NEW MODEL ATMOSPHERES FOR DB WHITE DWARFS AND COMPARISON WITH OBSERVATIONS

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I. Introduction

About eight years have elapsed since the publication of an extensive grid of model atmosphere calculations for DB white dwarfs by Wickramasinghe(1972), and some selected data on colours and line strengths by Bues(1970), Shipman(1971,1972), Strittmatter and Wickramasinghe(1971), and Wickramasinghe and Strittmatter(1970). Since then only rather few theoretical results applicable to individual objects have been published by e.g. Wickramasinghe and Whelan(1977), Shipman, Greenstein, and Boksenberg(1977). On the other hand, a large amount of observational material on DB stars has accumulated, mainly through the work of Greenstein(1976), Wickramasinghe and Bessell(1977), Hintzen and Strittmatter(1974), Wickramasinghe et al.(1975), Wegner(1973,1979), Schulz(1979), Bessell and Wickramasinghe(1978), Oke(1974), and Liebert(1977).

Since computing facilities have also increased as to allow easily the incorporation of line blanketing effects by hydrogen and helium lines as well as energy transport by convection into a model atmospheres program we decided to repeat such calculations in order to obtain a consistent grid of DB model atmospheres between T_{eff} = 12000 to 30000 K, log g = 7.0, 7.5, 8.0. Detailed results on colours, line strengths, and profiles have been given elsewhere (Koester(1979)); in this paper we present only a short description of the computation procedures and a first comparison with mostly new and unpublished observations.

II. Model atmospheres

The procedures employed in the calculations are basically the same as those used for our large grid of DA atmospheres (Koester, Schulz, Weidemann(1979)). They follow the differential formulation of the atmospheric equations and use the method of variable Eddington factors. Line blanketing by helium lines and Balmer and Lyman lines of hydrogen is included. The abundance ratios by number of helium, hydrogen, and metals are:

$$n_{He} : n_H : n_{metals} = 10^5 : 1 : 1.5$$

(see e.g. Bues(1970), Strittmatter and Wickramasinghe(1971)).

Convection is included in the numerical code according to the standard mixing length theory (Böhm-Vitense(1958)), with ratio of

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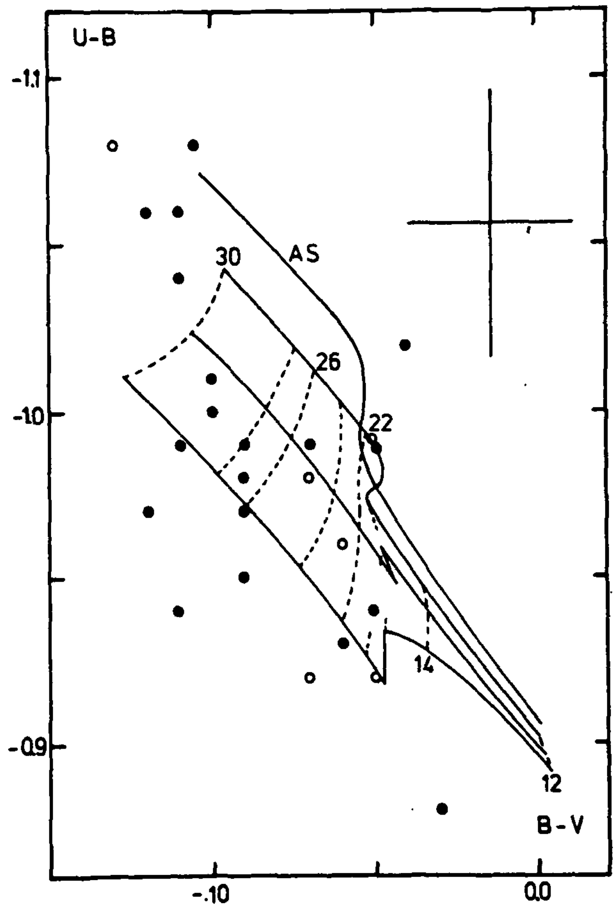
mixing length to pressure scale height equal to 1. For the final models we calculated theoretical colours in the Johnson UBV and Strömgren uvby systems, Greenstein's multichannel indices, line profiles and equivalent widths.

III. Observations

In Fig. 1-4 we present observational data on DB stars together with the corresponding theoretical calculations. In all diagrams the continuous lines are lines of constant log g = 7,7.5,8 (Fig. 1-3: lower left to upper right, Fig. 4: top to bottom), while broken lines indicate constant temperature (numbers: T_{eff}/1000 K). Filled dots mark apparently "normal" DB, open dots objects classified DBA,DBF, DBpec or else, in two cases also DB with widely differing data in the literature. The crosses show typical observational uncertainties. Main sources of data are:

a) Johnson UBV (Fig.1)



The main source is the series of papers by Greenstein(1974 and earlier) and Eggen and Greenstein(1967 and earlier). Besides the relatively large observational errors - compared to the intrinsic scatter - there exists a considerable uncertainty in the calibration of the theoretical colours. The curve labelled AS has been computed for log g = 8 with filter functions from Adžhusenis and Straižhis(1969), whereas for the other grid those of Matthews and Sandage(1963) were used. Calibration relations in both cases were taken from Schulz(1978).

Fig.1 (left)
UBV diagram of DB white dwarfs

b) Strömgren uvby (Fig.2)

Data are from Graham(1972), Bessell and Wickramasinghe(1978), and Wegner(1979). The theoretical calibration relations are also from Schulz (1978).

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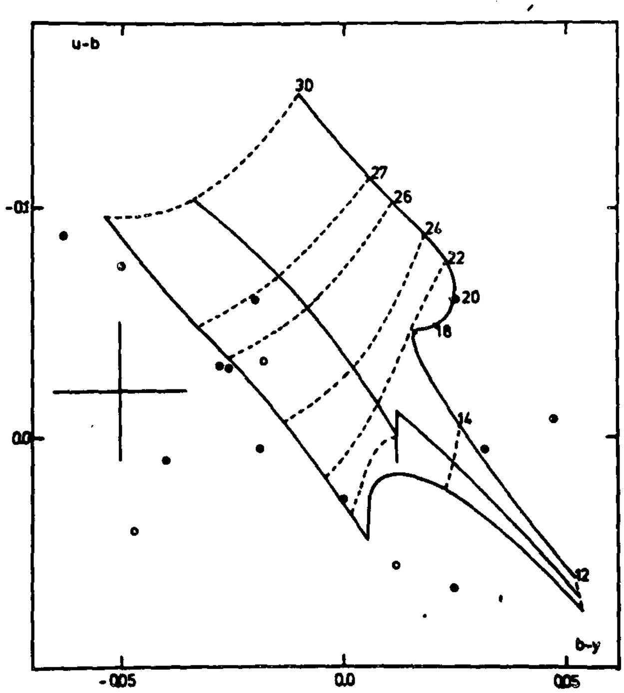

Fig.2: Strömgren two-colour-diagram of DB white dwarfs.

c) (u-v)-(g'-r'), Greenstein multichannel indices, Fig.3

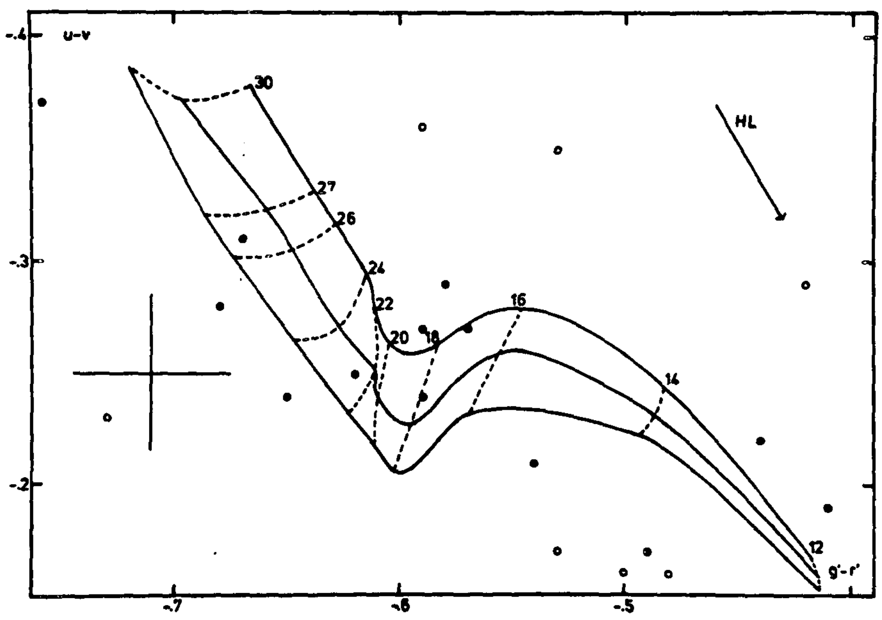

Fig. 3

These observations were kindly made available by Greenstein(1979). g' and r' are measured at 4808 resp. 7353 Å , somewhat different from g and r (4717 resp. 6944 Å). This change has been made in order to avoid the position of helium lines. The arrow labelled HL gives the correction applied to the observations to get on the absolute flux scale of Hayes and Latham(1975).

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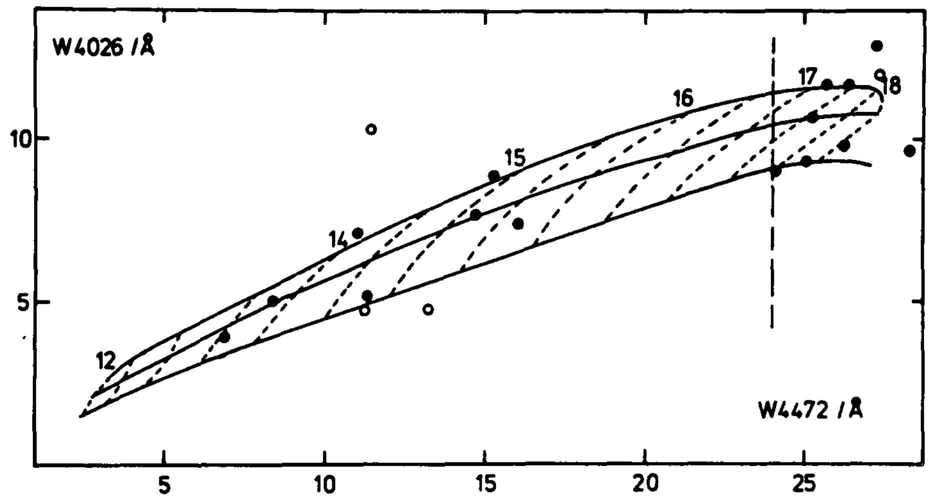
d) Equivalent widths of HeI λ4026 (including λ4009) and λ4472 (including λλ 4388,4438,4517) Fig. 4:



Data on line profiles and equivalent widths were obtained from more than 40 spectra taken by G. Wegner and H. Schulz at S.A.A.O. and kindly made available. A detailed analysis will be published together with Schulz and Wegner.

Although it is known that line strengths in DB atmospheres depend little on gravity, Fig. 4 shows that it is nevertheless possible to get at least a rough estimate below $T_{eff} \approx 18000$ K, provided the measurements and calculations are referred to the same "continuum" points. To the right of the vertical broken line a unique solution is not possible since W4472 and W4026 decrease with increasing temperature.

IV. Conclusions

Rather than discuss individual objects only two general conclusions shall be drawn in this paper:

(i) The temperature range of the DB seems to extend up to 30000 K, well above the upper limits of $\approx$ 20000 K obtained by Bues(1970) and Strittmatter and Wickramasinghe(1971), but in line with Greenstein's(1976) conclusions.

(ii) Although individual gravity determinations are obviously subject to large uncertainties, Fig. 1 - 4 indicate a mean log g for the whole group around 7.5. Indeed, a straightforward numerical evaluation for 25 objects yields

$$\langle \log g \rangle = 7.42$$

corresponding to a mean mass of 0.27 $M_\odot$ on the carbon mass-radius relation. If this value is not changed drastically by the detailed analysis we are led to the conclusion - originally suggested by Bues(1976) - that the mean DB mass is considerably smaller than the mean mass of 0.58 $M_\odot$ found for the DA by Koester, Schulz and Weidemann(1979).

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