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Modeling the Lunar Plasma Wake

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We study the solar wind interaction with the Moon using a three-dimensional hybrid plasma solver (particle ions and fluid electrons). The Moon, without any global magnetic field and very thin atmosphere, is a non-conducting obstacle to the solar wind plasma flow. The solar wind plasma impacts the lunar surface and is absorbed there, leaving a plasma void and forming a wake structure in the lunar night-side. The solar wind protons fill in the wake through thermal plasma expansion and electric charge separation. As the solar wind expands into the wake, the solar wind magnetic field increases as a consequence of a diamagnetic current driven by the pressure gradient across the wake boundary. The solar wind protons accelerate along the magnetic field lines towards the central wake and increase the protons number density there. Observations in the wake at different altitudes show a low-density population of the solar wind protons intruding into the lunar wake with higher energies than the ambient solar wind energy. We model the lunar wake and study its dependencies on the interplanetary magnetic field and then investigate how the solar wind protons can access the low-altitude (100 km) lunar wake. The solar wind usually has bi-Maxwellian velocity space distribution at the distance of the Earth from the Sun. Therefore, we also discuss the role of this anisotropic distribution and the effect of the lunar surface plasma absorption on the kinetic properties of the solar wind protons at 100 km altitude above the Moon in the lunar wake. The number of protons in a particle-in-cell solver at the lunar night side is too small to examine the proton kinetics there. However, to improve the velocity space resolution, we present a Backward Liouville method for particle-in-cell solvers. We show that the model can explain the reported observations of higher proton energy and lower density than the ambient solar wind in the low-altitude wake. Additionally, a large temperature anisotropy is found at close distances to the Moon on the lunar night-side as a consequence of the lunar surface plasma absorption effect. Finally, we compare the simulation results with the preformed observations.