INTERMITTENT TRANSITION TO IRREGULAR PULSATION
WITH MASS LOSS IN HYDRODYNAMIC MODELS

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Introduction

Hydrodynamic simulations of non-linear pulsation for less-massive cooler supergiants have been perfoemed by several authors (Tuchman, Sack and Barkat, 1979; Fadeyev and Tutukov, 1981; Fadeyev, 1982, 1984; Nakata, 1987; Buchler et al., 1987). The outburst of large amplitude pulsation at times is one of common features of these models, and renders mass-loss from the atmosphere of pulsating stars by generating strong shock waves.

Models and results

To find out routes of the transition from limit cycles to this type of irregular pulsation, we performed hydrodynamic simulations for a series of models the luminosity $\log(L/L_{\odot}) = 3.505$, and $Te = 5300$ K with a narrow range of the mass, $1.4\ M_{\odot} \leq M \leq 1.5\ M_{\odot}$ by using the hydrodynamic code, TGRID (Simon and Aikawa, 1986).

With decreasing the mass, we confirm a transition from limit cycles to the irregular oscillations. The models which show the irregularity keep stationary oscillations with the amplitude of the corresponding limit cycle of massive models for a while (the laminar phase), but gradually get kinetic energies of pulsation and move towards oscillations with much larger amplitudes, and then finally dissipate the kinetic energies by generation of strong shock waves, causing an outburst of irregular oscillations.

Analysis

The nature of the transition is finally specified by examining the dissipation of the kinetic energies in stable models, as the pulsation starts with larger amplitudes than their limiting amplitudes. We find that the rates of the dissipation are so small that the pulsation with these amplitudes might be marginally stable.

Furthermore, the oscillation starting with even larger amplitudes gets the kinetic energies until it reaches a limit where the oscilla- tion induces strong shock waves and dissipates its kinetic energies (see Fig. 1). Thus we conclude that the model which has the stable limit cycle near the transition has another unstable fixed point with a larger amplitude. The transition therefore is induced by the

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disappearance of these two fixed points, as the mass, the control parameter in our case, is varied, and exactly fits the intermittency of Pomeau and Manneville (1981) proposed as an universal route to chaos in dissipative systems.

It is suggested that the outbursts of the irregular oscillations with mass-loss often observed in hydrodynamic models of less-massive supergiants may be in consequence of this intermittent transition.

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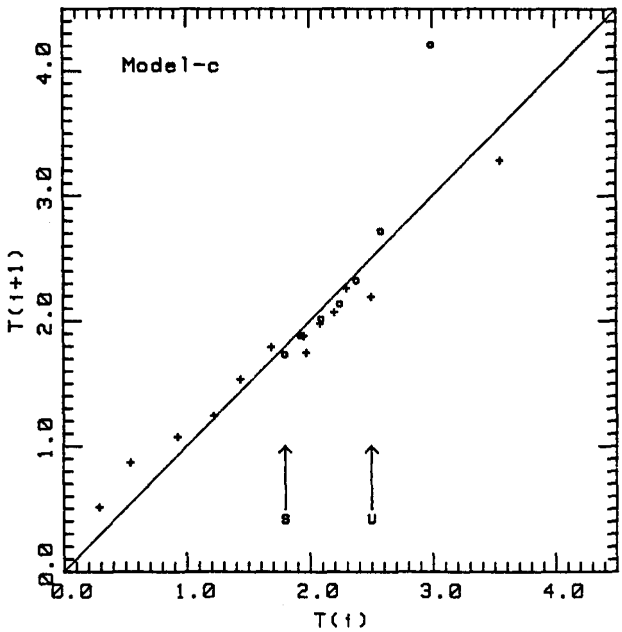

Fig.1 - Dissipation structure of a stable model. The resulting kinetic energies T(i+1) after one cycle against the input kinetic energies T(i) are plotted. If T(i+1) < T(i), the input oscillation is damped, and if T(i+1) > T(i), the oscillation is excited. The model has a stable limit cycle indicated by an arrow with "s". The rates of dissipation for oscillation with larger amplitudes than the limit cycle are so small that the oscillations might be marginally stable. Furthermore, for even larger amplitudes, the model has another unstable fixed point indicated by an arrow with "u". These are characteristics of stable models near the transition.

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