COMET SAMPLES RETURNED BY THE STARDUST MISSION

The Stardust Sample CoI's: D. E. Brownlee[1], G. Flynn[2], Friedrich Hörz[3], L. Keller[3], K. McKeegan[4],S. Sandford[5], P. Tsou[6], and M. E. Zolensky[3], [1] Dept of Astronomy, Univ. Washington, Seattle, WA 98195 brownlee@astro.washington.edu, [2]SUNY Plattsburg, Plattsburg, NY. [3]NASA Johnson Space Center, KR, Houston, TX, [4]UCLA, Los Angeles CA, [5]NASA Ames, MtView, CA, [6]JPL, Pasadena, CA.

On January 2, 2004 Stardust passed 234 km from the surface of comet Wild 2 and captured thousands of particles in its 1000 cm^2 of silica aerogel collection tiles. The samples returned to Earth on January 15 and are currently undergoing a six month examination by the Preliminary Examination Team before they are open to general allocation by NASA. This presentation will briefly describe the samples and the importance of their source.

The comet sampled by Stardust is 81/P (Wild 2), a 4.5 km oblate spheroid that has been in its present orbit as a Jupiter family comet (JFC) since a close encounter with Jupiter in 1974. Just prior to this recent Jupiter encounter, the comet's perihelion was near Jupiter and its aphelion was just beyond the orbit of Uranus. Assuming that Wild 2 is a typical JFC, the expectation is that it formed in the Kuiper belt, just beyond Neptune, and was stored there for nearly all of the age of the solar system [1]. As a typical JFC, Wild 2 probably spent only a few million years in its transition from a Kuiper belt object to a inner solar system JFC orbit. It's history in the inner solar system is unknown.

With its current ablation rate, the comet would lose its volatiles on a 10^4 year timescale. Since its 1974 orbit change, the comet has lost only a few meters of surface averaged over the entire nucleus. The presence of mesas, pillars, >100m cliffs and large deep depressions on the surface of Wild 2 [2] suggest that surface erosion has greatly exceeded what is possible from the observed water loss rate over the past 31 years. It is likely that Wild 2 has been in the inner solar system before and that the comet has perhaps lost ~100 m or more of its original surface. The observation of classic impact craters on Temple 1 by the Deep Impact mission [3] and Wild's apparent lack of similar craters (with classic crater forms) suggests that the exposed surface of Wild 2 is younger than that of Temple 1, also a JFC. The surfaces of Halley and Borrelly also did not have apparent classic impact craters. The volatile loss times of JFCs is shorter that their dynamical lifetimes in the inner solar system and an observed JFC is most likely to be in its middle age and with a substantial loss of original surface. Although Wild 2 may have lost the surface that was exposed during its long residence in the Kuiper belt, it seems unlikely that this alteration would have any effect on the returned samples with regard to properties that are preserved in samples stored at room temperature conditions.

The particles returned by Stardust were collected in the coma and had been released by the comet only hours before. The images of Wild 2 and the three other comets that have been directly imaged, suggest that much of the dust emission from these comets occurs in jets. On Wild 2, 22 small jets were observed; many of them were highly collimated. For comet Borrelly, a case was made that the gas jets from that comet left the nucleus at supersonic speed from sub-surface regions of pressurized gas [4]. Although particles in jets may fragment during and after ejection, comet dust is known to be porous and fragile and the forces involved in fragmentation are likely to be too small to cause actual material damage, other than gentle separation of components. An interesting modification that plausibly could happen in jet forming regions is condensation of gaseous molecules that are less volatile than water. Such molecules, formerly trapped in water ice, could condense both on "airborne" particles and the walls of subterranean chambers and conduits.

The dust particles sampled in the coma of Wild 2 are likely to include whole particles, fragments and conglomerates of the original solids that the comet accreted from. The presence of the 9.7 µm IR "silicate feature" proves that Wild 2 is releasing submicron particles as well as larger ones. The presence of such small particles by processes related to sublimation of ice, suggests that these tiny particles were either encased in ice or are submicron components weakly bonded to other materials. It is very difficult to generate submicron silicates by any process either on the surface of a rocky icy body or in its interior. It is likely that the released small particles are just the original small particles that accreted along with volatiles to form the comet. It is likely that they were never significantly processed.

An important aspect of the Stardust samples is they were released from subsurface regions that retain ice. The survival of ice intimately mixed with dust implies that the samples have probably always been preserved below the ~150 K sublimation temperature of ice. This is significant because even the most “primitive” comets probably contain components that have been heated or otherwise modified. The Kuiper belt objects include many >500 km bodies that presumably contain thermally and aqueous altered materials in their interiors. Collisional breakup of these bodies must distribute altered fragments that then accrete into the regoliths of other Kuiper belt objects. Like asteroids, comets should also contain collisional debris from other small bodies. In addition to materials from large disrupted bodies, alteration can occur on any cometary body in regions of impacts, such as the larger impact craters seen on Temple1 by the Deep Impact mission. If Wild 2 contains regions of material that have never been significantly heated as well as pristine regions, the dust released by gas emission should come from unaltered ice-rich regions- the source of sublimation and the driver of cometary activity.

References:

[1] Duncan, M.J., Levison, H.F. (1997) Science 276, 1670-1672. [3] A'Hearn, M.F., et al (2005). Science 310, 258-264. [2] Brownlee, D.E., et al (2004). Science 304, 1764-1769. [4] Yelle, R.V. (2004) Icarus 167, 30-36.