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Galileo dust data from the jovian system: 2000 to 2003

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ABSTRACT

The Galileo spacecraft was the first man-made satellite of Jupiter, orbiting the planet between December 1995 and September 2003. The spacecraft was equipped with a highly sensitive dust detector that monitored the jovian dust environment between approximately 2 and 370 R_J (jovian radius R_J=71 492 km). The Galileo dust detector was a twin of the one flying on board the Ulysses spacecraft. This is the tenth in a series of papers dedicated to presenting Galileo and Ulysses dust data. Here we present data from the Galileo dust instrument for the period January 2000 to September 2003 until Galileo was destroyed in a planned impact with Jupiter. The previous Galileo dust data set contains data of 2883 particles detected during Galileo's interplanetary cruise and 12 978 particles detected in the jovian system between 1996 and 1999. In this paper we report on the data of additional 5389 particles measured between 2000 and the end of the mission in 2003. The majority of the 21 250 particles for which the full set of measured impact parameters (impact time, impact direction, charge rise times, charge amplitudes, etc.) was transmitted to Earth were tiny grains (about 10 nm in radius), most of them originating from Jupiter's innermost Galilean moon Io. They were detected throughout the jovian system and the impact rates frequently exceeded 10 min^{-1}. Surprisingly large impact rates up to 100 min^{-1} occurred in August/September 2000 when Galileo was far away ($\approx$280 R_J) from Jupiter, implying dust ejection rates in excess of 100 $\mathrm{kg\,s}^{-1}$. This peak in dust emission appears to coincide with strong changes in the release of neutral gas from the Io torus. Strong variability in the Io dust flux was measured on timescales of days to weeks, indicating large variations in the dust release from Io or the Io torus or both on such short timescales. Galileo has detected a large number of bigger micron-sized particles mostly in the region between the Galilean moons. A surprisingly large number of such bigger grains was measured in March 2003 within a four-day interval when Galileo was outside Jupiter's magnetosphere at approximately 350 R_J jovicentric distance. Two passages of Jupiter's gossamer rings in 2002 and 2003 provided the first actual comparison of in-situ dust data from a planetary ring with the results inferred from inverting optical images. Strong electronics degradation of the dust instrument due to the harsh radiation environment of Jupiter led to increased calibration uncertainties of the dust data.

1. Introduction

The Galileo spacecraft was the first artifical satellite orbiting Jupiter. Galileo had a highly sensitive impact ionization dust

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detector on board which was identical with the dust detector of the Ulysses spacecraft (Grün et al., 1992a, 1992b, 1995c). Dust data from both spacecraft were used for the analysis of e.g. the interplanetary dust complex, dust related to asteroids and comets, interstellar dust grains sweeping through the solar system, and various dust phenomena in the environment of Jupiter. References can be found in Krüger et al. (1999a, 2010).

In Section 1.1 we summarise results that are related to dust in the Jupiter system. A more comprehensive overview of the investigation of dust in the jovian system was given by Krüger (2003) and Krüger et al. (2004).

1.1. Summary of results from the Galileo dust investigations at Jupiter

The Jupiter system was found to be a strong source of dust when in 1992 Ulysses flew by the planet and discovered streams of dust particles emanating from the giant planet's magnetosphere (Grün et al., 1993). These were later confirmed by Galileo (Grün et al., 1996a, 1996b) and measured again by Ulysses in 2003–2005 during its second flyby at the planet (Krüger et al., 2006c; Flandes and Krüger , 2007). During its two Jupiter flybys, within a distance of 3 AU from the planet, Ulysses measured 11 and 28 dust streams, respectively.

At least four dust populations were identified in the Jupiter system with Galileo (Grün et al., 1997a, 1998):

(i) Streams of dust particles with high and variable impact rates throughout Jupiter's magnetosphere. They are the extension of the streams discovered with Ulysses outside Jupiter's magnetosphere. The particles are about 10 nm in radius (Zook et al., 1996) and they mostly originate from the innermost Galilean moon Io (Graps et al., 2000). Because of their small sizes the charged grains strongly interact with Jupiter's magnetosphere (Horányi et al., 1997; Grün et al., 1997a, 1998; Heck, 1998), and they are a natural laboratory to study dust–plasma interactions. The dust streams mostly show a dust-in-plasma behaviour, i.e. the particle motion can be described by single particle dynamics, while only some portions of those Galileo orbits displaying the highest dust stream fluxes (Galileo orbits E4, G7, G8, C21) satisfy the minimum requirements for a dusty plasma where collective effects dominate particle motion (Graps, 2006). The dust streams served as a monitor of Io's volcanic plume activity, showing that periods with high measured dust fluxes are most likely connected with heavy volcanic eruptions on Io (Krüger et al., 2003a). The dust streams measurements revealed significant dust flux variations with jovian local time (Krüger et al., 2003b) consistent with theoretical expectations (Horányi et al., 1997), demonstrating that the dust measurements probe the plasma conditions in the Io torus. Graps (2001) and Flandes (2005) investigated dust charging mechanisms in the jovian magnetosphere and in Io's plumes. The particles reach an equilibrium potential of approximately +5 V and they collect most of their charge within about 20 R_J from Jupiter. Dust measurements of the Cassini spacecraft at its Jupiter flyby in 2000 showed that the grains are mostly composed of sodium chloride (NaCl) formed by condensation in Io's volcanic plumes (Postberg et al., 2006).

(ii) Dust clouds surrounding the Galilean moons which consist of mostly sub-micron grains (Krüger et al., 1999d, 2000, 2003c). These clouds were detected within the Hill spheres of the moons and the grains were secondary ejecta particles kicked up from the moons' surfaces by hypervelocity impacts of interplanetary micrometeoroids (Krivov et al., 2003; Sremčević et al., 2003, 2005). The majority of the ejecta grains follows ballistic trajectories and falls back to the moons' surfaces while a small fraction can even leave the gravity field of the moons and go into orbit about Jupiter.

(iii) Bigger micron-sized grains forming a tenuous dust ring between the Galilean moons and further beyond. The measured dust mass distribution peaks at about 2 μm (assuming spherical grains with density 1 g cm^{-3} Krüger et al., 2006b). This group is composed of two sub-populations, one orbiting Jupiter on prograde orbits and a second one on retrograde orbits (Colwell et al., 1998; Thiessenhusen et al., 2000). Most of the prograde population is maintained by grains escaping from the clouds that surround the Galilean moons (Krivov et al., 2002a). Dusty motes most likely released from the surfaces of the irregular outer satellites of Jupiter were also found to about 300 R_J from Jupiter, showing both prograde and retrograde orbits (Krivov et al., 2002b).

(iv) On 5 November 2002 and 21 September 2003—before Galileo was destroyed in a planned impact with Jupiter—the spacecraft traversed Jupiter's gossamer ring twice and provided the first in-situ measurements of a dusty planetary ring (Krüger, 2003; Moissl, 2005; Krüger et al., 2009) which is also accessible with astronomical imaging techniques. These fly-throughs revealed previously unknown structures in the gossamer rings: a drop in the dust density between the moons Amalthea and Thebe, grains orbiting Jupiter on highly inclined orbits and an increase in the number of small grains in the inner regions of the rings as compared to the regions further away from the planet. All these features can nicely be explained by electromagnetic forces on the grains that shape the gossamer rings (Hamilton and Krüger, 2008).

1.2. The Galileo and Ulysses dust data papers

This is the tenth paper in a series dedicated to presenting both raw and reduced data from the Galileo and Ulysses dust instruments. Grün et al. (1995c, hereafter Paper I) described the reduction process of Galileo and Ulysses dust data. In the even-numbered Papers II, IV, VI and VIII (Grün et al., 1995a; Krüger et al., 1999a, 2001a, 2006b) we presented the Galileo data set spanning the ten year time period from October 1989 to December 1999. The present paper extends the Galileo data set from January 2000 to September 2003, which covers the Galileo Millenium mission and two traverses of Jupiter's gossamer ring until the spacecraft impacted Jupiter on 21 September 2003. Companion odd-numbered Papers III, V, VII, IX and XI (Grün et al., 1995b; Krüger et al., 1999c, 2001b, 2006a, 2010) provide the entire dust data set measured with Ulysses between 1990 and 2007. An overview of our Galileo dust data papers and mission highlights is given in Table 1.

The main data products are a table of the number of all impacts determined from the particle accumulators and a table of both raw and reduced data of all "big" impacts received on the ground. The information presented in these papers is similar to data which we are submitting to the various data archiving centres (planetary data system, NSSDC, etc.). The only difference is that the paper version does not contain the full data set of the large number of "small" particles, and the numbers of impacts deduced from the accumulators are typically averaged over several days. Electronic access to the complete data set including the numbers of impacts deduced from the accumulators in full time resolution is also possible via the world wide web: http://www.mpi-hd.mpg.de/dustgroup/.