**INVESTIGATION OF VARIATION IN CHRISTIANSEN FEATURE WITH ALBEDO ON THE MOON USING THE DIVINER, M$^3$, AND KAGUYA DATASETS**. N. Kumari[1] and T. D. Glotch[1], and K. A. Shirley[2], [1]Department of Geosciences, Stony Brook University, Stony Brook, NY, 11794 (nandita.kumari@stonybrook.edu), [2]Department of Atmospheric, Oceanic, and Planetary Physics, University of Oxford, Oxford, UK.

**Introduction:** Thermal infrared (TIR) spectroscopy is an effective tool for studying the composition of terrestrial planets in the solar system. In this wavelength region, silicate minerals display a peak corresponding to the wavelength where the index of refraction passes unity, leading to an emissivity maximum known as the Christiansen feature (CF) [1]. The CF position is an indicator of the degree of silicate polymerization within a mineral, occurring at longer wavelengths for silica-poor chain silicates and at shorter wavelengths for silica-rich framework silicates [3]. To use this feature for identification and quantification of composition, it is important to correct the spectra for various factors that can modify the CF position independent of composition.

One of the major issues known to complicate spectroscopy in the visible/near-infrared (VNIR) region is space weathering, which results in the formation of agglutinates and nanophase-iron rims, reducing the albedo of the surface along reddening the continuum slope and subdued mineral absorptions[4]. Prior to the Lunar Reconnaissance Orbiter (LRO) mission, it was presumed that space weathering would have minimal effects in the TIR region due to the nano-scale nature of the space-weathered rims being undetectable at the longer wavelengths. However, TIR measurements of the Moon by the Diviner Lunar Radiometer Experiment on board LRO, demonstrated that space weathering tends to influence the position of the CF [2].

A study carried out by [5] using laboratory measurements under simulated lunar environment conditions suggests that albedo influences the CF position as well. Since space weathering tends to reduce the visible albedo of the surface, in this study we have investigated the effects of albedo on the CF using Diviner, the Kaguya Multiband Imager (MI) and Moon Mineralogy Mapper (M$^3$) datasets. Here we have used the swirl sites, regions of high visual albedo and space weathering variability but similar bulk mineralogy [6], to understand the effect of albedo on CF.

**Datasets and Methods:** In this study, we used the Diviner channels 3, 4 and 5 corresponding to 7.55-8.05 µm, 8.1-8.4 µm and 8.38-8.68 µm to obtain CF maps of lunar swirls examined by [6]. After obtaining the CF maps, we measured the variation of CF with respect to albedo for on-swirl and off-swirl regions. The albedo of each region was measured from the Kaguya MI reflectance band 2 dataset corresponding to 750 nm.

In addition to the swirls, we also measured the variation of CF with respect to albedo on and off the rays of three young, fresh craters. The rayed craters were chosen from the rayed crater catalog of [6]. To make sure that any observed variation is not due to mineralogical differences, we used the M$^3$ datasets to choose mineralogically uniform regions for comparison. A scatterplot and histogram of the CF for these regions was plotted to observe the difference. The bins in the histogram have been calculated using Freedman-Diaconis Estimator [8].

**Results:** Figure 1 shows the measurements obtained from the swirls located on the far side of the Moon in Van de Graaff crater (27° S,172° E). The scatterplot of CF and albedo from the on and off swirl region display a shift in CF with increasing albedo to shorter wavelengths, consistent with [6]. This shift becomes more apparent in the normalized histogram plotted for on and off swirl sites (Fig 1).

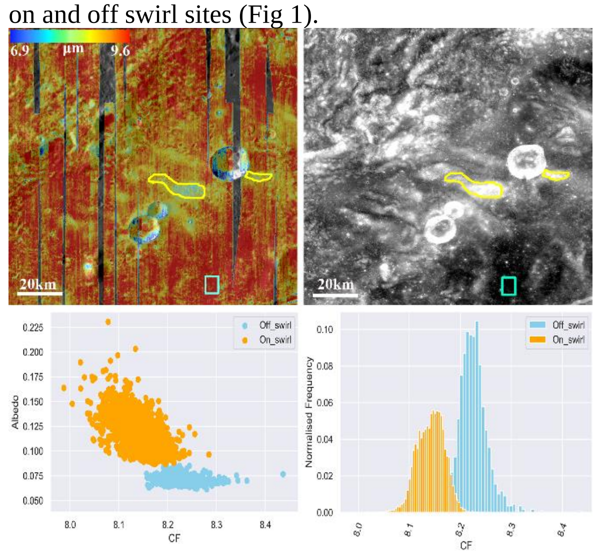


Fig 1a) CF map of the Van de Graaff swirl overlaid on LRO Wide Angle Camera (WAC) map. The yellow boundaries indicate the on-swirl and the cyan boundary indicates the off-swirl site used in the study. b) Kaguya MI albedo map of the same region. c)Scatterplot of CF Vs Albedo for the on-swirl(orange) and off-swirl(blue) regions d) normalized histogram of the CF values on-swirl and off-swirl.

We observe that the CF for the on-swirl sites with high albedo lies near 8.15 µm while for the off-swirl low albedo regions lie near 8.25 µm. A similar trend has been observed for the other swirls used in this study.

In addition to the swirl sites, we also examined the crater rays of Copernican crater Giordano Bruno (35.9° N,102.8° E). To ensure that the CF variation is not due to the mineralogical variation within the sites we first carried out a mineralogical survey of the sites of interest using integrated band depth (IBD) composites and obtained the spectral signatures to find that the sites are pyroxene rich as shown in Fig 2.

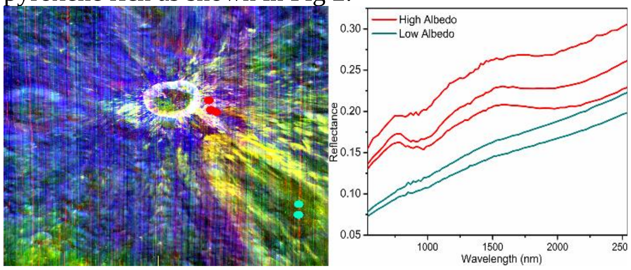


Fig 2. RGB composite of Giordano Bruno with R-IBD 1μm, G-IBD 2μm, and B- 1.489μm displaying the mineralogical variation of the area of interest. The red dots corresponding to the red spectra are from high albedo regions and the cyan dots in bottom right corner corresponding to green spectra are from low albedo region.

The variation in the absorption depth of the observed spectra is due to variation in space weathering of the selected regions. Following this, we inspected the variation of CF with respect to albedo in these regions as shown in Fig 3.

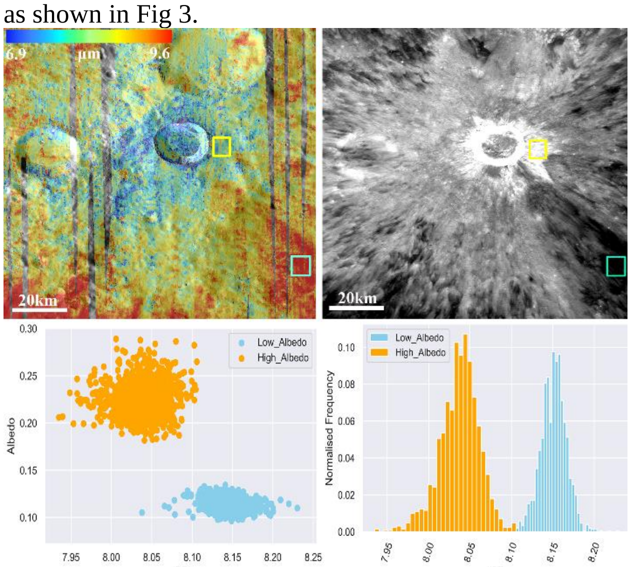


Fig 3a) CF map of Giordano Bruno crater overlaid on LRO Wide Angle Camera (WAC) map. The yellow boundaries indicate the on-swirl and the cyan boundary indicates the off-swirl site used in the study. b) Kaguya MI albedo map of the same region. c) Scatterplot of CF vs albedo for the on-ray (orange) and off-ray (blue) regions d) Normalized histogram of the CF values on-ray and off-ray.

Fig 3 shows a similar shift in the CF values of the regions with higher albedo as the on-swirl sites. The CF values tend to shift to shorter wavelengths with increasing albedo despite having similar mineralogical composition. Here the mean of CF values for the regions with high albedo lie near 8.04 μm and those with low albedo lie near 8.15 μm.

**Discussion**: The study carried out by [2] displayed a shift in CF with respect to space weathering. This effect of space weathering on CF was attributed to the compositional physical effects and thermal gradients [2]. The lunar regolith vertically displays a high thermal gradient due to the low thermal conductivity of the regolith. Under ambient conditions a regolith surface remains more or less isothermal through heat transfer through gas molecules in pore spaces. However, on airless bodies, heat flow is limited to the grain contacts, resulting in formation of a warm layer beneath the surface known as solid-state greenhouse effect [9,10]. The depth of this layer depends on the infrared absorption coefficients of the regolith components [3]. The CF shift to longer wavelengths for the lower albedo space-weathered regions can be explained by this phenomenon.

**Ongoing work:** We further plan on investigating sites with high silica content which might help us understand the correlation between lunar surface and the warm layer at different locations. This work can be further used as a base for understanding such effects on other airless bodies and to obtain precise results and support ongoing and future missions to Mercury (MERTIS on board BepiColombo) and asteroids (e.g., OTES on OSIRIS-REx).

**References:** [1]Conel J.E(1969), *JGR*,73,1614-1634, [2]Lucey P. G. et al. (2017) Icarus, 283, 343-351 [3] Logan L.M. et. al. (1973) *JGR* 78,pp. 4983-5003 [4] Pieters C. M. et. al. (2000), *MAPS 35*,1101-1107 [5] Shirley K. A.and Glotch T.D. *LPSC 2018*, contribution no. 2083 [6] Glotch T.D. et. al. 2015, *Nature Communications 6,6189* [7] McEwen E.S. et. al. (1997), *JGR,9231-9242*.[8] Freedman, D. and Diaconis, P. (1981) *Z. Wahrscheinlichkeitstheorie verw Gebiete* 57**,** 453–476 [9] Logan L. M. and Hunt G. R.(1970), *JGR*, pp-6539-6548 [10] Henderson B.G. and Jakosky B.M. (1997) *JGR*,pp-6567-6580