THERMAL INFRARED OBSERVATIONS OF THE MOON DURING LUNAR ECLIPSE USING THE AIR FORCE MAUI SPACE SURVEILLANCE SYSTEM.

P. O. Hayne[1], P. G. Lucey[2], T. R. Swindle[3], J. L. Bandfield[4], M. A. Siegler[5], and D. A. Paige[6] [1]NASA-Jet Propulsion Laboratory, California Institute of Technology (MS 183-801, 4800 Oak Grove Drive, Pasadena, CA 91109; Paul.O.Hayne@jpl.nasa.gov), [2]University of Hawaii, Manoa, [3]Air Force Research Laboratory/Maui Optical and Supercomputing Observatory, [4]Space Science Institute, [5]Planetary Science Institute, [6]University of California, Los Angeles.

Introduction: Thermal infrared measurements of airless planetary bodies provide crucial information on the physical nature of their surfaces. Diurnal and seasonal temperature profiles depend on the properties (porosity, grain size, composition) of the material within the reach of the thermal wave. Data from the Lunar Reconnaissance Orbiter's (LRO) Diviner radiometer [1] have fully characterized the thermal behavior of the Moon at its diurnal and seasonal timescales [2], which places strong constraints on the physical properties of the upper ~10 – 100 cm. However, the properties of the uppermost ~1 cm are poorly constrained, because the thermal mass of the surface layer is small compared to the total mass involved in the thermal wave. In addition, because the lunar rotation period is long compared to many solar system objects, it is difficult to directly compare the well-characterized lunar case to measurements of more rapidly rotating objects, especially asteroids.

Lunar eclipses provide variation in illumination on a timescale of a few hours, similar to the rotation rate of many objects, especially asteroids. Accurate, time-resolved eclipse cooling measurements of the lunar surface can directly constrain the properties of the upper layer and enable direct comparison of the well-characterized lunar regolith to that of asteroids and other objects with thermal measurements [3, 4, 5] (Fig. 1).

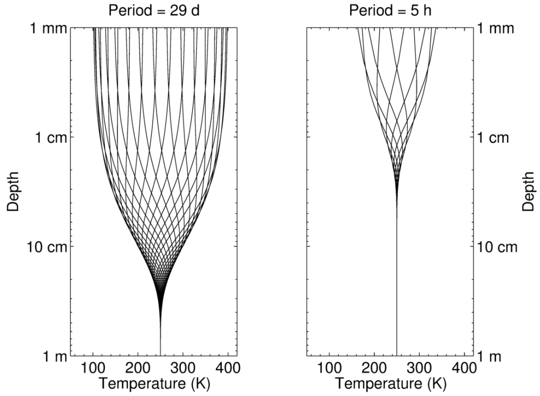

Figure 1: Model subsurface temperature calculations show the different depth penetration of the diurnal (left) and eclipse (right) thermal waves.

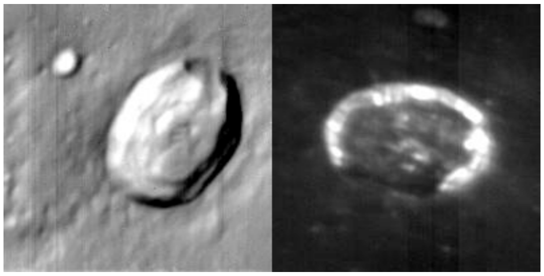

Figure 2: Thermal IR measurements of Kepler crater prior to (left), and during (right) the total lunar eclipse of Oct. 8, 2014, acquired by the 3.7-m Air Force AEOS telescope.

Observations: We utilized the Air Force Research Laboratory's 3.7-m Advanced Electro-Optical System (AEOS) telescope on the summit of Haleakala, Maui, Hawaii to acquire data with a thermal imager during the total lunar eclipse of October 8, 2014 [6]. The instrument measures radiance in two spectral bands in the region ~8 – 12 µm. The observation and calibration strategies were similar to those of an earlier campaign during a partial lunar eclipse [4], but optimized to target several regions of interest several times before, during, and after eclipse to capture the full temperature cycle.

Results: Preliminary analysis of the AEOS data reveals a variety of features and intriguing spatial differences in cooling behavior. Warm features indicate rocks larger than a few cm surrounding young impact craters, as well as exposed bedrock in the walls of large craters and rills (Fig. 2). Bright lobes within the Reiner Gamma "swirl" anomaly remain cool relative to the surrounding regolith during the initial phases of eclipse cooling (Fig. 3). We will investigate two hypotheses to explain this behavior: 1) cooler temperatures result from the lobes' higher albedo, or 2) a thin insulating dust layer exists at the surface of the bright lobes. Either of these conclusions would have implications for Reiner Gamma's formation mechanisms [7]. Also of great interest were the unexpectedly high temperatures measured by AEOS during the eclipse within a "cold spot" previously observed by Diviner (Fig. 4). These unexplained impact-related features have a dis-

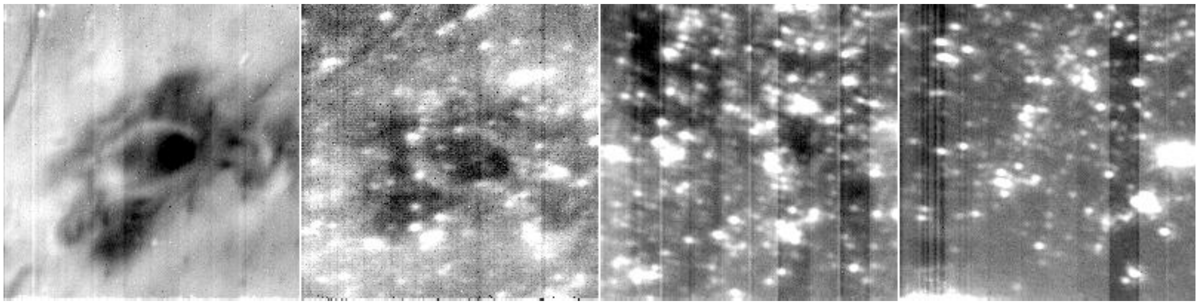

Figure 3: Thermal data (uncalibrated) of Reiner Gamma "swirl" anomaly during various phases of the eclipse (Left to right: ~1 h prior to penumbra, penumbral phase, early umbral phase, late umbral phase). Note that the orientation and position of the image varies from frame to frame. The relatively cold (black) appearance of RG's lobes is initially due to their higher albedo. The many bright spots during eclipse are warm rocks within and around young impact craters.

tinct thermal signature in the Diviner nighttime data indicative of highly insulating material [8]. Their complete non-detection in the eclipse data suggests vertical layering that may shed light on their origins.

References: [1] Paige, D. A., et al. (2010) *Space Sci. Rev.* 150.1-4,125-160 [2] Vasavada, Ashwin R., et al. (2012) *J. Geophys. Res.* 117.E12 [3] Saari, J. M., and R. W. Shorthill (1963) *Icarus* 2, 115-136 [4] Lucey, P. G. (2000) *Int. Symp. on Opt. Sci. and Tech.* [5] Hayne, P. O., et al. (2011) *AGU Fall Mtg. Abstracts*, Vol. 1 [6] http://eclipse.gsfc.nasa.gov [7] Hemingway, D. and I. Garrick-Bethell (2012) *J. Geophys. Res.* 117.E10 [8] Bandfield, J. L., et al. (2014) *Icarus* 231, 221-231

Acknowledgements: Part of this work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

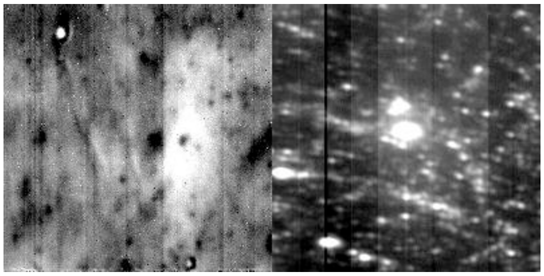

Figure 4: Thermal data (uncalibrated) of a lunar "cold spot" feature prior to (left) and during (right) eclipse.