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Simulation of Hypervelocity Dust Impacts with a 2MV Dust Accelerator Facility

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Abstract

The Dust Accelerator is a unique European facility which allows the investigation of hypervelocity dust impacts onto various materials. The facility is designed to study the interaction of micro-grain impacts with target materials like planetary analogues, metals or interplanetary dust collector materials. The accelerator provides a laboratory platform for the study of interplanetary dust impacts and the design and calibration of dust sensor instrumentation.

Facility Description

Dust grain materials from nano to micron sizes are accelerated, using a 2 MV Van-de-Graaff accelerator, to velocities between 1 and 60 km/s [1]. These velocities are relevant to the study the dust properties in planetary rings of the giant planets and impact ejecta processes on the surfaces of small bodies (asteroids, comets) as well as moons and planetary surfaces. Common impact speeds of micrometeoroids onto interplanetary probes are between 5 and 20 km/s.

Figure 1 : Acceleration path and dust source of the 2 MV Van-de-Graaff dust accelerator.

The dust accelerator facility of the Max-Planck-Institut für Kernphysik consists of a dust particle source, an acceleration path (Fig. 1), a linear drift pipe with a particle selection unit and an experiment chamber (Fig. 2). The dust source is made out of titanium and contains a dust reservoir, a tungsten needle as charging electrode inside the reservoir, an extraction plate and a beam collimator [2]. The dust source can be operated with micron and submicron sized metal powders, organic microspheres (PMPV, latex) or even minerals (pyroxene, anorthite, olivine). However, dust source materials which carry dielectric surfaces have to be coated with a conductive layer by appropriate processes [3,4,5]. Submicron grains carry high charge-to-mass ratios and reach highest impact speeds. Dust power mixtures with grain sizes between 0.1 μm and 3 μm provide stable operation conditions with dust fluxes up to 50 particles per second (Fig. 3). The dust particle properties are measured in realtime by sensitive beam detectors [6] and the accelerator can be operated in a single-shot mode (dust grains outside a certain speed or mass window are deflected).

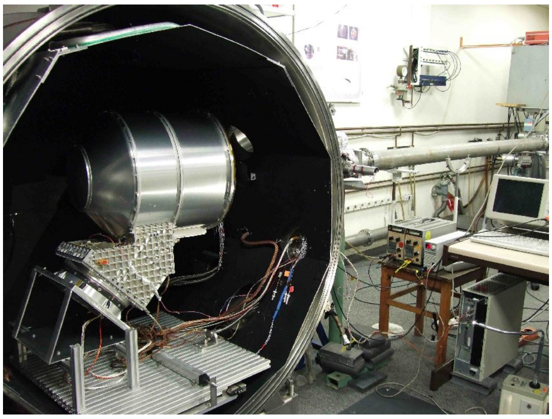

Figure 2: Big experiment chamber of the dust accelerator facility with the Cosmic-Dust-Analyser.

Applications

Studies at the dust accelerator are multi-disciplinary and belong to geoscience, physics, chemistry, astrophysics and astrobiology. Phenomena under study include dust charging,

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dust magnetosphere interactions, dust impact flashes and the possibility of obtaining compositional measurements of impact plasma plumes. Such data has been shown to be of direct relevance to space missions like Galileo, Ulysses, Cassini, Rosetta, Stardust, New Horizon or BepiColombo. Future projects to the Moon, to the inner Solar System (Solar Probe Plus), to the Jovian system and to Saturn will carry dust instrumentation which has to be developed with the help of micrometeoroid impact simulations in the laboratory. Further studies are related to the recent Stardust mission which collected and returned samples of interplanetary and interstellar dust grains to Earth. Sample preparation and analysis requires the study and understanding of grain-collector material interaction during hypervelocity impacts.

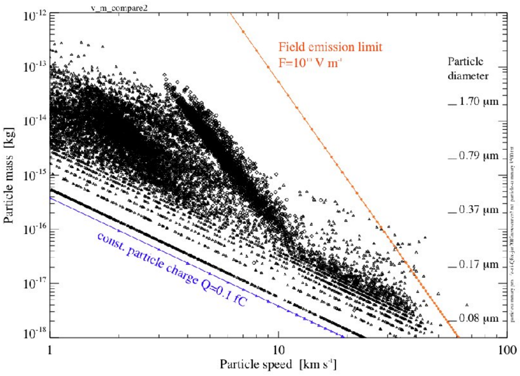

Figure 3: Dust grain speed and mass distribution of accelerated iron and nickel dust particles. The parallel lines at the bottom represent small but constant grain charges.

Test and calibration of dust collectors and of in-situ dust detectors onboard interplanetary probes or Earth satellites is a major application of the facility. The laboratory generation and analysis of in-situ mass spectra of high-speed organic micro-grain impacts is essential for astrobiology studies and provide the basis for an understanding of the composition of interplanetary or interstellar micrometeoroids.

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