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Magnetosphere of Hot Jupiter HD209458b and transit absorption in lines related to the upper atmosphere

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Using the global 3D multi-fluid HD and its extension to MHD we simulated the measured HD209458b transit absorption depths at the FUV lines, and at the NIR line (10830 Å) of metastable helium HeI(2^3S) triplet, paying attention to possible change of the absorption profiles due to the presence of planetary intrinsic magnetic field. As continuation of our previous studies of HD209458b (*Shaikhislamov et al. 2018, 2020*), the inclusion of the HeI(2^3S) line into consideration and the comparison with corresponding measurements allows to constrain the helium abundance by He/H ~ 0.02, and stellar XUV flux at 1 a.u. by F_{XUV} ~10 erg cm^2 s^{-1} at 1 a.u. For the first time, we studied the influence of the planetary dipole magnetic field with a model which self-consistently describes the generation of the escaping upper atmospheric flow of a magnetized hot Jupiter, formation of magnetosphere and its interaction with the stellar wind. We simulated the absorption in the most of spectral lines for which measurements have been made. MHD simulations have shown that the planetary magnetic dipole moment μ_P = 0.61 of the Jovian value, which produces the magnetic field equatorial surface value of 1 G, profoundly changes the character of the escaping planetary upper atmosphere. The total mass loss rate in this case is reduced by 2 times, as compared to the non-magnetized planet. In particular, we see the formation of the dead- and the wind- zones around the planet with the different character of plasma motion there. The 3D MHD modelling also confirmed the previous 2D MHD simulations result of *Khodachenko et al (2015)* that the escaping PW forms a thin magnetodisk in the equatorial region around the planet. The significantly reduced velocity of PW at the low altitudes around the planet, and especially at the night side, results in the stronger photo-ionization of species and significantly lower densities of the corresponding absorbing elements. Altogether, the reduced velocities and lower densities result in significant decrease of the absorption at Lyα (HI), OI, and CII lines, though the absorption at HeI(2^3S) line remains nearly the same.

As it was shown in our previous papers, the dense and fast stellar wind, interacting with the escaping upper atmosphere of HD209458b, generates sufficient amount of Energetic Neutral Atoms (ENAs) to produce significant absorption in the high-velocity blue wing of the Lyα line. However, according to the performed 3D MHD modelling reported here, the planetary magnetic dipole field with the equatorial surface value of B_p=1 G prevents the formation of ENAs, especially in the trailing tail. This effect opens a possibility to constrain the range of planetary magnetic field values for the evaporating hot Jupiters and warm Neptunes in the stellar-planetary systems where sufficiently strong SW is expected.

The presented results fitted to the available measurements indicate that the magnetic field of

HD209458b should be at least an order of magnitude less than that of the Jupiter. This conclusion agrees with the previous estimates, based on more simplified models (e.g., *Kislyakova et al. 2014*) and much less observational data, when only Lyα absorption was considered. We believe that the application of 3D MHD models simulating the escape of upper atmospheres of hot exoplanets and the related transits at the available for measurement spectral lines, sensitive to the dynamics of planetary plasma affected by the MF, opens a way for probing and quantifying of exoplanetary magnetic fields and sheds more light on their nature.

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Khodachenko, M.L., Shaikhislamov, I.F., Lammer, H., et al., 2015, ApJ, 813, 50.

Shaikhislamov, I. F., Khodachenko, M. L., Lammer, H., et al., 2018, ApJ, 866(1), 47.

Shaikhislamov, I. F., Khodachenko, M. L., Lammer, et al., 2020, MNRAS, 491(3), 3435-3447