R009-25
B 会場 ：11/7 AM2 （10:45-12:30）
12:00〜12:15

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Effects of planetary intrinsic magnetic fields on the atmospheric ion escape from exoplanet TOI-700 d

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The atmospheric escape from a planet can be greatly affected by existence of a planetary intrinsic magnetic field. For example, a strong dipole intrinsic magnetic field of ancient Mars may have reduced the atmospheric ion escape rate (Sakata et al., JGR, 2020, 2022). There have been many studies which focus on atmospheric escape from planets in our solar system. However, space environments around exoplanets can be very different from those around Earth because of differences in the stellar X-ray and EUV (XUV) radiation, stellar wind, and strength of the planetary intrinsic magnetic field. In this study, we investigated how the space environment affects the atmospheric escape from a terrestrial exoplanet in the habitable zone of a M dwarf star with a focus on the effects of the intrinsic magnetic field.

We focused here on exoplanet TOI 700 d, which is the first Earth-sized planet in the habitable zone (HZ) discovered by the Transiting Exoplanet Survey Satellite (TESS) (Gilbert et al., AJ, 2020; Rodriguez et al., AJ, 2020). The host star is a M dwarf star, which has lower surface temperature, thus closer HZ to the host star, and stronger XUV radiation in HZ than the solar system around a G-type star. Another important difference is that direction of the interplanetary magnetic field (IMF) around the planet may be dominated by the radial component because of the proximity to the host star and planet. The IMF orientation can change the atmospheric escape rate from the exoplanet. In this study, we simulated the atmospheric ion escape from TOI-700 d.

To model the space environment around TOI-700 d, we used the REPPU-Planets multi-species MHD simulations (e.g., Terada et al., JGR, 2009; Sakata et al., JGR, 2022). Our model solved three-dimensional multispecies MHD equations including continuity equations for 11 ion species (O^+, ${O_2}^+$, ${CO_2}^+$, NO^+, CO^+, ${N_2}^+$, N^+, C^+, He^+, H^+, Ar^+) from the bottom of the ionosphere to the inter-planetary space where a constant stellar wind is assumed. The model includes photoionization, electron impact ionization, charge exchange, ion-neutral reactions, dissociative recombination, collisions (ion-electron, ion-neutral, electron-neutral). As stellar wind conditions, number density, velocity, and temperature were set to 450 cm^{-3}, 470 km s^{-1}, and 1.3 x 10^6 K, respectively, by referring to previous studies (Cohen et al., ApJ, 2020; Dong et al., ApJL, 2020). IMF was assumed to be a Parker spiral with an angle of 4^o or 45 ^{o} degrees and a magnitude of 12 nT. Also, the stellar XUV flux was set between 1 and 50 times of the current Earth value. We assumed a Venus-like atmospheric composition that depends on the stellar XUV flux as the input neutral atmosphere based on Kulikov et al. (SSR, 2007). Since there is no information on the intrinsic magnetic fields of TOI-700 d, we assumed a global dipole magnetic field and direction of the dipole moment is perpendicular to the ecliptic plane of the stellar system. To investigate the dependence on the strength of the intrinsic magnetic field, the equatorial surface strength of the dipole magnetic field was set between 0 nT to 1000 nT. In the 1000 nT case, it is strong enough to deflect the stellar wind and expected to reduce the atmospheric ion escape rate (Sakata et al., JGR, 2022). When the exoplanet does not possess the intrinsic magnetic field (0 nT case), the high XUV condition results in the large ion escape rate to remove the atmosphere within a few billion years. The existence of the strong magnetic field reduces the escape rate. In the presentation, effects of the global planetary magnetic field on the ion escape mechanisms will be also reported in detail.