Binary tidal evolution as a sculptor of circumbinary planet architectures

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Abstract

Circumbinary planets are expected to form within circumbinary discs and to migrate inward until they approach the disc inner cavity, close to the dynamical stability boundary imposed by the central binary [1, 2]. Yet the observed population does not cluster at strict marginal stability. Instead, known circumbinary planets typically orbit at a small but significant offset from the critical radius, suggesting that present-day circumbinary architectures may preserve the imprint of post-formation evolution rather than reflecting a purely primordial disc-truncation configuration [3]. Previous tidal studies have shown that direct star–planet tides are generally too weak to produce significant planetary migration in circumbinary systems [4]. In this context, a natural and still little explored possibility is that the binaries themselves are not static hosts: if they shrink and circularise through long-term tidal dissipation, the circumbinary stability boundary should retreat with time, potentially widening the planet–stability gap even when the planets themselves remain nearly unchanged.

This presentation will explore this idea from a population-level dynamical perspective, motivated by the observed distribution of circumbinary planets relative to the critical stability limit. I will show that, over a broad region of parameter space, surviving planets can remain nearly quasi-fossilised in semimajor axis and eccentricity while the stability boundary moves inward as the binary evolves. In this regime, the final offset from marginal stability is produced mainly by binary tidal evolution rather than by additional post-disc planetary migration. I will further discuss how this mechanism depends strongly on the binary mass ratio: unequal-mass binaries preferentially preserve long-lived survivors, whereas near-equal-mass systems become much more efficient at destabilising planets through ejections and collisions. These results suggest that the present-day architecture of circumbinary planets may encode a fossil record of binary tidal evolution, and that the observed circumbinary population may reflect not only formation and migration, but also the long-term secular evolution of their host binaries.

References

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