About the stability of circumbinary planets: binary properties and migration scenarios

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Abstract

Since their first detections in the 2010s, circumbinary planets have continued to challenge our understanding of planet formation and dynamics. Fewer than twenty are currently confirmed around main-sequence binaries, despite the fact that multi-star systems are very common [1]. Most known systems lie close to the dynamical stability limit of their host binaries [2], and only a handful are part of multi-planet systems. While observational biases contribute to this trend, they cannot fully account for the scarcity and inward concentration of circumbinary planets [3], suggesting that dynamical processes play a major role in shaping their long-term survival.

We investigate the dynamical stability of circumbinary multi-planet systems, focusing on configurations with two Super-Earths embedded in a circumbinary protoplanetary disk. Using N-body simulations coupled with a migration prescription, we explore how the binary mass ratio q_B and eccentricity e_B affect planetary stability. We also consider two migration pathways: planets migrating sequentially, and planets migrating together and captured into a planet–planet mean-motion resonance.

Based on more than 1,000 simulations, our results indicate that two-planet inward migration can, in some cases, be halted through resonance capture with the binary. In contrast to previous purely N-body studies (e.g., [4]; [5]), such configurations appear to remain stable over long timescales, suggesting the existence of an additional stable location beyond the disk's inner edge. We further find that the binary parameters q_B and e_B play a key role in shaping the stability landscape of multi-planet systems. Within the explored parameter space, some regions support long-term stability, whereas others appear highly unstable. These stability regions may be highly sensitive to the migration timescales (i.e., to disk properties and planetary masses). Finally, our simulations suggest that systems in which two planets enter resonance while migrating together are more likely to form stable multi-planet configurations, particularly around highly eccentric binaries.

These results help identify stable configurations of circumbinary planetary systems across a wide range of binary parameters, providing valuable guidance for selecting and monitoring promising targets for ongoing and future observational campaigns such as BEBOP, Gaia, and PLATO.

References

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