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Is there a correlation between metal abundance and pulsation in sdB stars?

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Abstract. Like several other classes of pulsating stars (e.g. the PG 1159 stars), pulsating subdwarf B stars coexist with non-pulsators in the same region of the $T_{\rm eff} - \log g$ diagram. And as with other pulsators, the reason for this is unclear. The pulsations in sdBs are believed to be driven by the heavy element ionisation (of especially iron) at the base of the stellar photosphere. It has been suggested that perhaps the amount of iron-group elements at the stellar surface may be a discriminating factor. We have analysed high-resolution UV echelle spectra of 5 sdBs obtained using HST/STIS to test this hypothesis and find that there is no clear and consistent difference between the abundances of pulsators and non-pulsators. This poses the question: what is the physical reason for pulsators and non-pulsators to be spectroscopically similar?

Key words. Stars: abundances – Stars: subdwarfs – Stars: oscillations

1. Introduction

After the discovery of pulsations in sdB stars (Kilkenny et al. 1997), it soon became clear than there is an overlap between pulsators and non-pulsators in the in the $T_{\rm eff} - \log g$ diagram (Koen et al. 1999). In this study the question we set out to answer is: what is the physical reason why, when examining a pair of otherwise spectroscopically identical sdBs, one pulsates and the other does not? The pulsation theory of Charpinet et al. (1997) for pulsating sdBs suggests the pulsation driving is due to the ionisation of heavy elements, especially iron, at the base of the photosphere. Diffusion calculations by Charpinet et al. suggested that the surface iron abundance of the pulsators should be higher than the non-pulsators. Observations by, e.g. Heber & Edelmann (2004) and Heber et al. (2000), find that the iron abundance in most sdBs is approximately solar, independent of pulsation. Other iron-group elements are not easily detectable from ground-based observations, so we have to go to space. The focus of this paper is therefore the search for different abundances of iron-group elements in pulsators and non-pulsators. We refer the reader to O'Toole & Heber (2005) for a full discussion of all our results.

2. Observations and Spectrum Synthesis

Our observations were obtained using the *Space Telescope Imaging Spectrograph* (STIS) onboard the *Hubble Space Telescope*

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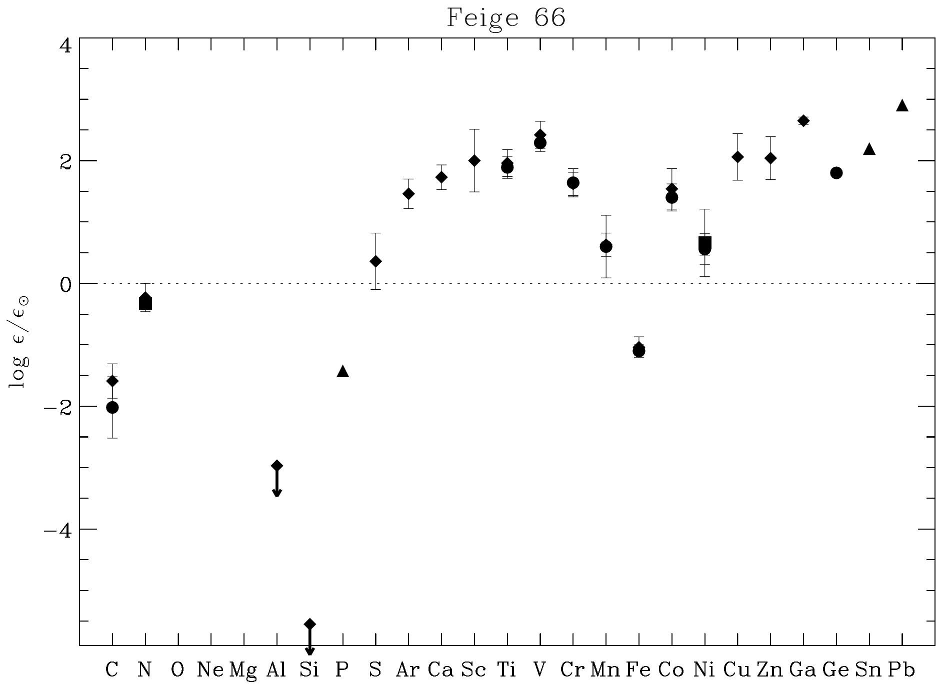

Fig. 1. Abundances of 41 ions measured in Feige 66. The symbols represent the following: diamonds – doubly ionised; circles – triply ionised; squares – quadruply ionised; and triangles – measurements from one line only.

(HST) with program #8635 (PI: Heber). We observed three pulsators (Feige 48, PG 1219+534, PG 1605+072) and two non-pulsators (Feige 66 and CD −24°731) in the near- and far-UV (NUV and FUV) with the high-resolution echelle gratings E230M (R = 30 000) and E140M (R = 45 800). The wavelength ranges of the spectra are 1700-2370 Å in the NUV and 1160-1730 Å in the FUV. Additionally, two very high-resolution spectra of the non-pulasting sdBs Feige 66 and CPD −64°481 were found in the HST archive. These observations were made with the E140H grating (R = 114 000) and cover the wavelength range 1163-1363 Å.

The UV spectra of sdB stars are very complex, with large numbers of blended iron-group absorption lines making any analysis very difficult. Thankfully the rotation velocities of these stars is very low (typically less than ∼5 km s^{-1}), so that there are at least some unblended lines that can be measured. The exception is PG 1605+072, where rotation and a large pulsation velocity amplitude conspire to make even analysis using spectrum synthesis nearly impossible. We do not consider this star in this paper. Also, as CD −24°731 is in a close binary, we consider it is not as good a comparison star to the apparently single PG 1219+534 as Feige 66, which is also apparently single. For this reason SB 707 will not be considered here.

A more detailed description of our analysis technique will appear in a forthcoming paper (O'Toole & Heber 2005). Briefly, equivalent widths of as many lines as possible were measured, and where the continuum was poorly defined we have carried out spectrum synthesis to determine abundances.

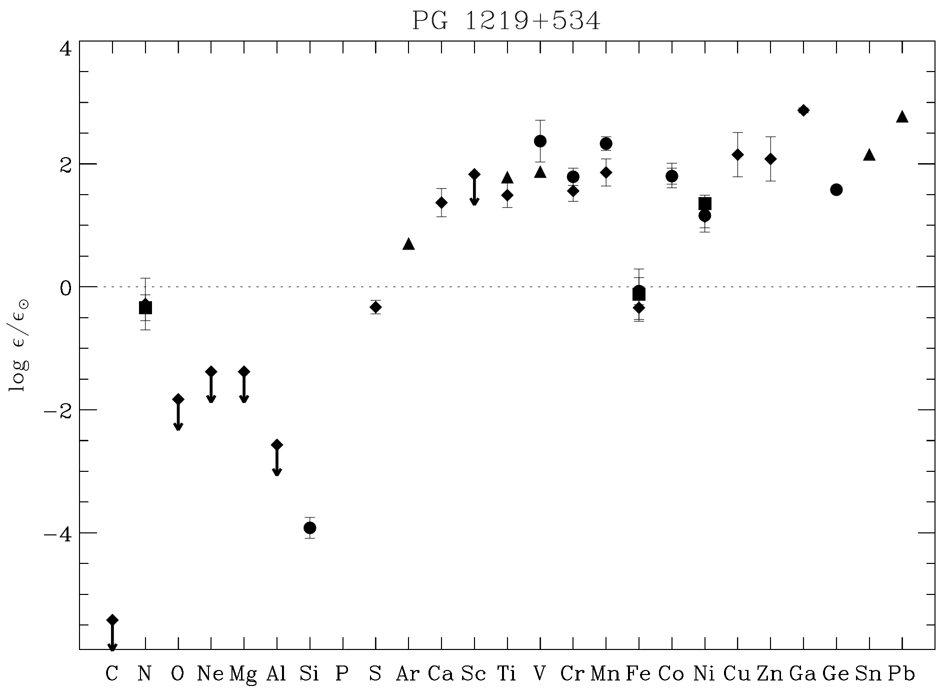

Fig. 2. Similar to Figure 1, but for PG 1219+534.

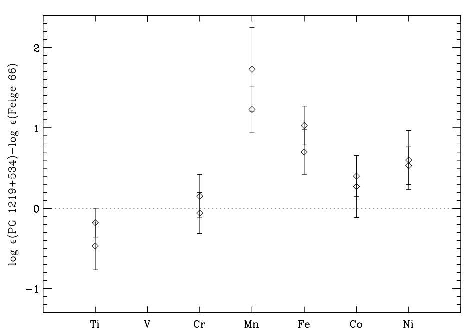

Fig. 3. Difference between iron-group abundances for PG 1219+534 and Feige 66. Upper limits are indicated by downwards arrows.

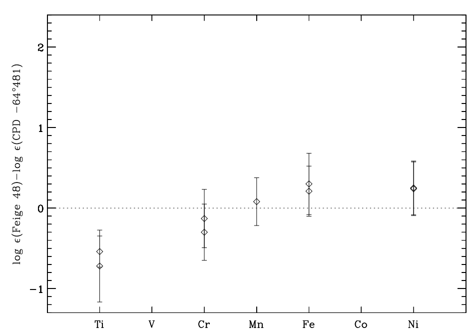

Fig. 4. Similar to Figure 3, but for Feige 48 and CPD −64°481.

3. Results

In our sample we have two pulsator/non-pulsator pairs – that is, pairs of stars with similar parameters: PG 1219+534/Feige 66 and Feige 48/CPD −64°481.

The abundance patterns of Feige 66 and PG 1219+534 are shown in Figures 1 and 2, respectively. While the light elements (He–Si) are depleted, most heavy elements are strongly enriched by a factor of ∼ 100. This is true for the iron group with the notable exception of iron itself (about solar), as well as the very heavy elements such as lead. Among the light elements, there are two main differences. Feige 66 shows lines of carbon, but no silicon, whereas for PG 1219+534 this is reversed. The nitrogen abundance is identical for the two stars.

In Figure 3 we show the differences between the iron-group abundances in this pair of objects. There is a noticeable difference in iron, nickel and especially manganese in these objects. PG 1219+534 – the pulsator – has 8-10 times more iron, about 3-4 times more nickel and around 300 times more manganese than Feige 66. Based on these results alone, we might be in a position to claim some kind of correlation. Things are never so simple, however.

Heavy elements are also enriched compared to solar composition but to a much lesser extent in Feige 48 and CPD *–64°481*. Differences between iron-group abundances for Feige 48 and CPD –64°481 are shown in Figure 4. Here, unlike the previous pair of stars, we see no clear over-abundance in Feige 48 – the pulsator – compared to CPD –64°481, the non-pulsator, although we do note that the latter star has more titanium that the former. And while there may be a very small difference between iron and nickel abundances, it is within the measurement errors. The two stars in fact show almost identical abundance patterns overall. Note also from Figures 3 and 4 that sdBs with similar temperatures have the same chromium abundance.

4. Discussion

As mentioned in Section 1, the initial diffusion calculations by Charpinet et al. (1997) suggested that the surface abundance of iron might be higher in the pulsators than the nonpulsators. From our results we can say that this is most likely not the case. We do note however, that based on new calculations by Fontaine (these proceedings), no difference is to be expected. The fact that we *do* see a difference in iron abundances between the hot pair but not the cooler pair suggests more theoretical work on the diffusion of iron, along with other iron-group elements, needs to be done. What other effects are at play here?

One interesting thing to note from comparison of Figures 1 and 2 is that silicon is present, although strongly depleted, in PG 1219+534 but almost completely absent from Feige 66. A sharp drop-off in silicon abundance in sdBs hotter than ~32 000 K has been observed by, e.g. Lamontagne et al. (1985). This question has been addressed in more detail by O'Toole (2004); however, in this paper we speculate that perhaps the detection of silicon in PG 1219+534 is a sign it is closer to the Zero-Age Extreme Horizontal Branch than Feige 66, possible if the objects have difference core masses. However, the cooler pair of sdBs, Feige 48 and CPD –64°481 have almost identical silicon abundances, indicating that silicon is also not a factor that discriminates between pulsators and nonpulsators.

Since there is currently no way to distinguish between a pulsating sdB and a nonpulsating one spectroscopically, we must ask, is there any discrimintaing factor?

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