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Calibration of the Cassini Cosmic Dust Analyzer

J. Simolka (1), R.Srama (1), T. Albin (1, 2), S. Bugiel (1), S. Kempf (3), Y. Li (1), G. Moragas-Klostermeyer (1), F. Postberg (4), H. Strack (1)
(1) Institute of Space Systems – Universität Stuttgart, Germay (2) Carl von Ossietzky Universität Oldenburg, Germany (3) University of Colorado at Boulder, USA (4) Universität Heidelberg, Germany
(simolka@irs.uni-stuttgart.de / Fax: +49 711 685 63596)

Abstract

The Cosmic Dust Analyzer (CDA) onboard the Cassini spacecraft detects micron and sub-micron sized particles in the Saturn environment since 2004. The impact ionization based instrument measures the positive and negatives charges of the impact plasma generated by striking particles. This signals yield the impact velocity and the particle mass. Therefor the instrument needs to be carefully calibrated. Calibration is performed utilizing the dust accelerator facility in Heidelberg which is able to accelerate micron and sub-micron sized dust particles to velocities relevant in space. Particles on circular orbits in Saturn's ring plane allow cross calibration of the dust telescope since their velocity and mass range is well known. However, since the initial calibration the scientific knowledge of the local dust environment has drastically improved (thanks to Cassini). At the same time laboratory testing facilities evolved over the years and allow a better recreation of actual conditions nowdays. Especially a larger variety of dust types particularly of mineral compositions is available nowadays.

1. Introduction

When a dust particle hits the detector target it gets partially or completely ionized. Furthermore – dependent on the impact velocity – the impact generates ejecta (particle and target fragments) which can cause secondary and even tertiary impacts. These events shape a plasma cloud which is separated by an electric field. Negative charges are collected at the target and positive charges at the ion collector. The target consists of two separate parts. The large target area of the impact ionization detector consists of a gold coated hemisphere with a diameter of 40 cm . The smaller chemical analyzer target is part of CDAs time of flight mass spectrometer. Figure 1 shows a schematic drawing of CDA and two impact events with correlating signals.

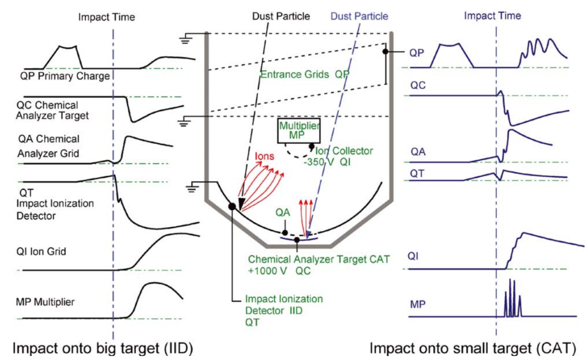

Figure 1: Schematics of CDA. Two exemplary impact events and their correlating signals are shown for an impact on the large target and on the chemical analyzer target. [3]

2. Particle Velocity and Mass Determination

For modeling Saturn's dust environment the size and velocity of the dust grains is of particular interest. These (and more) properties can be obtained from CDA's measurements.

2.1 Impact Velocity

Previous impact ionization detectors have shown a correlation of the charge signal rise times and the impact velocity – independent from the particle mass and impact angle. [1] CDA uses this phenomena to determine the velocity of striking particles (Further measurements and effects are considered for better accuracy). The rise time is defined by the time intervall between 10% and 90% of the signal waveform's peak value. [3] The slight dependency of the particle composition is not considered in the current calibration model. The particle velocity can be derived from the impact velocity and the velocity of the spacecraft.

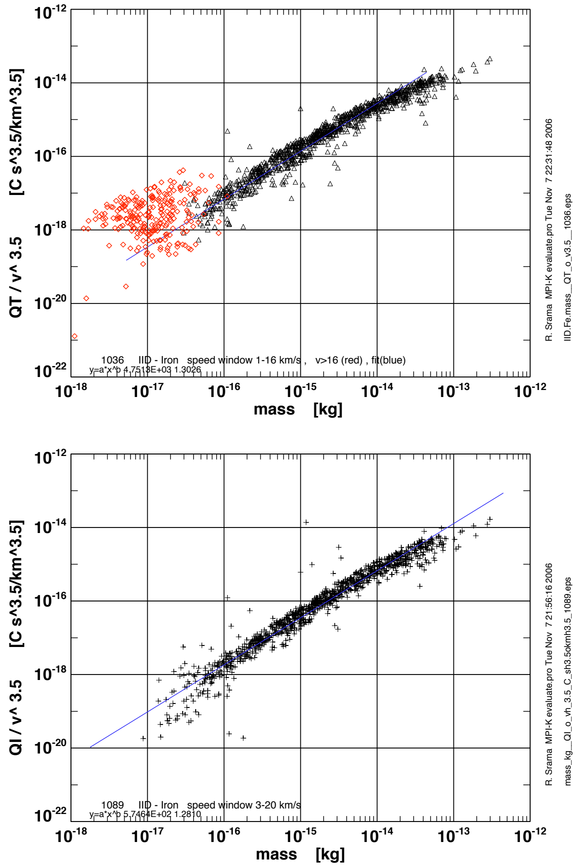

Figure 2: This is the example of an included figure.

2.2 Particle Mass

There is a well known empirical relationship between the impact charge Q, impact velocity v and particle mass m. The amount of the generated impact plasma increases with higher particle mass and velocity.

$$Q \sim m^{\alpha} \cdot v^{\beta} \quad (1)$$

Direct measurement of the impact charge and determination of the impact velocity cf. 2.1 yield the particle mass.

Figure 2 shows the ratio $Q/v^{3.5}$ over the particle mass m for measurements taken in the laboratory. The upper graph corresponds to negative charges measured at the target while the lower graph reflects the positive charge measurements at the ion collector. The red symbols in the upper graph correlate with impact events with a velocity > 16 *km/s* indicating a regime where no secondary impacts occur. [2] The speed exponent β is set to 3.5 which yields a clearly discernible trend over the shown velocity range.

3. Summary and Conclusions

CDA is investigating the dust environment at Saturn for over a decade now. The collected data helped to obtain a better understanding of the local evolution of micron and sub-micron sized particles. One of the particles' interesting properties are their velocity and mass. The gained scientific knowledge and advanced laboratory facilities allow us to redifine the instruments calibration model. The poster presents the latest methods and an outlook into the recalibration of the cosmic dust analyzer.

References

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