FTIR STUDIES OF PLANETARY MATERIALS: THE IMPACT OF TEMPERATURE AND VACUUM ON SPECTRAL FEATURES

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Introduction:

-The **IRIS** (InfraRed spectroscopy for Interplanetary Studies) laboratory produces spectra for a database for the ESA/JAXA BepiColombo mission to Mercury [1].
-Onboard of BepiColombo is a mid-infrared spectrometer (MERTIS-Mercury Radiometer and Thermal Infrared Spectrometer) to map spectral features in the 7-14 µm range (spatial resolution ~500 m) [2-5].
-These infrared spectra allow determining the mineralogical compositions of the surface.
-Temperature and pressure have an effect on mid-infrared spectra [e.g., 5-7].
-Therefore, we conducted studies of samples in our collection under simulated hermean surface conditions.

-Here we present the spectra of the finest size fraction (<25 µm) of forsterite, enstatite, and labradorite.
-Of particular interest are the Christiansen Feature (CF) (a reflectance low), the Transparency Feature (TF), typical for the finest particles, and the Reststrahlenbands (RBs), representing the molecular 'fingerprint` of the materials.

Samples and Techniques:

-We choose natural samples of forsterite (ID 249), enstatite (ID 53) and labradorite (ID 28) to cover common minerals in remote sensing.

-Analyses were made using a Bruker VERTEX 70v IR spectrometer at the IRIS (Infrared & Raman for Interplanetary Spectroscopy) laboratory in Münster with a Harrick heating stage in a Praying Mantis Diffuse Reflectance Accessory (Fig.1).
-We measured mid-infrared reflectance of mineral powders.
-Temperatures ranged from room temperature up to 723 K.
-The pressures are of the order of 10^{-3} Pa.

References:

[1] Benkhoff J. et al. (2020) Planetary and Space Science 58: 2-20. [2] Hiesinger H. et al. (2020) Planetary and Space Science 58: 144–165. [3] Stojic, A.N. et al. (2021) Icarus 357: 114162. [4] Reitze M.P. et al. (2021) EPSL 554: 116697. [5] Donaldson Hanna et al. (2017) Icarus 283: 326-342. [6] Reitze (2016) 19th EGU General Assembly, Abstract #17491 [7] Reitze et al., (2018) LPSC XLIX, Abstract #1983

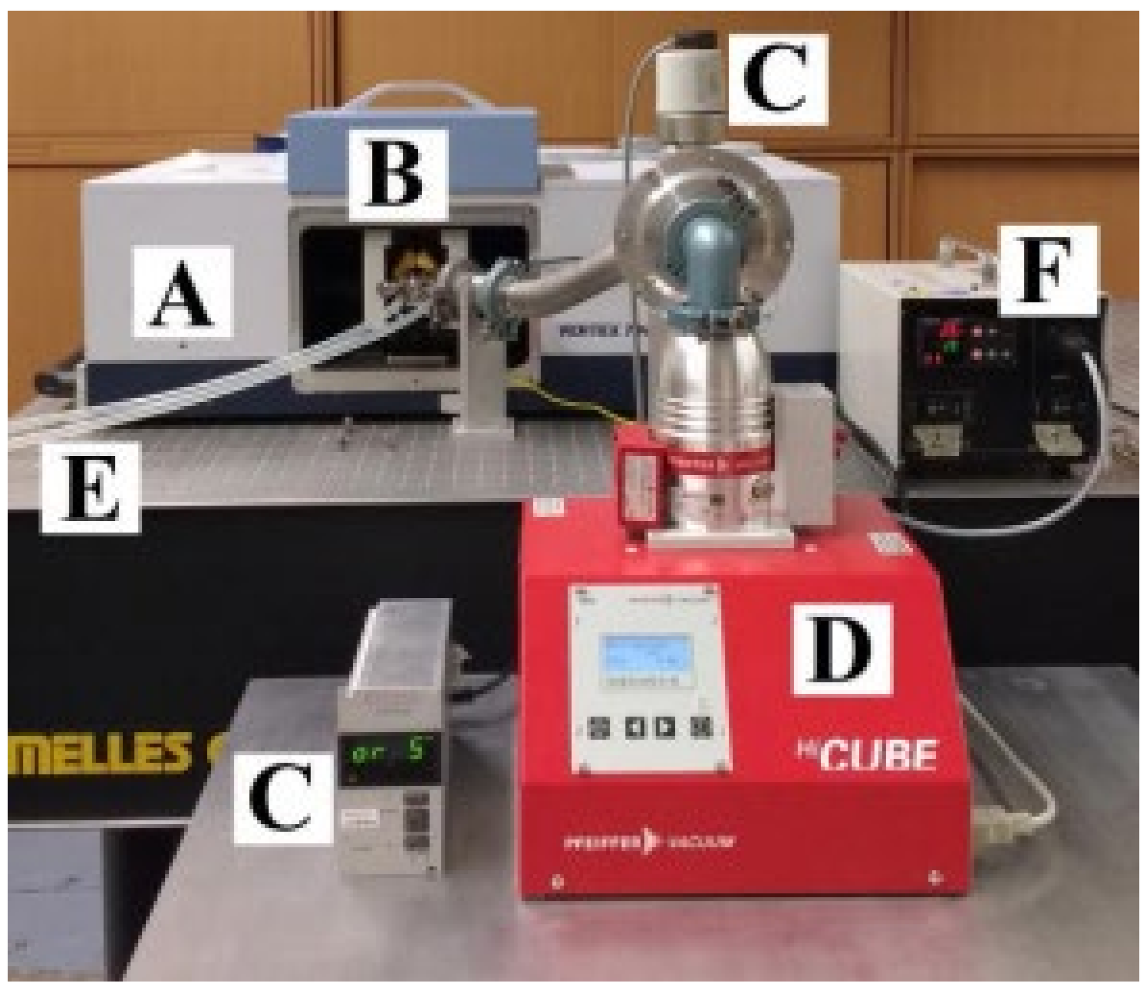

Fig.1: The Harrick Heating Stage and Praying Mantis set-up in the IRIS lab in Münster. (A) Spectrometer with detector; (B) Praying Mantis with sample chamber; (C) Vacuum gauge head and corresponding controller; (D) Vacuum pump; (E) Flexible tubes for water cooling system, which cools the housing of the sample chamber; (F) Heat controller.

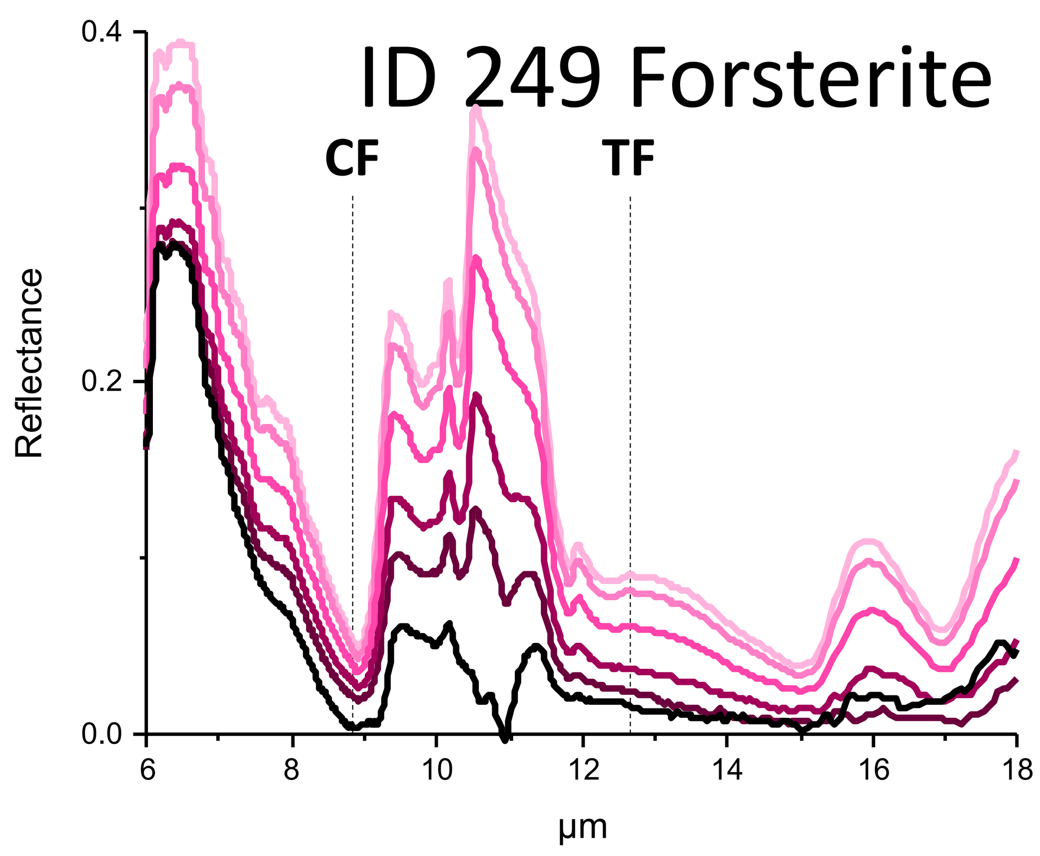

Fig.2a: Mid-infrared reflectance spectra of forsteritic olivine (ID 249) obtained under temperatures from 24°C (bright) to 350°C (dark). CF: Christiansen Feature, TF: Transparency Feature.

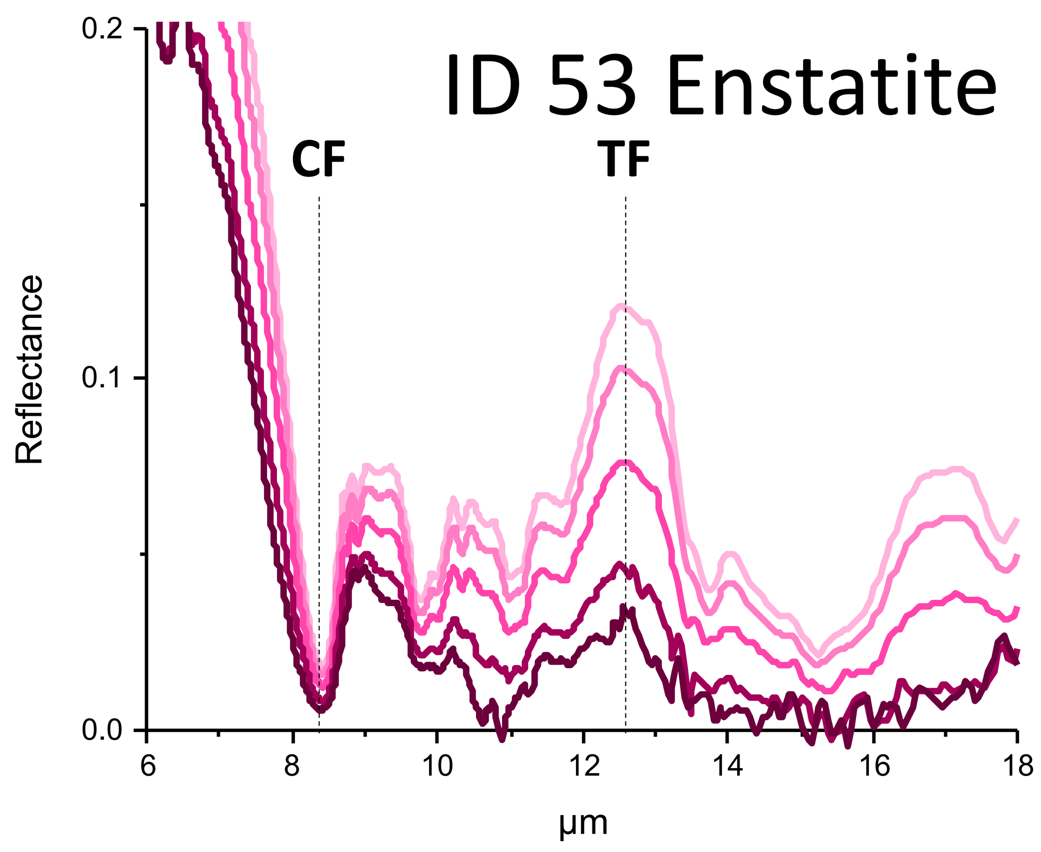

Fig.2b: Mid-infrared reflectance spectra of enstatite (ID 53) obtained under temperatures from 24°C (bright) to 400°C (black). CF: Christiansen Feature, TF: Transparency Feature.

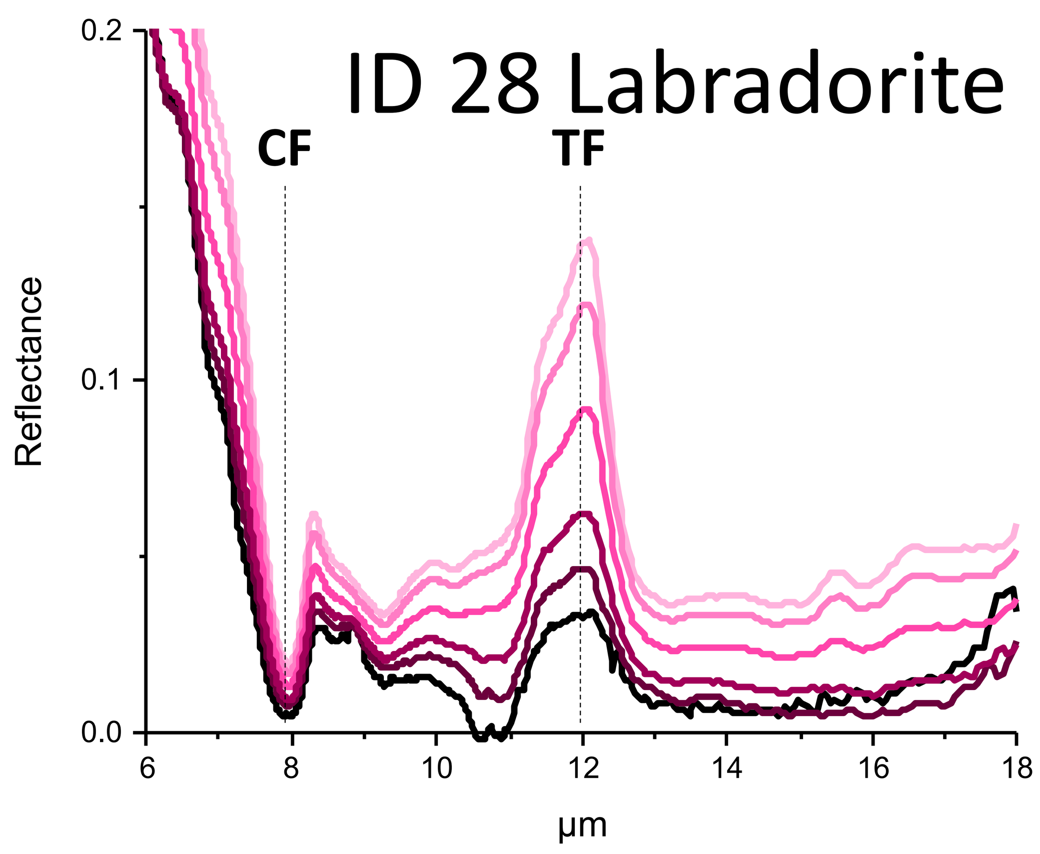

Fig.2c: Mid-infrared reflectance spectra of labradorite (ID 28) obtained under temperatures from 24°C (bright) to 400°C (black). CF: Christiansen Feature, TF: Transparency Feature.

Results:

-At temperatures over 400°C, spectra show high noise and were omitted (Fig.2a-c).

-Forsterite (Fig.2a)

-For the forsterite (ID 249), the CF shifts from 8.91 µm at room temperature to 8.77 µm at 400°C. Similarly, the TF shifts from 12.96 µm to 12.55 µm. The shift of the RBs varies, with a clear shift of the 9.35 µm feature to 9.53 µm. The strong RB at 10.59 µm also shifts, but at temperatures over 300°C an inflection appears in the 10.5 µm-11.0 µm range, which increases in intensity with temperature, and which is also observed in the other samples.

-Enstatite (Fig. 2b)

Similar, enstatite (ID 53) has the CF shifting from 8.41 µm (24°C) to 8.31 µm (400°C), while the determination of the exact position of the TF at higher temperatures was not possible. Of the RBs, the feature at 8.8 µm (24°C) shifts to 8.9 µm (400°C).

-Labradorite (Fig.2c)

Labradorite (ID 28) shows only a small shift of the CF (7.96 µm to 7.93 µm at 350°C), while the TF moves significantly from 12.09 µm to 11.94 µm at 350°C.

-Discussion

The heated sample itself emits. This emitted radiation is partly scattered into the interferometer, modulated, and back directed to the sample.
-This causes a complex superposition of detected signals. Therefore, intensities of the signal are affected, resulting in a decreasing intensity with increasing temperature [5-7].

Summary and Conclusions:

-Our ongoing work using a heating and vacuum set-up in reflectance provides a fast method to investigate the spectral behaviour of minerals und realistic planetary conditions.
-However, the impact and mitigation of potential artefacts requires future attention. For general studies and investigation of parameters (e.g., shift of band positions) the technique shows promise.