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THE TEMPERATURE OF THE HOT DB GD 190

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Abstract. We are currently in the midst of an investigation of hydrogen and carbon abundances in hot DB white dwarfs. Our HST UV spectra give evidence that hot DBs contain traces of carbon which can be used to determine the temperatures of these objects. We present the results of our investigation of GD 190.

Key words: stars: interiors – stars: individual: GD 190

1. INTRODUCTION

White dwarfs are the evolutionary endpoints for the majority of stars. We have long known that they come in two dominant flavors based on atmospheric composition, with hydrogen atmospheres (DA) comprising 80 % of the population and helium atmospheres (DB) the remaining 20 %. The relative rarity and corresponding faintness of the DBs as a group makes them more difficult to study and hence their general properties are not as well understood as the DAs.

One of the primary uncertainties associated with hot DB white dwarfs is their measured temperatures. Accurate knowledge of $T_{\rm eff}$ for just these objects is a particularly important step towards locating and mapping the helium instability strip (Bradley & Winget 1994). The instability strip's observed location and whether all DBs with the appropriate temperatures pulsate, tell much about the overall similarity of DBs as a class and limit possible theoretical models for both driving mechanisms and convection.

As a pleasant offshoot of our ongoing investigation of carbon and hydrogen abundances in hot DBs, we have identified an additional method with which to accurately determine the temperatures of DBs between $\approx$ 21 000 and 25 000 K. Our HST UV spectra give evidence that hot DBs contain detectable traces of carbon (Provencal et al. 1999). White dwarfs in the temperature range mentioned above display features of both C I and C II. In the following analysis, we demonstrate for how this happy circumstance can be used to limit $T_{\rm eff}$ in the hot DB white dwarf GD 190.

2. THE DATA

In 1996, we obtained GHRS spectra of the hot DB white dwarf GD 190 (Fig. 1). The spectra are centered on 1335 Å, span approximately 35 Å and have dispersions of $\approx$ 0.07 Å per diode. Our exposure times were calculated to achieve a modest signal to noise ratio of about 25. The complete journal of observations is given in Table 1.

The data reduction process consists of flux and wavelength calibration transforming raw data into calibrated spectra describing flux as a function of wavelength. The primary steps of flux calibration include the elimination of dead diodes, conversion to count rates, removal of diode to diode variations, corrections for dead-time losses and the removal of vignetting effects. We subtract the background contribution and convert to absolute flux using the ratio of empirical count rates to established fluxes from spectroscopic standard stars. Wavelength calibration is achieved through observation of on-board calibration lamps. Most of the reductions are accomplished using the HST pipeline calibration routines in STSDAS.

Table 1. The complete journal of observations.

Observation	Instrument	Wavelength	Integration
GD 190			
z3g70107t	GHRS G160M	1330.6 Å	4132.3 s
PG 0112+104			
z3g60205m	GHRS G160M	1330.6 Å	3699.2 s

3. ANALYSIS

Our primary motivation for obtaining this data is the determination of the carbon surface abundance in GD 190. We rely primarily

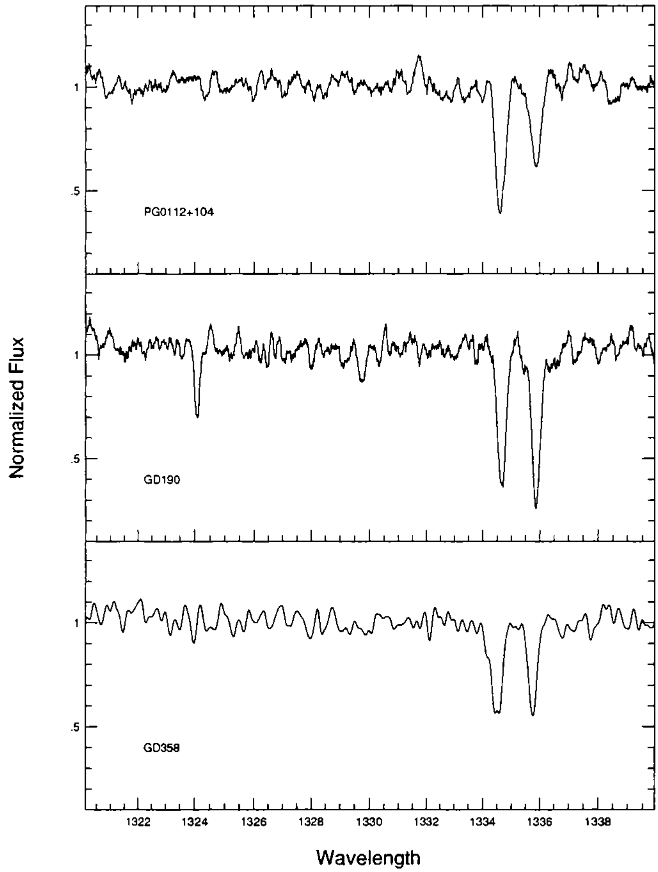

Fig. 1. GHRS spectra of PG 0112+104, GD 190 and GD 358 centered on 1330.6 Å. We clearly detect the C II doublet at 1334.532 and 1335.708 Å. While the blue component often originates in the interstellar medium, the 1335.708 Å line results from transitions to a level slightly above ground state and depopulates spontaneously in the ISM. The presence of both components demonstrates that the carbon is photospheric in all three cases.

on the 1335.708 Å line as we have shown that the ISM is an important contributor in the L α region (Provencal et al. 1996, Provencal et al. 1999) and therefore the 1334.532 Å line is contaminated by ISM absorption. The 1335.708 Å line transition arises from a level slightly above ground state and depopulates spontaneously under conditions in the ISM; it is free from contamination.

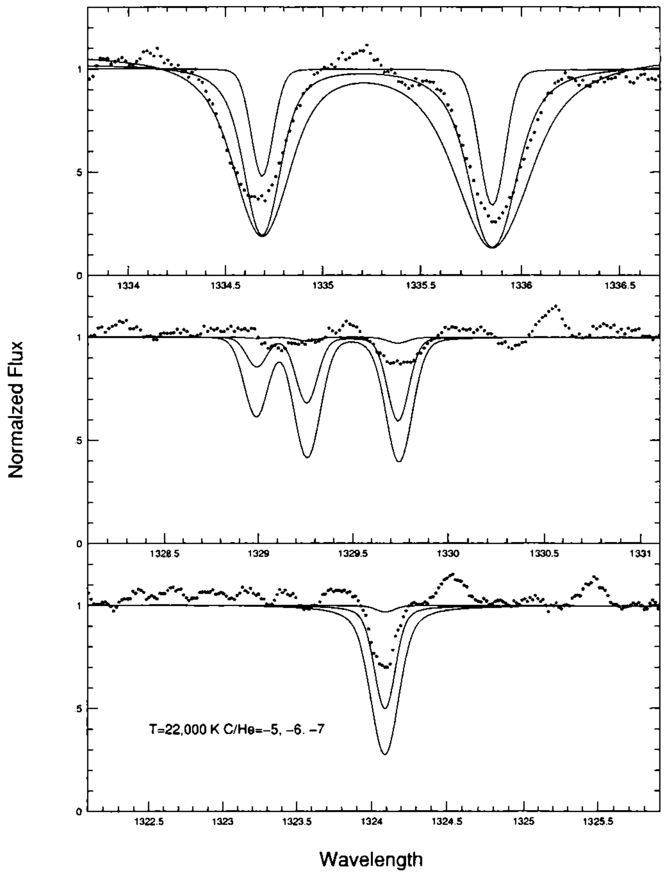

Fig. 2. GD 190 UV spectra near 1335 Å compared with 22 000 K $\log g = 8.0$ models (solid lines). The models have carbon abundances of log(C/He)=–5, –6, and –7. While the C II lines (top and lower panels) can be fit with an abundance of log (C/He) ≈ –6, we cannot simultaneously fit both ionization states with this temperature.

GD 190's spectra presents the added advantage of an additional C II line (1324.08 Å) and the presence of the C I 1329 Å multiplet. Fig. 2 compares the normalized spectra with 22 000 K models having carbon abundances of log (C/He) = –5, –6 and –7. The models are generated with the stellar atmospheres code TLusty (Hubeny, 1988). The temperature of 22 000 K is near the result of Beauchamp et al. (1999). We find we cannot fit C I and C II simultaneously.

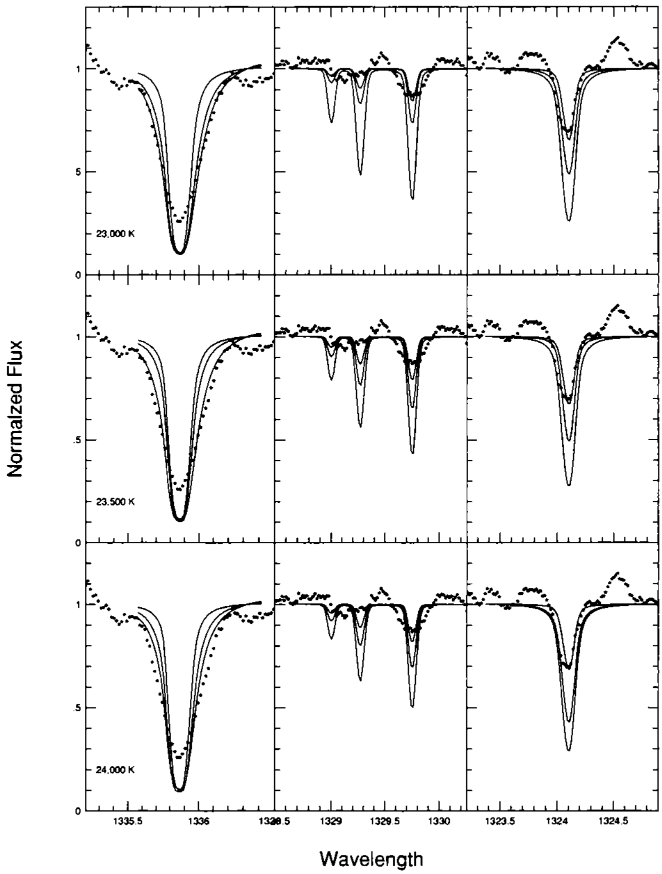

Fig. 3. An exploration of temperature and carbon abundance for GD 190. The first column presents the C II 1335 Å line, the second column is C I 1329 Å and the last column is C II 1323 Å. The top panel compares GD 190 with three theoretical 23 000 K models with log (C/He)= –5.2, –5.6, and –5.9 (solid lines). The middle panel increases the temperature to 23 500 K and the bottom panel uses 24 000 K models. All models are $\log g = 8.0$.

The C II features are fit quite nicely with an abundance of ≈ -6, but the C I features are not well predicted by that model.

In an attempt to reconcile the problem, we explored a range of reasonable temperatures. Fig. 3 presents models with temperatures ranging from 23 000 to 24 000 K and log (C/He) = –5, –5.5 and –6. Using simple chi-square analysis, we find a best fit of 23 500 ± 500 K and log (C/He)$=-5.5 \pm 0.3$. The modest signal to noise precludes a more precise fit, but we believe Figs. 2 and 3 show the temperature to be higher than 22 000 K because of C I's weakness but lower than 24 000 K because the C II 1335 Å line becomes too narrow.

4. CONCLUSIONS

Beauchamp et al. (1999) present an extensive analysis of optical spectroscopy of DB stars. The authors find that the location of the instability strip is sensitive to the amount of hydrogen mixed into the helium atmospheres. They find the instability strip between $22\,400 < T_{\rm eff} < 27\,800$ K for pure helium atmospheres and $21\,800 < T_{\rm eff} < 24\,800$ K for undetectable traces of hydrogen.

GD190 is a hot DB helping to define the red edge of the instability strip. Our analysis of its Lα spectrum places an upper limit of log (H/He) < -6 for the hydrogen surface abundance. (Provencal et al. 1999). The carbon based effective temperature of $T_{\rm eff} = 23\,500 \pm 500$ K places GD 190 within the pure helium instability and well above the hydrogen tainted instability strip as defined by Beauchamp et al. (1999).

Our sample of hot DB spectra in the 1335 Å region currently includes three stars, all of which display photospheric carbon. We believe that given spectra of improved S/N ratio we can accurately determine the temperatures of hot DBs between $21\,000 < T_{\rm eff} < 25\,000$ K.

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