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g Modes in F Stars – A Non-adiabatic Investigation of the Stability of g Modes in γ Doradus Stars

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Abstract. We investigate a sequence of $1.5\,M_\odot$ models for g-mode instabilities. For the computation of the nonradial, non-adiabatic oscillations we make use of the Riccati method introduced by Glatzel & Gautschy (1992) to integrate the pulsation equations as given by Unno et al. (1989).

By now it is fairly well accepted that the γ Doradus stars form a separate group of pulsating stars (Kaye et al. 1999 and references therein). Since the multi-periodic variations of these stars have periods of roughly 20 dynamical time scales and longer, it is believed that they are caused by high-order g modes. Moreover, since the γ Doradus stars are clearly not a subclass of any of the other A/F-type variable or peculiar stars in this part of the HR diagram, it is expected that the successful modelling of these stars will offer additional insight into stellar physics.

Dziembowski (1995) suggested that the γ Doradus stars might be understood as the He-II partial ionisation analogue of the slowly pulsating B (SPB) stars. However, an early stability analysis of an evolutionary sequence of $1.5\,M_\odot$ models by Gautschy & Löffler (1996) did not reveal any unstable modes in the appropriate period range.

The current non-adiabatic survey of the stability of g modes in a sequence of stellar models with $1.5\,M_\odot$ shows that it is essential to include progressive boundary conditions at the stellar surface. The resulting instabilities are caused by the combined influence of the so-called iron-bump opacities just below the convective envelope, the He-II ionisation and the boundary conditions.

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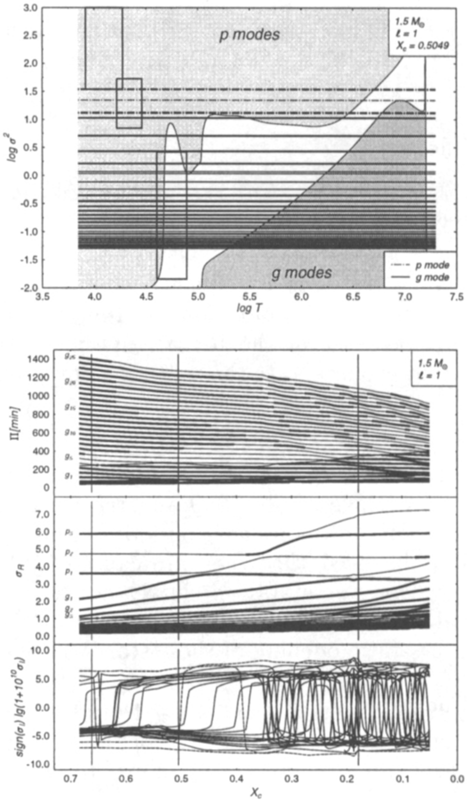

Figure 1. Top: The propagation diagram for a selected model shows the propagative (shaded) and the evanescent (white) regions for the p and g modes. From this diagram, it is evident that the p-mode cavity is not closed, but open, and that progressive boundary conditions must be used at the stellar surface (photosphere). The open rectangles indicate the location of the H I, He I and He II ionisation zones: The vertical boundaries of the rectangles give the loci of 5% and 95% ionisation for the three ionisation stages. The horizontal boundaries give the thermal time scales of the stellar envelope above these loci, converted to a normalised frequency σ. Bottom: The mode spectrum for the complete model sequence shows a pattern of alternating stable and unstable modes which is a result of the progressive boundary conditions. Analysis of the work integrals shows that the destabilisation is due to strong driving in the He II ionisation zone. Since this ionisation zone is located within the evanescent region, such driving can only occur if the complex phase angle of the eigenfunctions is rotated out of the zero position by the κ-mechanism acting on the iron bump located just inside the g-mode propagation zone below the convective envelope.

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