NON-ADIABATIC EFFECTS ON PULSATION PERIODS

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INTRODUCTION

It is well known that the difference between the adiabatic pulsation periods and the corresponding non-adiabatic periods is small in classical Cepheids. However, the difference becomes significantly large in low surface-gravity models (e.g. Aikawa 1984a). In this paper we shall discuss the origins of the difference between the two pulsation periods. The weight functions for non-adiabatic pulsation periods are introduced in analogy to those of Epstein (1950) for adiabatic periods.

ACOUSTIC WAVES IN RADIATION FIELDS

Non-adiabatic pulsations are influenced by the interaction between acoustic waves and radiation fields. Two important parameters characterize the interaction (e.g. Vincenti and Kruger 1965). They are:

$$N_{Bo} = \rho C_\rho a/\sigma T^3, \tag{1}$$

$$\tau_a = \kappa/\omega \ , \tag{2}$$

where $\underline{a}$ is the adiabatic sound speed, κ is the specific opacity, and ω is the frequency of the acoustic motions. We examined the behavior of these quantities in the envelope of classical Cepheids and the low surface-gravity stars and we find the star is divided into three regions according to the coupling between the the acoustic waves and the radiation (Mihalas and Mihalas 1983; Zhugzhda 1983):

I: adiabatic region,
II: interaction region,
III: isothermal region.

We also plotted the peak of the weight functions of the fundamental mode. The peak is in Region I for the classical Cepheid while it is in Region II for the model with low surface gravity. This fact shows that the pulsation periods of classical Cepheids are determined essentially in the adiabatic region and, on the contrary, those of the low surface-gravity are strongly affected by the region where the acoustic waves are coupled tightly to the radiation field. This is the first conclusion of this paper.

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PROPAGATION SPEED OF ACOUSTIC WAVES IN RADIATION FIELDS

The travel time of the adiabatic sound wave from the center to the surface of a star is nearly equal to the adiabatic pulsation period (Lamb 1945). We shall discuss the difference between the adiabatic and the corresponding non-adiabatic pulsation periods in terms of the propagation speed of acoustic waves.

In Region I, the acoustic waves propagate with the adiabatic sound speed. Thus non-adiabatic effects do not significantly influence pulsation periods. In Region III, the acoustic waves propagate with the isothermal sound speed, so acoustic waves have longer travel times than adiabatic sound waves. It is expected that the non-adiabatic effects in this region make the pulsation periods longer.

Region II is very complicated. The acoustic mode changes its speed from the adiabatic to the isothermal sound speed gradually. On the other hand, the thermal-diffusion mode has a phase speed of 1 to 2 times the adiabatic sound speed in this region. It is noted that the acoustic waves are still tightly coupled to the radiation in the latter mode. Thus the effective propagation speed of acoustic waves must be considerably higher than the adiabatic sound speed in this region. Hence, the non-adiabatic effects will make the pulsation period shorter.

We conclude that the characteristics of the non-adiabatic weight functions are explained qualitatively by these arguments. This is the second conclusion of this paper.

Finally, we conclude that the non-adiabatic effects are quite important in low surface-gravity pulsating stars. The details will appear in Aikawa (1984b).

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