Magnetism & activity in the K2 dwarf V471 Tau[1]

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Introduction

Over the past decade, magnetic fields have been studied for stars in a wide range of spectral classes, with a specific focus on solar-like stars of various masses, rotation rates, and ages. Thanks to its ability to reconstruct large-scale surface magnetic fields, Zeeman-Doppler Imaging technique[2] (ZDI) brought new insights to the subject establishing the critical role of the stellar internal structure on the overall topology of the large-scale field. These magnetic maps suggested that the dynamo mechanism at play in the convective zone also evolve and adjust throughout the star's life.

With mostly single stars studied so far, the K2 dwarf of the V471 Tau binary system offers a unique opportunity to examine how tides affect the magnetic topology and differential rotation compared to the single-star analog AB Dor (similar mass, temperature, and rotational period).

Methods

We analysed spectropolarimetric data of the close-binary system V471 Tau acquired in Nov/Dec 2004 and Dec 2005. Photospheric lines of the K2 dwarf companion were identified after correcting for the orbital motion of the system and used to produce average profiles with enhanced signal-to-noise ratio. We used ZDI to characterise the surface distribution of brightness and magnetic features at the surface of the K2 dwarf from the shapes and rotational modulation of the averaged Stokes *I* and *V* profiles.

Surface maps

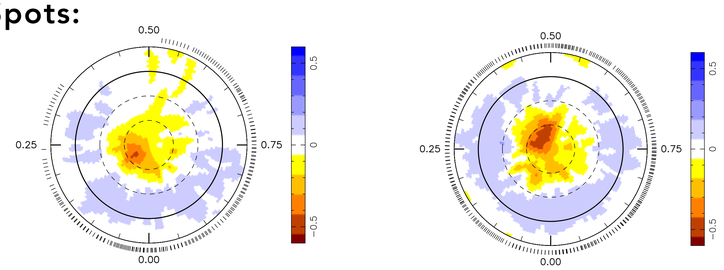


FIGURE 1: Surface brightness distributions for the data sets acquired in Nov/Dec 2004 (left) and Dec 2005 (right).

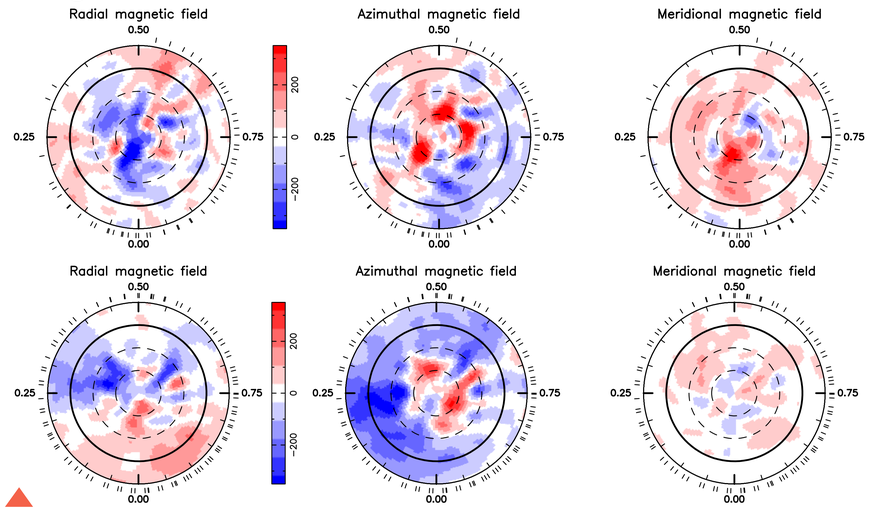


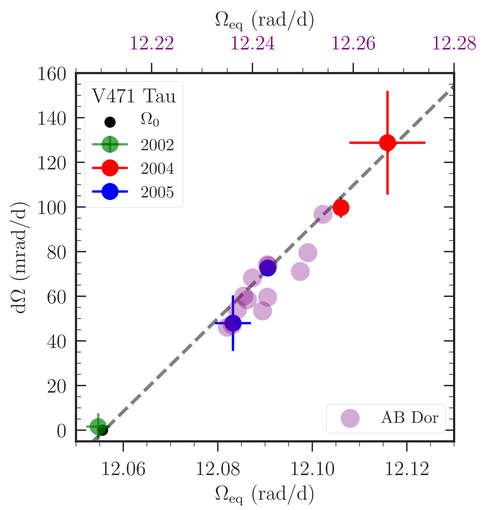
FIGURE 2: Polar view of magnetic field topology for Nov/Dec 2004 (top) and Dec 2005 (bottom). From left to right, the columns show respectively the radial, azimuthal (i.e., toroidal), and meridional components of the large-scale magnetic field. Magnetic field strengths are saturated at 350 G, with red shades representing positive values and blue shades negative values.

Differential rotation

Thanks to the ability of ZDI to recover spatial information from sets of phase-resolved spectropolarimetric observations, it is possible to retrieve information on differential rotation at the star's surface by finding out the recurrence rates of reconstructed features as a function of latitude.

We assume a Sun-like surface shear law: $\Omega(\theta) = \Omega_{\rm eq} - {\rm d}\Omega \cos^2(\theta)$.

FIGURE 3: Differential rotation at the K2 dwarf's surface obtained with our Nov/Dec 2004 (red) and Dec 2005 (blue) data sets with $\pm 1\sigma$ level provided. A prior measurement in 2002 is shown in green[3] and the angular velocity if the star was rotating as a solid body in black. For comparison, we include shear measurements reported for the analog AB Dor[4,5] as purple circles after scaling the x-axis to the same rotation rate so that measurements for both stars can be compared.



Prominences

The Hα spectrum of our Nov/Dec 2004 observations revealed the presence of a prominence at a stable location over 7 rotation cycles. Our results suggest that closed loops of the stellar magnetosphere extend out to the prominence, likely sustaining it against centrifugal ejection[6].

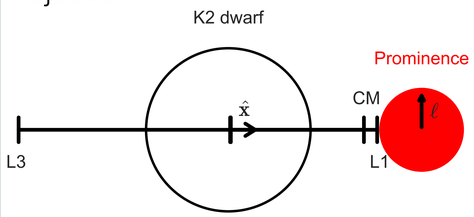
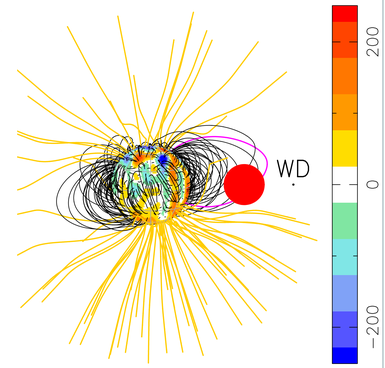


FIGURE 4: Schematic view of the binary system V471 Tau in the presence of a prominence. Distances to the center of mass and to the Lagrange points L_1 and L_3 are indicated.

FIGURE 5: Potential field extrapolation of the surface field obtained with ZDI reconstructions in 2004. The WD star (black dot) and the prominence (red circle) are also shown. Field lines crossing the prominence are coloured in magenta.



Summary

We reconstructed for the first time the large-scale magnetic field at the surface of the K2 dwarf and reported new detection of its surface differential rotation. Our results provide evidence for temporal variations in the surface shear of the K2 dwarf, making it even more similar to its single-star analog AB Dor.

References

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3. Hussain et al. (2006). MNRAS, 367, 1699.
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6. Jardine et al. (2020). MNRAS, 491, 4076.

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