Part III

Observations and Modeling of the Local Bubble and the SXRB

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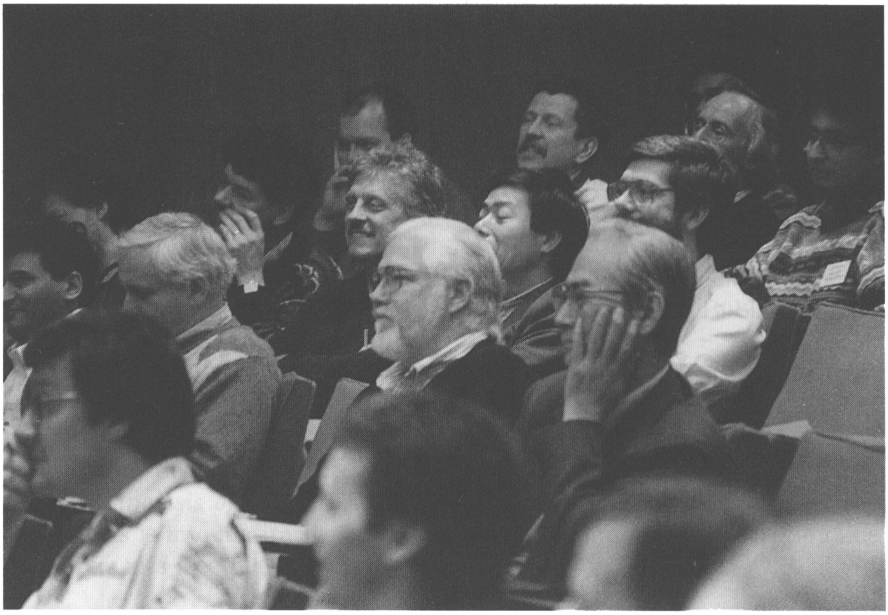

The audience wide awake even during long sessions.

The conference desk: always on the spot.

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The Interstellar and Circumstellar Environment of White Dwarfs

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Abstract. We have studied the EUV spectra of 13 DA white dwarfs, observed by the *EUVE* satellite, paying attention to the possible sources of absorbing material along the lines-of-sight in both the local interstellar medium and in the photospheres of the stars themselves. The range of interstellar column densities seen are consistent with our previous understanding of the local distribution of material. Absorption from interstellar He II is found in the direction of five stars, allowing us to measure directly the He ionization fraction and estimate, indirectly, that of H. The weighted mean ionization fractions along these lines-of-sight are 0.27 ± 0.04 and 0.35 ± 0.1 respectively. Where He II is directly detected, the observed ionization fractions are not correlated with direction or with the volume/column density of material along the line-of-sight. Furthermore, the limits on the amount of He II established in all other directions completely encompass the range of observed values. Indeed, all the data can be consistent with more or less constant He and H ionization fractions throughout the local ISM. However, observation of very hot DA stars, indicating higher He II columns, might contradict this picture if the material is not photospheric or circumstellar.

1 Introduction

It is generally accepted that the solar system resides inside a relatively dense local interstellar cloud a few parsecs across with a mean neutral hydrogen density of $\approx 0.1\text{cm}^{-3}$ (e.g. Frisch 1994, Gry et al. 1995). This cloud, the so-called local cloud or surrounding interstellar cloud (SIC) itself lies inside a region of much lower density, often referred to as the local bubble. The general picture that has built up is one where this bubble has been created by the shock wave from a past supernova explosion, which would also have ionized the local cloud. The current ionization state of the local cloud is then expected to depend on the recombination history of the ionized material i.e. the length of time since the shock wave passed through. However, if the flux of ionizing photons from hot stellar sources is significant, the net recombination rate may be reduced (Cheng & Bruhweiler 1990; Lyu & Bruhweiler 1996).

Prior to the launch of *EUVE*, few spectroscopic observations were available with which to study H and He in the local interstellar medium (LISM). With the ability to detect features arising from interstellar He I and He II, *EUVE* has presented us with an important and unique opportunity of providing direct tests of model predictions.

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2 EUV Spectroscopy

We present here a detailed study of a sample of 13 DA white dwarfs observed by *EUVE* . The details of our data reduction and analysis techniques can all be found in our recent papers (e.g. Barstow et al. 1997a). Briefly, we compared the predictions of synthetic white dwarf spectra, folded through a model of the interstellar opacity, with the observations to determine the physical parameters describing the star and the local ISM. The combination is specified by 7 independent parameters – effective temperature (T_{eff}), log surface gravity, helium abundance (or H layer mass for a stratified model) a distance/radius related normalisation constant, H I column density, He I column density and He II column density. However, from Balmer line fits to the optical data, T_{eff} and log g are known within narrow bounds. Furthermore, a measurement of V magnitude, from optical photometry, can be used to determine the normalisation. Hence, only four parameters are completely unknown.

3 The Ionization of the Local ISM

Photoionized He II can be clearly detected in 5 of the white dwarfs studied – GD659, REJ1032, PG1123, REJ2156 and GD246 (see e.g. figure 1), from which the He ionization fraction (f_{He}) can be calculated and the H ionization fraction (f_H) inferred (assuming a cosmic He/H ratio, see Barstow et al. 1997a). In other cases, only limits to the ionization fraction can be obtained. Values of f_H ($[N_H - N_{H\,I}]/N_H$) and f_{He} ($N_{He\,II}/[N_{He\,I} + N_{He\,II}]$)calculated from the best fit column densities are listed in table 1. There appears to be no particular relationship between direction and the degree of ionization measured. The weighted mean ionization fractions of He and H in those five directions where He II is detected are 0.27 ± 0.04 and 0.35 ± 0.1 respectively. In low column density directions, the absence of detected He II features could easily be a threshold effect because the edge is simply too weak to detect. It is clear that the level of the upper limits, the errors on the measured values and the range of uncertainty associated with the values implied from the model comparisons all overlap substantially. Hence, there is no evidence that the He and H ionization fractions are not close to the weighted mean values in any of the directions probed with these observations.

4 Evidence for Helium in the Spectra of Very Hot DA Stars

Our conclusion that helium could be uniformly ionized might be contradicted by recent studies of the very hot ($\approx$ 60000K) white dwarfs G191−B2B and REJ0457−281 (Lanz et al. 1996; Barstow et al. 1997b). To explain the EUV

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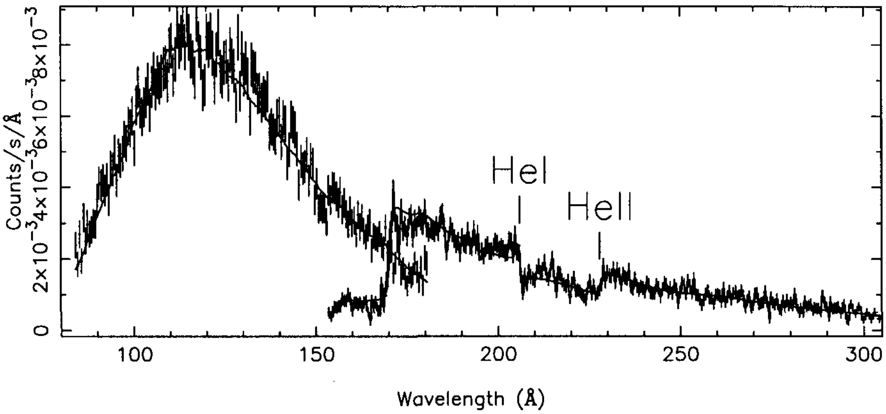

Fig. 1. EUV count spectra of REJ2156−546 compared to the best fit ISM/photospheric model, showing the interstellar absorption edges at 228Å (He II) and 206Å (He I). The apparent feature at 170Å is an instrumental artifact produced by aluminium in a thin film filter.

Table 1. The ionization fractions of H and He in the ISM.

Star	f_H			f_{He}		
	Value	-1σ	$+1\sigma$	Value	-1σ	$+1\sigma$
GD659	0.16	0.00	0.50	0.42	0.29	0.58
GD71	0.00	0.00	0.28	0.04	0.00	0.32
REJ0715−705	0.00	0.00	0.79	1.00	0.00	1.00
REJ1032+535	0.46	0.30	0.56	0.27	0.20	0.34
PG1123+189	0.43	0.13	0.65	0.20	0.15	0.26
GD153	0.00	0.00	0.28	0.00	0.00	0.36
HZ43	0.19	0.00	0.34	0.40	0.29	0.50
CoD−38 10980	0.00	0.00	1.00	0.00	0.00	1.00
BPM93487	0.17	0.00	1.00	1.00	0.00	1.00
REJ2009−605	0.00	0.00	0.63	0.04	0.00	1.00
REJ2156−546	0.34	0.00	0.57	0.39	0.28	0.46
GD246	0.20	0.04	0.45	0.23	0.17	0.30
REJ2324−547	0.57	0.00	0.74	0.13	0.00	0.35

spectra of both these stars it is necessary to include significant levels of He II opacity in the photospheric/interstellar models. If completely interstellar, the He II ionization fraction is ≈ 80% . Preliminary studies of several other stars near this temperature yield similar results (Barstow et al. 1997c). However, since any possible He II features must be blended with large numbers of heavy element lines in these objects, the presence of He II is only implied rather than directly detected. Furthermore, even if it is not an artifact of limitations in the stellar model atmospheres, it is impossible to decide whether the He II resides in the photosphere, in the circumstellar environment, or in the interstellar

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medium. Hence, while, as a group, these stars do not yet contradict the current results we must remain somewhat cautious.

5 Discussion

The value and apparent uniformity of the He and H ionization fractions we see are important in considering the physical mechanisms that might give rise to the levels of ionization observed. Recent measurements, made in the direction of ϵ CMa, indicate that the electron density in the local cloud is $\approx 0.09\text{cm}^{-3}$, giving a H ionization fraction no greater than 50% (Gry et al. 1995), in keeping with our result. Our observations are also consistent with the predictions of Lyu and Bruhweiler's (1996) time dependent ionization calculations, considering the recombination of the LISM following shock heating from a nearby supernova. For our mean ionization fractions, we estimate an elapsed time of 3-4 million years since the onset of the recombination phase.

In the light of this apparent agreement, we should consider whether we are sampling just material in local cloud or also in the surrounding medium. The latter is more tenuous but the effects are integrated over greater distances. Our data indicate that a significant fraction of the interstellar absorption observed lies outside the cloud in most of the lines-of-sight we have examined. Importantly, this is so for all those directions in which we detect ionized He. Hence, the ionization fractions reported here may not represent the conditions in the local cloud and the agreement with the measurements of Gry et al. (1995) and predictions of Lyu and Bruhweiler (1996) could be purely fortuitous.

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