

MAGNETOSPHERES OF HOT JUPITERS: ON THE PHYSICAL PHENOMENA POTENTIALLY OBSERVABLE IN RADIO

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Abstract

The identification of possible sources of electromagnetic emissions in exoplanetary magnetospheres and the estimation of their efficiency, as well as potential detectability, is a challenging task of the present day theoretical astrophysics. It is closely related with the understanding and consistent description of the key physical processes in the nearby exoplanetary space plasmas, and requires first of all an appropriate model of an exoplanetary magnetosphere. A comparative look at physical conditions in known and well measured magnetospheres of the solar system planets and those expected by exoplanets, shows that a direct application of the scenarios and views developed for the solar system planets to exoplanets, in spite of certain importance, may not always correctly reflect the specifics of the exoplanets. This first of all concerns the case of the so-called Hot Jupiters – giant exoplanets, orbiting close to their host stars. The existence, power efficiency, and detectability of various sources of electromagnetic emission in the magnetospheres of Hot Jupiters are nowadays widely investigated. In that respect, we present here a generalized model of a Hot Jupiter large scale magnetosphere and consider several phenomena which might influence the exoplanetary radiation.

Our approach is based on a combination of two kinds of models: 1) a generalized paraboloid magnetosphere model (PMM), which calculates a large-scale magnetosphere topology produced by the whole variety of magnetic field and electric current sources, e.g., planetary magnetic dipole, magnetopause and magnetotail currents, etc.; and 2) a 2D multi-fluid MHD model of the upper atmosphere of a planet, heated and ionized by the stellar XUV radiation, which incorporates the basic hydrogen photochemistry, gravitational and rotational forces, and takes into account a realistic solar-type XUV spectrum. A key feature of the specific conditions in the magnetosphere of a close-orbit giant exoplanet, which we consequently take into consideration in our modeling, consists in the presence of an expanding atmospheric material which forms a kind of escaping planetary wind (PW), not typical for the solar system planets.

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The interaction of outflowing plasma of the PW with the rotating planetary magnetic dipole field results in the formation of an extended current-carrying magnetodisk around the planet. According to the PMM modeling, the magnetic field produced by magnetodisk ring currents, usually dominates above the contribution of intrinsic planetary magnetic dipole of an exoplanet and finally determines the size and structure of the whole planetary magnetosphere [Khodachenko et al., 2012, ApJ 744, id.70]. It results in 40–70% larger magnetosphere scales, as compared to those traditionally estimated with taking into account only the planetary dipole. The larger magnetosphere scales of Hot Jupiters have to be properly taken into consideration during the estimation of power of the related electromagnetic radiation sources. Besides that, the dynamical MHD modeling of the magnetodisk reveals a cyclic character of its behavior, comprised of consequent phases of the disk formation followed by the magnetic reconnection with the ejection of a ring-type plasmoid [Khodachenko et al., 2015, ApJ 813, id.50]. Such quasi-periodic dynamics might cause the specific sources of electromagnetic radiation inside the magnetosphere which could be considered for detection.

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