ARTEMIS observations of micrometeoroid-impact charging of the lunar surface

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February 23, 2022
THEMIS/ARTEMIS SWT
Micrometeoroid-Impact Charging

Hyper-velocity MM impacts are known to efficiently generate free charge

LADEE/LDEX measurements show that the MM-impactor flux is highly concentrated near dawn (~6-8 LT)

[e.g., Horányi et al., 2015; Szalay and Horányi, 2016]
MM-Impact Surface Charging at the Moon

Electron reflectometry by ARTEMIS can remotely sense the lunar surface potential.

MM-impact charging drives the dawnside lunar surface potential less negative than plasma currents do.
Main Points

Geophysical Research Letters

ARTEMIS Observations of Lunar Nightside Surface Potentials in the Magnetotail Lobes: Evidence for Micrometeoroid Impact Charging

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Summary (adapted from Poppe et al., GRL, 2021):

1. Using electron reflectometry, ARTEMIS can sense the electrostatic potential of the lunar surface (w.r.t. the spacecraft)
2. During periods in the low-density terrestrial magnetosphere, ARTEMIS observes less negative nightside potentials than expected from theory
3. These low-magnitude potentials are highly correlated with connection to the lunar dawn hemisphere
4. Micrometeoroid-impact charging dominates the surface and near-surface plasma environment in shadowed, low-density environments
5. Other planetary bodies may be subject to this process under such conditions
Backup Slides
Surface Charging & Electron Reflectometry (ER)

Main charging currents are ambient ion/electron collection, photoemission (dayside), and secondary electron emission.

Remotely sensed electron distributions inform us about the crustal magnetic field strength and the electrostatic potential at the lunar surface.

An ‘Anomalous’ ARTEMIS ER Observation

Feb 26, 2021

(a) Moon within the terrestrial magnetotail

(1) Moon within the terrestrial magnetotail

(b) ARTEMIS P1 transits through the lunar shadow & is magnetically connected to nightside surface

(2) ARTEMIS P1 transits through the lunar shadow & is magnetically connected to nightside surface
An ‘Anomalous’ ARTEMIS ER Observation

Sun-Earth aligned B - Lobes

Down-going electron flux

Up-coming electron flux

Up/Down electron flux ratio

Why is the nightside lunar surface less negative than theory predicts?
Inferred surface potentials are consistently less negative than theory for the dawn hemisphere, increasingly so for lower ambient densities, consistent with MM-impact charging of the lunar surface.
MM-Impact Surface Charging: Implications

MM-impact charging may be an important charging process in mini-wake / non-neutral shadowed regions – i.e., a “current of last resort”?

[e.g., Farrell et al., 2010; Zimmerman et al., 2011, 2013]

MM-impact charging may be important at other airless bodies with either:

(a) low-density ambient plasmas, and/or
(b) high-flux or high-velocity micrometeoroid impact distributions
MM-Impact Surface Charging at the Moon

(a) $f(V)\sim V^{4/2}$

(b) $Q_{imp}\sim V^{4/2}$

(c) Electric Temperature [eV]

(d) Eq. Potential / Electron Temperature

after Pokorny et al. (2019), Fig. 5