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Intrusion of the solar wind ions into the lunar low-altitude wake observed by SELENE (KAGUYA)

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The moon spends more than 80 percent of time staying in the solar wind (SW), where a quasi-vacuum region called the lunar wake is formed on the night side. A part of SW electrons, having higher thermal speeds than ions come to the lunar night-side region more easily than SW ions, and resultant electron-rich status of the lunar wake yields a bipolar (inward) electric field at the wake boundary. Therefore, it has been widely supposed that SW ions can be gradually accelerated toward the lunar night side along the SW magnetic field by the bipolar electric field. Here we show the detection of a pair of energy gain and loss signatures when the SELENE (KAGUYA) orbit crosses the wake in the direction perpendicular to the SW magnetic field. These signatures are detected at $\sim$100 km altitude near the wake boundaries, and the locations of the energy gain and loss are roughly fixed in the coordinated system whose axes refer to the SW magnetic field direction. The analysis of these locations suggest that they are accessible by SW ions having a limited range of Larmor phase angles in the SW, which are sensitive to the direction of SW magnetic field. Particle orbit calculations show that the energy gain and loss are due to the bipolar electric field around the wake boundary, and that acceleration and deceleration let the SW ions come to the mid- to low-latitude regions in the midnight meridian. It is stressed that an observer in the rest frame of the SW sees that the SW ions always gain energy by the bipolar electric field, while an observer in the rest frame of the moon sees that a pair of energy gain and loss occurs when the spacecraft crosses the lunar wake boundaries. Our result shows emergence of proton particle dynamics around the near-moon space, and suggests that the SW ions may relatively easily access to the low-latitude and low-altitude region on the lunar night side.