Integrated spectroscopic study of Apollo 16 sample and anorthositic Lunar meteorite. P. Tripathi[1], A. Maturilli[2], G. Alemanno[2], [1]Indian Institute of Technology Roorkee, Uttarakhand, India, ptripathi@ce.iitr.ac.in, [2]Planetary Laboratories Department, Institute for Planetary Research, DLR, 12489 Berlin, Germany.

Introduction: Interpreting surface composition of the Moon and other airless bodies relies on spectroscopic techniques spanning visible, near-infrared, and thermal infrared wavelengths. This study utilized an integrated spectroscopy approach to measure a suite of lunar rock sample, a lunar meteorite and lunar minerals. The objective was to demonstrate the methodology for building a robust spectral library to support interpretation of data from future lunar missions focused on understanding surface compositions and resource potential [1-2].

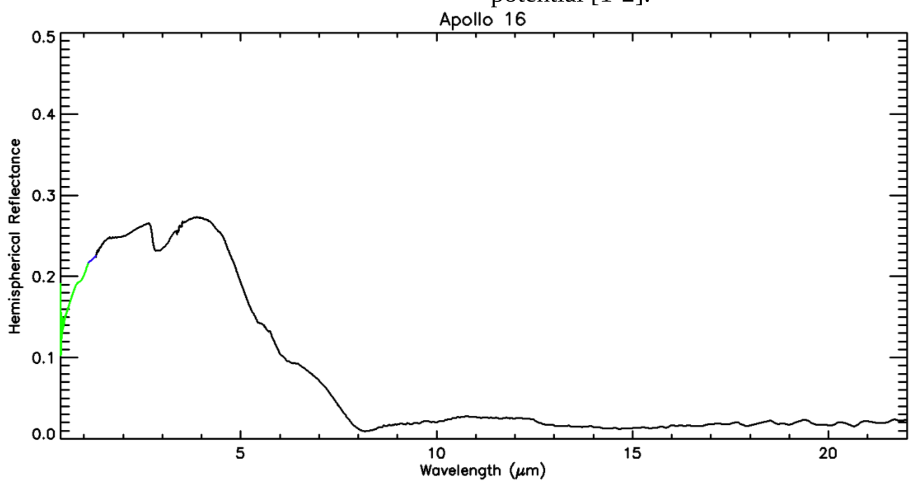

Fig 1. Calibrated hemispherical reflectance for the Apollo16 sample (VIS to MIR)

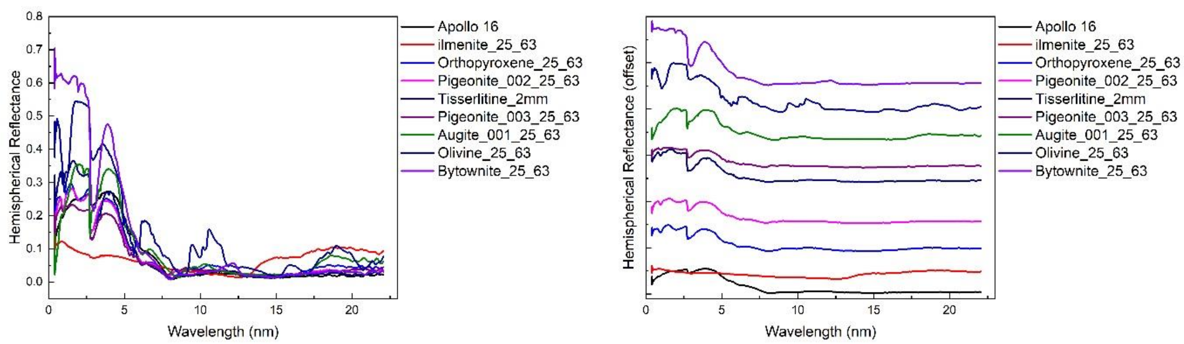

Fig. 2 Hemispherical reflectance of Apollo 16 sample and lunar minerals (VIS to MIR), particle size 25-63 µm

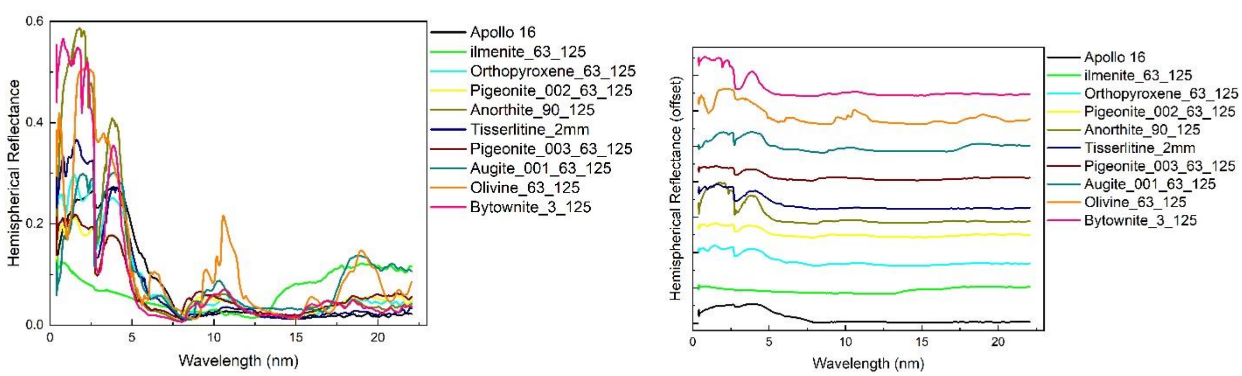

Fig. 3 Hemispherical reflectance of Apollo 16 sample and lunar minerals (VIS to MIR), particle size 63-125 µm

Methods: The analog samples characterized included 15 lunar mineral endmembers (pigeonite, augite, ilmenite, orthopyroxenes, olivine, anorthite, and bytownite), Apollo 16 regolith (62231.44), and the Tisserlitine 001 lunar meteorite. Materials were fine powders sieved to grain sizes of 25-125 µm. Spectroscopic measurements were performed under vacuum with the Bruker Vertex 80V FTIR instruments at the Planetary Spectroscopy Laboratory. Bidirectional reflectance spectroscopy utilized attached visible and near-infrared detectors to acquire spectra at illumination angles of 30° and 45° relative to the sample surface normal. Hemispherical reflectance measurements collected visible and near-infrared spectra separately using integrating spheres. Emission spectroscopy measured thermal emission from 6 to 20 µm at controlled sample temperatures of 70°C, 100°C, and 130°C. In total, 204 high quality spectra were obtained over a spectral range from 0.2-150 µm with resolution from 0.1-8 cm-1.

Results and Future work: Fig. 1 presents a calibrated hemispherical reflectance for the Apollo16 sample from VIS to MIR and it shows a clear hydroxyl group feature near 3 µm [3-4]. Despite originating from different locations on the lunar surface, Apollo 16 lunar sample and Tisserlitine 001 which is a Lunar (feldspathic regolithic breccia) showed striking similarities in the visible and near-infrared bidirectional reflectance spectra, as both samples exhibited absorption features characteristic of lunar highland compositions, including broad 1 and 2 µm bands indicating the presence of pyroxenes [5-7]. The Tisserlitine 001 sample had slightly more pronounced pyroxene bands, but the overall spectral shape and absorption features were comparable. This observation was made during the recording of spectrum as shown in Fig. 2 (grain size of 15-63 µm) and Fig. 3 (grain size of 63-125 µm). We are working on calibration of other spectra and will publish the spectral library soon.

For emissivity spectra primary observation shows that smaller grain sizes exhibited clearer diagnostic absorption features related to mineral compositions. Elevated temperatures revealed variations in spectral properties due to changes in thermal emission, molecular vibrations, and phase transitions. More information is expected from the calibrated spectra. The integrated dataset enables detailed characterization of the lunar sample, meteorite and lunar minerals for interpretation of surface composition and mineralogy. Fig. 2 and Fig. 3 shows that ilmenite has the highest overall reflectance, followed by orthopyroxene and pigeonite. Anorthite and bytownite have relatively low reflectance across most of the wavelength range. Also, olivine has a distinct absorption feature around 10 µm. It was seen that Tisserlitine 001 has a unique spectral signature that doesn't closely resemble any of the other minerals.

Conclusion: This study successfully characterized 15 lunar minerals, the Apollo 16 sample (Highlands), and the Tisserlitine 001 lunar meteorite using integrated spectroscopy techniques. By acquiring high-quality reflectance and emission spectra of relevant lunar materials, an integrated spectral library has been built that will aid in interpreting data from future lunar missions. The spectra obtained for the Apollo 16 sample and Tisserlitine 001 meteorite showed common absorption features linked to lunar pyroxenes, while also exhibiting unique differences. Further calibration and analysis of the full spectral dataset will refine the spectral library for identifying lunar mineralogy and chemistry from orbital or landed spectral measurements. This will support determining in situ resource utilization potential and improving understanding of lunar formation processes. The methodologies employed in this study offer a promising approach for spectral characterization in planetary exploration beyond lunar materials.

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