木星氷衛星電離圏探査に向けたパッシブレーダーの数値シミュレーション

Numerical simulation of passive radar for ionospheric explorations at Jupiter's icy moons

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Jupiter's icy moons such as Ganymede, Callisto, and Europa may harbor subsurface liquid water oceans. While only Earth has oceans on the surface in the current solar system, multiple icy bodies like the icy moons of giant planets are considered to have oceans in their subsurface under the icy crust. So, the icy bodies are potentially more universally habitable environments than the Earth-type bodies. Ionospheres of icy moons contain essential information for understanding habitable environments because the ionospheres are formed as a result of external energy supplies and internal oceanic and crustal activities. Especially, density distribution of ionospheric electrons has one of the important keys to understand the ionization processes and the structure of neutral atmosphere due to suppering and sublimation on the surface and putative water plumes from the subsurface oceans. However, the structures are still unclear because previous observation methods, such as the ground-based radio occultation and the in-situ observation using upper hybrid resonance emissions, have difficulties of limited spatial range of observations. Therefore, we have been developing a new radar exploration method using the Jovian radio waves to overcome the limitation listed above. The purpose of this study is to examine density distribution of the ionospheric electrons and its generation processes on each of Jupiter’s icy moons.
To establish the new exploration method, we have developed a numerical simulation that emulates the propagation of the Jovian radio waves around the moons. This tool enables us to estimate the density distribution using observation results of the Jovian radio waves during the flybys at the moons. We derived electron density by applying the new method to the Galileo PWS data and examined generation process of the ionosphere.
We found that the maximum electron density of Ganymede’s ionosphere during the Galileo Ganymede 01 flyby is about 25 –100 cm-3 in the lower-latitude region connected to closed magnetic fields and 100 –250 cm-3 in the higher-latitude region connected to open magnetic fields. The difference between the two regions may reflect nonuniform charged particle precipitation into Ganymede as the electron and ion precipitation estimated by Liuzzo et al. (2020) and Poppe et al. (2018). For the case of Callisto, we found that the maximum electron density of Callisto’s ionosphere during the Galileo Callisto 09 and 30 flybys is about 2,100 cm-3 in the day side and 25 –700 cm-3 in the night side. The difference between the day side and night side is thought to reflect the effect of sublimation as atmospheric production suggested by Vorburger et al. (2015). Thus, our results indicate the difference in the generation process between Ganymede and Callisto ionospheres by adding further information on ionospheric conditions with the new method.
As a next steps, in order to verify icy moons’ 3D atmospheric models proposed in the preceding study

and to make extended studies for ionospheric formation processes, we plan to modify our calculation code to emulate the refraction of the Jovian radio waves in 3D space. We also plan to further develop our code to emulate the reflection and transmission in the icy moons to examine feasibility of passive radar observation for the icy crust and underlying ocean.
Combining these new simulations and applying them to upcoming data from the Radio & Plasma Wave Investigation (RPWI) onboard with the Jupiter ICy moons Explorer (JUICE), the energy supply system and activity levels of the icy moons will be elucidated, which will provide much detailed information to better understand habitability on the icy moon's.

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