Chaotic Celestial Pachinko

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Poincare first discovered chaos through the homoclinic/heteroclinic tangle in the 3-body problem. NASA/JPL's Genesis Mission to collect solar wind samples near L1 uses the heteroclinic behavior between L1 and L2 for the design of its low-energy Earth-return trajectory (6 m/s total deterministic delta-v for the entire mission after launch in 2001). Work on this trajectory led us to the computation of heteroclinic cycles between periodic orbits around L1 and L2. The chain of homoclinic and heteroclinic cycles provide a system of dynamical channels guiding the motions of minor bodies from the Zodiacal dust to objects beyond the Kuiper Belt. In particular, this paper provides a mathematically rigorous dynamical explanation using symbolic dynamics for the phenomenon of the Temporary Capture of comets by Jupiter (see Ross' presentation at this conference for details). Furthermore, the dynamical channels of each of the Sun-Planet and Planet-Satellite pairs provide a network of dynamical tunnels spanning the entire Solar System. The transport of dust, asteroids, comets, and Kuiper Belt objects are all affected by these ancient and hither-to-unknown passage ways in the Solar System. This transport mechanism is closely tied to mean-motion resonance structures, thereby determining in part the morphology of the Solar System from the Zodiacal Dust Torus to the various ring and belt structures within the Solar System. Many interesting applications of this theory to new space mission concepts are possible such the "Petit Grand Tour" of Jovian satellites where the tour provides free Temporary Captures at each Satellite, and low-energy lunar missions with ballistic captures. See Koon's presentation for details. This work is a collaboration with W.S. Koon, J.E. Marsden, and S.D. Ross.