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STARSPOT MODELLING OF KEPLER SOLAR-TYPE PULSATORS

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Abstract. In the absence of resolved observations of a star, starspot modelling provides the opportunity to reconstruct maps of brightness inhomogeneities in the stellar photosphere. This approach is particularly important in the context of the PLATO mission, where interferometric observations will be available only for a small subset of the observed stars. Therefore, in order to explore the possibility to construct reliable starspot models of moderately active solar-type stars that will be at the core of PLATO science, we implemented a Bayesian continuous grid model accounting for spots and faculae contribution. We demonstrate the robustness of our method by comparing the reconstructed solar spot longitudinal distribution with the actual observed distribution during Cycles 23 and 24. Applying the method on ten *Kepler* asteroseismic targets, we find signatures of stable active nests for seven of them and we investigate cyclic modulations that might be related to magneto-inertial waves propagating in the envelope, opening the perspective to probe the magnetic field amplitude in the tachocline.

Keywords: solar-type stars, stellar rotation, starspots, space photometry

1 Introduction

Modelling brightness inhomogeneities on the stellar surface is important in order to explore properties of stellar active regions, understand rotation/activity relation and mitigate the impact that stellar activity has on exoplanet characterisation. As solar-type pulsators with moderate level of activity will constitute the core sample of the upcoming Planetary Transit and Oscillation of Stars mission (PLATO, Rauer et al. 2014), we explored the possibilities offered by starspot modelling on a set of solar-type pulsators observed by the *Kepler* satellite (Borucki et al. 2010).

2 Validation of the methodology

The `loupiotes` software*, implementing a continuous-grid starspot model (see e.g. Lanza 2016), was developed for this purpose (Breton et al. 2024). The code was validated by reconstructing solar surface brightness variation over Cycle 23 and Cycle 24 using observation from the Sun Photometers of the Variability of Solar Irradiance and Gravity Oscillations instrument (VIRGO/SPM, Fröhlich et al. 1995; Jiménez et al. 2002). We were able to reconstruct both the main longitudinal features of sunspot distribution and the variation of total sunspot coverage over the two cycles.

3 Active nests in Kepler targets

We analysed the *Kepler* light curves of ten solar-type stars with detection of acoustic oscillations. Our starspot map reconstruction provided clear evidence of the existence of longitudinal persistent active nests in four cases, with three additional possible detections. Interestingly, as shown in Fig. 1, in the regime we studied, the existence of active nests has no apparent dependence on on the Rossby number *Ro* or on the magnetic activity level.

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*The documentation is available at: `https://loupiotes.readthedocs.io/en/latest/`.

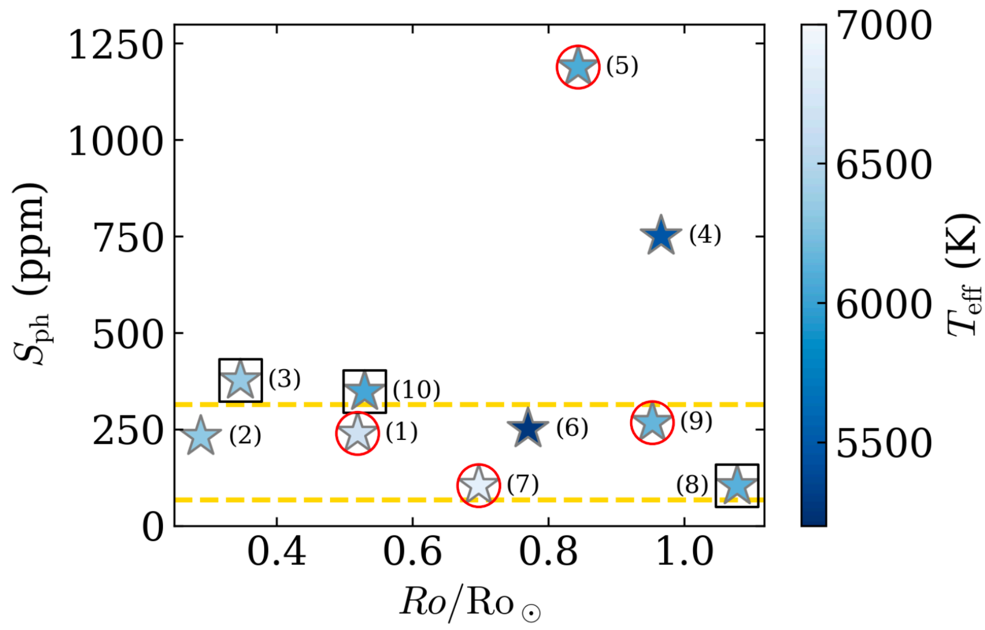

Fig. 1. Photometric activity indicator (e.g. Mathur et al. 2014) vs diagram for the 10 Kepler solar-type pulsators analysed in this work. Stars with clear active nest detection are singled by red circles, stars with possible detections by black squares. Figure taken from Breton et al. (2024).

4 Conclusions

Using a starspot modelling approach, we detected persistent active nests in the light curve of several solar-type pulsators. The explanation for the existence of these nest probably resides in dynamo-related mechanisms driving emergence of magnetic tubes with longitudinal coherence.

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