Dust Telescopes and Active Dust Collectors:
Linking Dust to Their Sources

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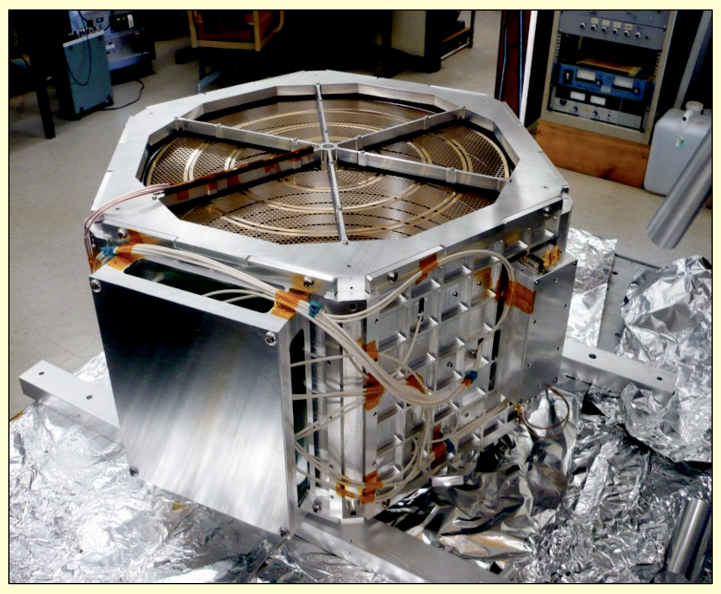
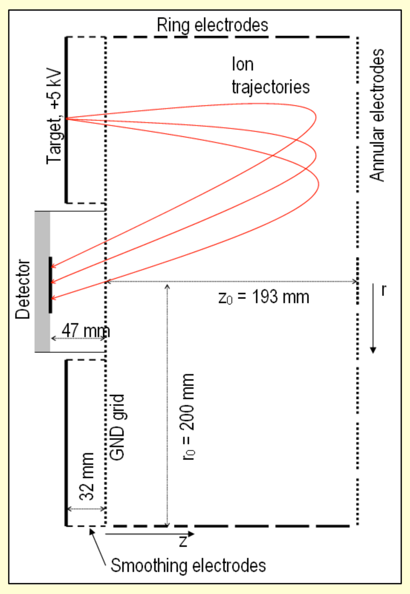
Abstract. Cosmic dust particles from remote sites and times are treasures of information. By determining the dust particles' source and elemental properties, we can learn about the environments where they were formed and processed. Born as stardust in the cool atmospheres of giant stars or in novae and supernovae explosions, the particles are subsequently modified in the interstellar medium. Interplanetary dust that originates from comets and asteroids represent even more processed material at different stages of Solar System evolution. Interstellar and interplanetary dust particles from various sources can be detected and analyzed in the near-Earth space environment.

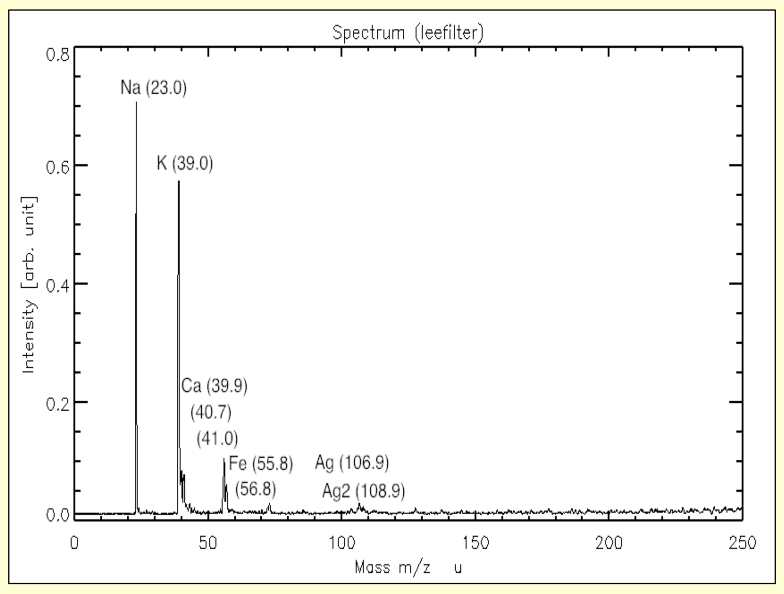
The newly developed instruments, the Dust Telescope and Active Dust Collector, are able to determine the origin of dust particles and provide their elemental composition. A Dust Telescope is a combination of a Dust Trajectory Sensor (DTS) [1] together with an analyzer for the chemical composition of dust particles in space. Dust particles' trajectories are determined by the measurement of induced electric signals when a charged grain flies through a position sensitive electrode system. A modern DTS can measure dust particles as small as 0.2µm in radius and dust speeds up to 100km/s. Large area chemical analyzers of 0.1 m^2 sensitive area have been tested at a dust accelerator and it was demonstrated that they have sufficient mass resolution to resolve ions with atomic mass number up to >100 [2]. The advanced Dust Telescope is capable of identifying interstellar and interplanetary grains, and measuring their mass, velocity vector, charge, elemental and isotopic compositions.

An Active Dust Collector combines a DTS with aerogel or other dust collection materials, e.g. those used on the Stardust mission. The combination of a DTS with a dust collector provide not only individual trajectories of the collected particles but also their impact time and position on the collector which proves essential for finding and collecting sub-micron sized grains.

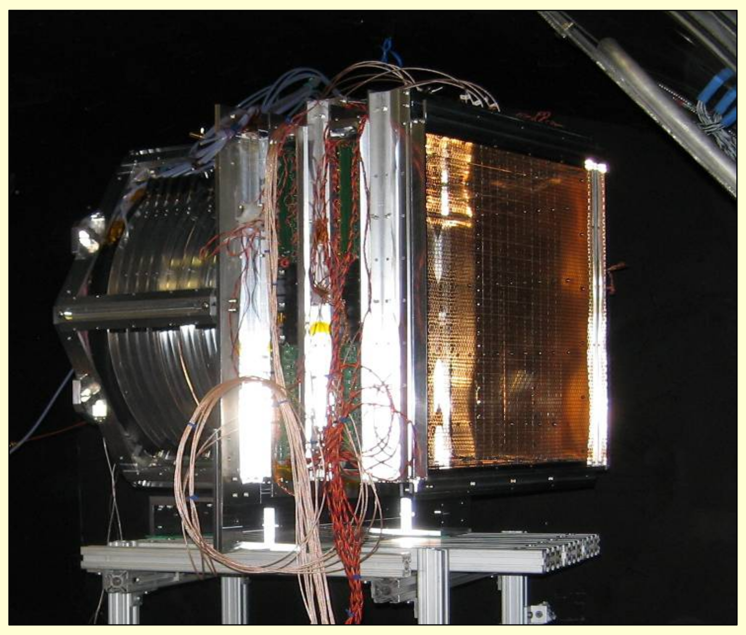
Chemical Analyzer. The Chemical Analyzer (CA), *left*, operates on the basis of impact ionization. Hypervelocity impacts (> 1 km/s) on a solid surface result in the evaporation and partial ionization of the dust and target materials. The ions are extracted from the impact plume, and analyzed in the time-of-flight (TOF) fashion. The geometry of the CA is shown *middle* below. The effective target area, considering the effect of the grids in front, is approximately 900 cm^2. The figure *right* shows the measured mass spectrum of a typical particle. The largest peaks in the spectra correspond to Na and K ions as usually observed for simple projectile-target material pairs at low velocity [3], [4]. The Fe (projectile material) and Ag (target material) peaks are visible at m = 56 Dalton and m = 107 and 109 Dalton, respectively. The CA has high mass resolution of m/dm >100.

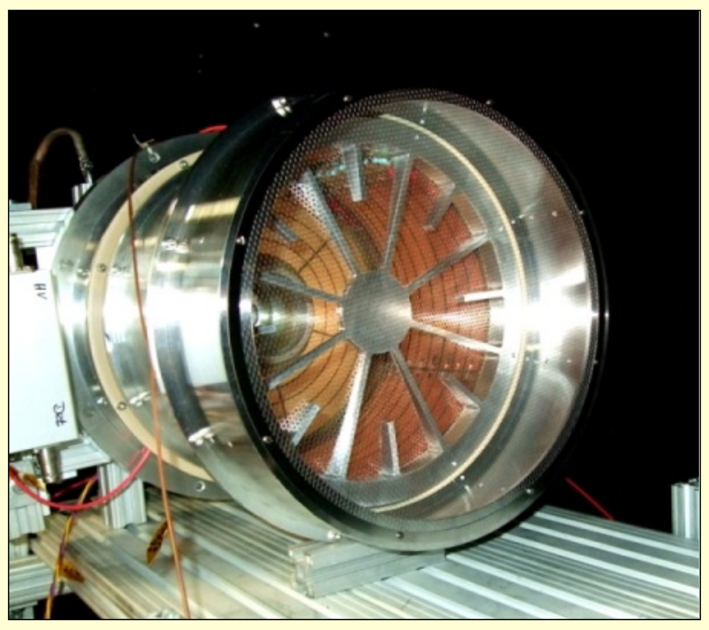






Dust Telescope. The Dust Telescope is a combination of a Dust Trajectory Sensor together with a high mass resolution Chemical Analyzer. Several prototypes of Dust Telescopes have been fabricated and tested at the dust accelerator facility. On the *left* is a prototype instrument with a large ~ 0.1 m^2 area for the analysis of interplanetary and interstellar dust (approx. 20 kg for a flight instrument). The *right* picture shows a laboratory version of a small Dust Telescope (~0.02 m^2, ~5 kg,) for high flux environments (e.g. near the sun, cometary tails or planetary rings). The combination of a DTS and CA provides a full picture of the impacting dust particles, measuring their trajectory as well as their elemental composition.





References.

[1] Auer, et al., Characteristics of a dust trajectory sensor, Rev. Sci. Instrum. 79, 084501, 2008

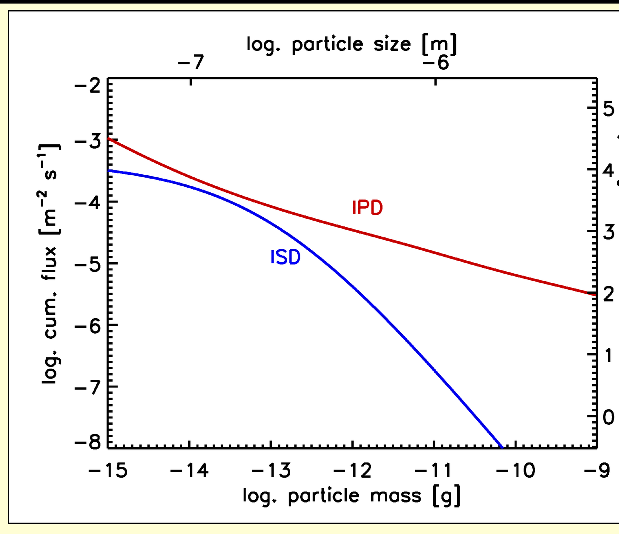
[2] Srama et al., Development of an advanced dust telescope, Earth, Moon and Planets, DOI: 10.1007/s11038-005-9040-z, 2005

[3] S. Auer and K. Sitte, "Detection technique for micrometeoroids using impact ionization," Earth Planet Sci. Lett. 4, 178-183, 1968.

[4] S. Auer and K. Sitte, "Detection technique for micrometeoroids using impact ionization," Earth Planet

Science Opportunities.

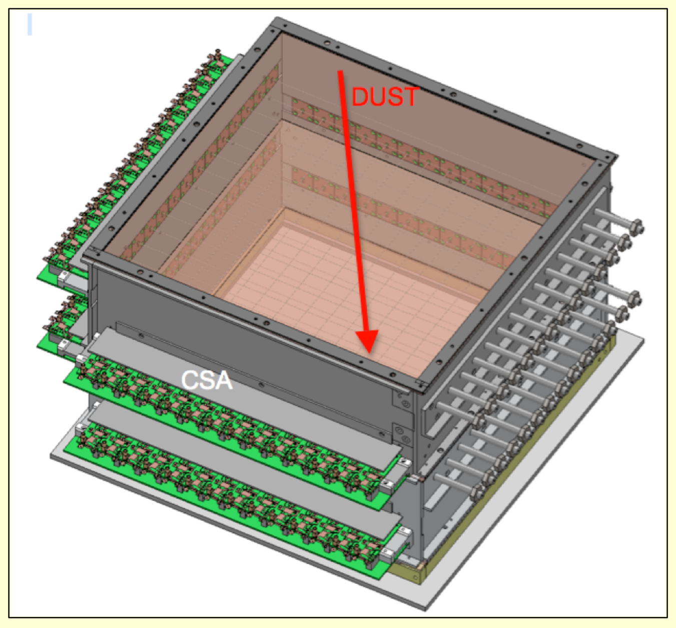
- Analyze **interstellar dust** and probe the heliosphere (DUNE) with improved chemical composition analysis.
- **Sample return missions** similar to STARDUST with enhanced information about the time of impact and trajectory reconstruction. Better particle locating and tracing of imbedded impacts.

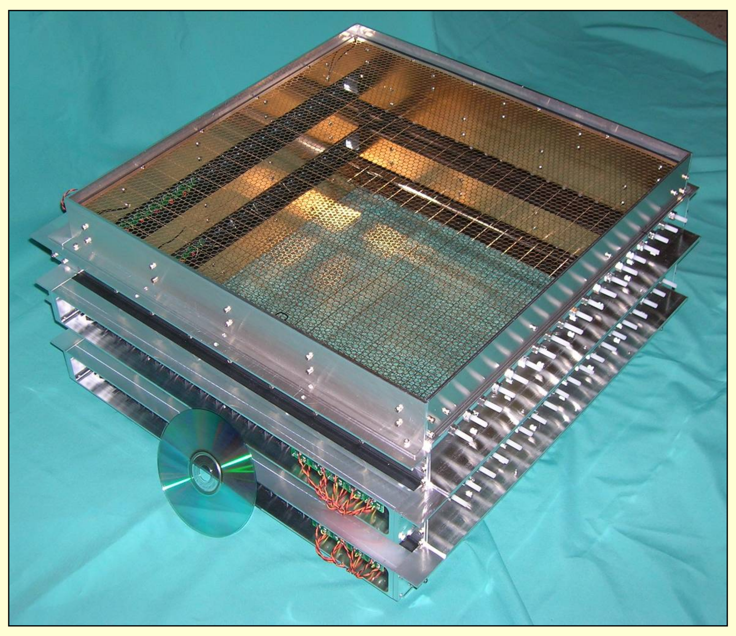


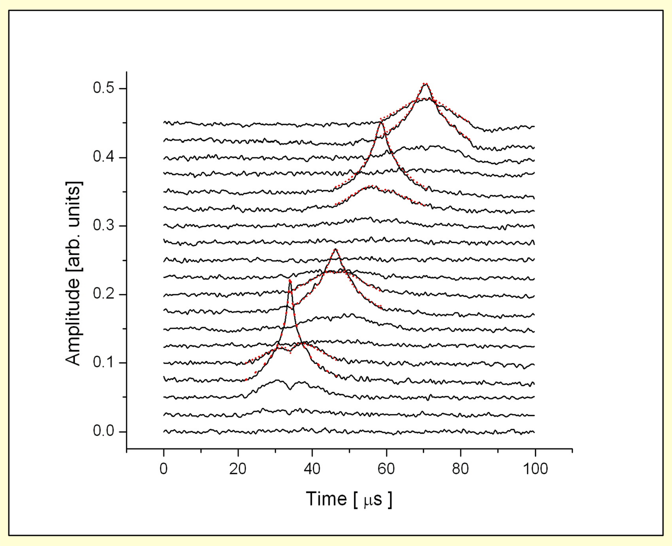
Interplanetary and interstellar dust flux at 1 AU. The interstellar flux varies by a factor 3 during the 22 year solar cycle.

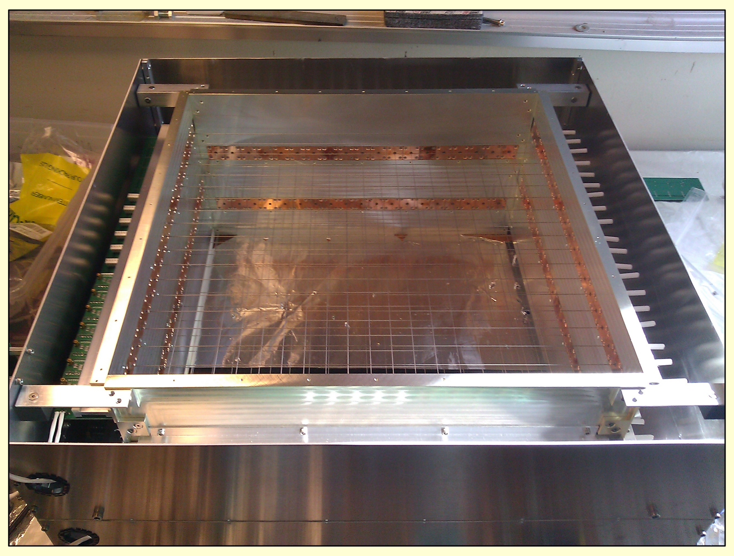
- The new dust instruments will improve future dust collection of interplanetary dust particles providing information about the particles' sources.
- Map the surface composition to a spatial resolution of about 10 km in orbit about the Moon, the Galilean satellites, or any airless planetary object.

Dust Trajectory Sensor. The trajectory of a charged dust particle is calculated from the measurement of induced charges from a particles passing through an array of wire electrodes connected to individual charge sensitive amplifiers. The DTS contains four planes, each with 19 wires. The planes are arranged in an orthogonal orientation. The trajectory sensor measures dust charges $>10^{-16}$ C and allows to determine trajectories of submicron-sized grains with accuracies of ~1° in direction, and ~1% in speed.



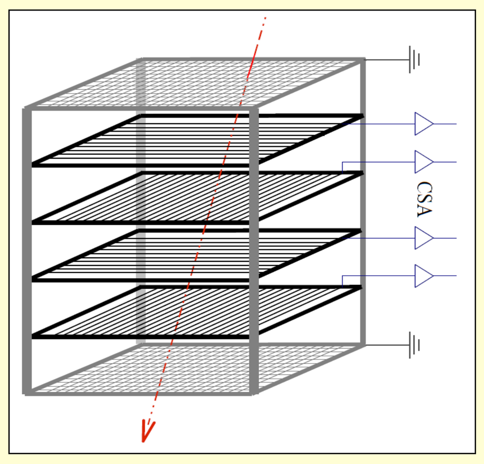


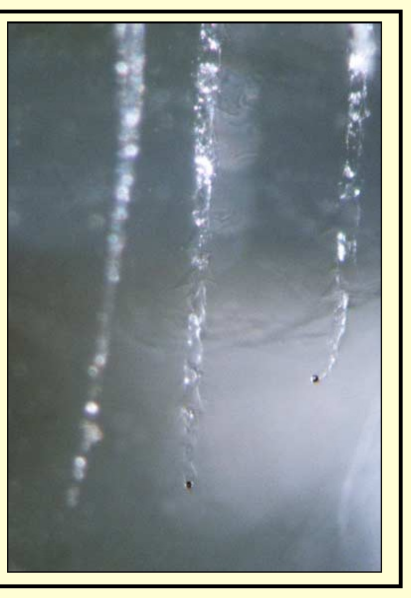




Top left shows a schematic of the electrode wire array. The detection region is defined by a shielding box which acts as a signal reference ground. *Bottom left* shows a typical charge signal set across 19 wires in 4 planes. The largest signals indicate the electrode of closest approach in each plane. The red is the best fit yielding the trajectory information and charge of the dust particle. Two prototype DTS instruments are shown *top* and *bottom right*, the latter being an improved second revision which is currently undergoing testing.

Active Dust Collector. Combination of a DTS with an aerogel or any other dust collector material (impact films) provides individual trajectories of the collected particles and their impact time and position on the collector. From the trajectory given by the DTS mounted before the collector, the impact position can be determined to better than 1 mm accuracy. The accuracy of the velocity vector will be sufficient to distinguish interstellar particles from interplanetary ones .





Development Stages. A number of prototypes of Chemical analyzers and Dust Trajectory sensors have been developed and tested at the Heidelberg dust accelerator facility. In addition, a combined CA DTS Dust Telescope has also been developed and has shown to have m/dm > 100 mass resolution, 1 – 100 fC dust charge sensitivity range, 1 – 100 km/s velocity range, < 1% accuracy in velocity and < 1° directional accuracy. Aerogel has been well characterized and determined viable during the STARDUST mission and accelerator testing.

Conclusions. A capable Dust Telescope instrument offers a complementary method by analyzing the small particulates released from the surface. In-situ mass spectroscopy analysis of the ejected dust particles from orbit thus can reveal detailed information about the composition of the surface. Active Dust Collectors will open new doors of interplanetary and interstellar dust research where the impact position of the collected grain will be known to sub-mm accuracy significantly easing the location of the grain on the collector material.