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# MODELS OF PLANETARY RINGS.

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The Voyager occultations provide several uniform and high quality data sets for Saturn, Uranus and Neptune. We intercompare these data and develop theoretical models for the particle sizes and the particle transport.

Ring Size Distribution. A bimodal size distribution model has been developed for Saturn's rings which allows an inversion of Voyager ring occultation data (PPS, UVS and RSS) and the determination of vertically integrated number densities at three reference particle radii for three regions: supracentimeter sized particles at a reference radius of 1 cm; subcentimeter sized particles at a reference radius of 4 µm; and dust or micron-sized particles at a reference radius of 0.034 µm. The variations of these number densities permits quantification of the particle size distribution in Saturn's rings. We find that the size distribution is described by an inverse cube power law down to particle sizes of about 4 µm and for particles smaller than 4 µm or "dust," a gamma (Hansen-Hovenier) distribution is found be adequate. We characterize the classical rings of Saturn (A, B, and C) by applying the model to 14 relatively large featureless regions (600-1000 km in width). Our results indicate that dust is nearly constant in all three main rings, about 6.87 x $10^{19}$ particles $m^{-2}$ at a reference particle size of 0.034 µm for rings C and B and 7.54 x $10^{19}$ particles $m^{-2}$ in ring A; and exhibits a slight anti-correlation with supracentimeter-sized particles. Inner regions of all three rings are dustier than the corresponding outer regions, which may be related to the observation that inner regions of the rings are relatively unperturbed compared to the outer regions where most of the resonances occur. Subcentimeter-sized particles increase outward in the rings, with a maximum in ring B, similar to the variation of supracentimeter-sized particles. The ratio of subcentimeter-sized particles to supracentimeter-sized particles appears to be constant for each ring, possibly an indication that smaller particles are produced by collisions of the particles, rather than mere release of dust regoliths from their surfaces.

Torques and Resonances. A kinetic equation has been solved numerically for a flattened planetary ring which is perturbed gravitationally by a near-by satellite. The Krook kinetic equation for planetary rings (see Brophy and Esposito (1989), or Shu and Stewart (1985)) is solved in two spatial dimensions, and in time, with interparticle collisions, and with satellite forcing, and without self-gravity. The phase-space fluid numerical method (Brophy et al. (1990)) is extended by two-dimensional systems by ignoring negligible high-order velocity moments. In simulations of satellite induced wakes, we verify the role of local shear reversal and angular momentum flux decrease as described by Borderies et al. (1983). A new result is that the amplitude of wakes is limited by purely kinematic effects, even in the absence of collisions.

The results of a simulation of an inner Lindblad resonance location, as the distribution approaches steady-state, are presented in detail. The surface mass density, pressure tensor components, and mean velocities are calculated during the simulation. The detailed mechanisms of local torque balance and forced eccentricity "damping" at resonance are illuminated. The angular momentum flux perturbations play the critical role of balancing the satellite torque on the surface mass density asymmetry. The eccentricities very close to resonance are limited by collisional phase mixing. The resulting steady-state distribution feels a net radially integrated torque of essentially zero from the satellite, though the torque on radially confined regions can be large. We show that previous calculations of the torque (which asserted nonzero net torque) were based on impossible assumptions for the damping term which do not conserve momentum, and that our simulation results are consistent with the unaltered equations of motion. The considerations of energy conservation do not contradict the vanishing net angular momentum transfer since the particle velocity dispersions and eccentricities also adjust to new values in the resonance region.

Satellite Wakes. An explicit expression is derived for the phase-space density of a planetary ring perturbed by a nearby satellite. The derivation is facilitated by working in guiding center variables instead of local position and velocity variables and by neglecting collisions between ring particles. The usual equations for perturbed streamlines are recovered by taking first order moments of the phase-space density. The local surface density and the local mean velocity in a nonlinear satellite wake are obtained in the form of convergent infinite series. Unlike previous estimates based on streamline crowding, this surface density is positive definite because the finite velocity dispersion of ring particles streamlines of finite width. In other words, the phase-space density describes streamlines of finite width. The finite width of streamlines limits the maximum value of the local surface density that can result from streamline crowding. This result is consistent with numerical phase-space fluid simulations of perturbed rings reported by Brophy, Esposito, and Stewart (1991). The local mean velocity components in the satellite wake are found to deviate from the sinusoidal form of the streamline equations, and this deviation grows as the wake moves downstream from the shepherding satellite. These results suggest that collisional stresses between neighboring streamlines should depend on the second-order derivatives of the streamline parameters because the local mean velocity is itself a strong function of the first-order derivatives of the streamline parameters.