Research Article

Simon Kreuzer*, Andreas Irrgang, and Ulrich Heber

Spectroscopy of hot subdwarf binaries

Abstract: We present a status report of our spectroscopic analysis of subdwarf binaries consisting of a subdwarf and a F/G/K-type main-sequence companion. These systems selected from SDSS photometry show significant excess in the (infra-)red which can not be explained by interstellar reddening. Inspection of SDSS spectra revealed that most of them are composite spectrum sdB binaries. Once their spectra are disentangled, a detailed spectral analysis can be carried out. It reveals T_{eff}, log g and the metal abundance of each individual star. The cool companion is of particular interest, because its spectrum reveals the original chemical composition of the binary.

1 Introduction

Binaries consisting of a hot subdwarf and a F/G/K-type main-sequence companion are important to understand the outcome of interacting binary evolution. Their origin and formation history is still partially unclear. The spectral analysis is rendered difficult, because the contribution of both stars to the composite spectrum needs to be disentangled. Here, we present a status report of our spectroscopic analysis of subdwarf binaries.

2 Spectral analysis strategy

To model composite spectra, a numerical code was developed which allows quantitative spectral analysis. The PHOENIX grid (Husser et al., 2013) of stellar spectra for the F/G/K stars as well as a grid of synthetic spectra calculated from non-LTE model atmospheres (Nemeth et al., 2012) for the subdwarf component were used. The code allows us to decompose the spectrum of a binary system and hence find the contribution of each star to the combined flux. In order to obtain the best fitting combination of parameters of both stars a standard Chi-square minimization fitting routine is used. The analysis reveals T_{eff}, log g, and the helium abundance of the subdwarf and T_{eff}, log g, the metal

abundance of the cool companion. Reddening due to interstellar extinction is also taken into account. In order to test the code, it is applied to sets of mock spectra. High velocity horizontal branch and sdB stars were selected from a sample consisting of 6500 stars from the SDSS data base by colours (see Figure 1). Quantitative analyses of 3 stars (SDSS J083350+110104, SDSS J161943+240716, SDSS J215054+131651) spread amongst the 65 outliers in Figure 1 are carried out using SDSS and BOSS spectra (see Figure 2). From an error analysis using confidence maps we show that even low resolution (R $\sim$ 2000) and low S/N ($\sim$ 40) spectra provide enough information to determine the parameters listed above with sufficient accuracy. Finally, the high-resolution spectrum of PG1104+243 was analyzed. We observed a high degeneracy between the surface gravities of both stars. Furthermore, the accurate calibration is an important issue. Our routine is fully automated and can be applied to a large sample of spectra to search for binary systems in future work.

3 Preliminary Results

In two-colour diagrams composite spectrum sdBs are found as seemingly reddened outliers to the single star squences because the cool companion provides more flux in the (infra-)red. The spectra of 33 of the outliers are obvious composite spectrum sdBs which could be confirmed by visual inspection using line identifications (*e.g.* Mg triplett around 5170 Å). Only one of them was identified as a cataclysmic variable, 31 are sdB composite binary candidates. We used the new code to analyse three stars from the sample using SDSS and BOSS spectra where one of them did not show obvious signs of a cool companion in

Corresponding Author: Simon Kreuzer: Dr. Karl Remeis-Observatory & ECAP, Astronomical Institute of the Friedrich-Alexander University Erlangen-Nuremberg, Sternwartstr. 7, 96049 Bamberg, Germany; Email: simon.kreuzer@fau.de
Andreas Irrgang, Ulrich Heber: Dr. Karl Remeis-Observatory & ECAP, Astronomical Institute of the Friedrich-Alexander University Erlangen-Nuremberg, Sternwartstr. 7, 96049 Bamberg, Germany
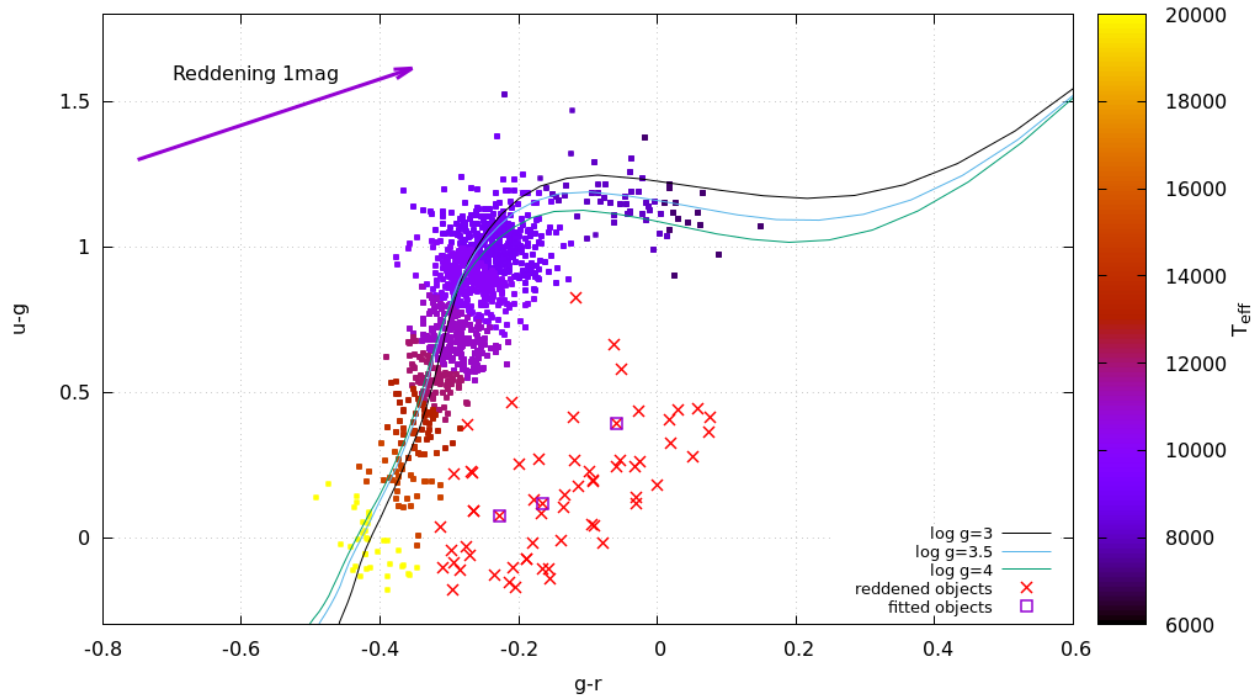
Figure 1. Color-color diagram of a hot star sample, over-plotted with lines of constant log *g* according to Castelli & Kurucz (2004). The sample is divided 'by eye' into different temperatures. The reddening vector corresponds to a reddening of 1 mag due to interstellar extinction, according to Kim & Lee (2007). Objects marked as red asterisks seemingly show strong reddening, but interstellar extinction is unlikely to be the cause of the red excess. Visual inspection of their spectra revealed that most of them have a cool companion. Objects marked with squares were fitted using our new code. Plot adapted from Kreuzer (2013).
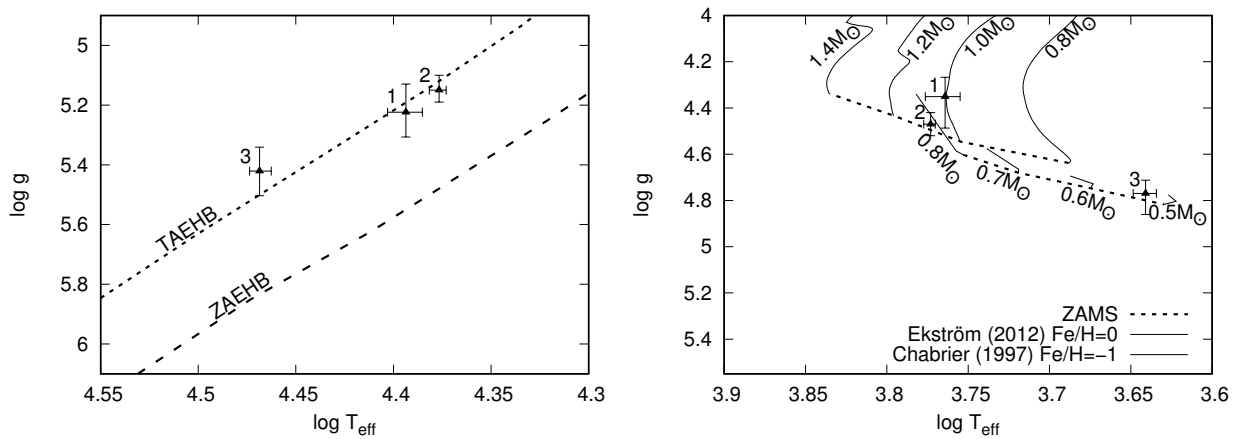

Figure 2. Left: : Fitted parameter of the hot subdwarf of three candidates (1: SDSS J083350+110104, 2: SDSS J161943+240716, 3: SDSS J215054+131651) from the SDSS sample, overplotted with zero and terminal age extreme horizontal branch (ZAEHB and TAEHB, respectively) tracks from Dorman et al. (1993). The sdB primaries lie close to the TAEHB. Right: Fitted parameters of the cool companion of the same candidates from the SDSS sample, overplotted with the evolutionary tracks from Chabrier & Baraffe (1997) (sub-solar metalicity) and Ekström et al. (2012) (solar metalicity).

the spectrum. The results are shown in Figure 2. The sdB primaries are formed close to the terminal age extreme horizontal branch, while the cool companions fit to commonly accepted evolutionary models for main sequence stars. Fi-

nally, the high-resolution spectrum of PG1104+243 was analyzed and compared to Vos et al. (2012). All free parameters agreed within their error ranges.

4 Outlook

The long-term goal is to study technical possibilities in the quantitative spectroscopy of multiple-star systems and the development of a fast method for their decomposition. By determining the metalicity of the cool companion, the binary may be associated to a specific stellar population *e.g.* the Galactic disk or the Halo population. A combination with a photometric analysis of SEDs would be rewarding to constrain the parameters more strictly. Furthermore, this tool will provide important constraints on the population in addition to the 3D kinematics which will be provided by Gaia.

References

Husser, T.-O., Wende-von Berg, S., Dreizler, S., Homeier, D., Reiners, A., Barman, T. et al. 2013, A&A, 553, A6.

Németh, P., Kawka, A., & Vennes, S. 2012, MNRAS, 427, 2180-2211.

Vos, J, Østensen, R.H., Degroote, P., De Smedt, K., Green, E.M., Heber, U. et al. 2012, A&A, 548, 6.

Castelli, F. & Kurucz, R. L. 2004, ARA&A, 5087.

Chabrier, G. & Baraffe, I. 1997, A&A, 327, 1039-1053.

Kim, S. S. & Lee, M. G. 2007, PASP, 119, 1449–1461.

Kreuzer S., 2013, A search for HVS candidates via simulation of trajectories, B. Sc. thesis, University Erlangen-Nuremberg, Bamberg, Germany.

Ekström, S., Georgy, C., Eggenberger, P., Meynet, G., Mowlavi, N., Wyttenbach, A. 2012, A&A, 537, A146.

Dorman, B., Rood, R. T., & O'Connell, R. W. 1993, ApJ, 419, 596–614.