THE HR DIAGRAM OF WHITE DWARFS

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The lone dot in the lower left of Russell's original diagram (1914) was disregarded, since it did not fit into his suggestive scheme of giant-to-dwarf evolution. Bottlinger (1923) - in his nearly forgotten study of photoelectric color indices - seems to be the first who, with the evidence of the then three classical white dwarfs, invoked a new equation of state and clearly rejected all other possibilities of explanation. Kuiper (1941) summarized the knowledge obtained during the thirties, mainly by his spectroscopic work. A decade later Luyten (1952) presented impressive HR diagrams based on admittedly crude color indices and, for many more objects, on reduced proper motions.

The new era of photoelectric UBV photometry was opened by Harris III (1956), soon to be extended to the large surveys of Eggen and Greenstein (1965 and sequ.), for which Greenstein secured high quality spectroscopy with the 200" telescope.

Quantitative evaluation started with Greenstein (1958), and the full theory of stellar atmospheres was applied to a first sample of 22 DA stars by Weidemann (1963). The result demonstrated that white dwarfs do have the radii and surface gravities expected for completely degenerate configurations with $\mu_e = 2$. It seemed thus justified to enlarge the sample considerably by inclusion of all stars for which no distances were known but for which radii were derived from surface gravities. The resulting HR diagram is shown in Weidemann (1968).

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New information was obtained by Strömgren photometry (Graham, 1972) which with a clearly outlined DA cooling sequence disproved the so-called two-sequence hypothesis, and moreover showed an astonishingly small range in surface gravities (Weidemann, 1971). A smaller scatter in radii has recently been confirmed by Greenstein (1976) in his evaluation of multi-channel observations, on plotting visual absolute magnitudes against new color indices which are good temperature indicators.

At the same time Schulz (1977) has evaluated all available DA observations (parallaxes, UBV, uvby, Hβ equivalent widths, complete scans by Oke (1974) and Greenstein (1974)), and tried to determine best values of surface gravity, effective temperature and radius by a weighted least square analysis, on comparison with model atmospheres available in the literature. Since the results showed systematic deviations around 10000 K as well as differences between high and low temperature objects, a new set of model atmospheres has been calculated by Koester (1977). On application of the Schulz method we now obtain the HR diagram of Fig. 1 which clearly demonstrates a constant average radius all the way from the hot to the cool end of the DA sequence. Again, no indication of more than one sequence is visible. The average radius is log $R/R_\odot = -1.90 \pm 0.10$, corresponding to a mass range of $0.55 \pm 0.2\ M/M_\odot$ on the Hamada-Salpeter mass-radius

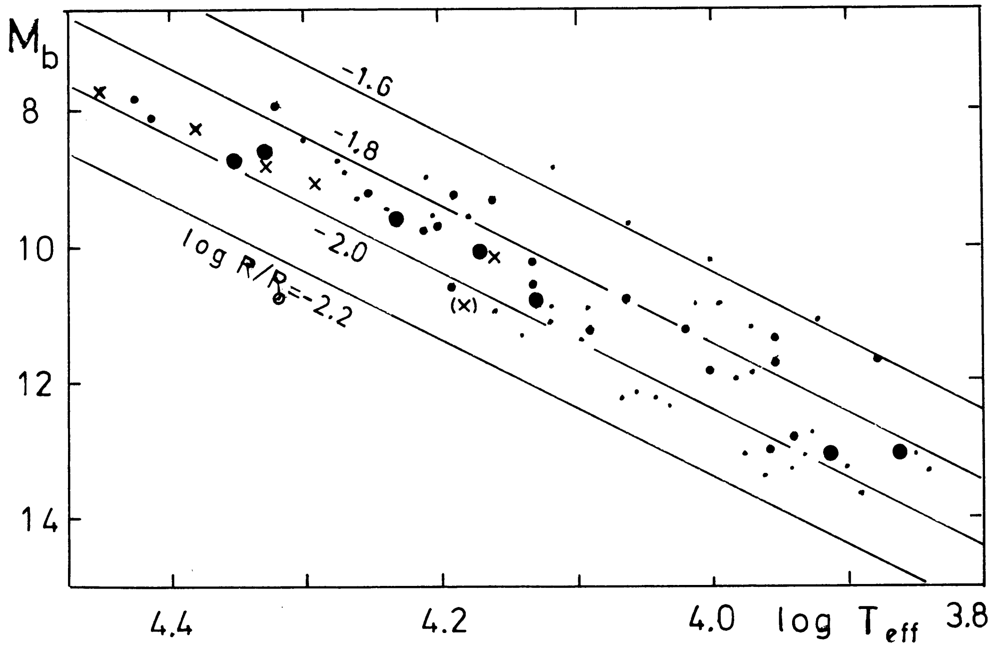

Fig. 1. HR diagram for white dwarfs of spectral type DA.
●: uvby, UBV, good parallaxes, •: ditto, distances less reliable;
· : UBV photometry only, or uncertain parallaxes; ×: Hyades.

relation for C-configurations. The surface gravity scatter is even smaller, and corresponds to a mass range from 0.40 to 0.65 $M_\odot$ for two thirds of the stars for which Strömgren photometry is available. Details will be published elsewhere (Koester, Schulz and Weidemann, 1977). The narrow mass distribution of white dwarfs is the result of considerable mass loss in pre-white dwarf stages, combined with the shape of the initial mass function and effects of galactic evolution (for details see Weidemann, 1977).

The data for the hotter non-DA stars (DB, DC, 4670 Å) are still too uncertain as to establish systematic differences in gravities, masses or radii compared to the DA sample. As far as the coolest degenerates is concerned, the atmospheric composition is less clear, and models are preliminary (Shipman, 1977, Wehrse, 1977).

In this context two facts should be stressed: There seems to be no 'red deficit' if due consideration is given of selection effects (Sion and Liebert, 1977), and, second, the number of established degenerates with cooling ages larger than 2×10^9 yrs is so small as to exclude at present any direct use of degenerates as probes of the galactic past. However, there exists an indirect possibility: We can already rule out certain models of galactic evolution which are not compatible with the narrow mass distribution and the population characteristics of white dwarfs (Weidemann, 1978).

REFERENCES

Bottlinger, K.F. (1923). Veröff. Univ. Sternwarte Berline-Babelsberg 3, Heft 4.
Eggen, O. and Greenstein, J.L. (1965). Astrophys. J. 141, 83.
Graham, J. (1972). Astron. J. 77, 144.
Greenstein, J.L. (1958). Encycl. of Physics 50, 161. Springer Vlg. Berlin.
Greenstein, J.L. (1974). kindly communicated.
Greenstein, J.L. (1976). Astron. J. 81, 323.
Harris III, D.L. (1956). Astrophys. J. 124, 665.
Koester, D. (1977), to be published.
Koester, D., Schulz, H. and Weidemann, V. (1977). in preparation.
Kuiper, G.P. (1941). Colloquium on Novae and White Dwarfs. Hermann, Paris, p. 201.
Luyten, W.J. (1952). Astrophys. J. 116, 283.
Oke, J.B. (1974). Astrophys J. Suppl. 27, 21.
Russell, H.N. (1914). Popular Astronomy 22, 275.
Schulz, H. (1977). Die Massenverteilung der Weissen Zwerge vom Spektraltyp DA. Thesis, Univ. Kiel.
Shipman, H.L. (1977). Astrophys. J. 213, 138.
Sion, E.M. and Liebert, J. (1977). Astrophys. J. 213, 468.
Wehrse, R. (1977). Sec. Europ. Workshop on White Dwarfs, Monte Porzio, Memoria Soc. Astronomica Italiana, in press.

Weidemann, V. (1963). Zeitschr. f. Astrophysik 57, 87.
Weidemann, V. (1968). Ann. Rev. Astron. Astrophys. 6, 351.
Weidemann, V. (1971). In IAU Symposium No. 42, White Dwarfs. W.J. Luyten, ed., D. Reidel, Dordrecht, p. 81.
Weidemann, V. (1977). Astron. Astrophys. 59, 411.
Weidemann, V. (1978). In IAU Symposium No. 76, Planetary Nebulae, in press.

DISCUSSION

LIEBERT: How dependent are your interesting conclusions about the spread of gravities and radii on the use of the models by Koester rather than older calculations?

WEIDEMANN: They are very dependent on them. The old models, e.g. by Wehrse, were calculated with solar helium abundance, whereas the new models are practically pure hydrogen (H/He = 10^5, H/Metals = 10^4 solar).

LIEBERT: Then the new color-color diagram results are due more to changes in model chemical composition rather than the model programs themselves?

WEIDEMANN: Yes, partly, but there remain minor unexplained differences, e.g. in comparisons with the models of Wickramasinghe and Strittmatter.

GREENSTEIN: Did you include the objects with Strömgren photometry by Richard Green? They show a larger intrinsic scatter than did John Graham's, and might be considered to indicate a larger true variation in log g for the degenerate stars.

WEIDEMANN: Yes, Green's data were included with the exception of those at high temperatures, which show a large unexplained scatter.

SHIPMAN: The large scatter for log g values determined from any two-color diagram - Strömgren or multichannel - at high temperatures is due to the small change in observed color with variations in log g at high temperatures.

WEIDEMANN: You are right, but this has been incorporated by the weights assigned. The scatter in Green's data, however, is much larger observationally than Graham's.

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