SOME PROPERTIES OF HOT, HIGH-GRAVITY, PURE HELIUM ATMOSPHERES

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I. Introduction

Model atmosphere analyses of white dwarf spectra have contributed significantly to our understanding of the properties of degenerate stars. In particular, the pioneering investigations of Bues (1970), Strittmatter and Wickramasinghe (1971) and Shipman (1972) have provided the first reliable determinations of the effective temperature and surface gravity of these objects (see Shipman 1979 and Weidemann 1978 for recent results). We now know with certainty that the hydrogen-rich white dwarf sequence extends at least over the range $T_e \sim 6000$ - 60,000K. In contrast, the hottest identified helium-rich white dwarfs seem to reach $T_e \sim 25{,}000$K only, a puzzling result since the progenitors of DB white dwarfs should presumably also be helium-rich.

Some very recent observational results have an important bearing on this problem. First, spectroscopic observations in the visual of the hot white dwarf HD 149499B by Wegner (1978) reveal a nearly continuous spectrum, with no evidence of hydrogen Balmer lines or HeI λ4471, but with HeII λ4686 present (W_λ = 9.4Å). This is exactly the signature expected from a hot, hydrogen-deficient degenerate dwarf. Furthermore, IUE observations have revealed the presence of ionized helium lines at $\lambda\lambda$1640, 2385, 2511, 2733 in the spectrum of that object (Wray, Parsons, and Henize 1979). Secondly, the survey of blue, high-latitude objects conducted by Green (1977), with the subsequent visual observations of Green and Liebert (1979), has revealed the existence of a number of apparently hot degenerate stars with a variety of helium line strengths. These objects are thus prime candidates for the elusive progenitors of the DB white dwarfs.

With this exciting observational perspective in mind, we have undertaken a systematic investigation of the properties of hot, high-gravity, pure helium atmospheres which parallels the work of Wesemael et al. (1979) on pure hydrogen atmospheres. As in the preceding reference, the emphasis has been placed on predictions of both visual

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and far-ultraviolet continuum fluxes and absorption line profiles. We present here some *preliminary* results of this investigation. Further details and results of these calculations will be found in Wesemael (1979) and Wesemael and Van Horn (1979).

II. The Model Atmosphere Calculations

The model atmosphere calculations have been performed with the Rochester version of the Auer and Mihalas stellar atmosphere program (Mihalas, Heasley, and Auer 1975). All calculations assume plane-parallel geometry, pure helium composition, hydrostatic equilibrium, and steady state statistical equilibrium, and use the complete linearization method of Auer and Mihalas (1969). The grid of model atmo-

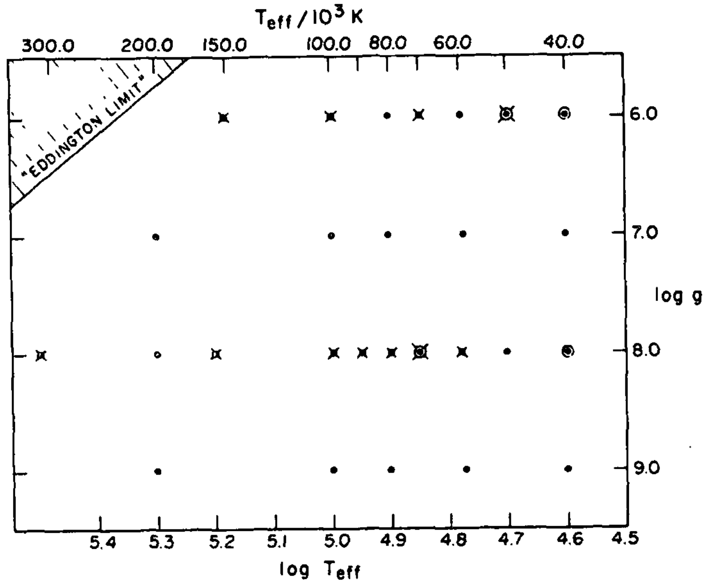

Fig. 1 - The location in the (g,T_{eff}) diagram of the pure He model atmospheres discussed in this paper. Each filled circle corresponds to an unblanketed, LTE model. Open circles and crosses indicate where helium-line blanketed and NLTE/C models respectively have been computed as well. The diagonal line corresponds to the Eddington limit calculated for electron scattering opacity.

spheres presently available is shown in Figure 1. The solid line defines the Eddington luminosity for a pure electron scattering opacity. The surface gravity of our models ranges from $g = 10^6 cm\ s^{-2}$, appropriate to the subdwarfs, to $g = 10^9 cm\ s^{-2}$, appropriate to the most massive white dwarfs ($M \sim 1.2M_{\odot}$).

Most of the models are in LTE and neglect blanketing by the helium lines. In addition to these, we have also calculated a smaller grid of NLTE models and a preliminary grid of helium-line blanketed models to assess the importance of these effects. Our NLTE calculations assume detailed radiative balance in the lines (and are thus NLTE/C according to the designation of Auer and Mihalas 1972). The LTE, helium line blanketed calculations were performed by including *explicitly* the contribution of both HeI and HeII lines to the opacity calculations. A set of 22 neutral helium lines, for which electron impact widths and shifts are available (Griem 1974), was chosen for that purpose. In addition, we included the contributions of the first few members of the series originating from the n=1 through n=4 levels of the ionized helium atom.

Absorption line profiles for both neutral and ionized hydrogen were also computed to allow detailed analyses of visual and ultraviolet line spectra of hot degenerate stars. For the isolated HeI lines λλ3889, 4438, 4713, 5047, 5876, 6678, and 7065, profiles were computed with the use of the electron widths and shifts, and ion broadening parameters tabulated by Griem (1974). For the neutral helium lines λλ4026, 4387, 4471, 4921, and 5015, which exhibit forbidden components at electron densities typical of the atmospheres of white dwarfs, the broadening theories of Shamey (1969), Barnard, Cooper, and Smith (1974, 1975), and Barnard and Cooper (1970) were used. For the ionized helium transitions at λλ1085, 1640 and 4686, the broadening theory of Griem (1974), originally due to Kepple, was used.

III. Results

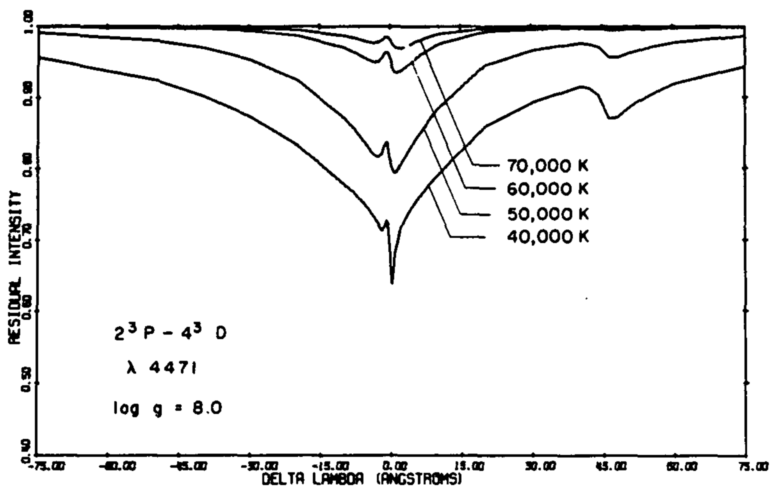

Fig. 2 - Line profile of the 2^3P - 4^3D λ4471 transition in HeI as a function of effective temperature. The surface gravity is log g = 8.0.

Figure 2 shows the behavior of HeI λ4471 at log g = 8.0 for a selection of models. The equivalent width (measured from -150Å to +150Å) is 22.5Å at T_{eff} = 40,000K and decreases to 1.7Å at 60,000K. A strong gravity dependence of the equivalent width is also observed. At log g = 6.0, the width varies from 8.8Å at 40,000K to 0.3Å at 60,000K. Strong HeI, such as λ4471, could thus be used as gravity indicators in degenerates up to T_{eff} ~ 60,000K, provided T_{eff} is known to sufficient accuracy. We note also the presence of the forbidden component 2^3P - 4^3P λ4517Å, which has been observed in the DB white dwarf WD 1542+18 ≡ GD190 by Liebert et al. (1976). The

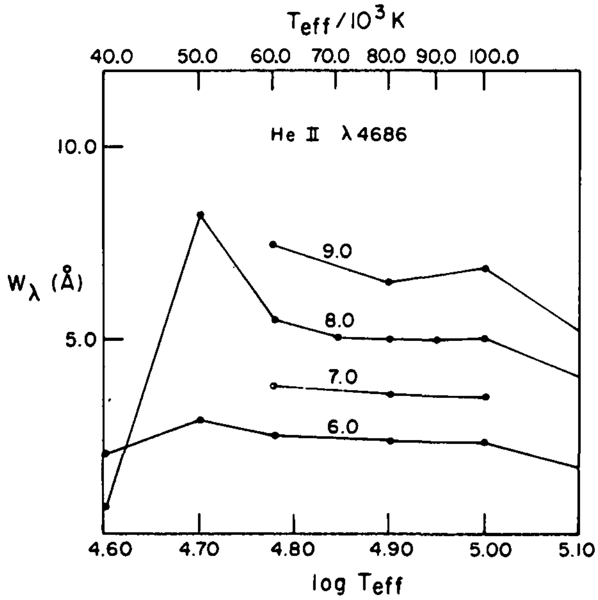

Fig. 3 - Equivalent width of the HeII λ4686 transition as a function of effective temperature for various surface gravities.

variation of HeII λ4686 as a function of T_{eff} is shown in Figure 3 for a variety of surface gravities. For the log g = 8.0 model, the equivalent width measured from -100Å to 100Å peaks at T_{eff} ~ 50,000K, and remains at about W_λ ~ 5Å up to T_{eff} ~ 100,000K. This confirms the result of Koester, Liebert, and Hege (1979) obtained with a high helium content (He/H = 100). However, the same behavior is also observed at lower gravities (W_λ ~ 2.5Å over the same temperature range for log g = 6.0). This may preclude the possibility of distinguishing unambiguously very hot degenerates from sdO stars from the λ4686 line, as was suggested by Koester et al.

Preliminary results from our helium-line blanketed calculations indicate that the flux near the multichannel G wavelength ($2.12\mu^{-1}$) will be affected by the presence of HeI λ4713 for effective temperatures up to T_{eff} ~ 40,000K; specifically we find the blanketed G-R color to be redder than the unblanketed value by 0.12 mag and 0.28 mag at T_{eff} = 40,000K and log g = 6.0 and 8.0 respectively. In addition, our NLTE calculations, within the assumption of detailed radiative balance in the lines, indicate that NLTE effects in the continuum are negligible for T_{eff} as high as 100,000K at log g = 8.0. The equivalent widths of the helium lines, however, are appreciably affected: we find an increase in the equivalent width of ~ 18% in λ4686 and of a factor ~2 in λ4471 over the LTE values for a T_{eff} = 60,000K, log g = 8.0 model.

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