RADAR SCATTERING PROPERTIES OF YOUNG LUNAR CRATER EJECTA BLANKETS USING MINI-RF.

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Introduction: The Miniature Radio Frequency (Mini-RF) instrument flown on NASA's Lunar Reconnaissance Orbiter (LRO) is a Synthetic Aperture Radar (SAR) with a hybrid dual-polarimetric architecture. I.e., the instrument transmits a circularly polarized signal and receives orthogonal horizontal and vertical linear polarizations (and their relative phase) [1]. The information returned by the radar can be represented using the classical Stokes parameters [S_1, S_2, S_2, S_4] [2], which can also be used to derive a variety of other products that are useful for characterizing radar scattering properties of the lunar surface.

To investigate the scattering properties of lunar crater ejecta blankets, we use two products derived from the Stokes parameters: the circular polarization ratio (CPR) and the m-χ decomposition of S_1. Radar returns from the young craters provide insight into the scattering properties of ejecta blankets, differentiation between ejecta properties in different lunar terrains, and possible identification of styles of ejecta deposition and mixing. Examining these properties for young craters across the surface of the Moon, in both mare and highlands terrain, provides a new perspective on the ejecta emplacement process and surface evolution due to impacts. Further, comparing Mini-RF returns with other data sets (e.g., optical, FUV, VNIR) allows deeper insights into the surface (and near subsurface) evolution of the Moon, and improve our understanding of the primary weathering process on the moon and how ejecta emplacement processes modify the surface.

Observations of Scattering Properties: Average profiles of the Stokes parameters (e.g., S1 and S4), CPR, and the m-χ decomposition of S1 were calculated as a function of radius for each crater. Though some commonalities in the scattering profiles are seen for all observed craters, differences are noted with crater diameter and between craters in different terrains. CPR signatures differ between mare and highlands regions, and have (with few exceptions) logical progressions with crater size. For example, larger craters tend to have higher CPR near the crater rim than smaller craters within similar terrains. For the majority of highlands craters (and for select mare craters), the CPR profile is characterized by a "bench" of high CPR before evolving to lunar background values, likely representing areas of ejecta mixing with lunar regolith. Though seen around mare craters, this same profile shape is not seen universally for craters in the mare.

The m-χ story is less straightforward. Craters in both major terrain types, and across diameter ranges, fall into each of three categories [3]. Possible variables that could affect the scattering characteristics include: crater age, degradation state, terrain type, local variations within terrains (e.g., layering), or crater diameter.

New views of subsurface layering: New observations suggest that measures of lunar crater ejecta CPR can isolate the surface expression of discrete subsurface layering within mare terrain [4]. Average CPR profiles outward from the crater rim were analyzed for twenty-two young mare craters and observations across a range of crater sizes and relative ages exhibit significant diversity within mare regions. Comparing these CPR profiles with LROC imagery shows that the magnitude of the CPR may be an indication of crater degradation state, which may manifest differently at radar compared to optical wavelengths. Comparisons of radar and optical data also suggest relationships between subsurface stratigraphy and structure in the mare and the amount of blocky material found within the ejecta blanket [4]. Initial examination of NAC images for all craters with a "shelf" in the CPR profile showed outcrops of distinct layers in the crater walls. When the CPR plateaus at the crater rim and extends outward a short distance layers were noted at the top of the crater rim in a capping layer. These high CPR plateaus may be due to the capping layer fragmenting differently than material beneath it, or to the presence of impact melt at the crater rim [e.g., 5]. If, instead, the shelf was farther away from the rim in the CPR profile, these layered outcrops were documented farther down the crater walls. If no shelf is seen in the CPR no layering is visible in the crater walls. These observations suggest that surface CPR measurements may be used to identify near-surface layering, providing a new way to examine the near subsurface of the mare.

Conclusions: Radar observations provide a powerful way to examine crater ejecta processes across the lunar surface. These observations become increasingly powerful when paired with other data sets, providing a new perspective on surface evolution processes (e.g., ejecta emplacement and degradation).

References: : [1] Raney, R. K. et al. (2011), *Proc. of the IEEE*, 99, 808-823; [2] Stokes (1852), Trans. of the Cambridge Phil. Soc. 9, 399; [3] Patterson, G.W. *et al.* (2014) *LPSC,* Abstract No. 2720; [4] Stickle, A.M. et al. (2016) *Icarus, LRO Special Issue*, in press; [5] Neish et al. (2014), *Icarus 239*, 10-117.