The Effect of Magnetic Fields on Electrostatic Dust Lofting

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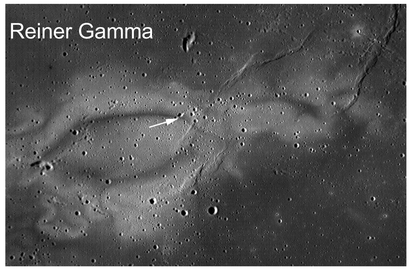
MOTIVATION

Electrostatic dust lofting was first suggested as a mechanism to explain the lunar horizon glow. Further examples of phenomena that could involve dust lofting include the dust ponds on asteroid 433 Eros and comet 67P, the intermittently appearing 'spokes' in Saturn's rings, and the unexpectedly smooth surface on Saturn's icy moon Atlas. Dust lofting may have also contributed to the Reiner Gamma anomaly and other so-called Lunar Swirls. Our understanding of electrostatic dust lofting has increased substantially by introducing the patched charge model, but the effect of imposed magnetic fields is still poorly understood. Electrostatic dust lofting, in magnetic anomaly regions might be responsible for the formation of the lunar swirls.



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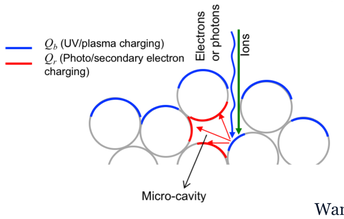
PATCHED CHARGE MODEL

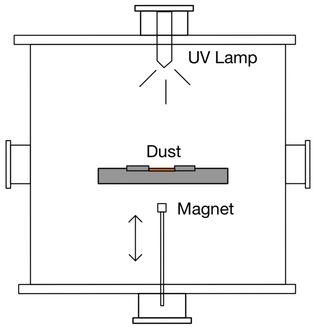


Wang et al., 2016

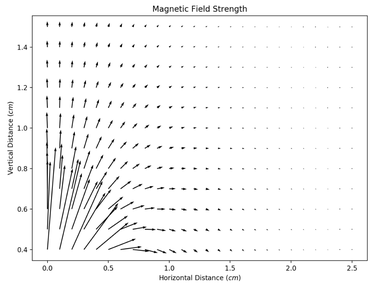
- Dusty surfaces are exposed to the solar wind and high-energy photons in space.
- "Micro-cavities" absorb emitted photoelectrons and secondary electrons, causing patches of large negative charge to build up on the surrounding insulating dust particles.
- Repulsion between particles with the net large negative charge can become large enough for them to be lofted.

METHOD

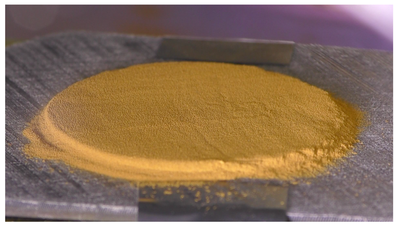
- Mars simulant: JSC-Mars-1.
- Dust is placed in a crater 4.0 cm in diameter and 0.2 cm deep on an insulating plate.
- Exposed to ultraviolet radiation at a wavelength of 172 nm.



- Magnet starts 0.5 cm below dust and is moved away from the surface throughout the trial in discrete, 5 mm intervals.
- Future trials will move the magnet in smaller intervals to increase resolution.
- The magnet is ~ 1.5 kG in strength and the dipole moment is oriented perpendicular to the dusty surface.

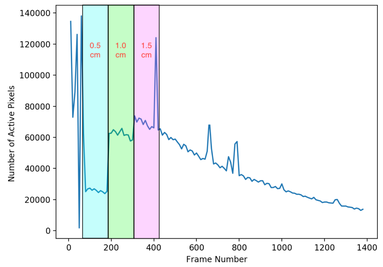


- Data is taken using a video camera, which records the surface of the dust in a time-lapse at 1 fps.
- By subtracting frames, we can see where changes to the surface are located and quantify the activity as a function of time and location on the surface.



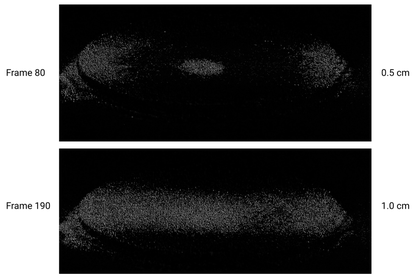
RESULTS

OVERALL ACTIVITY

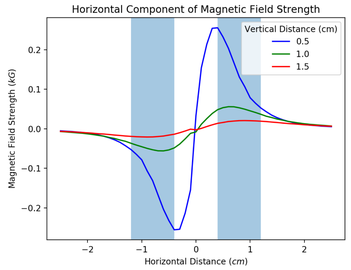


- The activity increases when the magnet moves farther from the dust, indicating that magnetic fields inhibit lofting.
- The effect of the magnetic field diminishes when the magnet is >1.5 cm from the surface.
- The activity decreases as time elapses, as expected from the removal of microcavities and less packed upper layers of dust (Hood et al., 2018).
- Spikes are from random camera shakes and will be smoothed out by conducting more trials.

LOCALIZED ACTIVITY



- While magnetic fields decrease activity, the amount is largely dependent on the orientation of the local magnetic field.
- When the magnet is close to the surface, activity is most reduced where the magnetic field is parallel to the surface.
- In the cusp region where the magnetic field is normal to the surface, activity remains unaffected.



DISCUSSION

We show that the presence of magnetic fields drastically changes both the local and global behavior of electrostatic dust lofting.

- Dust activity is well controlled by magnetic fields.
- Global activity is reduced proportional to the strength of the magnetic field.
- Local activity diminishes in different amounts depending on the orientation of the magnetic field.

FUTURE

Problems to be solved:

- The charge-to-mass ratio of a dust particle is too small to be affected by the Lorentz force. It is speculated that magnetic fields must control the dust charging process and subsequent lofting and mobilization.
- Simulation work is being done in conjunction with the experiments of this poster.

- Before and after photos of dust due to exposure from UV radiation with two oppositely polarized magnets imbedded beneath the surface showing "swirling."

While future laboratory studies will explore these issues, in situ measurements are ultimately needed to better understand dust lofting on airless planetary bodies, including lunar swirl regions.

REFERENCES

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- Schwan, J., X. Wang, H.-W. Hsu, E. Grün, and M. Horányi (2017), GRL, 44, 3059–3065.
- Hood, N., Carroll, A., Mike, R., Wang, X., Schwan, J., Hsu, H.-W., & Horányi, M. (2018). GRL, 45, 13,206–13,212.