OSCILLATIONS OF HB RED VARIABLE STARS

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Abstract. Using a nonlocal time-dependent theory of convection, we have calculated the linear non-adiabatic oscillations of the Horizontal Branch (HB) stars, with both the dynamic and thermodynamic coupling between convection and oscillations been carefully treated. Turbulent pressure and turbulent viscosity have been included consistently in our equations of non-adiabatic pulsation. When the coupling between convection and oscillations is ignored, for all models with $T_e \leq 7350K$, the fundamental through the second overtone are pulsationally unstable; while for $T_e \leq 6200K$ all the models are unstable up to (at least) the 9th overtone. When the coupling between convection and oscillations is included, the RR Lyrae instability strip is very well predicted. Within the strip most models are pulsationally unstable only for the fundamental and the first few overtones. Turbulent viscosity is an important damping mechanism. Being exclusively distinct from the luminous red variables (long period variables), the HB stars to the right of the RR Lyrae strip are pulsationally stable for the fundamental and low-order overtones, but become unstable for some of the high-order overtones. This may provide a valuable clue for the short period, low amplitude red variables found outside the red edge of the RR Lyrae strip on the H-R diagram of globular clusters. Moreover, we present a new radiation modulated excitation mechanism functioning in radiation flux gradient regions. The effects of nonlocal convection and the dynamic coupling between convection and oscillations are discussed. The spatial oscillations of the thermal variables in the pulsational calculations have been effectively suppressed.

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1. Discussion and Conclusions

We have reported the detailed study of HB variables in our recent work in Xiong *et al* (1997a, 1997b), in which the physical justifications and our numerical efforts can be found. The main results of our work can be summarized as the following,

1. When not considering the coupling between convection and oscillations, it is not possible to explain the red edge of the RR Lyrae instability strip. The true reason for the existence of the red edge of the RR instability strip is because of the coupling convection and oscillations. Our numerical results show that, when taking the coupling into consideration, all low temperature HB models with $T_e \leq 5940K$ have their fundamental and low-order overtones ($n \leq 3$) pulsationally stable. The turbulent viscosity is an important damping mechanism of oscillations.
2. For the low temperature red HB star models some of the high-order overtones ($n \geq 4$) become pulsationally unstable. This might be the clue for the red variables found outside the RR Lyrae instability strip in globular clusters by Yao and his collaborators.
3. Radiation Modulated Excitation exists in radiation flux gradient regions at the top and bottom of convection zone.
4. The spatial oscillations are due to the local treatment of convection. They can be suppressed effectively by non-local treatment of convection.

The effects of convection on the instability can not be omitted for the blue HB stars ($T_e \geq 7000K$), although the convective envelope is already very shallow and convective energy transport becomes negligible ($L_c/L \ll 1$). We took a numerical test, in which the dynamic coupling was omitted. The results shows that all the low-order overtones become pulsationally stable. We are reluctant to draw any further conclusion on the pulsational properties of the blue HB stars because there are some undetermined factors. This problem deserves future investigation. High-precision photometry of variables is available for us to determine whether there are low-order unstable modes in the blue HB stars.

References

Xiong D.R., Deng L. & Cheng Q.L. (1997a), *submitted to ApJ*
Xiong D.R., Cheng Q.L. & Deng L. (1997b), *submitted to ApJ*