Identification of Stardust Analogs in Aerogel Using Raman Spectroscopy

Lamont-Doherty Earth Observatory
Columbia University | Earth Institute

Kim V. Fendrich[1] and Denton S. Ebel[1,2]

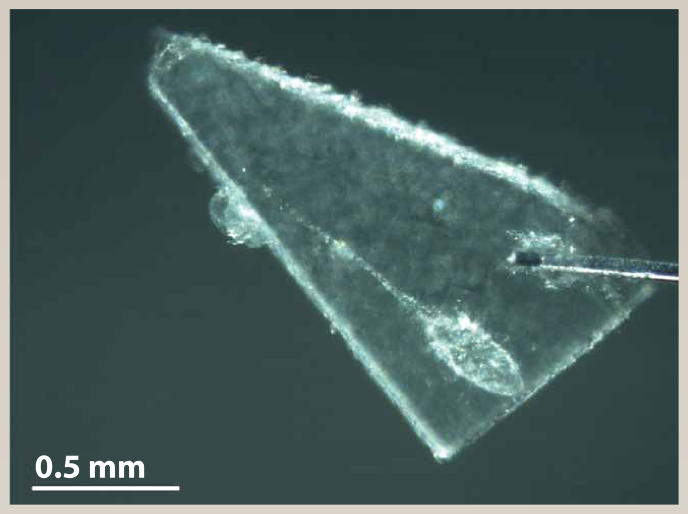
[1]Department of Earth and Planetary Sciences, American Museum Natural History, New York, NY 10024 (kfendrich@amnh.org)
[2]Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, 10964

American Museum of Natural History

LPSC 2017
Abs. # 2999

Introduction

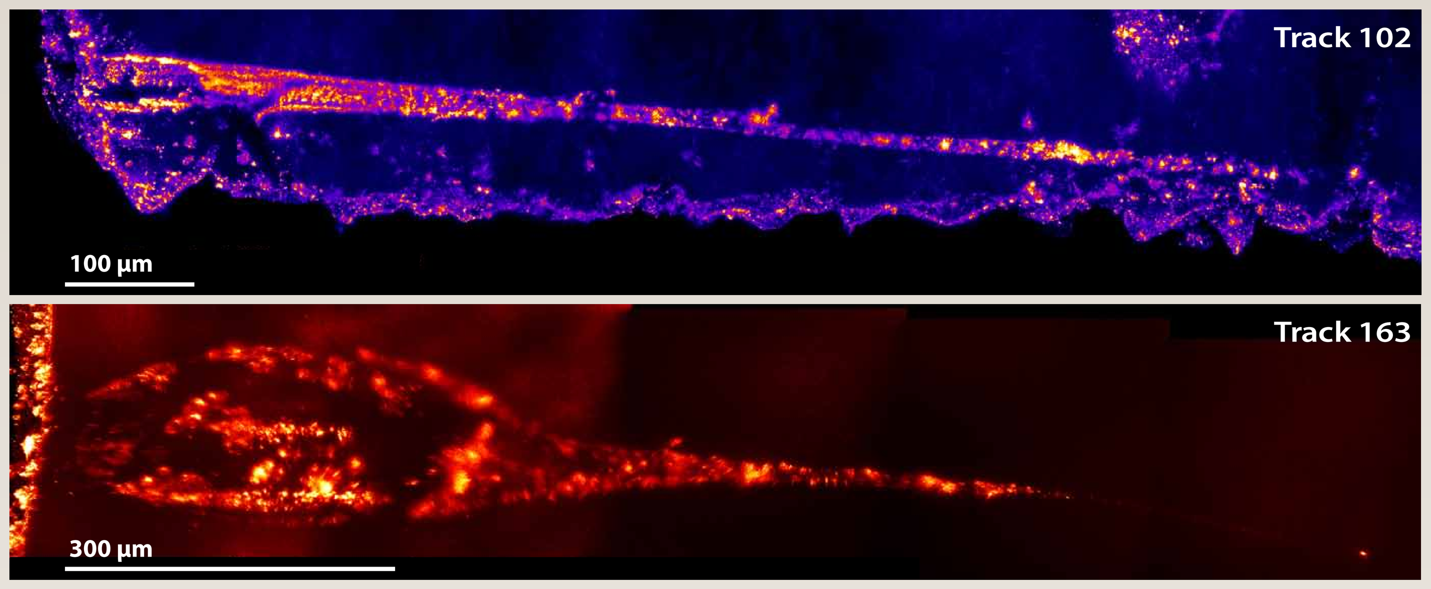
In 2006, NASA's Stardust mission returned a capsule to Earth with particles collected from the coma of comet 81P/Wild 2. Cometary particles were collected by impact into low-density silica aerogel at a relative velocity of 6.1 km/s [1]. Upon impacting the aerogel, particles left behind tracks of melted and compressed aerogel and void space, shedding material along the way. Keystones, or thin slices of aerogel containing individual tracks, are extracted for analysis (pictured at right).



Aerogel keystone. (NASA JSC)

We do 3-dimensional and stereo-pair XRF mapping of tracks. Raman spectroscopy permits identification of minerals by class and type, allowing us to focus on grains with the greatest potential to bear valuable chemical and isotopic information on the history of the solar system.

A Zeiss LSM710 Laser Scanning Confocal Microscope (LSCM) is used to perform 3-dimensonal mapping of whole Stardust tracks at high resolution (<80 nm/pixel, pictured below).



Examples of "carrot" (T102) and "bulbous" (T163) shaped tracks. Track morphology can provide information on the nature of captured grains [2, 3]. These images are two-dimensional projections of three-dimensional reflectance data collected on the Zeiss LSM 710.

Experimental Setup

A Princeton Instruments spectrograph and CCD camera were coupled to the Zeiss LSM710 at AMNH.

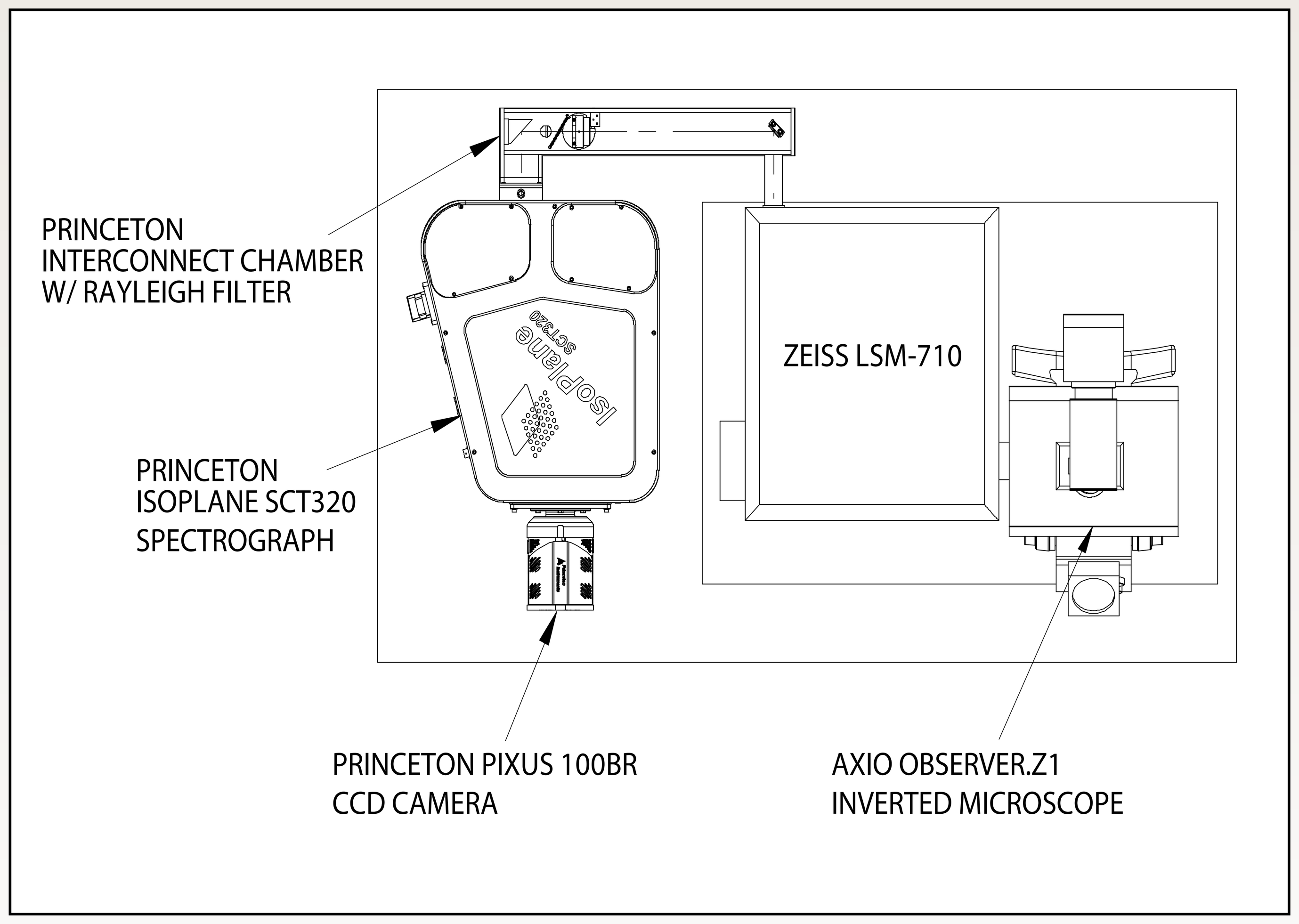
Benefits of using:

The confocal microscope

- Enhanced ability to locate small grains
- High resolution imaging
- 3-dimensional mapping
- Minimizes excitation volume

Raman Spectroscopy

- Non-destructive
- Produces rapid results
- Capable of distinguishing crystalline cometary grains from amorphous melted or compressed aerogel [4]
- In principal, may be used to quantify relative abundance of Mg/Fe in olivine [5]



Schematic of the LSCM-Raman setup at AMNH

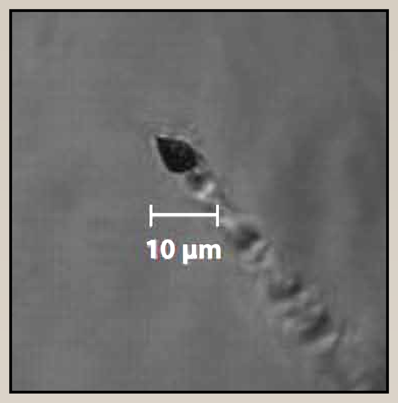
Challenges:

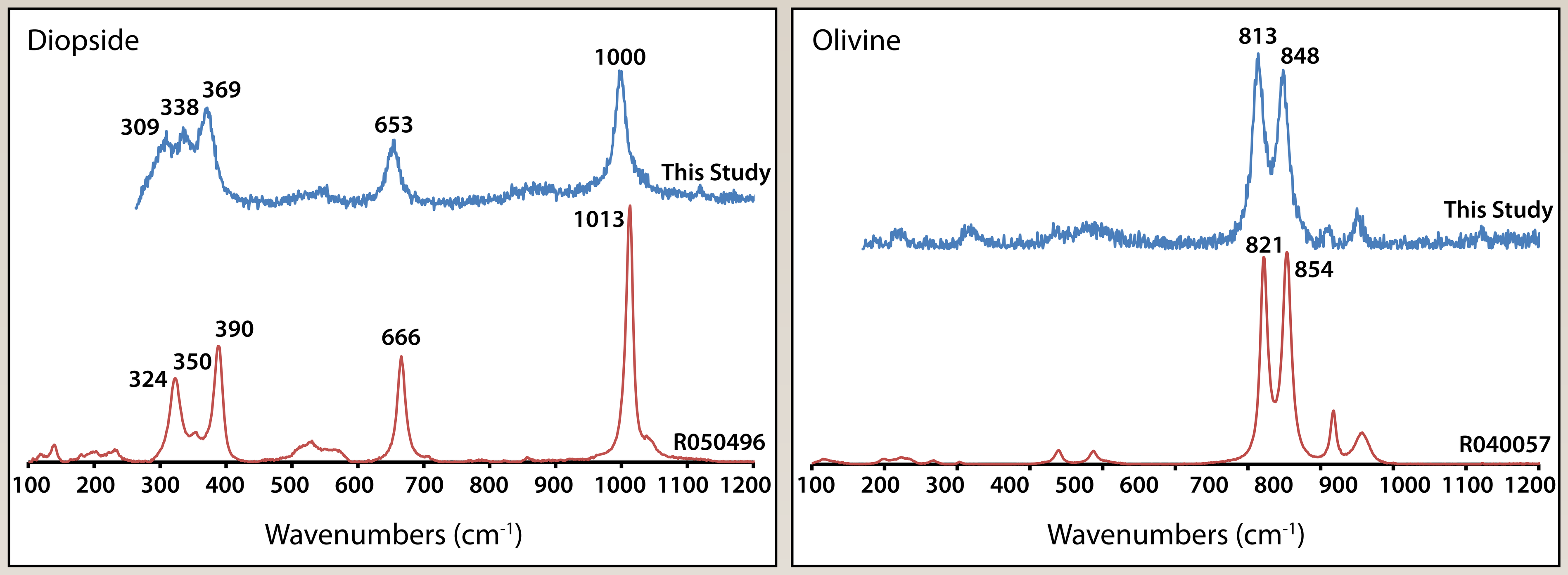
- Small grains produce a weak Raman signal
- Laser power at the sample is relatively low (also a benefit)
- Polymineralic cometary grains may prove more difficult
- Some aerogel is naturally fluorescent

Results

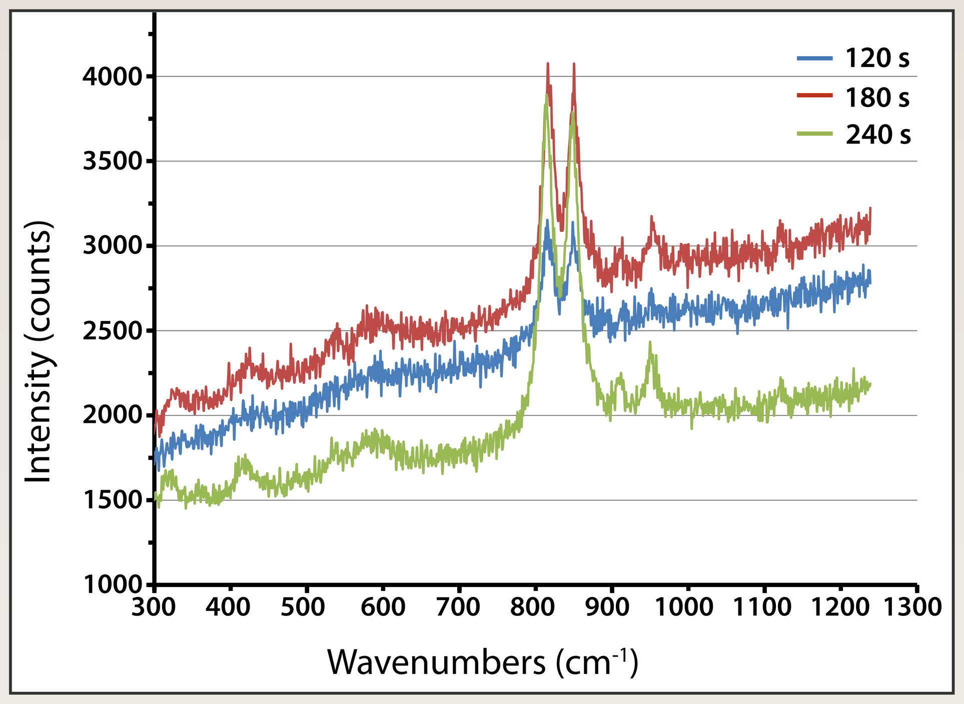
Two mineral grains that were fired into Stardust-like aerogels at the University of Kent light gas gun facility were analyzed. In both cases, a 514 nm Ar-ion laser was used, generating ~3.5 mW of power at the sample through a 40x objective (measured using a power meter).

A Raman spectrum of an aerogel-embedded grain of diopside ~18 µm in diameter was acquired with an integration time of 180 seconds, whereas an integration time of 240 seconds was used for a smaller olivine grain (~5 µm, pictured at right) for improved signal-to-noise ratio.





Raman spectra of diopside (left) and olivine (right). Blue spectra, collected in this study, overlie reference spectra from the University of Arizona's RRUFF database (rruff.info). The reported spectra have been background corrected and their intensities have been exaggerated by a factor of 10 for comparison.



Dwell time affects spectral intensity. These three spectra were collected on the same olivine grain as above with different integration times, demonstrating that the spectrum is detectable even at shorter dwell times. It is important to note that the integration time required to obtain a spectrum is dependent on many factors including the size of the grain, the type of mineral, the laser power etc.

Outlook

The LSCM-Raman system at AMNH is fully operational. This work demonstrates the successful identification of minerals at <20 µm size in aerogel. The use of Raman spectroscopy can expedite the search for high-value cometary grains, such as Ca-, Al-rich minerals [6].

Our goal is to select grains of interest to be harvested for investigation through collaboration with colleagues at the University of Chicago. The Chicago Instrument for Laser Ionization (CHILI) [7] can yield detailed chemical and isotopic analyses.

We are ready to request allocation of Stardust tracks from CAPTEM for Raman investigation of Wild 2 cometary grains.

Acknowledgments:

We gratefully acknowledge assistance from M. J. Burchell and M. C. Price at the University of Kent for providing the samples of mineral grains in aerogel that were used in this study. Research is supported by NASA LARS NNX16AI32G (DSE). The LSM710 was obtained by AMNH with partial support from NASA LARS NNXIOAH06G (DSE).

References:

[1] Brownlee D. (2014) *Annu. Rev. Earth Planet. Sci., 42*, 179–205. **[2]** Burchell M. J. et al. (2008) *Meteoritics & Planet. Sci., 43.1*, 23-40. **[3]** Kearsley A. T. et al. (2012) *Meteoritics & Planet. Sci., 47.4*, 737-762. **[4]** Price M. C. et al. (2012) *EPSC*, EPSC2012-333. **[5]** Foster N. J. et al. (2013) *GCA, 121*, 1-14. **[6]** Simon S. B. et al. (2008) *Meteoritics & Planet. Sci., 43.11*, 1861-1877. **[7]** Stephan T. (2016) *International Journal of Mass. Spec., 407*, 1-15.