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Observations of the Radar Scattering (Phase) Function of Copernican Crater Ejecta on The Moon Using Mini-RF

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Abstract

The Mini-RF radar is current operating in a bistatic configuration and examining a variety of lunar terrains as a function of bistatic angle. Here, we examine the ejecta blankets of Copernican aged craters on the lunar surface in both S- and X-band to examine the scattering properties of young crater ejecta. Several observed craters exhibit a clear opposition effect at low bistatic (phase) angles, which is consistent with optical studies of lunar soils done in the laboratory. These observations are the first time this effect has been measured on the Moon at radar wavelengths. Differences in the CPR behaviour as a function of bistatic angle may also provide opportunities for relative age dating between Copernican craters.

1. Introduction

The Mini-RF instrument onboard NASA's Lunar Reconnaissance Orbiter (LRO) is currently acquiring bistatic radar data of the lunar surface at both S-band (12.6 cm) and X-band (4.2 cm) wavelengths in an effort to understand the scattering properties of lunar terrains as a function of bistatic angle. Previous work, at optical wavelengths, demonstrated that the material properties of lunar regolith can be sensitive to variations in observation phase (bistatic) angle [1-3]. This sensitivity gives rise to the lunar opposition effect and likely involves contributions from shadow hiding at low phase angles and coherent backscatter near zero phase [1]. Mini-RF bistatic data of lunar materials indicate that such behaviour can also be observed for lunar materials at the wavelength scale of an X- and S-band radar. Here, the Circular Polarization Ratios (CPRs) of the ejecta from 10 lunar craters are characterized as a function of phase (bistatic) angle. Work to characterize other radar products (e.g., total backscattered power, polarization products) is ongoing. Observing the scattering behaviour of continuous ejecta blankets at multiple radar wavelengths can provide information regarding the size/frequency of scatterers emplaced as ejecta, as well as unique insight into the rate of regolith breakdown on the Moon.

1.2 Bistatic Operations

Radar observations of planetary surfaces provide important information on the structure (i.e., roughness) and dielectric properties of surface and buried materials [4-7]. These data can be acquired using a monostatic architecture, where a single antenna serves as the signal transmitter and receiver, or they can be acquired using a bistatic architecture, where a signal is transmitted from one location and received at another. The bistatic (phase) angle is a function of the angle between the incident radiation to the surface and the backscattered radiation. In bistatic configuration, Mini-RF acts as the receiver for the backscattered energy from the lunar surface; the transmitters are the Arecibo Observatory (AO) at S-band and the DSS-13 Antenna at Goldstone in X-band. This architecture maintains the hybrid dual-polarimetric nature of the Mini-RF instrument [8] and, therefore, allows for the calculation of the Stokes parameters (S_1, S_2, S_3, S_4) that characterize the backscattered signal (and the products derived from those parameters).

2. Observations

A useful product derived from the Stokes parameters is the Circular Polarization Ratio (CPR),

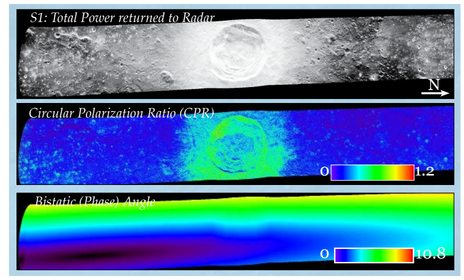
$$\mu_C = \frac{(S_1 - S_4)}{(S_1 + S_4)} \qquad (1)$$

CPR information is commonly used in analyses of planetary radar data [4-7], and is a representation of surface roughness at the wavelength scale of the radar (i.e., surfaces that are smoother at the wavelength scale will have lower CPR values and surfaces that are rougher will have higher CPR values). High CPR values can also serve as an indicator of the presence of water ice [9].

As part of the Mini-RF bistatic observation campaign, CPR information for a variety lunar terrains is being collected over a range of bistatic angles. Patterson *et al*. [10] analyzed the ejecta properties as a function of bistatic angle for three young craters: Byrgius A, Kepler, and Bouguer. Both Kepler and Bygius A exhibited an opposition effect, while Bouguer did not. Patterson *et al.* [10] suggest that the radar scattering characteristics of the continuous ejecta for these three craters, coupled with age estimates based on crater statistics and geologic mapping, imply a relationship between the opposition response of the ejecta and the age of the crater (i.e., Byrgius A is the youngest of the craters observed and shows the strongest response). Thus, recording the CPR response as a function of bistatic angle may be a way to determine relative age between deposits.

Here, we examine the ejecta of 10 Copernican- and Eratosthenian aged craters that range from 4 to 69 km in diameter [13] and document CPR characteristics as a function bistatic angle in order to test that hypothesis. The spatial resolution of the data varied from one observation to another as a function of the viewing geometry, but averaged ~100 m, providing 25 effective looks.

Four of the examined craters (Byrgius A, Aristarchus, La Condamine S, and Kepler exhibit CPR characteristics suggestive of an opposition effect in S-band: higher CPR at lower bistatic (phase) angle. X-band observations of Anaxagoras and Kepler also suggest an opposition surge at low bistatic angle, though relatively constant CPR in S-band at higher bistatic angles. The increase in CPR occurs near 2–4 degrees bistatic angle. These craters occur in both highlands and mare regions, and are all characterized as young. Three other examined craters (Bouguer, Harpalus, Anaxagoras) exhibit CPR that remains relatively constant across bistatic angle. This may be for a couple reasons: 1) The craters are older (though most are still Copernican), and so the opposition effect will be less pronounced; or 2) insufficient data have been acquired to characterize the opposition behavior of the crater ejecta. An opposition effect may be present but not yet observed. Schomberger A, La Condamine S, and Kepler exhibit scattering properties as a function of bistatic angles that differ from the other observed crates, with areas of relatively constant CPR at various CPR values (e.g., **Figure 1**). The oldest crater observed (Hercules, which is classified as Eratosthenian) shows no indication of an opposition response across phase angle space. Continuing observations are targeting these regions to increase the bistatic angle coverage. Additional study is ongoing to fully characterize the CPR response with viewing geometry for these young craters.



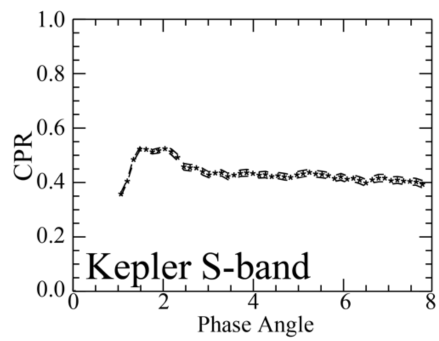


Figure 1. Observations of Kepler Crater using Mini-RF. (top) Total power returned to the radar, CPR of the crater and surrounding terrain, and bistatic (phase) angle of the observation. (bottom) CPR as a function of phase for Kepler crater in S-band.

References

[1] Hapke et al. (1998), *Icarus*, 133, 89-97; [2] Nelson et al. (2000), *Icarus*, 147, 545-558; [3] Piatek et al. (2004), *Icarus*, 171, 531-545. [4] Campbell et al. (2010), *Icarus*, 208, 565-573; [5] Raney et al. (2012), *JGR,* 117, E00H21; [6] Carter et al. (2012), *JGR,* 117, E00H09; [7] Campbell (2012), *JGR*, 117, E06008; [8] Raney, R. K. et al. (2011), *Proc. of the IEEE*, 99, 808-823; [9] Black et al. (2001), *Icarus*, 151, 167-180; [10] Patterson, et al. (2017), *Icarus*, 283, 2-19; [11] Morota et al. (2009) *Met. Planet. Sci.* 44(8), 1115-1120; [12] Koenig et al. (1977) *Proc. LPSC*, 8, p. 555; [13] Baldwin (1985) *Icarus* 61, 63-91; [14] Ulrich (1969) USGS Map I-604(LAC-11);[13] Stickle et al. (2018) *LPSC* Abstract #2007.