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A new analysis of Galileo dust data near Jupiter

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Abstract

We present results of our reanalysis of the complete Galileo Dust Detection System (DDS) data set in the Galileo satellite region. By studying the directional information for observed impacts, we investigate the populations that can describe the observed impacts. This involves developing a model of the set of detectable orbits at each impact location. The current data in this region is found to be insufficient to determine the contributing populations.

1. Introduction

Dust populations within the Jovian system contribute to our understanding of dynamical behaviour, impact hazards, and the erosion and contamination of satellite and ring surfaces. The Galileo Dust Detection System (DDS) provided the only real insight into the dust environment outside of the main Jovian ring system. However, the micron-sized dust impacts within the Galilean satellite region are not consistent with prograde, circular impacts [2]. Previous research has found that two populations are required to describe the observations: a prograde population that could be mainly explained by impact ejecta from Galilean satellites [7]; and a retrograde population [4, 11], which could represent interplanetary and interstellar dust particles captured due to focusing by the strong Jovian magnetosphere [2, 1].

Because we now have the complete data set consisting of up to two times as many impacts, a reanalysis is warranted [9]. We also consider additional possible sources including particles escaping from Jupiter's Gossamer rings [6], outer Jovian satellites [8], and focused interplanetary or interstellar particles on hyperbolic trajectories past Jupiter. Including Galilean satellite ejecta and magnetospherically-captured dust particles, this provides six potential source populations. Here we investigate whether the observed distributions of 'large' particles (roughly micron-sized grains in impact charge classes $AR \geq 2$) in the denoised Galileo DDS data set [5, 10] are consistent with the expected distributions for each of these six possible sources.

2 Analysis

We are interested in whether certain orbits are visible to the Galileo DDS at the location of each impact. This defines the set of orbits that can describe the observed impact. The DDS pointing direction and opening angle are the only constraints on the incoming particle direction: since this opening angle is large (140°), it is not possible to define a narrow range of orbital elements for each observed dust grain. In addition, uncertainties in measured speeds are a factor of ~ 2 [3].

However, conclusions on the orbits required to explain a set of particles are possible. For instance, we can determine the percentage of DDS impacts that can be explained by orbits with different eccentricity limits, for both prograde and retrograde orbits. Only $\sim 70\%$ of $AR = 2$ and $\sim 90\%$ of $AR \geq 3$ impacts can be explained by prograde orbits with eccentricities < 0.1. For $AR = 2$ impacts, eccentricities up to 0.75 are required to explain 90%.

Additionally, we can determine which DDS impacts can be described by each of the six populations given in Section 1 (Fig. 1). It is apparent that Galilean satellite ejecta cannot explain more than 70% of $AR = 2$ impacts, or 80% of $AR \geq 3$ impacts. The failure of interstellar dust (ISD) to explain many of the impacts is expected, as the geometry of Galileo with respect to the ISD dust is poor for detection of ISD. Most highly eccentric or hyperbolic sources (outer satellite ejecta, interplanetary particles, and Jovian ring particles) can explain most impacts.

Finally, we are currently studying the effective sensitive area of the DDS detector as a function of time and ROT angle (the only measure of impact direction). This provides the effective detector area that each population 'sees' as it approaches the detector: a populations that sees a larger area is more likely to be detected. There is insufficient data to determine the population that has the sensitive area map that is the best fit

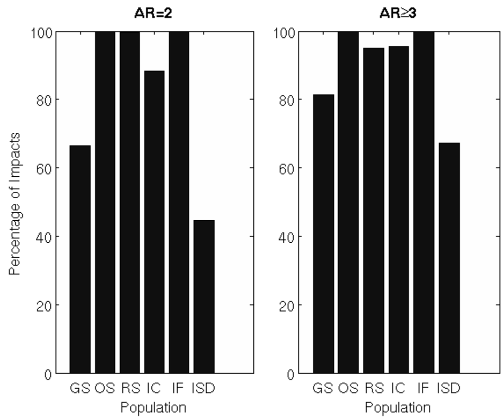

Figure 1: Percentage of $AR = 2$ and $AR \geq 3$ data sets that can be dynamically explained by each of six different orbital populations. The acronyms GS, OS, RS, IC, IF and ISD stand respectively for Galilean satellite ejecta, outer satellite ejecta, Jovian ring paritlces, captured interplanetary particles, interplanetary particles on flyby orbits through the jovian system, and interstellar dust.

to the data set. We find that no one population is a good match to $AR = 2$ data, such that two dominant sources are necessary (likely given that $\sim 30\%$ of $AR = 2$ impacts require $e > 0.3$). A second significant population may also be necessary for $AR \geq 3$. Though captured interplanetary particles provide a good fit to the data, a solution for $AR \geq 3$ may also exist that does not require a large retrograde population.

3. Summary

We find that eccentricities greater than 0.1 are required to explain $> 20\%$ of impacts, and that a small number of impacts require orbital solutions with eccentricities in excess of 0.75. The large detector opening angle restricts the conclusions that can be deduced from the directional information: we find that it is probable that a combination of sources are required to explain the observations.

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