Chapter 8

GOING FURTHER

In this chapter, I describe some paths for future work, in order to advance this Jovian dust streams research.

8.1 Time-Frequency Analysis of Ulysses Dust Detector Data

The Ulysses dust detector was the first instrument to detect the Jovian dust streams, however the last concentrated effort to work with this dataset for learning more about the Jovian dust streams was Zook et al.'s (1996) work. I wish to analyze the Ulysses data with some of the time-frequency tools that I developed in this thesis for the Galileo dust detector data. I expect to see the same 30-day periods seen by the previous investigators, plus I hope to see some patterns of frequency modulations and new periods, especially in the region closest to Jupiter.

8.2 Material Properties Parameters and the Particle's Trajectory

When simulating dust particle trajectories, a number of free and coupled parameters are involved. I can quantify the range, or error, on each of the parameters if I encapsulate the problem in a Bayesian framework. This section presents a rigorous mathematical approach to answering the question: "How does the range of material properties affect the particle's trajectory?" This mathematical approach gives the reliability of the estimates of the free parameters for a given dust particle trajectory.

The forces on the dust particle which determine its trajectory is the sum of the forces for planetary gravity, light pressure, Lorentz force and solar gravity. In the next diagram, I indicate which material properties are involved in that force calculation.

(The values in parentheses indicate that they are correlated.)

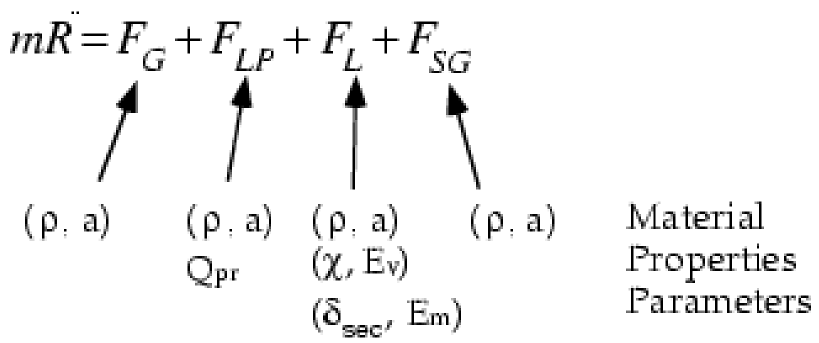

Figure 8.1 : Free and coupled parameters.

- (ρ, a) = particle density and radius.
- Q_{pr} = radiation pressure scattering coefficient, which is dependent on (ρ, a) via β, the ratio of radiation pressure force to solar gravitational force acting on the particle.
- (χ, E_ν) = photoelectric yield for the photoelectron emission current and the energy (usually Maxwellian) distribution of photoelectrons released from grain when a photon impacts onto the dust particle.
- $(\delta_{\text{sec}}, E_m)$ = maximum yield of secondary electrons released at E_m by a high energy impacting electron or ion.

We want to find the probability distribution of our seven free parameters, given a computed trajectory $\vec{R}$, and given relationships between the parameters I:

$$\text{prob}\ (\rho, a, Q_{pr}, \chi, E_\nu, \delta_{\text{sec}}, E_m, \mid \left\{\vec{R}\right\}, I)$$

The joint distribution of all conditions of the seven free parameters given by the dust trajectory data is proportional to the likelihood that the free parameters will produce the trajectory, times the degree of belief attributed to the parameters before the trajectory computation:

$$L \ = \ \log_{\text{e}}[\text{prob}\ (\rho, a, Q_{pr}, \chi, E_\nu, \delta_m, E_m \mid \left\{\vec{R}\right\}, I)]$$

$$\propto \log_{\text{e}}[prob\ (\left\{\vec{R}\right\} \ \mid \rho, a, Q_{pr}, \chi, E_\nu, \delta_m, E_m, I) \times \text{prob}\ (\rho, a, Q_{pr}, \chi, E_\nu, \delta_{\text{sec}}, E_m \mid I)\ ]$$

$$L \ = \ \log_{\text{e}}[\text{prob}\ (\rho, a, Q_{pr}, \chi, E_\nu, \delta_{\text{sec}}, E_m \mid \left\{\vec{R}\right\}, I)]$$

Let $\{x_j\}$ = our free parameters. Then the best estimate of our free parameters is given by a solution to the simultaneous set of equations:

$$\frac{\partial}{\partial x_i} L|_{\{x_{0j}\}} = 0$$

The reliability of the estimate can be given by the "spread" of the above distribution by applying a Taylor expansion around the best estimate point, with the quadratic term most influencing the spread.

$$L = L(x_0) + \frac{1}{2} \sum_{i=1}^{7} \sum_{j=1}^{7} \frac{\partial^2 L}{\partial x_i \partial x_j}|_{x_0} (x_i - x_0)(x_j - x_0) + ...$$

Then the exponent of the L yields the approximation for the multidimensional probability distribution function describing the range of the seven free parameters.

$$prob\ (\{x_j\} \mid \left\{\vec{R}\right\}, I) \propto \exp\left[\frac{1}{2}(x_i - x_0)^T \nabla\nabla L(x_0)(x_i - x_0)\right]$$

where the double nabla $\nabla\nabla L$ is the symmetric 7x7 matrix of second partial derivatives of L and I show the transpose of the difference vector.

This is essentially a multidimensional least-squares fitting problem, where the reliability of the estimates of the free parameters falls out in a natural way.

If we wish to know the reliability of only one of the seven free parameters, then we would "marginalize" (in Bayesian terminology) by isolating one free parameter and integrating out the others. This would help us gain understanding for how one of the parameters influences the others in a dust particle trajectory calculation.

8.3 A More Appropriate Magnetic Field

This thesis follows trajectories of particles from the inner magnetosphere to the outside of the magnetosphere, and it was shown in this work, that the particle's trajectories are sensitive to the magnetic field model employed. Therefore, it is important to apply a suitable magnetic field model that is appropriate to Jupiter's magnetosphere as a whole.

I have, so far, treated the magnetic field as a *static* magnetic model. In order to continue treating the dust trajectories with a static magnetic field, two possibilities to improve the static model are:

1. Look to the Galileo magnetic field instrument data to compare measurements with the output of Connerney's models (O_4 and O_6), in order to determine which model is more accurate. Our Heidelberg dust group recently received some magnetic field data from the Galileo magnetometer team, therefore, we have the means to answer this question.

2. Supplement Connerney's models or implement another magnetic field model, which is more suitable to Jupiter's outer magnetic field. Connerney lists several possibilities in (Connerney 1981, pg. 7681) that would be more suitable to the outer magnetic field.

If one wishes to go further to simulate the dust particle trajectories, in as realistic a way as possible, then one should use real-time magnetic field data for all dust particle trajectories. The model then becomes a *dynamic* model.