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Asteroseismology of the β Cephei star ν Eridani using differentially-rotating models

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Abstract

This work is focused on asteroseismic modelling of B stars using differential rotation in both the equilibrium models and the oscillation computations. We discuss the possibility of inferring information on the internal structure from the analysis of asymmetries of rotationally split modes. In particular we present some preliminary results on the well-known β Cephei star ν Eridani for which at least three triplets have been identified as g_1, p_1 and p_2 ($\ell = 1$), respectively.

Introduction

A seismic analysis of the oscillation spectrum of ν Eridani was performed by Pamyatnykh et al. (2004). In that work only three frequencies were fitted and they fail to predict the mode excitation of the broad observed frequency range due to the presence of the ($\ell = 1, p_2$) mode. Nevertheless, Pamyatnykh et al. (2004) also inferred some properties of the internal rotation rate using the values of rotational splittings of two dipoles ($\ell = 1$) identified as g_1 and p_1. In particular, their results suggest that the mean rotation rate in the μ-gradient zone is about three times higher than in the envelope for their two standard models fitting the three aforementioned frequencies. Motivated by these results, we aim at performing a complete modelling of ν Eridani taking into account the effect of rotation up to the second order and, using a radial differential rotation (shellular rotation) described by Suárez, Goupil & Morel (2006). In addition, the list of observed frequencies and mode identifications is taken from the updated work of Jerzykiewicz et al. (2005).

The seismic model & analysis of multiplet asymmetries

Models were computed assuming two types of rotation profiles: uniform rotation (the total angular momentum is globally conserved during evolution), and differential rotation (with the hypothesis of local conservation of the angular momentum). The models were assumed to rotate with $v \sim 7\,\mathrm{km\,s^{-1}}$ at the surface. Adiabatic oscillation spectra were computed using the adiabatic code Filou (Tranh Min & Léon, 1999; Suárez, 2002), which corrects the eigenfrequencies up to second-order effects of rotation (including near degeneracy) and takes a radial variation of the rotation profile (shellular rotation, Suárez et al. 2006) into account.

The search for models that fit the observed frequencies ($\sim$ 5% of error in frequency match) yields a mass of $M = 7.13\,\mathrm{M}_\odot$, a metallicity of $Z = 0.019$, and an overshoot parameter of $d_{\mathrm{ov}} = 0.28$. In order to place the model in the photometric error box and to obtain instability of the observed modes, we use a metallicity of $Z = 0.019$ in which we consider a non-standard central hydrogen abundance of $X = 0.50$ (see Ausseloos et al. 2004). The oscillation frequencies and the identified ($g_1, \ell = 1$), and ($p_1, \ell = 1$) triplets were fitted by such models with an age around 16.2 Myr, and considering rotational velocities (at the surface) ranging from 5 to $7\,\mathrm{km\,s^{-1}}$. In addition to this, a supplementary ($p_2, \ell = 1$) triplet is also identified. The differentially-rotating models are found to show a mean rotation rate in the core about $2.5-3$ times faster than on the surface, supporting the predictions given by Pamyatnykh et al. (2004).

Analysis of asymmetries of the rotational split $\ell = 1$ triplets, reveals significant differences when assuming uniform or differential rotation. As expected, the variations of the rotation profile near the core and the μ gradient zone, affects principally the g_1 triplets. Indeed, the comparison with the observed asymmetries indicates that the differentially rotating model would reproduce the asymmetries for the three triplets better than the uniformly rotating one. However, for such a low rotation velocity, the observed asymmetries are very small and then, model discrimination becomes difficult. Thus, in order to better examine the behaviour of these asymmetries, further work for fast rotators is then required (Suárez et al., in preparation).

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Some people are busy working even between the sessions: Hans Kjeldsen, Peter Reegen, Karen Pollard and Laszlo Kiss with their laptops.