MAPPING EFFECTS OF DISTANT PERTURBATIONS ON PARTICLE-PLANET ENCOUNTERS

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The Öpik method (1) for estimating the effects of gravitational encounters of a particle (*e.g.* planetesimal) with a planet or a planetary embryo breaks down for small encounter velocities because the distant-approach trajectories are slightly modified by perturbations of the heliocentric orbits (2), not because of a breakdown (suggested in 3) of the two-body approximation at encounter. According to (2), the distant perturbations change the geometries of arrival at the planet, usually keeping the same arrival relative velocity as the unperturbed trajectory, but shifting the approach path parallel to the unperturbed one. Thus a beam of particles on initially parallel paths targeted to be centered on a head-on collision was generally shifted by distant approach perturbations so particles near the edge of the beam actually encountered the planet head-on (2). It was speculated (2) that this shift might conserve the outcome statistics by replacing particles shifted away from the planet by others shifted closer.

To test that hypothesis, for a variety of cases we have numerically followed the evolving distant perturbations of a beam of particles en route to a planet. At any point in their approach, their orbits can be represented by the arrival paths they would have if allowed to proceed unperturbedly to the planet. Thus a beam of particle that actually followed the Öpik approximation would be represented by a set of unchanging parallel arrival vectors. A shifted beam as described in (2) would appear to shift gradually sideways, while retaining its formation.

We plot the characteristics of such an approaching beam as a set of darts hitting a target plane (or "b-plane") centered on the planet. The length and direction of a dart show its relative velocity and the tip is at the arrival position. The plots show a view direction normal to the target plane. Information on the length of a dart is given by the size of a dot on its tail. The plots shown here show the initial trajectory set needed in order to arrive as a centered parallel beam at a planet.

We can only show a couple of sample results without quantitative consideration, due to short space. Fig. 1 shows a case where the beam is simply shifted sideways by distant approach perturbations. Fig. 2 shows a much more complex evolution because the particles are on orbits with extremely low eccentricities. Units of distance are in terms of the planet's orbital radius. Analysis of our extensive set of such evolution diagrams is providing insight into the statistical mechanics of encounters, which will be useful in modeling planetary accretion.

References: (1) Öpik, E.J., 1976, Interplanetary Encounters, Elsevier; (2) Greenberg, R., *et al.*, 1988, Icarus **75**, 1; (3) Wetherill, G.W., and Cox, L.P., 1984, Icarus 60, 40, and 1985, Icarus **63**, 290.

Figure 1

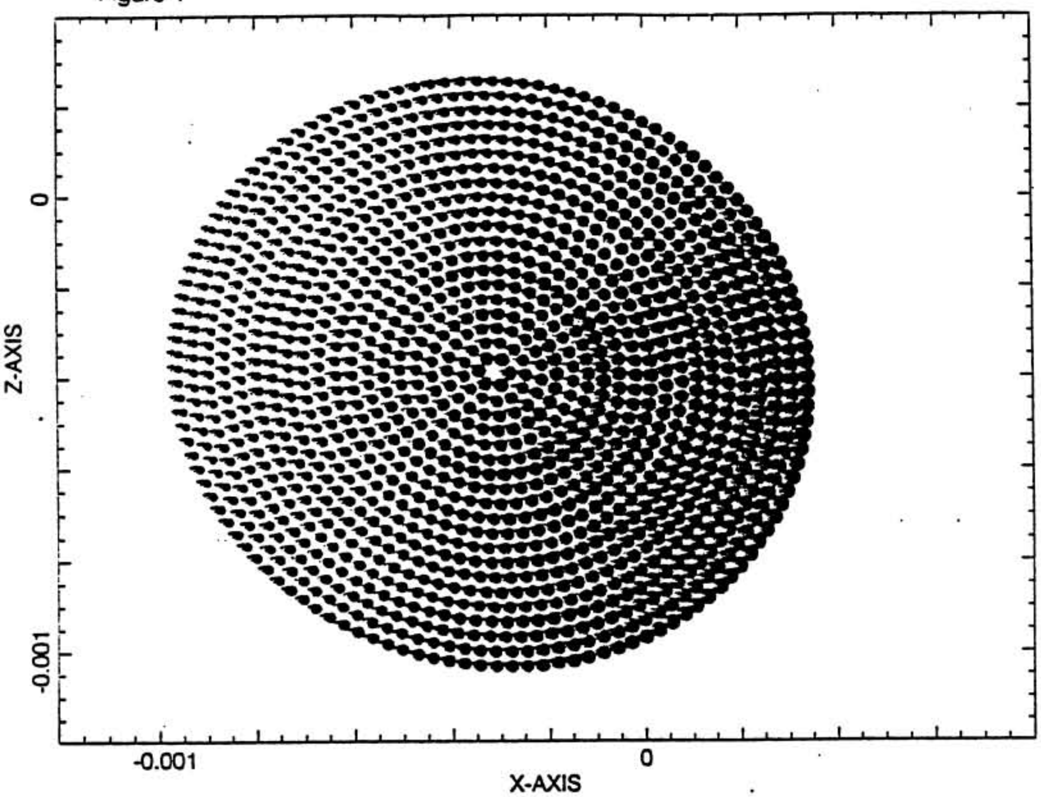

Figure 2