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Hydrodynamic Simulations of Convection

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1. Introduction

Convection is one of the most problematic components of almost every model of a pulsating star. RR Lyrae stars, in particular, have a narrow convection zone at the outer layers, and a model without convection cannot get the red edge of the instability strip (see for example Kollath et al., 2000).

In recent years, the common approach is to use non-local time-dependent extensions to the Mixing Length Theory of convection (Bono et al., 1997; Feuchtinger, 1999). These models have many free parameters that need to be calibrated. In this paper we report on a preliminary work in which a different approach is used: 2D hydro simulations similar to the red giant model in Asida (2000). This approach was used by Deupree (1975, 1977) but we used a much better numerical resolution and focused on comparison with MLT results.

2. Results

As a preliminary study we started with a model of an "RR Lyrae-like" star, which is about one thousand degrees cooler than the red edge: $M = 0.6M_{\odot}, L = 60L_{\odot}, T_{\rm eff} = 5200\,{\rm K}$, and $Z = 0.002$. In such a case, as the star should not pulsate, comparison with MLT is easier.

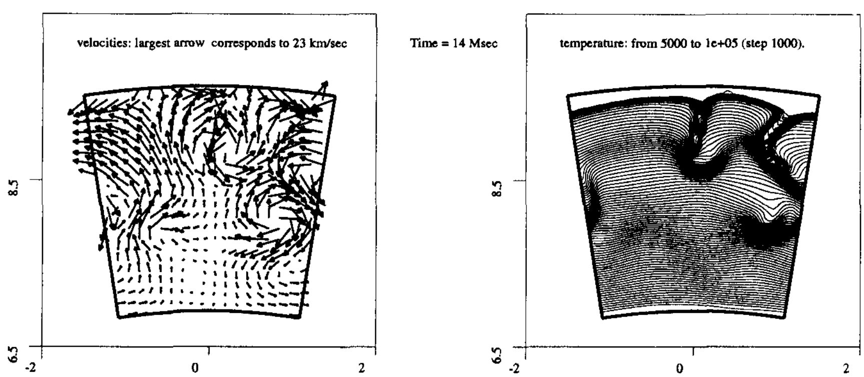

Figure 1. 2D flow: velocities and temperatures.

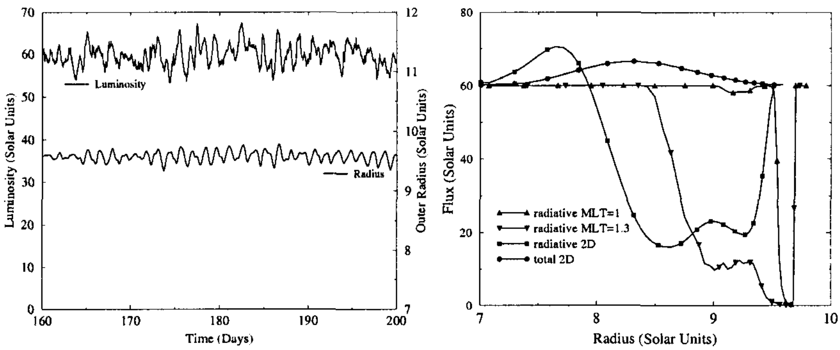

Figure 2. Left: Variability with time, Right: Averaged flux profiles.

As we can see from Fig. 1 the usual 2D convective flow was formed: narrow and fast down streams, overshoot to the stable region at the bottom with a different flow pattern (see also Asida & Arnett, 2000). Since the outer boundary was free to move, we got small variability in luminosity and outer radius (Fig. 2, left) but overall the simulation seemed to be stable, so we can take time average of the flux in the simulation and compare it to simple 1D MLT results.

In Fig. 2 (right) we present this comparison by looking at the radiative flux: the convection zone is much wider in the 2D simulation than in the 1D model with mixing length parameter of 1 (even wider than in the 1.3 model); convection is less effective (radiative flux is more than third of the total flux everywhere). The penetration below, with negative convective flux is evident. Important effects needed to be addressed in the future are resolution and dimensionality.

References

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