Investigation of Physical properties of Lunar Crater Facies using Radar Imagery

T. Samaddar[1] and J. Mehar[1], [1]Indian Institute of Remote Sensing, Dehradun, India (tamalsamaddar@gmail.com)

Introduction: Lunar radar remote sensing provides a concise understanding of the physical properties of the lunar regolith. The Miniature Radio Frequency (Mini-RF) onboard the Lunar Reconnaissance Orbiter (LRO) provides an excellent opportunity for such studies due to the high quality of radar data available with a near global coverage. Here we have utilized Mini-RF radar images for detailed investigation of the impact craters Thales and Giordano Bruno to identify and characterize specific crater facies units such as rough boulder units, impact melts and melt flows. These features aren't completely visible in optical images unless different high-resolution datasets are used. We present observed signatures of certain morphological units of impact craters for a better and swift characterization using the physical properties of the lunar surface.

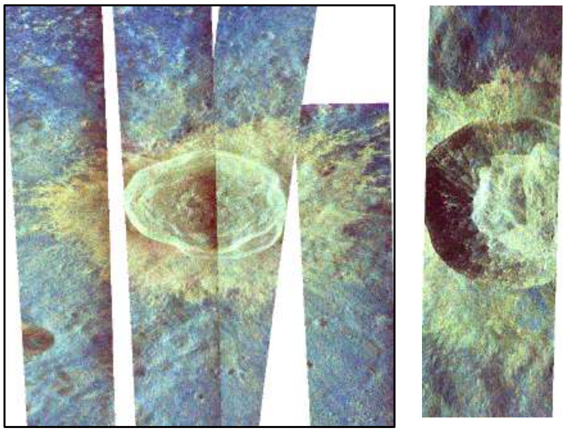

Figure 1 - Thales crater m-chi image (left), part of giordano bruno crater m-chi image used (right)

Data: We have used Map projected calibrated dataset (MAPCDR) product in the case of the Mini-RF data specifically the derived products of the classical stokes parameters (S1,S2,S3,S4) [1]. The stokes parameters have been utilized to derive its child parameters which have been utilized for analysis. LROC Wide Angle Camera (WAC) imagery has been used as the basemap and the LROC Narrow angle camera (NAC) [2] for detailed study and correlation with the observed radar signatures.

Methodology: Stokes child parameters have been utilized for characterizing the physical properties. The degree of polarization, m, and the Poincare ellipticity, χ, have been utilized to derive the m- χ decomposition technique [3]. Here the physical properties of the scattering mechanisms are observed by differentiating between double bounce (even), volumetric (diffuse) and single bounce (odd) scattering by assigning them Red, Green and Blue color codes. The equations utilized for this method are-

$$m = (S_2 2 + S_3 2 + S_4 2)^{1/2} / S_1$$

$$\mathrm{Sin}2\chi = -S_4 / (m * S_1)$$

$$Red = (m * S_1 * (1 + sin2\chi)/2)^{1/2}$$

$$Green = (S_1 * (1 - m))^{1/2}$$

$$Blue = (m * S_1 * (1 - sin2\chi)/2)^{1/2}$$

Results and Discussion: Both the selected craters have prior reported presence of intriguing features that make them good cases for our study of mapping specific units using radar data. In the case of the highly rough and large scale boulders and blocks present on the lunar surface, high amount of even bounce and odd bounce scattering take place due to the rocks acting as a mixture of corner reflectors and smooth reflectors in case of large blocks [4]. The impact melts and flows although having a smooth appearance in optical imagery, however, are highly rough particles in similarity with the rough proximal ejecta blanket just beyond the crater rim [5]. Impact melts and such units thus show high volumetric scattering due to numerous rock particles and fragments present in the lunar regolith. Both of these characteristic signatures have been observed and utilized here to identify rough boulder units, melt pools, rough proximal ejecta blanket (degraded Thales crater), melt flow boulders using radar data. The features identified with the radar data show very good correlation upon detailed inspection with the 0.5 m/px NAC imagery.

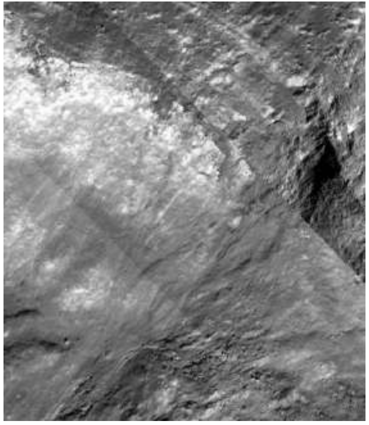

Figure 2 - northern wall of thales crater showing boulders and melt flow

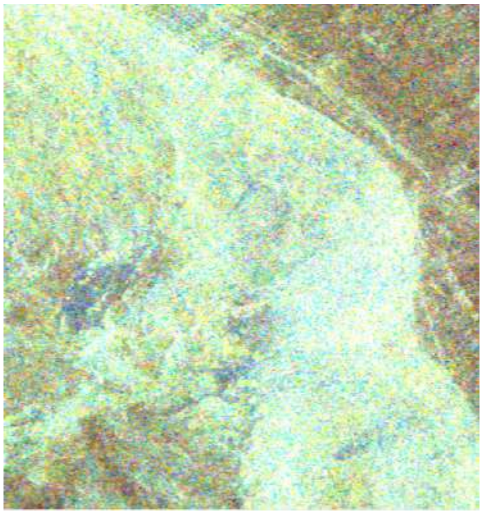

Figure 3 - Same part of thales crater in m-chi showing the boulders as bluish shade along with the melt flow

m-χ decomposition shows really characteristic scattering information about the lunar regolith and is very useful in differentiating between features at reasonable resolutions. It is very useful for characterizing degraded craters in the lunar farside for effective ejecta mapping and facies studies. The signatures observed helped in the physical study of the craters reaffirming the importance of radar data for crater studies as a critical and complementary dataset.

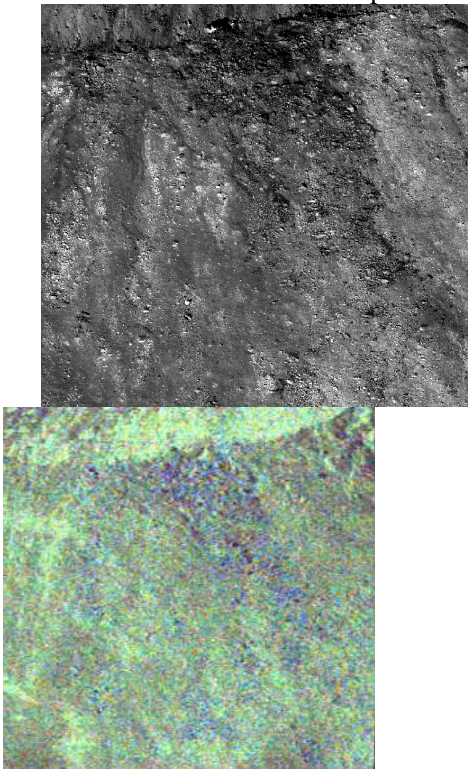

Figure 4 - Southern wall of bruno crater showing characteristic purple backscatter for rough boulder units in the m-chi image. (top) NAC imagery of same area

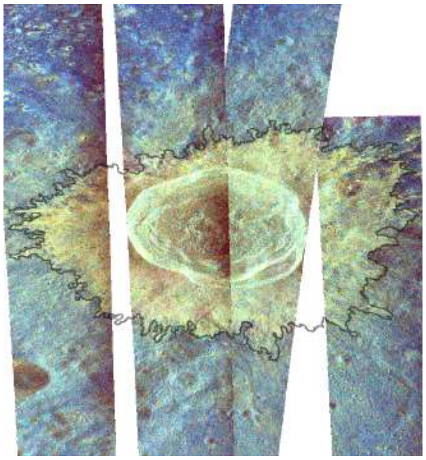

Figure 5 - Proximal ejecta blanket mapping for degraded thales crater.

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References: [1] G. G. Stokes, "The Illumination and polarization of the sunlight sky on Rayleigh scattering," *Trans. Cambridge. Phil. Soc*, vol. 9, p. 399, 1852.[2] M. S. Robinson *et al.*, "Lunar reconnaissance orbiter camera (LROC) instrument overview," *Space Sci. Rev.*, vol. 150, no. 1–4, pp. 81–124, Jan. 2010, doi: 10.1007/S11214-010-9634-2/METRICS.[3] R. K. Raney *et al.*, "The m-chi decomposition of hybrid dual-polarimetric radar data with application to lunar craters," *J. Geophys. Res. Planets*, vol. 117, no. E12, pp. 0–21, Dec. 2012, doi: 10.1029/2011JE003986.[4] R. K. Raney *et al.*, "The lunar mini-RF radars: Hybrid polarimetric architecture and initial results," *Proc. IEEE*, vol. 99, no. 5, pp. 808–823, 2011, doi: 10.1109/JPROC.2010.2084970[5] L. M. Carter *et al.*, "Initial observations of lunar impact melts and ejecta flows with the Mini-RF radar," *J. Geophys. Res. Planets*, vol. 117, no. E12, pp. 0–09, Dec. 2012, doi: 10.1029/2011JE003911.