Let's Sweep: The Effect of Evolving J_2 on the Resonant Structure of a Multi-Planet System

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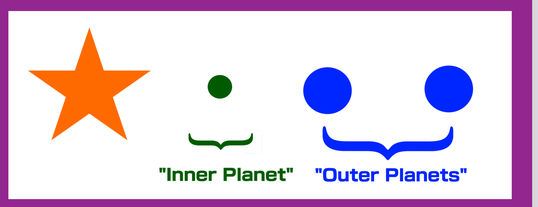
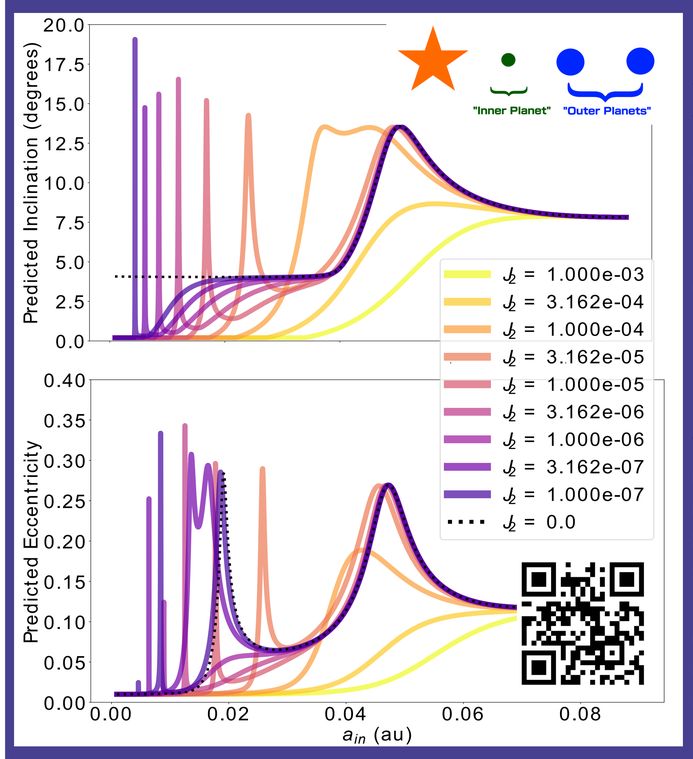
Paper Link:

Introduction

As an FGK star slows down its oblateness (parametrized by the quadrupole moment, J_2) changes, this leads to the precessions of planets' longitudes of ascending node and arguments of periapsis. This can bring multi-planet systems into-and out of secular resonance, potentially misaligning or destabilizing them.



Impact of J_2 on Secular Resonances

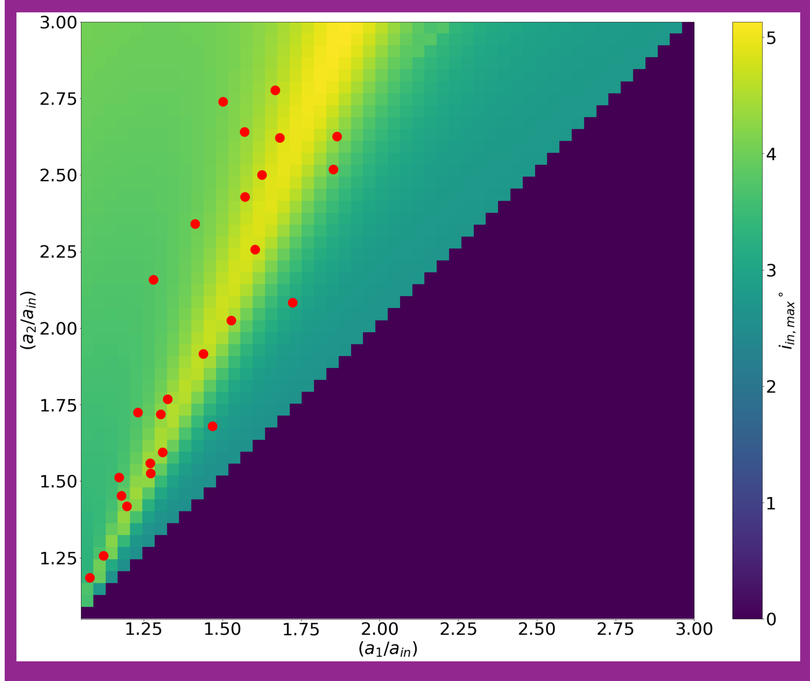


In 3-planet systems, the inner planet can *enter* a secular (long term) resonance with the outer two planets if the system architecture satisfies certain conditions (see plot on lower right of poster). Secular resonance excites eccentricity and mutual inclination. Later the planet may *leave* the resonance.

(Left) The effect on the inner planet of a three-planet system from the perturbations of the outer two planets as a function of inner planet semimajor axis. Several curves with different stellar J_2 values are shown. Maximum inclination (top) eccentricity (bottom). An animated version of the plot is available, which is far superior

How Many Observed Three-Planet Systems are in Secular Resonance? (In Prep)

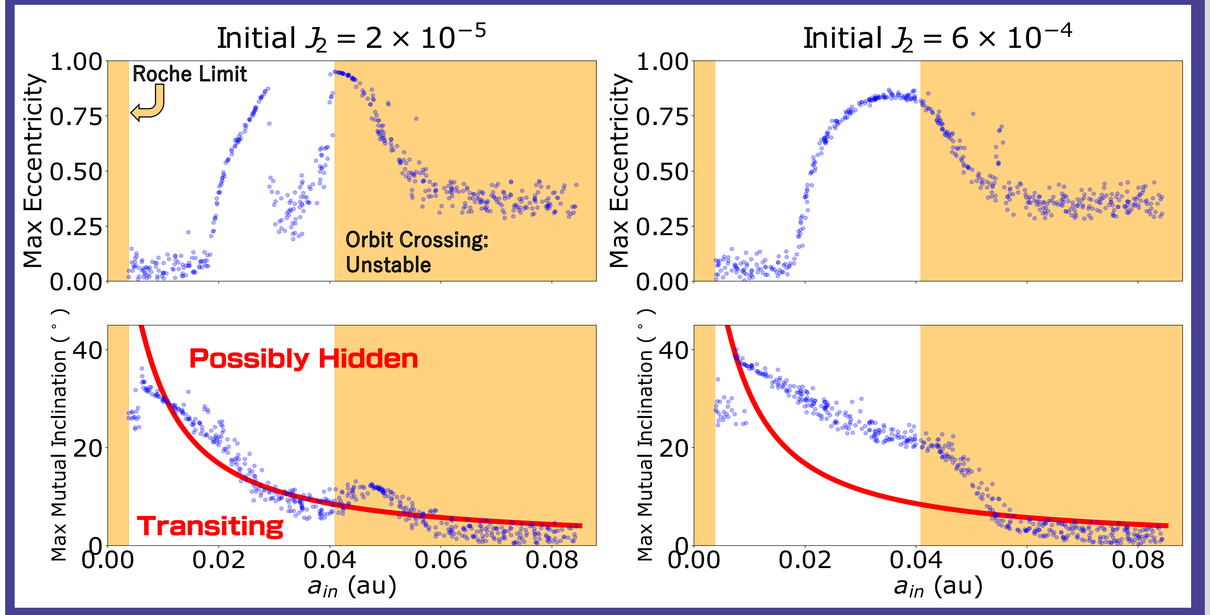
The answer depends primarily on the period ratios in the systems!



(Left) Landscape of secular resonance for three-planet systems with small semimajor axis ratios. The location of the Secular Resonance Regime is determined by the outer two planets` masses. The plot shown is for systems where all three planets are 6 Earth Masses. Annotated are 26 observed three-planet systems orbiting FGK stars. Many of them lie in the Secular Resonance Regime, indicating their mutual inclinations may undergo significant evolution.

HD 106315 Can Host a Stable, Transiting Inner Planet

HD 106315[1,2] has two, transiting warm Neptunes. Can this system host a inner detectable Earth-size planet? Below I show, a Monte Carlo of a possible hidden planet to this system. A winkle here, is the initial oblateness (J2) of the star. If the initial J_2 is high (right column), eccentricities and mutual inclinations are high. If, however, initial J_2 is low (left column), an island of low-eccentricity and low mutual inclination exists between 0.025-0.04 au. A planet can hide there!



Takeaways

- J_2 moves secular resonances in exoplanet systems
- J_2's time evolution brings many more orbital configurations into secular resonance than would otherwise be the case
- This has significant impacts on stability and coplanarity

HD 106315 Parameters[1, 2]

Object	Mass	a(au)	e	i	Ω
HD 106315	1.09 $M_\odot$				
Inner Planet	1.0 $M_\oplus$	$0.005 - 0.085$	$0 - 0.2$	$9 - 16°$	$0°$
HD 106315 b	12.6 $M_\oplus$	0.097	0.09	14.3°	$0°$
HD 106315 c	15.2 $M_\oplus$	0.1536	0.22	10.8°	$0°$

References

[1] Barros, S. C. C., H. Gosselin, J. Lillo-Box, D. Bayliss, E. Delgado Mena, B. Brugger, A. Santerne, et al. "Precise Masses for the Transiting Planetary System HD 106315 with HARPS." Astronomy & Astrophysics 608 (December 2017): A25. https://doi.org/10.1051/0004-6361/201731276.

[2] Zhou, George, Joseph E. Rodriguez, Andrew Vanderburg, Samuel N. Quinn, Jonathan Irwin, Chelsea X. Huang, David W. Latham, et al. "The Warm Neptunes around HD 106315 Have Low Stellar Obliquities." The Astronomical Journal 156, no. 3 (August 10, 2018): 93. https://doi.org/10.3847/1538-3881/aad085.