Mineralogical characterization of the Apollo 16 and lunar simulant samples through Mid-Infrared spectral analysis

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Overview

We analyzed lunar simulants and one **Apollo 16** sample via Mid-Infrared (MIR) spectroscopy to disentangle compositional signatures from grain-size artifacts (***Volume Scattering***).

- **Key finding 1**: Fine dust completely coats coarse grains, dominating the spectral signature (***Coating Effect***).
- **Key finding 2**: ***Band Depth (BD)*** *and* ***Full Width (FW)*** are highly sensitive tracers of physical porosity and multiple scattering paths, rather than simple compositional averages.

Introduction

MIR spectroscopy is a primary tool for distinguishing mafic mare from felsic anorthosite.
In particular, two parameters play an important role:

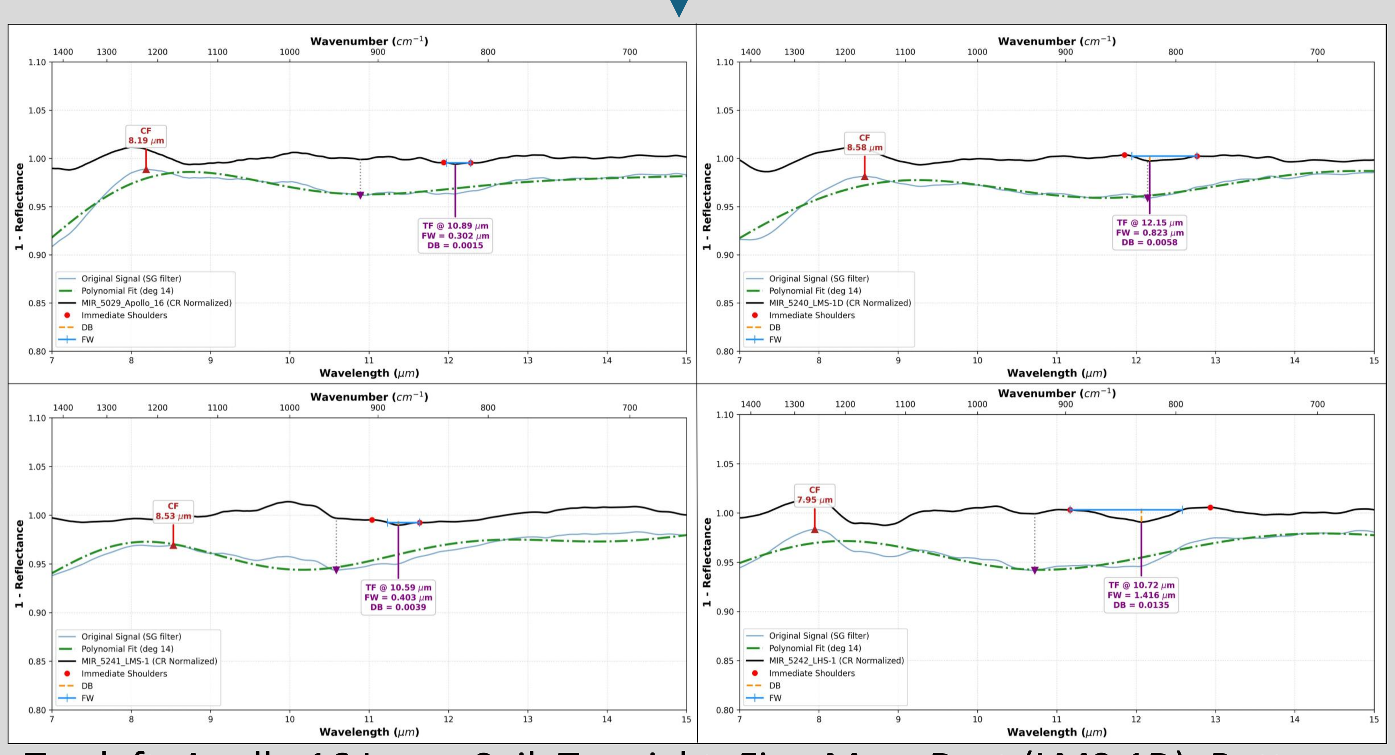
- ***Christiansen Feature (CF)***, sensitive to felsic minerals at shorter wavelengths and mafic minerals at longer wavelengths (~7.5 to 9.5 µm).
- ***Transparency Feature (TF)***, as indicator of fine fractions, located where the absorption coefficient reaches a minimum (~11–13 µm).
- The **challenge** is**:** how do physical grain size variations interfere with these compositional markers in intimate mixtures?

Methodology

- **Samples:** Apollo 16 (62231.44), endmembers (LHS-1 25A, LMS-1, LHS-1, LMS-1D, LHS1D), and their intimate mixtures.
- **Measurements:** Hemispherical reflectance spectroscopy under vacuum (Bruker Vertex 80V FTIR, DLR Planetary Spectroscopy Laboratory).
- **Pre-processing:**
  - *Calibration* on the reflectance inversion.
  - *Smoothing (Savitzky-Golay)* to remove noise without distorting band shapes.
- **Feature Extraction:**
  - *CF* and *TF* Positions extracted from the smoothed original spectrum to avoid distortion.
  - Band Geometry (*BD* and *FW*) calculated on *Continuum Removed (CR)* normalized curves. A global polynomial fit modeled the background slope.

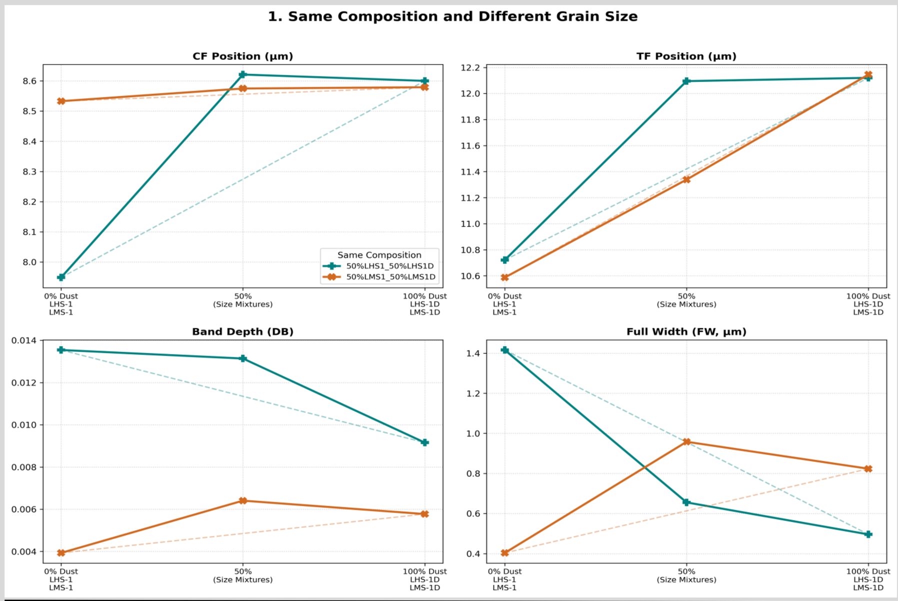
Apollo 16 sample (62231.44) prepared for MIR measurements

Bruker Vertex 80V FTIR spectrometer at DLR PSL (Image: Maturilli et al., 2022)

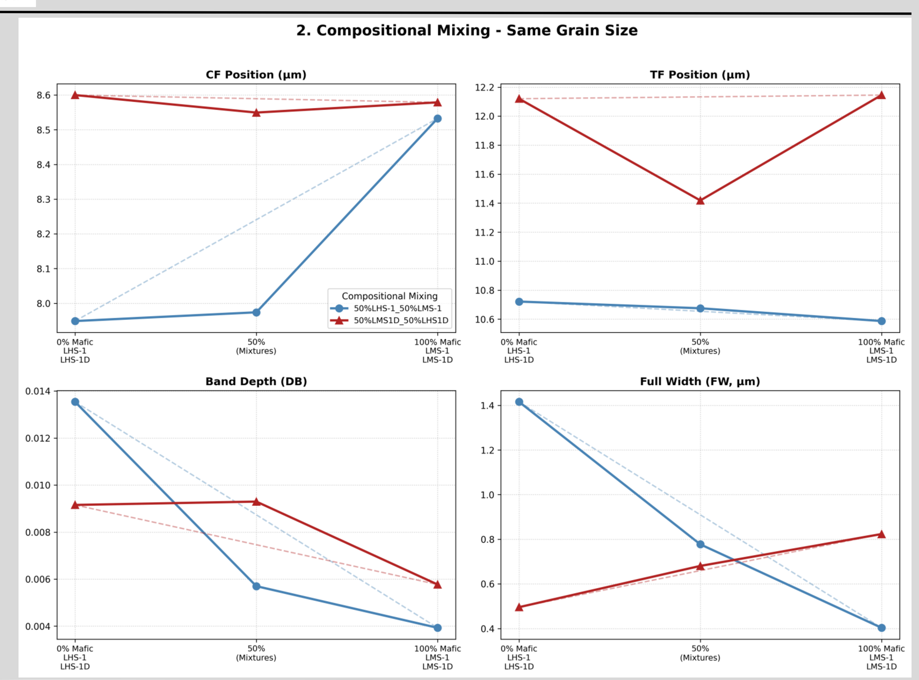


Top left: Apollo 16 Lunar Soil. Top right: Fine Mare Dust (LMS-1D). Bottom left: Coarse Mare (LMS-1). Bottom right: Coarse Highland (LHS-1).

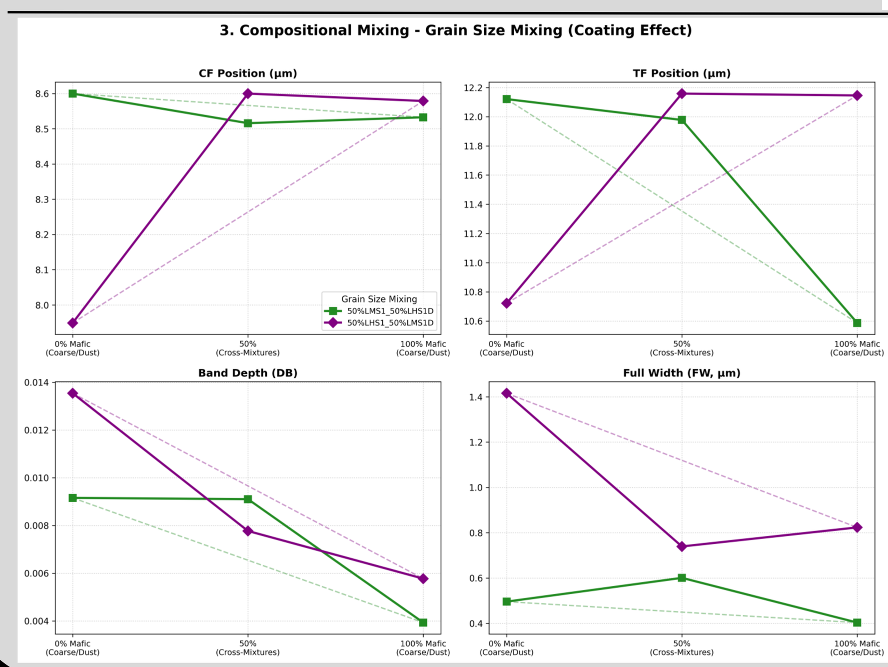
Results



- Adding fine dust («1D») shifts both CF and TF to longer wavelengths simultaneously. Felsic dust artificially mimics mafic signatures (**dust problem**).



- Coarse grains exhibit linear mixing (**areal mixing**). Fine dust mixtures show highly non-linear, "V-shaped" anomalies (**areal vs volume scattering**).



- In mixtures of coarse grains and fine dust, the spectral parameters jump immediately to the values of the pure dust endmember (**coating effect of cross-mixtures**).

Discussion

- Fine particulates physically coat larger grains. The instrument is effectively "blinded" by the superficial dust, completely masking the composition of the coarse rock core (**coating effect**).
- BD and FW exhibit strong, complex, non-linear trends. They are indicators of the sample's **physical structure**, tracking changes in macroporosity and the multiple scattering pathways introduced by fine dust.
- The real lunar soil **Apollo 16** shows affinities with coarse simulants (low BD, minimal TF-CF distance). This is likely due to space weathering reducing volume scattering compared to fresh laboratory dust.

Conclusions

- **Grain size overrides composition** in intimate physical mixtures, the fine dust fraction dictates the overall spectral response.
- The simultaneous redshift of CF and TF can lead to ambiguous interpretations of felsic materials in remote sensing data.
- Future spectral unmixing models for the lunar surface must explicitly account for non-linear volume scattering induced by dust.

Acknowledgments/references

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References:

Lucey, P. G., et al. (2021). *JGR: Planets*, 126, e2020JE006777.
Prem, P., et al. (2022). *The Planetary Science Journal*, 3(7), 180.