Spectroscopy of Stardust from 200nm to 16M (with a gap in the middle)

Conference or Workshop Item

SPECTROSCOPY OF STARDUST FROM 200nm TO 16μm (WITH A GAP IN THE MIDDLE). Monica M. Grady[1,2], A. Morlok[3], C. D. Fernandes[1] and D. Johnson[1], [1]Planetary and Space Sciences Research Institute, The Open University, Walton Hall, MK7 6AA, UK (m.m.grady@open.ac.uk); [2]Dept. Mineralogy, The Natural History Museum, London SW7 5BD, UK; [3] Dept of Earth and Planetary Sciences, Kobe University, Nada, Kobe, Japan.

Introduction: Assuming that all goes to plan, cometary material from the STARDUST mission will be distributed to the Preliminary Examination Teams by the end of January 2006, and the earliest results will be presented at Houston in March 2006. It is in this spirit of optimism that, as part of the spectroscopy PET, we submit this abstract, describing the techniques that we hope to apply to recovered cometary particles. We anticipate that there will be two subsets of particles available for study: material embedded in aerogel, and impacted into the gold foil aerogel supports. Each sub-set will require different handling and analytical protocols. We will measure the UV/Vis spectra of returned Stardust materials in order to (i) observe whether or not there is an absorbance present that can be compared with the 217.5nm interstellar absorption band; (ii) make qualitative analyses of the presence (or otherwise) of organic molecules within the grains and assign bond identities and (iii) assess the relative abundances of hydrated and anhydrous minerals within grains on the basis of OH features, extending the work of [1] to lower wavelengths. Complementary measurements of IR spectra will look at (i) silicate structure and composition and (ii) determine the presence (or otherwise) of hydrated minerals and carbonates.

Techniques: UV/Vis spectroscopy is a technique that utilizes the excitation of valence electrons within an atom as a tracer of atomic or molecular bonds. In contrast, IR spectroscopy is a measure of the vibration of bonds within a molecule. The two techniques therefore give complementary information about materials. We employ two separate instruments to determine spectral signature. For UV/Vis spectroscopy (wavelength range 200 – 950nm), we use a Craic optical microspectrophotometer system fitted with xenon lamps, whilst IR spectroscopy measurements are carried out using a Perkin Elmer Spectrum One IR workbench coupled to a Perkin Elmer AutoImage microscope fitted with IR transparent CsI windows (wavelength range 2.5-16.7μm). Both instruments can acquire data by transmission and reflectance, and both are able to measure spectra from powders, discrete grains or from polished mounts. Spectra have been measured on a range of standard materials, plus grains separated from meteorites in order to provide a library of spectra against which the Stardust particles may be compared [2]. The spectral characteristics of aerogel have also been determined, in order to see whether or not it would be feasible to take spectra of particles whilst still embedded within the substrate.

Results:

Aerogel is an extremely low density silica, and its spectra exhibit features characteristic of silicates. So its IR transmission spectrum has a pronounced absorption at around 10μm, from the Si-O vibration, and a second at around 3μm from H_2O or OH. The UV/Vis reflectance spectrum of a broken fragment of aerogel (Figure 1) shows a pronounced absorption at around 220nm. Given its strong IR activity, it is unlikely that the IR spectra of grains will be measurable whilst still embedded in aerogel, but optical spectroscopy might be possible.

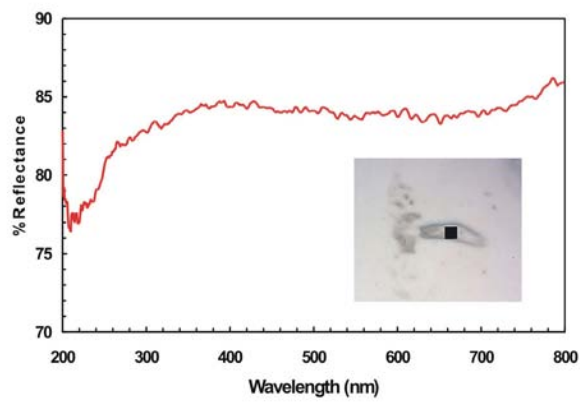


Figure 1: UV/Vis reflectance spectra from a fragment of aerogel (inset). The black square is the 10 x 10μm aperture through which the spectrum was acquired.

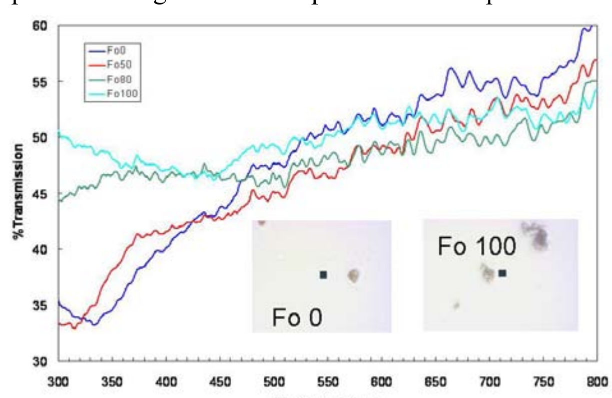


Figure 2: UV/Vis transmission spectra of individual olivine grains of different forsterite composition.

The black square is the 5 x 5 µm aperture through which the spectra were acquired.

Mineral standards. Spectra from single grains of synthetic crystalline olivine (from Fo_0 to Fo_{100}) have been obtained, in order that the silicate can be used as a reference material for both spectroscopic techniques. It is well known that the main IR bands shift wavelength with composition. There are spectral matches between magnesian-rich olivines (and pyroxenes) and comets [2, 3]. Preliminary measurements of olivine grains of different forsterite composition (Figure 2) indicate that more iron-rich olivines have a higher absorbance at the blue end of the spectrum than more magnesian end-members.

Meteorite grains. As part of a long-term project to compare the spectra of meteorite grains (measured in the laboratory) with spectra from astrophysical dust (from telescope observations), and also serving as a trial run for Stardust grains, we have been recording the IR and UV/Vis spectra of grains separated from meteorites. IR measurements have been made in transmission of very fine-grained powders (e.g., Figure 3). We are also able to measure grains in thin section [4], and have found that IR data for oxides and silicates in CAI match well with observations of evolving circumstellar disks and oxygen-rich AGB stars. The utility of UV/Vis spectroscopy has mainly been assessed through reflectance data, such as is shown in Figure 4 from a clump of grains from the Orgueil CI1 chondrite. Although our new microspectrophotometer is not yet fully calibrated, the spectra indicate regions where phyllosilicates are in greater abundance relative to anhydrous silicates. There is also possible indication of organic material present.

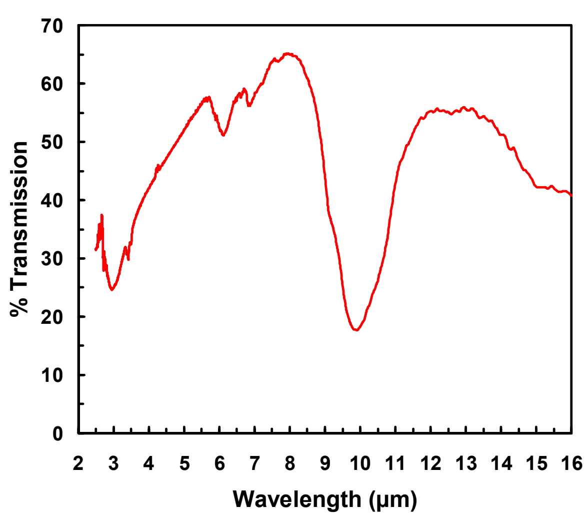
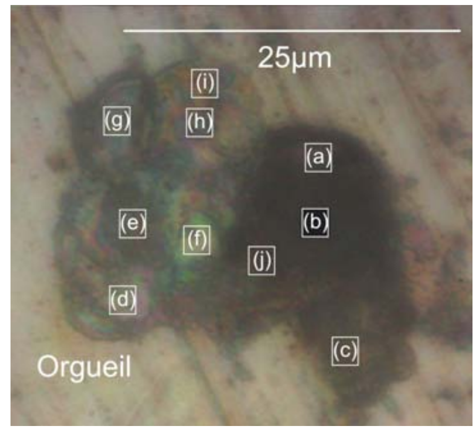


Figure 3: IR transmission spectrum of the Alais CI1 carbonaceous chondrite showing features resulting from silicates and phyllosilicates.

(a)



(b)

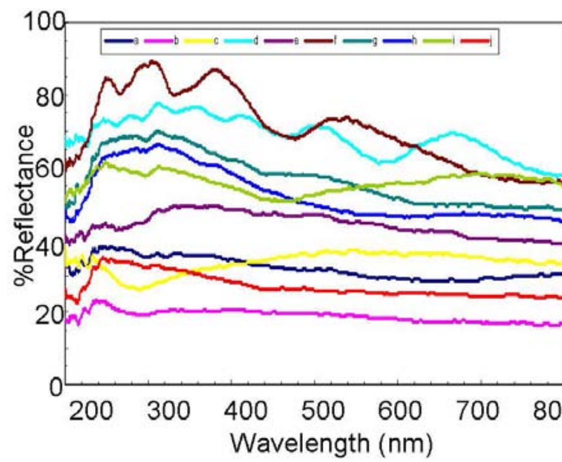


Figure: 4: (a) clump of grains from Orgueil CI1 chondrite, showing the positions from which UV/Vis spectra were acquired. The squares are the size of the aperture, ~ 2 x 2µm; (b) reflectance spectra from Orgueil, keyed to the grains shown in (a).

Summary: UV/Vis and IR spectroscopy are complementary, non-destructive techniques that can be used to identify the presence of a range of organic and inorganic, hydrated and anhydrous minerals within micron-sized grains. We look forward to applying these techniques to the Stardust materials.

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References: [1] Bradley J. P. et al. (1996). *MAPS 31,* 394-402. [2] Morlok A. et al. (2005). *LPS XXXVI*, Abstract #1646. [3] Wooden D. H. et al. (2004). *Ap. J. 612*, L77-80. [4] Morlok A. et al. (2005). *LPS XXXVI*, Abstract #1644.