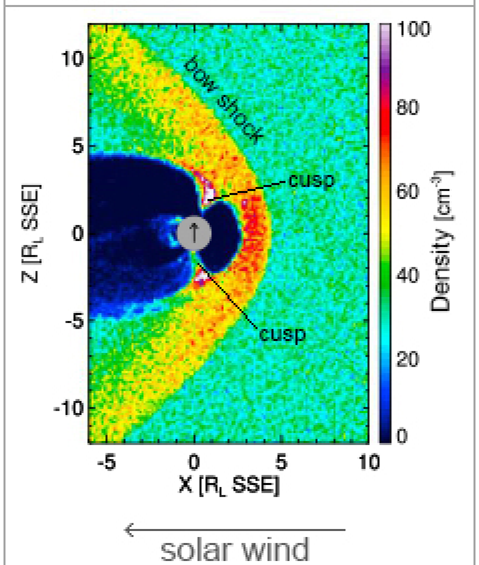
Solar Wind Interactions with a Lunar Paleo-magnetosphere

How would an ancient, global magnetic field on the Moon and its associated paleo-***magnetosphere*** interact with the incoming, charged particles in the ***solar wind plasma***? Would a paleo-magnetosphere shield the lunar surface from solar wind bombardment? Answering these questions improves our understanding of processes that were influenced by the Moon's paleo-magnetosphere, such as the accumulation and ***space weathering*** of volatiles in the polar regions. This is the work being undertaken by Ian Garrick-Bethell (University of California, Santa Cruz/Kyung Hee University, South Korea), Andrew Poppe (University of California, Berkeley/SSERVI NASA Ames), and Shahab Fatemi (Swedish Institute of Space Physics, Kiruna).

Model Results for the Interaction of a Lunar Paleo-magnetosphere with the Early Solar Wind



(From Garrick-Bethell, I., *et al.*, 2019, *GRL*, doi: 10.1029/2019GL082548.)

Using computer models of the plasma environment with solar wind parameters appropriate for ~2 billion years ago, Garrick-Bethell and coauthors simulated its interaction with a lunar paleo-magnetosphere. The researchers applied Amitis, a fast, 3D computer model of plasma (kinetic ions and fluid electrons). They modeled the solar wind as H^+ and used lunar surface paleo-magnetic field strengths of 0.5μT, 2μT, and 5μT (microteslas) at different orientations. (Earth, by comparison, has a surface magnetic field strength ranging from ~20 to 60μT.) Shown on the left is a 2D plot of one of the Moon-modeling results of plasma density for the case of a spin-aligned 2μT equatorial surface magnetic field strength. The magnetic dipole moment is vertical, as indicated by the small black arrow. The solar wind flows from right to left.

In addition to the bow shock showing where the solar wind is diverted around the lunar magnetosphere, the modeling results clearly indicate the two polar cusps (areas of focused field lines) where solar wind plasma funnels down to the lunar surface. The polar cusp phenomenon is well known—at Earth's polar cusps the solar wind's charged particles enter and precipitate to our planet's high-latitude ionsophere (where they can activate auroras).

Analyses of Apollo lunar samples suggest the Moon had a global magnetic field and magnetosphere ~1–4.25 billion years ago. Garrick-Bethell and colleagues' results suggest the lunar surface would have been mostly shielded from solar wind H^+ bombardment for the lifetime of the core dynamo. Yet they also found that if the magnetic field were aligned with the Moon's spin axis, then the lunar poles would have experienced focused bombardment of solar wind H^+ and increased space weathering.

The modeling results indicate that an interaction of a lunar paleo-magnetosphere with the early solar wind affected the competing processes of implantation, accumulation, and space weathering of solar wind H^+ on the lunar surface. Their modeling did not include what may have happened to the plasma flow when the Moon passed through Earth's magnetosphere (see a related **PSRD** CosmoSparks report:

Flux of O^+ Ions from Earth to the Moon). Garrick-Bethell and coauthors also say paleo-magnetosphere/solar wind interactions and the flux of solar wind H^+ to the surface would be further complicated if the Moon had an ancient transient atmosphere, which has been suggested as a product of volcanic outgassing (see **PSRD** article: ***Volcanism and an Ancient Atmosphere on the Moon***). Because the issues of volatile evolution throughout lunar history, especially of polar volatiles, are so important to future exploration, we will be seeing more exciting work on the relationships between magnetic fields, solar wind, and surface volatiles.

See reference:

· Garrick-Bethell, I., Poppe, A. R., and Fatemi, S. (2019) The Lunar Paleo-magnetosphere: Implications for the Accumulation of Polar Volatile Deposits, *Geophysical Research Letters,* v.46, p. 5778-5787, doi: 10.1029/2019GL082548. [***abstract***]

See also:

· Fatemi, S., Poppe, A. R., Delory, G. T., and Farrell, W. M. (2017) AMITIS: A 3D GPU-based Hybrid-PIC Model for Space and Plasma Physics, *Journal of Physics: Conference Series,* v. 837(1), 012017, doi: 10.1088/1742-6596/837/1/012017. [***open access article***]

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