STATISTICAL INVESTIGATIONS OF THE LUMINOSITY DISTRIBUTION OF THE SPECTROSCOPIC WHITE DWARF SAMPLE

Edward M. Sion

Department of Astronomy
Villanova University

1. Introduction

In the nine years since Symposium No. 42 at St. Andrews, Scotland, the number of spectroscopically identified white dwarfs has grown from 285 then to over 750 spectroscopic degenerates now. Significant increases in the number and quality of faint star parallaxes and the multichannel spectrophotometry at the 5.1m Hale reflector by Jesse Greenstein has made possible a major breakthrough in the color-luminosity relation for white dwarfs. Of the present sample only ninety-one stars lack measured colors. Over 300 white dwarfs have multichannel colors while over 200 have Strömgren photometry due primarily to Graham (1972), Eggen and Bessell (1978), Wegner (1979), and Green (1977, 1979). Green's north galactic pole survey of hot white dwarfs will present Strömgren colors for each of several hundred stars in his sample. At the time of this writing it is anticipated that Green's blue survey will add 500 - 700 new white dwarfs with spectra and measured colors. Thus by the first half of 1980 the spectroscopic white dwarf sample will number between 1300 and 1500 stars.

The most recent comprehensive analysis of the kinematics and luminosity function of white dwarfs was that of Sion and Liebert (1977) with a sample of 424 stars. The availability of the larger new sample with improved colors permits crucial statistical investigations of the absolute magnitude distribution function, $N(M_V)$ of a substantially larger sample and an updated derivation of the general white dwarf luminosity function corrected for the selection effects controlling their discovery. In this work I will concentrate on statistical investigations of the distribution function $N(M_V)$. Derivation of the general white dwarf luminosity function, local space density and kinematical analyses will be published separately (Sion, 1979).

2. Data Sources and Distribution of Degenerate Spectral Types

Since the appearance of the Catalogue of Spectroscopically Identified White Dwarfs by McCook and Sion (1977) newly identified degenerate stars have been added by Greenstein et al. (1977, paper X), Greenstein (1979, paper XI), Green (1977), Liebert et al. (1979), Hintzen (1979), Tapia (1979), Wickramasinghe and Bessell (1977), and Eggen and Bessell (1978). The work by Green (1977) provides a complete sample of hot white dwarfs identified spectroscopically from candidates

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selected for ultraviolet excess without regard to proper motion. All other sources provide spectroscopic observations of proper motion stars.

The current distribution of degenerate spectral types is shown in Table 1. The tabulated entries do not include disputed spectral types, composite spectra, hybrid classifications or peculiar spectra. The DO stars include the newly discovered hot hydrogen deficient white dwarf HD 149499B. The DA total number includes stars classified as DA,F.

Table 1

Distribution of Degenerate Spectral Types

DO	DA	DB	DC	DF,DG,DK	C_2(λ4670)
7	505	48	124	52	17

3. Color-Luminosity Calibrations

Absolute magnitudes were computed for every star with measured colors according to the following order of priority: multichannel (MC) colors, Strömgren colors and UBV photometry. Color class stars were excluded except for DB stars, for which we assume B-V = -0.1.

Stars with multichannel colors were assigned luminosities from the g-r calibration of Greenstein (1976). All but a few of these stars can be found in Greenstein et al. (1977) and Greenstein (1976, 1979).

For stars with Strömgren colors, the absolute magnitude was calculated from

$$M_v = 7.56(b-y) + 11.50 \qquad (1)$$

which is from a linear regression on Graham's (1972) data. This formula includes all spectral types and has a dispersion $\sigma = 0.27$. See Green (1977) for a more detailed discussion.

For stars with broad band colors the calibrations of Sion and Liebert (1977) were used. These calibrations are based upon Greenstein's multichannel observations of degenerate parallax stars for those stars having both MC and UBV colors. For DA stars with $B-V < 0.4$

$$M_v = 11.246(B-V + 1)^{0.60} - 0.04486 \qquad (2)$$

with dispersion $\sigma = 0.24$ while for non-DA stars with $B-V < 0.4$

$$M_v = 11.916(B-V + 1)^{0.44} - 0.01136 \qquad (3)$$

with dispersion $\sigma = 0.25$.

For $B-V > 0.4$, line blanketing no longer separates the DA and non-DA sequences so we adopt Greenstein's relation

$$\begin{aligned} M_v &= M_{1.85} + 0.05 \\ &= 12.643 + 5.1894\,X = 3.9600\,X^2 + 1.4742\,X^3 \end{aligned} \qquad (4)$$

with $X = (B-V)_{MC}$ and dispersion $\sigma = 0.17$ magnitudes. The index $(B-V)_{MC}$ transforms to broad band B-V by $(B-V)_{MC} = [(B-V) - 0.14]/0.94$.

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For the hottest stars, B-V < -0.1, the absolute magnitudes from any of the above calibrations must be viewed with caution with multi-channel colors yielding the best estimates.

4. The Distribution Function of DA and Non-DA Stars

Analysis of relative differences in the number-absolute magnitude distributions of DA and non-DA white dwarfs can directly yield information about the evolution of these stars, if one takes proper account of selection effects. The availability of Green's (1977) complete sample of hot white dwarfs discovered by color alone permits two separate determinations of the distribution function, $N(M_V)$, one for the "motion selected" spectroscopic sample and the other for the "color selected" spectroscopic sample. The proper motion stars are cooler (redder) on the average and have a higher average tangential motion (larger mean μ). On the other hand the Palomar-Green (PG) sample is bluer and can be combined with the Lowell GD stars which have small motions and tend to be bluer than the larger proper motion sample.

The distribution function of the proper motion sample per quarter magnitude inteval is shown in figure 1. The corresponding histogram for the PG stars and GD stars is shown in figure 2.

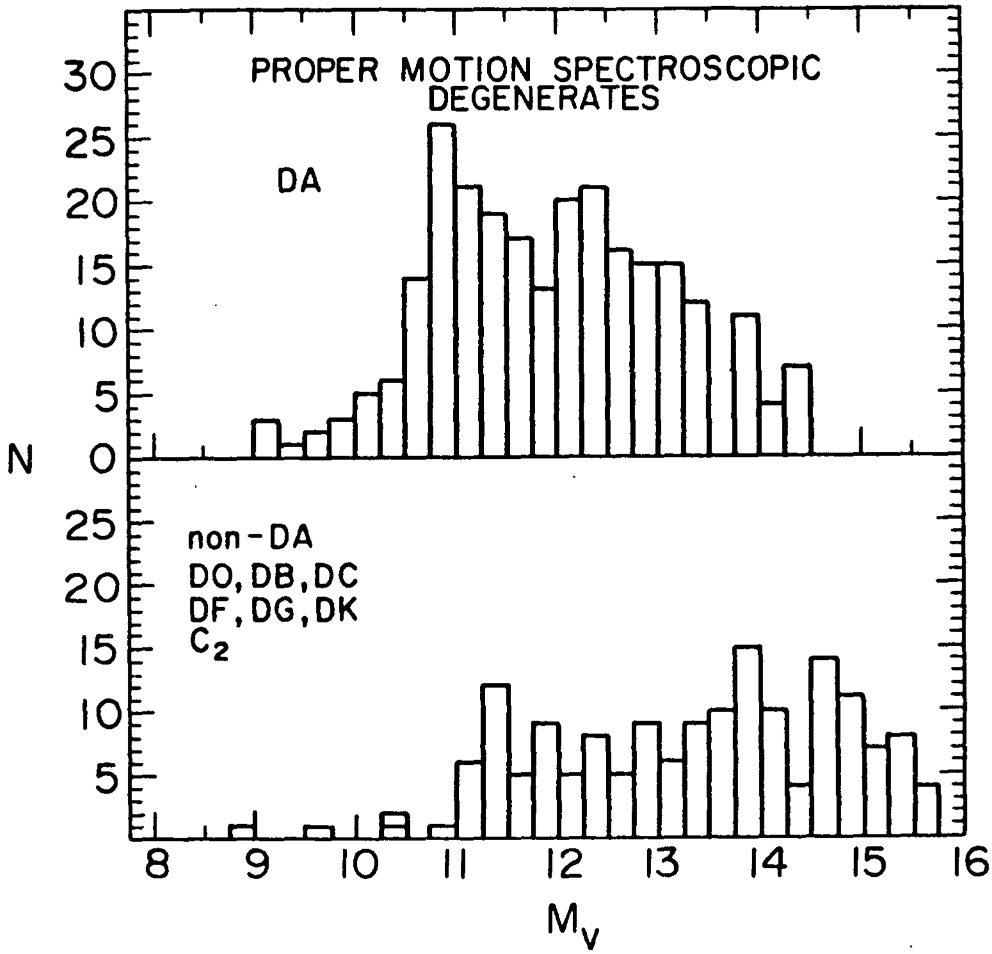

Figure 1

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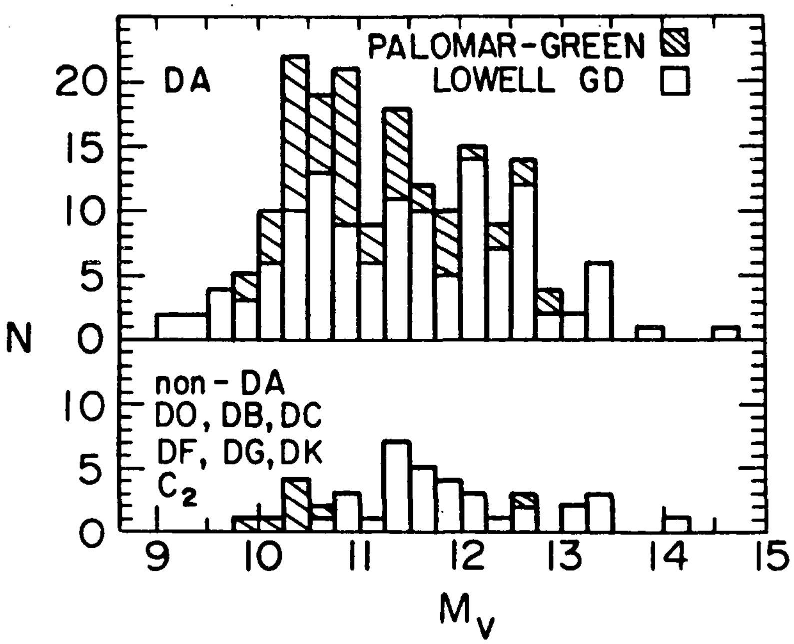

Figure 2

Based upon figures 1 and 2 the relative number of non-DA stars hotter than the DB range ($10.5 \le M_v \le 11.75$) is nearly in expected proportion with that of the DA sample. For $M_v \le 10.5$ there are 65 DA stars and 11 non-DA stars if one includes HD149499B. In the range of DB luminosities, we find 176 DA stars and 42 non-DA stars. Thus the currently expected number of hot non-DA stars is around 15, close to the actual number, 11. With $M_v \le 12.5$ as a division between the hot and cool ends of the distribution function, the ratio of DA to non-DA stars among the PG sample is 6:1 while among the GD stars it is 4:1 and among the proper motion sample the ratio is slightly over 3:1. With the new GD sample, we count 74 DA stars and 15 DB stars whereas in Greenstein (1969) there were 30 DA stars and 9 DB stars. Thus the updated sample of GD stars <u>does not</u> indicate a higher frequency of DB stars among the GD sample than among the sample in fig. 1.

The most interesting and important question is whether the relative proportion of DA and non-DA stars changes from the hot end of the distribution function to the cool end. Can selection effects explain the differences between the DA and non-DA distributions or do physical interpretations involving stellar evolution explain them? In order to answer these questions we determine the proportion of DA and non-DA stars in three magnitude intervals from the hot end to the cool end. Since the Balmer lines of hydrogen become weaker and narrower at $M_v \gtrsim 13$ and may disappear entirely at $M_v \gtrsim 14$, the faintest interval is taken at $M_v = 13.5$ in order to minimize spectroscopic selection. The results are shown in table 2.

Table 2

Relative Proportion of DA and Non-DA Stars

Interval	N_{DA}	N_{non-DA}	Ratio
$10.5 \le M_v \le 11.5$	147	32	4:1
$11.5 < M_v \le 12.5$	118	40	3:1
$12.5 < M_v \le 13.5$	84	37	2:1

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The ratio of hydrogen dominated stars to helium-dominated stars significantly decreases toward the faint end of the distribution. Several selection effects must be taken into account. We expect the mean $\bar{\mu}$'s of DA and non-DA stars to be similar within a specific M_V interval. There is little reason to expect that DA and non-DA stars do not have equal discovery probability and color-bolometric correction differences between the two types are small. The major uncertainty occurs in the interval 12.5-13.5 where spectral classification of DA and non-DA stars becomes difficult. Uncertainty in the assigned spectral types at this magnitude interval is the major source of concern.

The results in table 2 seem to indicate that at least some cool DA stars evolve into non-DA helium-dominated stars when the deepening convective envelope mixes away the thin outer layer of hydrogen. An independent test of this proposed evolutionary scheme can be performed with the Palomar-Green sample when it is completed.

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