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FUSE observations of intermediate temperature DA: atmospheric parameters and metal abundances

J Dupuis[1], V Hénault-Brunet[2], P Chayer[3], S Vennes[4] and J W Kruk[5]

[1] Agence Spatiale Canadienne,6767 Route de l'Aéroport, Longueuil, Québec J3Y 8Y9, Canada
[2] Département de Physique, Université de Montréal, C.P. 6128, Succ. Centre-Ville, Montréal, Québec H3C 3J7, Canada
[3] Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218, USA
[4] Department of Physics and Space Sciences, Florida Institute of Technology, Melbourne, FL 32901, USA
[5] Department of Physics and Astronomy, The Johns Hopkins University, 3400 N. Charles St., Baltimore, MD 21218, USA

E-mail: `jean.dupuis@asc-csa.gc.ca`, `henault@astro.umontreal.ca`, `chayer@ststci.edu`, `svennes@fit.edu`, `kruk@pha.jhu.edu`

Abstract. We present results from our analysis of a sample of DA white dwarfs having effective temperature below 25,000 K observed with the *FUSE* satellite with the goals of better understanding the origin of metals detected in the atmosphere of these stars. When possible, we combine the *FUSE* spectra with the *IUE* spectra and determine atmospheric parameters by fitting the Lyman line profiles. In general we find a good agreement with published values based on fits of the Balmer series. We observe that the continuum in the blue wing of the Lyman α line profile is generally lower in comparison with model spectra and that the discrepancy appears to become less important at higher effective temperature. The agreement between models and observations is excellent at wavelengths shorter than 1100 Å, which gives us confidence in the determination of atmospheric parameters. Finally, using adopted atmospheric parameters; we have performed a detailed analysis of the composition of these stars. In several instances, we have observed the presence of silicon and in one case that of carbon. For each star in the sample we have either measured or set an upper limit on the presence of key species such as C II, C III, Si III, and Si IV. We then compare the measured abundances with equilibrium abundance predicted by radiative levitation theory for each star. In this limited sample, we find that when detected, the abundance of silicon is in good agreement with theory. However there are several cases where the upper limits are smaller than the predictions and one case where it is considerably larger.

1. Introduction

White dwarfs are generally believed to have metal-poor atmospheres because of short timescales for gravitational settling at their surface. Radiative levitation can effectively offset gravitational settling down to effective temperatures as low as 20,000 K according to Chayer et al. (1995). In view of the recent discoveries of metal lines in white dwarfs cooler than 20,000 K by Zuckerman et al. (2003), it is of interest to assess the role played by radiative levitation in intermediate temperature white dwarfs
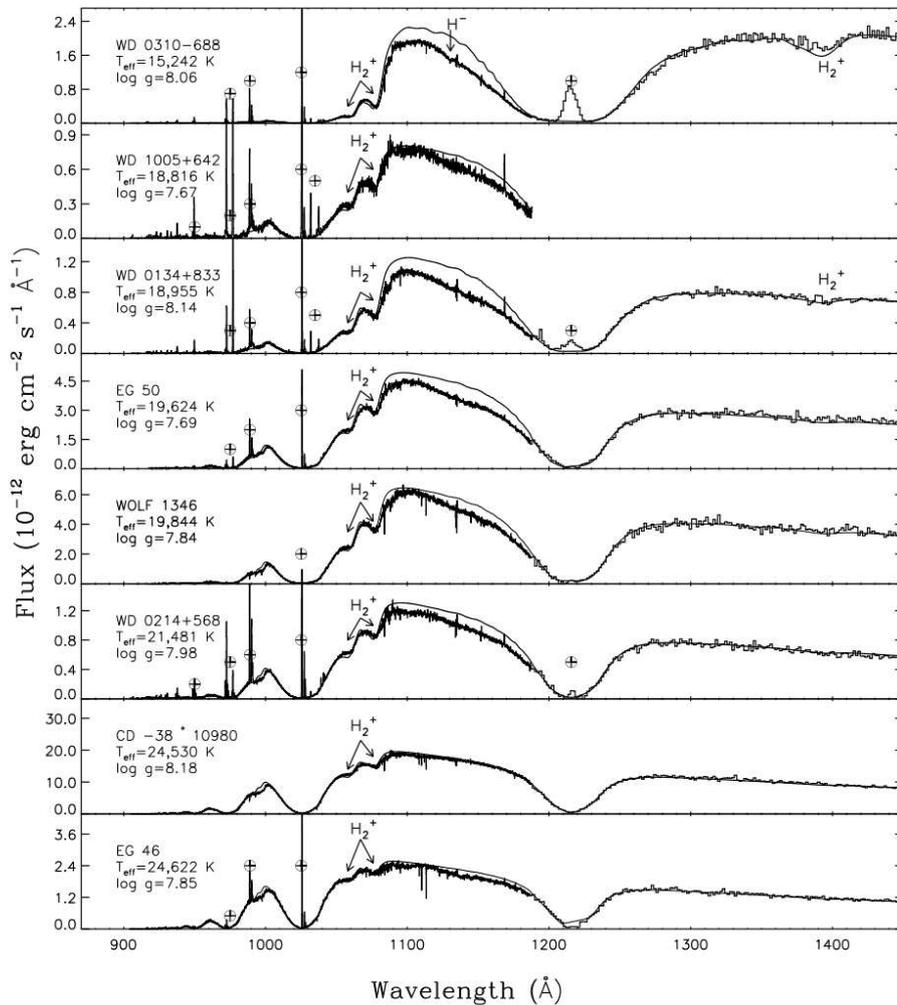
Figure 1. Combined *FUSE* and *IUE* DA spectra (in histogram) compared to the best-fit models (full black line). Airglow emission lines are identified by the Earth symbol. When visible, H^- absorption features and quasi-molecular H_2^+ absorption features are identified. Stellar parameters determined from Lyman series fit are shown on the left side of each graph.

2. Analysis

We observed several DA white dwarfs with temperature lower than 25,000 K down to 12,000 K with the *FUSE* satellite under guest observer time. We also augmented the sample with observations of other objects available in the *FUSE* archive. When available, low dispersion *IUE* spectra of these stars were combined with the *FUSE* spectra.

The Lyman series profiles are a powerful diagnostic to measure the stellar parameters of DA white dwarfs. We therefore fitted a grid of model spectra to the observed far-UV spectra (see Fig.1 for a representative subset) of our sample of stars in order to determine these atmospheric parameters and compare the results with those obtained from fits of the Balmer series profiles. In general, we find a satisfactory agreement between the two techniques, although

some inconsistencies still persist in the blue wing of Lyman-α.

With these validated stellar parameters, we computed grids of synthetic spectra for key species likely to be present in the far-UV spectrum of white dwarfs, and used them to measure or set upper limits on the photospheric abundance of C, Si, P, and S. Silicon is detected in four of the stars of the sample (see best-fit spectra in Fig. 2 and Fig. 3) and also carbon in one of them.
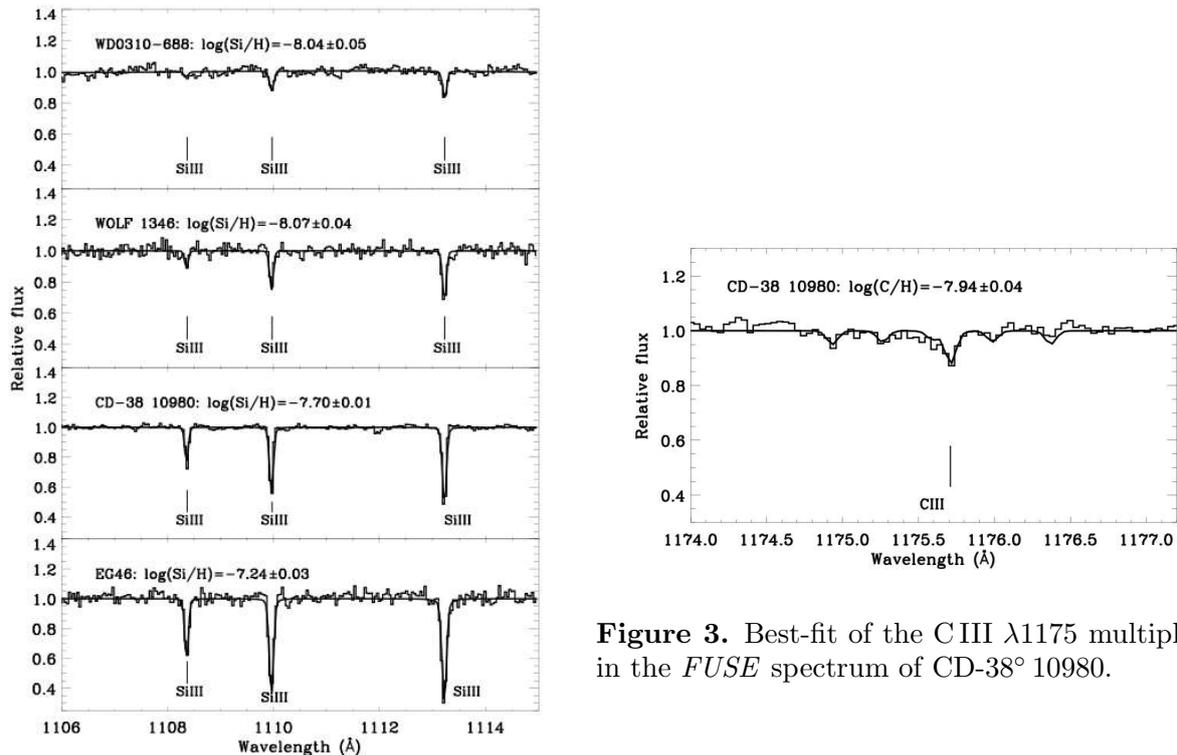

Figure 3. Best-fit of the C III λ1175 multiplet in the *FUSE* spectrum of CD-38° 10980.

Figure 2. Sections of far-UV spectra showing detected Si III lines (in histogram) and the best-fit synthetic spectra (full curve).

3. Discussion

o Figure 4 shows the upper limits and abundances determined with the method discussed above for the larger sample of DA considered in our study. These results are compared with the equilibrium abundance predicted by radiative levitation theory (Chayer et al. 1995).

In the few stars where silicon is detected, there is relatively good agreement with the theory. However, when silicon is not detected, our upper limits often fall well below the predicted level. Although phosphorus is expected to be supported at a similar level, it is not detected in any of the stars in this sample, despite stringent upper limits in some cases. These very low upper limits call for the interplay of a mechanism capable of depleting the atmospheric reservoir of silicon and phosphorus. An hypothetical wind may be an interesting process to consider over evolutionary timescales, even though there is no strong evidence for significant mass loss in white dwarfs in this intermediate temperature range.

Carbon is detected in the spectrum of CD-38° 10980, well in excess of the abundance predicted by radiative levitation theory if we assume a photospheric origin for the detected carbon. We note
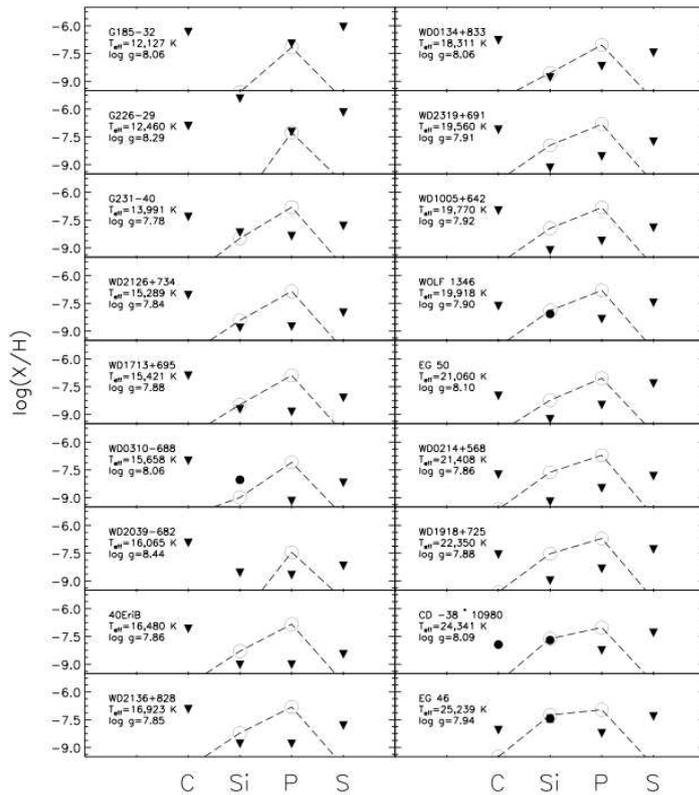
Figure 4. Logarithm of the number density of C, Si, P, and S relative to hydrogen for a sample of DA stars, assuming a photospheric origin. Upper limits are represented by upside down triangles and abundance measurements are represented by filled circles. Empty circles joined by dashed lines represent the abundances predicted by the equilibrium radiative levitation theory.

that the presence of carbon in the *FUSE* spectrum of CD-38° 10980 went unnoticed by Wolff et al. (2001). In case of an excess abundance with respect to radiative levitation predictions, we may explain the carbon abundance by accretion but this may ask for a peculiar abundance pattern of elements for the accreted material. It has also been proposed in Holberg et al. (1995) that the origin of carbon and silicon in this star may be circumstellar . For the other stars, the upper limits on the carbon abundance are not stringent enough to confront the theory.

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