The Secular Evolution of Disk-Planet and Ring-Satellite Systems

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We are investigating the secular evolution of planetary and satellite systems as they interact with a particle disk having some mass. We consider two distinct systems: (i.) the giant planets as they orbit interior to a massive primordial Kuiper Belt, and (ii.) Saturn's rings and satellites. We apply the low-order analytic solution of Brouwer and Clemence (1961) to obtain the secular evolution of the planets/satellites and the low-mass disk particles. When applied to a primordial Kuiper Belt that is assumed to have a mass of a few tens of Earth masses, we find that the giant planets launch a long wavelength disturbance of dimension $\lambda \sim 10$ AU that propagates back and forth across this friction-free disk. This wave propagation results in very mild excitation of the Kuiper Belt that spans its entire width. This evolution is quite distinct from that seen in a massless Kuiper Belt which experiences only localized orbital excitation at secular resonances.

When this model is applied to Saturn's satellites and rings (whose masses conform with current estimates), we see no signs of comparable wave action. Ring gravity does not appear to have any obvious role in the secular evolution of this system, but we are still looking for possible subtle influences. Instead, the rings behave the same as massless particles that adopt the forced motions imposed by the satellites. We find that the main rings' longitudes of periapse $\tilde{\omega}$ and ascending node Ω stay coherent over time, and this allows the A and B rings to precess as two independent and somewhat rigid bodies under the influence of various satellites. Curiously, the break in the A and B rings' precession rates occurs right in the Cassini Division, and we are investigating whether this is an accidental coincidence or due to some cause and effect.

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