Stardust Wild 2 dust measurements

Conference or Workshop Item

STARDUST WILD 2 DUST MEASUREMENTS. S. F. Green[1], N. McBride[1], M. T. S. H. Colwell[1], J. A. M. McDonnell[1], A. J. Tuzzolino[2], T. E. Economou[2], B. C. Clark[3], Z. Sekanina[4], P. Tsou[4], D. E. Brownlee[5], [1]PSSRI, The Open University, Walton Hall, Milton Keynes, MK7 6AA, UK, s.f.green@open.ac.uk, [2]Laboratory for Astrophysics and Space Research, Enrico Fermi Institute, University of Chicago, 933 East 56th St, Chicago Ill 60637, USA, [3]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Drive, Pasadena CA 91109, USA, [4]Lockheed Martin Astronautics, P.O. Box 179, MS-B0560, Denver, CO 80201, USA, [5]Astronomy Department, University of Washington, bx 351580, Seattle, WA 98195, USA.

Introduction: The Stardust Dust Flux Monitor Instrument (DFMI) detected almost 9000 dust impacts over a broad mass range of 10^{-14} to 10^{-6} kg during the 236 km flyby of comet 81P/Wild 2 on 2 January 2004. Cometary dust particles, trapped in the volatile ices of the nucleus since their formation, contain information on the conditions in the pre-solar nebula, its precursor interstellar cloud and nucleosynthetic processes in the stars from which their constituent grains originally formed. The primary objective of Stardust is to capture these samples intact and return them to the Earth for in-depth microanalysis [1]. These dust grains are the source of a major component of interplanetary dust and large (sub-mm and larger) grains are observed in cometary dust trails forming relatively long lasting meteoroid streams, which gradually dissipate into the zodiacal dust complex. Micron sized (and somewhat smaller) grains can be swept out of the inner solar system by solar radiation pressure. The contribution of comets to the total interplanetary dust complex, and the subsequent dynamics of the individual grains, are critically dependent on the dust mass (or size) distribution. Furthermore, the dust-to-gas ratio in cometary nuclei provides constraints on the conditions in the region in which it formed. DFMI provided time resolved dust fluxes and mass distributions in the inner coma of comet Wild 2 at the highest resolution yet obtained.

DFMI: The DFMI [2] combines small area but high sensitivity PVDF (polyvinylidene fluoride) sensors with two piezoelectric acoustic sensors, mounted on the first two layers of the spacecraft Whipple dust shield, to measure the flux of larger particles. The PVDF sensors each had four mass channels with thresholds from 10^{-14} kg (particle radius ~ 3 μm) to 10^{-7} kg. The front shield acoustic sensor could detect particles of mass larger than 3 x 10^{-11} kg (~50 μm diameter), while the second sensor detected penetrating particles of mass > 2 x 10^{-7} (~ 1 mm diameter).

The objectives of the Stardust Dust Flux Monitor Instrument (DFMI) were to:

1) Measure the interplanetary dust flux,
2) Determine particle fluxes during the 81P/Wild 2 flyby,
3) Determine the particle mass distribution in the coma of 81P/Wild 2,
4) Provide the context for the collected dust samples,
5) Monitor the dust environment at P/Wild 2 for spacecraft health and interpretation of anomalies.

Although an unidentified noise source prevented interplanetary cruise measurements, the instrument worked flawlessly throughout its 30 minutes of operation in the inner coma of comet Wild 2.

DFMI Encounter measurements: The first dust detections were made by the front shield acoustic sensor, 264 s before closest approach (at a cometocentric distance r = 1630 km). The event rate gradually increased up to closest approach and then decayed afterwards with a second period of high activity between +620 s (r = 3810 km) and +720 s (r = 4420 km). The last detected particle was at +922 s at a cometocentric distance of r = 5650 km [3].

The spatial distribution of dust was highly non-uniform, with short duration bursts of impacts implying localized spatial density changes of orders of magnitude on scales of less than a km [3]. Long exposure images of the comet reveal large numbers of jets projected nearly around the entire perimeter of the nucleus, many of which appear to be highly collimated, with angular sizes of a few degrees [4].

The overall mass distribution in the inner coma is dominated by the largest grains, with an average cumulative mass distribution index of α = 0.75±0.05 (where the number of particles of mass m or larger, $N(m) \propto m^{-\alpha}$). However, the mass distribution was also highly variable during the flyby and almost 80% of the detected impacts occurred during the second period of high activity, ~4000 km from the nucleus, where small grains dominated, with α = 1.13±0.2 [5].

Jets and Fragmentation: The detection rates are characterized by structure on timescales of seconds ('swarms' with spatial scales of 10s of km) and fractions of a second ('bursts' with spatial scales of less than 1 km) [3].

The swarms have dimensions consistent with the jets seen in the Stardust NAVCAM images. Many of the swarms can be correlated with the positions of jets [6] although definitive solutions are not possible due to lack of knowledge of the nucleus rotation rate and grain terminal velocities.

The enormous variations in dust spatial density over distances of a few hundred metres, which characterize the bursts, cannot be explained by grain dynamics within the coma, particularly as they occur outside the innermost coma, where gas drag is no longer the dominant force. Particle fragmentation provides the only viable explanation [3],[5],[7]. The bursts result from the passage of Stardust through expanding dust clouds resulting from extended fragmentation. The second period of high activity results from outgassing and/or fragmentation of a large (10s of metres diameter) boulder [6].

The interpretation of this highly structured coma as due to a combination of jets and particle fragmentation has been received with some skepticism. The evidence will be reviewed and common criticisms refuted. Comparisons with results from The P/Halley and P/Grigg-Skjellerup flybys indicate that the same processes occurred in both comets for which in-situ dust data are available and therefore may be common in comets in general.

References:

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