

Secular Theory, Libration, Circulation and Extra-Solar Planets

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The eccentricities and alignment of nodes of two planets in orbit about a star vary on the secular timescale. Three possible modes of alignment are possible: aligned libration, circulation, and anti-aligned libration. We show that first order secular theory fails to determine the alignment of some extra-solar planetary systems, even in the low eccentricity ($e < 0.1$) regime. Higher order expansions of the disturbing function are not analytic, and therefore secular theory is not useful in determining the dynamics of these systems. Instead numerical integrations are the most practical method for identifying the alignment. We can then use this characterization to determine how close planets approach each other during a secular period. This distance is therefore a usefully quantity for characterizing planetary systems. We find that the boundary between stable and unstable systems lies at a distance of approximately 2 mutual Hill radii. As this method can only be reliably applied to 10 planetary systems, this result is preliminary.