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E. Michel, A. Hui-Bon-Hoa (eds), COROT Seismology Working Group, Milestone Meeting, Paris, September 25–26, 2000
http ://dasgal.obspm.fr/ michel/MilestoneProc
/SWGproc2000.html

A computer code for nonradial, nonadiabatic, stellar pulsations

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ABSTRACT

We present the nonradial, nonadiabatic stellar pulsation code written by M.-A. Dupret written in the frame of his PhD thesis. A special attention has been brought to the treatment of the external layers.

The computer code

For the needs of his PhD thesis M.-A. Dupret has written a computer code for nonradial, nonadiabatic pulsations of stellar models. The code assumes that the given model is spherically symmetric. So, in presence of rotation, it can only give the frequency splitting computed by the usual perturbation method (Ledoux 1951 and many textbooks, for instance Cox 1980 and Unno et al. 1989). This method is restricted to slow rotation cases, i. e., when the rotation frequency is much less than the pulsation frequency. We have however projects to use non perturbative methods to take rotation into account.

The interaction between convection and pulsation is a very difficult matter. In its present state, the code ignores the perturbation of the convective flux. It is probably good enough for an internal convective zone where the oscillation is adiabatic and the convection very efficient, but it is not appropriate when the model has an external convective layer. So it is not suited for the computation of solar-like star oscillations but we may hope rather good results for δ Scuti variables and more massive stars.

The strong point of the program is the particular attention given to the surface boundary conditions and the careful treatment of the perturbation in the atmosphere. The diffusion approximation used to describe the radiative flux in the interior is no longer valid in the atmosphere where the optical depth is of the order of unity or smaller. The temperature distribution in the atmosphere is described by a numerical model, such as a Kurucz model, $T = T(\tau, T_{\mathrm{eff}}, g_{\mathrm{e}})$. During the pulsation, the atmosphere is supposed to remain in radiative equilibrium and the variation of the temperature is given by the linearized form of the previous relation,

$$\frac{\delta T}{T} = \frac{\partial \ln T}{\partial \ln T_{\mathrm{eff}}} \frac{\delta T_{\mathrm{eff}}}{T_{\mathrm{eff}}} + \frac{\partial \ln T}{\partial \ln g_{\mathrm{e}}} \frac{\delta g_{\mathrm{e}}}{g_{\mathrm{e}}} + \frac{\partial \ln T}{\partial \ln \tau} \frac{\delta \tau}{\tau} \, .$$

In this way, reliable eigenfunctions can be obtained in the atmosphere of the pulsating star. Figure 1 shows an example of the run of the temperature variation in the atmosphere (at the right of the vertical line). The differences in the temperature profiles of the adiabatic and nonadiabatic cases are noticeable.

We are considering two applications of this code. The first one is, of course, the computation of the frequencies of the normal modes of stellar models. This is the first step for doing asteroseismology. As it

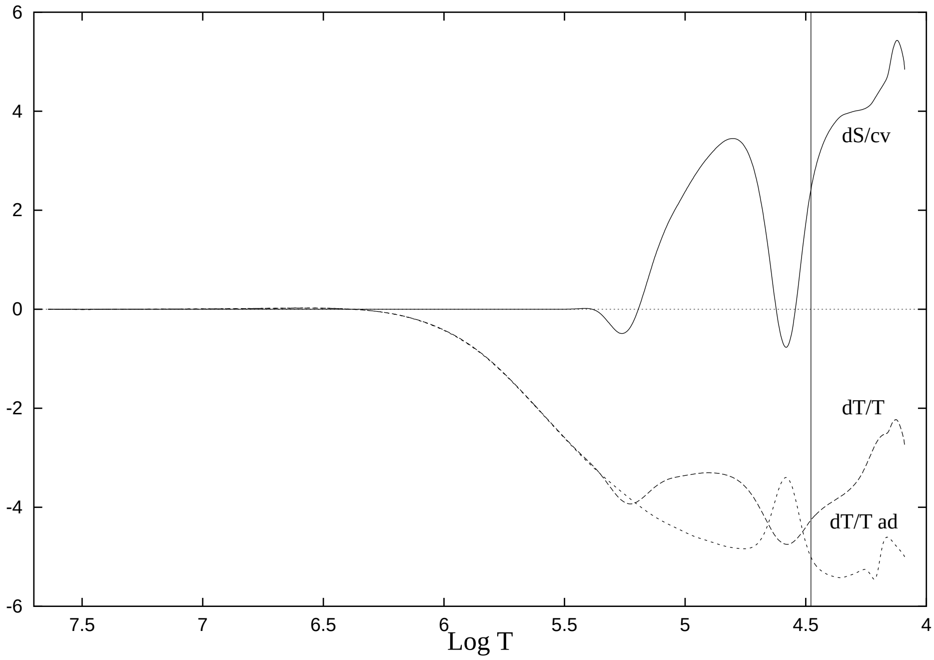

Fig. 1.— Real parts of the eigenfunctions $\delta S/c_v$, $\delta T/T$ and $\delta T/T_{ad}$ for the $\ell = 1$, p_1 mode of a 10 $M_\odot$ model near the end of the core hydrogen burning phase

is a nonadiabatic code, it can predict which modes should be excited. The comparison with modes really observed in a star will put further constraints on its structure.

The second application needs spectroscopic observations. It takes advantage of the reliable temperature variations in the atmosphere given by the program. This enables the computation of better line profile variations during the pulsation. A collaboration on this subject has been initiated with J. De Ridder. We hope that this advance will help in the identification of the modes.

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