

THE STARDUST- A SUCCESSFUL ENCOUNTER WITH THE REMARKABLE COMET WILD 2

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On January 2, 2004 the Stardust spacecraft completed a close flyby of comet Wild2 (P81). Flying at a relative speed of 6.1 km/s within 237km of the 5 km nucleus, the spacecraft took 72 close-in images, measured the flux of impacting particles and did in-situ compositional analysis of freshly released dust with a time-of-flight mass spectrometer. The primary goal of the mission is to collect >500 particles >15µm diameter and return them to Earth on January 15, 2006. The cometary particles ranging in size from a micron to ~100 microns were collected in low density silica aerogel. After returning over a hundred 2x4x3 cm aerogel collection cells will be processed at the curatorial facility at the NASA Johnson Space Center and 5 to 100 micron size extracted cometary particles will be distributed to analysts by a system that will be based on the allocation procedures for cosmic dust, Antarctic meteorites and lunar samples.

The flyby appears to be an unqualified success. Although there were considerable challenges for imaging, including tracking the comet at 1.5 degrees per second with a 200 mm lens, the optical navigation camera was used for scientific imaging with great success. The images are sharp images, with little motion smear and only minor effects due to scattering within the camera optics. The initial dust flux data indicate the flux was similar or greater than predictions, and that the expected quantity of particles was collected. The data indicate that a half dozen or more large particles penetrated the first layer of the multi-component “stuffed” Whipple shield that was designed to protect the leading edge of the Stardust spacecraft from hypervelocity impacts of particles as large as 1 cm diameter. The dust impact data clearly show time variability consistent with the spacecraft

passing through discrete jets of out-flowing particles.

Although imaging was a secondary science objective, the images taken during the flyby provided the best yet images of a cometary nucleus and revealed remarkable insight into the nature of Wild2, its evolution and its emission of volatiles and solids into space. The images were taken at intervals giving stereo pairs and a wide range of phase angle coverage. Every other exposure was a long exposure that tended to overexpose the nucleus but provide good conditions for detecting sunlight scattered from dust entrained in gas jets emanating from active surface regions. Each long exposure image clearly shows about a half dozen jets. Stretching the images show many more and it is likely that the comet contains dozens of jet producing regions that are activated by solar illumination during a full spin period. Many of the jets are highly collimated and appear to be derived from small regions (<<1km) on the surface. To first order the jets appear to be predominantly radial. Lines drawn from jets back the surface always intersect depressions but actually associating features with jets is complicated by the abundance of features on the surface of Wild2.

The surface of the comet is quite remarkable in that it is covered with features ranging in size up to about 2km, nearly half the size of the object. Although detailed analyses have yet to be done and the images have yet to be properly processed, it is rather clear already that the Wild 2 surface differs from imaged asteroids, and the other two imaged comet nuclei- Halley and Borrelly as well as the ice-rich surfaces of Callisto and Ganymede. Wild2 has an exceedingly rough surface covered with large,

deep flat bottomed depressions that are bounded by steep walls. Some of these features are round and may be impact craters while others are not round, have scalloped edges and do not appear to be impact craters. Most of the depressions are large and there does not appear to be a population of small impact craters similar to the continuum in crater size observed on other icy bodies. Some areas appear to be distinctly blocky at scales of 10's of meter size, and there are a number of scarps as well as flat regions. Some flat regions appear to contain fractures. Positive relief with high angle slopes (hills and cliffs) exist up to 150 m high. Linear features are seen that may indicate slumping. Scarps and high angle positive relief features suggest that the near surface must have modest cohesive strength and they cannot be merely composed of loose powdery materials. Many surface features are remarkably crisp and sharp, unlike the subdued nature of regolith covered asteroids. It may also have albedo features but even preliminary assessment thereof will require proper processing. Thus the surface is surprisingly rich with topographic features and may also have albedo features.

The surface of Wild2 is dramatically different and more complex than available images of Halley and Borrelly. The Deep Space 1 images of Borrelly [1] show the best surface detail but most of the surface of that comet is comparatively smooth without the large scale the circular features and depressions seen on Wild2. It is possible that the more complex nature of Wild2 is related to its orbital evolution. Wild2 is a Jupiter family comet that was perturbed to its 5.24 to ~1.5AU orbit by a ~13 Jovian radii flyby encounter of Jupiter on 9/9/1974. Prior to that time it was on a 25 to 4.97 AU orbit with an orbital period of 57 years. Like other Jupiter family (JF) comets it is presumed to have been derived from the Kuiper belt and have spent billions of years in distant solar orbits.

Wild2 is a fresh comet in the sense that it has only had 5 perihelion passes in its present orbit. It is unknown if it has had an earlier period of solar irradiation and strong ablation in the inner solar system. It is likely that Wild2, as a Jupiter family comet, has been inside Jupiter's orbit before in the past million years, about 10 times is typical for a JF comet [2]. Typical active comets are believed to survive only a few thousand years before they either disintegrate or become inactive. With high ablation rates interior to 2.5 AU, typical comets should probably not retain ancient surface features such as craters made by long term exposure in the outer solar system. Wild2 may have had only a modest solar ablation exposure in the inner solar system and it may retain ancient impact features, perhaps related to the early history of the Kuiper Belt.

The H₂O production rates derived from Lyman alpha measurements for Wild2 indicate that Wild2 ablates about 10⁷ tons of water during each of its present orbits. Using a density of 0.5, for porous ice, this implies an average surface recession rate of only a quarter of a meter per orbit. If the ablation occurs from only 5% of the surface then the mean surface recession rate in active areas will be on the order of 5 m/orbit.

The apparent mix of possible impact craters and possible ablation craters on Wild2 provide a remarkable opportunity to investigate fundamental aspects of gas production, crust production and temporal evolution of active comets. It may also provide insight into a variety of processes that occurred in the Kuiper Belt. Comparison of Wild2 with data on Halley and Borrelly [1] will provide a remarkable opportunity to investigate the diversity among comets and what such diversity might tell about the nature and evolution of the solar system's primordial ice-rich bodies.

[1] Britt et al (2004) *Icarus* in press. [2] Levison H. F. and Duncan M. J. (1997) *Icarus* 127,13-27.