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Characterisation of the Outer Solar System dust by Cassini-CDA

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Introduction

We analyse 13 years of data acquired by the Cosmic Dust Analyser (CDA) and its Entrance Grid (EG), Chemical Analyser Target (CAT) and Impact Ionisation Detector (IID) subsystems on-board the Cassini spacecraft around Saturn. We confirm the presence of exogenous dust, originating from the interplanetary space and permanently crossing the Saturnian system. We analyse the range of possible heliocentric orbital elements in order to identify their possible origin. We observe large particles whose dynamics is compatible with 'old' collisional debris from the Kuiper-Belt, migrating inward the Solar System under influence of the Poynting-Robertson drag, or relatively fresh grains from recently discovered cometary activity of Centaurs. A population of particles entering the Saturn's system with high velocities can be linked to Halley-type comets as parent bodies. Smaller particles detected by the CAT subsystem, could also have active Centaurs as their parent bodies.

1. Data analysis

The major difficulty we are facing is the identification of comparatively very rare exogenous particles in an environment dominated by E ring particles. In the densest regions of the E ring, the CDA instrument is saturated by E ring impactors, therefore 'masking' contributions from other sources. Fortunately, the Cassini spacecraft has been flying on orbits for a wide range of inclinations and eccentricities while touring Saturn during the past seven years such that regions with reduced E ring contribution can be exploited for our study. Regions more favorable for the search of exogenous particles are typically as far as possible from Saturn, or, 'far enough' from the equatorial plane of Saturn, in order to avoid the bulk of the E ring particles, as well as regions were the plasma density saturates the EG subsystem. When EG data could be acquired, the particles orbital elements can be constrained to sufficient accuracy to inambiguously discriminate E ring particles from interplanetary dust particles (IDPs). CAT data are used to estimate the impact speed of the particles from the Time-of-flight spectra recorded upon impacts on the chemical analyser target. Although uncertainties in impact direction and speed determination exist, we find a population of relatively small exogenous particles, whose heliocentric orbital elements can be constrained as they cross the Saturn's Hill's radius (Fig.1 and Fig 2.).

2. Results and Discussion

The orbital elements of the IDPs are plotted on Fig. 1. The presence of IDP raining onto the Saturn's system is by itself an important result providing constraints on evolutionnary processes like, for example, the compositional evolution of atmosphere-less icy surfaces (icy moons and Saturn's main ring system) and of the atmospheres of Titan and Saturn. As importantly, from its vantage point at Saturn, about 10 AU from the Sun, the CASSINI-CDA data cast light on the dust populations of the outer solar system, their parent bodies and generation process.

We find that Jupiter Family Comets (JFCs) cannot be a dominant source for the dust that CDA measures at Saturn. In turn, our measurements appear in good qualitative and quantitative agreement with the dynamical signature of KBO dust expected at Saturn. We find, however, that KBO dust cannot be distinguished at Saturn dynamically from particles released by Centaurs/TNOs, whose cometary-like activity at large heliocentric distances has been recently discovered. Grains released by Halley types comets, with high-heliocentric inclinations are reported, in addition to the interstellar dust flow as reported by previous mission (Ulysses, Galileo in particular).

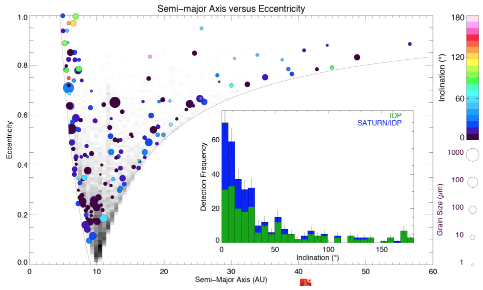

Figure 1: Orbital elements of the exogenous particles detected by the EG subsystem. The circles represent the heliocentric orbital elements of all exogenous solutions in an eccentricity versus semi-major axis plot. The symbol color indicates the inclination of the IDP orbits with respect to the ecliptic and the symbol size scales with the particle radius. The inset shows the corresponding inclination distribution.

Hints on particle composition and possible particle streams are discussed.

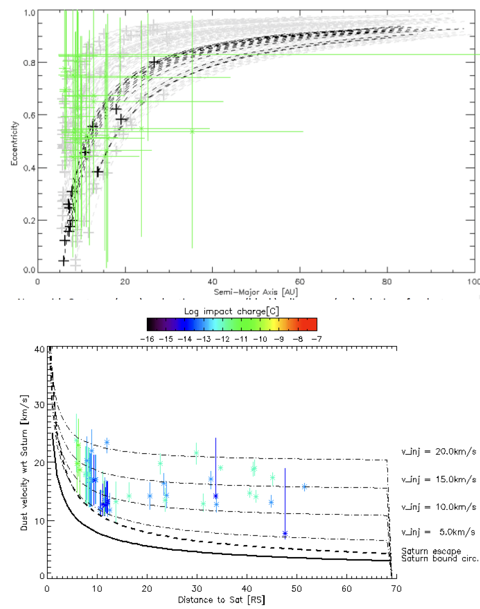

Figure 2: Lower panel: velocity of the particles detected with the CAT subsystem with respect to Saturn, compared to the escape velocity, and the velocities expected as function of the radial distance to Saturn, for particles injected inside the Saturn's system with various injection speeds and undergoing gravitation focusing. Upper panel: eccentricity versus semi-major axis plot of the exogenous particles. The grey crosses are the (a,e) values for known Centaurs and the black crosses indicate known active Centaurs. The dashed lines correspond to the (a,e) values that a grain released from a given Centaur can have depening on its solar radiation pressure to gravity ratio.