MID- AND FAR-INFRARED SPECTROSCOPY AT THE ADVANCED LIGHT SOURCE. S. Bajt[1], G. A. Graham[2], J. Bradley[2], A. J. Westphal[3], A. L. Butterworth[3] and M. C. Martin[4], [1]Lawrence Livermore National Laboratory, 7000 East Avenue, L-395, Livermore, CA 94550, USA (bajt@llnl.gov), [2]Institute for Geophysics and Planetary Physics, Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, CA 94550, USA, [3]Space Sciences Laboratory, University of California at Berkeley, Berkeley, CA 94720, USA, [4]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA.

Introduction: Dust is an important constituent of the galaxy. Much of what we know about dust has been inferred from astronomical observations and from laboratory analysis of Interplanetary Dust Particles (IDPs), which are fragments of comets or asteroids collected in the Earth's stratosphere. In particular, infrared spectroscopy data of dust in space and of IDPs can be directly compared and matched with known mineral databases obtained in laboratories to deduce their chemical and mineralogical composition. We anticipate that in 2006 cometary dust particles collected during the recent successful encounter of STARDUST mission with comet Wild-2 will become available for study in the laboratory. In preparation we have formed the Bay Area Particle Analysis Consortium (BayPAC), whose main mission is to develop and investigate extraction and in-situ analysis techniques for cometary dust particles captured in aerogel. In this abstract we describe the efforts in improving and extending infrared spectroscopy techniques to analyze small particles.

It is likely that the Stardust particles will be on average about the size of typical IDP (few microns to few tens of microns) or even smaller. Due to their small size a very bright infrared source such as a synchrotron is needed to obtain their infrared spectra. The technique is being developed using IDPs, particles captured in aerogel on MIR space station, and particles obtained by crushing larger meteorite pieces or particular minerals. The research on individual IDPs using infrared microspectroscopy has been to date almost exclusively done at the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory [1,2]. Here we report data from the infrared microspectroscopy beamline at the Advanced Light Source (ALS) at Lawrence Berkeley National Laboratory where we have recently extended the capabilities to include the far-infrared (100-500 cm^{-1}) region. While mid-infrared spectroscopy is used to study organic functional groups, far-infrared spectroscopy is especially suitable for identifying silicates, sulfides and oxides.

Technique: The infrared microspectroscopy beamline 1.4.3. at the Advanced Light Source, LBNL has been used to measure IDPs and particles trapped in aerogel collected on the MIR space station. The beamline is equipped with a ThermoNicolet Magna 760 FTIR bench and a SpectraTech Nic-Plan IR microscope (Fig. 1).

Fig. 1: A photograph showing the setup with Nicolet 760 FTIR Bench on the left hand side and Nic-Plan IR Microscope in the middle.

The synchrotron source can be focused to a diffraction-limited spot size onto a sample, and then the reflected or transmitted light is measured. For the mid-IR this spot size is 3 to 10 microns in diameter (Fig. 2).

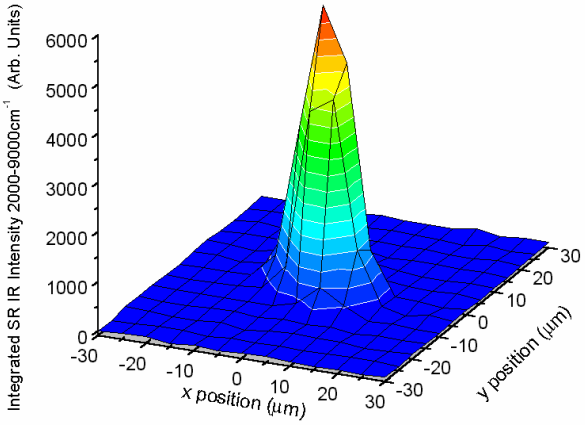

Fig. 2: Spot size in mid-infrared at ALS beamline 1.4.3. is 3 to 10 microns.

An MCT-A detector and KBr beamsplitter are used for mid-IR microspectroscopy. For the far-IR, we have modified the microscope by adding a sliding mirror which steers the light from the internal detector towards an external detector. We use a liquid helium cooled silicon bolometer (Infrared Laboratories) with

1000 cm^{-1} cut-on filter, and a solid silicon beamsplitter. This gives adequate performance covering the 100 – 700 cm^{-1} range, and the focused synchrotron spot size remains diffraction-limited (Fig. 3) with the beam size equal to 0.8 λ.

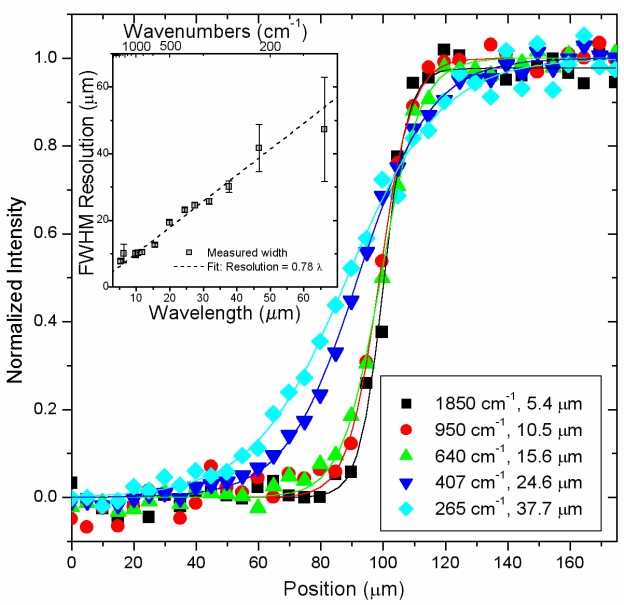

Fig. 3: Plot of the intensity as a function of position for five representative wavelengths. The sharpness of the measured edge allows the determination of the resolution. The measured resolution as a function of wavelength is shown in the inset.

Results: A limited number of IDPs, mostly TEM sections, have been measured in the mid- and far-infrared regions. Individual particles extracted from aerogel collectors from the MIR space station have been studied as well. Our preliminary results show that the particles extracted from aerogel always contain some aerogel residue, whose peaks overlap with the hydrocarbon peaks from chondritic material. A HF-vapor etching technique is being investigated to overcome this problem [3].

We obtained infrared data from an anhydrous IDP, *Benavente*. This particular IDP is of considerable interest because isotopic imaging with nanoSIMS showed a region enriched in ^{15}N and depleted in ^{13}C [4]. A FIB section from near the anomalous region was imaged using nanoSIMS prior to performing infrared spectroscopy analysis and high-resolution TEM imaging. Infrared spectroscopy data from the 3 x 10 micron FIB slice sandwiched between Pt and Au layer show a prominent C-H stretch feature at ~ 3.4 μm, characteristic of hydrocarbon (Fig. 4). The positions of the bands within the feature are consistent with those of aliphatic hydrocarbons, but a significant aromatic hydrocarbon cannot be ruled out. Bands characteristic of nitrogen-bearing species (e.g. –CN) were not observed. We believe that this is due to low nitrogen abundance in the FIB section (only 1-2 wt.%) as inferred by nanoSIMS and TEM. However, the similarity of the magnitude of the N anomaly to that of the C- and N- anomalous region suggest that both anomalies are associated with organic carbon.

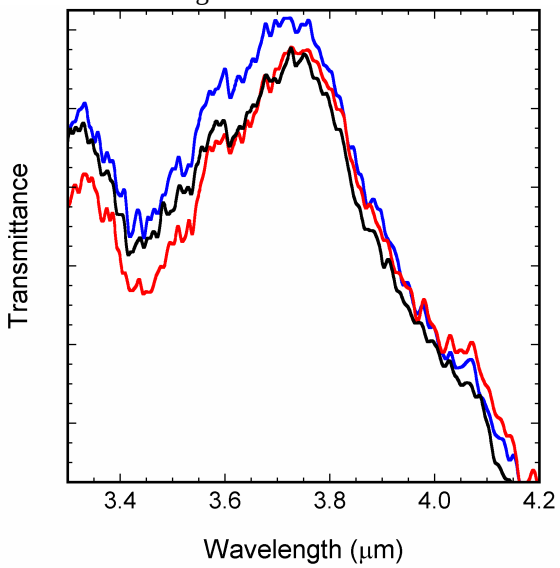

Fig. 4: Three characteristic spectra obtained on *Benavente* FIB section showing peaks at ~ 3.4 μm, typical for hydrocarbons.

References: [1] Keller L. P. and Flynn G. J. (2003) *LPSC XXXIV*, 1903–11904. [2] Molster F. J. et al. (2003) *LPSC XXXIV*, 1148-1149. [3] Westphal A. J. et al., (2004) *LPSC XXXV*, this volume. [4] Floss C. et al. (2004), accepted in *Science*.

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