FOUR COLOR PHOTOMETRY OF DB WHITE DWARFS

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ABSTRACT

Observations of 22 DB stars using the *uvby* photometric system are discussed. In the [(*b-y*),(*u-b*)] diagram, these objects define a relatively tight sequence, but the interpretation is hampered by the lack of a precise knowledge of atmospheric element abundances in these stars. The recent models of Koester (1979) show a larger gravity separation for the DB's using Strömgren photometry and appear to fit the observations better than earlier theoretical results. Due to the tightness of the DB sequence at the hot and cool ends, respectively, there appears to be evidence for restricted ranges in log *g* and the atmospheric hydrogen abundance.

I. INTRODUCTION

This paper discusses whether Graham's (1972) discovery that the DA stars define a sequence in the [(*b-y*),(*u-b*)] diagram that is sensitive to log *g* can be carried over to the DB white dwarfs. Early investigators, *e.g.* Strittmatter & Wickramasinghe concluded that *uvby* photometry is unsuitable for studies of the DB stars and Graham's (1972) original list of white dwarf Strömgren photometry only contained seven objects. Therefore it was impossible to fully check this for a long time. However, Koester's (1979) new models predict a larger separation in log *g* and due to Bessell & Wickramasinghe (1978), Eggen & Bessell (1978), and Wegner (1979), a total of 22 objects can now be studied. Also in the multichannel data of Greenstein (1976) there is a suggestion of a sequence for the DB stars which should carry over to the Strömgren data.

II. COMPARISON OF OBSERVATIONS AND MODELS

The observational data were taken from the following sources: Graham (1972), Bessell & Wickramasinghe (1978), Eggen & Bessell (1978), and Wegner (1979). All objects have been classed spectroscopically as

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DB. For an object observed by more than one author, the measurement of Wegner (1979) was adopted. This was to ensure that as many data as possible were made with a homogeneous filter set. Two measures by Green (1977) lie outside the color range discussed and could not be used.

Five additional stars were observed using the No. 2 Kitt Peak 0.9 m telescope during June, 1979 and preliminary results are summarized in Table I where the final column gives the number of nights' observations. These measurements were reduced as described in Wegner (1979), except extinction coefficients and reduction programs available at the Kitt Peak National Observatory were used.

TABLE I

New Photometry of Additional DB Stars

Name	y	(b-y)	(u-b)	N
G200-39	15.01	+0.022	+0.093	1
G256-18	14.88	-0.043	+0.060	2
GD233	14.51	-0.036	+0.012	1
GD358	13.62	-0.049	0.000	2
GD378	14.38	-0.030	-0.055	2

Early models for He-rich stars, applicable to DB stars have been described by Bues (1970, 1971), Wickramasinghe & Strittmatter (1972) and Shipman (1972, 1979). However, these models neglected either convection or line blanketing or both effects. More detailed models have recently been calculated by Koester (1979). Fig. 1 compares some of these models in the [$(b-y)$,$(u-b)$] diagram with the observations for 22 stars.

It can be seen that the bluer or therefore hotter models of Bues (1971) and Koester (1979) diverge, presumably from the inclusion of line blanketing and convection in the latter's models. Bues' models are typical of the earlier models and illustrate qualitatively the effect of changing the hydrogen abundance. Two effects seem to be predicted: (1) at the hot end of the DB model loci the new models show a gravity separation, and (2) at the cool end there is a differentiation due to different hydrogen contents.

The observations show a fairly well defined sequence in Fig. 1. Note that it differs from that defined by Graham's (1972) seven data points. The positions of the two most outstanding points in Fig. 1, EG77 and EG133, appear due to observational error because they lie closer to the mean sequence in the [$(v-y)$,$(u-b)$] diagram. Koester's models seem an improvement over the older theoretical results because they reproduce the empirical sequence's shape better. The T_{eff} range would extend from about 30,000 to 12,000 °K. However, taken at face value a mean log g near 7 is indicated. The interpretation of the DB sequence depends both on log g and the He:H ratio, so this is not a clear cut conclusion as Koester's (1979) models were calculated for only one composition, *viz.* He:H = 10^5.

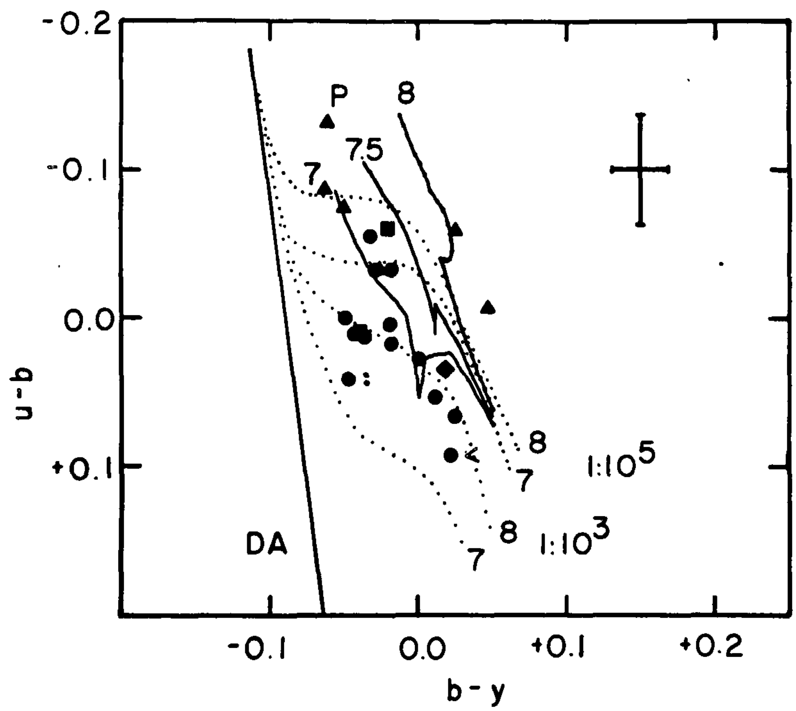

Fig. 1 - *Comparison of observation and theory for four color measurements of white dwarfs spectroscopically verified as spectral class DB. Symbols refer to the following sources of data: Dots (Wegner 1979 and Table I), triangles (Graham 1972), squares (Bessell & Wickramasinghe 1978), diamond (Eggen & Bessell 1978). The Koester (1979) models are represented by the solid curves and values of log g are indicated. Bues' (1971) models are the dotted curves with labled abundance ratios, H:He, and log g. The position of the log g = 8 pure hydrogen sequence according to Koester, Schulz, & Weidemann (1979) is the line 'DA'. The error bar is the external error of Wegner (1979) measured relative to Graham (1972).*

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From a strictly observational standpoint, the normalizations of the colors may be different for the DA and DB stars. The work of Schulz (1978) refers to the DA's. This needs further checking before an actual numerical value can be given to log *g*.

Two counterexamples to the log *g* = 7 interpretation are GD40 (Shipman, Greenstein & Boksenberg 1977) and G200-39 (Liebert, Gresham & Hege 1979). These objects are shown in Fig. 1 by the symbols (:) and (<) respectively. The first object appears to have log *g* = 8.2±0.5 from the Ca II line profiles and therefore could be moved by line blanketing. The second shows Balmer lines and has He:H $\sim 4 \times 10^3$. The star LDS785A (Wickramasinghe & Whelan, 1977) has also been found to show Balmer lines and more of these objects will probably be discovered. Thus Koester's models with He:H $\sim 10^5$, may not be applicable to all of the observed stars.

The effect of changing the hydrogen abundance can be seen in Fig. 1 from Bues' results for the cooler models. The observations give the impression that the range in He:H cannot be large because of the small apparent observational scatter.

III. CONCLUSIONS

Strömgren four color photometry appears to be useful for studying DB white dwarfs. In the [(*b*-*y*),(*u*-*b*)] diagram, the empirical sequence is as narrow as the observational scatter. Further models and observations appear needed to fully understand this because of the coupling of log *g* and the atmospheric abundances. Also there may still be some problems with the normalization of the colors. Nevertheless, two conclusions can be drawn: (1) Koester's (1979) hot models show a gravity spread which the observed stars do not, so the DB's could have a restricted mass range and (2) the cool models are expected to show a separation for different H:He ratios which also is not observed.

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