The Secular Evolution of the Primordial Kuiper Belt

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A model of the secular interactions that are exerted between planets and a particle disk is described. The disk is treated as discrete gravitating rings having a finite thickness h due to the particles dispersion velocities. Since ring-thickness softens their gravitational potentials, the system's time-evolution is readily obtained from the familiar Laplace-Lagrange secular solution for the planets but with the Laplace coefficients softened over a scale h/a.

This rings model is used to simulate a number of Kuiper Belts having masses M=30 earth-masses (eg., its primordial mass) down to its current M=0.1 earth-masses. As long as these Belts are sufficiently thin, these systems are awash in apsidal density and nodal bending waves launched by the giant planets. Initially, long apsidal density waves propagate outwards until they reflect at either the disk's outer edge or at a Q-barrier, whereupon they return as short density waves. These short density waves are nonlinear, i.e., adjacent streamlines are crossed, and this causes the fractional variation in the disk's surface density to exceeds unity.

The giant planets also launch long nodal bending waves which have two possible fates: (i.) bending waves reflect at the disk's outer edge and return as long waves, or (ii.) the waves stall at a site in the disk where the wavelength has become smaller than the disk thickness. This is noteworthy since the accumulation of stalled bending waves can loft particles into high-inclination orbits.

These waves' interesting behavior allow for all sorts of speculative Kuiper Belt histories. For instance, if the edge of this stall-zone migrated inwards to 50 AU due to the Belt's mass-erosion, then wave-stalling can toss distant KBOs into high-inclination orbits as well as terminate the low-inclination component of the Main Belt at 50 AU. Further cosmogonic implications of these waves will also be discussed at conference time.

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