FAR-IR SPECTROSCOPY OF INTERPLANETARY DUST, CIRCUMSTELLAR SILICATE ANALOGS, AND AEROGEL: A PRELUDE TO STARDUST SAMPLES. L. P. Keller[1] and G. J. Flynn[2]. [1]Code SR, NASA/JSC, Houston, TX 77058 (Lindsay.P.Keller@jsc.nasa.gov), [2]Dept. Physics, SUNY, Plattsburgh, NY 12901.

Introduction. Infrared (IR) spectroscopy is the primary means of mineralogical analysis of materials outside our solar system. The identity and properties of circumstellar grains are inferred from spectral comparisons between astronomical observations and laboratory data from natural and synthetic materials. The Infrared Space Observatory (ISO) obtained IR spectra from numerous astrophysical objects over a wide spectral range (out to 50 cm^{-1}) where crystalline silicates and other phases have distinct features. The next generation of IR observatories will provide higher sensitivity and better wavelength resolution to extend these measurements to even longer wavelengths.

Interplanetary dust particles (IDPs) are particularly important comparison materials because some IDPs contain carbonaceous material with non-solar D/H and $^{15}N/^{14}N$ ratios [1,2] and silicates with non-solar O-isotopic ratios [3], demonstrating that these IDPs contain preserved interstellar material. Here, we report on micro-Fourier transform (FT) IR spectrometry of IDPs, circumstellar silicate analogs, and silicates in aerogel that encompass much of the spectral range covered by ISO. The aerogel measurements are important because samples of comet dust collected in aerogel will be returned to Earth for analysis by the STARDUST mission in January of 2006.

Methods. For the far-IR measurements reported here we used a modified Spectra-Tech Irμs IR microscope installed on Beamline U4IR of the National Synchrotron Light Source (Brookhaven National Laboratory). The original KBr beamsplitter (which limits measurements to >400 cm^{-1}) was replaced with a solid substrate Si beamsplitter that allows access to the full far-IR region (400-10 cm^{-1}), although mechanical vibration limits practical measurements to a cut-off of ~50-60 cm^{-1}. For detecting wavelengths greater than the 15 μm (< 660 cm^{-1}), an external, liquid He-cooled blackened-Si bolometer detector was used. The IDP and mineral standards were analyzed on thin Formvar substrates. For the aerogel measurements, the samples were self-supporting. FTIR spectra were collected in transmission mode over the wavelength range from 15 to 200 μm (660-50 cm^{-1}) with 4 cm^{-1} resolution and converted to absorbance for comparison purposes.

Results and Discussion. Figure 1 compares the IR spectra of an ~20 μm anhydrous IDP (L2005*A4, a fragment from a deuterium-rich cluster IDP) with spectra from forsterite (Mg_2SiO_4), clinoenstatite ($MgSiO_3$), and sputter-deposited amorphous olivine (Fo90) standards. Inspection of the IDP spectrum shows that both forsterite and clinoenstatite features are present in the IDP spectrum superimposed on a significant glassy component. Also shown in Figure 1 are ISO spectra from comet Hale-Bopp [4] and a young stellar object (HD100546) [5]. The similarity between the Hale-Bopp and IDP spectra is remarkable.

IR spectra of the major phases in primitive anhydrous IDPs (crystalline Mg-rich silicates, GEMS [6], Fe-sulfides [7], organics) match spectral features observed in astronomical observations of comets and young stellar objects. We have identified a number of minor phases in IDPs such as anorthite ($CaAl_2Si_2O_8$), fassaite [$Ca(Mg,Al)(Al,Si)_2O_6$] and gehlenite ($Ca_2Al_2SiO_7$) using transmission electron microscopy (TEM). These minor phases occur with presolar silicates identified in the same particles with combined NanoSIMS/TEM measurements. Far-IR measurements on mineral standards (Figure 2) show that these phases have characteristic features that should be searched for in ISO spectra of comets and young stars. Plagioclase (An80) shows two major far-IR features at ~26 and 45 μm. Fassaite has a diagnostic far-IR feature at ~62 μm, and gehlenite exhibits a strong 39 μm feature and a broader feature centered at 66 μm. An FTIR spectrum for hibonite ($CaAl_{12}O_{19}$), an expected circumstellar condensate [8], exhibits a strong far-IR feature at ~82 μm (Figure 2).

We have also obtained preliminary far-IR spectra of individual 20 μm forsterite (Mg_2SiO_4) grains in aerogel (Figure 3) in order to evaluate whether or not this technique would be amenable to *in situ*, non-destructive analysis of STARDUST samples. The measurements are compromised somewhat by saturation of the strong Si-O bending vibration from the thick aerogel substrate, but there are "windows of opportunity" both above and below the aerogel feature where crystalline silicates have diagnostic bands. For example, the strong 33 μm band in a single 20 μm -sized forsterite grain is easily detected even in thick (>100 μm) slabs of aerogel (Figure 3). The long wavelength bands in olivines and pyroxenes are not only diagnostic for the crystalline structure that is present, but can also be used for compositional analysis (e.g. Mg/Fe ratio). The preliminary results demonstrate that it is possible to obtain mineralogical information on small particles in aerogel.

Conclusions. Far-IR spectra of primitive IDPs show absorption features from crystalline silicates similar to those observed in ISO spectra of comet Hale-Bopp and young stars. Far-IR spectra of STARDUST samples would provide a fast, non-destructive technique for *in situ* mineralogical characterization for these important samples prior to other analysis techniques.

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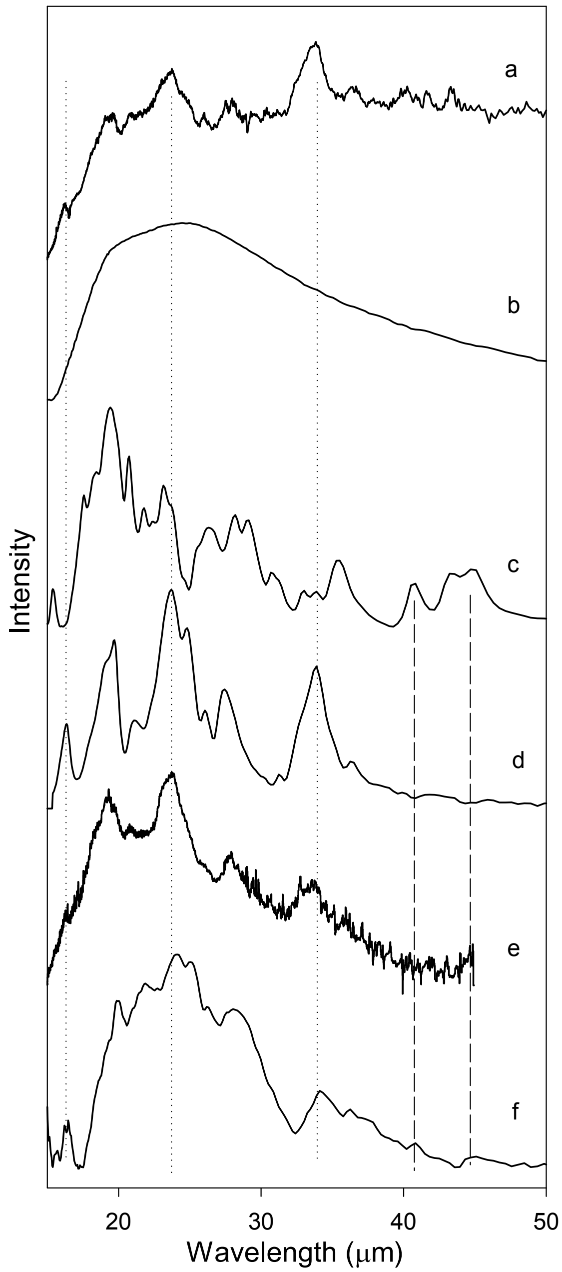

Figure 1. Far-IR spectra for amorphous olivine (b), clinoenstatite (c), forsterite (d) and IDP L2005*A4 (f). Also shown are ISO spectra from HD100546 a young stellar object [5] (a) and comet Hale-Bopp [4] (e). Dashed lines and dotted lines indicate prominent clinoenstatite and forsterite bands, respectively.

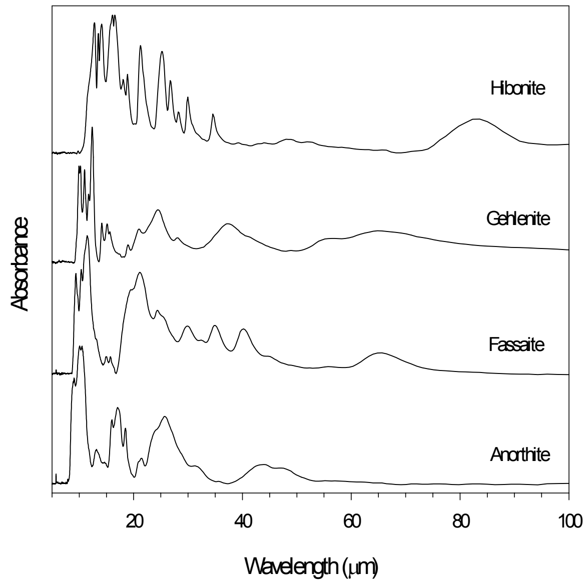

Figure 2. Far-IR spectra from candidate circumstellar grain types. Anorthite (Lake Co. OR), fassaite (Val di Fassa, Italy), gehlenite (Allende meteorite), and synthetic hibonite. Anorthite and fassaite are common minor phases in primitive IDPs.

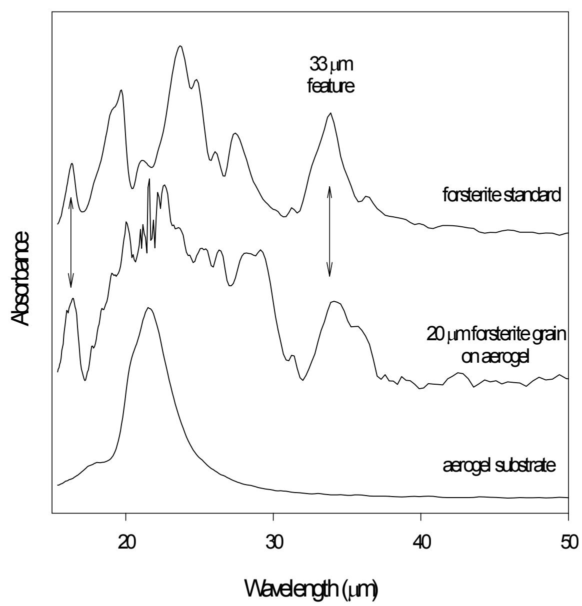

Figure 3. Far-IR specrtra of the forsterite standard, the aerogel substrate, and a single 20 μm forsterite grain on an aerogel substrate.