Current balance at the lunar night-side surface in the terrestrial foreshock

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There forms a tenuous region called the wake behind the Moon in the solar wind, and plasma entry/refilling into the wake is a fundamental problem of the lunar plasma science. High-energy ions and electrons in the foreshock of the Earth's magnetosphere were detected at the lunar surface in the Apollo era, but their effects on the lunar night-side environment have never been studied. Here we show the first observation of bow-shock reflected protons by Kaguya (SELENE) spacecraft in orbit around the Moon, confirming that solar wind plasma reflected at the terrestrial bow shock can easily access the deepest lunar wake when the Moon stays in the foreshock (We name this mechanism 'type-3 entry'). In an intermittent type-3 entry event, the kinetic energy of upward-going field-aligned electron beams decreases from 80 eV to 20 eV or electron beams disappear as the bow-shock reflected ions come accompanied by enhanced downward electrons. According to theoretical treatment based on electric current balance at the lunar surface including secondary electron emission by incident electron and ion impact, we deduce that incident ions would be accompanied by a few to several times higher flux of an incident electron flux, which well fits observed downward fluxes. We conclude that impact by the bow-shock reflected ions and electrons raises the electrostatic potential of the lunar night-side surface.