HST/STIS observations of sdBV stars: testing diffusion and pulsation theory

S. J. O’Toole (otoole@sternwarte.uni-erlangen.de) and U. Heber
Dr. Remeis-Sternwarte, Astronomisches Institut der Universität
Erlangen-Nürnberg, Sternwartstr. 7, Bamberg D-96049, Germany

P. Chayer
Dept. Physics and Astronomy, Johns Hopkins University, 3400 N. Charles St.,
Baltimore MD 21218, USA

G. Fontaine
Département de Physique, Université de Montréal, CP 6128, Station Centre-ville,
Montréal, QC H3C-3J7, Canada

D. O’Donoghue
South African Astronomical Observatory, PO Box 9, Observatory 7935, South
Africa

S. Charpinet
Observatoire Midi-Pyrénées, 14 Avenue E. Belin, 31400 Toulouse, France

Abstract. We present the initial results of an abundance analysis of echelle UV
spectra of 5 hot subdwarf B (sdB) stars. These stars have been identified as core
helium burning objects on the extreme Horizontal Branch. Around 5% of sdBs
show short-period acoustic mode oscillations. Models predict that these oscillations
are due to an opacity bump caused by the ionisation of iron group elements. The
necessary metal abundance has to be maintained by diffusive equilibrium between
gravitational settling and radiative levitation. However, analyses of high resolution
optical spectra has revealed that we cannot discriminate between pulsating and
non-pulsating sdBs on the basis of the surface iron abundance. We have therefore
obtained HST/STIS observations of 3 pulsators and 2 non-pulsators in the near and
far UV to measure the surface abundance of elements that are unobservable from the
ground. The overall aim of our study is to test diffusion and pulsation calculations
by searching for significant differences between these surface abundances.

Keywords: stars: subdwarfs — stars: abundances

1. The problem

Models of pulsating subdwarf B stars suggest that the pulsations are
driven by an opacity bump due to iron and other metallic species at
temperatures of $\sim 2 \times 10^5$ K in the sdB envelope (see Charpinet et al.
2001 for a review). The models require a sufficient abundance of Fe
at an appropriate level in the envelope, an abundance which can be
maintained by diffusive equilibrium between gravitational settling and
radiative levitation. While these models give rise to pulsations in hot sdBs, they do not yet explain why, when given two spectroscopically similar stars, one will pulsate and the other will not. This overlap in the log \( g - T_{\text{eff}} \) plane was demonstrated by Koen et al. (1999). Fontaine & Chayer (1998) suggest different mass-loss rates as one possible explanation, whereby a star with a higher mass-loss rate may have a depleted Fe abundance, and therefore not show pulsations.

The goal of this project is to investigate the metal abundances of 3 pulsating sdBs and 2 non-pulsating sdBs using HST/STIS UV spectra, and to determine whether or not the latter stars’ abundances are significantly different from those of the former stars. With these observations we can derive abundances for elements not observable from the ground, e.g. the iron group. If there are no significant differences between the abundances patterns, then this may suggest that the stellar winds suggested by Fontaine & Chayer are the discriminating factor.

The second (but no less important) goal of the project is to compare detailed abundances in all five stars with the predictions of diffusion theory.

2. The targets

Observations were made using the Space Telescope Imaging Spectrograph (STIS) onboard HST. We used medium resolution gratings in echelle mode in both the far UV (grating E140M) and the near UV (grating E230M). The FUV spectra contain 42 useful orders with wavelength range 1149-1730 Å, while the NUV contain 40 orders with wavelength range 1635-2365 Å. Of the 3 pulsators observed, PG 1219+534 and Feige 48 were observed for two orbits in both the far UV and near UV, while PG 1605+072 was observed twice in the far UV, but only once in the near UV. Ton S-227 and Feige 66 were observed once in the far and once in the near UV. These two stars do not show pulsations, but are spectroscopic twins of PG 1219+534.

3. Initial results: metal abundances in the NUV

Due to the large number of metal lines, it was difficult to determine the continuum level for each spectrum, meaning that the errors for each abundance presented may be underestimated. In order to overcome the substantial line blending in the spectra, we used a solar metallicity model and adjusted the abundances of each element until \( \chi^2 \) was minimised. This was done using Michael Lemke’s version of
Figure 1. Abundances for four sdB stars, derived from near UV HST/STIS spectra.

From our preliminary analysis, we find no significant differences between abundances of pulsating and non-pulsating sdBs. In particular the abundances of PG 1219+534 and Ton S-227 are remarkably similar. There is a noticeable difference between the abundance pattern of Feige 48 and the other 3 stars. The hotter, higher surface gravity stars all show supersolar iron group abundances, while for Feige 48 these...
elements have solar abundances. The stand out element is calcium, which is supersolar in all 4 stars. These effects appear to be due to “selective diffusion”, i.e. the interplay between radiative levitation and gravitational settling. It is yet to be seen whether diffusion models can explain these effects.

4. Comparisons, conclusions and future work

We can compare the results presented here with previous work by Heber et al. (2000) and Baschek et al. (1982). For Feige 48 and PG 1219+534, Heber et al. measured (or set upper limits) for 6 species we have measured from high-resolution spectra taken with the Keck telescope. A slightly lower Fe abundance is the only noticeable difference between our results and that of Heber et al. All other elements are in reasonable agreement. This lower Fe abundance is also seen in FUSE spectra (Chayer, these proceedings). Because of the relative inaccuracy of the atomic data available to the Baschek et al. (1982) analysis of Feige 66 using high-resolution IUE spectra, it is difficult to compare their results with ours. However, we can say that, apart from calcium, the agreement appears to be reasonably good. Overall we believe that our analysis is consistent with the analyses of Heber et al. (2000) and Baschek et al. (1982).

All of the high log $g$ stars have supersolar iron group element abundances, and in particular PG 1219+534 and Ton S-227 appear to be very similar, while Feige 48, with a substantially lower log $g$, has approximately solar abundances. Do these results present a problem for the Charpinet et al. Fe driving model? At this stage we do not want to draw any premature conclusions: more abundance analyses of pulsating and non-pulsating sdBs are needed to see any heavy element abundance patterns (e.g. Chayer et al., in preparation). High resolution optical and FUV observations or more sdB stars should clarify the driving mechanism.

5. References

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