GRAVITY INDICATORS IN DB WHITE DWARFS

D.T. Wickramasinghe
Royal Observatory
Edinburgh
U.K.

Abstract: Theoretical helium line spectra in the wavelength region $\lambda\lambda$ 3000-6000Å are presented and possible spectroscopic gravity indicators are discussed. The feasibility of using spectrum synthesis techniques for the analysis of DB white dwarfs is investigated.

Introduction Although considerable advances have been made in the analysis of the atmospheres of DA white dwarfs, similar progress has not been achieved with the DB white dwarfs. The problem posed by the DB white dwarfs is more difficult for several reasons. Firstly the atmospheric structure is not as well determined since convection plays an important role in high gravity helium atmospheres over a wide range of effective temperature. Secondly, as a result of the complex nature of the HeI line spectrum, the determination of the effective temperature and gravity is a non-trivial problem. Many of the lines are strongly blended and often contaminate the colour bands used for quantitative studies of these objects. Ideally, spectrum synthesis techniques should be used. In this paper we present preliminary results which illustrate the feasibility of using spectrum synthesis techniques for the analysis of DB white dwarfs. We show in particular that several commonly observed line segments can be used for the determination of gravities in DB white dwarfs.

Computation of models and HeI line spectra.

Various investigators have constructed model atmospheres for DB white dwarfs (Bues (1970), Wickramasinghe (1972), Shipman (1979)) and

https://doi.org/10.1017/S0252921100075680 Published online by Cambridge University Press

a comparison has been made by Shipman (1979). Our previous grid of models (Wickramasinghe (1972)) does not cover a sufficient range in effective temperature to be of use for our present investigation. We have accordingly computed a new grid of model atmospheres using the computer program ATLAS. The atmospheric helium to hydrogen ratio by number, $\frac{He}{H}$, was set equal to 10^4 and the metal abundance was taken to be 10^{-2} of the solar value. In general the structure of the atmosphere is insensitive to further reductions in the hydrogen and metal abundance provided $T_e \gtrsim 15000$ K. Convective energy transport has been included in all the models using the standard mixing length theory with the ratio of mixing length to scale height set equal to unity. For each model the helium line spectrum in the wavelength region λλ 3000-6000Å was computed including all HeI lines of appreciable strength. A full account of these computations including details of the broadening theories used will be given in a subsequent paper. The theoretical spectra for log(g) = 8.0 are shown in figure 1. This figure illustrates the fact that the HeI line strengths reach a broad maximum in the temperature range 20000 K $\lesssim T_e \lesssim$ 30000 K.

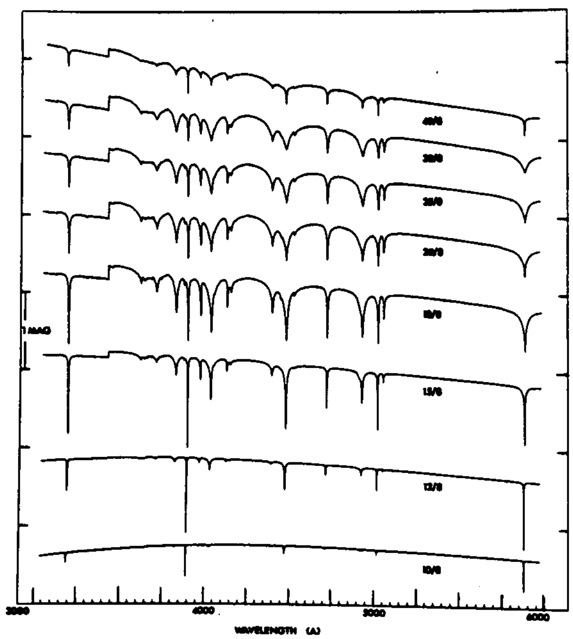


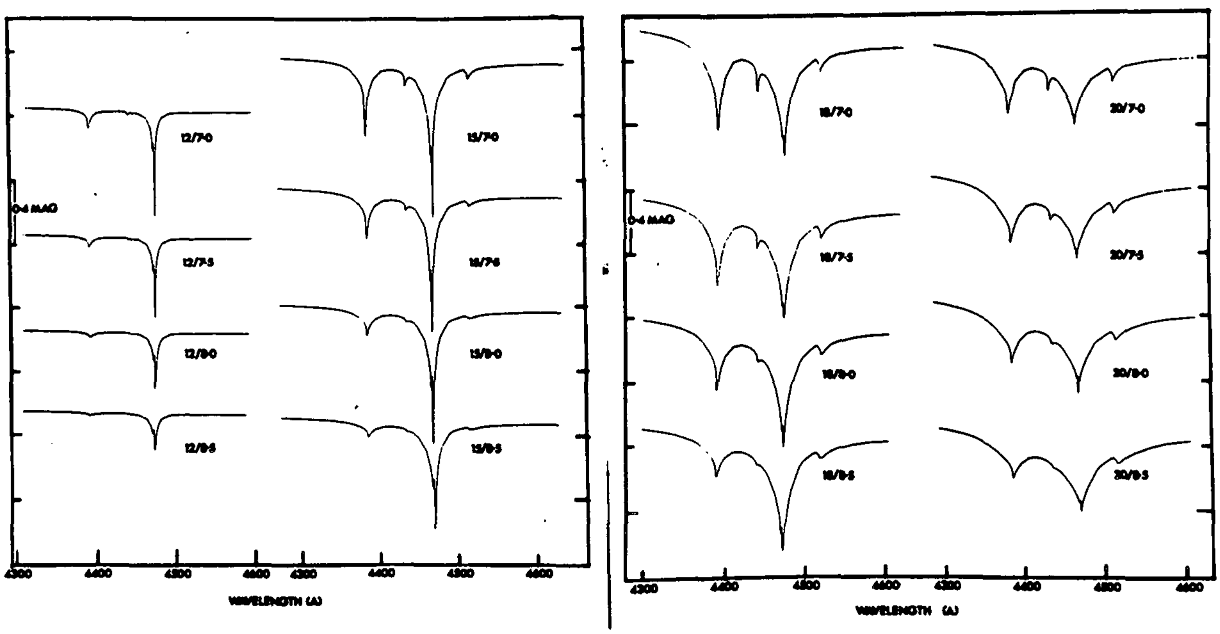
Figure 1: Theoretical HeI line spectra in the wavelength region λλ 3000-6000Å.

https://doi.org/10.1017/S0252921100075680 Published online by Cambridge University Press

Gravity sensitive line segments.

On the basis of the Griem (1968) broadening theory for HeI λ 4471 and its components, Wickramasinghe and Strittmatter (1970) predicted that the 2^3P-4^3P forbidden component should be detectable at λ 4516Å in DB white dwarfs. The temperature and gravity dependence of this component was not fully investigated at that time. Subsequently Liebert et al. (1976) discovered this component in the strong lined DB white dwarf GD 190. Several other DB white dwarfs are also now known to show this line. (Liebert 1977 , Wickramasinghe and Whelan 1977). There has been some speculation that this component may be used as a gravity indicator in DB white dwarfs.

In figures 2 and 3 we illustrate the temperature and gravity dependence of the HeI lines in the line segment λλ 4300-4600Å which includes the 2^3P-4^3P component. The other lines are HeI 4388 (2^1P-5^1D), HeI 4438 (2^1P-5^1S) and HeI 4471 (2^3P-4^3D, 4^3F). The 2^3P-4^3P, D, F lines were computed using the broadening theory of Barnard et al. (1969, 1974) including ion dynamic corrections. The HeI 4388, 4438 lines were broadened using the theory outlined by Griem (1974).



Figures 2 and 3 The gravity sensitivity of the λλ 4300-4600A line segment.

https://doi.org/10.1017/S0252921100075680 Published online by Cambridge University Press

We note that since the HeIλ4516 component is weak it is unlikely that it can be used effectively as a gravity indicator unless good quality high resolution data are available. Note also that due to the lack of contrast between the core and the wings, this component gives the impression of being weaker in the higher gravity stars although in reality it is much broader and extends to longer wavelengths. On the other hand the line segment $\lambda\lambda$ 4300-4600Å as a whole is seen to be strongly gravity dependent. If the effective temperature can be determined by photometric means, the relative strengths of the lines within this blend can be used to determine the gravity.

Shipman et al. (1977) have used the gravity sensitivity of HeI 4471/HeI 4388 to determine the gravity of the cool white dwarf GD 40 where the lines are unblended. In general when blending occurs, spectrum synthesis techniques will have to be used. As an illustration of this method, we show in figure 4 an attempt to match the observed spectrum of the strong lined DB white dwarf GD 190 (Liebert et al. 1976) with theoretical models. The fit is reasonable, but we emphasise that the spectra are of low resolution and that the value assumed for the effective temperature is quite uncertain. (Liebert et al. 1976 , Shipman 1972). We have also computed HeI 4471 and 4516 using the Griem theory. Both theories predict the λ 4516 component at roughly the observed strength.

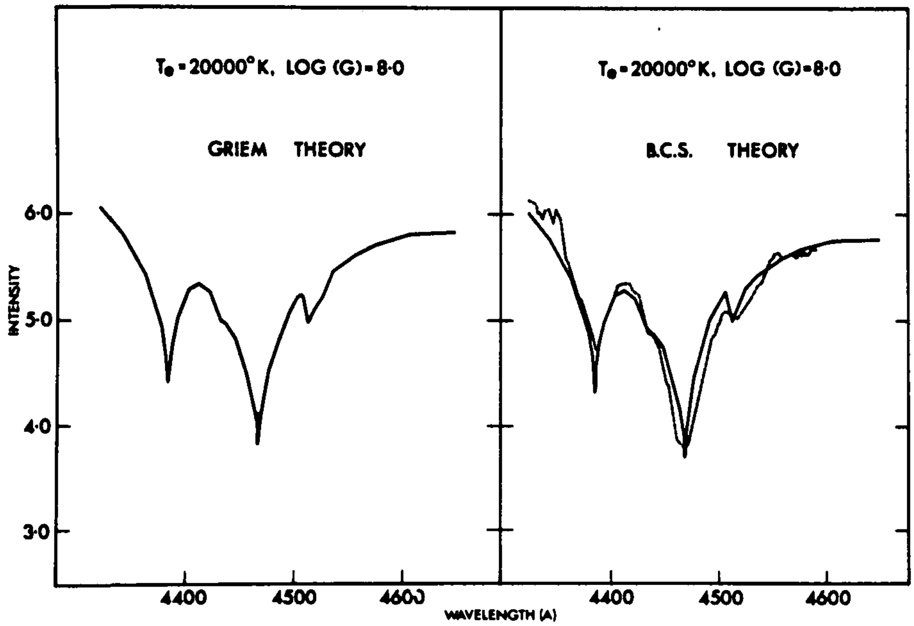


Figure 4 Comparison of theory with observations of GD 190.

https://doi.org/10.1017/S0252921100075680 Published online by Cambridge University Press

The weakening of HeI 4388 relative to HeI 4471 may be understood as follows. When He^- is the dominant opacity source, the Stark wings of the lines will be nearly gravity independent since the ratio of line to continuous opacity is approximately independent of electron density. However in the core region, this ratio decreases with increasing electron density. As a result, the weaker lines, which are less saturated, show a dependence on gravity near the line core. The wing region shows some gravity dependence since the atmospheric structure varies with log g due to effects of convection. These considerations suggest that other weak lines may be used as gravity indicators. We illustrate this is figure 5 where the wavelength region λλ 3550-4200Å is shown in detail.

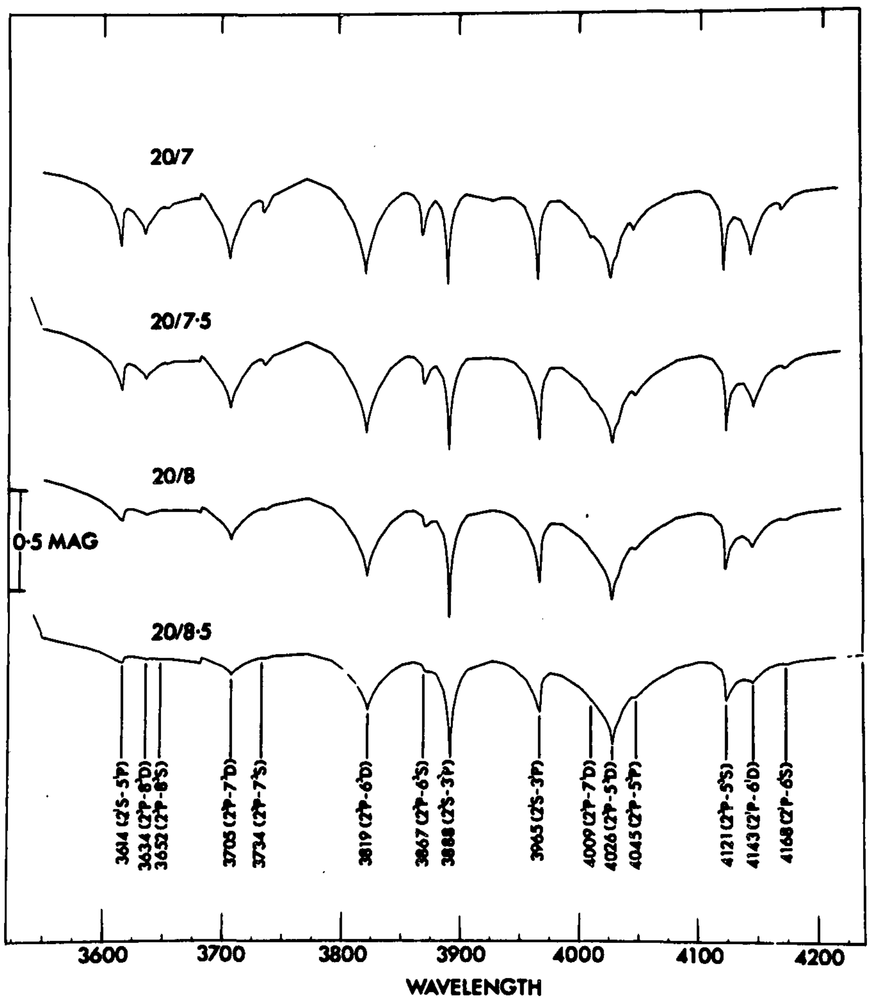


Figure 5 The gravity dependence of the spectral region λλ 3550-4200Å.

https://doi.org/10.1017/S0252921100075680 Published online by Cambridge University Press

Several weak lines are seen to be gravity dependent. In particular the strength of HeI 3965 relative to HeI 4026 may also prove to be a useful gravity indicator.

References

Barnard, A.J., Cooper, J. and Shamey, L.J., 1969, Ast. Astrophys., 1, 28

Barnard, A.J., Coopèr, J., and Smith, E.W., 1974, J. Quant. Rad. Transfer, 14, 1025

Bues, I., 1970, Astron. and Astrophys., 7, 91

Griem, H., 1968, Ap.J., 154, 1111

Griem, H., 1974, Spectral Line Broadening by Plasmas (Academic Press)

Liebert, J., 1977, Ap.J., 214, 446

Liebert, J., Beaver, E.A., Robertson, J.W., and Strittmatter, P.A., 1976, Ap.J. Letts, 204, L119

Shipman, H.L., 1972, Ap.J., 177, 723

Shipman, H.L., 1979, Ap.J., 228, 240

Shipman, H.L., Greenstein, J.L., and Boksenberg, A., 1977, A.J., 82, 480

Wickramasinghe, D.T., 1972, Mem. Roy. Ast. Soc., 76, 129

Wickramasinghe, D.T., and Strittmatter, P.A., 1970, Mon. Not. Roy. Ast. Soc., 150, 435

Wickramasinghe, D.T., and Whelan, J., 1977., Mon. Not. Roy. Ast. Soc., 178, 11P

https://doi.org/10.1017/S0252921100075680 Published online by Cambridge University Press