TEMPERATURES FOR HOT AND PULSATING HELIUM-RICH (DB) WHITE DWARFS OBTAINED WITH THE *IUE* OBSERVATORY

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ABSTRACT. Ultraviolet energy distributions are analyzed for several hot, helium atmosphere DB white dwarfs, including the four known pulsating stars which define an empirical DB instability strip. Temperatures are derived exclusively from fits to the ultraviolet energy distributions. The blue edge of the empirical DB instability strip lies at 30,000 ± 4,000 K, and the red edge lies near 24,000 ± 2,000 K. The hottest DB star -- and the only known one hotter than the instability strip -- is PG0112+104 at or above 30,000 K. This leaves no known helium-atmosphere degenerate stars in the interval $30{,}000 \leqslant T_e \leqslant 45{,}000$K.

1. INTRODUCTION

The DB white dwarfs are those with helium-rich atmospheres that are hot enough for neutral helium lines to be seen in their spectra, but not hot enough for He II lines to be seen. Several important investigations have produced estimates of temperatures and other parameters for most of these stars, but the estimates remain very uncertain for those with $T_e > 18{,}000$ K. The determination of more accurate temperatures for the hotter DB stars is now important for two reasons: (1) Winget and collaborators have recently found several pulsating stars among the hottest known DB's, and it is important to establish the existence and the boundaries of the presumed instability strip for

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this new kind of variable star; (2) While the DB stars should range from about 11,000 K to about 40,000 K, above which He II lines will appear, there is currently no reliable determination of a DB having $T_e > 30{,}000$ K. At the same time, Wesemael et al. (1985) have analyzed nineteen of the hotter DO stars, and the coolest of these has $T_e \approx 45{,}000$ K. This leaves a gap at $30{,}000 < T_e < 45{,}000$ K in which no helium-atmosphere degenerate star is currently known.

The IUE observatory can play an important role in improving the temperature determinations for the hot DB stars. The IUE cameras cover a wavelength interval ($\lambda\lambda$1200-3000) which includes or is very near the Planckian peak; thus improved temperatures may be estimated from spectrophotometry of only modest quality. In the last few years, we have attempted to identify and observe with IUE the hot DB stars in the Palomar-Green Survey, as indicated from optical data. These include all four known pulsating DB stars. We report here the preliminary results of our ultraviolet spectrophotometry of these objects.

2. IUE ENERGY DISTRIBUTIONS AND EFFECTIVE TEMPERATURES

Low-dispersion IUE observations of several newly-observed PG objects were obtained in 1982-1984. Blanketed model atmosphere grids useful for comparison with these observations are available from Wesemael (1981), Koester (1980), and Wickramasinghe (1983). We have combined here the hotter Wesemael set with the cooler Wickramasinghe set (the W grid) for comparison with the observations and the predictions of the Koester models (the K grid). Two sets of IUE effective temperatures were derived for each observed star, one from the W and one from the K grid. The effective temperatures determined for our newly-observed objects will be given elsewhere.

In Figure 1 we illustrate the fitting of two of the hottest stars in our sample. GD358 is the first discovered pulsating DB star (Winget et al. 1982), while PG0112+104 was found to be hotter than GD358 based on optical spectrophotometry (Oke et al. 1984, hereafter OWK), and non-variable. Consistent fits for the SWP fluxes for both stars and both model sets are possible at temperatures of 29-30,000 K for PG0112+104 and 27-28000 K for the pulsating star GD358. In each case, the lower temperature is assigned from the K grid, while the W fit is 1,000 K higher. However, while there is good agreement between the K and W model fits to the IUE data for both hot stars implying that they differ in T_e by $< 2{,}000$ K, it is noteworthy that the temperature estimates using optical data (and the K grid) differ by a greater amount. OWK assign PG0112+104 a temperature of 28,900 K, in nice agreement with the IUE fits, and suggesting that this is the hottest known DB star. Yet the same authors (see Koester et al.

1985) favor an optically-derived temperature of 24,000 K for GD 358. The latter seems to be in sharp disagreement with the SWP region fits for both W and K models.

If we assume that an instability strip exists for DB stars (Winget et al. 1982, 1983) analogous to the well-defined temperature region of the ZZ Ceti (DA) variable stars, then these two stars may bracket the high temperature boundary near 27-28,000 K. Alternatively, since GD358 has the bluest energy distribution at IUE wavelengths of the four known pulsating stars, the high temperature boundary could be as low as 24,000 K if we use the optically-determined temperature.

In Figure 2, two somewhat cooler stars are plotted in the same way for comparison with the two grids. PG1654+160, which pulsates (Winget al. et 1984), appears to fit about 25-26,000 K, although the noisy LWR points appear too high (indicating a cooler temperature) for both model sets. The non-pulsating PG0853+164 may be assigned a fit near 22,000 K for both W and K curves. If there is a well-defined lower temperature limit to a pulsational instability strip, our results for GD190, 1654+160 and 1115+158 suggest that it is near 24-25,000 K, using IUE fluxes.

3. CONCLUSIONS

The temperature determinations reported herein from IUE data generally support the expectation of Winget and Fontaine (1982) and Winget et al. (1983) that an instability strip exists for pulsating DB stars. Realistically, the high temperature boundary is 30,000 ± 4,000 K, using IUE temperature determinations. The low temperature boundary is most likely within the interval 24,000 ±2,000 K. Of course we are a long way from establishing whether all stars within the instability region actually pulsate, but the ordering of temperatures made from using the IUE energy distributions (regardless of the values of temperatures assigned) is consistent with this hypothesis. The empirical instability strip seems to lie close to that predicted by Fontaine et al. (1984) using ML3 convection (26-29,000 K).

Following this investigation, there remains only one normal DB star, PG0112+104, with (1) a temperature likely to be above the high temperature boundary for pulsational instability, and (2) an effective temperature near 30,000 K or above. For this conclusion we emphasize that the OWK optical determination is in excellent agreement. The new IUE results strengthen the hypothesis of a temperature gap at 30-45,000K, between the several dozen known and well-studied DB stars and the ~ 20 hotter DO stars. The statistical significance of this result is discussed in Wesemael et al. (1985).

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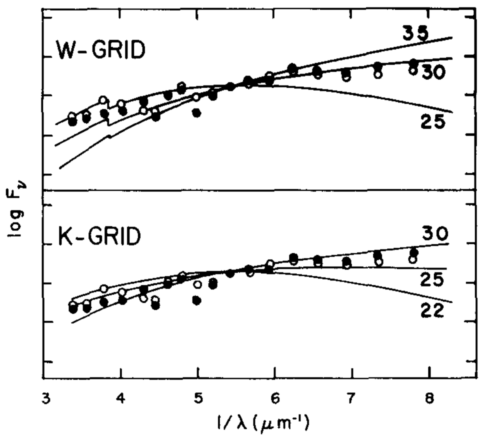

Fig. 1 - *IUE* energy distributions for PG0112+104 (filled circles) and GD358 (open circles), together with model fluxes from the W and K grids. Temperatures are in units of 10^3 K.

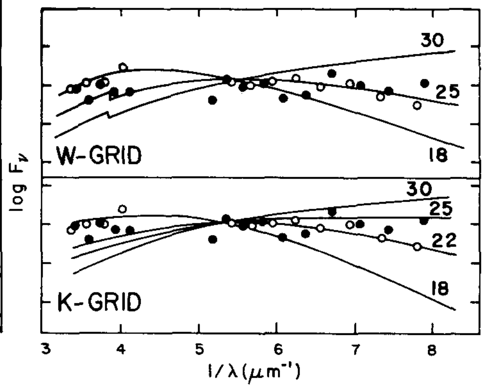

Fig. 2 - Same as Fig. 1, but for PG1654+160 (filled circles) and PG0853+164 (open circles).