Simulating the Asterospheric Magnetic Field of Exoplanet Host Stars

Mei Maruo[1], Alison O. Farrish[2], David Alexander[2] and Marc DeRosa[3]
[1]Kyoto University, [2]Rice University, [3]Lockheed Martin Advanced Technology Center

Finding Habitable Planets

- Potentially habitable exoplants have been discovered orbiting other stars
- Finding a habitable planet could fulfill a long-standing dream of humankind to discover the potential for life elsewhere than the Earth
- Finding how stars' magnetic field interacts with that of the planets' is crucial (Fig. 1)
- A magnetic model of the Sun enables explorations of the interrelationships between stellar properties and the large-scale magnetic fields

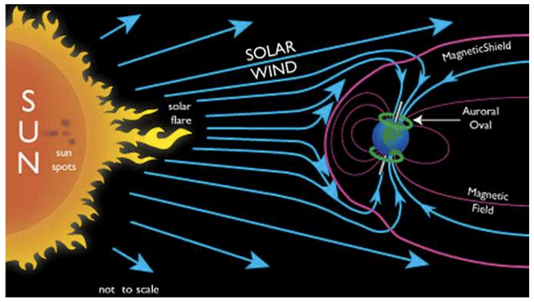


Fig. 1 | Representation of the Sun-Earth interaction. If Earth did not have a strong magnetic field, the solar wind would erode our atmosphere making the planet uninhabitable.

Flux Transport Model (SFT)

- Empirical model of flux emergence and dispersal on stars' surface with activity
- Inputs tunable parameters that control flux emergence, surface flows, rotation rate etc.
- Outputs distributed magnetic flux and large-scale field

Potential Field Source Surface Model (PFSS)

- 3D magnetic field model from the surface boundary distributions
- Inputs Sun's surface magnetic flux
- Outputs observations of field lines and large-scaled magnetic field of the corona

Model and Simulation: SFT and PFSS

We characterize the magnetic activity of a range of stars by using the observed physical relationships between various stellar parameters (e.g. rotation rate, cycle duration, flux emergence, and meridional flow). These relationships are used as input to the Rice SFT model to simulate the emergence and evolution of the stellar magnetic field (e.g. Fig. 2). This model simulates the magnetic field distributions of an exoplanet host star over a range of timescales, allowing us to explore the star's large scale magnetic field using the PFSS model (e.g. Fig. 3).

Fig. 2

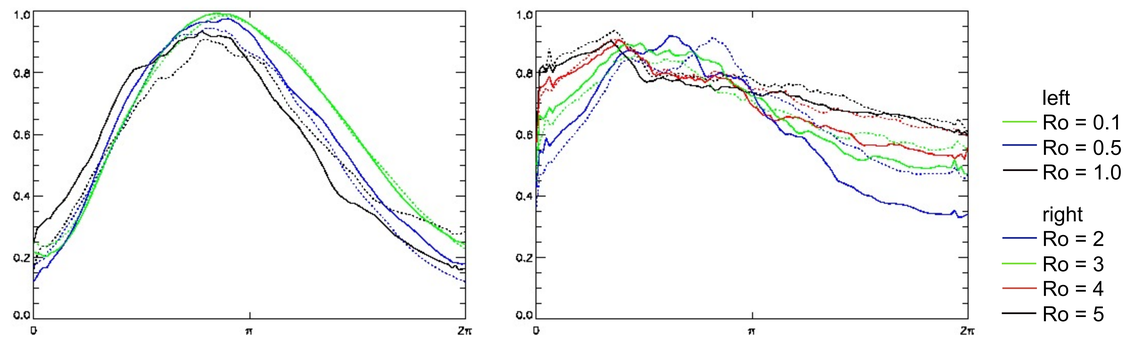


Fig. 2 (above) | Normalized flux distribution averaged over stellar cycle for seven different stars differentiated by Rossby number compared to the sun (period's first phase in solid and second in dashed line).

Fig. 3 (right) | Simulated magnetograms and extrapolated large scale field for Rossby number equal to 5 times that of the Sun (top) and 1/10th that of the Sun (bottom).

Rossby Number: $R_o = P_{rot} / \tau_c$
Rotation Period: P_{rot}
Convective Turnover Time: τ_c

Fig. 3

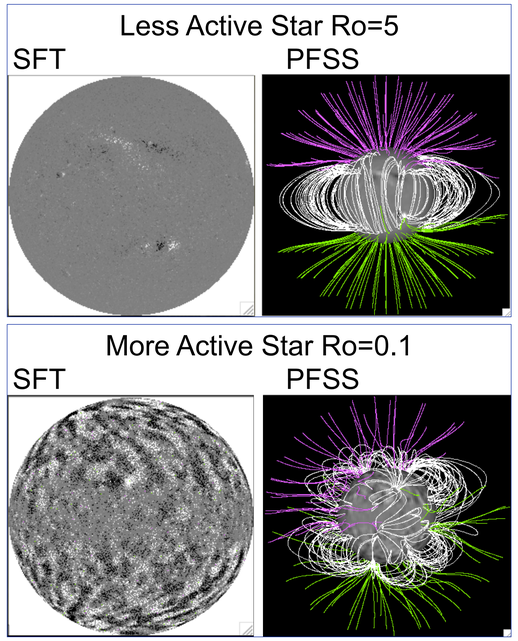
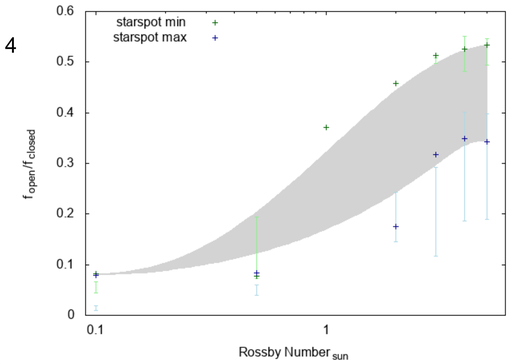


Fig. 4



Potential for Star-Planet Interaction

- Amount of open magnetic flux provides the means by which the stellar wind expands into the interplanetary medium
- More active stars (lower Rossby numbers) have a significantly lower relative amount of open flux compared to less active stars. Therefore, while the amount of magnetic energy in the wind is significantly higher, there is less of a cross-section for interaction.

Fig. 4 | The variation of the open-to-closed magnetic flux ratio as a function of stellar activity between the star spot maximum and minimum shown in the shaded area (as defined by the Rossby number compared to the sun). Each star incorporates observed correlations between stellar rotation rate, cycle duration, flux emergence and meridional flow.

Future Research

- Potentially exoplanet hosting stars provide information relevant to the habitability of exoplanets
- Combination of stellar relationships with magnetospheric modeling of Earth-like exoplanets may provide a fuller picture of exoplanet-host star interaction and habitability

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