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Are Transient Lunar Phenomena in Aristarchus Crater Surface Optical Effects?

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Abstract

Aristarchus crater is the most prolific site for Transient Lunar Phenomena. Possible simple explanations for such phenomena could be sunglint from portions of parallel aligned near-specular surfaces, the opposition effect, or internal reflections from volcanic glass beads. An observational data base of TLPs, was used to investigate these theories, along with a control dataset of routine observations. However no definitive evidence in support of any of these ideas was been found.

1. Introduction

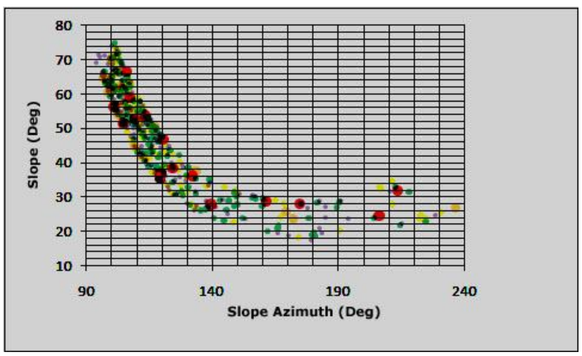

Figure 1: Slope angle Vs Slope Azimuth needed for sun glint for each of the TLPs observed at Aristarchus crater. Purple=weight 1. Green=weight 2. Yellow=weight 3. Orange=weight 4. Red-weight 5.

Transient Lunar Phenomena (TLP) have been observed against the Moon's surface for centuries by astronomers [1] and can last from a fraction of a second upto several hours. Could simple optical explanations such as sunglint off crystal facets [2], opposition effects in the porous soil [3], and rainbows and glories [4] from internal reflection from pyroclastic glass beads, explain these TLP? We analyzed the catalogs of Middlehurst [5], Cameron [1,6], and the archives of the British Astronomical Association (BAA) and the Association of Lunar and Planetary Observers (ALPO) to recover all known dayside TLP Aristarchus reports, along with a representative dataset of non-TLP observations.

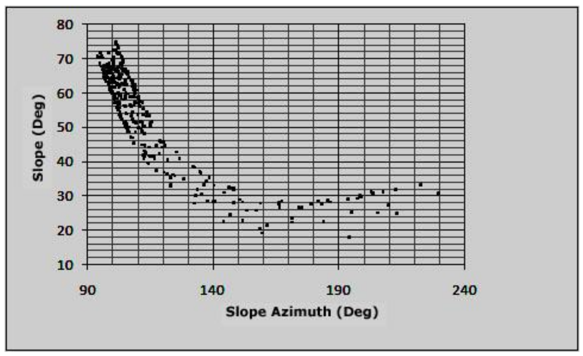

Figure 2: Slope angle Vs Slope Azimuth needed for sun glint for each of the control observations.

Unfortunately the duration of TLPs has not always been recorded, and the start of events may often have been missed. Therefore in this study all TLP are considered as candidates for the above effects. Although the Moon has no large areas of polished surfaces, there could exist exposed stratified rock faces that have a patch work mosaic of near-parallel crystal facets that act as a multi-specular surface. A similar effect has been suggested for telescopic sunglint effects seen on Mars [7] but with ice crystals. The Moon rotates at approximately ~0.5°/hour, and so the time needed to rotate through the Sun's angular diameter will be 1 hour. However for sunglint processes the amount of rotation needed is half of this i.e. 0.25°, or approximately 30 minutes. This defines the minimum duration of TLP possible from sunglint, and in practice due to mis-alignment of crystal facets, this would mostly probably be longer. The opposition effect explanation for TLP is likely to offer events of many tens of minutes, due to the relatively broad angular extents of pores in lunar soil, but can at least produce colours [8]. Only multiple internal reflection from pyroclastic glass beads could offer both shorter duration events and colour.

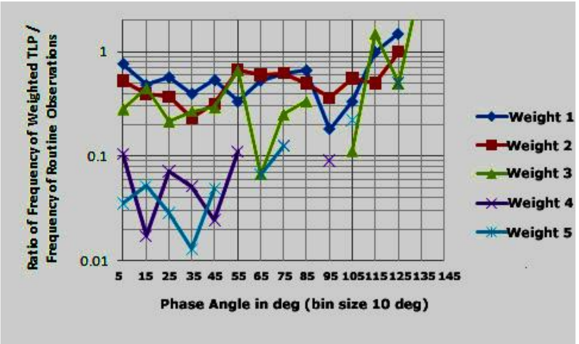

Figure 3: Ratio of weighted TLP observations to routine observations Vs Phase. 10° phase bins used.

2. Method

A total of 491 dayside TLP reports of Aristarchus were used. The reports were categorized into weights of 1 (194 TLP), 2 (146 TLP), 3 (111 TLP), 4 (24 TLP), 5 (16 TLP). The higher the weights, the more reliable the reports were [9]. For comparison 367 routine observations, where no TLP were seen, were used as a control dataset. Hypothetical slopes and slope azimuths were calculated for each observation such that light from the Sun reaching the lunar surface, at Aristarchus, would be reflected back to the observer on Earth in a specular way.

For evidence of opposition effects, or multiple internal reflection within glass beads, it is necessary to do a ratio of the histogram of the phase angle for each TLP, and divide this through by the corresponding histogram for the control dataset. If there are specific phase angles where these effects occur, then this will be revealed as peaks in the ratio plot, getting stronger at higher weights. The opposition effect should be strongest at 0° phase angle.

3. Results

Figure 1 shows that if sunglint was an explanation, then the bulk of this would have to come from west to southwest facing very steep slopes of upto 75°. The control dataset in Figure 2, reveals a similar distribution. In fact the maximum slope in measured topography, in the vicinity of Aristarchus, is 18° in the LOLA 1/32° DEM.

Evidence for high ratios of TLP to routine observations,, does not reveal itself at specific phase angles in Figure 3. Although there is a hint of a trend of more TLP occurring for all weights at high phase angles.

6. Summary and Conclusions

Specular reflection is not a reasonable explanation for the TLPs in Aristarchus based upon LOLA derived slopes at a 1 km spatial scale because these are insufficiently steep to produce sunglint. However if there were smaller scale steeper slopes, for example rock faces on stratified layers in the crater rim terraces, then this might produce sunglint. If this was the case then there appears to be no preferred slope azimuth when comparing the control dataset to the TLP dataset.

We also investigated whether there were any particular preferred phase angles ranges at which TLP had been seen, and again found no specific preferences. This infers that the other optical effects: prismatic internal refraction and the opposition effect are not key players in explaining TLP in Aristarchus.

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