Lunar Soils on Swirls: Their Photometric Properties and Possible Migration in a Non-uniform Magnetic Field

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Introduction

Lunar swirls, known as magnetic and albedo anomalies [1], are unique geologic features on the surface of the Moon, for whose formation four primary hypotheses have been proposed: cometary impact [2], solar wind shielding [3], electrostatic dust lofting and redistribution [4], and magnetic sorting [5]. The three hypotheses other than solar wind shielding could result in dust migration and/or regolith structure alteration, which involve photometric studies of lunar soils on swirls [6].

We will study the photometric properties of three geologic units in the Reiner Gamma swirl region (Fig. 1), i.e., bright ribbons (BR1-BR3), dark lanes (DL1-DL2), and surrounding maria (MR1-MR2), using Lunar Reconnaissance Orbiter Camera (LROC) Wide Angle Camera (WAC) observations. Then we will propose a refreshing mechanism for lunar soils on swirls to interpret their albedo patterns, and discuss possible processes involved in dust migration in a non-uniform magnetic field.

Reiner Gamma Swirl

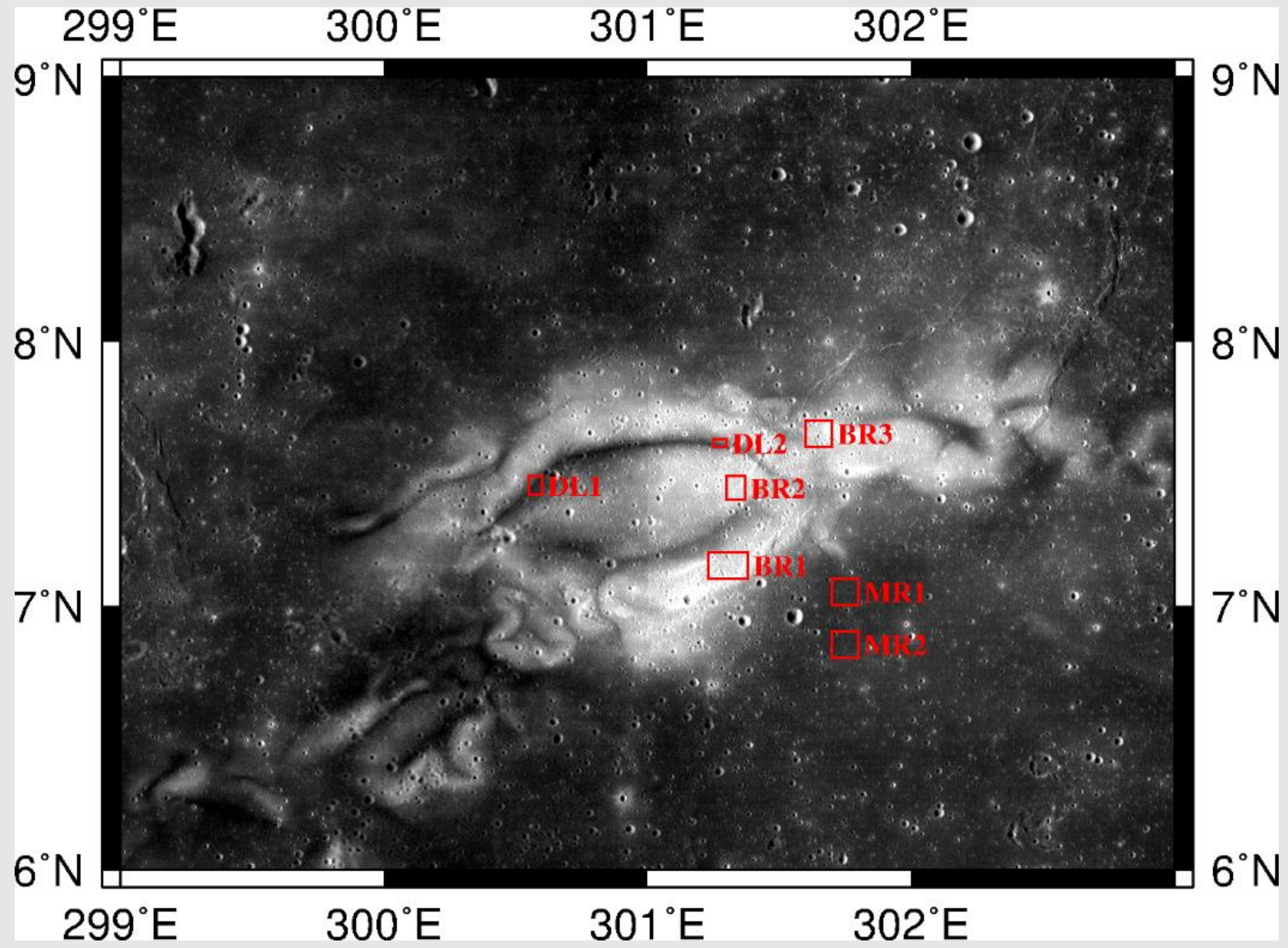

Fig. 1. LROC WAC 643 nm image for Reiner Gamma region and study areas: bright ribbons (BR1-3), dark lanes (DL1-2), and nearby maria (MR1-2).

Conclusions

- Photometric modeling showed that dust migration might occur from bright ribbons to dark lanes.
- Kinetic simulation and magnetic separation experiment for lunar soils indicated that dust migration can be driven by locally high-gradient magnetic field.
- These dust transported is fine, elongated, and mature portion of lunar soils. Therefore, it can provide a refreshing mechanism for swirl formation, no matter soil maturation was caused by solar wind or micrometeorite.

Discussion

The local inhomogeneity at small scales, providing driving force for dust migration, is produced by solar wind's interaction with lunar magnetic anomalies and might be caused by perturbations/fluctuations/instabilities in a plasma system.

Data

LROC WAC

- Feb. 2010 ~ Oct. 2011
- 643 nm, orbit@50 km, phase angle as low as 6°

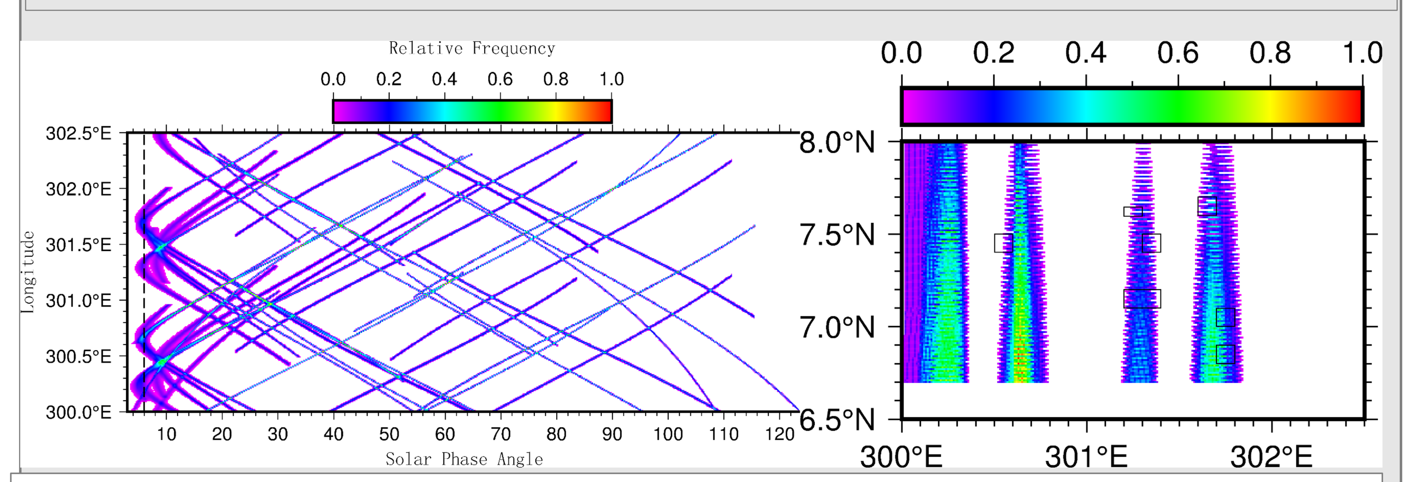

Fig. 2. LROC WAC data covering Reiner Gamma region.

M³ Spectra

- Bright ribbons vs. Dark lanes and Maria, distinct
- Dark lanes vs. Maria, similar
- Hydration feature @DL1

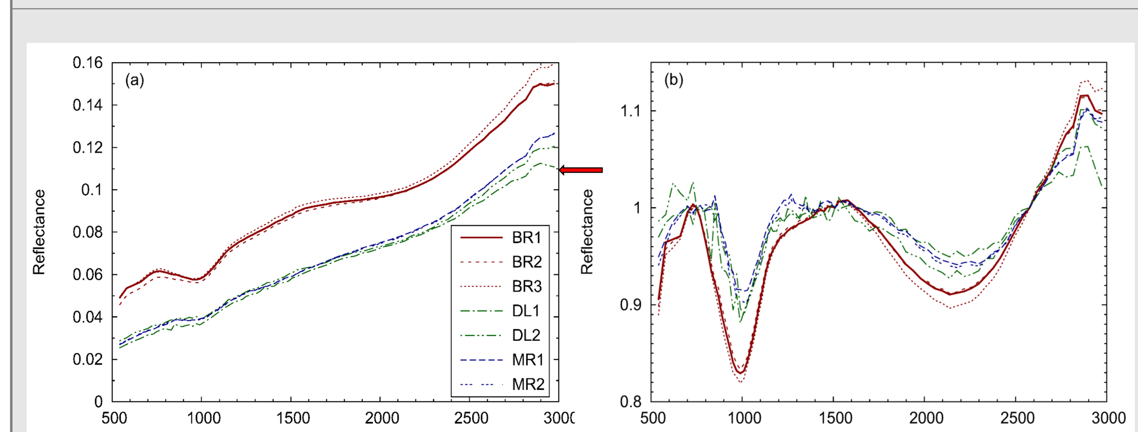

Fig. 3. M³ spectra (a) Original (b) Continuum-removed.

Modeling

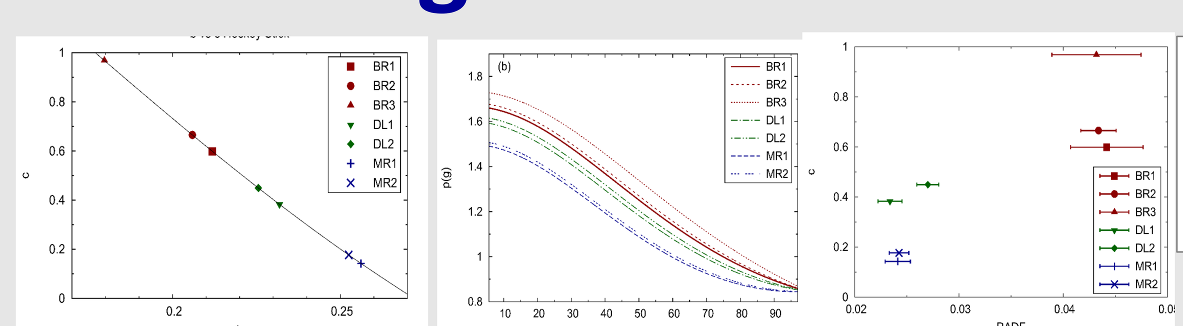

Fig. 4. Henyey-Greenstein function: parameter values and phase curves.

- Photometric modeling using Hapke's function [7] without roughness.
- Bright ribbons vs. Dark lanes and Maria, distinct, photometric anomaly correlated with strong horizontal magnetic field [8].
- Dark lanes vs. Maria, spectrally similar [9] (Fig. 3) , different phase function parameter values (Fig. 4).

Dust Migration

- Force on dust (magnetic moment $\boldsymbol{m}$) in $\boldsymbol{B}$: $\boldsymbol{F}$ = gradient($\boldsymbol{m}\cdot\boldsymbol{B}$) [10].
- Surface-darkening processes are possibly driven by magnetic field gradient [11]; Fine soil grains can be attracted and trapped by locally high-gradient magnetic field (e.g., magnetized steel wool) [12].
- Domain state with decreasing size: multi-, single-, superparamagnetic
- Elongated grains are strongly magnetic due to shape anisotropy.
- Elongated, fine (more mature, [13]) dust can be levitated [4], and possibly be transported due to local inhomogeneity in a non-uniform field.

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Acknowledgments

This research was funded by the National Natural Science Foundation of China (U1231103, 41473065, 41373068), Natural Science Foundation of Shandong Province (JQ201511 and ZR2015DQ001), and Young Scholars Program of Shandong University, Weihai (2015WHWLJH14).