Towards Understanding Thermal Transfer on Airless Bodies with the Oxford Space Environment Goniometer

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By comparing a thermal model of surface temperatures on airless bodies to those measured by remote sensing, it is possible to constrain surface composition, roughness, emissivity, density, albedo as well as subsurface (several meters deep) temperatures. For objects with relatively low obliquity <5% (such as the Moon or Ceres), in equatorial regions where the illumination of the surface is at incidence angles >70^o, a 1D model is sufficient to accurately model the surface temperature. However, in polar regions where the illumination of the surface can be permanently at low incidence angles (<70^o) large shadows are cast, and inside these shadows, the surface temperature is driven by scattered radiation from illuminated regions. A 3D thermal model (3DTM) with full ray tracing and an accurate scattering function is therefore required to model these shadowed regions. Knowledge of how the surface of an airless body (such as the Moon or asteroids) scatters visible and thermal radiation is then required for 3DTMs.

Using a non-Lambertian scattering function within a 3DTM for an airless body gives modelled temperature profiles which change by 10s of kelvin compared with Lambertian temperature profiles. Understanding how scattering affects temperature on airless bodies puts constraints on the areas for which volatiles such as water ice can be identified in cold traps in the polar regions of the Moon and on asteroids such as Ceres. It also helps define the magnitude of the YORP and Yarkovsky effects on asteroids, as scattering affects their surface temperature profiles. Goniometer measurements taken at low incidence angles can further our understanding of such scattering effects and hence, we require new experimental data to validate models of surface roughness and provide new thermal emission data.

The Oxford Space Environment Goniometer (OSEG) is a novel goniometer system inside a vacuum chamber specifically designed to measure how visible and infrared radiation is scattered from a particulate surface. OSEG can take Bidirectional Reflectance Distribution Function (BRDF) and Directional Emissivity (DE) measurements for lunar regolith samples and regolith simulants across visible (0.4 - 0.7µm) and thermal/far infrared wavelengths (5 - 400µm). The BRDF is the function (often modelled by the Hapke BRDF model) which describes how visible and near infrared light is scattered from a surface. It only defines how visible and near infrared light is scattered and does not describe how infrared is emitted from a surface. However, the DE (or emission phase function) describes how infrared light is emitted from a surface for all viewing angles. OSEG is currently setup in visible BRDF measurement mode to measure Apollo lunar regolith and lunar regolith simulant samples across 0–70^0 reflection, 0–70^0 incidence, 0–360^0 azimuthal and down to 6^0 phase angles.

At THERMOPS-III, I will present the latest BRDF measurements from OSEG and show how these measurements can be used to improve the accuracy of 3DTMs and hence, be applied to calculate the YORP and Yarkovsky effects for asteroids with known shape models.