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3D SIMULATIONS OF TILTED MAGNETOSPHERES OF WEAK-LINED T TAURI STARS

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We perform 3D time-dependent numerical MHD simulations of the wind and magnetospheric structures of weak-lined T Tauri stars, in the case there is a misalignment between the axis of rotation of the star and its magnetic dipole moment vector. The model allow us to study the interaction of a magnetized wind with a magnetized exoplanet. Such interaction gives rise to reconnection, generating electrons that propagate along the planet's magnetic field lines and produce electron cyclotron radiation at radio wavelengths. This radio emission could be detectable by LOFAR in the near future.

Determining realistic stellar magnetic field topologies and wind dynamics are important to understand interactions between exoplanets and the star. Recent spectropolarimetric measurements indicate that the surface magnetic fields on T Tauri stars are more complex than that of a simple dipole and are often misaligned with the rotational axis of the star (Donati et al. 2007, 2008). Vidotto et al. (2009a,b) performed 3D numerical MHD simulations of stellar winds and showed that the plasma-β is a decisive factor in defining the wind magnetic configuration, and the heating index γ in determining the wind structure. In this work, we extend the study performed in Vidotto et al. (2009a) by allowing the stellar rotation and magnetic moment vectors to be inclined with respect to each other.

To perform the stellar wind simulations, we use BATS-R-US, a 3D ideal MHD numerical code (Powell et al. 1999). We adopt typical stellar mass ($M_\star = 0.8\ M_\odot$) and radius ($r_0 = 2\ R_\odot$). The grid is initialized with a 1D hydrodynamical wind for a fully ionized plasma of hydrogen. The star is considered to be rotating as a solid body with the rotation axis in the z-direction. Because the star is rotating and the magnetic field is anchored on the stellar surface, the simulations with an oblique magnetosphere have a periodic behavior with the same period of rotation of the star. Depending on the physical conditions and grid size, after a certain number of stellar rotations, the system has relaxed and such periodic behavior is achieved.

An orbiting planet interacts with the wind of the host star. By assuming a close-in giant planet with the same mass and radius as Jupiter and a magnetic field intensity of 50 G, we estimate the reconnection rate and power released when reconnection between magnetic field lines of the planet and the stellar wind takes place. The power released with the reconnection event $P_{\rm rec}$ can be decomposed into a power released from the dissipation of kinetic energy carried by the stellar wind P_k and a power released from the magnetic energy of the wind P_B (e.g., Zarka 2007). The magnetic power P_B can be estimated as the Poynting flux of the stellar wind impacting on the planetary magnetospheric cross-section. For a planet at orbital radius $r \simeq 0.05$ AU, the ratio between maximum and minimum released power due to a variation in the incident wind is a factor of 3.7 for case of the misalignment angle ($\theta_t = 30°$). Part of this released energy can be used to accelerate electrons, generating radio emission (Jardine & Cameron 2008) $P_{\rm radio} = \eta P_{\rm rec}$. The efficiency η in the conversion of $P_{\rm rec}$ into radio emission depends on the details of the physical processes that generate the radio emission (e.g., on the cyclotron-maser instability). Our estimates show that the radio power emitted is about 5 orders of magnitude larger than the non-thermal radio power emitted by Jupiter. This suggests that the stellar wind from a young star has the potential to generate strong planetary radio emission, which could be detected by LOFAR. More details of this work can be found in Vidotto et al. (2010).

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