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Electron Instabilities and Phase Space Holes Concentrated in the Lunar Plasma Wake: Theory and Observation

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When the supersonic, superAlfvénic solar wind flow encounters the Moon, a non-magnetic obstacle much larger than an ion gyro radius, ions are excluded from the downstream region and a plasma wake is formed. Plasma flows into the wake along solar wind magnetic field lines downstream of the Moon. Electrons fill in the wake faster than ions due to their higher thermal velocity, setting up an electrostatic potential structure in the wake. Electrostatic instabilities are driven as more solar wind plasma streams into the wake and interacts with this potential structure. In particular, an unstable electron distribution function is predicted to form where low-energy electron trajectories stagnate against the negative wake potential [1]. The relaxation of this instability is predicted to generate electron phase space holes [2] and significantly impact the merging of the wake and background solar wind.

High-cadence electric field observations from the two ARTEMIS spacecraft, orbiting the Moon at distances up to 11 lunar radii, are used to test these predictions by searching for signatures of electron phase space holes in the vicinity of the lunar wake. ARTEMIS data demonstrate that electron holes are highly concentrated in the lunar wake [3]. Of all electron holes detected by ARTEMIS within 11 lunar radii of the Moon, 96% are found in the lunar wake. Further, the spatial distribution of those holes with respect to the wake center is found to be consistent with theoretical expectations.

In this presentation, we discuss the theoretical basis for expecting electron phase space hole generation in the lunar wake, as well as the supporting simulation and observational evidence. Additional features of the observations, such as a possible perturbation of wake instabilities due to solar wind current sheets, are also discussed.

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3. I.H. Hutchinson and D. M. Malaspina, "Prediction and Observation of Electron Instabilities and Phase Space Holes Concentrated in the Lunar Plasma Wake", *Geophysical Research Letters*, **45**, 2018, 3838, https://doi.org/10.1029/2017GL076880