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Convection-Induced Oscillatory Thermal Modes in Red Giants: A New Type of Stellar Oscillation

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Abstract. A new type of oscillatory thermal mode has been found in red giant stars. The modes arise because of the interaction of stellar oscillations and convective energy transport. All the modes found are highly damped. However, it is possible that a different treatment of convection could lead to unstable modes capable of explaining the long secondary periods observed in some red giants.

While seeking an explanation for the long secondary periods observed in some semiregular variables (Houck 1963; Wood et al. 1999), a search was made to see if radial pulsation modes with suitably long periods existed. Modes with such periods ($\sim$10 times longer than the first overtone period) were indeed found.

The linear nonadiabatic pulsation code of Wood & Sebo (1996) was used to look for eigenvalues ω, where a time dependence $\exp(\omega t)$ was assumed. The most important point about these calculations is that an explicit time dependence of convective energy transport was used. It was assumed that during pulsation the convective velocity v changes on a convective time scale τ (a scaled value of the ratio of mixing-length to convective velocity) such that $\dot{v} = \dot{v}_0/(1 + \omega\tau)$, where $\dot{v}_0$ is the rate of change of convective velocity given by instantaneous mixing-length theory (see Wood 1974, 1976).

Some lower-order eigenvalues and eigenfunctions are shown in Fig. 1. The newly found eigenvalues are part of a *family* of modes stretching away almost parallel to the real ω axis. If either instantaneous ($\tau = 0$) or no ($\tau = \infty$) adjustment of the convective velocity is assumed, the modes disappear. Furthermore, if the acceleration term in the momentum conservation equation is removed, the eigenvalues are essentially unaffected. Hence, these modes are *thermal* modes. Since they occur because of the explicit inclusion of time dependence of convective energy transport, the modes are designated convection-induced oscillatory thermal (COT) modes.

Modes of the type found here have almost certainly not been found before. Saio, Wheeler, & Cox (1984) did find a long-period strange mode, which they labeled Type I, in some luminous helium stars. However, since they did not allow any convective flux variations in their calculations, it seems unlikely that their strange modes are related to the COT modes found here.

The COT modes studied here are highly damped. However, it may be that another treatment of convection could give rise to unstable COT modes capable of explaining the long secondary periods in semi-regular variables.

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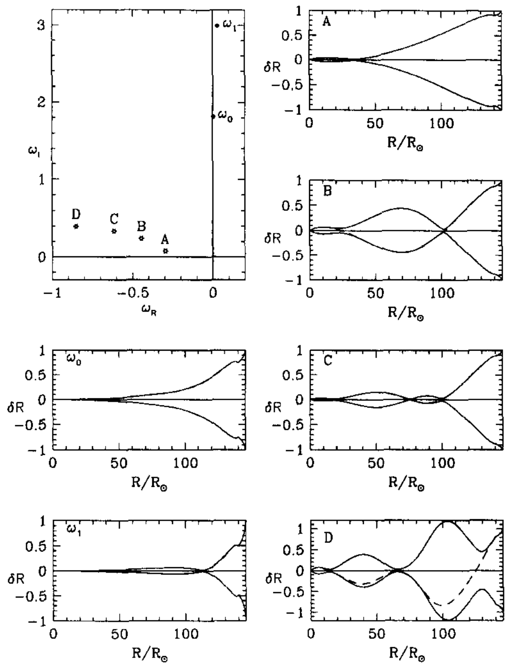

Figure 1. Linear nonadiabatic eigenvalues (scaled to $(GM/R^3)^{\frac{1}{2}}$) for an LMC AGB star with $M = 1.5\,M_{\odot}, L = 3200\,L_{\odot}, Y = 0.27$ and Z=0.008 (upper left). The eigenvalues of the first two normal modes are shown as filled circles while the eigenvalues of the COT modes are shown as stars. Eigenfunctions are also shown, with solid lines showing the eigenfunction amplitude, and dashed lines showing the radial displacement δR as a function of radius at the time of maximum surface radius.

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