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Insights on the Zodiacal Cloud Dust Populations at Saturn from CASSINI-CDA

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Abstract

We report the detection of exogenic dust within the Saturnian's system by the Cassini-Cosmic Dust Analyser (CDA). We compare the dynamical signature of the detected grains with the signature expected for different dust populations at 10 AU, like particles originating upon collisions within the Kuiper Belt and drifting inward the Solar System under PR drag, cometary grains and interstellar dust. We aim with CDA data at providing new constraints on the relative contribution of these dust populations to the Zodiacal Cloud at 10 AU and a lower bound estimate of the exogenic dust mass flux in-falling into the Saturnian system.

1. Introduction

The so-called Zodiacal Dust Cloud (hereafter ZDC) is the ensemble of micrometeoroid particles that fills the Solar System. Particles created upon collisional processes between parent bodies (like asteroids) and by cometary activity are referred to as Interplanetary Dust Particles (IDPs). The knowledge on the outer ZDC (beyond Jupiter's orbit) dust populations t far less detailed than for the inner Solar System, mainly because of the very sparse amount of data (in-situ and remote sensing) available beyond 5 AU. Only three spacecraft carrying in-situ dust detectors provided detections of dust grains in the outer Solar System: Pioneer 10 and Pioneer 11 as reported in and more recently New Horizon -SDC on its way to Pluto. However, these spacecraft did not collect enough data to distinguish unambiguously the source of the particles. Cassini-CDA, orbiting Saturn since 2004, is, in turn, an ideal observatory to monitor the outer ZDC dust populations and observe the constant rain of exogenic dust falling into the Saturnian System.

2. CDA Subsystems Data

We look for the signature of exogenic grains in different CDA subsystem's data: the Impact Ionization Detector (IID), the Entrance Grid (EG) and the Chemical Analyzer Target (CAT). Both IID and CAT detects the impact particles on their respective targets in the mass range 10^{-18} kg-10^{-12} kg (corresponding to sub-micron to micron sized particles) and for velocities ranging from 2 to 40 kms^{-1} . Upon IID and CAT impacts, the speed vector directionality can be constrained by the instrument field of view (45° for IIT and 28° for CAT). In case of impacts on the CAT target, a Time-of-Flight mass spectra (TOF) is generated, from which not only the elemental composition of the particle can be inferred, but also an independent lower limit estimate of the impact velocity. The EG subsystem, in turn, is sensitive to large grains (>2 μm) by detecting the electrostatic charge carried on their surface (QP signal). For such events, the speed vector direction can be reconstructed and the velocity directly estimated with high precision (within a few percent).

3. Data analysis and Discussion

Different methods of analysis must be used depending on the CDA subsystem that triggered the grain detection. We show that individual grain trajectory can be reconstructed if the grain was detected by the EG subsystem, allowing in many case an unambiguous detection of exogenic grains. The trajectory of exogenic particles is traced backward to the injection location at the Hill's sphere of Saturn and their heliocentric orbital elements determined.

As for CAT triggered impacts, we observe TOF spectra suggesting high impact velocities on the detector. Coupled with arguments on the directionality and the distribution of specific TOF

signals on the sky sphere, we identify likely interstellar grain candidates. The IID data, in turn, needs to be analysed statistically, as the velocity and direction determination is too coarse for an unambiguous identification of individual grains. In this case, our observable is the radial distribution of the number of grains detected beyond Titan's orbit. Taking gravitational focusing into account, we infer the average velocity and mean volume number density of exogenic grains outside Saturn;s Hill's sphere needed to fit the radial grain detection frequency profile observed by CDA-IIT.