Migration of circumbinary planets

How circumbinary discs form multi-planet systems and lose giants

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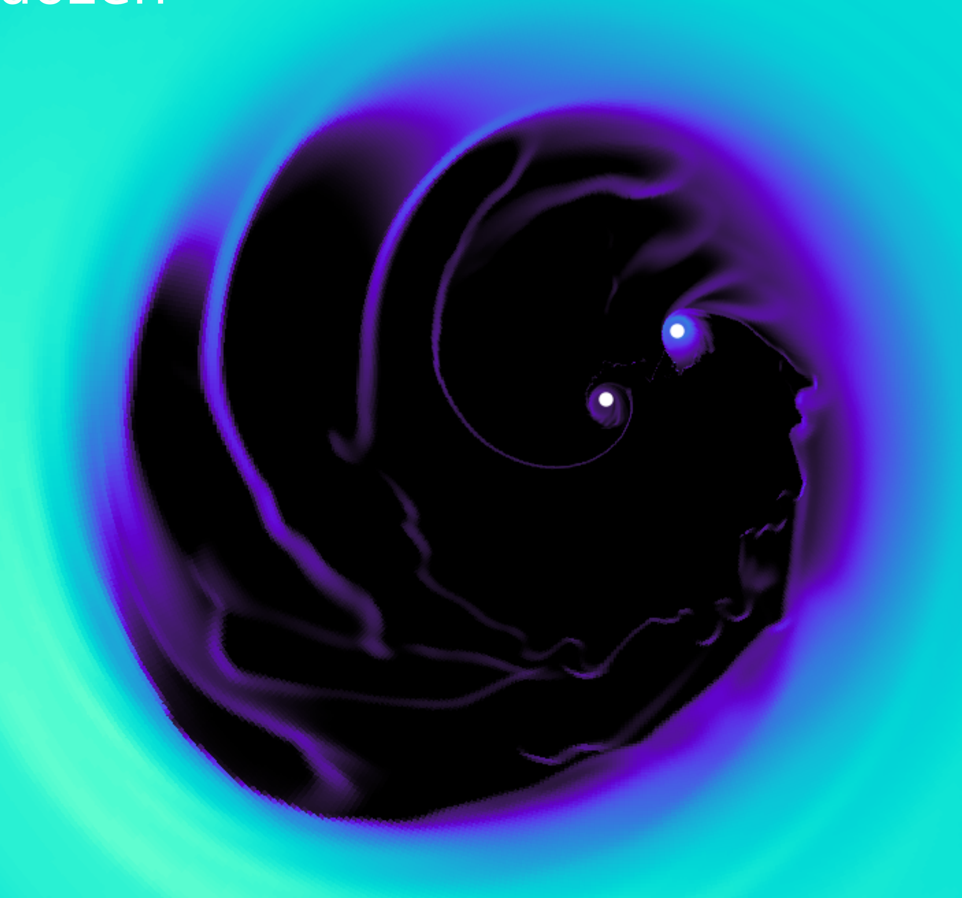
The potential of binary stars carves a large inner cavity with eccentric orbits that reach deep into the disc (see in the middle). Still, about a dozen planets have been observed in circumbinary orbits closer than 5 binary seperations. All these planets have masses not above a $1M_{Jup}$.
Planet migration helps to understand why the mass of the close circumbinary planets is constraint.



Here, we run 2D hydrosimulations (PLUTO) with integrated n-body interactions for 10^5 binary orbits in a viscous loc. isothermal disc with a viscous $\alpha=10^{-3}$ and H/R=5%. We vary the planet mass between 0.1 M_{Jup} - 10M_{Jup} and see how the gap opening and the gravitational interaction of binary stars, planets and disc alters the migration. And we study how multiplanet systems can reach stable orbits close to the binaries.

How mass changes migration

Embedded planets

If planets are not gap opening they move with the excited disc on orbits that are marginally eccentric following the same precession as the disc. Gap opening depends on the disc pressure and turbulence.
0.1 M_{Jup} is gap opening for cooler, less turbulent discs (H/R~0.04, $\alpha=10^{-4}$) comparable to what would be the case for Kep-35b or Kep-64b. Thus the observations tell us that disc are not very viscous.

Gap-opening planets

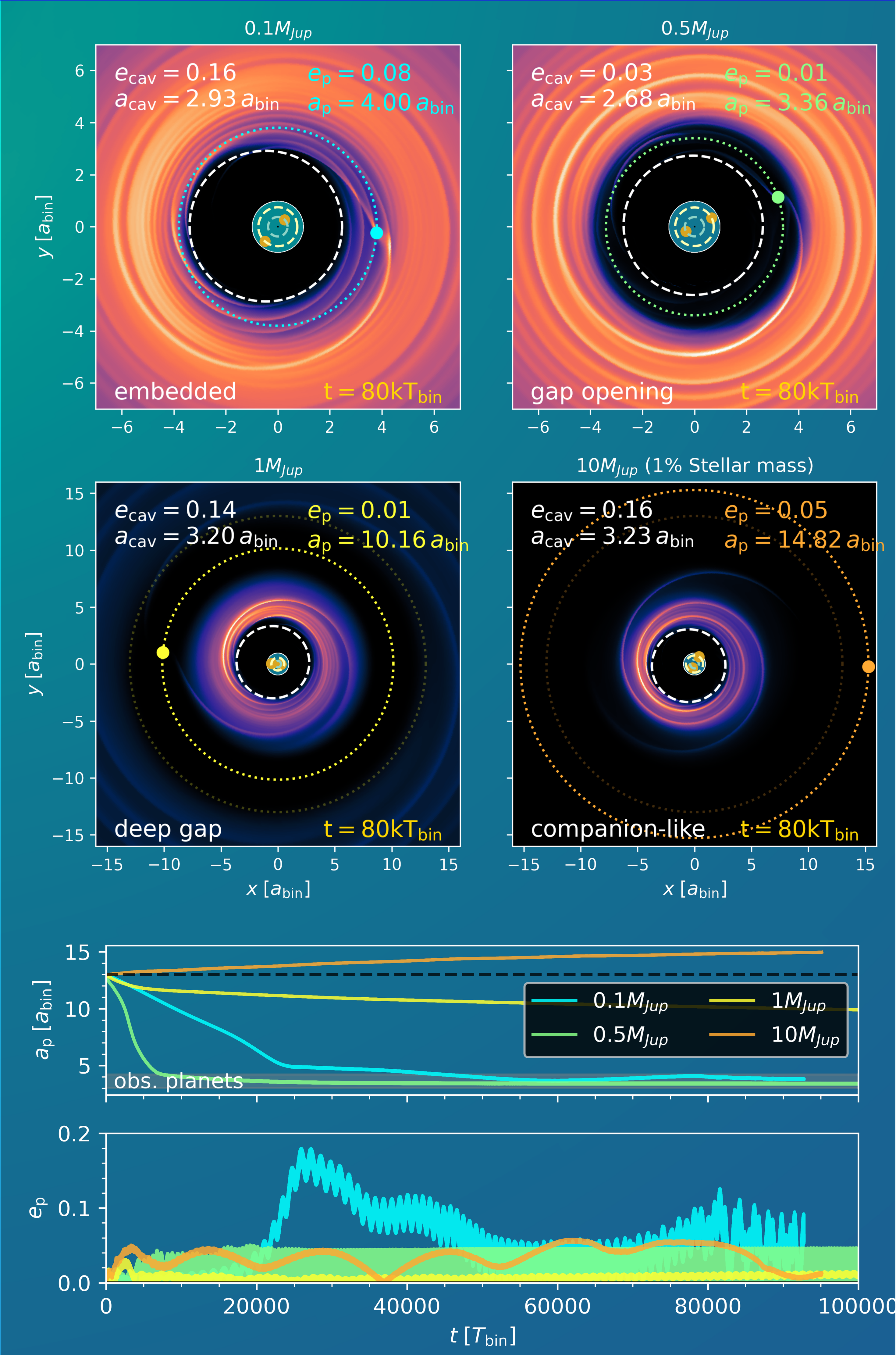
If planets open gaps in the disc they can overcome the drag of the excited disc and migrate on more circular orbits all the way to the inner cavity. At the edge of the disc the migratio stalls. The planet now inbetween the binary and the disc, shields the disc from the wakes that the binary sends into the disc and allows the cavity to circularize.

Deep gap planets

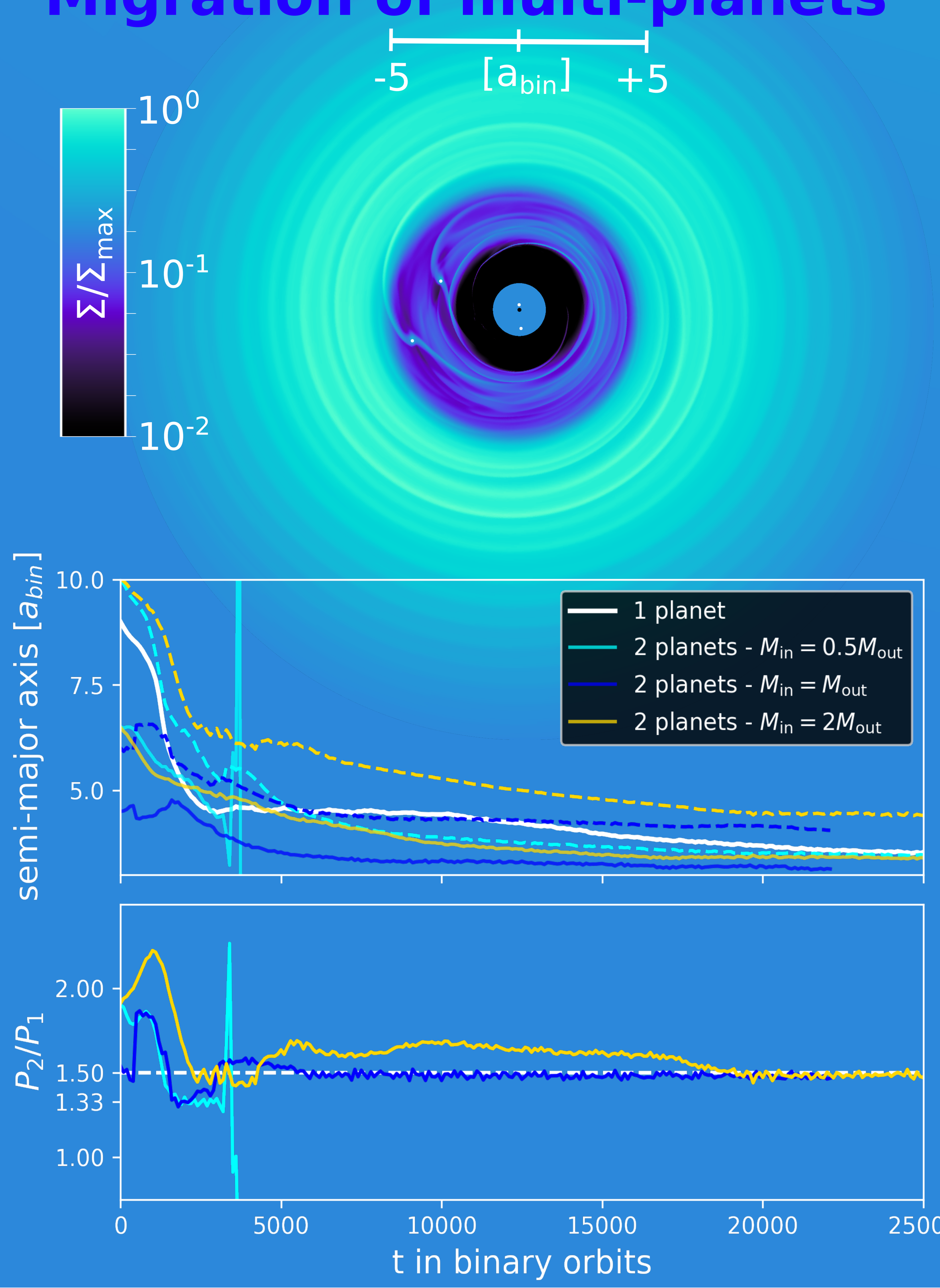
Planet that create very deep gaps (≥1MJup) separate the inner and outer disc motion fully, slowing their own migration while in the disc.
If they reach the cavity edge, however, they their presents stops the excitation of the binary onto the outer disc, such that the disc beyond their orbit slowly continues to push them in until the reach an orbit that is destabilzed by the binary and they are scattered out.

Companion-like planets

Planet beyond a few Jupiter-masses can reach eccentric orbits start to migrate outwards also in single star systems (e.g. Dempsey+21).
This also happens for circumbinary planets.
The pale dotted line shows the initial orbit of the planet that slowly continues to migrate outwards.
At this regime of masses the planet acts more like a hieracial companion than a planet bound by the viscous accretion of the disc.



Migration of multi-planets



Planet migration slows when planets get close to the highest density and disc eccentricity. This is stronger for lower mass planets. Thereby, lighter planet that migrate in sequence can more easily destabilize each other, or be destabilzed by following more massive planets.

Massive planets that of similar mass can migrate in resonance into the inner cavity, which allows them to migrate slightly further than a similar single planet.

Disc properties are important for a successful migration, lower viscosities, pressures and densities can help the planet to clear their surrounding, slow their migration and thereby their relative approach.

TAKE-HOME

Gap opening circumbinary planets (<1M_{Jup}) get park in stable orbits inside the cavity.

Super-Jupiters can reverse migration and move outward also in binary systems.

Multiplanets move in resonance and their combined migration stalls at the inner cavity.

Migration strongly depends on the disc.

→ Observed planets also imply thresholds for the disc physics.

References:
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