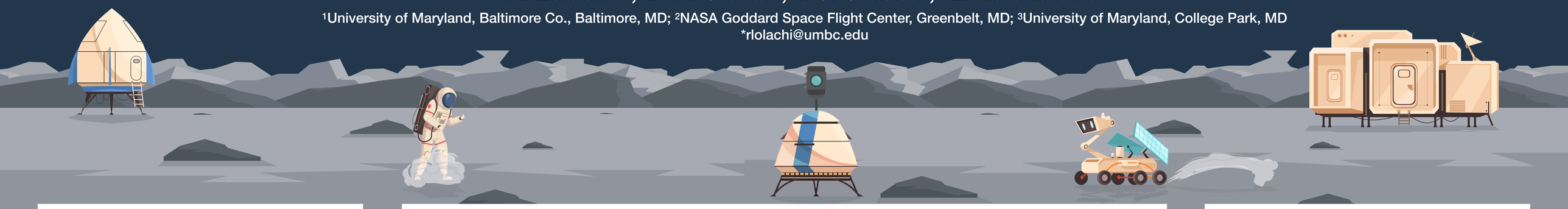
Optical monitoring of the dust environment at lunar surface exploration sites

NESF2020-013

R. Lolachi[1]*, D. A. Glenar[1], T. J. Stubbs[2], L. Kolokolova[3]

[1]University of Maryland, Baltimore Co., Baltimore, MD; [2]NASA Goddard Space Flight Center, Greenbelt, MD; [3]University of Maryland, College Park, MD

*rlolachi@umbc.edu



I Motivation

Dust can be a nuisance and hazard for lunar exploration[1]. The dust environment can be monitored by measuring how it scatters sunlight. This approach has the advantages over in situ dust detectors of being sensitive to very small dust grains and providing full-site monitoring with a single instrument.

II Grain Scattering Properties

- Scattering property interpolation grids of lunar "Irregular" grains were computed using the Discrete Dipole (DDA) method[2].

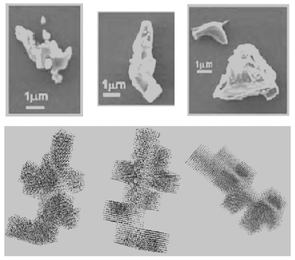


Fig. 1 | Irregular dust grains and corresponding DDA shape models[2].

- Larger grains are computed using the Hapke equivalent-slab method with diffraction by random gaussian spheres.
- Grain refractive indices are "Average Moon" values of Shkuratov et al.[3]
- Excellent grid validation against lab measurements of JSC-1a lunar simulant[4].

III Dust Radiance Simulations

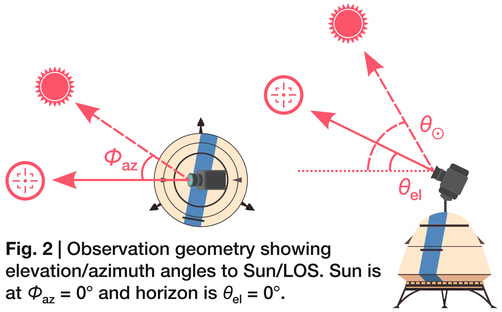


Fig. 2 | Observation geometry showing elevation/azimuth angles to Sun/LOS. Sun is at Φ_{az} = 0° and horizon is θ_{el} = 0°.

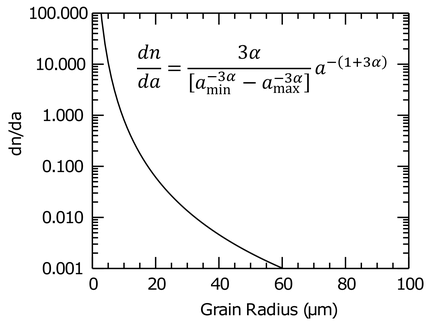


Fig. 4 | Differential dust size (radius, a) distribution[5]. See table for equation coefficients.

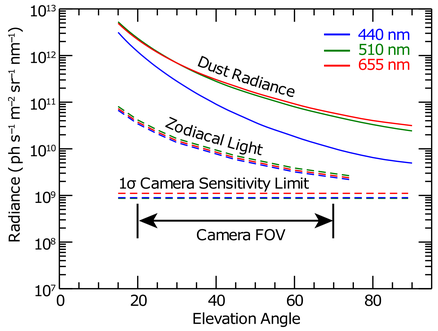


Fig. 6 | RGB Dust radiance strip at Φ_{az} = 0° compared with Zodiacal Light[6] and sensitivity limits for Hamamatsu S10747-0909 back illuminated CCD arrays, 512 x 512, 24 mm px, f/1 optics, t = 1 s, FOV = 53°.

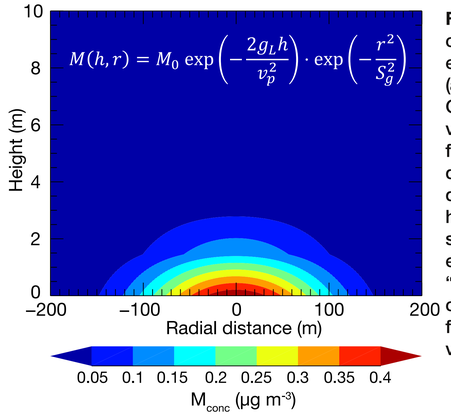


Fig. 3 | Dust mass concentration across exploration site (assumes a Gaussian for the velocity distribution function of ejected dust). Note difference in horizontal/vertical scaling giving exaggerated "corners" in contours. See table for equation variables.

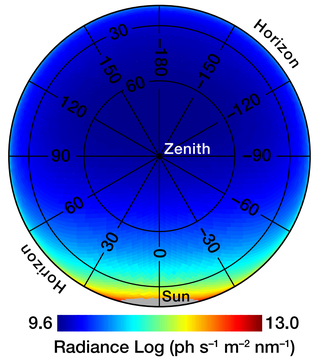


Fig. 5 | Monochromatic all-sky radiance map at 440 nm (blue) as seen by detector, computed for dust seen in Fig. 3. Area within 15° of Sun greyed out due to being too bright.

Parameter	Description	Value
$\theta_{\odot}$	Solar elevation angle (°)	4
h	Height coordinate above surface (m)	Variable
r	Radial surface distance from observation point (m)	Variable
α	Power law exponent for size distribution	0.91
ρ	Grain density (kg m^{-3})	2500
a_{min}	Min. grain radius (μm)	0.1
a_{max}	Max. grain radius (μm)	1000
h_{det}	Height of detector above surface (m)	1
M_0	Max. surface mass concentration (μg m^{-3})	1
S_g	Horizontal scale length (m)	100
g_L	Lunar surface gravity (m s^{-2})	1.62
v_p	Most probable grain velocity (m s^{-1})	2
F_{M0}	Peak mass deposition flux (g m^{-2} hr^{-1})	$2 \cdot 10^{-3}$
F_{dep}	Site mass deposition rate (g hr^{-1})	65

Tbl. 1 | Coefficients used for model and resulting dust mass deposition flux.

IV Remarks

- Site dust characterization achievable using an automated (simple) swivel off-the-shelf camera (e.g. Hamamatsu).
- Dust abundance and effective grain size are readily measurable.
- Periodic response calibration can be accomplished using constant (and bright) zodiacal light.
- Future work (in progress) will include larger grain size DDA models, polarization effects and geometric optics.

Literature cited

[1] Wagner, S. 2012, The Apollo experience lessons learned for Constellation lunar dust management (PDF). TP-2006-213726. Johnson Space Center, Houston.
[2] Richard, D. et al. 2011. Light scattering by complex particles in the Moon's exosphere, Planetary and Space Science, 59, 1804–1814.
[3] Shkuratov, Y. et al. 1999. A Model of Spectral Albedo of Particulate Surfaces: Implications for Optical Properties of the Moon, Icarus, Volume 137, Issue 2, 235–246.
[4] Escobar-Cerezo et al. 2018. An Experimental Scattering Matrix for Lunar Regolith Simulant JSC-1A at Visible Wavelengths, The Astrophysical Journal Supplement Series, Volume 235, Issue 1, article id. 19, 9.
[5] Horányi, M. et al. 2015. A permanent, asymmetric dust cloud around the Moon. Nature 522, 324–326
[6] Leinert, C et al. 1998. The 1997 reference of diffuse night sky brightness, Astron. AstroPhys. Suppl., 127, 1–99.

Acknowledgments

This work has been funded by funded by the NASA/GSFC Internal Scientist Funding Model (ISFM) Exospheres, Ionospheres, Magnetospheres Modeling (EIMM) team and NASA's Lunar Reconnaissance Orbiter (LRO) mission. Vector art was created by using adapted graphics from Vecteezy.com.

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