Mid-Infrared Reflectance Studies of Carbonaceous Chondrites and their Components. A. Morlok[1], B. Schiller[1], I. Weber[1], M. Melwani-Daswani[2], A.N. Stojic[1], M.P. Reitze[1], T. Gramse[1], S.D. Wolters[3], K.E. Bauch[1], H. Hiesinger[1], M.M. Grady[3,4], J. Helbert[5] [1]Institut für Planetologie, Wilhelm-Klemm Str. 10, 48149, Germany (morlokan@uni-muenster.de),[2]Jet Propulsion Laboratory, California Institute of Technology,[3]School of Physical Sciences, Open University, Milton Keynes MK76AA, UK, Dept.,[4]Earth Sciences, The Natural History Museum, London, UK, [5]Institute for Planetary Research, DLR, Rutherfordstr. 2, 12489 Berlin, Germany

Introduction: Infrared spectroscopy is a method to investigate the surface mineralogy of planetary bodies. The mid-infrared range (here 2 µm-18 µm) is of particular interest owing to the wealth of spectral features of silicates in this region [1,2].

For the interpretation of remote sensing data, laboratory spectra are necessary. In this study, we present laboratory data for a series of size fractions of bulk carbonaceous chondrites (C4-C2). In addition, mid-infrared spectra from Calcium-Aluminum-Rich Inclusions (CAIs) from micro-FTIR analyses are presented.

The results are part of an ongoing effort to create a data base for the ESA/JAXA BepiColombo mission to Mercury [3,4], but will be also of particular interest for the comparison with spectra from primitive asteroids. Here, for the first time, spatially resolved mid-infrared data is available from two asteroids recently visited by space probes, 162173 Ryugu (Hayabusa2) [5] and 101955 Bennu (OSIRIS-REx) [6].

Samples & Techniques:

Bulk carbonaceous chondrites: We selected five carbonaceous chondrites (CC) for bulk powder analyses: HaH280 (CK4), Allende (CV3), Murchison and NWA10574 (CM2), and ungrouped C2 Tagish Lake, of which always at least 1 g of the sample was crushed and sieved into size fractions: 250 µm-125 µm, 125 µm-63 µm, 63 µm-25 µm and <25 µm. FTIR Analyses of the size fractions were made using a Vertex 70v at the IRIS laboratory, Westfälische Wilhelms-Universität of Münster, using a non-specular geometry (20°incidence; 30° exit angle) after calibration on a diffuse gold standard. Each spectrum is a mean of 512 scans.

Micro-FTIR studies of CAI: Four polished blocks of CAIs in Allende (CV3), Ornans (CO3) and Vigarano (CV3) [7] were analyzed in-situ using a Perkin Elmer AutoIMAGE FTIR microscope at The Natural History Museum in London. Aperture size ranged from 20 µm to 100 µm, a gold mirror was used for calibration. 50 scans were added to calculate a mean for each spectrum.

Results: *Bulk carbonaceous chondrites:* CK4 HaH280, CV3 Allende, and CM2 chondrite NWA10574 show spectra dominated by forsterite and pyroxene features (Fig.1) [8,9]. For example, the CF (Christiansen Feature; reflectance minimum) of Allende is at 9.2 µm- 9.3 µm. The strongest RB (Reststrahlenband) is at 11.1 µm-11.3 µm. The TF (Transparency Feature; characteristic for the smallest size fraction) is located at 12.6 µm.

Murchison CM2 and the ungrouped C2 Tagish Lake (Fig.1) show mainly phyllosilicate features [10,11]. In Murchison, the strongest RB is around 10.5 µm – 10.6 µm. A broad TF is superposed by bands from 10.8 µm - 12.3 µm, the CF is at 8.6 µm - 8.7 µm. In Tagish Lake, the CF ranges from 11.2 µm - 12.1 µm. The strongest RB is at 9.8 µm, and the CF ranges from 8.9 µm-9.0 µm.

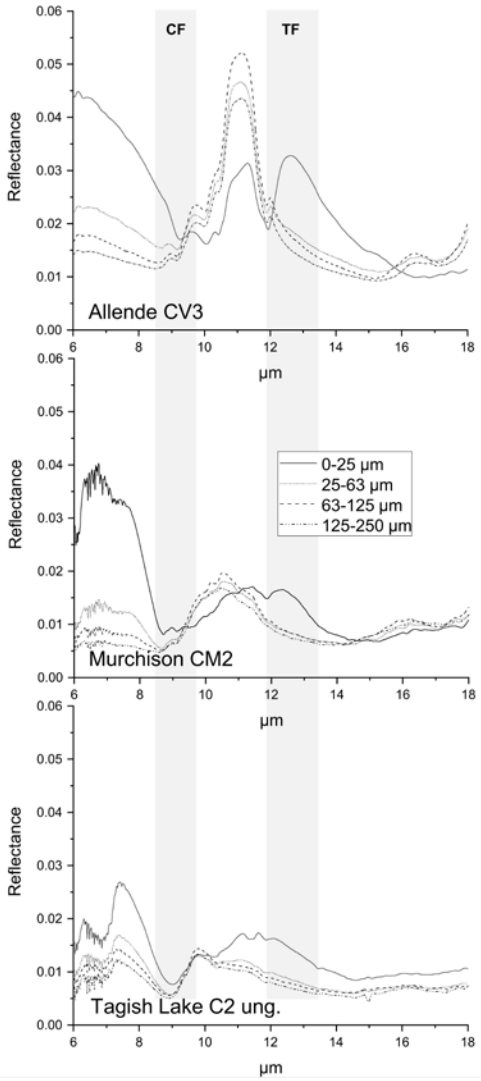

Fig.1: Mid-infrared spectra of bulk size fractions. CF=Christiansen Feature, TF=Transparency Feature.

Micro-FTIR studies of CAI: Spectra of CAIs from Allende, Vigarano, and Ornans exhibit spinel bands from 14.1 µm - 14.3 µm [14]. Melilite was found in the Vigarano and Ornans samples with features between 11.7 µm and 12.4 µm. Nepheline and sodalithe features in alteration phases are around 14 µm in the Allende CAI (Fig.2).

Discussion: For comparison with remote sensing data from asteroids, spectra for the finest size fractions (<-25 µm) were turned into emissivity using Kirchhoff's law (Emission=1-Reflectance) (Fig.3). A comparison of the finest size fractions with remote sensing data of asteroids shows some similarity between a linear mixture of Allende and Murchison and the spectra of D-type asteroid 253 Mathilde [13].

Conclusions & Outlook: Mid-infrared spectra of size fractions from type 2 to 4 carbonaceous chondrites show only rough similarity to C and D-type asteroids. We recommend further investigation of diverse samples, but also effects such as space weathering [14,15] in order to derive mineralogical information from asteroid spectra.

Acknowledgments: B. Salas (Open University) assisted on the use of the Advanced Optimal Extraction software for Spitzer spectra. This work is based in part on observations made with the Spitzer Space Telescope, which is operated by the Jet Propulsion Laboratory, California Institute of Technology under a contract with NASA. This research utilizes spectra acquired by David W. Mittlefehldt, Richard P. Binzel, Beth E. Clark , and Takahiro Hiroi with the NASA RELAB facility at Brown University.

A.Morlok, I.Weber, A.N.Stojic and M. P. Reitze are supported by the DLR funding 50 QW 1302/1701 in the framework of the BepiColombo mission.

References: [1] Salisbury J.W. et al. (1993) *Icarus* **92**, 280-297 [2] Morlok A. et al. (2019) *Icarus* **324**, 86-103 [3] Helbert et al. (2007) *Adv. Sp. Res* **40**, 272-279 [4] Hiesinger H. et al. (2010) *Plan.Sp.Sci* **58**, 144-165 [5] Watanabe S. et al. (2017) *Space Sci. Rev.*, **208**,3–16 [6] Lauretta, D. S. et al.:(2017) *Space Sci. Rev*. **212**, 925–984 [7] Morlok A. et al. (2008) *MAPS* **43**, 1147–1160 [8] Hamilton V.E. (2000) *Jour.Geo.Res.* **105**, 9701-9716 [9] Lane M.D. et al. (2011) *Jour,Geo.Res.* **116**, E0810 [10] Michalski J.R. et al. (2006) *Jour.Geo.Res.* **111**, E03004 [11] Glotch T.D. et al. (2007) *Icarus* **192**, 605-622 [12] Fabian D. et al. (2001) *A&A* **37**3, 1125-1138 [13] Kelley M.S. (2007) LPSC XXXVIII, Abstract #2366 [14] Weber I. et al., EPSL 115884, [15] Stojic A.N. et al. (2019) EPSC 2019, Abstract #521

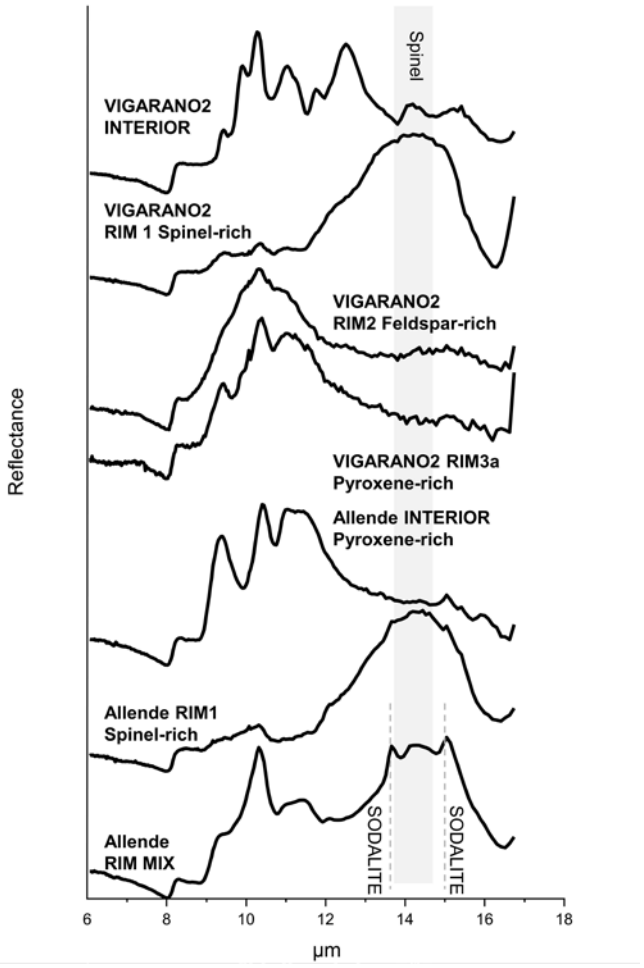

Fig.2: Spectra from micro-FTIR studies of parts in CAIs from Vigarano and Allende.

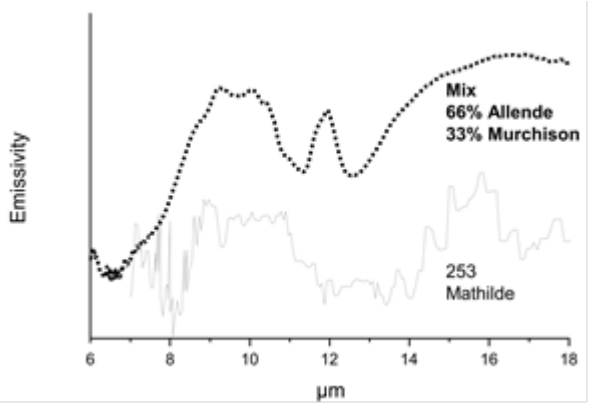

Fig.3: Comparison of a mixture of Allende and Murchison material to the Spitzer spectrum of asteroid 253 Mathilde (in emissivity).