*Stars and their variability observed from space*
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# EFFECT OF THE MAGNETIC FIELD ON PERIOD SPACINGS OF GRAVITY MODES IN RAPIDLY ROTATING STARS

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**Abstract.** Stellar magnetic fields play a crucial role in the evolution of the angular momentum of stars and in their interactions with stellar/planetary companions. Spectropolarimetric surveys provide us with observational constraints on surface magnetic fields, but we have very few direct constraints on internal magnetic fields. Asteroseismology allows us to probe stellar interiors and is thus an excellent candidate to obtain new constraints on this magnetism. In this context, we developed a perturbative treatment of a large-scale fossil-like mixed magnetic field (i.e. poloidal and toroidal) in the traditional approximation of rotation (which neglects the horizontal component of the rotation vector) to investigate its effect on the period spacing patterns of gravity modes in rapidly rotating stars. We then applied it to a representative model of the slowly pulsating B-type star HD 43317 and show how the magnetic signatures are different from those of rotation and chemical mixing.

Keywords: asteroseismology, waves, stars: magnetic field, stars: oscillations, stars: rotation

## 1 Introduction

Gravity waves are crucial in stellar physics. First, they allow us to probe the internal properties of intermediate-mass and massive stars (see e.g. Van Reeth et al. 2018). Second, they redistribute angular momentum and chemical elements across the whole Hertzsprung-Russell diagram (Talon & Charbonnel 2005; Mathis et al. 2013; Rogers 2015). Finally, they contribute to tidal dissipation in close-in multiple stars and planetary systems (Ogilvie & Lin 2007).

Surface stellar magnetic fields can be detected using spectropolarimetric measurements of the Zeeman effect. In contrast, there are no direct constraints on the internal properties of stellar magnetic fields. Asteroseismology is a promising way to obtain such new constraints.

Internal magnetic fields can modify the propagation of waves and the frequency of eigenmodes. When the rotation is slow and the field is weak enough to be considered as a perturbation of the non-magnetic system, their main effect is to generate splittings of modes of same radial order and angular degree, but different azimuthal orders. This effect has been studied for pressure modes in rapidly oscillating Ap stars with an oblique dipolar field (Shibahashi & Takata 1993), and for gravity modes in slowly pulsating B-type (SPB) stars with an axisymmetric dipolar field (Hasan et al. 2005). When the field is stronger, it has been proposed as a possible explanation for depressed mixed modes in red giant stars (Fuller et al. 2015; Loi & Papaloizou 2018).

Typical intermediate-mass and massive stars, such as $\gamma$ Doradus, $\delta$ Scuti, SPB, $\beta$ Cephei, or Be stars, rotate rapidly, and thus require a non-perturbative treatment of rotation (Ballot et al. 2010). The traditional approximation of rotation (TAR), which neglects the horizontal component of the rotation vector, allows to efficiently compute gravity and Rossby modes for seismic modelling (Van Reeth et al. 2016). In the present work, we investigate the perturbative effect of a dipolar magnetic field with both poloidal and toroidal components, which correspond to a stable fossil magnetic field (Duez et al. 2010), on gravity modes computed in the TAR.

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## 2 Magnetic frequency shifts

The formalism used to compute the magnetic frequency shifts is presented in Prat et al. (2019). This formalism is applied to a representative model of HD 43317, which is a magnetic, rapidly rotating, SPB star (Buysschaert et al. 2018). Figure 1 shows that the magnetic field generates sawtooth-like signatures on period spacing patterns. The key result is that these signatures are different from rotational or chemical signatures and can

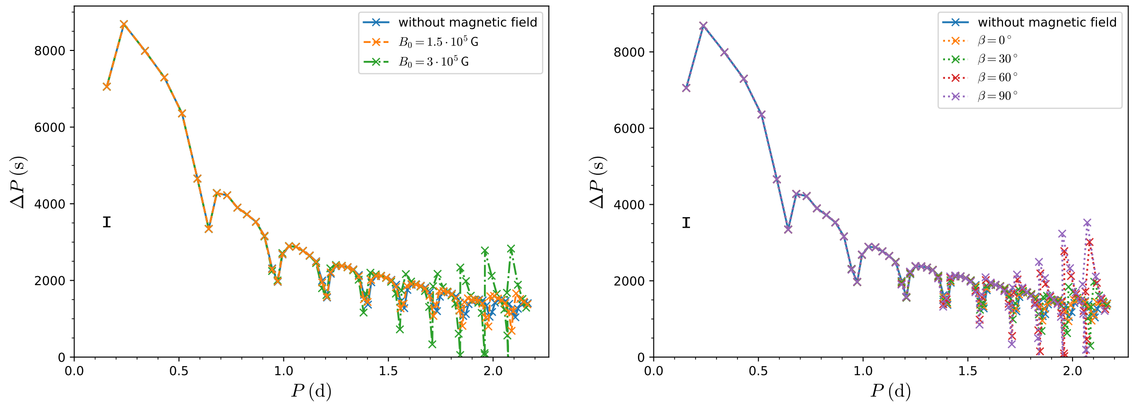


**Fig. 1.** Period spacings of dipole ($\ell = 1$) zonal ($m = 0$) gravity modes. **Left:** axisymmetric case with different magnetic field strengths. **Right:** oblique case with different obliquity angles for $B_0 = 10^5$ G. The error bar corresponds to typical uncertainties from a nominal Kepler light curve with a duration of 4 years.

thus be used to detect internal magnetic fields. As illustrated in Fig. 1, magnetic signatures scale with the square of the magnetic field strength, and they are also stronger for oblique fields, with a maximum for an obliquity angle of 90°.

## 3 Conclusions

This work shows that it should be possible to detect internal magnetic fields from asteroseismic measurements. To be able to constrain the properties of such fields, it is necessary to observe and identify a large number of low-frequency gravity modes. A similar technique could be used to extract additional information from Rossby modes. Future work will be dedicated to more complex magnetic configurations.

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