*Radial and Nonradial Pulsations as Probes of Stellar Physics*
*ASP Conference Series, Vol. 259, 2002*
*C. Aerts, T.R. Bedding, & J. Christensen-Dalsgaard, eds.*

# Driving g-Mode Pulsation in $\gamma$ Doradus Variables

Yanqin Wu

*CITA, University of Toronto, Toronto, CANADA*

**Abstract.** Surface convection zones in $\gamma$ Doradus variables (early F-type g-mode pulsators) can drive pulsation via the 'convective driving' mechanism. This mechanism is first proposed and studied in the context of ZZ Cetis (hydrogen-envelope white dwarfs with g-mode pulsations) by Brickhill (1991) and Goldreich & Wu (1999). We implement and develop the convective driving theory to suit the environments on $\gamma$ Dors, in particular, stronger super-adiabatic gradient and weaker convective flux than those in white dwarfs. This results in a spectrum of gravity-modes being excited in the observed temperature range. However, there are more remaining problems than those that are solved.

$\gamma$ Doradus variables are early F-type dwarfs that pulsate with periods from 0.4 to 3 days, with amplitudes below 0.1 magnitude. The pulsations are associated with non-radial gravity-modes.

The surface structure of a typical $\gamma$ Dor determines the excitation mechanism. The driving region, where the thermal time-scale $\tau_{\rm th} \sim$ mode period $\sim 1$ day, coincides with the bottom of the surface convection zone. The opacity ($\kappa$) bump, the operating region of the opacity-driving mechanism, resides within this convection zone. Convective flux variations during pulsation may quench driving from the opacity bump (but see Guzik et al., 2000). The convection turn-over time ($t_{\rm cv}$) is of order hours and much shorter than the pulsation mode period. So 'convective driving' is a likely candidate for exciting g-modes.

The basic feature of 'convective driving' is that when convection turn-over time is much shorter than pulsation period, variations of the convection zone during pulsation can be approximated by those between models of slightly different effective temperatures. Integrating these variations over a pulsation cycle, we obtain a work integral that is positive. The positive sign is partly contributed by the fact that the partial ionization zone coexists with the convection zone (Brickhill, 1991; Goldreich & Wu, 1999). We find a spectrum of g-modes that are overstable in the observed mass and temperature ranges.

Many theoretical uncertainties remain in understanding the excitation. Some of these involves rotation. $\gamma$ Dor stars are fast rotators. Rotation distorts stellar structure both dynamically (centrifugal force) and thermally (meridional circulation). Both are more significant in the upper envelope where the mode is being excited. Coriolis force associated with the fast rotation influences the structure of the pulsation mode. It is difficult to trust results ignoring rotation.

Some difficulties arise from convection. $\gamma$ Dor convection zones are largely super-adiabatic. For a star at a given $T_{\rm eff}$, the theoretical structure of the convection zone can differ strongly when different mixing-length parametrizations



https://doi.org/10.1017/S0252921100016948 Published online by Cambridge University Press

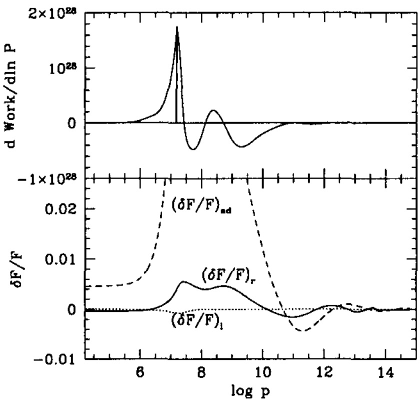


Figure 1. Differential work integral (upper panel) and fractional flux variations (lower panel, including adiabatic and non-adiabatic) as functions of pressure (cgs, logarithmic), for an overstable $\ell = 1$, one-day period g-mode in a $1.5M_\odot$ zero-age main-sequence star (model courtesy of Christensen-Dalsgaard). Convection extends from photosphere to $p \sim 10^7$ dyn cm$^{-2}$.

are adopted. This causes difficulty when comparing the theoretically predicted instability strip with the observed one. Turbulence in the convective region removes kinetic energy from the pulsation mode, which can be described as a turbulent viscosity. However, the rate of energy removal also depends on the velocity gradient of the mode in the convection zone. This is difficult to obtain self-consistently, mostly due to uncertainties in the radiative-convective boundary layer. The convective overshoot region also introduces turbulent damping. This is again uncertain.

At the moment it seems premature to compare theory against observations. HD 209295 exhibits both p- and g-mode oscillations (Handler et al., these proceedings). This offers the exciting possibility for both excitation theory and asteroseismology.

## References

Brickhill, A. J. 1991, MNRAS, 251, 673

Goldreich, P. & Wu, Y. 1999, ApJ, 511, 904

Guzik, J. A., Kaye, A. B., Bradley, P. A., Cox, A.N., & Neuforge, C. 2000, ApJ, 542, L57