ON THE EFFECT OF EMERGING ANGLE ON EMISSIVITY SPECTRA: APPLICATION TO SMALL BODIES. A. Maturilli[1], J. Helbert[1], M. D'Amore[1], S. Ferrari[1], [1]Institute for Planetary Research, German Aerospace Center DLR, Rutherfordstr. 2, 12489 Berlin, Germany – alessandro.maturilli@dlr.de

Introduction: Dependence of laboratory measured emissivity spectra from the emerging angle is a subject that still needs a lot of investigations to be fully understood. Most of the precedent works are based on measurements of flat, solid surfaces (mainly metals) and they are not easily usable for the analysis of remote sensing data. Especially small bodies (c.f. asteroid Itokawa, the target of JAXA Hayabusa mission) have a very irregularly shaped surface, hence the spectra from those regions are very difficult to compare with laboratory spectra, where the observing geometry is always close to "nadir".

At the Planetary Emissivity Laboratory (PEL) of the German Aerospace Center (DLR) we have set-up a suite of measurements to investigate this problem, by dividing the experiment in 4 separate sessions. As a first step, we measured emissivity for the same quartz sample shaped in 5 different ways: flat, oblique, concave, waves, and "fairy castle" configuration. Those measurements were performed in air, at moderate sample temperature (150°C).

Then we measured emissivity of two endmembers and their binary mixture (50% each in volume) in air, at moderate sample temperature (150°C), for a very small emerging angle (2.3°), for the smaller (<25µm) and the larger (125-250µm) of our typical grain size fractions. Successively, we measured the emissivity of two (very different in color and grain size) endmembers and their binary mixture (50% each in volume) in vacuum at moderate temperature (100°C as typical of asteroid daily temperature), for 0°, 5°, 10°, 15° emerging angles. The last experiment, still undergoing, consists of measuring two asteroid analog materials (meteorite Millbillillie and a synthetic enststite) in vacuum, at a typical near-earth asteroid dayside temperature (100°C), for emerging angles 0°, 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°. Complementary reflectance measurements were taken for all the experiments.

Experimental set-ups: At PEL we use two instruments equipped with external chambers to measure emissivity. The Bruker VERTEX 80V Fourier Transform Infrared-Spectrometer (FTIR) can be operated under vacuum to remove atmospheric features from the spectra. An external evacuable chamber is used to measure emissivity: it contains a motor-driven carousel for up to 12 samples in the same working session, thermal sensors for each sample and a webcam for monitoring the activities inside the chamber. Induction heating system allows to heat up the samples (in stainless steel cups) from 50°C to higher than 800°C. Bruker A513 accessory is used to obtain biconical reflectance with variable incidence angle *i* and emission angle *e* between 13° and 85° at room temperature, under purge or vacuum conditions, in the 1 to 100 µm spectral range.

The Bruker IFS 88 FTIR spectrometer has an attached emissivity chamber for measurements at low to moderate temperatures [1, 2], that can be cooled down to 0° C. Samples can be heated from room temperature to 150°C in a purging environment. A Harrick SeagullTM variable-angle reflection accessory allows measurement of the biconical reflectance at room temperature, under purging conditions in the extended spectral range from 0.4 to 55 µm, for *i* and *e* from 5° to 85°.

For the measurements in air and in vacuum with small emerging angles (<15°, first three experiment described above) we used aluminum wedges (see Figure 1), for the measurements in vacuum with all the emerging angles from 0° to 80° (step 10°) we used custom-designed stainless steel wedges.

Figure 1. Aluminum wedges with 5° and 10° degree inclination.

Emissivity vs emergence angle: Figure 2 shows emissivity for the same quartz sample whose surface was shaped in 5 different modes. Appreciable changes can only be observed in the Reststrahlen region (8-10µm) and in the region below 5µm. Those results are very close to the one obtained in [3].

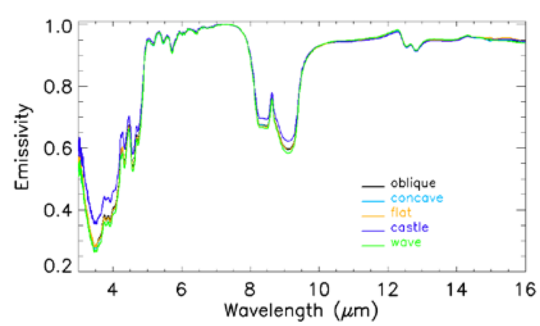

Figure 2. Quartz 45-63µm sample with 5 surface shapes.

In Figure 3, we show the results of the second experiment. From this set of data we can conclude that in air, for low inclination angles (2.3°) no significant differences are observed between plane and inclined spectra. Surface scattering effect seems to influence more the larger grain size separates.

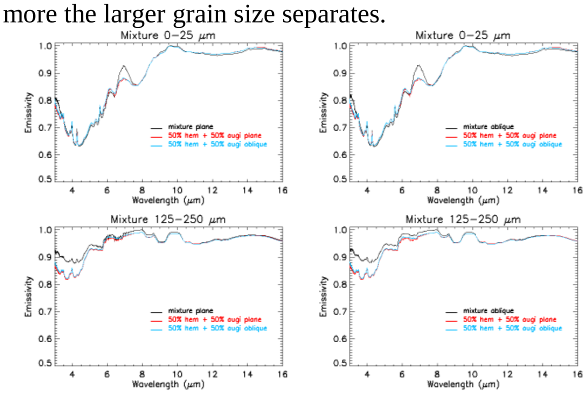

Figure 3. Deconvolution of a binary mixture (upper <25μm, lower 125-250μm) by using plane and inclined measurements.

Even when increasing the inclination angles in vacuum, the spectra still are not showing differences. We measured the endmembers and the mixture at 0°, 5°, 10°, 15° inclination and we could hardly see a change in the spectra.

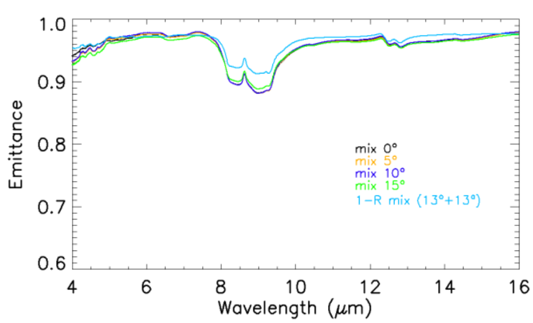

Figure 4. Emissivity of a binary mixture with increasing inclination angles.

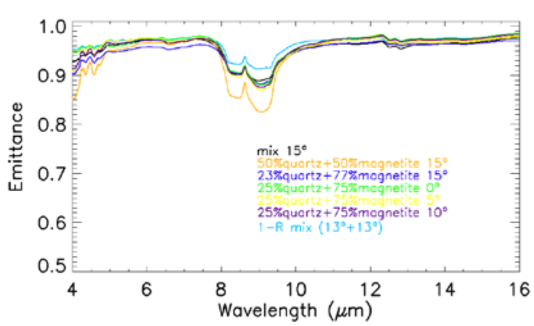

Figure 5. Deconvolution of a 15° inclined binary mixture by using endmembers measured with increasing inclination angles.

This is confirmed from the deconvolution we show in Figure 5, showing that we get the same results from linear deconvolution when using the 0°, 5°, 10°, or 15° inclined endmembers. In this case the linear deconvolution method shows its limit, because we mixed a bright material having deep and intense spectral features with a dark and spectrally flat one; the grain sizes were also different, so instead of finding a 50%+50% composition, the linear deconvolution algorithm provides results around 25%+75%.

Summary: The PEL laboratory is already providing emissivity measurements for asteroid analogs in view of future space missions to asteroids [4]**.** To understand the influence of emerging angles on emissivity spectra we built up a series of experimental measurements. We found spectral variations in the emissivity of the same quartz sample whose surface was shaped in 5 different ways. We measured emissivity in air and in vacuum, for surface temperatures close to asteroids daily temperature, and we found that for small emerging angles (<15°) the spectra still show no significant differences. This result is already important because it means that for quasi-flat surfaces the analysis of remote sensing emissivity spectra can be succesfully carried on with laboratory spectra with 0° inclination. We are currently performing the last set of measurements, in vacuum and at 100°C surface temperature for two asteroid analogs with inclination angle from 0° to 80° with a 10° stepping Figure 6).

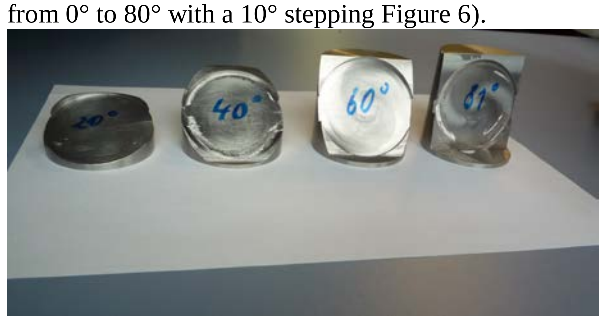

Figure 6. Some of the wedges that will be used to measure inclined emissivity of asteroid analog samples.

References: [1] Maturilli A. et al. (2006) *PSS*, **54**, 1057. [2] Maturilli A. et al. (2008) *PSS*, **56**, 420. [3] Wald A. E. and Salisbury J. W. (1995) *JGR*, **100**, 24665–24675. [4] Maturilli A..et al. (2014), *LPS*, XXXXV, this meeting.