Collisional Histories of Comets and Trojan Asteroids: Insights from Forsterite and Enstatite Impact Studies.
S. M. Lederer[1], E. A. Jensen[2], D. H. Wooden[3], S. S. Lindsay[4] , D. C. Smith[5], M. J. Cintala[1], K. Nakamura-Messenger[6], and L. P. Keller[1], [1]NASA Johnson Space Center, Houston, TX, USA (susan.m.lederer@nasa.gov), [2]Planetary Science Institute, [3]NASA Ames Research Center, [4]New Mexico State Univ., [5]California State Univ. San Bernardino, [6]ESCG Jacobs Sverdrup.

Introduction: The history of small bodies is dynamic, and suggests that their surfaces may not be as pristine as previously envisioned. Comets undergo many collisions throughout their 4½ billion year lifetime. But perhaps the Late Heavy Bombardment, as suggested by the Nice Model [1], [2], [3], has had the greatest effect on small relics of solar system formation such as the Trojan asteroids, which may have a Kuiper Belt, and thus cometary origin. Collisions that occurred between small bodies such as these may harbor historic signatures that we can detect in spectra taken with both ground and space-based observatories.

Experiments: We have conducted a suite of impact experiments that investigate how shocks originating from impacts between small bodies and by micrometeoroid impacts might affect the crystalline structure of refractory components commonly found in comet dust. In this study, we focus on two minerals: forsterite (Mg-rich olivine) and orthoenstatite (Mg-rich pyroxene). These two refractory components have been identified in Stardust grains collected from Comet Wild 2 [4], and signatures of these silicates are observed in the 8 - 13 μm spectral region of the dust comae of comets (e.g. Comet Tempel 1 [5] and Hale-Bopp [6]).

A set of experiments were designed to determine whether the physical mainifestations due to shocks imposed by collisions might also cause alterations in the infrared spectra of minerals.

3.18-mm ceramic speheres impacted the targets at velocities of ~2.0, 2.45, and 2.8 km s^{-1}. These are typical encounter speeds in the Kuiper Belt, and would also be experienced by Trojan asteroids. Ceramic (aluminium oxide, $\rho \sim 3.6$ g cm^{-3}) was chosen to simulate impacts by rocky materials. Targets included whole (solid rock) and granular samples. All experiments were carried out in the JSC Experimental Impact Lab using the vertical gun.

Analysis: Shocked samples were analyzed using a Fourier Transform Infrared Spectrometer (FTIR). A representative spectrum of ceramic was subtracted from all impacted spectra and compared with spectra of samples that were not impacted (see Jensen et al., this meeting for further details).

Laboratory spectra demonstrate that shock can cause the wavelengths of the peaks to both shift longward (or shortward, depending on the peak), as well as cause the amplitude of the peaks to change. Lindsay [7] investigated how variations in the length of the axes of the crystalline structure of forsterite might affect the absorbance in the 8 - 13 μm spectral region, using a discrete dipole approximation. The observed changes (amplitude changes and wavelength shifts) in the impacted laboratory spectra can be explained by either elongating or shortening the axes of the crystals.

Shocked samples were also evaluated with a Transmission Electron Microscope (TEM). Dislocations on the order of 10^{10} cm^{-2} were observed, which is attributed to deformation at high strain rates and low temperatures [8], [9]. Similar planar dislocations were observed in TEM images of two Stardust grains [10] [11], which were attributed to shocks that occurred prior to aerogel capture.

Summary and Conclusions: Impacts into forsterite and orthoenstatite at speeds typically encountered by comets demonstrate that shock imparted by collisions is detectable in the infrared signatures of their dust. The spectral signatures can be traced to physical alterations in their crystalline structures, as observed in TEM imaging and modeled using a dipole approximation. These results yield tantalizing insights into the collisional history of our solar system, as well as the history of individual comets and Trojan asteroids.

References: [1] Bottke W.F. and Levison H. F. (2008) *LPS* XXXIX, *1447*. [2] Levison H. F. et al. (2009) *Nature, 460, 364-366*. [3] Morbidelli A. et al. (2009) *Icarus, 202, 310-315*. [4] Zolensky et al. (2006) *Science, 314, 1735-1739*. [5] Harker et al. (2007) *Icarus, 191, 432-453*. [6] Harker et al. (2002) *Astrophys J, 580, 579-597*. [7] Lindsay et al. (submitted), *ApJ* [8] Ashworth and Barber (1975) *Earth and Planet. Sci Letters, 27, 43-50*. [9] Ashworth (1985), *Earth and Planet. Sci Letters,73, 17-32*. [10] Keller L. P. et al. (2008) *Geochim. Cosmochim. Acta, 72, A459.* [11] Tomeoka K. et al. (2007) *LPS XXXVIII, 1267.*

Acknowledgements: Funding was provided by the NASA PG&G grant 09-PGG09-0115, NSF grant AST-1010012, and a Cottrell College Scholarship through the Research Corporation. Special thanks to F. Cardenas of the NASA Experimental Impact Laboratory at NASA JSC.