Stars and their variability observed from space
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MAGNETO-ROSSBY WAVES AND SHORT-TERM PERIODICITY IN SOLAR-TYPE STARS

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Abstract. Magnetic activity and variations of solar-type stars are governed by dynamo layers below or inside the convection zone. This layer is supposed to be much shorter than the stellar radius, so large-scale magneto-Rossby waves can be trapped inside. The waves may cause variations in the dynamo magnetic field and can thus can trigger quasi-periodic eruptions of magnetic flux towards the surface, which will modify stellar light-curves seen in *Kepler, CoRoT* and *TESS* data. The spherical harmonics of magneto-Rossby waves of different order and degree can lead to multiple short-term periodicities in the light-curves. Theoretical oscillation spectra of magneto-Rossby waves and the short periods observed in stellar activity will allow us to estimate the magnetic field strength in the dynamo layer. The seismology of stellar interiors, combined with magneto-Rossby wave theory in solar-type stars having different rotation periods, opens a new domain of research into understanding stellar evolution.

Keywords: Stars: activity, magnetic field

1 Introduction

Chromospheric activity in main-sequence stars based on Mount Wilson Ca II H and K observations has solar cycle-like periodicity (Wilson 1978). The empirical relation between cyclic (P_{cyc}) and rotational (P_{rot}) periods shows clearly an increase in P_{cyc} with increasing P_{rot} (Saar & Brandenburg 1999). Recent *Kepler* and *CoRoT* collected huge amounts of data on stellar activity, thus offering an excellent basis to search for Sun-like periodicities in other stars. The main period in solar activity is around 11 years, which means that the ratio of cyclic to rotational periods is approximately 150 for the Sun (the solar rotational period is around 26 days). On the other hand, solar activity also displays a shorter periodicity of 150–180 days ("Rieger-type" periodicity), which is actually correlated with solar-cycle strength (Gurgenashvili et al. 2016). Several stars from *CoRoT* (Lanza et al. 2009) and *Kepler* (Bonomo & Lanza 2012) data showed $P_{cyc}/P_{rot} \sim 4-6$, which is within the range of Rieger periodicity in the Sun. The two cases cited clearly indicate the existence of periodicity in stellar activity, and to the need for further systematic and comprehensive analyses. The most plausible mechanism for solar Rieger-type periodicity is connected with magneto-Rossby waves in the internal dynamo layer (Zaqarashvili et al. 2010), which enables us to probe the layer of the observed periodicity in solar activity (Gurgenashvili et al. 2016; Zaqarashvili & Gurgenashvili 2018). This technique of seismology can also be applied to solar-like stars at different stages of evolution by searching for short term periodicity in their light-curves.

2 Magneto-Rossby waves and seismology of dynamo layers in solar-like stars

The dispersion relation of magneto-Rossby waves in the internal dynamo layers can be written as follows (Gachechiladze et al. 2019):

$$\omega = -\frac{2m\Omega}{3l(l+1)}\left(1 + 2\sqrt{1 + \frac{81}{8}l(l+1)\frac{B^2}{4\pi\rho\Omega^2 R^2}}\right) \tag{2.1}$$

where Ω is the stellar angular velocity, B the magnetic field strength in the layer, ρ the layer density, R the distance of the layer from the stellar centre, m is the order and l is the degree of spherical harmonics of the magneto-Rossby waves. The dispersion relation shows that the periodicity depends on angular velocity and magnetic field strength, as well as the spherical harmonic order and degree (see Fig. 1). Periods determined from observations therefore enable us to estimate the magnetic field strength in a star's dynamo layers.

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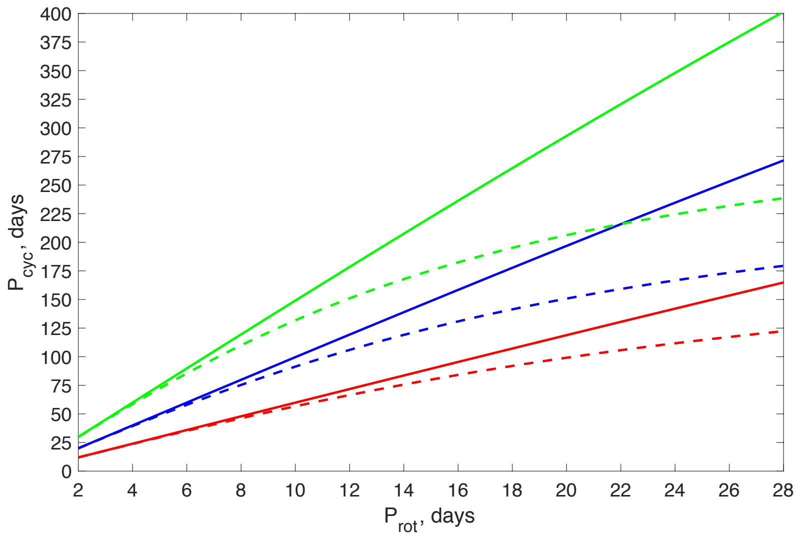

Fig. 1. Periods of magneto-Rossby wave spherical harmonics *vs.* stellar rotation period. Red, blue and green lines show the spherical harmonics of degree l=3, 4 and 5, respectively. Solid and dashed lines correspond to magnetic field strengths of 10 kG and 50 kG. The spherical harmonic order is $m = 1$.

3 Conclusions

Magneto-Rossby waves in dynamo layers of solar-like stars may lead to periodic variations in the dynamo magnetic field strength. Those variations may trigger quasi-periodic eruptions of magnetic flux towards the surface, which can modulate stellar light-curves and could be observed in *Kepler, CoRoT* and *TESS* data. Spherical harmonics of magneto-Rossby waves with different degrees have different periods, and could lead to multiple periodicities in light-curves. The periods of magneto-Rossby waves depend on the magnetic field strength (see Fig. 1), so periods determined from observations (given a theoretical dispersion relation) may allow us to probe the dynamo layers of solar-like stars. Stars having different rotation periods will then indicate how the star's dynamo magnetic field has evolved. The seismology of stellar interiors using magneto-Rossby waves can thus open up a new research area for studying stellar evolution.

This work was supported by the Austrian Science Fund (FWF) project P30695-N27 and by Georgian SRNSF project 217146. This paper resulted from discussions at workshops of the ISSI team, "Rossby waves in astrophysics" organized in Bern, Switzerland.

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