**Eccentric Extrasolar Planets: The Jumping Jupiter Model**

(Marzari F. & Weidenschilling, S.J., 2002, Icarus, **156**, 570.)

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**Abstract**

Since the mid-1990's, over a hundred planets have been detected in nearby Sun-like stars. Many of these planets were discovered by Doppler measurements of stellar radial velocities. This method is biased towards massive planets with short orbital periods. The estimated minimum mass (M sin(i)) of these planets ranges from 0.4 to 10 Jupiter masses. Their orbital periods suggest orbits with semimajor axes between 0.1 to 4 AU. These planets are dubbed "hot Jupiters" because of their masses and their proximity to their stars.

In the Solar Nebula theory, Jupiter is thought to have formed by the gradual accumulation of planetesimals into a core that gravitationally captured a gaseous envelope from the surrounding nebula. The giant planet had to have formed beyond the "snow line" where ices could condense into solids. Unless the "snow lines" are very close to the stars in the nearby systems, it is difficult to form "hot Jupiters". Therefore a migration mechanism called the Jumping Jupiter Model is suggested by Marzari & Weidenschilling (2002) (hereafter MW) to explain the formation of these "hot Jupiters".

MW suggest that these "hot Jupiters" formed further out in the stellar system and then migrated closer through dynamical interactions in multi-planet systems. They followed the evolution of three Jupiter-mass planets around a solar-mass star through 3-D numerical integrations of the orbits. The results from the simulations suggest that the most likely outcome of gravitational scattering by close enounters is the ejection of one of the planets. One of the two remaining planets moves closer to the star while the other goes into a larger orbit around the star. If one of the three planets is more massive, the more massive planet usually moves closer to the star after the ejection of one of the others. This is consistent with observations because the planet that moves further out in the stellar system cannot be detected by the Doppler method due to its long orbital period. The distribution of eccentricities in the simulated data is uniform, but there is an excess of low eccentricity orbits from observations. Tidal dissipation and long-term perturbations from the more distant planets may explain the discrepancy. The distribution of semimajor axes in the simulated data suggest that it is difficult to form new orbits with semimajor axes that are less than half the initial semimajor axis of the innermost planet. Additional migration mechanisms like tidal coupling may be needed to explain the orbits.