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Jovian Dust Bursts

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Six streams of dust were unexpectedly detected by the Ulysses dust detector while this spacecraft was approximately within one AU distance from Jupiter (Grün et al., 1993). Stream durations ranged from hours to days for individual streams. It was clear that the dust in these streams (or bursts), from their directionality of approach to the spacecraft and from the nearness of stream occurrences to Jupiter, emanated from the Jovian system.

Following the original report, Baguhl et al. (1994) later relaxed the criteria for differentiating true dust impacts from "noise pulses" and found almost triple the number of dust impacts in the six streams already found. They also found 5 more streams that, except for one stream, clearly emanated from the Jovian system. The criteria were relaxed in such a way as to not introduce "noise events" into the data. The one stream that was not clearly of Jovian origin occurred about 1 AU before Jupiter closest approach (JCA); the particles in that stream had an average arrival direction that was about 80 degrees, in spacecraft rotation angle (phi-angle), south of the line-of-sight (los) direction to Jupiter. The most distant stream observed occurred about 2 AU from Jupiter, after JCA. The corresponding stream-associated particles for this stream arrived, on average, from about 20 degrees south of the los direction to Jupiter.

Besides the stream mentioned above with the 80 degree mean phi-angle from the los direction, five other streams had mean phi-angles that were from 20 to 60 degrees from the los direction to Jupiter. If only gravitational forces were acting on these Jovian dust grains, they would have arrived from almost exactly the los direction to Jupiter. The fact that they did not means that a strong non-gravitational force was acting on the particles. This force could only be the VxB (Lorentz) force due to the solar wind-imbedded magnetic field acting on the electrically charged dust grains as they traveled from Jupiter to the Ulysses spacecraft. The velocity, V, is the vector difference between the particle velocity and the solar wind velocity Both the solar wind velocity and the magnetic field vector components were measured on the Ulysses spacecraft, and could be extrapolated to the constantly changing dust particle location during its flight from Jupiter to the spacecraft.

Trajectories were modelled backward in time starting with particle impact on the Ulysses dust sensor. Magnetic field and solar wind velocity vectors were averaged over either one or six hour intervals, and the acceleration on the particle was assumed to be constant during the averaging interval. For two streams, both intervals of averaging were used and the corresponding trajectories were compared with each other. No important differences of results were observed between the two averaging intervals. If a "reversed-time" trajectory approached within 50 Rj of Jupiter, it was assumed that a particle could be released from the Jovian magnetosphere and, in forward time, impact the Ulysses dust sensor; i.e., we had a potential "solution" to the actual trajectory a dust grain might follow after being accelerated by the Jovian magnetosphere.

We typically modelled over ten million possible (or "make-believe") trajectories of charged dust trajectories backward in time from the time of impact of each stream on the spacecraft. Using a random number generator, we varied the dust grain radius between 0 and 0.1 microns, the grain impact velocity between 20 and 500 km/s, the phi-angle between 0 and 360 degrees, and the angle of approach of the dust grain to the Ulysses spin axis between 15 and 155 degrees. For each set of 4 parameters, we modelled a single trajectory. We assumed that the grain was of density 1 g/cm^3 and charged to +5 volts which, with varying dust grain radius, produced many different charge-to-mass ratios. The purpose was to find which model trajectories, with which particle parameters, could have been emitted from the Jovian system (within 50 Jovian radii) such that they impacted the Ulysses dust sensor at the mean **observed** spacecraft rotation angles during stream occurrences.

The left hand part of Fig. 1 shows the relationship for computed trajectories between assumed phi-angles and particle radii for the 2347 trajectories (out of 10^7 trials) that approached within 50 Rj of Jupiter; each dot shows the result for one trajectory. This stream was the 8th stream observed, and occurred 87 days after JCA at a distance of 1486 Rj from Jupiter. The right hand part of this figure shows phi-angle vs impact velocity. The observed mean approach angle for the 31 particles of this stream was 32 degrees in rotation angle from ecliptic north, or 22 degrees south of the los direction to Jupiter which is at 54 degrees (The value for phi-angle and stream duration is changed somewhat from that of Baguhl et al., 1994). It is seen that the large particles all arrive from the los direction to Jupiter; the width in rotation angle, for large particles, is due to the 100 Rj width of the jovian magnetosphere (the assumed source region). Only particles smaller than about 0.01 micron radius fall within a 10 degree band about the observed mean phi-angle of 32 degrees; for 31 particles arriving from a single direction, the 20°-wide band gives, with better than 95% confidence, the mean arrival direction of that stream, as seen by the rotating 140° field-of-view dust instrument. This stream does not show the discrimination in velocity that some of the other streams do; but, put together, the data for all streams show that only streams with velocities above about 200 km/s can satisfy both the observed phi-angle data and the instrument threshold criteria. Flight times from Jupiter to the Ulysses spacecraft for this stream ranged around 5 days, plus or minus two days, for particles that fell within the 10 degree band, and were above the instrument threshold for detection.

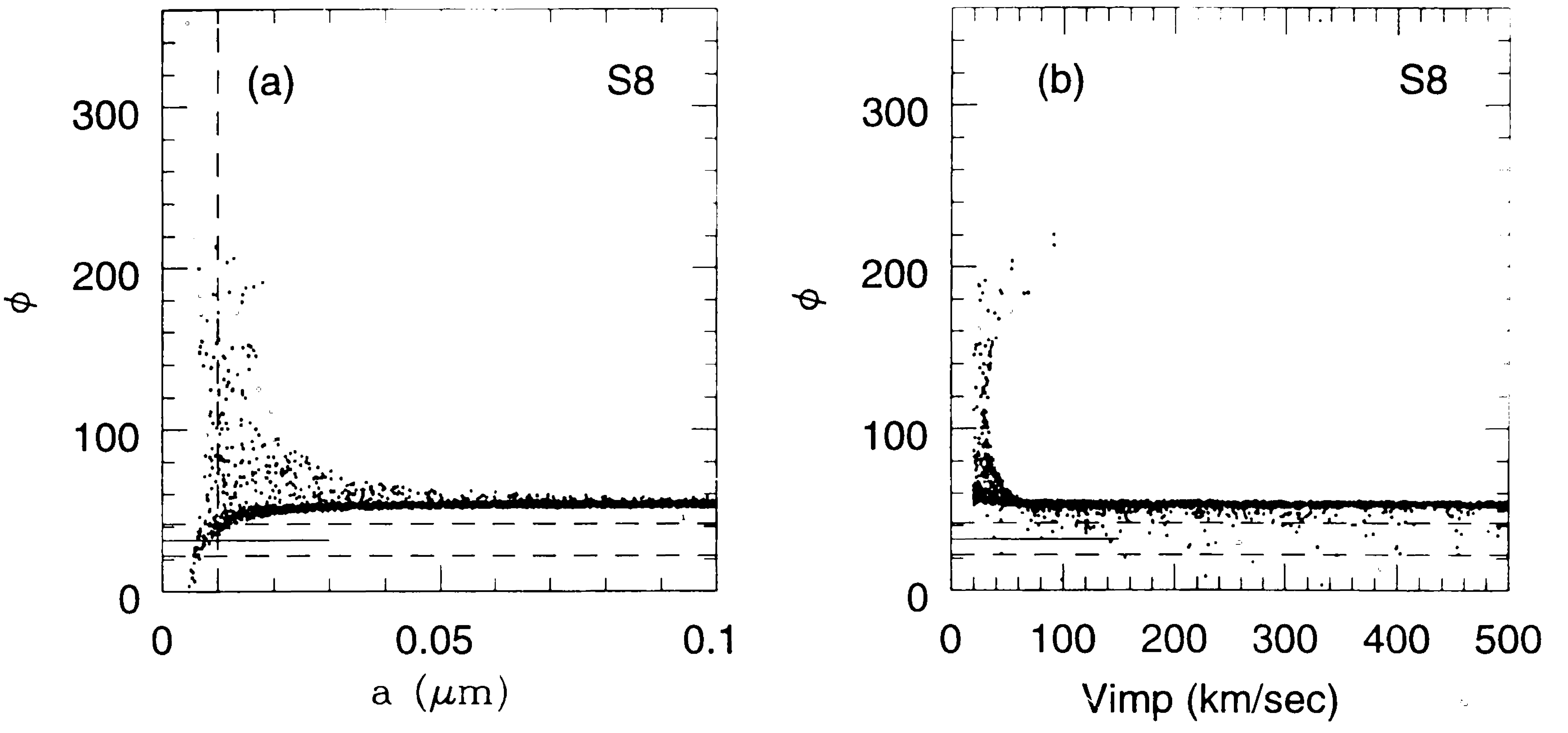

Fig. 1. Trajectory analyses for stream S8. This stream of 31 particles lasted about 75 hours and was tightly grouped in rotation angle, with all but one impact occuring within a 55° spread of rotation angles. The median time of occurance of this stream was 87.4 days after JCA and at a distance of 1486 Rj (approx. 0.7 AU) from Jupiter. The left figure shows phi-angle vs particle radius for 2347 calculated trajectories that passed within 50Rj of Jupiter in reversed time. The right figure shows phi-angle vs particle impact speed for the same data. The horizontal dashed lines 10° above and below the measured mean phi-angle for this stream (at 32°) give approximate 95% confidence limits on the true location the measured mean phi- angle. The vertical dashed line is drawn, for visual convenience, at a = 0.01 microns.

We evaluated the angle with respect to the ecliptic plane (very near the jovian equatorial plane) with which particles can leave the jovian system and impact the Ulysses dust sensor. This was done at many locations along the Ulysses trajectory, and it was found that, under the continuous stream hypothesis, particles should be striking the Ulysses dust sensor at times when they are not. For this reason we believe, rather weakly, that the dust particles leave the jovian system in bursts rather than as a continuous stream.

References

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