EPSC Abstracts
Vol. 13, EPSC-DPS2019-980-1, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The Hyper-Velocity Dust Research Laboratory at the Institute for Space Systems at the University of Stuttgart

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Abstract

Electrostatic accelerators provide micrometer-sized particles as projectiles for hypervelocity impact experiments [2]. After being located for over 5 decades at the Max-Planck-Insitute for Nuclear Physics in Heidelberg (MPI-K/HD), the dust accelerator has been moved to the Institute for Space Systems (IRS/UniS). This relocation provides the opportunity to optimize the set up of the accelerator and the whole dust research laboratory. This includes significant progress regarding the cleanliness of the facility, the detection, monitoring, and selection of the particles as well as the experimental environment and equipment. Furthermore, a major effort has been started to gain a deeper understanding of the charging and acceleration of the dust particles, laying the groundwork for a further development of the dust sources.

1. Introduction

In the past five decades various dust detection instruments on spacecraft have been used successfully to investigate in situ the physical, dynamical, and chemical properties of cosmic dust in the Solar System. These instruments use the fact of the particle impinging onto a target and the physical processes which origin from this event. This can be for example the emerging of an impact ionization plasma from a metal plane target or the track of the particle in an aerogel. To calibrate an instrument and to get a deeper understanding of the processes involved, hypervelocity impact measurements under similar and well defined conditions are required. For this purpose, a Van-de-Graaff type ion accelerator was modified at the MPI-K/HD in the late 1960ies [5]. The accelerator was equipped with a dust source capable of charging and accelerating dust particles (Fig. 2).

The accelerator [2] covers a large portion of the speed and size ranges needed for most cosmic applications with velocities between 1 to about 80 $\mathrm{km\,s^{-1}}$ (Fig. 1). It is capable of accelerating metallic particles and C, as well as organic compounds such as Polystyrene and coated mineral dust [1, 3, 4].

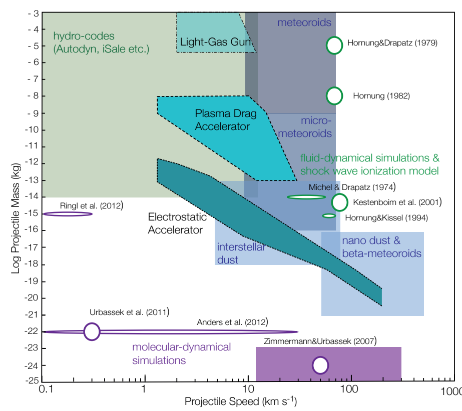

Figure 1: Mass versus velocity ranges for the three common micro-particle accelerators, dust populations in the Solar System and the ranges covered by models describing HVIs.

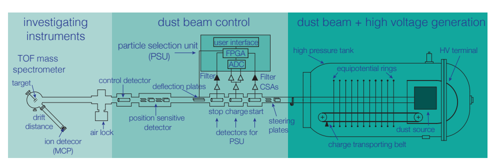

Figure 2: Schematic of a dust accelerator.

After being located for over 5 decades at the MPI-K, the dust accelerator has been moved to the IRS/UniS. This relocation gives us the opportunity to optimize the set up and the also the whole dust research laboratory in its entirety.

2. Charging and Acceleration

The dust beam originates from the dust source within the high voltage terminal of the accelerator.

After exiting the source, the dust particles are ac-

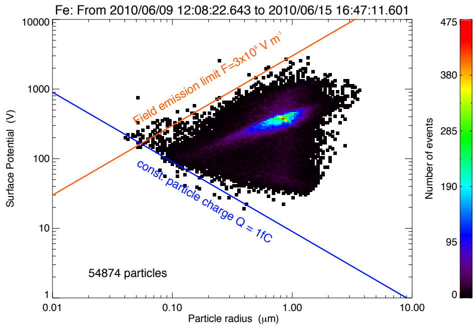

Figure 3: The surface potential $\Phi = q / 4\,\pi\,\epsilon_0\,r$ for iron particles in dependence on the particle size [5].

celerated in the electrostatic field towards the experimental set-up. Before reaching the target, the particles are registered, characterized, and eventually selected while passing the beam line detectors of the Particle Selection Unit (PSU).

To reach high particle velocities, two requirements must be met. Both the accelerator potential and the charge-to-mass ratio q/m of the particles must be as high as possible. The electrical field strength $F = \Phi/r$ at the surface is limited by ion field emission. Assuming the maximum field strength is constant for all particle sizes for one particular material, broad fundamental relationships for the dynamical parameters of homogeneous spherical particles can be found. A further effort to gain a deeper understanding of the working principles of the dust source(s) and to design an enhanced dust source type started about a year ago and has already lead to first simulation results [6].

3. Particle Selection and Detection

Further downtime beam line, the particles are detected by a chain of detectors measuring the particle's primary surface charge using an induction tube and a charge-sensitive amplifier (CSA). The resulting signals are then processed and analyzed by the PSU.

Nanodust in the lab: Recent upgrades to the beam line instrumentation and electronics now allow for the reliable selection of particles at velocities of 1 to $80\,\mathrm{km\,s^{-1}}$ and with diameters of between 0.05 μm and $5\,\mu\mathrm{m}$. The new control instrumentation and electronics, together with the wide range of particle types and particle rates between 1 min^{-1} to $1000\,\mathrm{s}^{-1}$, allow the controlled and systematic investigation of hypervelocity impact phenomena across a wide range of impact parameters specifically for nanometer sized particles.

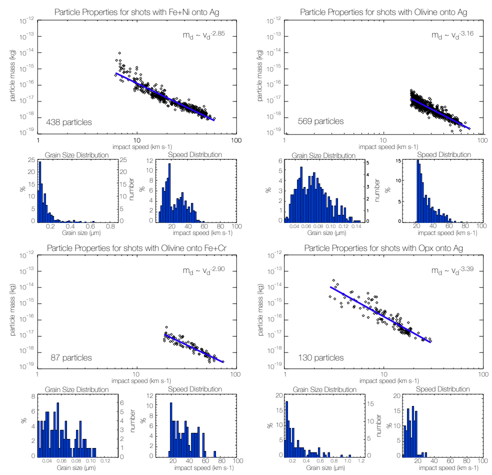

Figure 4: Existing lab data sets for nanometer-sized dust particle impacts.

4. Applications

The physical phenomena occurring during hypervelocity micro-particle impact are manyfold and are the basis for the variety of applications. The processes of interest are particle fragmentation, impact ionization, impact flashes, charge induction, microphony and mass spectrometry. Their detailed investigation using latest analyzing techniques like high-speed cameras and sensitive high-resolution spectrometers promise new instrument concepts and insights into short timescale high-pressure states of matter.

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