ABSORPTION SPECTRA (2-25 MICRONS) OF CARBONACEOUS CHONDRITES (CI, CM, CV AND CR): MINERALOGY AND “WATER” ABUNDANCE. P. Beck[1], A. Garenne[1], L. Bonal[1], E. Quirico[1] , G. Montes-Hernandez[2] and B. Schmitt[1], [1]UJF-Grenoble 1 / CNRS-INSU, Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) UMR 5274, Grenoble, F-38041, France, beckp@obs.ujf-grenoble.fr. [2]UJF-Grenoble 1 / CNRS-INSU, Institut des Sciences de la Terre (IsTERRE)

Introduction: Carbonaceous chondrites are typically mixture of minerals, metals and organic compounds. Although they are considered as amongst the most primitive solar system samples, asteroidal processes are recorded in their mineralogy. Metamorphic events have been described (short and long duration) as well as secondary minerals formed by interaction with a water-rich fluid [1-2]. During the aqueous alteration episode, water was incorporated within hydrous minerals, “stabilized” and made deliverable within the inner part of the solar accretion disk [3].

Our objective here is to have a quantitative understanding of the infrared spectra of carbonaceous chondrites, to help in constraining astronomical observations of asteroids and cometary dust tails. We combine transmission IR spectroscopy (extinction spectra), providing information on the mineralogy and mineral phase hosting water, to water quantification using thermogravimetric analysis (TGA).

Methods: Transmission spectra have been obtained on a series of 17 CM, 2 CR, 5 CV, 2 CI and 4 ungrouped C2 chondrites. In each case, about 30 mg of sample have been powdered, out of which 1 mg was extracted and diluted in KBr for IR measurement in transmission. Our dataset covers the 2 to 25 µm spectral range. For each sample, 3 measurements have been performed after heating the pellets successively to 25°C, 150°C and 300°C. Chunks of the same meteorites were also extracted and powdered for TGA analysis performed with TGA/SDTA 851e Mettler Toledo under the following conditions: sample mass of about 15 mg, platinum crucible of 150 µl, heating rate of 10 $°C.min^{-1}$, and inert N_2 atmosphere of 50 $ml.min^{-1}$. About 15 reference minerals were also analyzed as standards. In the case of one of the CR chondrite, a matrix-enriched portion of the sample was prepared and compared to a bulk rock fragment.

IR group systematic: The CR, CV, CM and CI chondrites show quite distinct spectra in the SiO_4 bending (~10 µm) and stretching regions (~20 µm) (Fig. 1). All spectra obtained on the CV meteorites are almost identical and reflect the dominance of olivine in their mineralogy. The CI samples show an asymmetric peak with a maximum located at lower wavelength than CV and CR. This is in agreement with the dominance of phyllosilicates in their mineralogy. In the case of the CRs, a broad 10-µm band is present, on top of which small peaks are observed. This type of 10-µm band can be interpreted as the combination of amorphous and crystalline silicates, but this interpretation might not be unique though.

Hydration signature at 3-micron: In almost all samples, hydration can be directly detected from the presence of a 3-µm band. The dataset obtained here using bulk samples diluted in KBr pellets confirms our previous results on raw matrix fragments [4], i.e. an evolution in band shape (maximum intensity and barycenter) with aqueous alteration. The intensity of the 3-µm band, when normalized to that of the SiO_4 bending at 10-µm, shows a fair correlation with the amount of water we derive from thermogravimetric analysis. This amount of water is well correlated with the aqueous alteration sequence defined by [5]. It is also clear that the so-called metamorphosed CM chondrites (MCM) have experienced a dehydration event as evidenced by a smaller 3-µm band and a lower amount of water contained in the samples.

The silicate feature (SiO_4 tetrahedron): As discussed before, the 10-µm region, where the SiO_4 tetrahedon modes are found, is quite distinctive from group to group. This region also shows a clear evolution with the extent of aqueous alteration for CI and CM, that is defined here by the amount of water contained in the sample. The heavily altered CI have a 10-µm band made of a single peak that is similar to that found for terrestrial saponite. With decreasing alteration degree a secondary peak at 11-µm increases, that can be attributed to an increase of the olivine content. The intensity of this secondary peak is greatly correlated to the intensity of the 3-µm band (the more intense the 3-µm band is the less intense the olivine peak, Fig. 2). This result suggests that the proportion of phyllosilicate can be easily estimated from the SiO_4 streching band.

Comparison to cometary dust: Similarly to what is done in the NIR between reflectance spectra of meteorites and asteroids, the transmission spectra obtained here can be compared to emission spectra measured on cometary dusts [6]. Under the hypothesis that the emitting grains are small with regards to wavelength, the emission spectra should be similar to the transmission spectra of a virtually identical material.

Of the 4 meteorites families studied here, only one shows a reasonable match with observations of cometary dust. This is the CR family for which cometary affinities have been proposed in the past. The spectra of the CR3 samples show a fair agreement with dust emission spectra from Tempel-1 [7].

Conclusion: The mineralogical diversity of carbonaceous chondrites is revealed through theire infrared signatures. Each group (CI, CV, CR, CM) appears to have an original silicate feature. The amount of water determined by TGA is related with spectrocopic signatures of water (the 3-µm band). Aqueous alteration extent, if defined by the amount of water, can be readily estimated by these two methods. The measurements of transmission spectra of carbonaceous chondrites make it possible to compare directly to fine-grained dust emission (i.e. comeraty tails, debris or accretion disks). In the case of Tempel-1 only one meteorite group shows a reasonable agreement, namely the CR chondrites. This does not imply that Tempel-1 dust is strictly identical to CR-like material but rather confirms the low abundance of phyllosilicates in cometary dust.

References: [1] Bonal L. et al. (2006), GCA 70, 1849-1863. [2] Brearley A.J. (2006) MESS II, Univ. of Arizona Press. [3] Ciesla F. and Lauretta D. (2005) EPSL 231, 1-8. [4] Beck P. et al., (2010) GCA 2010 74, 4881-4892. [5] Rubin et al. (2007) 71, 2361-2382. [6] Knacke R.F. and Krätschmer W. (1980) A&A 92,281-288 [7] Gicquel et al. (2012) A&A 542, A119.

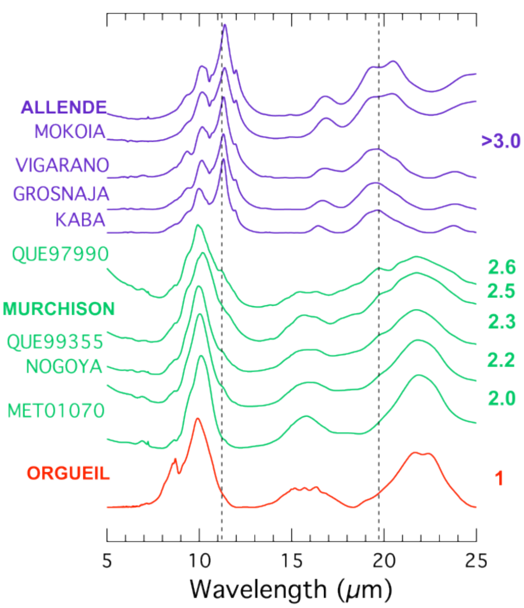

Figure 1: Transmission spectra of selected CI (red), CV (purple) and CM chondrites (green). The spectra of CV chondrites are dominated by olivine, while that of Orgueil by a saponite-like phyllosilicate. Mineralogy of CM chondrites is intermediate. The presence of the 11-µm feature appears correlated to the extent of aqueous alteration, as defined by the scheme proposed by Rubin et al. (2007).

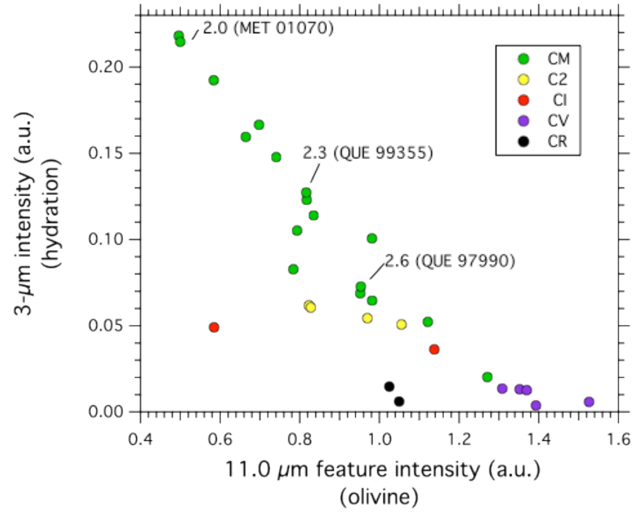

Figure 2: The 3-µm band intensity (normalized to the SiO_4 streching mode) as a function of the intensity of the olivine peak at 11-µm. An hydration-dehydration trend is present.

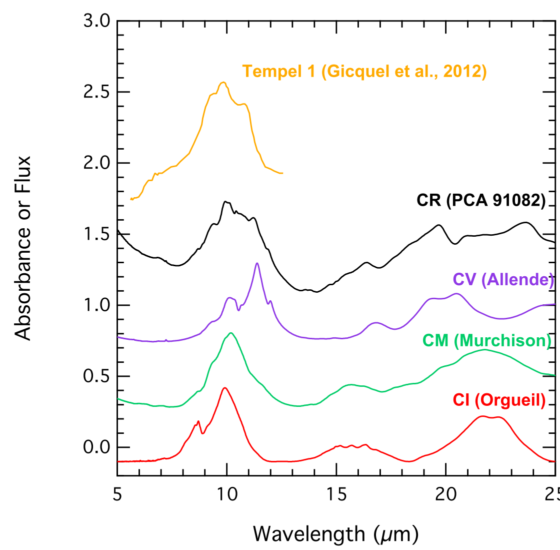

Figure 3: A comparison of the silicate features of carbonaceous chondrites and dust emission from comet Tempel-1 [7].