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Interaction between a close-in exoplanet with the magnetosphere of its host star: ohmic dissipation, magnetic torque, planetary migration, inflation, and mass loss

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Abstract

We use the unipolar inductor model to study the interaction between a close-in exoplanet and the magnetosphere of its host star. We calculate the electric conductivity in the stellar atmosphere and planetary interior and ionosphere, as well as the ohmic dissipation and magnetic torque associated with this interaction. We then determine the effect of the magnetic torque on planteray migration, and of the ohmic dissipation on planetary inflation and mass loss.

1. Introduction

More than seven hundred extrasolar planets have been detected around solar type stars. About 20% of these planets orbit their stars at distances less than 0.05 AU, which suggests that planetary migration has taken place. Yet, very few planets have been so far found within 0.02 AU to their host stars, although such planets would be the easiest to detect. Both migration barriers and mechanisms which destroy or remove planets that migrate too close to their stars may therefore co-exist.

Several of the close-in Hot Jupiters also have radii (measured by transit) larger than predicted by evolution models [4] and some appear to lose mass [10][11].

2. Interaction between a close-in planet and the magnetosphere of its star

Young T-Tauri stars can have magnetic field strengths up to several thousand gausses at the surface [2][6]. Planets within 0.05 AU thus encounter external fields of up to a few tens of gausses. We model a close-in planet as a spherically symmetric body with a conductivity profile, and we assume that the planet does not have a dynamo. The relative motion of these (poorly) electrically conducting planets in the stellar magnetic field induces an electro-motive force and an induced current [7][8].

2.1 Planetary migration

This current is dissipated inside the planet and the star and is also subject to a magnetic torque. In the framework of the unipolar inductor model [5] between a Super Earth and its star [8], we show that the torque may affect planetary migration in a time scale adequate to compete with the torque from the disk or the stellar tidal torque on the planet.

2.2 Planetary inflation

We also investigate the effect of the ohmic dissipation on the internal structure, especially the radii of Hot Jupiters [7]. Previous investigations suggest that a heat input below the radiative region in the planet may account for Hot Jupiter inflated radii [1][3]. We therefore estimate the likely location of ohmic dissipation due to the induced current and estimate its impact on the planet’s internal structure.

2.3 Ionosphere and mass loss

Inflated planets may also lose mass through Roche lobe overflow or if an external energy source increases the velocity of the gas molecules in the envelope above the escape velocity. Murray-Clay et al. [10] argues that the photo ionization of the atmosphere of a hot Jupiter does not result in significant mass loss. However, the ionosphere of close-in planets is subjected to an intense stellar UV irradiation, which results in an important increase in the electric conductivity on the dayside of the planet's upper atmosphere. The ohmic dissipation due to the interaction with the stellar magnetic field thus provides an additional heat source in the ionosphere. We calculate the outflow generated by the ohmic dissipation in the planetary ionosphere in order to determine whether this mechanism can lead to significant mass loss for close-in planets.

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