INFRARED SPECTROSCOPY OF CIRCUMSTELLAR DUST: SIGNS OF DIFFERENTIATED MATERIALS ? A. Morlok[1,4], M. Köhler[2], M. M. Grady[3] [1]Department of Earth and Planetary Sciences, Faculty of Science, Kobe University, Nada, Kobe 657-8501, Japan <morlok70@kobe-u.ac.jp> [2]Institut für Planetologie, Wilhelm-Klemm-Str.10, 48149 Münster, Germany <koehlert@uni-muenster.de> [3]Planetary and Space Sciences Research Institute, The Open University, Walton Hall, Milton Keynes, MK7 6AA, England, UK M.M.Grady@open.ac.uk [4]Department of Mineralogy, The Natural History Museum, Cromwell Road, London SW7 5BD, UK.

Introduction: Thanks to the introduction of new telescopes, both on Earth (e.g. ESO) and space (SPITZER), much improved infrared data of dust in circmstellar and debris disk of young and evolved solar systems has become available recently. While much work is focussed so far on the evolution of pristine materials in the early phase of such objects, there is a growing amount of observations indictaing that dust is also produced in by collisional events and cascades, where already accreted bodies collide and produce a new generation of dust materials [1, 2].

Dust materials formed in such events comes from parent bodies where the original mineralogy was possibly changed by alteration processes like metamorphism, aqueous alteration and differentiation. So when astronomical infared data is compared with laboratory data for interpretation, a study of analogue materials which underwent similar changes in the early stages of our own Solar System could be of interest.

In this part of an ongoing infared study of both undiffertiated and differentiated planetary materials, we use infared spectra obtained from achondrites for this purpose. These are meteorites coming from differentiated bodies, in which the material was completely or mostly molten at one point and then recrystallized.

Relatively few infared studies of achondrites have been made, mostly with focus on remote sensing of planetary surfaces [e.g. 3]. For infared studies of dust material, usually absorbance spectra are used, and such studies of achondrites are rare [4, 5].

The astronomical spectrum used for comparison is that of the dust around HD179218. This is an an ~1.3My old Herbig Ae star, in its passive disk state, where accretion of planetesimals could take place [6]. The complex infrared spectrum shows several strong bands (Fig.1), interpreted as a mixture of mineral phases dominated by clinoenstatite [6].

Samples: To represent typical achondrites, a series of samples from the collection at the Natural History Museum was used: Hajmah (a) (Ureilite, BM1980.M19), Bishopville (Aubrite, BM20795), Nova 003 (Brachinite, BM1993.M11), Kapoeta (Howardite, BM1946.141), Juvinas (Eucrite, BM90262), Johnstown (Diogenite, BM1959.828).

Techniques: Bulk samples of a series of achondrites were ground with an agate mortar to a fine grained powder (grain size <1µm). To avoid effects of sample heterogeneity, always amounts larger than 50mg were used. About 1 mg of powdered material was mixed with KBr-powder and pressed to pellets using an evacuated pellet press at 10tons/cm^2.

The pellets were dried for three days at 100C to avoid absorption of water. Infared spectra were obtained using a Perkin Elmer SpectrumOne workbench, at a spectra resolution of 4cm^{-1}.

For the comparison with the astronomical spectra, the spectra were normalized on the same resolution and intensity in the range of interest. For mixing calculations, in several cases (Fig.1a, b) simple least square optimization routine was applied to obtain mixtures of laboratory spectra most similar to the astronomical spectrum.

Astronomical Spectra: The astronomical spectrum of HD179218 used for comparison was provided by R. van Boekel (Amsterdam/ESO). It was obtained using the *Thermal Infrared Multi Mode Instrument 2* TIMMI2 instrument at the La Silla ESO observatory [6].

Results: Spectra of mixtures from first preliminary calculations are presented in Fig.1a-f. The broad, grey vertical bars mark a 0.1µm range between strong features in the astronomical spectrum of HD179218 (Fig. 1g) and potential equivalent bands found in the laboratory data of this study. The thin black lines show features of the astronomical spectrum which have not been found in the meteorite spectra presented here.

Spectrum (a) is a mixture of 75% brachinite and 25% howardite. Ureilite dominates spectra (b) and (c), the latter is pure ureilite, while former is a mixture of 95% ureilite and 5% howardite.

Spectrum (d) contains 80% ureilite and 20% eucrite, (e) 70% ureilite and 30% aubrite. A mixture of equal amounts of aubrite, eucrite and brachinite is presented with spectrum (f).

The strong olivine band 1 at ~11.3µm has strong equivalents in all the meteorite spectra. The second strong band (band 2) at 10.6 µm is very weak in spectrum (a). While clearly visible in (b), (c) and (d), it is shifted for more than 0.1 µm compared to the astronomical spectrum. In spectra (e) and (f), the band has an intensity similar to band 1, like in the astronomical spectrum. The smaller band 3 at 9.8 μm is not visible in (a), and only a broader feature in (b), (c) and (d). Band 4 at 9.4 μm has equivalent features in (b)-(f), but occurs only as shoulder in spectrum (a). Band 5 at 8.7 μm possibly appears as weak shoulder in spectrum (f). Two further weak bands at 11.6 and 12.6 μm has no equivalent in the meteorite spectrum.

Discussion and Conclusion: Mixtures of materials from differentiated meteorites can provide good matches for the astronomical infrared spectrum of the circumstellar material of HD179218. Especially mixtures of ureilites and eucrites (e), as well as aubrites, eucrites and brachinites (f) provide spectra very similar to the astronomical observation.

Recent dating of achondrites show that the formation of differentiated meteorites took place very early in our Solar System: Ureilites formed about 1-2My, howardites, eucrites and diogenites ~4.2My after formation of the Solar System [7, 8]. This overlaps with the estimated age of HD179218, about 1.3My [6]. Given a comparable timing of events and environment in our early Solar System and HD179218, the comparison of the infrared spectra could indicate the occurrence of differentiated material in the dust material of this evolving solar system.

This is, however, a simplified picture of the situation. Physical parameters like grain size or temperature effects have to be taken into account, as well as the occurrence of processed, but not yet accreted materials [6]. Also, future work will include more complex mixtures, including further differentiated and also chondritic materials.

References: [1] Okamoto K. O. et al. (2004) *Nature*, *431*, 660–663. [2] Bouwman J. et al. (2005) *A&A*, *401*, 577–592. [3] Salisbury J. W. et al. (1992) *Icarus*, *92*, 280–297. [4] Sandford S. A. (1984) *Icarus*, *60*, 115–126. [5] Sandford S. A. (1993) *MAPS*, *28-4*, 579-585. [6] Van Boekel R. et al. (2005) *A&A.*, *437*, 189-208. [7]Lee D.- C. et al. (2005) *LPS XXXVI*, Abstract #1638. [8] Kleine T. (2002) *Nature*, *418*, 952-955.

Acknowledgements: We want to thank Roy van Boekel for providing the spectrum of HD179218. The spectrum is based on observations made with ESO Telescopes at the La Silla or Paranal Observatories under programme ID 68.C-0536 and 70.C-0533

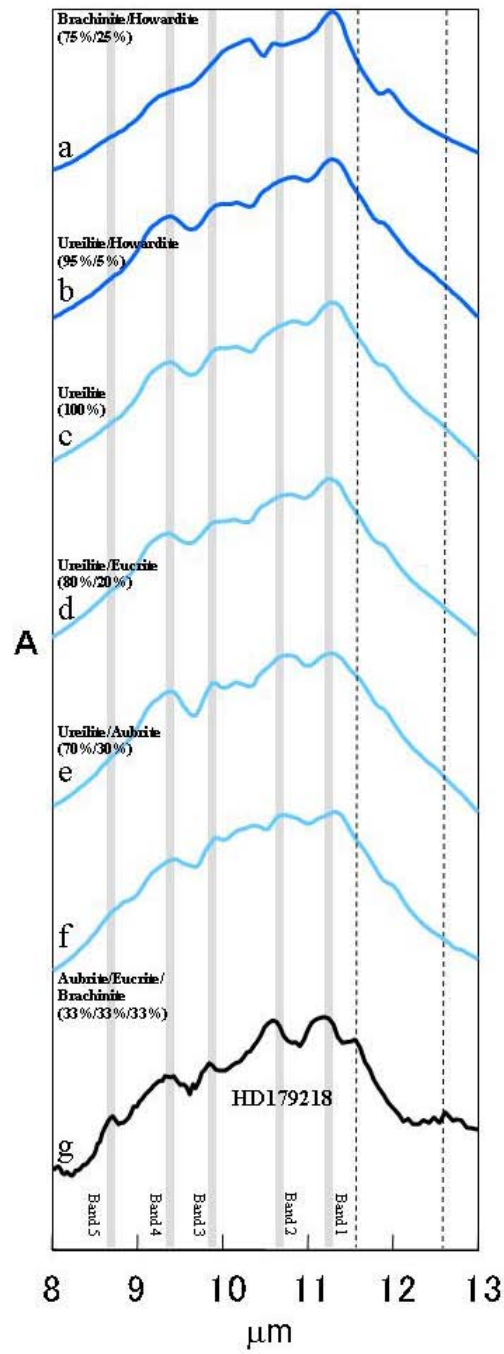

Fig.1a-g. Spectra of differentiated meteorites (a)-(f) (in brackets percentages of specific meteorites in calculated mixtures of different spectra). (a) and (b) are mixtures calculated using a least square routine. For comparison, the astronomical spectrum of HD179218 (g). When single spectra or binary mixtures are used, spectra dominated by Ureilites show a good similarity to this astronomical spectra (b)-(e). A mixture of three different types of achondrites (f) also gives a good result.