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A Goniometer Facility for Imaging Polarization and Photometric Studies of Planetary Regolith Analogs

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Abstract

Phase-ratio analysis is becoming a widely used technique to obtain sub-resolution information on the scattering behavior and particle size for the surfaces of airless bodies. Recently published examples have employed spacecraft images from the Moon, Mercury, Eros, and Vesta. Phase-ratio images can reveal anomalous photometric behavior. An anomaly can be interpreted in terms of the roughness or particle size, which are important for understanding the geologic pro-cesses that have affected the surface. However, conclusions to date have largely been limited to qualitative inferences. The lack of a comprehensive laboratory framework for interpretation precludes the derivation of more quantitative information from the data.

There is also growing interest in imaging polarimetry as a planetary remote-sensing technique. *Hayabusa* carried a camera (AMICA) designed to obtain polarization images of asteroid Itokawa. The forthcoming *Korea Pathfinder Lunar Orbiter* (KPLO) includes an instrument called PolCam that will collect multispectral/multi-polarization images of the Moon. Unlike reflectance and emittance spectroscopy, there has been relatively little laboratory work aimed at exploring the polarization behavior of planetary surface materials. Such foundational work is necessary for the PolCam and other future datasets to yield their greatest scientific return.

1. Introduction

I am in the process of establishing a Planetary Surface Texture Laboratory (PSTL) to explore the phase and polarization response of planetary regolith analogs as a function of illumination (*i*), viewing (*e*) and phase (*g*) angles. We will obtain data with an imaging polarimeter, which simultaneously collects co-registered images of a scene in multiple polarization states. A computer-controlled goniometer will permit the light source and the polarimeter to be moved through a range of (*i*, *e*, *g*) geometries. Soil analogs will be placed in trays that are large enough to permit different samples or preparations to be viewed together. Thus, a key innovative aspect of PSTL is the use of imaging, going beyond the spot measurements of most current facilities. The regolith analogs that we study will be characterized in terms of particle size-frequency distribution, and crucially, they will also be characterized in terms of shape. The size and shape analysis will be done with an instrument that extracts parameters including average particle diameter, sphericity, and convexity, as well as the standard deviations and size-frequency distributions of these parameters.

The data obtained with PSTL will be key for comparative analysis of surface texture, and also provides the basis for modeling studies. The comprehensive data in (*i*, *e*, *g*) space will be used for photometric modeling, e.g., fitting of Hapke parameters that can be linked to the known particle properties such as albedo, size, and shape. We plan to perform modeling to test empirical relations that connect particle size to polarization, and also develop rigorous radiative-transfer code that includes the four Stokes polarization parameters and allows for incorporation of particle size, packing, and shape.

PSTL represents a unique capability for imaging studies of the photometric and polarization behavior of regolith analogs that have been quantitatively characterized in terms of particle size and shape. By carrying out systematic investigation of well-characterized samples, we will provide the foundation for interpretation of phase-ratio image data from past and future planetary missions and for future polarization image data from missions like KPLO. The research will thus open new windows to aid in the understanding of the geological processes that have operated on surfaces throughout the Solar System. Remote assessment of particle shapes and sizes could also benefit site selection for *in situ* resource utilization.