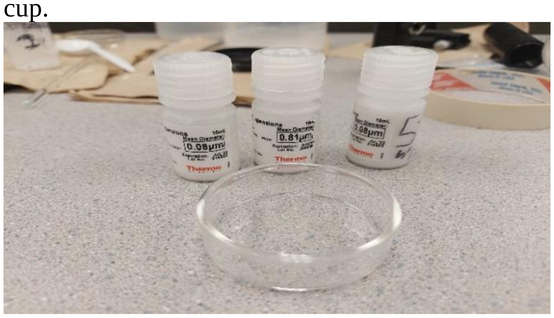
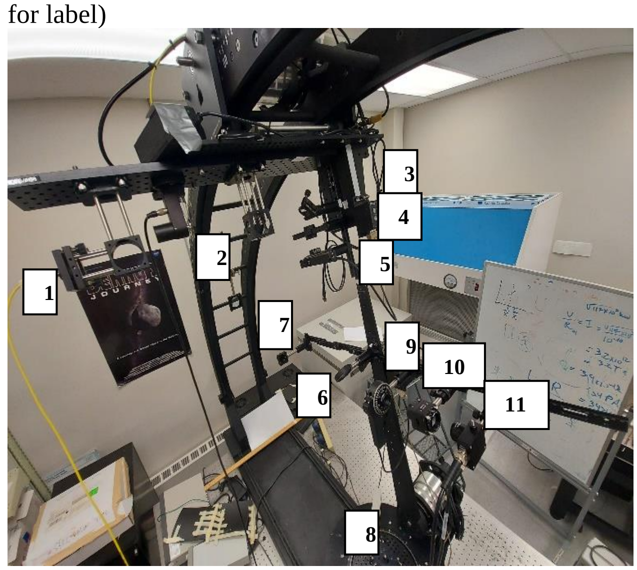
OPTICAL POLARIZATION STUDIES OF SUSPENDED BEADS IN AQUEOUS SOLUTION: AN ANALOG FOR RADAR SCATTERING IN ICY REGOLITHS. Antoine V. Bourget[1], Michael Daly[1], and David T. Blewett[2], [1]Dept. of Physics, 4700 Keele St, Toronto, ON M3J 1P, [2]Planetary Exploration Group, Johns Hopkins University Applied Physics Laboratory, Laurel, Md., USA. (antoine1@yorku.ca)

Background: The presence of ice mixed within the polar regolith of planetary bodies such as the Moon and Mercury has been theorized for years [1]. It is thought that a combination of the Moon's small axial tilt and the large variation in topographic relief near the poles result in large areas (more than 30,000 km^2 at both poles)[2] that remain in permanent darkness and thus are very cold[3], only receiving heat from background stars and from the interior of the Moon [4]. Radar observations of the poles of Mercury, the Moon, and Mars and icy satellites reveal unusually high CPR (circular polarization ratio). The purpose of the research is to understand the physical process behind the polarimetric anomalies using scattering theory as a framework. Current models for high CPR are based on radar waves propagating in a weakly absorbing medium (e.g., water ice, regolith), a series of random scattering events occur due to subsurface heterogeneity (e.g., buried rocks, voids). Those waves that scattered along identical paths but in opposite directions add coherently, resulting in unusual high strengths and polarization ratios of the backscattered radar signals relative to the more familiar and extensively studied terrestrial planets [5]. LPR (linear polarization ration), CPR, DCP (degree of circular polarization) and DLP (degree of linear polarization) are measured from a sample using a laser to quantitatively understand how beads affect single, and multiple subsurface scattering from low-high phase angle.

Experiment: Aqueous solutions of latex beads are useful because we can alter the size and concentration to generate different types of subsurface scattering. Figure. 1: 0.08 µm 10% (w/w), 0.81 µm 10% (w/w) and 0.08 µm 5% (w/w) concentration solution, and the sample cup.

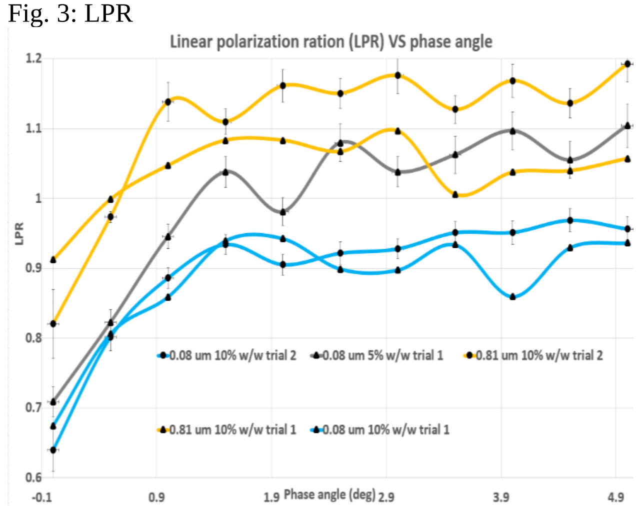


We measured the reflected intensity for several depths of solution to determine the influence of reflections from the bottom of the sample cup. The depth that minimize back reflections is 7 mm+/-0.5 mm. Figure 2 shows the multi-axis goniometer instrument setup (MAGI)[6], a 1064 nm laser source (1), a 250--Hz optical chopper (2), a 45º mirror (3), linear polarizer LP (4) and a quarter waveplate (QWP) at 45º (5) to generate right circular polarization. Components 1 to 5 are installed on a caddy traveling through 0º-5º phase angle. The secondary beam from the BS (6) is attenuated using ND filters (7) to prevent back reflection from the wall. Samples are placed on a platform (8) onto which the primary beam is directed. The polarimetric arm consists of a QWP (9), LP (10) and a photodiode detector (11) to measure polarization over 360º in 5º increments. The arm is set at 15º pitch to prevent specular reflections (surface scattering) from reaching the detector; polarimetric data are collected at 0.5º intervals from 15º -20º emergence angle. Figure. 2: MAGI setup (see text above for label)



Primary results:

Fig. 3: LPR



Interpretation:
Beads solutions are analogous to pockets of ice (beads) within the regolith (water), water reflects visible light but absorbs mid infrared. LPR (Fig. 3) measures multiple incoherent scattering and is inversely proportional to CPR (Fig. 4) and increases as phase angle increases. CPR measures coherent backscattering opposition effect (CBOE) which decreases as phase angle increases. CPR and LPR curves increase as the beads size approaches laser wavelength (0.83 µm 10% (w/w)), both curves are proportional to concentration due to a higher number of backscatters (0.08 µm 10% (w/w) and 5% (w/w)). DCP (Fig. 5) indicates the evolution of circular polarization over intensity ($|S_3|/S_0$), it increases if bead size is much greater or lower than wavelength because opposite sense polarization is dominant indicating low CBOE even at 0º (0.08 µm 10% and 5% (w/w)). DCP decreases if beads size approaches laser wavelength because same sense polarization is dominant at 0º indicating high CBOE at 0º, as phase angle increases multiple incoherent scattering increases but CBOE decreases (0.83 µm 10% (w/w)). DLP (Fig. 6) measures diffusivity, DLP curves are inversely proportional to beads size and concentration because bigger beads means lower mean free path (0.83 µm 10% (w/w)), as concentration decreases there is more diffuse scattering due to fewer beads number (0.08 µm 10% (w/w) and 5% (w/w)).

References:

1. Watson et al., 1961;Arnold, 1979.
2. McGovern et al., 2013.
3. Vasavada et al., 1999; Paige et al., 2010b.
4. Vasavada et al., 1999; Paige et al., 2010.
5. Hapke,1990; Ostro and Shoemaker, 1990; Peters, 1992.
6. Shaw et al., 2014.

Fig. 4: CPR

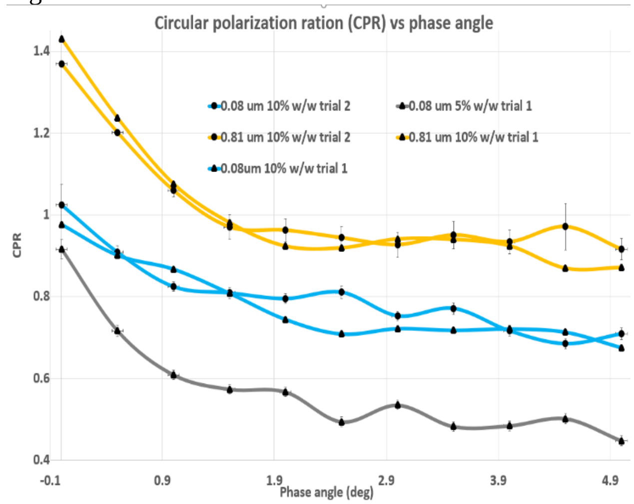


Fig. 5: DCP

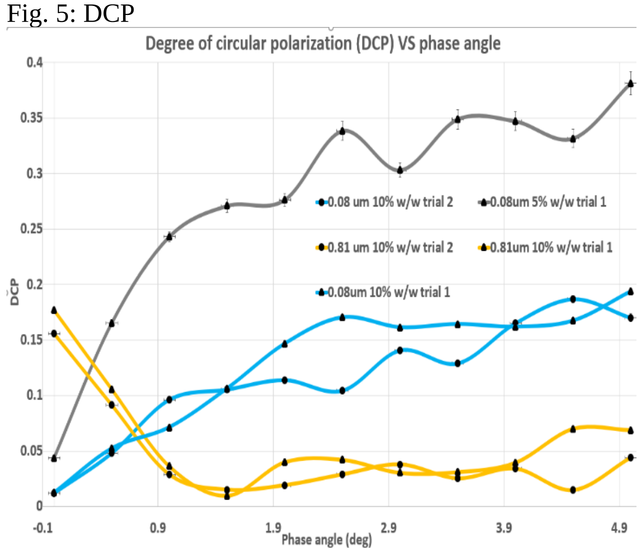


Fig. 6: DLP