Far infrared spectroscopy of mineral particles

Tatiana Brusentsova[a], Robert E. Peale[a], Andy Nissinboim[b], Joseph Boesenberg[b], Julie Leibold[b], George E. Harlow[b], Denton Ebel[b], Karl Hibbitts[c], and Carey Lisse[c]
[a]University of Central Florida, Orlando, FL 32816 USA

[b]American Museum of Natural History, New York, NY 10024 USA
[c] Johns Hopkins University Applied Physics Laboratory, Laurel MD 20723 USA

***Abstract*—Mineralogical characterization and far-infrared spectroscopy of laboratory analogues in the wavelength range 57 - 210 µm is performed for interpreting data from Herschel's Photodetector Array Camera and Spectrometer (PACS).**

I. Introduction And Background

MINERAL dust is born in outflows and explosions of evolved stars, is modified during residence in the interstellar medium, matures in planet-forming disks around young stars, and eventually aggregates into solar-system bodies. In all these environments, dust is abundant and complex. The Herschel Space Observatory will collect new mineralogically-characteristic sub-mm wave emission spectra of various astrophysical dust populations. We are performing detailed mineralogical characterization and spectroscopy of laboratory analogues in the wavelength range 57 - 210 µm for interpreting data from Herschel's Photodetector Array Camera and Spectrometer (PACS). This work directly enhances the scientific return from the ESA Herschel mission, which will include the following targets: Supernova remnants and ISM material (crystalline fraction and composition); moderately processed cold crystalline dust around young and mature stars; cometary dust (trails, coma, comparison to ISM material); zodiacal light; late type AGB stars; "O or C stars"; early galaxies.

Unique and novel characteristics of this work include direct measurement of 1 - 250 µm sizes, use of the American Museum of Natural History (AMNH) mineral, rock, and meteorite collections for real physical analogues, detailed physical characterization of those samples, measurement of far-IR temperature dependent dust and icy dust properties and far-IR effects of crystalline disorder, followed by comparison to state-of-the-art Spitzer studies of primitive and circumstellar dust, and comparison to Stardust mission returned samples. The work additionally impacts NASA Spitzer program, and indirectly the data and sample returns from the NASA Discovery Deep Impact and Stardust missions. Moreover, the prepared samples are cross-referenced into other databases such as the RRUFF (a Raman and X-ray Diffraction database) project so that these standards can be broadly applied in the sciences. The samples (crystals, powders, and pellets) are available through the standard sample loan program at the AMNH.

Species investigated include those that have been identified in planetary nebulae, supernova remnants, circumstellar disks, comets, Stardust, stratospheric IDP samples, the Moon, Mars, asteroids, and meteorites, or which are expected theoretically from condensation models. These include carbonates, olivines, pyroxenes, feldspars, phyllosilicates, oxides, sulfides, and of special note, *water ice* composites of such minerals.

Specimens are selected from the AMNH collection. Grains are examined under a microscope to manually select those with similar appearance, morphology, and absence of inclusions. Where applicable, crushing is used to separate sample from inclusions, magnetic impurities are removed with a magnet, and calcite deposits are dissolved away in 1 M HCl. X-ray scattering analysis is performed on the selected and powdered samples to verify crystal structure. Individual grains are mounted and analyzed by X-ray microprobe to verify chemical formula and spatial distribution of cations with the goal of selecting homogeneous grains. Presence of impurities is noted. The powders are further ground using a micronizing mill to ~1 µm sizes, after which the grain size distribution is determined using a scanning electron microscope. Then the powders are dispersed into polyethylene pellets, their far-IR spectra collected, and mass absorption coefficients calculated and interpreted. Finally, results are disseminated.

II. Results

At this writing, the selection and physical characterization of the following minerals have been completed: Olivines (forsterite, fayalite, monticellite), Pyroxenes (enstatite, diopside, angite, jadeite, aegirine) Amphibole (grunnerite). The following minerals have been selected, sorted, with x-ray powder x-ray analyzed: Carbonates (calcite, vaterite, dolomite, siderite, magnesite, rhodochrosite), and Feldspar (abile, anorthoclase, sanidine, microcline, orthoclase, oligoclase, labradorite, bytownite). Fig. 1 presents a photograph of bytownite crystals selected for this work together with a typical record of provenance. Fig. 2 shows that micrograins of bytownite are apparently uniform and free of inclusions. However, x-ray scattering suggests the possible presence of additional minerals, mainly labradorite. Such information is important because chemical composition and crystal structure affect the phonon modes responsible for the characteristic far-IR spectrum.

978-1-4244-2120-6/08/$25.00 ©IEEE.

Fig. 1. Photograph of crystals of the Feldspar Bytownite with record of provenance.

Fig. 2. Microscope image of Bytownite micrograins showing uniform inclusion-free morphology.

As an example, we present representative phyllosilicate far-IR spectra. The presence of carbonates and phyllosilicates in Young Stellar Objects (YSOs) or comets is controversial [e.g., Ref. 1]. The figure presents spectra of the phyllosilicates montmorillonite and hectorite. The wavenumber range of the Herschel PACS instrument is indicated. Hectorite's distinct PACS-band line has no analog in montmorillonite, making them easily distinguishable. Moreover, the hectorite line occurs at slightly lower wavenumbers than similar features that we observe in carbonates, Fig. 4. For the latter we note differences in the line shape between commercial reagent calcite and crystals grown in the lab, and also large differences in the relative strength of similar lines for different phases. Fig. 5 presents the spectrum of amorphous ice with a prominent line in the PACS range, suggesting the importance of characterizing icy composites. All such information will be useful in fitting the anticipated data return from Herschel.

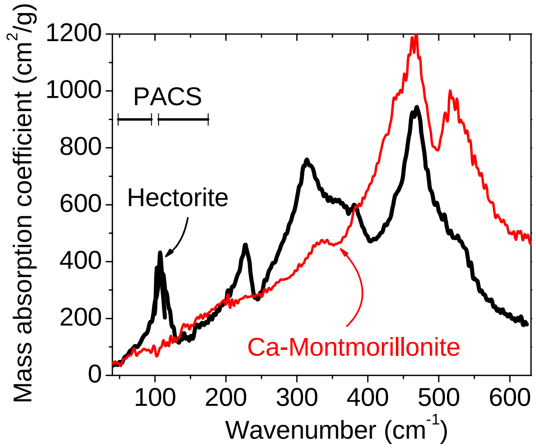

Fig. 3. Far-infrared spectrum of clay minerals showing strong differences in the spectral range of PACS.

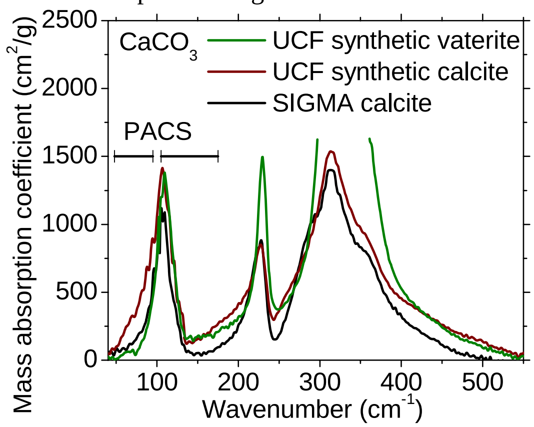

Fig. 4. Far-infrared spectrum of $CaCO_3$ phases vaterite and calcite.

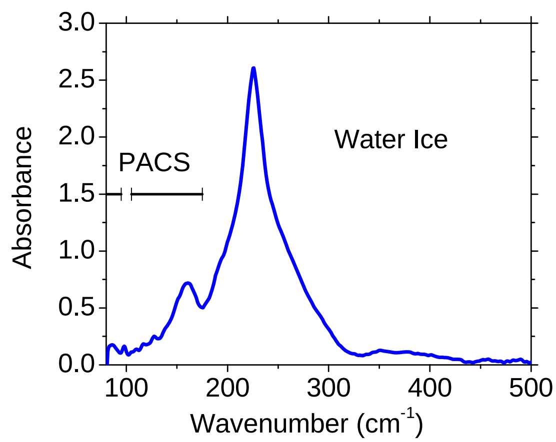

Fig. 5. Spectrum of amorphous ice at 80 K.

Reference

[1] A. Chiavassa, C. Ceccarelli, A. G. G. M. Tielens, E. Caux, and S. Maret, "The 90-110 μm dust feature in low to intermediate mass protostars: Calcite?," A&A 432, 547 (2005).

978-1-4244-2120-6/08/$25.00 ©IEEE.