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Stellar Wind Signatures in sdB Stars?

U. Heber

Dr. Remeis-Sternwarte, Astronomisches Institut, Universität Erlangen-Nürnberg, Bamberg, Germany

P. F. L. Maxted

School of Chemistry & Physics, Keele University, UK

T. R. Marsh, C. Knigge

University of Southampton, Department of Physics & Astronomy, UK

J. E. Drew

Imperial College of Science, Technology and Medicine, London, UK

Abstract. Subdwarf B (sdB) stars form the blue end of the horizotnal branch. Their peculiar atmospheric-abundance patterns result from diffusion processes. However, diffusion models fail to explain these anomalies quantitatively. From a NLTE model-atmosphere analysis of 40 sdB stars, we found that the more luminous (i.e. more evolved) stars have anomalous Hα and He I 6678Å line profiles, i.e. the lines are too broad and shallow, and may even show some emission. We interpret these anomalies as the signatures of a stellar wind, the first such detection in this class of star (if confirmed). Mass-loss may also explain the peculiar abundance patterns seen in sdB stars. High-quality UV spectra are needed to confirm that these stars do have stellar winds.

1. Introduction

Subdwarf B (sdB) stars are core-helium-burning stars with very thin hydrogen envelopes, which all have masses of 0.46-0.50 solar masses and can be identified with models of extreme-horizontal-branch (EHB) stars (Heber 1986).

The atmospheres of sdB stars are typically deficient in helium by more than one order of magnitude, but there is a wide spread from solar He/H to stars with He/H$<10^{-4}$. These He abundances are much too large to be accounted for by diffusion, i.e. by the balance between radiative levitation and gravity (Michaud et al. 1989), which predicts He abundances *lower* by two orders of magnitudes than the average observed He abundance of He/H$\approx10^{-2}$ (see Fontaine & Chayer 1997). Inasmuch as the diffusion timescale is small (10^4 yrs) compared to the EHB lifetime (10^8 yrs), *no* He should be visible in the radiative atmospheres: the puzzle here is not so much a lack of He, but an excess in the sdB atmospheres.

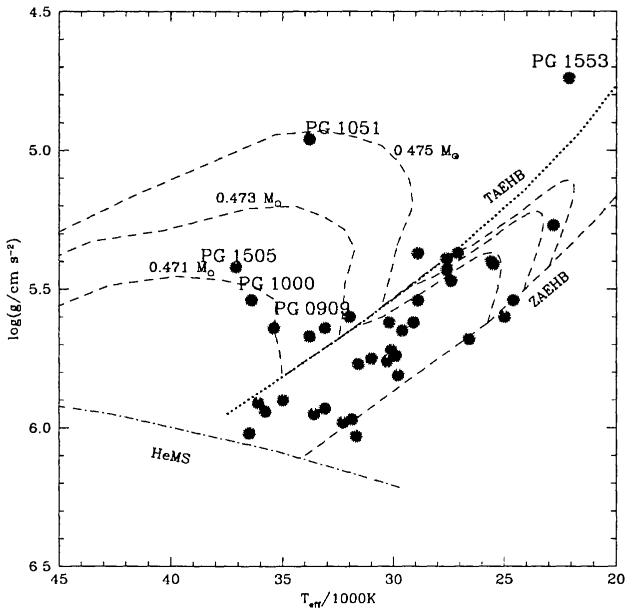

Figure 1. ($T_{\rm eff}$, $\log g$) diagram for the Maxted et al. (2001) sdB sample. Note that most stars are well matched by models for the extreme horizontal branch. Five stars (labeled by the first 4 digits of their PG catalog names) have already evolved from the EHB.

2. Diffusion and Mass Loss

Modeling of metal-diffusion in sdB stars is still in its infancy. First attempts were published by Charpinet et al. (1997) for Fe, and Unglaub & Bues (2001) for C, N and O; these had little success fitting the observational constraints (except for iron). Stellar winds have frequently been suggested as an explanation. The first realistic calculations were made by Fontaine & Chayer (1997) and Unglaub & Bues (1998, 2001). The observed He abundances can indeed be explained if a mass-loss rate of 10^{-14} to $10^{-12} M_\odot$/yr is adopted. Yet it is not clear whether diffusion models incorporating mass-loss can explain the metal-abundance anomalies, at the same time as the He abundance.

Mass-loss has been detected in sdO stars, which are, however, considerably more luminous than sdB stars. For example, HD128220B ($T_{\rm eff}$=40600K, $\log g$=4.5; Rauch 1993) displays strong, broad, blue-shifted N V lines produced in its stellar wind. Because sdB stars are less luminous, we expect the mass-loss rates to be lower than in sdO stars, and therefore harder to detect. Indeed, up to now there is no observational proof for mass-loss and, therefore, the mass-loss rate is still a free parameter for diffusion models.

The first hints about stellar winds came from the quantitative analysis of optical blue spectra obtained during the survey of Maxted et al. (2001). They derived atmospheric parameters of 40 sdB stars from Balmer (Hβ to H9) and He I lines using static NLTE model atmospheres (see Napiwotzki 1997). Their results are shown in Figure 1. As can be seen, all but five stars fall onto the Extreme Horizontal Branch, as expected. The five stars above the EHB in Fig. 1

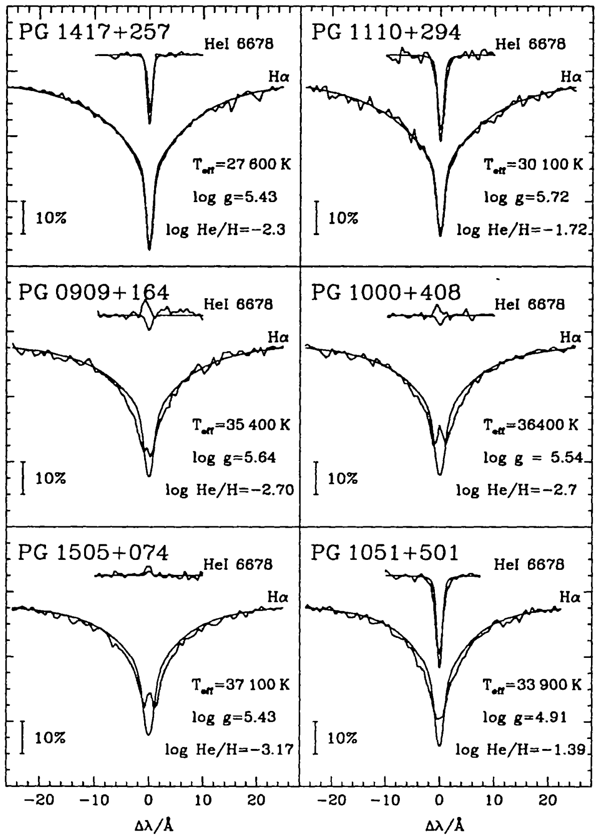

Figure 2. Comparison of synthetic line profiles of Hα and He I, 6678Å for two sdB stars on the EHB (top panels) and the post-EHB stars PG0909+164, PG1000+408, PG1505+074 and PG1051+501. Note that these are not fits to the observed line profiles. Model parameters have been derived from a fit to the stars' blue spectra. Note also that the Hα profiles in PG0909+164, PG1000+408 (middle panel) are slightly asymmetric.

probably have already evolved from the EHB. A comparison of theoretical Hα line profiles (synthesized for the atmospheric parameters derived from the stars' blue spectra, see Maxted et al. 2001) with the observations showed perfect matches for all stars except the four post-EHB stars (see Fig. 2).

By plotting the goodness-of-fit versus luminosity (Fig. 3) for the stars, a clear trend becomes obvious. The quality of the fit deteriorates with increasing luminosity. In the optical spectral range, Hα is the line most sensitive to stellar winds. Line asymmetries are another signature indicative of a stellar wind.

Because mass-loss rates of hot stars are expected to increase with luminosity (Pauldrach et al. 1998), we conjecture that the observed deviations of the Hα lines from the predictions of static NLTE models for the most luminous stars in our sample are caused by stellar winds. The somewhat asymmetric profiles of PG0909+164 and PG1000+408 make these two targets the best candidates.

sdB stars are a fairly homogeneous group of stars which evolve to higher luminosities (from $10^{-3.4}$ to 10^{-2} Eddington luminosities, see Fig. 3), into the regime where winds switch on. If one can show that some sdB stars do have

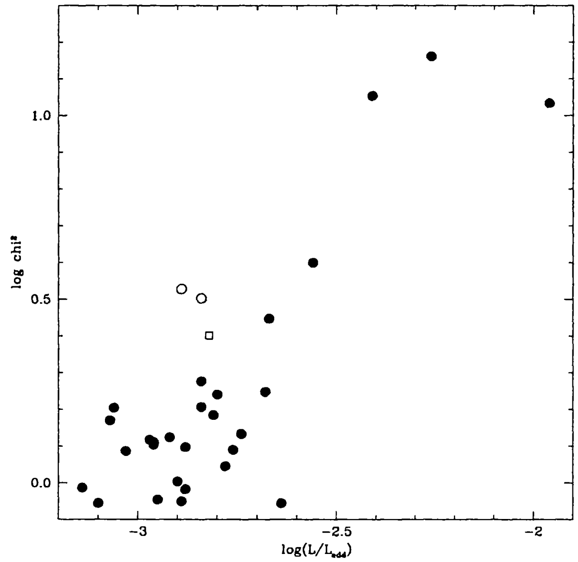

Figure 3. Quality of fit (reduced χ^2) as a function of stellar luminosity (expressed in units of the Eddington luminosity). The open symbols mark known (square) or suspected rotating stars. Rotational broadening has not been taken into account.

winds, it will provide an important test for line-driven wind models. High-quality UV spectra are needed to establish whether these stars actually have stellar winds.

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