EXTENDING THE WHITE DWARF SEQUENCE: PLANS AND PROSPECTS

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1. INTRODUCTION AND SUMMARY

The recent discovery that the parallax star LP701-29 is a white dwarf has firmly extended the degenerate sequence below $M_V = +16^m$ (Dahn et al. 1978). As the search for white dwarfs extends to cooler and fainter stars, however, it becomes particularly important to develop a plan for selecting candidates among the many thousands of red proper motion stars. We begin by assessing the completeness of the known sample within 10 parsecs in the northern two thirds of the sky. Some color-dependent selection effects must be evaluated, however, since these may preferentially inhibit the discovery of cooler stars. A correction factor for the missing low velocity white dwarfs is estimated. Then, Green's(1977) recent determination of the number density of blue degenerates is used to normalize various theoretical luminosity functions, the benchmarks against which the current sample out to 10 pc can be compared. It is concluded that the sample may be approaching completeness in the northern sky for white dwarfs with tangential velocities (v_T) $\gtrsim$ 40 km/sec ($\mu \geq 1\overset{''}{.}0$/yr.) and $M_{bol} < +15^m$. The implied luminosity function is thus consistent with that found by Sion and Liebert (1977). Below $M_{bol} = +15^m$ the different theoretical functions predict substantially different numbers.

It is proposed that the remaining search concentrate on finding more nearby stars with large proper motions, especially in the interval $15^m \leq M_{bol} \leq 17^m$, and then correcting for the missing stars of smaller motion. This approach offers the advantage of decoupling the degenerate star luminosity function problem from those posed by the disk M dwarfs and the background Population II dwarfs. Not that many faint stars of large proper motion remain

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unobserved in Luyten's catalogues, although some of them may have been missed. Some useful answers concerning the white dwarf density below the current M_{bol} limit should be forthcoming.

2. BARRIERS TO THE IDENTIFICATION OF COOL DEGENERATE STARS

2.1 Velocity Selection

All northern stars with $M_V > 13^m$ and $\pi \geq 0\overset{''}{.}1$ have proper motions in excess of 1"/yr and $v_T \geq 40$ km/sec. Yet many hot degenerates found on the basis of blue color have small space velocities. Thus the mean velocity characteristics of the known spectroscopic samples of blue and red stars differ greatly (Sion and Liebert 1977). There can be little doubt that the greater part of this velocity difference is due to velocity selection in the sample of cooler degenerates.

The cool white dwarf numbers can be corrected for the missing low velocity stars by assuming that the true velocity distribution is like that of old disk stars. The sample of non-emission late K and M dwarfs found independently of motion by the McCormick objective prism survey, and also appearing in Gliese's catalogue of nearby stars, was utilized for this purpose. See also Wielen(1974). Applying a correction is simple if it can be assumed that the northern 10 pc sample is nearly complete for $v_T \geq 40$ km/sec. Indeed, a spectroscopic and astrometric survey of catalogued stars with $\mu \geq 1''$ and $m_{pg} \leq 16^m$ is now nearly complete (see Greenstein's report to this Symposium, page 101). Degenerates with $M_{bol} \leq 15^m$ and $d \leq 10$ pc are no fainter than the red Palomar survey plate magnitude $(m_R) = 16^m$. Since 62% of the McCormick/Gliese stars have a lower velocity than 40 km/sec, the correction factor adopted is 2.6. For $\delta \geq -20^o$ there ought to be some $2.6 \times 9 = 23 \pm 8$ white dwarfs with $13 \leq M_{bol} \leq 15$ by this estimate.

2.2 Loss of Cool Degenerates in Composite Binary Systems

A cool white dwarf is particularly difficult to identify in an unresolved binary spectrum. Not only are such objects intrinsically faint, but they generally lack strong absorption features and may not show significant blue or red excesses relative to the other component. Since the most frequent companion is a K-M dwarf, blue degenerate stars in composite systems are often recognized. The sample of the nearest stars shows us, however, that there must be many degenerates which, regardless of color, will be hidden by bright companions like Sirius and Procyon. The simplest procedure for dealing with the bias effect on the luminosity function by close binaries is to remove them

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altogether and calculate a luminosity function only for single and common proper motions stars. Then the total number density must be expressed by summing this single star function and then incrementing it by an uncertain binary contribution.

2.3 Other Selection Effects

Three additional problems discussed by Liebert (1978) in conjunction with this work are (3) line blanketing among cool degenerates, (4) the problem of correct spectroscopic identification of cool degenerates, and (5) the incompleteness of the proper motion surveys for faint stars of large proper motion.

3. PREDICTED AND OBSERVED NUMBERS OF NEARBY DEGENERATES

Green(1977) derives a total number density of blue stars of $1.43 \pm 0.28 \times 10^{-3}$ for $M_V \leq 12^m.75$ and a less certain $2.42 \pm 0.57 \times 10^{-3}$ for $M_V \leq 13^m.25$. These values lie within the range of previous estimates. For convenience here the geometric mean of these values was adopted for $M_V \simeq M_{bol} \leq 13^m$. For the 84% of the northern two thirds of the sky with measured Luyten Palomar fields, this density corresponds to 4.2 stars with $M_V \leq 13^m.0$. Using this number as the normalization for the restricted 10 pc sample, various theoretical calculations then provide predictions for the numbers of cooler stars.

TABLE I
EXPECTED AND OBSERVED NUMBERS
WITHIN RESTRICTED 10pc VOLUME

Intervals		Theoretical				Observed	2.6x Observed
M_{bol}	M_V	SK	LVH	Sw	Mes		
$<13^m$	$<13^m$	4.2	4.2	4.2	4.2	4	--
13-14	13.0-14.0	3.9	3.0	4.2	4.2	3	8
14-15	14.0-15.3	7.4	3.2	4.9	8.4	4	10
15-16	15.3-17.2	14.1	2.9	5.6	16.8	2	5
16-17	17.2-20.	26.3	2.2	4.9	33.6	0	0

SK = Shaviv and Kovetz (1976) for $0.6M_\odot$
LVH = Lamb and Van Horn (1975) for $1.0M_\odot$
Sw = Sweeney (1976) for $0.51M_\odot$
Mes = Mestel cooling relation

The reasons for the different predictions for $M_{bol} > 15^m$ and other possible effects are reviewed in Liebert (1978).

It is proposed that a survey of large proper motion stars fainter than $m_R = 16^m$ would find nearly all low luminosity degenerates within 10 pc and with $v_T \geq 40$ km/sec. There are only 29 of these in Luyten's catalogues. An evaluation of the completeness of the surveys is necessary, but there are reasons for believing that this is not a critical problem. The different theoretical predictions of Table I may be tested within a relatively short time. In fact, the failure to find any lower luminosity stars in work so far on this Luyten sample (Liebert and Strittmatter 1978) indicates that there are actually fewer stars in the last M_{bol} interval than predicted by the continuous function of Shaviv and Kovetz (1976).

REFERENCES

Dahn, C., Hintzen, P., Liebert, J., Stockman, H. and Spinrad, H. (1978). Astrophys. J., in press.
Green, R. (1977). Ph.D. Thesis, California Institute of Technology.
Lamb, D.Q., and Van Horn, H.M. (1975). Astrophys. J., 200, 306.
Liebert, J. (1978). in preparation.
Liebert, J., and Strittmatter, P. (1978). in preparation.
Shaviv, G., and Kovetz, A. (1976). Astron. Astrophys., 51, 383.
Sion, E., and Liebert, J. (1977). Astrophys. J., 213, 468.
Sweeney, M. (1976). Astron. Astrophys., 49, 375.
Wielen, R. (1974). in Highlights of Astronomy, 3, ed. G. Contopoulos, D. Reidel Publishing Co., Dordrecht, Holland, p. 395.

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