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Sodium exosphere on Mercury, Moon, and Asteroids

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Abstract

Mercury and Moon have a thin sodium exosphere. It is suggested that sodium atoms are released by interaction between the surface and its environment. Sodium depletes at the surface after heated to the temperature of ~ 630°C. If an asteroid has not been heated at the temperature, the surface should contain sodium atoms and it forms the exosphere. We discuss the effect of solar wind impact to the surface of Mercury on the formation of sodium exosphere and the plan to detect sodium emission from the C-type asteroid's exosphere.

1. Introduction

1.1 Sodium on Mercury and Moon

Mercury has a thin atmosphere. It is often called a "surface-bounded exosphere" because its scale height near the surface is smaller than the mean-free path of atmospheric particles. Sodium density is relatively high in the detected neutral species of H, He, O, Na, Mg, K, and Ca [1-5]. In these species, the alkali atoms are thought to be released from the surface by photon-stimulated desorption [6, 7], thermal desorption [8], chemical sputtering [9], solar wind ion sputtering [10, 11], and micrometeoroid vaporization [12, 13]. In the detected species, sodium has been most investigated because its emission is brightest and it can be observed by ground-based telescopes. Though many observations have been done since its discovery in 1985, the source process of exospheric sodium atoms is still unclear. Moon has the sodium and potassium exosphere. The suggested dominant source process is photon-stimulated desorption. Additionally, solar wind impact induces diffusive transportation of sodium from depth to surface. It is called "gardening effect"

1.2 Sodium on asteroids

Sodium emission from the exosphere on asteroids has not been detected yet. However, assuming that an asteroid has not been so much heated in its formation, it should contain much volatile species, such as sodium, on the surface. Na abundance is probably higher than Mercury and Moon, which have been more heated in their formation. Then, a tenuous but detectable sodium exosphere could be formed around the asteroid.

2. Observation

MESSENGER spacecraft started its orbital observation of Mercury on March 2011 and is still in operation. We have performed the ground-based observation at the Haleakala Observatory from 2011 (Figure 1).

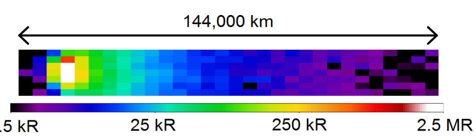

Figure 1: Mercury's sodium tail.

Most remarkable feature of Mercury's sodium exosphere is the concentration at high latitudes and its temporal variability. Sodium atoms are concentrated at the northern and southern high latitudes and its density is higher at southern high latitude than at northern high latitude. Moreover, concentration at northern side vanished although concentration at southern side was kept by the end of the observation. The cusp region, where the planetary magnetic field connects to the interplanetary field, is formed at high latitudes. Solar wind protons and other heavy ions precipitate more frequently at the cusp region than near equator. Thus, Potter and Morgan concluded that the concentration of sodium at high latitudes is mainly caused by solar wind sputtering. However, Kameda et al. [14] shows that the temporal variability of average sodium density is less than ~10%. Additionally, Yakshinskiy and

Maday [7] shows that the photon-stimulated desorption rate is higher than the other source processes. This issue is still to be clarified.

The MESSENGER/MAG detected the increase of the intensity of the interplanetary magnetic field around Mercury from Jan 2 to 5, 2012 (Figure 2). If the increase was caused by CME and the solar wind sputtering is the dominant source process of sodium exosphere, sodium density should increase and its emission should be brighter. However, no obvious increase of the intensity of sodium emission was detected in our observation (Figure 3).

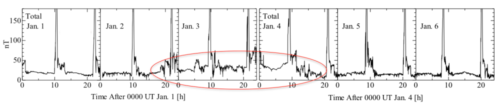

Figure 2: IMF detected by MESSENGER/MAG

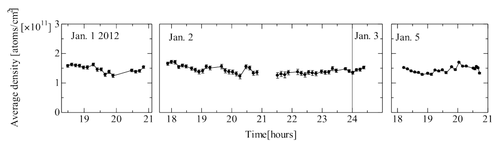

Figure 3: Average sodium density of Mercury exosphere

We plan to observe the sodium exosphere on the C-type asteroid. Hayabusa2 is the sample-return mission to the C-type asteroid, 1999JU$_3$. Emission from exospheric sodium around 1999JU$_3$ is detectable by Optical Navigation Camera (ONC) with the 0.59µm filter if the Na source rate on 1999 JU$_3$ is comparable with that on Mercury. Figure 4 shows the simulation result of the distribution of exospheric sodium. Because Na is one of the most volatile metallic elements, it would be lost upon heating; Na depletion would occur at ~ 630°C [14]. This Na depletion temperature is much higher than disappearance temperatures 400°C for 0.7µm and comparable to 600°C for 3 µm absorption bands, respectively. Moreover, the exospheric Na of planetary bodies is supplied from centimeters depth of subsurface, while the reflectance spectroscopy of solid surfaces is controlled by only a sub-millimeter thick surface layer. Thus, if the cm's-deep subsurface on 1999JU$_3$ has not been heated at temperatures >630°C, its Na abundance is probably higher than Mercury and Moon. Then, a tenuous but detectable Na atmosphere could be formed around the asteroid. If the heating history of 1999 JU3 surface is not uniform, exospheric Na distribution would exhibit nonuniformity. Such observations will be useful for understanding the devolatilization state of 1999 JU$_3$ and helpful for selecting the touchdown site.

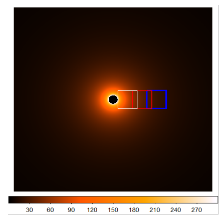

Figure 4: Sodium exosphere on 1999JU$_3$. The square shows the area of 2 km x 2 km. The intensity is shown in Reighley.

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