SPACE WEATHERING TRENDS ON THE MOON BASED ON STATISTICAL ANALYSIS OF SPECTRAL PARAMETERS.

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Introduction: Space weathering refers to the effect by which spectral and compositional properties of airless planetary bodies, exposed to interplanetary environment, continuously change. These changes include: albedo reduction, diminution of mineral absorption bands, and slope reddening (increase of spectral reflectance with higher wavelengths). Individual components causing space weathering are solar wind, galaxy radiation, and impacts of small bodies, so-called microimpacts [1]. Currently, the way these three effects influence the final state of a weathered surface remains unknown. By studying spectra of areas with different contribution of these effects, we may be able to distinguish between the different mechanisms. Our work aims on the Moon, where we can find specific areas called lunar swirls.

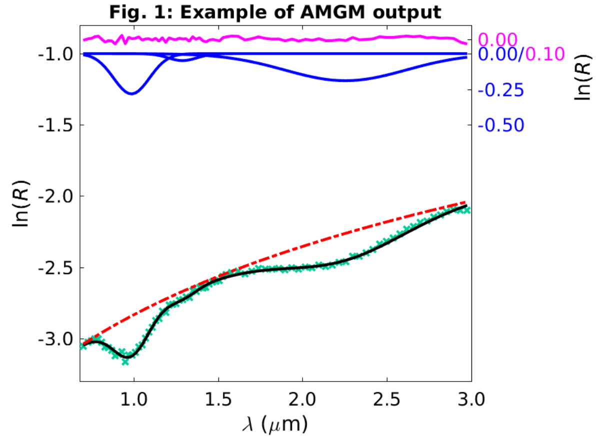
Lunar swirls are bright areas, where a locally higher magnetic field deflects the charged particles of solar wind; leaving microimpacts and galactic radiation to dominate. Most of known swirls are antipodal to big impact basins (for example Mare Ingenii swirl). There is an exception in Reiner Gamma swirl in Oceanus Procellarum [2].

Another area on the lunar surface is, for example, an immature crater and its ejecta with excavated fresh material. This material lacks the long-term exposure to the space weathering, hence, appears relatively fresh (immature). The rest of the lunar surface is, for long periods, influenced by contribution of all the space weathering effects, and therefore, is mature. We want to distinguish how the different effects change the spectra, by comparing spectral parameters of above-mentioned sites on the Moon.

Methodology: *Data.* For our research, we are using spectra taken by Chandrayaan-1 probe, specially its Moon Mineralogy Mapper (M^3) instrument. The data are freely obtainable through the Geoscience Node of NASA's Planetary Data System. Individual spectra contain 83 reflectance (R) samples for wavelengths λ ranging from 540 to 2976 nm.

Spectral manipulation. We treat the spectra with modification of already published code: Modified Gaussian Model (MGM) by J. M. Sunshine et al. [3]. Our adjustment of the code incorporates preprocessing routine that precomputes input parameters. Our routine fits absorption bands by quadratic functions, continuum is determined by fit of several chosen areas of the spectrum, and the routine also estimates number of bands intended for fitting. This modification allows us to use MGM (the Adjusted MGM – AMGM) on whole sets of spectra, not just on one at a time. Spectra must be similar, though, which is not an issue as we process mainly spectra from one area with the same geological settings during one run of the code. For an example of AMGM output, see Fig. 1 (green: M^3 data, red: continuum, blue: fitted bands, pink: root mean square, and black: final fit).

Fig. 1: Example of AMGM output



Additional processing methods. From AMGM, we obtain a set of spectral parameters (band widths, strengths, and positions, offset, slope, and curvature of a continuum) for every chosen spectrum within an area of interest. Typically, the studied area (e.g. fresh crater) contains information derived from tens to hundreds distinct spectral curves.

Statistical sample obtained by this procedure is then evaluated with use of histograms and cumulative distribution functions (CDF) of spectral parameter in question. CDF is defined as function describing the probability that random variable will take a value less than or equal to a given number. To determine, whether the distributions of the spectral parameter from two areas are similar or not, we use the Kolmogorov-Smirnov test and Q-Q (quantile-quantile) plot. Kolmogorov-Smirnov test quantifies the distance between two empirical distribution functions and, in our case, on 5% confidence level, rejects the hypothesis that the sample data we have are from the same distribution. Q-Q plot plots quantiles of the two empirical distributions against each other. Compared to linear trend, we reject the hypothesis that the distributions, the data belong to, are the same or at least similar.

Outcomes: From data we have at the moment, Reiner Gamma (RG) swirl behaves differently from Mare Ingenii (MI) swirl. This may correlate with different origin of RG (being non-antipodal to any large impact basin). For example, based on the 1 and 2 µm band's strength (*S*) histograms for different terrains (mature in-swirl, mature off-swirl, fresh in-swirl, and fresh off-swirl region), RG's mature swirl material seems to shows intermediate behavior between fresh and mature off-swirl zones (see Fig. 2); whereas MI's mature swirl material is rather similar to mature off-swirl zones.

Based on our recent data, no matter whether we evaluate fresh-crater spectra inside swirl (fresh-in) or out of it (fresh-out), our empirical distributions of sampled Full Width at Half Maximum (FWHM) of 2 µm band are the same, based on Kolmogorov-Smirnov test (see Fig. 3, where green squares denote that the distributions are on 5% confidence level the same, and blue that the distributions are different; "mature-in" stands for in-swirl mature region, "mature-out" off-swirl mature region).

Acknowledgements: We would like to thank Dr. Georgiana Kramer for her help with understanding M^3 data and discussions on lunar spectra.

References: [1] Pieters, C. M. and Noble S. K. (2016) *JGR Planets*, *121*, 1865–1884. [2] Kramer G. Y. et al. (2011) *JGR*, *116*, E00G18. [3] Sunshine J. M. et al. (1999) *LPSC*, *30*, 1306.

Fig. 2: Strength *S* of 2 µm band (RG)

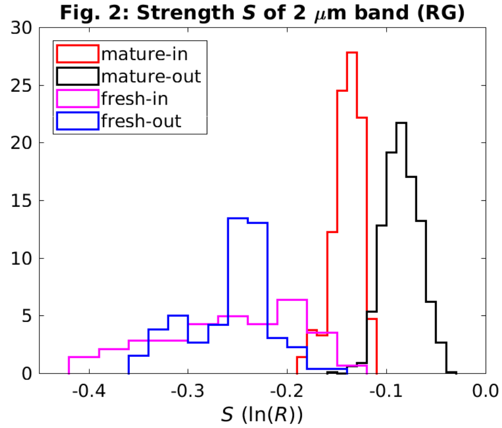


Fig. 3: Similarity of CDFs (FWHM at 2 µm)