Interactions between exoplanets and the stellar winds of young stars

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The topology of stellar magnetic field is important not only for the investigation of magnetospheric accretion, but also responsible for shaping the large-scale structure of stellar winds, which are crucial for regulating the rotation evolution of stars. We modelled the stellar winds of young stars by means of 3D MHD simulations, adopting simplified topologies of the stellar magnetic field.

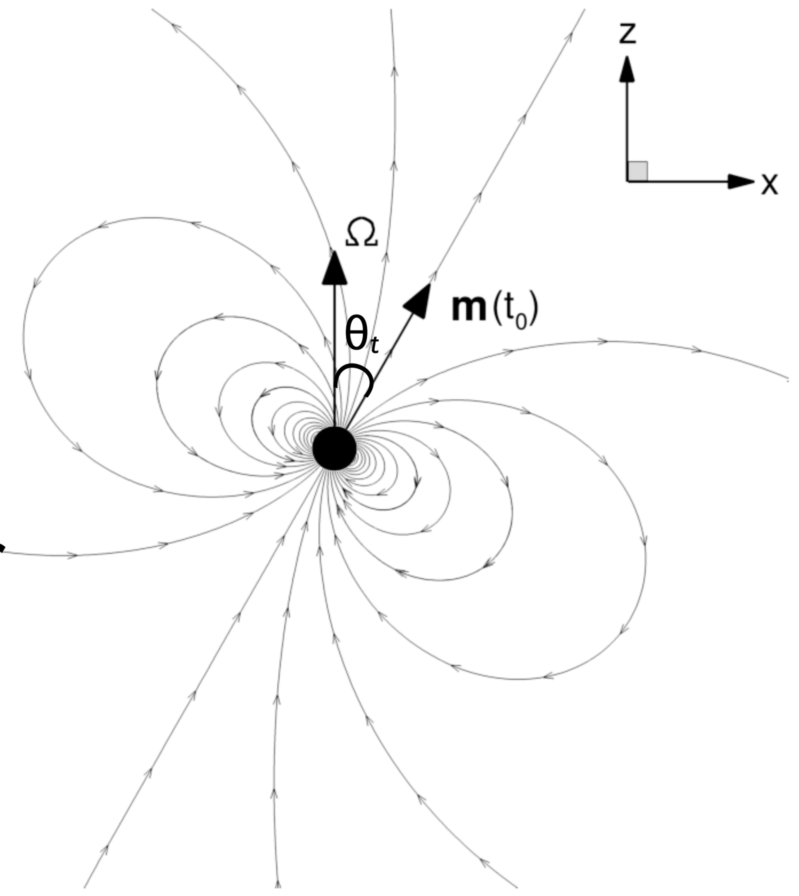

Fig.1: Magnetic field configuration adopted in the simulations at initial instant t_0. The dipolar magnetic moment ***m*** *is tilted with respect to the stellar rotation axis* **Ω** *by an angle θ_t.*

More about this work in Vidotto et al:
➡ApJ 703, 1734 (2009)
➡ApJ 720,1262 (2010)

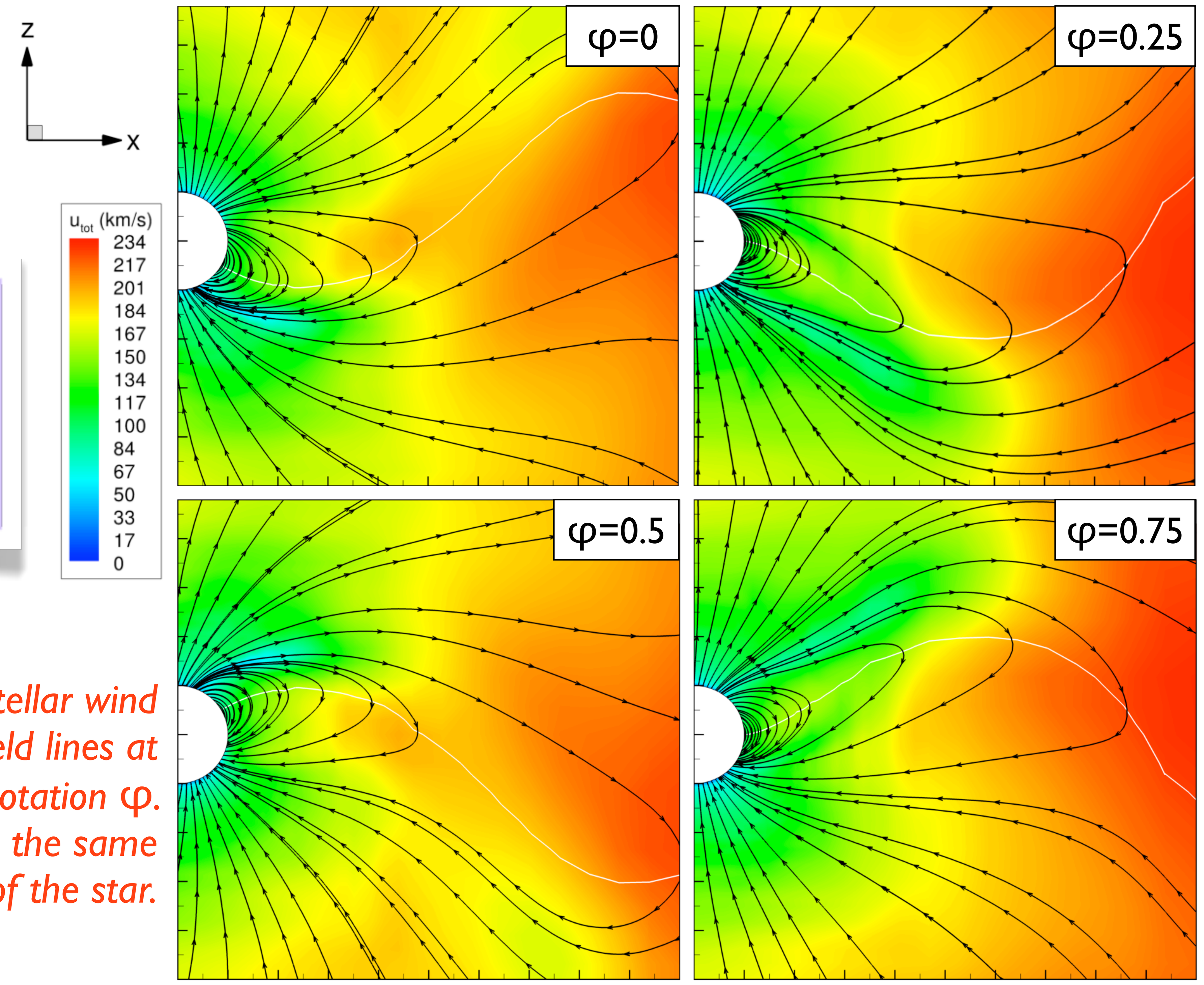

Fig.2: Evolution of the stellar wind velocity and magnetic field lines at different stellar phases of rotation φ. The wind is modulated with the same period of the star.

Because stellar winds of young stars are believed to have enhanced mass-loss rates compared to those of cool MS stars, the interaction of winds with newborn exoplanets might affect the early evolution of exoplanetary systems.

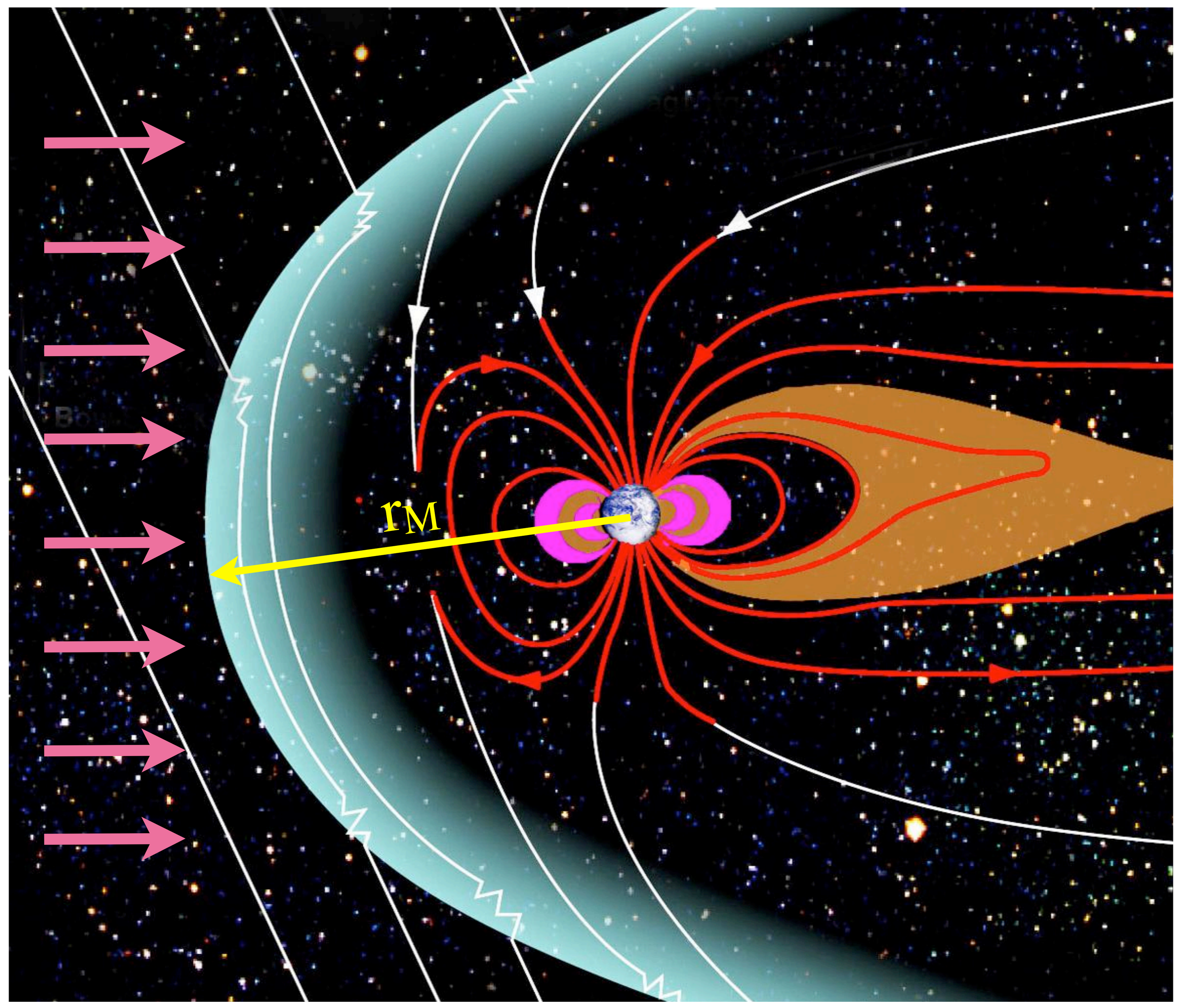

Fig.3: The stellar wind impacts on the magnetosphere of a planet, compressing it.

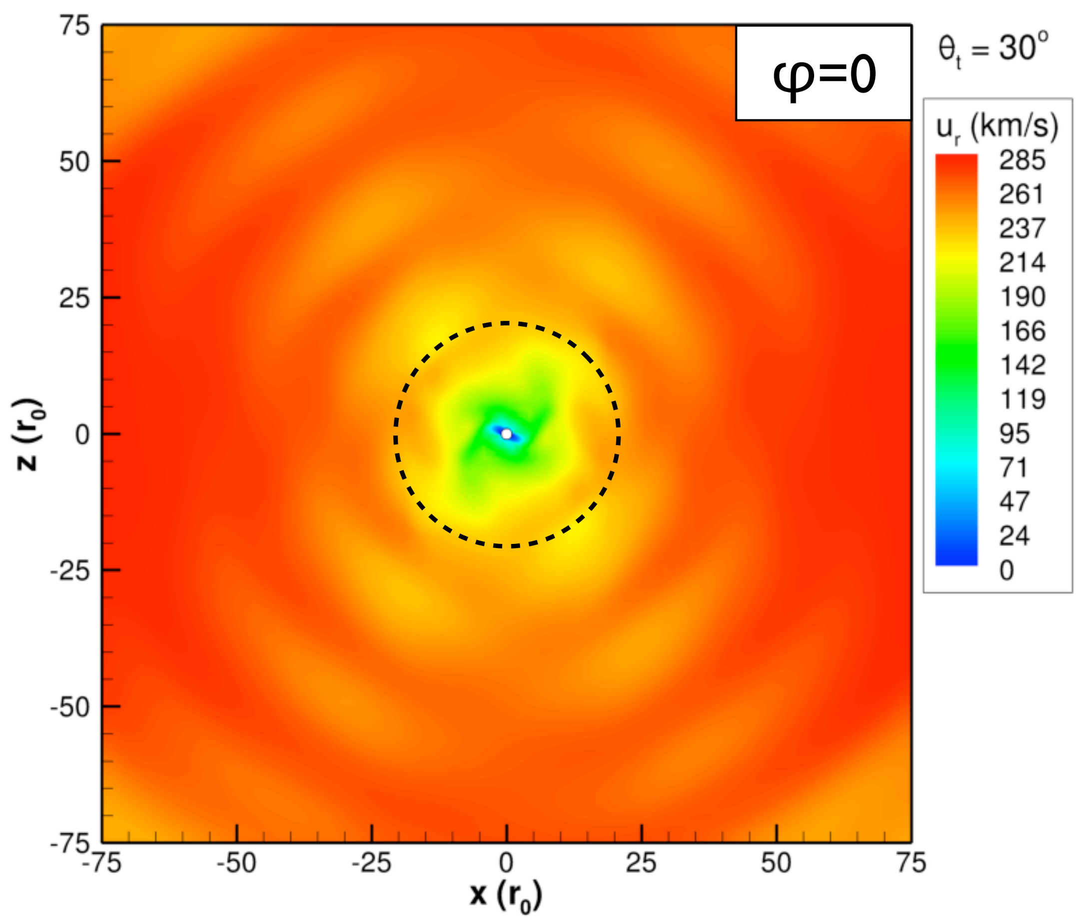

Fig.4: A hypothetical hot-Jupiter orbiting in the equatorial plane of a young star would interact with a stellar wind with varying conditions (e.g., velocities) along its orbit (illustrated by a dashed circle).

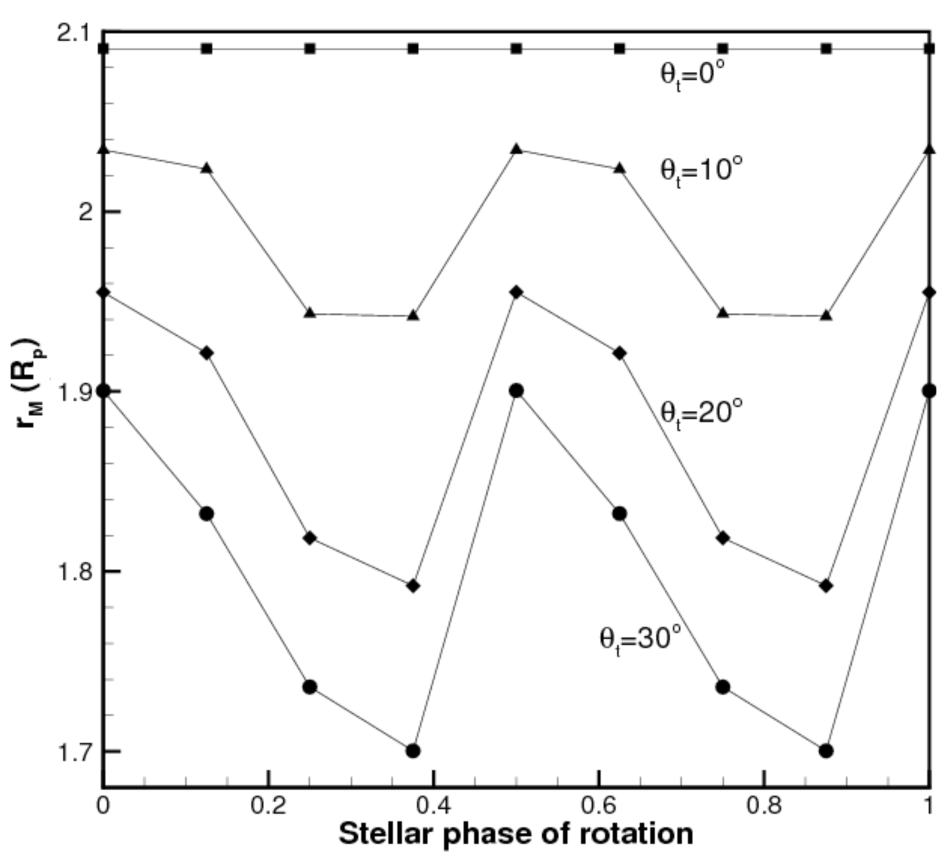

Fig.5: As a consequence, the sizes of planetary magnetospheres will vary as a function of the stellar phase of rotation. The hypothetical planet is assumed to be orbiting at 0.05AU and to have an intrinsic dipolar field of 50G.

This interaction can also give rise to observable signatures which could be used as a way to detect young planets, while simultaneously probing the presence of their still elusive magnetic fields.

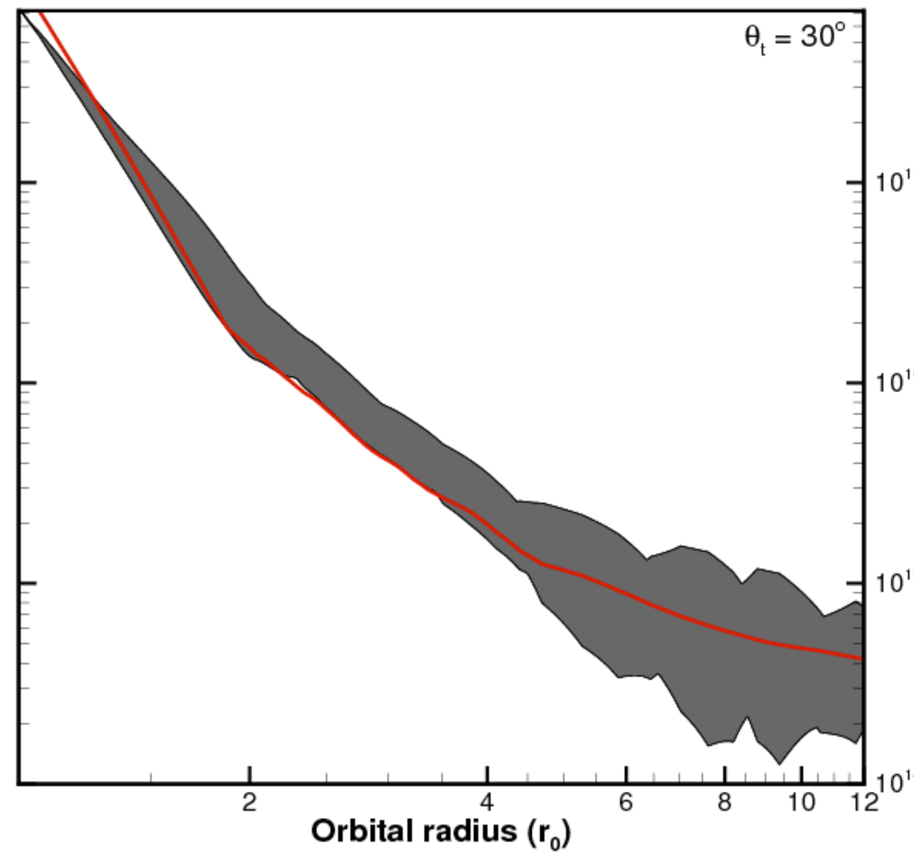

Fig.6: Predicted planetary radio emission generated in the interaction between a hot-Jupiter and the stellar wind. The shaded area lies between maximum and minimum powers that can be released in the interaction, according to the rotational phase of the star. The red curve assumes an aligned stellar dipole. For comparison, Jupiter radio emission is $\approx 10^{10.5}$W.

Torques from the stellar wind can remove orbital angular momentum of the planet, causing planetary migration.

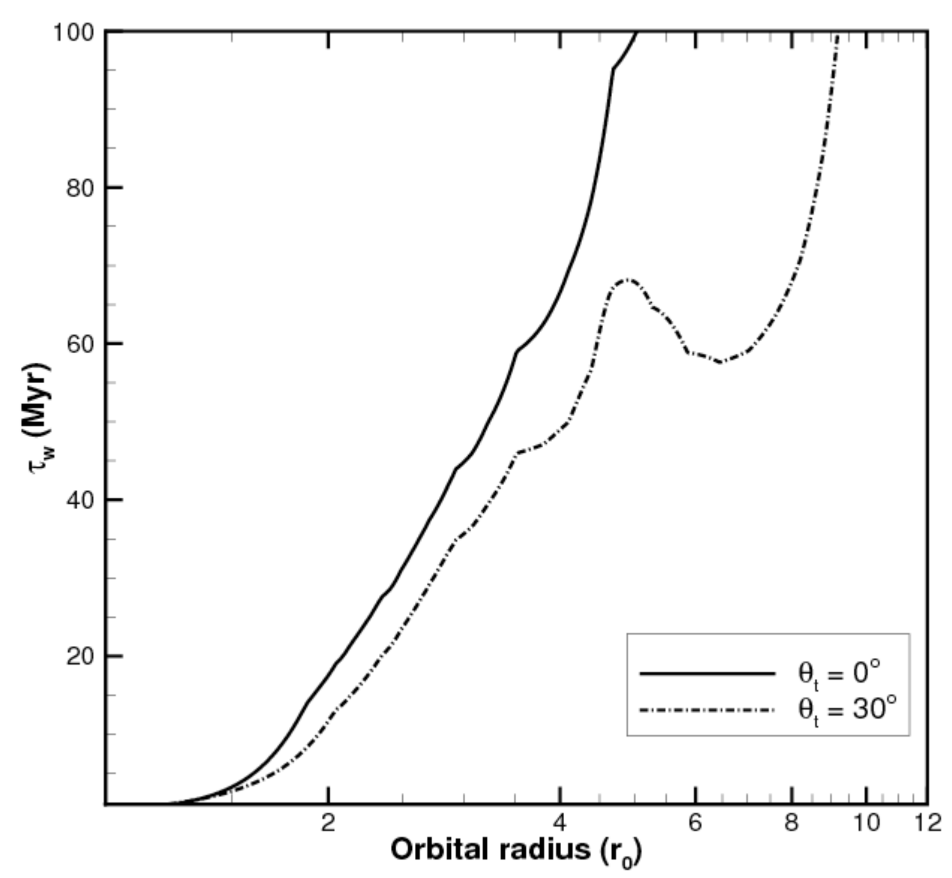

Fig.7: Timescales for planetary migration caused by torques from the stellar wind. Although τ_w are long (≫ timescale for disc dissipation), complex stellar fields are more efficient in causing planetary migration than aligned fields.

We showed that asymmetric field topologies can lead to an enhancement of the stellar wind power, resulting not only in an enhancement of angular momentum losses, but also intensifying and rotationally modulating the wind interactions with exoplanets.