except at the cyclotron resonance. However, additional resonances resulting from the Coulomb interaction may also contribute to this opacity and these may, under certain circumstances, appear as continuum features in the optical spectra.

Perhaps the greatest challenge, however, would be the construction of realistic model atmospheres and line profiles for magnetic white dwarfs at arbitrary field strengths at a level of sophistication that will enable effective temperatures and gravities to be determined from observations. This requires, in addition, the development of a theory of Stark broadening in strong magnetic fields.

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Third Session: Stellar Structure (Tuesday August 23, afternoon)

HORIZONTAL BRANCH EVOLUTION AND RR LYRAE STAR PULSATION

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For many years there has been a confrontation between stellar evolution and pulsation theories concerning the masses, luminosities, and compositions of the horizontal branch RR Lyrae variables. Masses obtained by Cox, Hodson & Clancy (CHC, 1983) were very low, but Kovacs (1985) and later Kovacs & Buchler (1988) suggested somewhat larger ones. Even later Simon & Cox (1991) verified CHC results, though still using the Los Alamos opacities. Petersen (1991, 1992) has also discussed this mass problem in some detail. The persistent discrepancy of 0.1 M⊙ or more between the evolution and pulsation masses was mostly ignored because neither theory could find any significant flaw in its analysis. Cox (1991), Kovacs, Buchler & Marom (1991), and Kovacs, Buchler, Marom, Iglesias & Rogers (1992) finally showed that larger double-mode pulsation masses, are consistent with evolution

https://doi.org/10.1017/S1539299600012193 Published online by Cambridge University Press

calculations to reproduce color-magnitude diagrams of globular clusters. Evolution tracks by many for years, especially the recent ones by Lee, Demarque & Zinn (1990), did require a much lower primordial helium abundance near the big bang value near Y = 0.23, and now this value, slightly enhanced by deep convection dredge-up in the earlier red giant stage, is also found to be appropriate for pulsation studies.

My large number of models with the OPAL opacities can be used to derive fits for the period-mean density relation, the period ratio dependence on masses, luminosities, and surface effective temperatures, and the Petersen diagram constant mass lines. It is very important to note that the old van Albada & Baker (1971) relation, widely used even today, is very out of date. It was based on Cox & Stewart (1970) opacities. But at least two opacity generations have passed now, and the fit coefficients have changed significantly.

With the masses of the RRd variables known, it is possible to construct theoretical Hertzsprung-Russell diagrams for globular clusters of both Oosterhoff groups. Trial distance moduli are used until the one is found that places the points in the theoretical instability strip. A larger distance modulus implies higher intrinsic luminosities for all the cluster stars, and in that case, they would be plotted still along the line with their period but considerably bluer and more luminous. The luminosity uncertainty must be less than 0.1 magnitude or the stars will not reside in the well-known theoretical instability strip. The mean bolometric magnitude for the M3 RR Lyrae variables is 0.56 with a well-known spread of over 0.1 magnitude. The distance modulus is m-M = 15.03, and the mean RR Lyrae luminosity is log $(L/L_\odot) = 1.67$.

Sandage (1993) has given a relation between the luminosity of horizontal branch RR Lyrae variables and metallicity. Using this formula the M3 stars should have a bolometric magnitude of 0.44. Such an increase of brightness form my $M_{bol} = 0.56$ would place the stars too blue and leave a big gap on the red side of the instability strip. Perhaps the formula has an intrinsic error of over 0.1 magnitude, but compared to luminosities proposed for RR Lyrae variables given in the past years, the agreement is actually rather good.

For M3 of Oosterhoff group I, one sees the fundamental mode pulsators are on the red side of the instability strip, and they do not get any bluer than the blue transition line. This indicates that the van Albada and Baker idea of hysteresis might be validated here and in the later clusters to be discussed. Evolution blueward will keep a star in the fundamental mode until it can no longer sustain that mode at the fundamental mode blue edge. For redward evolution, expected for Oosterhoff II clusters, the overtone mode will persist until it gets to the overtone red edge. Double mode cases exist anywhere in the "either-or" region, as one might expect if the cause is mode switching with just slight mass and composition differences between stars.

The luminosity required for the M15 stars to be in the theoretical instability strip results in a mean absolute bolometric magnitude of 0.32, with a smaller intrinsic spread as noted by Sandage (1987). The distance modulus is 15.17, corrected for 0.31 magnitude absorption, and the mean intrinsic log L/L⊙ is 1.77. The Sandage formula gives an absolute Bolometric magnitude of 0.27, very close to my value of 0.32 from instability strip fitting.

For M68 I have used a reddening of 0.03 mag in B-V, as given by Brocato, Castellani & Ripepi (1994). For this cluster the instability-strip-fitting absolute bolometric magnitude is 0.34, again with only a 0.1 magnitude spread. The corrected distance modulus as 15.14, and the mean log L/L⊙ = 1.76. Using the Sandage relation between absolute bolometric magnitude and metallicity, an absolute magnitude would be predicted to be 0.29, close to my value.

In the case of ω Cenauri, I have used the Sandage reddening of 0.10 to derive the distance modulus of 13.79 and the mean log L/L⊙ of 1.75. This gives a mean RR Lyrae variable bolometric magnitude of 0.36, typical of the Oosterhoff II group. But the metallicity given for this cluster is high, and the predicted absolute bolometric magnitude is much fainter at 0.47. This mixture of group I and II characteristics is well-known for this anomalous cluster, probably caused by some coalescence long ago. One feature is its large RR Lyrae luminosity spread, as seen for Oosterhoff I group clusters.

Storm, Carney & Latham (1992) suggested a B-V reddening for M5 of 0.02. My fitting of the data to the instability strip gives a mean bolometric absolute magnitude of 0.54, with very little spread due to the few plotted stars. The distance modulus, corrected for absorption, is m-M = 14.47, and the mean log L/L⊙ is 1.68. The expected bolometric magnitude from the Sandage formula is exactly the same as I get from the plot, 0.54.

1. New OPAL opacities give considerably larger mean RRd masses: 0.70 solar mass for Oosterhoff I and 0.76 solar mass for Oosterhoff II clusters.
2. These masses now agree well with those from horizontal branch evolution.
3. New OPAL opacities produce more hydrogen pulsation driving at blue edges and less sensitivity of them to the helium abundance.
4. The Van Albada-Baker hypothesis for mode behavior is verified using the new Bono-Stellingwerf transition lines derived from nonlinear time-dependent convection calculations.
5. Mean luminosities of globular cluster RR Lyrae variables do not depend much on their mass, but in a cluster log (period) varies as 0.83 log L-0.65 M. Masses vary in a given cluster by about 10 percent, as implied from the luminosity and period data.
6. The mean absolute magnitude for Oosterhoff I cluster RR Lyrae variables is about 0.55, and for Oosterhoff II clusters about 0.35, but variations from cluster to cluster make distance and age measurements difficult.
7. A helium composition of Y = 0.23 is compatible with evolution and pulsation.

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CEPHEIDS: PULSATION, EVOLUTION, OPACITY

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With the advent of new radiative opacities, the gross discrepancies in period ratio between observed stars and theoretical models have been eliminated in both the "beat" and "bump" Cepheid regimes (Moskalik, et al. 1992; Kanbur & Simon 1994). This paves the way for detailed modeling of the beat and bump stars.

We begin here by summarizing one such effort, the full description of which is given by Simon & Kanbur (1994). In this study, the slope of the evolutionary luminosity-mass relation is taken to be dlogL/dlogM = 4.0 (Stothers and Chin 1991) and the intercept determined by forcing models which follow this slope to also conform with the bump Cepheid resonance condition $P_2/P_0 = 0.50$ at $P_0 = 10d$ (Simon & Schmidt 1976; Buchler =et al. 1990). We then model separately each of the dozen known galactic beat Cepheids, subject to the just mentioned evolutionary constraint imposed by the 10-day resonance. We find masses and luminosities, ranging from $M = 4M_\odot$, log L = 3.0 at $P_0 = 3d$ to $M = 6M_\odot$, log L = 3.5 at $P_0 = 10d$. Furthermore, a range of metallicity, $0.01<Z<0.02$, is required among the beat stars, whose period ratios, P_1/P_0, are predicted to decrease as the metallicity rises. This trend has been observed (Andrievsky et al. 1993). However, "standard" evolutionary tracks for $Z = 0.02$ [e.g., the Geneva calculations (Schaller, et al. 1992) or the Padua calculations (Bressan, et al. 1993)] cannot produce Cepheids with parameters as given above - first because the models are somewhat underluminous at given mass, and second because the calculated blue loops do not reach the instability strip for $M = 7M_\odot$. On the other hand, the models described by El Eid (1994) do penetrate the strip at masses as low as 4 or 5 $M_\odot$, but display a luminosity-to-mass ratio considerably too small to satisfy the

https://doi.org/10.1017/S1539299600012193 Published online by Cambridge University Press