

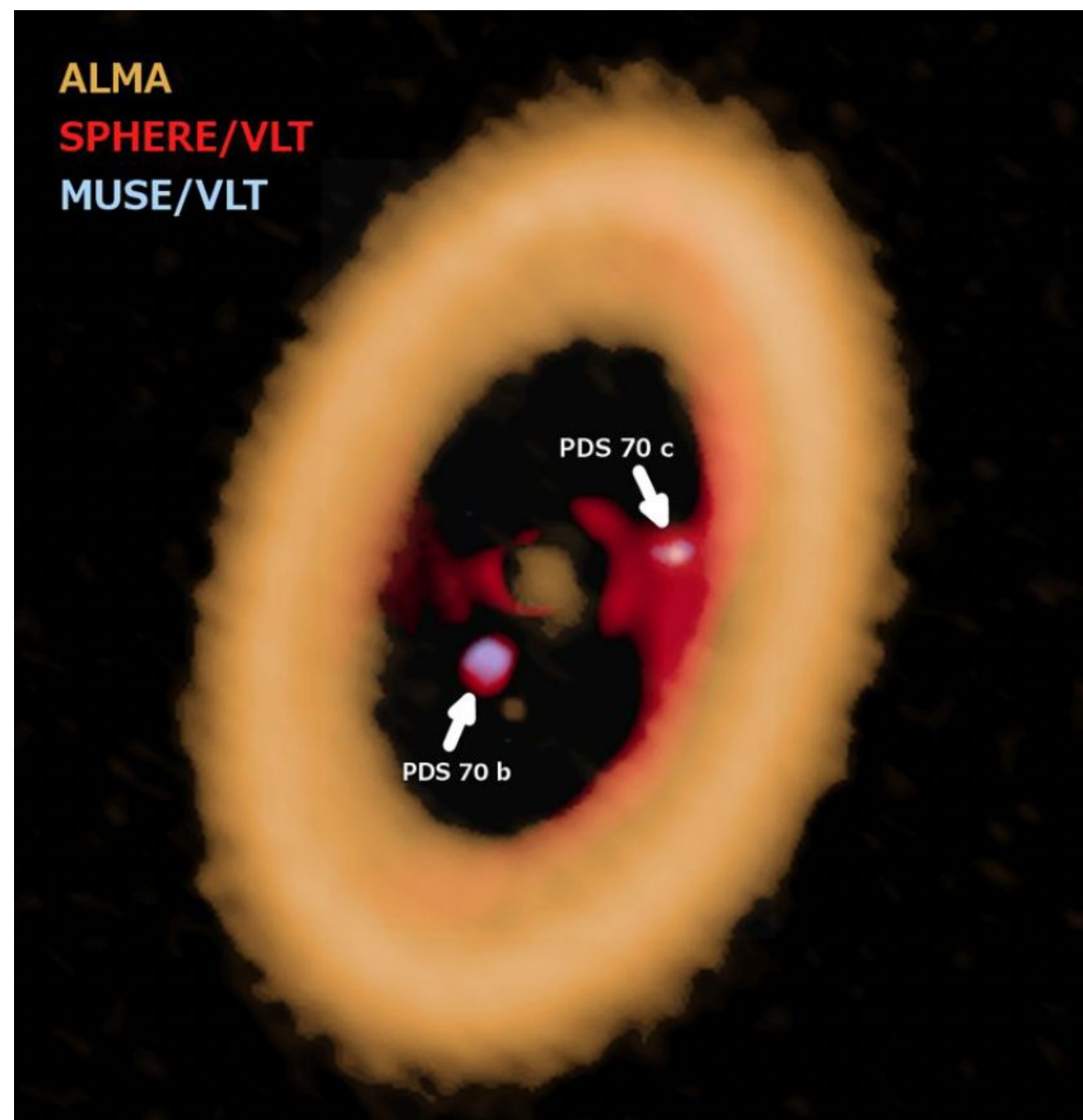
On the Orbital Evolution of Multiple Wide Super-Jupiters: How Disk Migration and Dispersal Shape the Stability of the PDS 70 System



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Introduction

- Many directly imaged planetary systems (HR 8799, PDS 70, Beta Pictoris) host multiple wide super-Jupiters in their first tens of Myr
- Due to their young ages and strong planet-planet interactions, **it is unclear whether these systems remain stable over Gyr timescales**
- PDS 70 (5 Myr old) has two imaged giant planets embedded in their natal disk: an ideal testbed for studying how planet-disk and planet-planet interactions affect a system's long-term orbital evolution



Above: The PDS 70 system as seen by various telescopes (Credit: A. Isella)

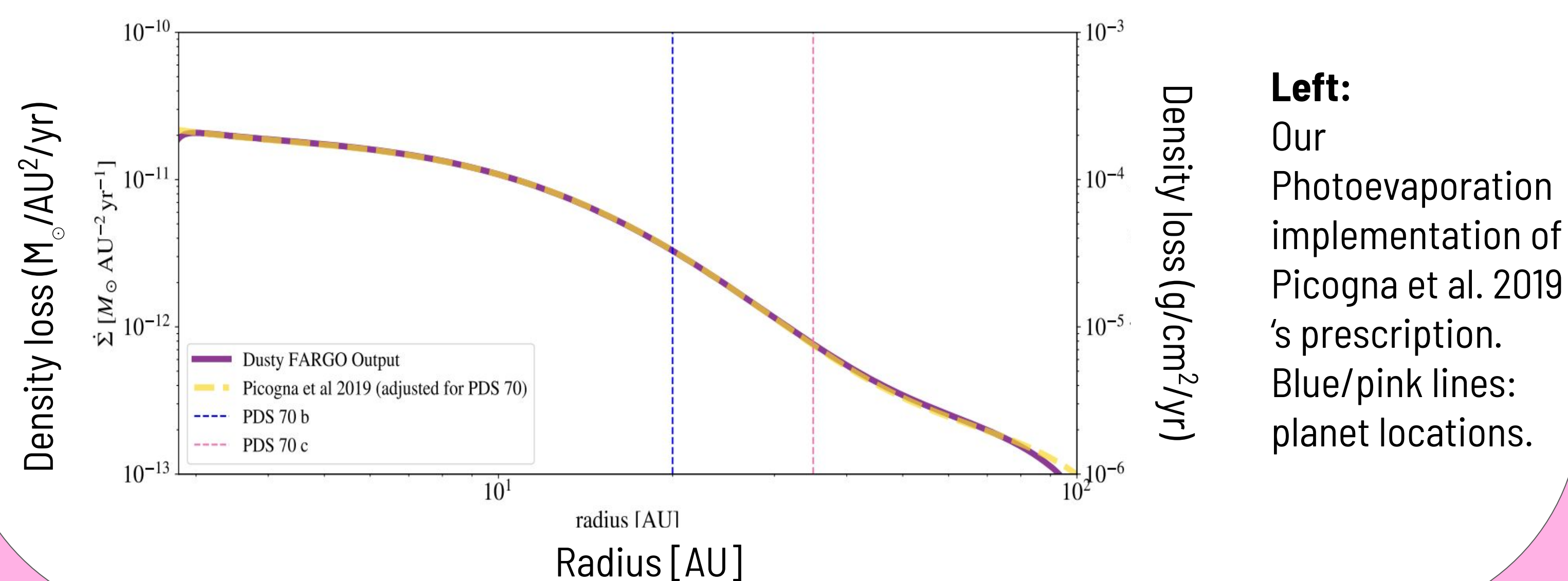
Methods

Disk Phase:

- Ran hydrodynamic simulations (Dusty FARGO-ADSG,) including photoevaporation for 5 Myr until disk dispersal
- Tested: 3 outer-planet masses (4, 7, 10 M_{Jup}) \times 4 photoevaporation rates (0, 0.1, 1, 10)

Post-disk Phase:

- Ran N-body simulations (REBOUND) for 1 Gyr
- Compared to N-body runs from updated orbit fits (octofitter)

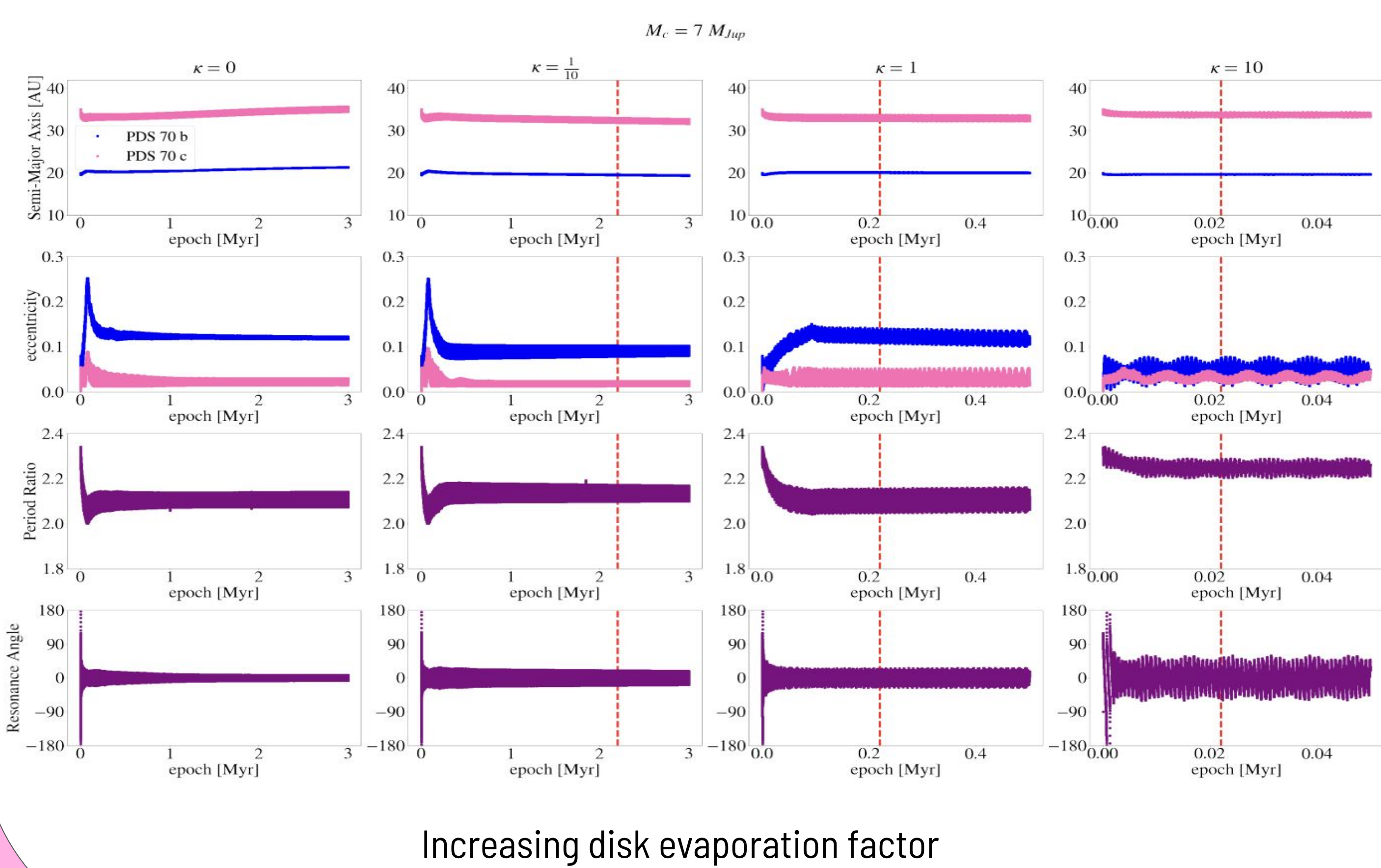


Left: Our Photoevaporation implementation of Picogna et al. 2019's prescription. Blue/pink lines: planet locations.

Results

Disk Dispersal and Planet Migration

Planets b and c lock into 2:1 MMR in all cases. Slower disk evaporation (lower κ) leads to a stronger resonance lock.



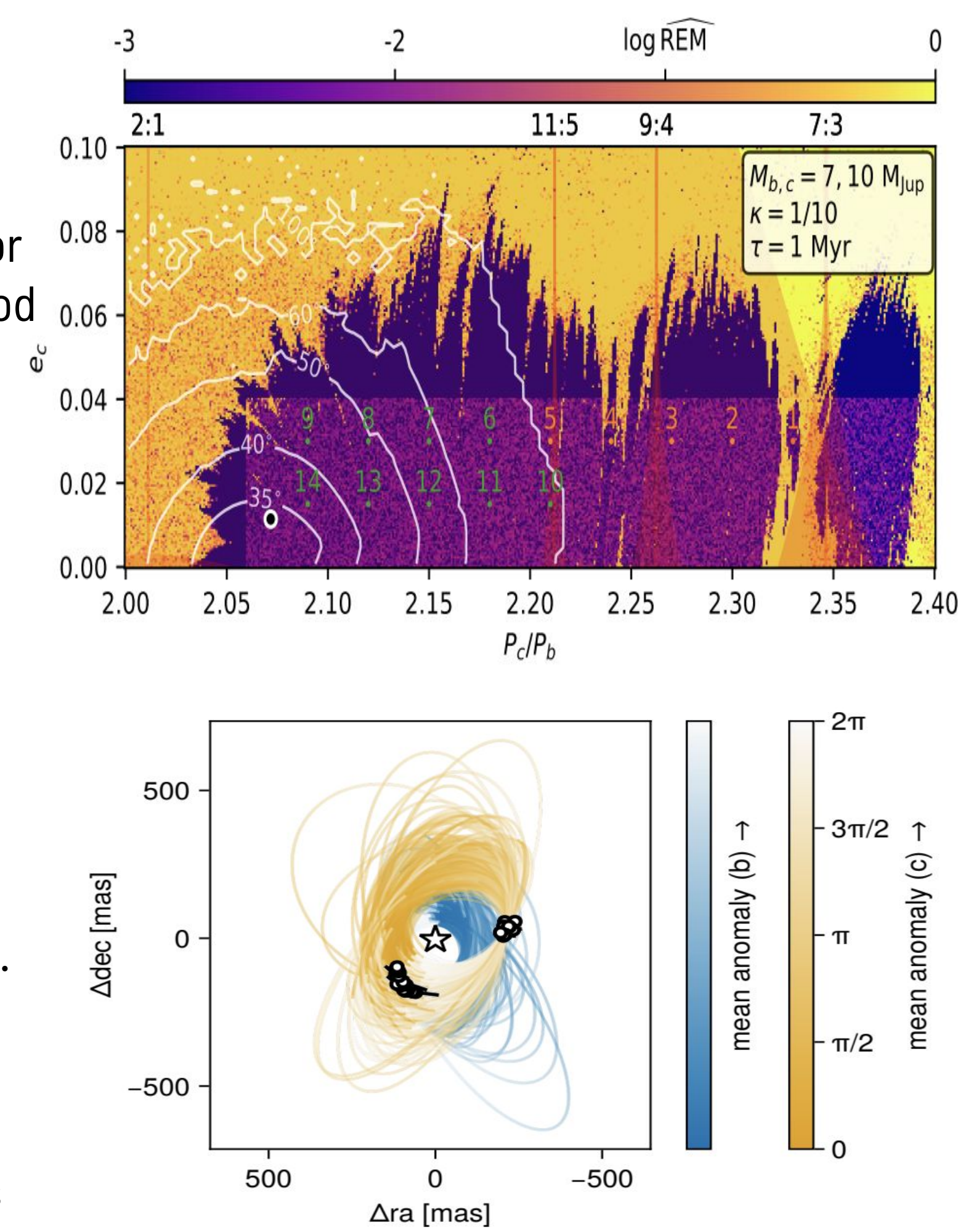
Increasing disk evaporation factor

Left: Disk-driven evolution of semi-major axis, eccentricity, period ratio, and resonant angle amplitude.

Top right: Post-disk N-body stability vs. period ratio and eccentricity. Purple = stable, yellow = unstable. White lines = resonant angle amplitude; black dot = hydrodynamic solution.

Bottom Right: Orbit fit from astrometry showing poorly constrained posteriors for both planets.

Long-Term Stability



The system is stable whenever the planets reside in the MMR, a configuration facilitated by disk migration. Because the long orbital periods leave orbit fits poorly constrained, most fit solutions lie outside the resonance, with only ~4% of solutions remaining stable.

Takeaways: The 2:1 MMR likely enables PDS 70's long-term stability. The disk's photoevaporation weakens the convergent migration to the MMR. Orbit fits from astrometry/RVs alone cannot reliably assess stability, as it requires a narrow resonant region difficult to capture with uncertain posteriors.

PDS 70 d?

Recent works (Christiaens et al. 2024; Hammond et al. 2025) suggest a third gas giant, PDS 70 d in the system. We extend one of our simulations to include this planet! **Scan the QR code to read the paper and see how the three-planet system evolves.**

