Investigation of the production mechanism and the circulation of lunar sodium atmosphere based on numerical simulation

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Small bodies in the solar system, such as the Moon and Mercury, are known to have Surface Bound Exosphere (SBE), which is a collision-free tenuous atmosphere. SBE is produced by particle ejection from the surface soil, though the details of ejection mechanism are not well understood. Because the Moon doesn't have an intrinsic magnetic field, the Moon is the most suitable target to investigate the SBE. Proposed production mechanisms of SBE on the Moon include (1) photon-stimulated desorption by the solar photons, (2) sputtering by solar wind particle, (3) thermal desorption by solar heating of the lunar surface, and (4) vaporization of micrometeorites. Production mechanisms (1), (2), and (3) are thought to depend on the solar zenith angle. Therefore the ejection rate of SBE will also depend on latitude on the Moon.

We have investigated lunar sodium exosphere based on a numerical simulation. In our simulation, photon-stimulated desorption by the solar photons, sputtering by solar wind particle and vaporization of micrometeorites are assumed as production mechanisms. Ejection speed of sodium atoms is determined according to the velocity distribution function of each ejection mechanism. Ejection direction is determined with the Monte Carlo method. The motion of atmospheric atoms is calculated as the restricted three-body problem (Sun, Moon, and a sodium atom) and time evolution of atoms ejection from the lunar surface is calculated using the four-order Runge-Kutta method.

Based on our simulation, it is concluded that sodium atoms in the regolith of the Moon should have been depleted in 3 billion years lunar history, when the amount of sodium atoms contained in Apollo samples is taken into account. Nevertheless, sodium atoms are still being released from the Moon, suggesting that some kind of supply or diffusion of sodium atoms out of the inner regolith must be working.