

Type-II entry of solar wind protons into the lunar wake as a general phenomenon

Masaki N Nishino^{1*}, Masaki Fujimoto¹, Yoshifumi Saito¹, Mariko Kawamura², Hideo Tsunakawa³, Yoshiya Kasahara⁴, Masaki Matsushima³, Futoshi Takahashi³, Hidetoshi Shibuya⁵, Hisayoshi Shimizu⁶, Yoshitaka Goto⁴, Kozo Hashimoto⁷, Yoshiharu Omura⁷, Atsushi Kumamoto⁸, Takayuki Ono⁸, Shoichiro Yokota¹

¹JAXA, ²The University of Tokyo, ³Tokyo Institute of Technology, ⁴Kanazawa University, ⁵Kumamoto University, ⁶ERI, The University of Tokyo, ⁷RISH, Kyoto University, ⁸Tohoku University

We study a type of solar wind entry into the lunar wake under various interplanetary magnetic field (IMF) conditions using SELENE (Kaguya) data. Our recent observations around the Moon revealed that so-called type-II (T2) entry of the solar wind protons into the near-Moon wake occurs when the IMF is dominated by the non-radial components (i.e. B_Y and/or B_Z). Under this condition a part of the solar wind protons scattered/reflected at the lunar dayside surface subsequently enters the central region of the near-Moon wake after a large-scale cycloid motion, which gives rise to electron acceleration and wave generation. The situation handled in the previous studies is that the magnetic field line around which the solar wind protons entering the wake are gyrating is detached from the lunar surface, and thus a possibility of the T2 proton entry into the region where field lines are connected to the lunar surface has not been considered yet. Here we report that the T2 entry process takes place under various IMF conditions, and that the protons can access the central wake region that is magnetically connected to the lunar nightside surface, which we categorize into the T2 entry with magnetic connection to the lunar surface (T2MC). Furthermore we show that the energy of the electron beams associated with the entered protons depends on the magnetic connectivity to the lunar nightside surface. Strong electron acceleration (up to several hundred eV to 1 keV) along the magnetic field associated with the T2 entry is prominent when the field line has its both ends in the solar wind, that is, when the magnetic field is detached from the lunar surface (i.e. the "original" T2 entry that we rename to T2MD). On the other hand, no significant electron acceleration is found in the T2MC cases, although an enhancement of the electron flux associated with the T2 proton entry is evident. Our results indicate that, while the T2 entry of solar wind protons into the wake itself does not require a special IMF condition but is a rather general phenomenon, the characteristic energy of associated electrons does show a strong dependence on the magnetic connectivity to the lunar surface.

Keywords: Solar wind-Moon interaction, Lunar wake, SELENE, Wave-particle interaction, Plasma entry into wake