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Stellar evolution in motion: Period spacings in γ Doradus stars

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Abstract. The years of available space-based photometry have led to the detection the dense oscillation frequency spectra for γ Doradus stars. Theory predicts the presence of non-uniform period spacing series in these frequency spectra, which contain information on the interior stellar structure. We have therefore developed a new method, based on the theoretical expectations and the observational spectroscopic studies, which allows us to detect such spacing patterns. The technique has a high success rate, with detections for ~60 % of the studied targets, though a notable deficiency is the inability to determine values for the degree l and the azimuthal order m.

1 Introduction

Thanks to recent space missions such as MOST, CoRoT and *Kepler*, it was found that multi-periodic non-radial pulsators, like γ Doradus stars, often exhibit dozens to hundreds of oscillation frequencies. This is a great advantage for asteroseismological modelling, as the rich frequency spectra provide far more constraints than the few frequencies which could be detected with ground-based observations.

Gamma Doradus stars are late A-/early F-type main sequence stars. They exhibit gravity-mode pulsations, which are excited by a periodic flux blocking mechanism at the bottom of the convective envelope [1,2]. Typical oscillation periods range from 0.3 to 3 d^{-1}.

According to the asymptotic theory, pulsations in γ Dor stars with the same values for the degree l and order m, but different radial orders n, are equidistantly spaced in the period domain [3]. However, recent studies have shown that chemical gradients near the convective core [4], rotation and mixing processes [5] cause characteristic non-equidistant deviations from such uniform patterns.

We aim to detect these non-uniform period spacing patterns, as they will allow us to study the evolution of the convective core and obtain an understanding of the mixing processes.

2 Methodology

We have developed a new method, based on the theoretical expectations and the observational spectroscopic studies, which allows us to detect such period spacing patterns. In these proceedings we present a short overview, and the interested reader is referred to [6] for a more detailed explanation.

In a first step, the oscillation frequencies are extracted from the light curve using a prewhitening method. The extracted frequency values are accepted if $\alpha < \frac{A_{freq}}{A_{loc}} < \frac{1}{\alpha}$, where A_{freq} is the amplitude of the extracted frequency, and A_{loc} is the amplitude of the original Fourier spectrum at the frequency f. The free parameter α is given a reasonable value, which we found to be $\alpha = 0.5$.

For relatively slowly rotating stars, we can then look for period spacing patterns by plotting the extracted oscillation periods in a period échelle diagram. However, given the typical rotation rates of γ Dor stars, we found it to be much easier to compute the period spacing between neighbouring

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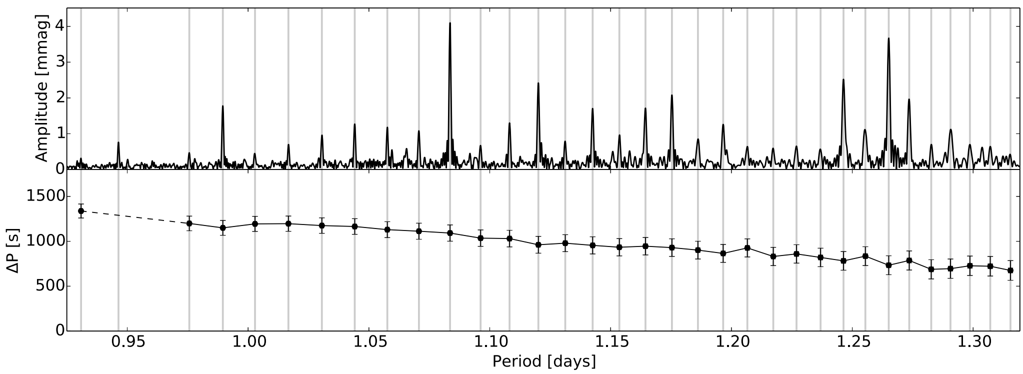

Fig. 1. *Top:* The part of the Fourier spectrum of KIC 11721304 for which a period spacing pattern was detected. The grey lines connect the oscillation periods with the corresponding spacing values in the bottom plot. *Bottom:* The period spacing pattern which we detected for KIC 11721304.

detected oscillation peaks in the Fourier spectrum. Because of rotational frequency shifts and the geometrical cancellation effects, many correspond to similar l and m values.

To allow the detection of more oscillation frequencies in the same series, the value of α is then iteratively lowered, and the already detected part of the spacing pattern serves as a reference for the acceptance of subsequently extracted oscillation frequencies.

3 Discussion & conclusions

This method led to the detection of period spacing patterns in many γ Dor stars, such as the one shown in Fig. 1. The relatively small spacing values as well as the downward slope of the plotted pattern indicate that these are prograde modes with rotationally shifted pulsation frequencies. In addition to the frequencies indicated in the figure, other frequencies with similar values were also detected. Possibly, these correspond to pulsations with different l and m values, but the precise origin is still unclear. Unfortunately, the presented method does not allow us to determine values for the degree l and the azimuthal order m. Therefore, detailed asteroseismological modelling is required to determine the nature of these additional frequencies. However, despite this shortcoming, we found the technique to be quite successful, with period spacing detections for ~60 % of our sample of γ Dor stars [7,8].

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