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Tidal formation of Hot Jupiters in binary star systems

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Abstract

More than 150 Hot Jupiters with orbital periods less than 10 days have been detected. Their in-situ formation is physically unlikely. We need therefore to understand the migration of these planets from high distance (several AUs). Three main models are currently extensively studied: disk-planet interactions (e.g. [3]), planet-planet scattering (e.g. [4]) and Kozai migration (e.g. [2]). Here we focus on this last mechanism, and aim to understand which dynamical effects are the most active in the accumulation of planetary companions with low orbital periods in binary star systems.

To do so, we investigate the secular evolution of Hot Jupiters in binary star systems. Our goal is to study analytically the 3-day pile-up observed in their orbital period. Our framework is the hierarchical three-body problem, with the effects of tides, stellar oblateness, and general relativity. Both the orbital evolution and the spin evolution are considered. Using the averaged equations of motion in a vectorial formalism of [1], we have performed $\sim$ 100000 numerical simulations of well diversified three-body systems, reproducing and generalizing the numerical results of [2].

Based on a thorough analysis of the initial and final configurations of the systems, we have identified different categories of secular evolutions present in the simulations, and proposed for each one a simplified set of equations reproducing the evolution. Statistics about spin-orbit misalignements and mutual inclinations between the orbital planes of the Hot Jupiter and the star companion are also provided. Finally, we show that the extent of the 3 day pile-up is very dependent on the initial parameters of the simulations.

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