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Influence of Star-Planet Magnetic Torques on Orbital Secular Evolution

Jérémy Ahuir (1), Antoine Strugarek (1), Mansour Benbakoura (1), Allan-Sacha Brun (1), Stéphane Mathis (1), Emeline Bolmont (1), Christophe Le Poncin-Lafitte (2), Victor Réville (3)

(1) Laboratoire AIM Paris-Saclay, CEA/Irfu Université Paris Diderot CNRS/INSU, Gif-sur-Yvette, France, (2) LNE-SYRTE, Observatoire de Paris, PSL Research University, CNRS, Sorbonne Universités, UPMC Univ. Paris 06, Paris, France, (3) UCLA Department of Earth, Planetary and Space Sciences, Los Angeles, CA, United States

Abstract

The discovery of more than 3000 exoplanets during the last two decades has shed light on the importance of characterizing star-planet interaction. We address this question by studying systems formed by a solar-like star and a close-in planet. We consider the joint influence on the star's rotation rate and planetary orbital evolution of a stellar wind, tidal and magnetic star-planet interactions. Despite recent significant advances in these fields, all current models use parametric descriptions to study at least one of these effects. Our objective is to introduce simultaneously ab-initio prescriptions of the tidal, braking and magnetic torques, so as to improve our understanding of star-planet systems and their long-term evolution.

To this end we develop a 1D numerical model of coplanar circular star-planet systems taking into account stellar structural changes, wind braking, tidal and magnetic interactions and implement it in a code called ESPEM (French acronym for Evolution of Planetary Systems and Magnetism). We follow the secular evolution of the stellar rotation assuming a bi-layer internal structure, and of the semi-major axis of the orbit. After comparing our predictions to recent observations and models, we perform tests to emphasize the contribution of ab-initio prescriptions. Finally, we isolate four significant characteristics of star-planet systems: stellar mass, initial stellar rotation period, planetary mass and initial semi-major axis; and browse the parameter space to investigate the influence of each of them on the fate of the system.

We find that depending on the characteristics of the system, tidal or magnetic effects can dominate. For very close-in planets, we find that both torques can make a planet migrate on a timescale as small as 10-100 thousands of years. Both effects thus have to be taken into account when predicting the evolution of compact systems. Finally, we provide a planet survival criterion based on the star-planet global parameters, determining whether or not the planet will undergo orbital decay due to tidal interaction and star-planet magnetic interaction.