

SOURCE PROCESS OF EXOSPHERIC SODIUM ON MERCURY AND TEMPORAL VARIABILITY OF SODIUM DENSITY. S. Kameda¹, M. Kagitani², and S. Okano². ¹Planetary Exploration Research Center, Chiba Institute of Technology (Chiba, Japan; kameda@perc.it-chiba.ac.jp), ²Planetary Plasma and Atmosphere Research Center, Tohoku University (Miyagi, Japan).

Introduction: Mercury has a very thin atmosphere. The surface pressure is less than 10^{-12} atm. Since its scale height is greater than the mean-free-path near the surface, Mercury's atmosphere is called "Surface-bounded exosphere. The Mariner 10 UV spectrometer detected the emission from H, He, and O atoms [1, 2], which are thought to be the solar wind origin. Subsequently, the emission from Na, K, and Ca atoms were detected by the ground-based telescope [3, 4, 5]. These alkali atoms are thought to be released from the surface b'y 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 relatively easily 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. In this paper, we show the past results of ground-based observations and discuss its source process.

Observation: Most remarkable feature of Mercury's sodium exosphere is the concentration at high latitudes and its temporal variability [14]. 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 high latitude vanished although concentration at southern high latitude was kept by the end of the observation.

The planetary magnetic field of Mercury is strong enough to sustain the solar wind magnetic fields and form a magnetosphere. 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 [10] concluded that the concentration of sodium at high latitudes is mainly caused by solar wind sputtering. However, Kameda et al. [15] shows that the temporal variability of average sodium density is less than ~10% (Figure 1). 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. In this paper, we compare the observed sodium density with the heliocentric distance, F10.7, sunspot number, and the distance from the ec-

liptic plane. We used the data listed by Potter et al. [17] and our data.

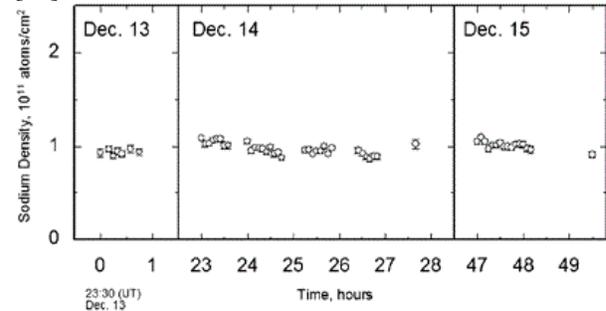


Figure 1: Temporal variability of average sodium density [15]

Figure 2 shows the average sodium density and the heliocentric distance. The long-term average solar photon and solar wind flux are inversely proportional to the square of the heliocentric distance. Although photon-stimulated desorption and solar wind sputtering are suggested to be dominant source processes of atmospheric Na, there is no correlation between the heliocentric distance and Mercury's Na density. Photon-stimulated desorption is caused by solar photons, whose energies are higher than UV energy [7]. The relationship between the solar EUV flux at the wavelength from 0 to 200 nm and the Na density is shown in Figure 3. We used the data obtained by SEE on TIMED. The solar flux at Mercury was estimated from that detected near Earth figuring out how many days of offset there is between Mercury and Earth in solar rotation from the Earth-Sun-Mercury angle and dividing the solar flux by the square of the value of the heliocentric distance of Mercury in AU. Solar wind flux also changes with time, which possibly causes temporal variability in the sputtered Na concentration. We compared the Na density with the solar wind proton flux (Figure 4). We used the data obtained by SWEPAM on ACE and estimated the solar wind flux considering the rotation of Sun and the orbital position of Earth and Mercury. As a result, the Na density is not correlated with the solar EUV flux or the solar wind flux. Therefore these observations do not support the theory that photon-stimulated desorption or solar wind ion sputtering is the dominant source process of Na.

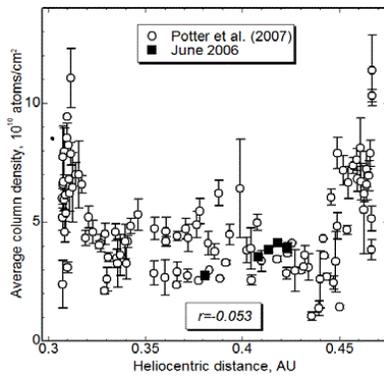


Figure 2: Average sodium density and heliocentric distance [16]

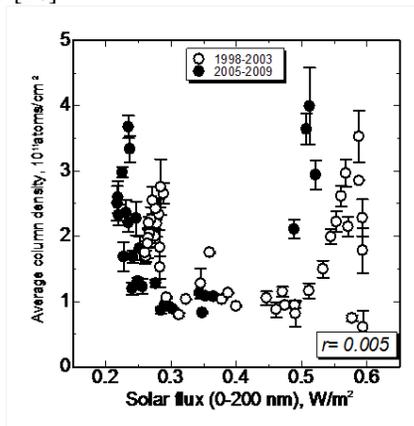


Figure 3: Average sodium density and EUV solar flux

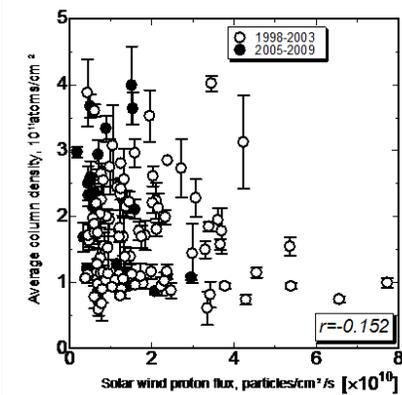


Figure 4: Average sodium density and solar wind flux.

Interplanetary dust distribution: Assuming that interplanetary dust (IPD) is concentrated on the ecliptic plane, IPD density should be dependent on the distance from the ecliptic plane. There is a weak negative correlation between Na density and the distance between Mercury and the ecliptic plane, which suggests that the Na release rate tends to be high when Mercury is near the ecliptic plane. In other words, the vaporization effect by IPD is the dominant release process. We have

also developed an IPD distribution model to investigate further the relationship between atmospheric Na density and IPD distribution. We assume that the average Na density in Mercury's atmosphere is proportional to the IPD density at Mercury. The inclination (i) and ascending node (Ω) of the symmetry plane of IPD are also free parameters. We searched the most relevant values for these four parameters using the least square method. Figure 5 shows the average Na density and the IPD vaporization yield estimated under the assumption that all Na atoms are released from the surface of Mercury on impact with IPD. The correlation coefficient can be more than 0.6 for $-104 < \Omega < 57$ and $i > 1.9$. Our results do not correspond completely with the past results, mainly because of the difference in the position of the observed IPD. Since the IPD density at Mercury is unknown, we cannot conclude whether the IPD vaporization is the dominant release process. Further observation of IPD distribution is necessary.

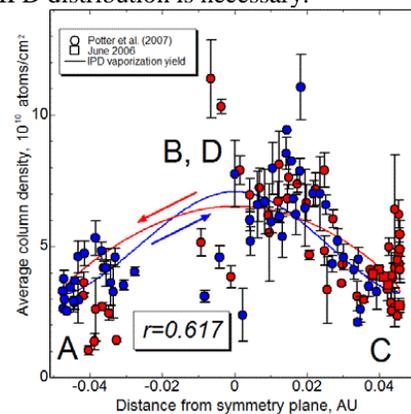


Figure 5: Average sodium density and Distance from ecliptic plane [16]

References: [1] Broadfoot, A. L. et al., (1974) *Science* 185, 166–169. [2] Broadfoot, A. L., et al (1976) *GRL* 3, 577–580 [3] Potter, A. E. and Morgan, T. H. (1985) *Science* 229, 651–653 [4] Potter, A. E. and Morgan, T. H. (1986) *Icarus* 67, 336–340 [5] Bida, T. A. et al (2000) *Nature* 404, 159–161. [6] McGrath, M. A. et al. (1986) *Nature* 323, 694–696. [7] Yakshinskiy, B. V. and Madey, T. E. (1999) *Nature* 400, 642–644. [8] Leblanc, F. and Johnson, R. E. (2003) *Icarus* 164, 261–281. [9] Potter, A. E. (1995) *GRL* 22, 3289–3292. [10] Potter, A. E. and Morgan, T. H. (1997) *Adv. Space Res.* 19, 1571–1576. [11] Killen, R. M. et al. (2004) *Icarus* 171, 1–19. [12] Morgan, T. H. et al. (1988) *Icarus* 75, 156–170. [13] Cremonese, G. et al. (1997) *Ap. J. Lett.* 490, 199–202. [14] Leblanc, F., et al..2009. *GRL* 36 L07201. [15] Kameda, S. et al. (2007) *PSS* 55, 1509–1517. [16] Kameda, S. et al. (2009) *GRL* 36, L15201 [17] Potter, A. E. et al. (2007) *Icarus* 186, 571–580.