DATA PROCESSING FOR SPACE MISSIONS: MID-FTIR REFLECTANCE MEASUREMENTS OF MINERAL MIXTURES. I. Weber[1], M.P. Reitze[1], A. Morlok[1], M. Heeger[2], T. Adolphs[2], K.E. Bauch[1], H. Hiesinger[1], A.N. Stojic[1], H. F. Arlinghaus[2], J. Helbert[3], [1]Institut für Planetologie (IfP), Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany (sonderm@uni-muenster.de); [2]Physikalisches Institut, Westfälische Wilhelms-Universität, Wilhelm-Klemm-Str. 10, 48149 Münster, Germany; [3]DLR, Institut für Planetenforschung, Rutherfordstr. 2, 12489 Berlin, Germany.

Introduction: Fourier-transform infrared spectroscopy (FTIR) is very common in space exploration, e.g., the VIRITS instrument on the Rosetta and the VIR instrument on the DAWN mission. In addition, the BepiColombo mission [1], launched in 2018, also contains a thermal infrared imaging spectrometer combined with a radiometer - the MERTIS instrument [2], which will investigate the spectral surface features of Mercury in the 7 µm – 14 µm range, with a pixel scale of about 500 meters.

In the Infrared and Raman for Interplanetary Spectroscopy (IRIS) laboratory at the Institut für Planetologie (IfP) in Münster we acquire spectra of a variety of materials. These are typical rock-forming minerals such as pyroxenes, olivine, and feldspar, as well as mixtures of them. We investigate meteorites, terrestrial rocks and impact rocks as well as experimentally produced glasses. The purpose of our studies is to generate a mid-IR reflectance database for space missions.

Here we present results *(a)* of the measurements of minerals – particularly of their mixtures – at different phase angels in order to simulate different orbital geometries. These investigations can be used directly for a program of data deconvolution [3,4], which is based on a spectral unmixing code.

Furthermore, we investigated the influence of space weathering (SW) *(b)*, which is typical for planetary objects without an atmosphere. Micrometeorite bombardment as one possible source of SW [5] was simulated with an 193 nm ArF UV excimer laser.

Samples and Techniques:

Samples: For the present study olivine (Ol=Fo_{91}) from Dreiser Weiher, Germany, and pyroxene (Px=En_{87}) from Bamble, Norway, were used to prepare a whole range of mineral mixtures starting with 100 weight percent olivine (Olivine 100), follow up with a mixture of 85 wt.% Ol and 15 wt.% Px (Ol85/Px15), Ol70/Px30, Ol50/Px50, Ol30/Px70, Ol15/Px85, ending with 100 wt.% pyroxene (Pyroxene 100).

Before starting the mixing process single minerals were ground in a steel mortar and a grain size fraction from 63 µm to 125 µm was used for subsequent IR measurements.

Techniques: - Light microscopy: A polarized light microscope was employed to determine the purity of the minerals.

- Electron microscopy: Sample characterization and quantitative analyses have been investigated using a JEOL JXA-8530F Hyperprobe electron probe micro analyzer (EPMA) equipped with five wavelength dispersive spectrometers (WDS) at the Institute for Mineralogy in Münster.

- IR spectroscopy: FTIR analyses of bulk powders were made with a Vertex 70v spectrometer at the IRIS laboratory in Münster. Analyses of all samples and mixtures were made with an A513 variable mirror reflectance stage at 13°(i) and 13°(e), 20°(i)/30°(e), and 30°(i)/30°(e), where (i) is the incident and (e) the emergent angle. Each powdered fraction was placed in an aluminum cup (diameter 10 mm, depth 2 mm). 512 scans were accumulated in order to achieve a high signal-to-noise ratio. A commercial diffuse gold standard (INFRAGOLD^{TM}) was used for background calibration. For SW experiments we placed pressed powder pellets in a Harrick Reaction Chamber to irradiate it in high vacuum. Therefore, the minerals and mixtures were covered with a custom-made dome for the measurements before and after irradiation.

- Irradiation experiments: The laser experiments were done with an excimer laser at the Physikalisches Institut in Münster. The laser beam hit the sample surface once it passes a MgF_2 window installed on top of the dome. The material was irradiated with an energy density of 2.45 J/cm^2 for each 10 ns pulse with 3 shots per point with a sample spot of ~ 0.2 mm^2 in focus. In order to achieve complete coverage of irradiation the sample was manually moved across the laser beam in discrete steps.

Results and Discussion:

(a) IR spectra generated at different phase angles in an A513 variable mirror reflectance stage of Ol 100, Px 100, as well as of mixtures with 85/15, 70/30, 50/50, 30/70, and 15/85 (in weight %, grain size fractions: 63 µm – 125 µm) are presented in Figure 1. Olivine (Olivine 100) and pyroxene (Pyroxene 100) show characteristic Christiansen Features (CF) and Reststrahlen bands (RB) for these silicates [6, Fig. 1]. The Ol85/Px15 sample shows a small, the Ol70/Px30 mixture develops a significant blue shift of the CF compared to the pure samples. Furthermore, a new RB shoulder at 9 µm and a peak splitting of the original Olivine 100 RB at 10.6 µm is evident. The RB shoulder at 11.3 µm appears as a separate RB feature. The characteristic pyroxene CF of the Ol30/Px70 and Ol15/Px85 mixture is shifted to longer wavelengths, which is similar to the original pyroxene RB at 10.4 µm with a red shift to 10.5 µm. Generally, the intensity of the reflectance decreases from olivine and olivine-rich mixtures to pyroxene and pyroxene-rich

mixtures. Additionally, it is remarkable that the olivine-rich mixture exhibits rather more of olivine reflectance features, contrary to pyroxene-rich mixture. When considering the phase angle, it is noticeable that smaller angles show higher and larger angles show smaller intensities. (Fig. 1)

(b) Results of IR investigations in vacuum of the mineral mixture ID 136 Ol30/Px70 before and after laser irradiation show equal CF and RBs as measurements made with an A513 (comp. *(a)*). But, although the Px content is higher the significant Ol RB feature at 10.6 µm is still dominant. After irradiation the RB between 10.5 µm and 11 µm is controlled by pyroxene. This can be a hint that pyroxene is more sensitive to SW induced by excimer laser bombardment compared to olivine. The samples are comminuted by pressing the pellets for laser bombardment, visible by the transparency feature (TF) in the IR spectra made before irradiation (Fig. 2). After irradiation the TF disappears. The absence of this feature indicates a renewed grain coarsening. Obviously, the darkening (Fig. 2) of the irradiated sample is an effect of agglutination, especially of the pyroxene.

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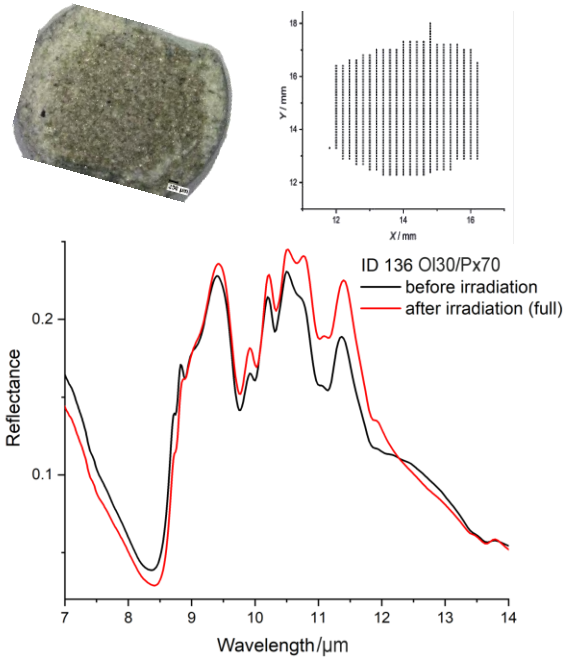

Fig. 2: Top left: Image of the sample surface of the mixture ID 136 Ol30/Px70 after irradiation with an energy density of 2.45 J/cm^2 for each 10 ns pulse with 3 shots per point. Top right: Spatial distribution of shots.
Bottom: IR reflectance spectra in the wavelength range from 7 – 14 µm of olivine (Ol) and pyroxene (Px) mixing ratio 30/70 before (black) and after irradiation (red).

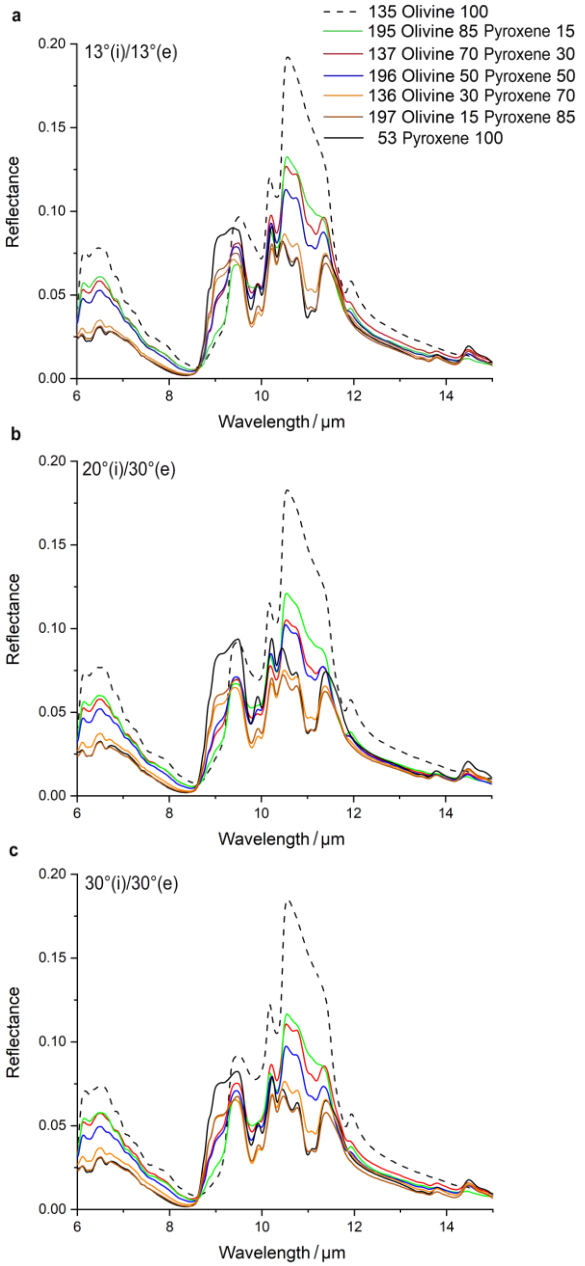

Fig. 1: IR reflectance spectra in the wavelength range from 6 µm – 15 µm.
Plotted are the pure samples Ol 100 black dashed and Px 100 black and the mineral mixtures Ol85/Px15 green, Ol70/Px30 red, Ol50/Px50 blue, Ol30/Px70 orange, and Ol15/Px85 brown.
a) Measurements at angles 13°(i) and 13°(e).
b) Measurements at angles 20°(i) and 30°(e).
c) Measurements at angles 30°(i) and 30°(e).

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