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Dust Orbits near Jupiter's Galilean Satellites: New Analysis of the Galileo DDS Data Set

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Abstract

We present initial results from our re-analysis of the complete Galileo Dust Detection System (DDS) data set in the Galilean satellite region. We focus on assessing the claim of [7] for detection of retrograde particles, which would have profound implications for the dominant sources of dust in the region. We model the full set of detectable orbits at each impact location, and are able to separate a fraction of impacts that cannot be the result of prograde or retrograde circular planar orbits. We discuss characteristics of the impact angle distributions that may suggest a retrograde source.

1. Introduction

Knowledge of the dust populations within the Jovian system contributes to our understanding of dynamical behaviour, impact hazards, dust sources, and contamination of satellite and ring surfaces. Previous work has concluded that not all Galileo dust impacts are consistent with prograde circular planar orbits [3], and also that there is evidence for retrograde orbits in the vicinity of the Galilean satellites [7]. These retrograde impacts were in the highest charge classes ($AR \geq 3$). This result is interesting because such dust may represent interplanetary and interstellar material captured by Jupiter's magnetosphere [2] [3]. Other possible sources for inclined near-circular dust exist also (such as scattering of prograde circular orbits [8]).

There is now a larger dataset of dust impacts from the Galileo DDS [6]: while the original work used data 1996-1998, we now have DDS data until 2003. However, impact angle directions for incoming particles have uncertainties of ±70° [5], and particle speeds have uncertainties of a factor of ~ 2 [4]. These restrict our ability to determine the orbits of observed impacts. For this re-analysis we use 'large' impactors (roughly micron-sized grains in impact charge classes $AR \geq 2$) in the denoised DDS dataset.

2. Modelling Detectable Impacts

We find the set of detectable orbits at a given location using Galileo's position and speed, the pointing direction of the detector and the 70° detector field of view. We determine that a large fraction of impacts must be either eccentric or inclined (Table 1). We can thus confirm that the full dataset cannot be explained by only circular planar orbits.

Table 1: The fraction of $AR = 2$ and $AR \geq 3$ impacts that are not explained by circular planar orbits.

Circular Orbits **Charge Class**	Not Pro.	Not Retro.	Neither Pro. nor Retro.
$AR = 2$	51%	58%	37%
$AR \geq 3$	38%	25%	12%

We can explain 95% of $AR \geq 3$ impacts with retrograde particles with inclinations greater than 150° and eccentricities less than 0.6: these tentatively match with the expected characteristics of magnetospherically captured particles [2]. However, we note that prograde particles with similar inclination and eccentricity limits are also possible. $AR = 2$ particles require very high eccentricities up to 0.9 in order to explain 95% of observed impacts.

3. Impact Probability

We also consider the most likely orbits. This is dependent on the sensitive area of the detector, the velocity of Galileo, and the calculated impact speed for the grain. The first two are combined to provide an 'effective sensitive area' probability [1]. We estimate the probability for each impact speed using a Gaussian distribution, with the impact speed and speed uncertainty of the particle providing the mean and standard deviation respectively. By multiplying the effective sensitive area probability by the impact speed probability we produce the total probability, for a range of eccentricity and inclination combinations (Figure 1). We define 'high probability' orbital combinations as those with probabilities $> 80\%$ of the maximum.

We find that only $\sim 10\%$ of $AR = 2$ locations but $\sim 38\%$ of $AR \geq 3$ locations have high probabilities of retrograde orbits. This demonstrates that $AR \geq 3$ have a higher chance of representing retrograde particles if they exist, but does not represent detection of retrograde orbits. In comparison, $\sim 90\%$ of $AR = 2$ and $AR \geq 3$ impacts have a high probability of prograde orbits.

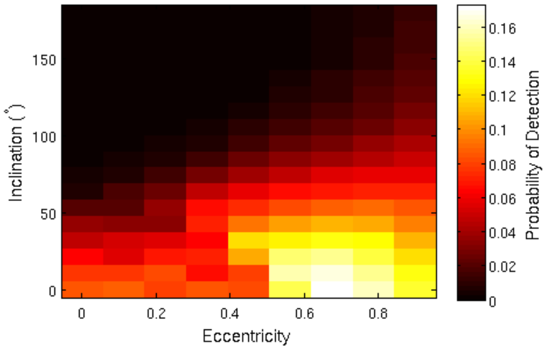

Figure 1: An example of the 'total' probability for different eccentricity and inclinations combinations.

4. Impact Angles

Previous work used a distinctive shift in the expected impact angle for circular planar retrograde impacts to demonstrate the presence of retrograde orbits [7]. We find that impact angles for all $AR \geq 3$ particles can be produced by eccentric prograde orbits. However, there is a significant gap in the $AR \geq 3$ impact angle distribution in a region reached by eccentric grains but not retrograde orbits. We are investigating whether this is evidence for retrograde grains or of observational bias.

5. Summary and Conclusions

We have shown that $\sim 27\%$ of DDS impacts are inconsistent with circular planar orbits. Magnetospheric capture mechanisms are not excluded as a source for the largest $AR \geq 3$ impacts. We are investigating the source for a small population of very eccentric $AR = 2$ particles. We are also studying the impact angle distributions further to determine whether the $AR \geq 3$ impacts are consistent or inconsistent with highly eccentric grains.

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