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Dust Counters onboard the *Cassini* spacecraft

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Abstract

We present revised data on dust particles registered by the Cosmic Dust Analyzer (CDA) aboard the *Cassini* spacecraft. The raw data is pre-selected and refined to a new structure that serves to a better investigation of local densities, flows, and properties of interplanetary dust. We explain how dead time correction, pointing, and the time scales are altered to calculate reliable particle densities. The new data is published on the website for the Magnetosphere and Plasma Science (MAPS), where correlations with different instruments can be enabled.

1. Introduction

The "dust counters" are an array of 27 numerators for impacts of dust grains on the CDA. Each impact is analysed by the onboard flight software immediately after its occurence. A dust particle hitting the sensitive area of the detector will produce various electric signals that are subject to a classification. The combined properties of the signals are interpreted by a sophisticated decision making algorithm. So, the counters serve as "containers" or "categories" for some common characteristics of the impact. The objective is to accumulate particles with special features in order to compare their frequency of appearance.

2. Arrangement of the Counters

The classification of the impacts is priority-sequenced. For example, the first check is whether different signals (charge, ionisation, etc.) are present, otherwise the event is sorted as "noise". If fulfilling the criteria for a classification, other attributes are checked: the amplitude and duration on the Chemical Analyzer Target and the Impact Ionisation Detector. Subsequently, the next criteria are checked unless an appropriate classification is found. Each impact is allocated a unique counter.

In the course of the mission the definitions experienced some changes, and so did the flight software. A major change occured in mid 2005. The thresholds for the particle registration are still being altered to adjust the sensitivity in the ambience of the spacecraft orbit: dense regions, ring plane crossings, flybys at moons etc. For example, when flying through a dense cloud, the number of very small particles will be high and the recording runs into saturation; large impacts are hardly triggered. For that reason, the "masscut" is lifted Consequently, some quantities like mass and velocity are appraised in accord to the environment. The impact events are called "weak", "strong", "fast", etc. They provide characteristics of dust particles *relative* to the environment. This procedure turned out successful, because it considers both, the environment and the long-term developments of the flight software. The scientific investigation was not influenced, and the results turned out quite precisely.

3. Emendations to the Data

The dust counters are integer values of impacts, N, and they are read out on a regular time period $dT = t_j - t_{j-1} = 64$ seconds. The impact rate $r = dN/dT$ is subject to various biases, but it does not provide the correct particle density at the spot of the spacecraft.

3.1. Dead Time Correction

The first correction applied to the raw counter data is the dead time. The procedure of determining and storing each impact event takes about 1 second, during which the instrument will be insensitive. In high density regions, the device is expected to go into saturation, and the impact rate will be systematically underestimated.

Since the statistics of dust impacts is based on the Poisson process, a reconstruction of the "true" rate, r', is possible as long as the statistical distribution of the impact times are known. The details of the correction method are discussed by Kempf (2006b). We deploy the formula as given in Srama (2009), his equation (3.43):

$$r' = 60.0 \frac{r}{1 - \tau r}, \tag{1}$$

where $\tau = 0.94$ s is the mean dead time of an individual event and r is the rate of registred particles dN within the interval $dT = 64$ s. This formula is easy to handle and yields almost identical results for a moderate impact frequency. Only if the instrument goes into saturation (impact frequencies ≈ 0.98 s^{-1}), the error exceeds 20% with respect to the Kempf-formula.

3.2. Dust Ram and Pointing

As the spacecraft moves along her trajectory, the orientation of the aperture (pointing of the boresight) will gradually change relative to other bodies in space. The dust flow is, in contrast, a resulting vector coming from the spacecraft motion and direction of particles, which is usually unknown as they would enter the instrument from any direction. The only trajectory to be reliably calculated is marked by the Kepler orbit. The assumption, that dust particles are on a Keplerian orbit, has to be made a priori, which may not necessarily be true. However, it is the only obvious reference and called the “dust RAM”.

The velocity $v_{\rm dust}$ of the particles can be obtained from the difference of the Keplerian circular velocity and the speed of the *Cassini* spacecraft, $v_{\rm Cass}$:

$$v_{\rm dust} = v_{\rm RAM} - v_{\rm Cass} \tag{2}$$

$$= \sqrt{\frac{GM_{\rm S}}{a}} - v_{\rm Cass}, \tag{3}$$

where G is the Gravitational constant, $M_{\rm S}$ the mass of Saturn, and a the distance of the particle (or spacecraft) from the planet’s center.

Furthermore, the instrument will be able to register only particles, if their incoming angle α is smaller than 47° relative to the boresight. We check whether or not the angle of the dust RAM, α, is exposed to the sensitive area $A_{\rm eff}$ of the CDA surface.

3.3. Adjustment of Time Scales

The data of the spacecraft ephemeris is provided at an interval of 120 seconds, while the counter data scales on a period of 64 seconds. These two different time scales are merged by the simple condition

$$t_i \leq t_{j1 \ldots jn} < t_{i+1}, \tag{4}$$

where the index i runs through the rougher-meshed time scale, and j are the fine-meshed tick marks.

4. Particle Density

From the revised data, the local particle density in space is calculated by

$$n = \frac{dN}{dV} = \frac{r'}{A_{\rm eff} \cdot v_{\rm dust}}, \tag{5}$$

where dN denotes the number of particles in the space volume dV, r' is the true counter rate, $A_{\rm eff}$ the sensitive area of the CDA exhibited to the dust RAM, and $v_{\rm dust}$ the relative velocity of the dust particles to the spacecraft.

The final data is structured in a matrix of 6 groups (Khalisi *et al.* 2011): counters of impacts on the detector wall, chemical target, ionisation detector, large impacts, sudden charge flares, and noise. The concept of the counters will reveal correlations with various physical properties that have been found by other *Cassini* instruments. The data is published on the website for the Magnetosphere and Plasma Science (MAPS) working group of the mission which fosters collaborative science.

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