# CONVECTIVE EFFECTS AND THE RR LYRAE INSTABILITY STRIP

R. F. Stellingwerf
Mission Research Corporation
Albuquerque, New Mexico

ABSTRACT: The effects of nonlinear, nonlocal, diffusive convection have been included in the structure equations of pulsational hydrodynamic analyses of a series of RR Lyrae models. We find a well-defined red edge of the unstable region that depends on mode of pulsation. It is shown that this result has strong implications for the nonlinear behavior of RR Lyrae stars.

## 1. CONVECTIVE STRUCTURE

Nonlinear RR Lyrae models containing convection as derived in Stellingwerf, 1982a,b have been computed for a range of effective temperatures, fundamental and first overtone modes, and helium abundances of Y = 0.2, 0.3. Most models have been studied at small amplitude (1 km/s) to determine the static convective structure and estimate the stability properties of the small amplitude pulsation. The structure of a typical convective envelope is shown in Figure 1. The unstable regions near the hydrogen and helium ionization zones are seen to be very thin (dashed line = L(c)/L, dotted line = T'/T), but the convective velocity (solid line) shows a much broader structure due to overshooting. Roughly half of the flux is carried by convection in the H zone, with only 10% being carried in the He zone.

The work curve for this model is shown in Figure 2. The total work (solid line) is decreased somewhat relative to the purely radiative model, but the turbulent pressure work (dashed line) contributes positive driving, and the eddy viscosity work (dotted line) is very small. This type of structure is typical of models in the instability strip. Only well to the red of the unstable temperature range do we find thick, efficient convective zones.



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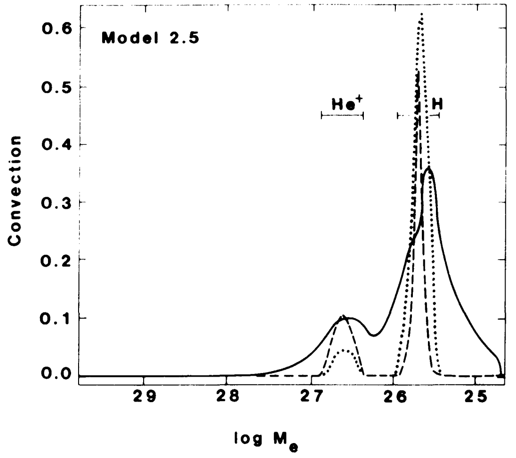


Figure 1

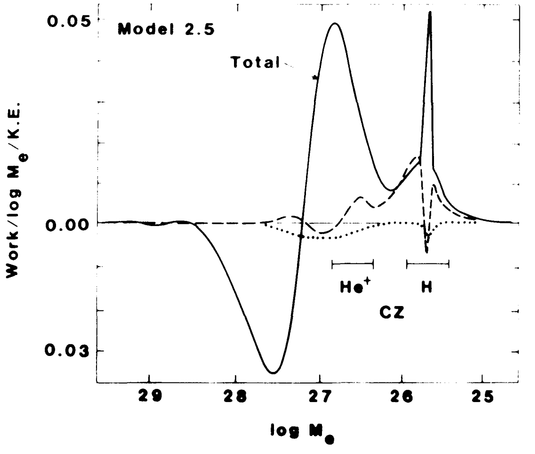


Figure 2

The growth rates for a sequence of models with Y = 0.3 spanning the instability strip are shown in Figure 3, where the dotted lines depict the growth rates of the same models without convection. The curves labeled "0" refer to the fundamental mode and the curves labeled "1" refer to the first overtone. We see that the effect of convection is to strongly stabilize the pulsation toward the red, with the overtone edge occurring well to the blue of the fundamental edge. At the blue extreme of the instability strip the effect is the opposite: convective models are slightly more unstable than radiative models.

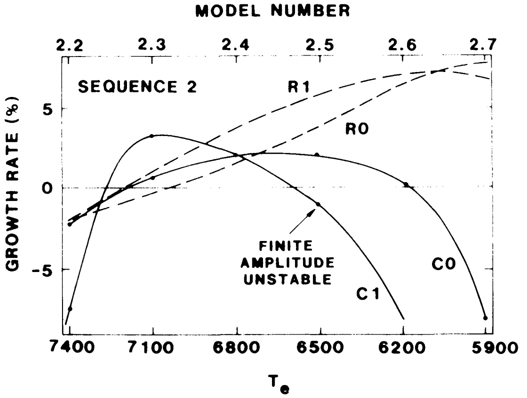


Figure 3

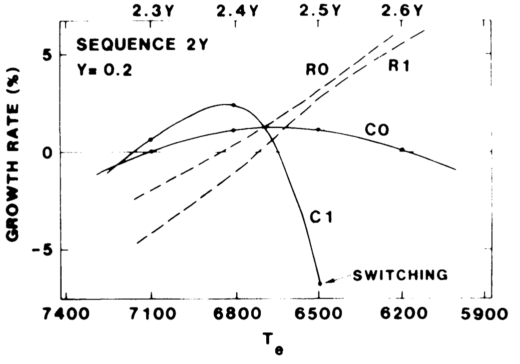


Figure 4

Models were also computed with lower helium abundance: Y = 0.2. The growth rates for these convective and radiative models are shown in Figure 4. It is seen that the convective models in this case show rather strongly enhanced pulsation toward the blue, so much so that the blue edges move only very slightly as Y is varied. If these preliminary results are correct, then determination of helium abundance from the temperature of the blue edge in globular clusters will be very difficult, if not impossible.

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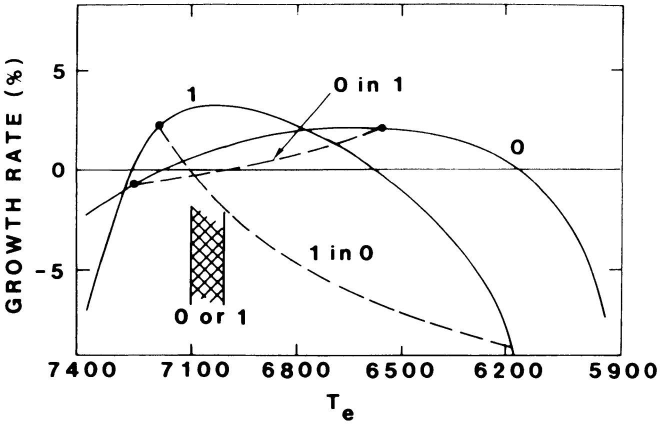


Figure 5

The structure of the growth rate diagrams shown in Figures 3 and 4 have implications for the nonlinear stability of the full amplitude pulsation. The reason for this is that the full amplitude switching rates from one mode to the other must coincide with the small amplitude growth rates at the edges of the instability strip. This phenomenon is well verified for radiative models. In the convective case, the switching rates are constrained at both edges of the strip, as shown in Figure 5. Here the solid lines are duplicated from Figure 3, and the dashed lines represent hypothetical switching rates: the growth rate of mode 0 in the full amplitude mode 1 (0 in 1), and vice versa. These curves must originate and end at the large dots on the solid curves. Nonlinear stability analyses must be calculated to find their behavior between these points. Figure 5 shows one possible configuration. It is clear that the dashed curves must cross the neutral growth rate line somewhere near the vicinity of the center of the instability strip. The points at which they cross this line are transition edges - in Figure 5 we have overtone pulsation toward the blue, fundamental pulsation toward the red, and a region in which both modes are stable (an hysteresis region) in the center (shaded). If the two curves cross exactly on the neutral line, then a sharp transition between modes is indicated. If the dashed curves cross above the neutral growth rate line, then a region of mixed mode behavior is indicated, as found observationally in the clusters M15 and M3. These are the only possibilities. Note that the transition lines must fall in the central region of the strip, and therefore must approximately parallel the edges of the strip. Clusters may have different types of mode switching behavior depending on luminosity or other parameters. Presently, it is believed that the presence of mixed mode stars indicates a stable mixed mode region, rather that a simple mode switch.

REFERENCES

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