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EVOLUTION VERSUS PULSATION ON THE HORIZONTAL BRANCH

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1. MASSES AND TEMPERATURES OF RR LYRAE STARS

In a recent study, Simon (1990) determined masses and temperatures for a large sample of RRc stars in ω Centauri. The method proceeded by comparing with the results of hydrodynamic modeling the three observed quantities: period, relative luminosity and Fourier phase, ϕ_{31}. An absolute mass, temperature and luminosity could then be specified for each star once a scale factor, i.e., a distance to ω Cen, was chosen. Although this distance is arbitrary the particular choice made by Simon (1990) yielded a mass range in agreement with the mass range of the RRd stars (Cox, Hodson and Clancy 1983) and with the Baade-Wesselink (BW) masses of three RRc field stars (Simon 1990, and references therein). The same choice also gave temperatures which correctly placed the RRc stars in the first overtone instability strip.

However, the ω Cen study also found a disconcerting lack of any correlation between mass and metallicity - that is to say, at given [Fe/H] a large range of masses was found, $\Delta \log M \sim 0.1$. This mass spread cannot be explained by the canonical evolutionary tracks of Lee, Demarque and Zinn 1990 (hereinafter LDZ) unless the lower mass stars are brighter, a condition which was not seen in the Simon (1990) results. A similar contradiction to evolution theory has been found in the absence of a mass vs. [Fe/H] correlation in BW studies of RR Lyrae field stars (Liu and Janes 1990a).

Very recently, Liu and Janes (1990b) obtained BW masses and luminosities for four RRab stars in the globular cluster M4. Although the BW method is subject to many uncertainties, the credibility of the Liu-Janes treatment is considerably enhanced by the fact that each of the M4 stars, analyzed independently, yielded a nearly identical distance. As found by Liu and Janes (1990b), the luminosity spread among the four stars is $\Delta \log L = 0.08$, while the mass spread is only $\Delta \log M = 0.02$! Although LDZ have not published calculations for a metallicity as large as that of M4 ([Fe/H] = -1.23), it is problematical whether their standard tracks can accommodate the Liu and Janes results.

On the other hand, a new set of calculations by Dorman,

Lee and VandenBerg (1990) could be consistent with pulsationally determined parameters in ω Cen and M4. These calculations, corresponding to high helium and/or enhanced oxygen, produce post ZAHB tracks in which a red loop is preceded by a blue loop at lower luminosity. This results in a double-valued luminosity function at given mass and metallicity, and in general a much weakened set of correlations between luminosity, metallicity and mass. At the same time, the oxygen enhancement tends to lower the evolution masses in the direction of those determined for the RRd stars. It should be noted, however, that the Dorman, et al. tracks will not explain the mass spread at constant metallicity in ω Cen if the RR Lyrae stars in that cluster are predominantly evolving redward as suggested by LDZ.

2. A TEST IS PROPOSED

The ω Cen results of Simon (1990) were subjected to a test in the form of a plot of theoretical temperatures vs. observed B-V colors. Since these two quantities are determined independently, a correlation between them must be taken as some vindication of the theoretical calculations. This correlation is shown in Fig. 1, where log Te is clearly observed to fall off as B-V increases. However, the slope here is only half as large as that predicted by model atmosphere calculations (e.g., VandenBerg and Bell 1985), a result whose implications clearly require further study.

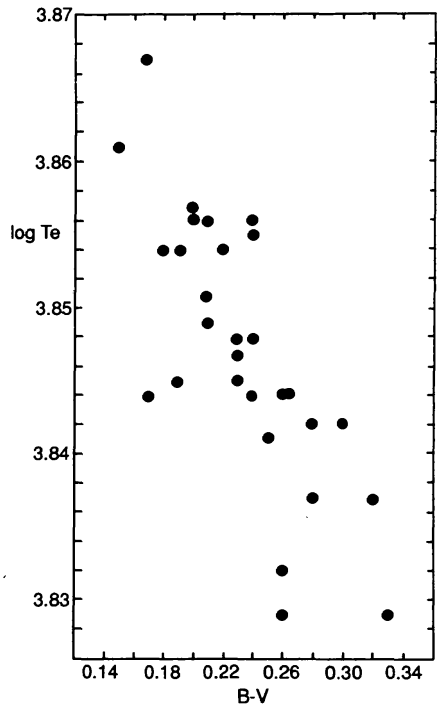

Fig. 1. Log Te vs. B-V for ω Cen RRc stars.

We now propose a similar test for the HB evolutionary tracks. Such a test may easily be performed in any cluster with an RR Lyrae sample with observed periods, metallicities and colors. For given helium abundance and oxygen enhancement the evolution calculations will give a relation of the form L = L(M,Te,Z), [for the Dorman, et al. (1990) tracks, mentioned above, two such expressions would be needed, one each for the blue and red loops], while the period/mean density pulsation law yields P = P(L,M,Te). Choosing a distance to the cluster gives absolute luminosities, whereupon the quoted relations yield a mass and temperature for each star. These parameters may then be subjected to consistency and plausibility checks, including a log Te (theoretical) vs. B-V (observed) plot as above. This kind of test should go a long way toward either bolstering the current evolution calculations or perhaps indicating the areas in which they could be improved.

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