45.80+01 04 50	0.01	sdB0 VI:He3
13 45 45.24−00 06 41	0.15	sdO9 VII:He21
13 46 35.68−00 18 04	0.09	sdA2 IV:He0
13 57 07.35+01 04 54	0.36	sdO6 VII:He30
14 15 56.68−00 58 14	0.21	sdB8 VI:He14
14 39 17.64+01 02 51	0.01	sdB6 V:He3
14 45 14.93+00 02 49	0.02	sdB1 VII:He11
15 27 08.31+00 33 08	0.45	sdO9 VIII:He35
15 29 05.62+00 21 37	0.06	sdO9 VII:He10
15 42 38.43−00 37 58	0.07	sdA2 III:He2

As our intention is to classify large quantities of spectra obtained from digital sky surveys such as the SDSS, we have trained an artificial neural network (ANN) to perform classifications onto the Drilling et al. (2000) scale. The ANN is a feed-forward back propagation network with an input layer of 901 nodes, two hidden layers of 5 nodes each, and an output layer of 3 nodes from which is obtained the spectral type, luminosity class, and helium class values determined by the network. The ANN was trained for 700 iterations on the same set of hot standards used by Drilling et al. (2000), with the spectra having been velocity corrected and resampled onto a uniform wavelength grid of 4050–4950 Å at a dispersion of 1 Å per pixel.

The results of applying the ANN to our sdB-He sample are presented in Table 1. Each spectrum was velocity corrected and resampled onto the same wavelength grid as was used for training the ANN. Error estimates (1σ) for each of the parameters determined by the ANN are ∼2 subtypes for spectral type, ∼1 subclass for luminosity, and ∼4 subclasses for the helium class.

The spectra from Ahmad & Jeffery (2003) were also classified with the ANN to check for consistency as these have previously been manually classified by J. S. Drilling. The ANN classification with the manual classification, within the above errors.

4. SPECTRAL ANALYSIS

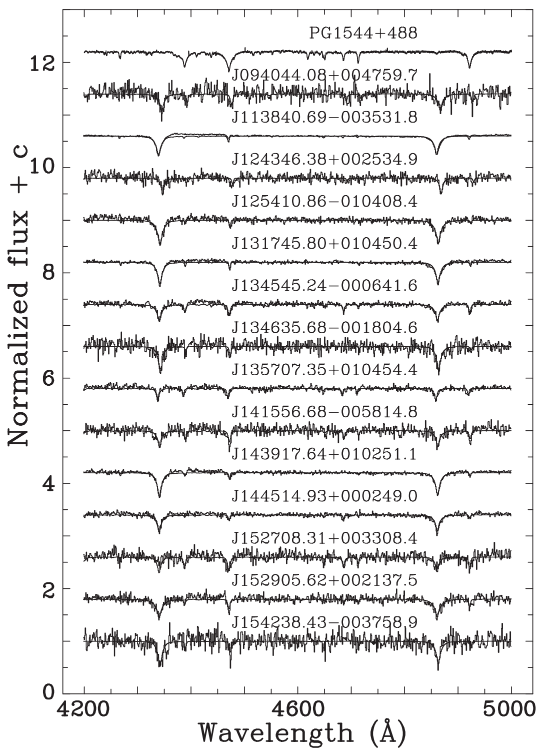

Fig. 1. Optical spectra of sdB-He stars (thick line) along with best fit model. The spectrum of the He-sdB star prototype – PG1544+488 is plotted on the top for comparison.

The physical parameters effective temperature ($T_{\rm eff}$), surface gravity ($\log g$) and helium abundance ($n_{\rm He}$) were measured from the optical blue (4200–5000 Å) spectra (Figure 1) using the latest version of the spectral fitting code SFIT2 and grid of high-gravity LTE models (cf. Ahmad & Jeffery 2003).

Note that the blue ends of the SDSS spectra are incorrectly normalized when corrected using the continuum provided by the SDSS therefore the region from 3900–4200 Å was not considered in the model fit. Given the low quality of the SDSS spectra the errors in $T_{\rm eff}$ are ± 1000 K, in $\log g$ are ± 0.4 and $n_{\rm He}$ are ± 0.05.

The sdB-He stars are plotted on the $T_{\rm eff}$ vs. $\log g$ diagram using the derived parameters in Figure 2. The respective helium abundances are listed in Table 1 as number fraction. From their position on the $T_{\rm eff}$ vs. $\log g$ diagram (Figure 2), half of our sdB-He stars are too luminous to be subdwarfs, the others have a distribution typical of He-sdB stars.

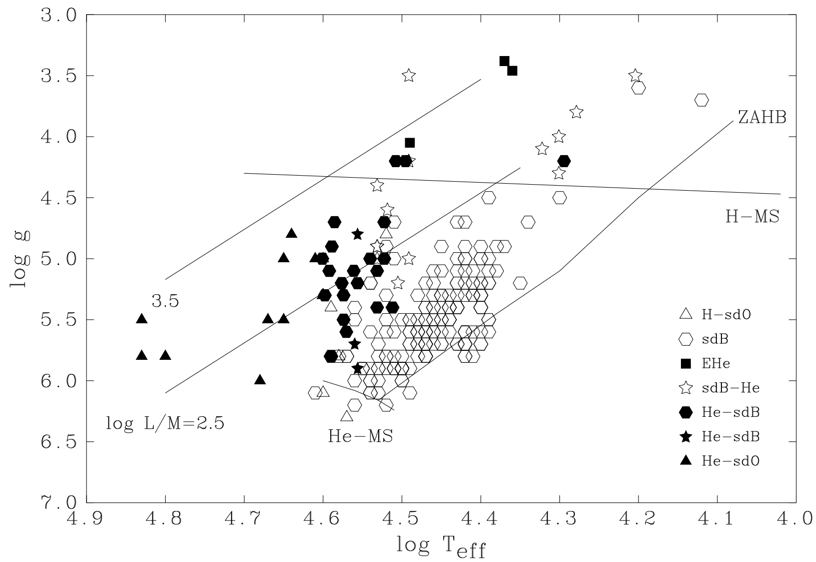

Fig. 2. Position of sdB-He stars on the $T_{\rm eff}$ vs. $\log g$ diagram shown with open star symbol. Other helium-rich objects like extreme helium (EHe) stars and He-sdO stars are shown with filled symbols. He-sdB stars from other work are shown by filled star symbol. For references see Ahmad & Jeffery (2003).

5. CONCLUSIONS

We have classified and parameterised a set of spectra of stars identified as sdB-He in the SDSS. It is clear from both spectral classification as well as parameterization that most of these stars show very little helium enrichment. Half of the stars in our sample have surface gravities too low to be subdwarfs. Out of the remaining subdwarfs only a handful are helium-rich (i.e. having $n_{\rm He} \geq 0.10$ or He class > 20), again pointing out the need for a homogeneous classification scheme for hot subdwarfs.

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