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Short-term variations of surface magnetism and prominences of the young sun-like star V530 Per

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Abstract. V530 Per is a solar-like member of the young open cluster α Persei, with an ultra-short rotation period (P$\sim$0.32d). We report on two spectropolarimetric campaigns using ESPaDOnS, aimed at characterizing the short-term variability of its magnetic activity and large-scale magnetic field. We used time-resolved spectropolarimetric observations obtained in 2006 and 2018 and reconstructed the brightness distribution and large-scale magnetic field geometry of V530 Per through Zeeman-Doppler imaging. Using the same data sets, we also mapped the spatial distribution of prominences through tomography of Hα emission. We reconstruct, at both epochs, a large, dark spot occupying the polar region of V530 Per while smaller (dark and bright) spots were reconstructed at lower latitudes. The maximal field strength reached $\sim$1 kG. The prominence pattern displayed a stable component that was confined close to the corotation radius. In 2018, we also observed rapidly evolving Hα emitting structures, over timescales ranging from minutes to days. The fast Hα evolution was not linked to any detected photospheric changes in the spot or magnetic coverage.

Keywords. stars: magnetic fields, stars: chromospheres, stars: individual (V530 Per)

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1. Introduction

A fraction of young solar analogs in open clusters possess short rotation periods, a puzzling observation indicating that the magnetic braking supposed to act during pre-main sequence evolution was less efficient than expected on these objects, compared to slow rotators observed at the same age. In the most extreme cases, these rapidly rotating stars reach the so-called saturated dynamo regime, and sometimes the supersaturated regime (Pallavicini et al. 1981; Prosser et al. 1996; Wright et al. 2011). We propose here to characterize the magnetic field and related phenomena (e.g., active regions, prominences) of a prototypical saturated star V530 Per (Cang et al. 2020, 2021).

2. Doppler tomography

By applying the Doppler Imaging method (Vogt, Penrod, & Hatzes 1987) using the code of Folsom et al. (2018), we recovered the surface brightness distribution of V530 Per. The reconstruction includes a solar-like differential rotation law, with a roughly solar shear level optimizing our model. We also applied the Zeeman Doppler Imaging

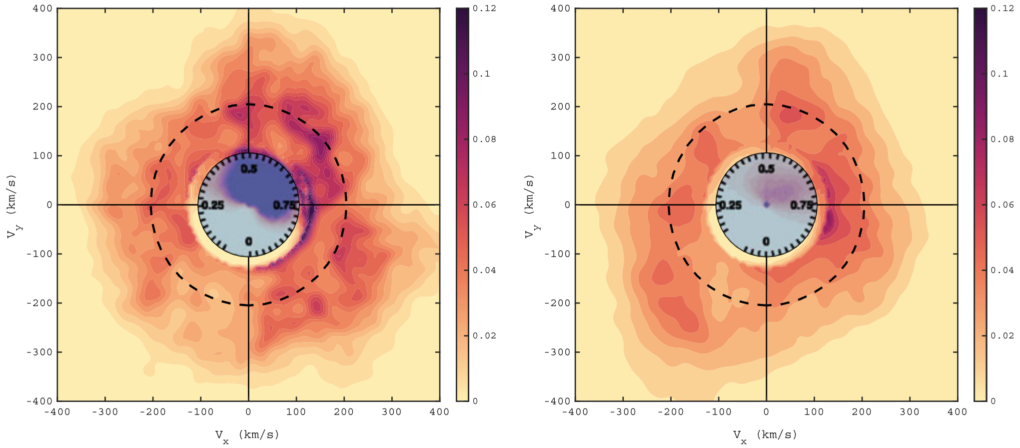

Figure 1. Prominence maps of V530 Per reconstructed from the data of two close nights (22&23 Oct 2018). The inner, filled blue circle represents the stellar surface. Radial ticks inside this circle give the rotational phases of Hα observations. The outer dashed circle is the corotation radius. The color scale depicts the local Hα equivalent width, in units of picometers per 8 km s^{-1} square pixel.

technique (ZDI, Semel 1989; Donati et al. 2006; Folsom et al. 2018) to model the two epochs of Stokes V data, in order to reconstruct the 2D magnetic field distribution of V530 Per. According to the maps, the average surface magnetic field is 177G in 2006 and 222G in 2018, with local peaks slightly above 1kG. About 2/3 of the magnetic energy belongs to the toroidal field component. Moreover, the complexity of the magnetic field is very high, with less than 7% of the magnetic energy stored in the dipolar component. We reconstructed prominence maps of V530 Per for each observational night, unveiling a stable component that was confined close to the co-rotation radius and short-term variations (see Fig.1). The total mass stored as prominences is $\sim 4.6 \times 10^{17}$ kg ($\sim 2.3 \times 10^{-13}$ M$_{\odot}$). Our observation also suggests that as much as 3.5×10^{16} kg of material has been removed from the system within one day.

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