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Generation mechanism for electrostatic waves over the lunar magnetic anomaly region

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The Moon is a regolith-covered planetary object having a characteristic surface bound exosphere [1]. The Moon lacks a global intrinsic magnetic field, however, regions of permanently magnetized crusts referred to as lunar magnetic anomaly (LMA) exists on the lunar surface [1]. Based on Lunar Prospector observations, it was speculated that "mini-magnetosphere" can exist over the magnetic anomaly regions [2]. Chandrayaan-1 discovered the existence of "mini-magnetosphere" over the LMA using energetic neutral atom (ENA) imaging [3]. Further, over the LMAs, deflection and heating of the incoming solar wind protons [4] and mirror reflection of the solar wind electrons [5] were reported. The incident solar wind particles counter stream relative to the deflected and mirror-reflected particles, eventuating in varied elementary plasma processes, viz., plasma instabilities and wave excitation that in-turn affects the lunar plasma environment. A wave of pertinent importance over the LMA is the electrostatic solitary waves (ESWs), which has been known to account for the electrostatic turbulence, particle acceleration and broadband electrostatic noise (BEN) generation in the magnetosphere flow boundary region [6].

The observations from recent lunar missions, viz., Kaguya and ARTEMIS have shown the existence of ESWs over the LMA and wake boundary regions [7, 8]. Further, the ESWs were found to be more concentrated inside the wake region when the Moon was in the upstream solar wind, and homogeneously distributed when the Moon was inside the geomagnetic tail [9]. The quantum of the studies on the occurrence and production mechanism of the ESWs in the lunar plasma environment have been focused mainly over the lunar wake region, whereas over the LMA region is quite limited. In our work, we have investigated in detail the occurrence and characteristics of ESWs over different LMA regions using the plasma and field observations from the ARTEMIS (Acceleration, Reconnection, Turbulence and Electrodynamics of Moon's Interaction with the Sun) mission.

ARTEMIS is a two probe (P1 and P2) mission derived from the THEMIS mission, elliptically orbiting the two Lagrange points of the Earth-Moon system with a period of ~25 hrs since 2011. We have used the data from electric field instrument (EFI), fluxgate magnetometer (FGM) and electrostatic analyser (ESA) on-board ARTEMIS. The amplitude (~ 15- 20 mV/m) of the ESWs propagating parallel to the ambient magnetic field observed over LMA was found to be higher than those observed in the rest of the lunar plasma environment. The generation of the ESWs over the anomaly regions was found to be associated with bi-steaming electron population. In order to identify the mode of the observed ESWs we have theoretically modeled the LMA plasma using a four-component magnetized plasma comprising of protons, Helium ions, suprathermal electrons and electron beam utilizing the Sagdeev pseudopotential formalism. The model aptly explains the observations in terms of slow and fast ion-acoustic solitons and electron-acoustic solitons. These observed ESWs can interact with the background plasma and can play a pivotal role in acceleration and heating of the particles over the LMA region.

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References

[1] Dhanya M. B., Bhardwaj A., Futaana Y., et al., *Geophys. Res. Lett.*, 44,4540-4548(2017).
[2] Lin R. P., Mitchell D. L., Curtis D. W., Anderson K. A., *Science*, 281, 1480-1484 (1998).
[3] Wieser M., Barabash S., Futaana Y., et al., *Geophys. Res. Lett.*, 37, 015103 (2010).
[4] Lue C, Futaana Y, Barabash S, Wieser M, et al., *Geophys. Res. Lett.,*38:03202(2011).
[5] Saito Y, Nishino M N, Fujimoto M., et al., *EPS*, 64, 83-92 (2012).
[6] Lakhina G. S., Singh S. V., Rubia R., and Sreeraj T., *Phys. of Plasma*, 25 (2018).
[7] Hashimoto K., Hashitani M., Kasahara Y., et al., *Geophys. Res. Lett.*, 37, 1–6 (2010).
[8] Hutchinson I. H., and Malaspina D.M., *Geophys. Res. Lett*, 45, 3838-3845 (2018).
[9] Malaspina D. M., and Hutchinson I. H., *J. Geophys. Res.: Space Phys*., 124 (2019).