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Stellar wind magnetic field influence on the exoplanet's magnetosphere

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Abstract

We consider an interaction of the close-in (with an orbital distance d < 0.3 AU) giant exoplanets ('Hot Jupiters') with the stellar wind magnetic field. The paraboloid magnetospheric model constructed for the 'Hot Jupiters' contains the intrinsic planetary magnetic dipole, the current system of magnetotail, magnetodisk, magnetopause currents, and the magnetic field of stellar wind, partially penetrated into the magnetospheric obstacle. The problem of stellar - planetary interaction includes not only consideration of influences of stellar radiation and plasma flows, but also the reconnection with the stellar wind magnetic field, which becomes especially strong during coronal mass ejections (CMEs).

1. Introduction

Calculations of the magnetospheric structure are performed in the paraboloid model developed for the close-in giant exoplanets ('Hot Jupiters') on the base of the terrestrial model [1]. Later this paraboloid model was modified for Jupiter and Saturn (e.g., [2]). The principle new element of the models for these giant fast rotating magnetized planets possessing sources of magnetospheric plasma is a powerful magnetodisk. Magnetic field of magnetodisk outside of it increases the intrinsic planet's field. Due to magnetodisk, the character magnetospheric size increases. We suggest that 'Hot Jupiters' also have massive magnetodisks provided by thermally expanding and continuously lost planetary hydrogen atmosphere heated and ionized by stellar XUV. Paraboloid model of the 'Hot Jupiter' magnetosphere includes the magnetic fields of the planet, magnetotail current system, magnetodisk, and shielding currents at the magnetopause. Here we also consider the stellar wind magnetic field partially penetrated into the magnetosphere. The coefficient of its penetration is taken to be k = 0.1.

2. Exoplanet magnetosphere controlled by the stellar wind magnetic field

The stellar wind at the orbits of exoplanets has a relatively high ambient magnetic field ($B > 10^{-2}$ G). We consider exoplanets with the orbital distances d equal to 0.045AU, 0.14AU, and 0.3AU, where AU is one astronomical unit. For each of these distances we obtain a set of the input model parameters which determine the magnetospheric state. We take into account specific properties of exoplanets which depend on d: mass loss, rotation rate, stellar XUV heating.

For d = 0.045AU we take arbitrary value (of the order of 100 nT) and orientation of the stellar wind vector $\boldsymbol{B}_{sw}$ determined by the exoplanet dipole moment (this direction is mostly important for reconnection).

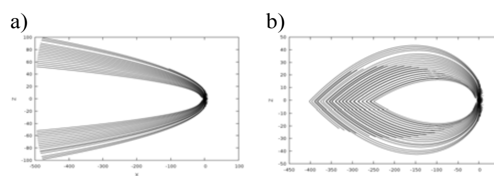

Figure 1: Exoplanet magnetosphere for d = 0.045AU. a) $\boldsymbol{B}_{sw}$=0; b) $\boldsymbol{B}_{sw}$ = {0, 0, -100} nT.

In Figure 1 the exoplanet magnetospheric magnetic field lines with footprints at the planet in the noon and midnight meridians are shown calculated for $\boldsymbol{B}_{sw}$=0 (a) and $\boldsymbol{B}_{sw}$ antiparallel to the planet's dipole magnetic moment (b). Here the stellar-magnetospheric coordinate system is used. It is seen that the stellar wind magnetic field significantly changes the exoplanet magnetospheric structure. In the case shown in Figure 1b, a specific type of magnetospheric magnetic field lines (named by us 'plasmoid-like') arises. These lines are not connected with the planet or interplanetary space. They are restricted inside the magnetosphere. Such type of lines could arise when the tail current system and magnetodisk are strong enough. The model parameters are as follows. The distance to the substellar magnetopause R_{ss} =10.4R_P; distances to the outer and inner edges of the magnetodisk are R_{rc1} = 9.8R_P, R_{rc2} = 2.28R_P, magnetic field at the outer edge of magnetodisk B_{rc1} = 15.9nT, the distance to the inner edge of the tail current sheet R_2=8R_P, the magnetic field at it B_t=-1446nT, the magnetic field at the exoplanet equator with radius R_P is B_0 = 144574nT.

a) b)

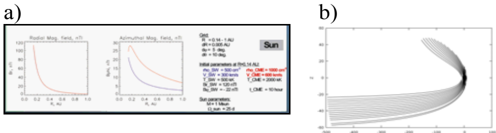

Figure 2: a) Numerical simulations of the stellar wind performed for a sun-type magnetized star; b) Exoplanet magnetosphere for d = 0.14AU, and $\boldsymbol{B}_{sw}$ = {120, -22, 0} nT.

In Figure 2a for a sun-type magnetized star the simulation of the stellar wind is shown for a continuous expansion of a stellar wind (in blue) and for the propagation of CME (in red). In Figure 2b the exoplanet magnetosphere for d = 0.14AU and $\boldsymbol{B}_{sw}$ = {120, -22, 0} nT is demonstrated. Again the strong influence of the stellar wind magnetic field on the magnetospheric structure is seen. Model parameters are: R_{ss} =9.95R_P, R_{rc1}=9R_P , R_{rc2}=3.33R_P, B_{rc1} =4.6nT, R_2=8.6R_P, B_t=-350nT, B_0 = 79645nT.

a) b)

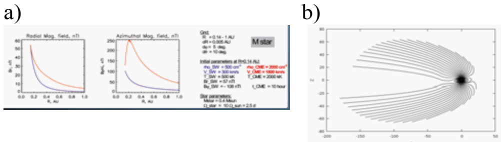

Figure 3: a) Numerical simulations of the stellar wind performed for a M-type magnetized star with the mass 0.4 of the solar mass and 10 times faster rotating then the Sun.; b) Exoplanet magnetosphere for d = 0.3AU, and $\boldsymbol{B}_{sw}$ ={25, -225, 0} nT.

In Figure 3a the MHD numerical simulation of the magnetized stellar winds from the M-star is presented. A continuous expansion of a stellar wind from a rotating magnetized star is shown in blue; the propagation of CME is marked in red. In Figure 3b the result of calculations in the paraboloid magnetospheric model is shown for the exoplanet located at distance d = 0.3AU from the host star. $\boldsymbol{B}_{sw}$= {25, -225, 0} nT is chosen for the case of CME propagation. Model parameters are: R_{ss}=28.4R_P, R_{rc1}= 27R_P, R_{rc2}=5.31R_P, B_{rc1}=3.5nT, R_2=5R_P, B_t=-310nT, B_0 =420000nT.

3. Summary and Conclusions

Calculations are performed in the constructed paraboloid model of the exoplanet ('Hot Jupiter') magnetosphere. It is shown that the stellar wind magnetic field plays important role in the interaction with the 'Hot Jupiter' magnetosphere. For calculations we used both the results of numerical simulation of the magnetized stellar winds, and examples for arbitrary reasonable values and mostly effective for reconnection orientations of the magnetic field in the host star's wind.

It was shown that due to the powerful magnetodisk and the tail current system, for the stellar wind magnetic field antiparallel to the exoplanet's dipole moment, a special type of magnetospheric field lines (which we called 'plasmoid-like') arises. These lines are not connected with the planet, neither with the interplanetary space. They are formed from the field lines whose both 'ends' go to the distant tail, if the stellar wind magnetic field equals to zero. If later the stellar wind magnetic field becomes antiparallel to the exoplanet's dipole magnetic moment, then due to reconnection these field lines occurred to be restricted inside the magnetosphere.

Acknowledgements

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References

[1] Alexeev, I. I.: The penetration of interplanetary magnetic and electric fields into the magnetosphere, J. Geomag. Geoelectr., Vol. 38, pp. 1199–1221, 1986.

[2] Alexeev, I.I., and Belenkaya, E.S.: Modeling of the Jovian Magnitosphere, Annal. Geophys., Vol.23, pp. 809-826, 2005.