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Magnetic geometry and activity of cool stars

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Abstract. Stellar magnetic field manifestations such as stellar winds and EUV radiation are the key drivers of planetary atmospheric loss and escape. To understand how the central star influences habitability, it is very important to perform detailed investigation of the star's magnetic field. We investigate the surface magnetic field geometry and chromospheric activity of 51 sun-like stars. The magnetic geometry is reconstructed using Zeeman Doppler imaging. Chromospheric activity is measured using the Ca II H& K lines. We confirm that the Sun's large-scale geometry is dominantly poloidal, which is also true for slowly rotating stars. Contrary to the Sun, rapidly rotating stars can have a strong toroidal field and a weak poloidal field. This separation in field geometry appears at Ro=1. Our results show that detailed investigation of stellar magnetic field is important to understand its influence on planetary habitability.

Keywords. star: activity, star: chromospheres, star: rotation, star: magnetic fields

1. Introduction

Stellar activity and magnetic field are known to play an important role in the evolution of a habitable planetary system. Our central star, the Sun, has a magnetic field of moderate strength that interacts with the orbiting planets, initiating different reactions in their atmospheres. We investigate the vector magnetic field and associated chromospheric activity of 51 sun-like stars to provide observational constraints for different space weather models.

2. Data collection

Majority of the stars were observed as part of the BCool project (Marsden *et al.* 2014, Petit *et al.* in prep). Few data were also taken from separate multi-epoch studies (Hackman *et al.* 2016; Rosén *et al.* 2016; Alvarado-Gómez *et al.* 2015). The rotation periods for these stars were taken from Wright *et al.* (2011) when not available in the original literature, to determine the rossby number (Ro). Ro is defined as the rotation period divided by the convective overturn time, τ_c, which is determined from the empirical relationship of Noyes *et al.* (1984).

3. Results

Figure 1 (Left) shows the chromospheric activity of the stars in our sample as a function of $B-V$. The large-scale geometry in terms of the poloidal field, axisymmetry, and the mean magnetic field B is shown. The grey lines separate the active and inactive stars, while the intermediately active stars lie in the middle. Majority out of the 51 stars lie in the active side of the figure, which is not surprising as stronger the activity (or field strength), easier is the detection. Active stars do not have any strong inclination towards purely poloidal (red) or toroidal (blue) large-scale field. Strong poloidal and toroidal field are both detected in these stars. The axisymmetry and B also show a wide range. Where

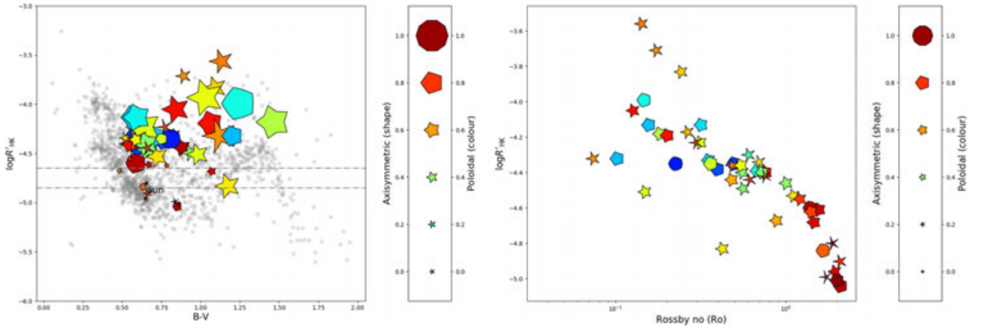

Figure 1. *Left*:Chromospheric activity vs $B-V$. The large-scale poloidal field, axisymmetry and mean field strength (B) of the total field is shown for 51 sun-like stars (the coloured symbols). Colour represents the magnetic energy of the poloidal field (strength increases from blue to dark red), shape represents the axisymmetry (increases from star to hexagonal shape) and symbol size increases with increasing B. Gray circles in the background are the chromospheric activity of ∼4000 stars with no large-scale field information (Boro Saikia *et al.* 2018). The grey lines show the intermediate activity range. *Right*: Chromospheric activity of the 51 stars vs Rossby number Ro. The symbols are the same as on the Right, except the symbol sizes are not scaled to B.

as the inactive stars, including the Sun, show a predominantly poloidal field structure but the axisymmetry can vary from one star to the other.

As magnetic field generation and amplification is influenced by the rotation of the star, Fig. 1 (Left) was plotted as a function of Ro (Fig. 1, Right). Chromospheric activity shows a linear trend with Ro for slowly rotating stars. For very fast rotators the trend is more scattered. At Ro⩾1, slowly rotating stars like our Sun have a dominant poloidal field.

4. Conclusion

Our results show that the large-scale magnetic field geometry of a sun-like star could be very different from the Sun. Additionally the large-scale geometry and Ro has a tight relationship, especially for older slowly rotating stars. The strong poloidal geometry at Ro⩾1 suggests that, as stars get older and rotate slower their dynamos operate in a similar manner. This might not be true for younger stars as suggested by the wide variety in field geometry. Hence it is very important to investigate the magnetic nature of central star to understand the associated space weather in different exoplanetary systems.

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