THE EFFECTS OF CONVECTION IN RR LYRAE STARS

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Abstract: The effect of convection in RR Lyrae stars has been investigated using nonlinear models that include the effects of time dependence, turbulent pressure, convective overshooting, and convection-pulsation interaction. The convective structure reduces to that of mixing-length theory in the limit of no time dependence and thick convective zones. Initial tests suggested that convection has an important effect on the stability and pulsation mode of these stars. We now have investigated the nonlinear nature of convection at limiting amplitude. Convection serves as a limiting amplitude mechanism for these stars by causing turbulence near the phase of minimum radius that damps the driving. A comparison with Geneva observations of RR Lyrae shows good agreement in the phase dependence and amplitude of the turbulent motions.

STABILITY

The effect of convection on the stability of RR Lyrae models is shown in Figure 1. Here the dashed lines are the linear growth rates for purely radiative models, while the solid lines show the growth rates with convection included, for modes 0 and 1. Several effects are evident. The red edge is present in the convective models, and is strongly mode-dependent. The blue edges have shifted a bit, an effect that becomes more important as helium abundance is lowered. These results are described in detail in Stellingwerf 1982a,b, 1984a,b.

LIMITING AMPLITUDE

A convective fundamental mode model at effective temperature 6500K (type b) has been integrated for 100 periods to limiting amplitude. The variation of the velocity and luminosity are shown in Figures 2 and 3 for the limit cycle motion. These are typical of an RR Lyrae "b" type star. Of most interest is the time dependent behavior of the convection, shown in Figure 4. Here the convective velocity and luminosity are plotted versus exterior mass at twelve phases of the motion.

Figure 1

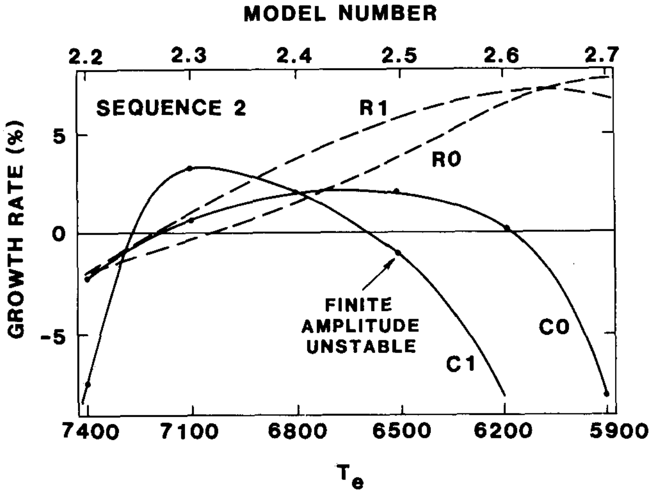


Figure 2

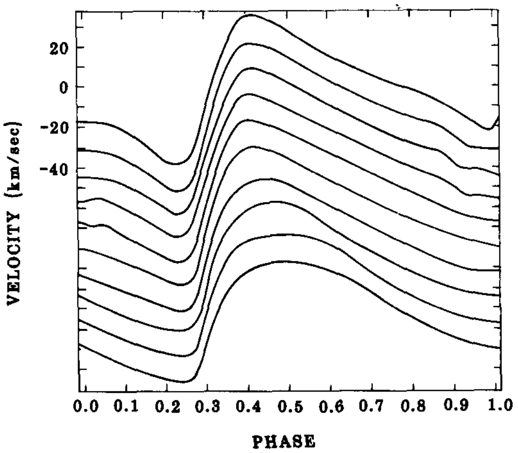
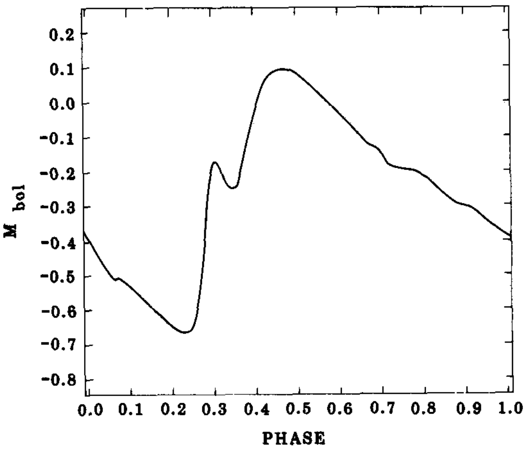
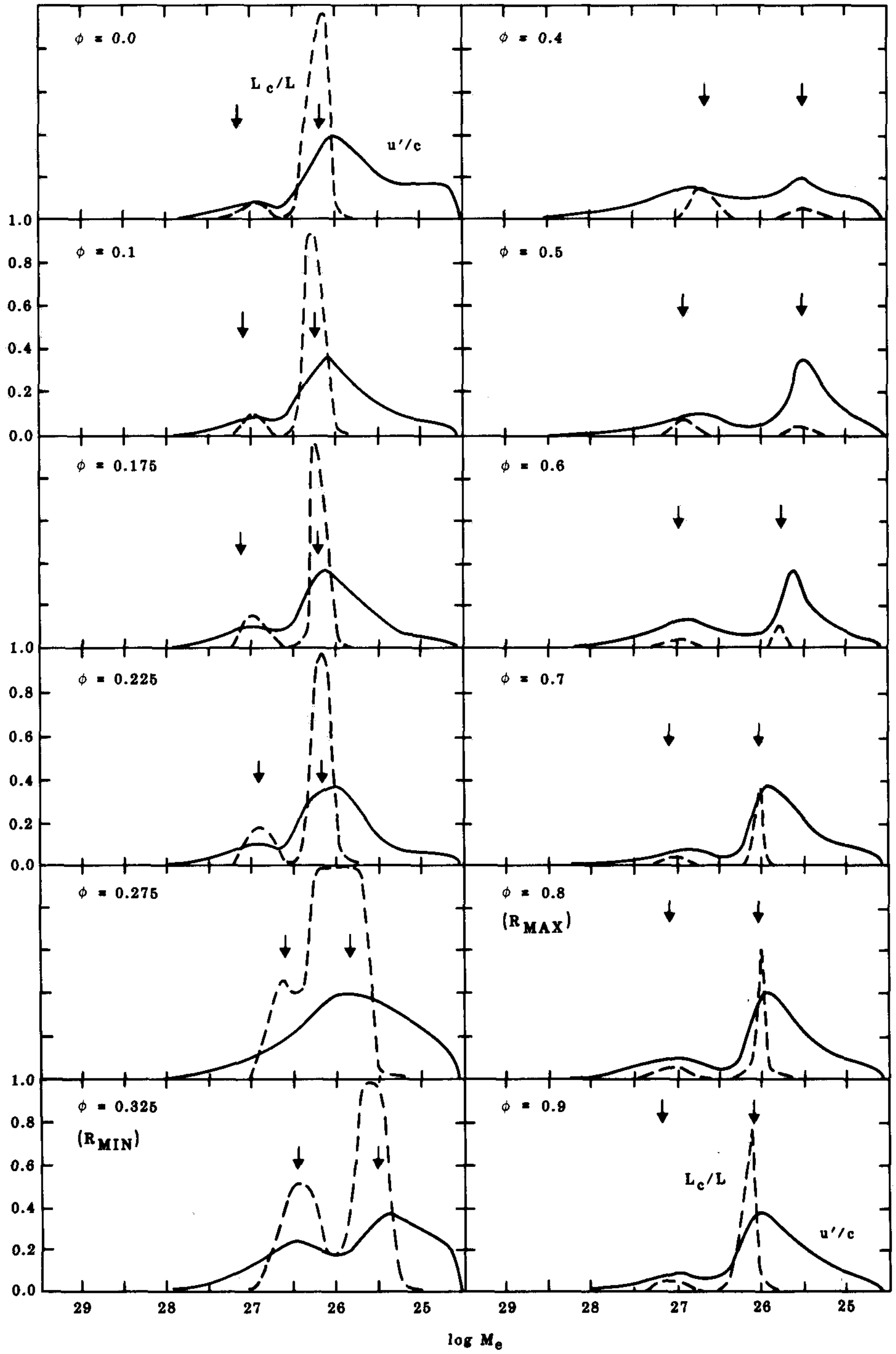


Figure 3



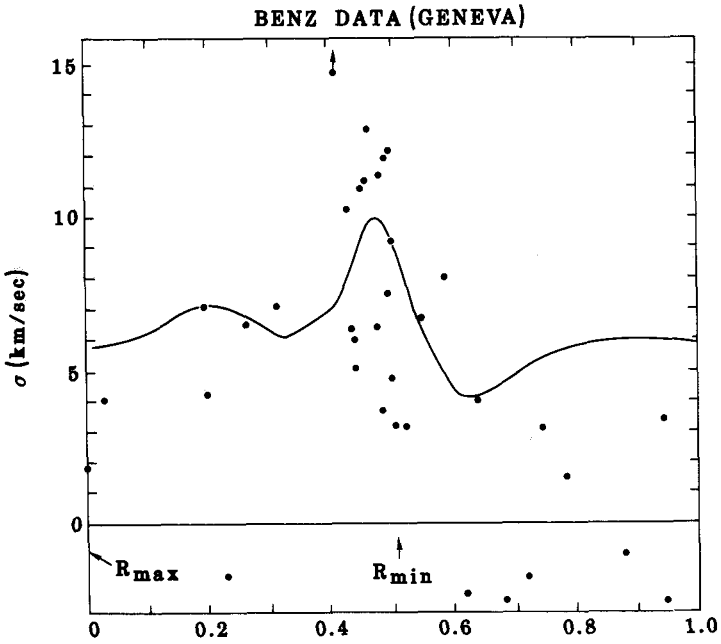
The structure at phase 0.8 (maximum radius) is very close to that of the static model. Following this phase, the convection strengthens, then remains essentially constant through phase 0.225. The arrows show the location of the ionization zones. At phase 0.275, just before minimum radius, the convection suddenly turns on very strongly - the two unstable zones merge, and convection carries all of the flux over a substantial region of the star. Then, at phase 0.325, just following minimum radius, the convection quite rapidly decreases nearly to zero. This behavior is apparently caused by the very strong compression and expansion occurring near the phase of minimum radius.

Figure 4


φ = 0.0
L c/L
u'/c
φ = 0.4
φ = 0.1
φ = 0.5
φ = 0.175
φ = 0.6
φ = 0.225
φ = 0.7
φ = 0.275
φ = 0.8
(R MAX)
φ = 0.325
(R MIN)
φ = 0.9
Lc/L
u'/c
1.0
0.8
0.6
0.4
0.2
0.0
29
28
27
26
25
log Me

The variation of the rms convective velocity in the atmosphere of the model versus phase of oscillation is shown in Figure 5. The range for this model is 5-10 km/sec. Also shown are preliminary data from Geneva depicting the measured variation of line widths corrected for projection. The peak in turbulence near minimum radius, as well as the subsequent decline are visible. These features are more prominent in several Cepheid observations reported by Benz and Mayor, 1982.

Figure 5



COMPARISON WITH RR LYRAE OBSERVATIONS

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