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MAGNETIC CYCLES OF COOL STARS

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Abstract. Starting in 2027, the ESA PLATO mission will deliver long-term photometric monitoring of Sun-like stars to study exoplanets and their host stars. In preparation, we initiated a spectropolarimetric campaign targeting cool stars in the PLATO South Field, selected for their potential magnetic variability. Observations with ESPaDOnS, SPIRou (CFHT), and Neo-Narval (TBL) provide complementary visible and infrared data to characterize surface magnetic fields. This work aims to identify magnetic configurations and their evolution, key to understanding stellar dynamos and the impact of stellar activity on planetary environments.

Keywords: Stellar magnetic fields, Cool stars, Stellar activity, Magnetic cycles, Spectropolarimetry, Photometry, Zeeman-Doppler Imaging (ZDI), M dwarfs, PLATO mission, SPIRou, ESPaDOnS, Neo-Narval.

1 Introduction

Magnetic activity plays a central role in the evolution of cool stars and their exoplanetary systems (Airapetian et al. 2020). Generated by dynamo processes in convective layers (Charbonneau 2020), stellar magnetic fields of cool stars drive surface phenomena such as spots, flares, and winds, and strongly affect planetary habitability. Spectropolarimetric observations, especially modeled with Zeeman-Doppler Imaging (Donati et al. 2006), allow us to reconstruct surface magnetic topologies. In M dwarfs, the long-term evolution of these fields remains poorly constrained (Morin et al. 2008; Bellotti et al. 2024). In preparation for the ESA PLATO mission, we have initiated a spectropolarimetric campaign targeting selected cool stars in the PLATO South field to investigate magnetic field diversity and lay the groundwork for future studies of stellar magnetic cycles.

2 Method

2.1 Target selection

We selected 22 cool stars from the PLATO South field (Montalto et al. (2021)), including 7 M dwarfs ($T_{\rm eff} <$ 3950 K) and 15 FGK dwarfs (5000 $K < T_{\rm eff} <$ 6400 K). The selection was based on stellar parameters derived from Gaia DR3 (Gaia Collaboration et al. (2021)), complemented by variability information derived from TESS light curves, from which stellar rotation periods were measured. We prioritized stars showing clear signs of magnetic activity, making them suitable candidates for spectropolarimetric monitoring of large-scale magnetic fields.

2.2 Polarimetric analysis

The longitudinal magnetic field component (B_z) was measured from Least Squares Deconvolution (LSD) profiles using the `specpolflow`* Python module. This method enhances the signal-to-noise ratio by combining many spectral lines, allowing the detection of circularly polarised Zeeman signatures and precise estimation of B_z. We also applied Zeeman-Doppler Imaging (ZDI) (Folsom et al. 2018), an inversion technique that reconstructs surface magnetic field maps by fitting synthetic polarized line profiles to observations iteratively. ZDI provides detailed information on the geometry and strength of large-scale stellar magnetic fields.

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*The SpecpolFlow package is available online at `specpolflow` : `https://github.com/folsomcp/specpolFlow`

3 Preliminary results

We obtained spectropolarimetric observations for 6 M dwarfs, enabling us to characterize their magnetic field configurations and rotational properties. The M5 dwarf AP Col, with a mass of 0.26 $M_\odot$ and a rotation period of 1.0129 days, exhibits a strong magnetic field dominated by an axisymmetric dipolar component. This configuration is typical for rapidly rotating mid-M dwarfs (Fig. 1, left). In contrast, CD-35 2213, an M4Ve star with a mass of 0.40 $M_\odot$ and a rotation period of 1.93 days, exhibits a different magnetic topology. Its large-scale field is primarily characterized by a non-axisymmetric dipolar component, accompanied by a significant and predominantly axisymmetric toroidal field. This magnetic geometry differs in its symmetry pattern from that of AP Col, which is unexpected given CD-35 2213's rapid rotation and mass (Fig. 1, right).

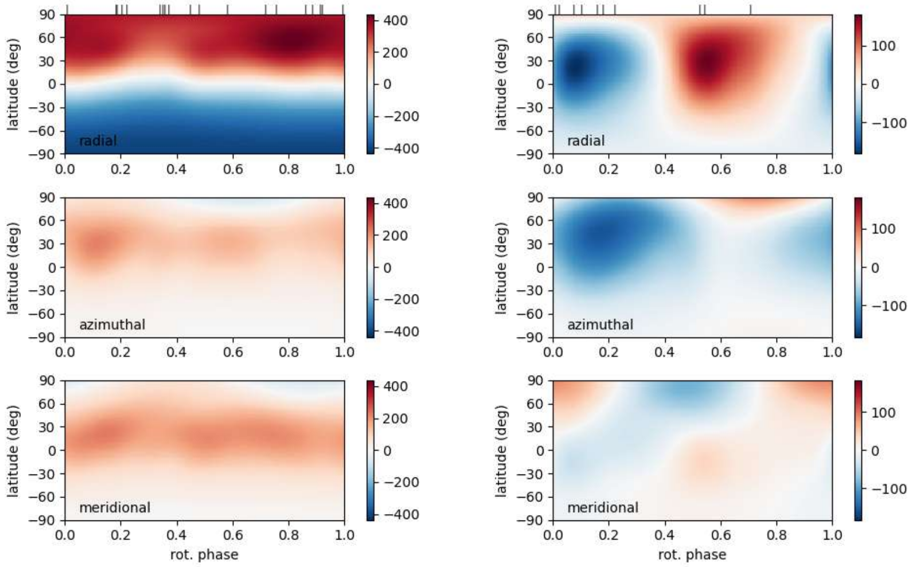

Fig. 1. Left: Zeeman-Doppler Imaging map of the large-scale magnetic field at the surface of AP Col. The radial (top), azimuthal (middle), and meridional (bottom) components of the magnetic field vector are displayed. The color bar range is set by the maximum of the magnetic field and illustrates the positive (red) and negative (blue) polarity. **Right:** Same as Fig. 1 left (radial, azimuthal, and meridional components of the magnetic field), but for CD-35 2213.

4 Perspectives

Our observing strategy has been successfully validated with the reconstruction of preliminary magnetic maps during the 2024B semester. A follow-up campaign will start in the 2025B semester to monitor the temporal evolution of the magnetic fields. The diversity of magnetic topologies observed in our sample highlights the complexity of stellar magnetism across different spectral types and rotation regimes. Future instruments such as Wenaokeao at CFHT, conceived as the next-generation spectropolarimeter combining the visible and near-infrared capabilities of ESPaDOnS and SPIRou, will be crucial for long-term spectropolarimetric monitoring. Along with Bellotti et al. (2024), Lehmann et al. (2024) and Bellotti et al. (2025), this program represents a first step towards a comprehensive study of stellar magnetic cycles.

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