

Concealing Circumbinary Planets with Tidal Shrinkage

Detection and Dynamics of Exoplanets

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What is a Circumbinary Planet (CBP)?

Exoplanet orbiting
around a binary
star system

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see talks by:
Amaury Triaud
Mohammad Farhat
Benjamin Montet
Thomas Baycroft

~32 detected

- **14 transiting**

Kepler: Doyle+ 2011, Welsh+ 2012, etc.
TESS: Kostov+ 2020, 2021

- **9 directly imaged**

Dupuy+ 2018, 2023; Janson+ 2019,
2021; etc.

- **5 microlensing**

Bennett+ 2016; Han+ 2017, 2020,
2024; etc.

- **>2 RVs**

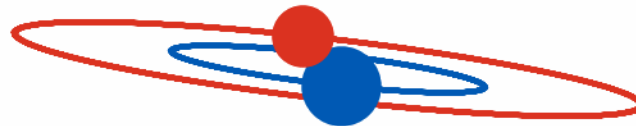
Correia+ 2005. Baycroft+ 2025, etc.

- **2 ETVs**

Borkovits+ 2016, Getley+ 2017

Eclipsing Binaries (EB)

- Star passes in front of companion
- **All transiting CBPs found around EBs**

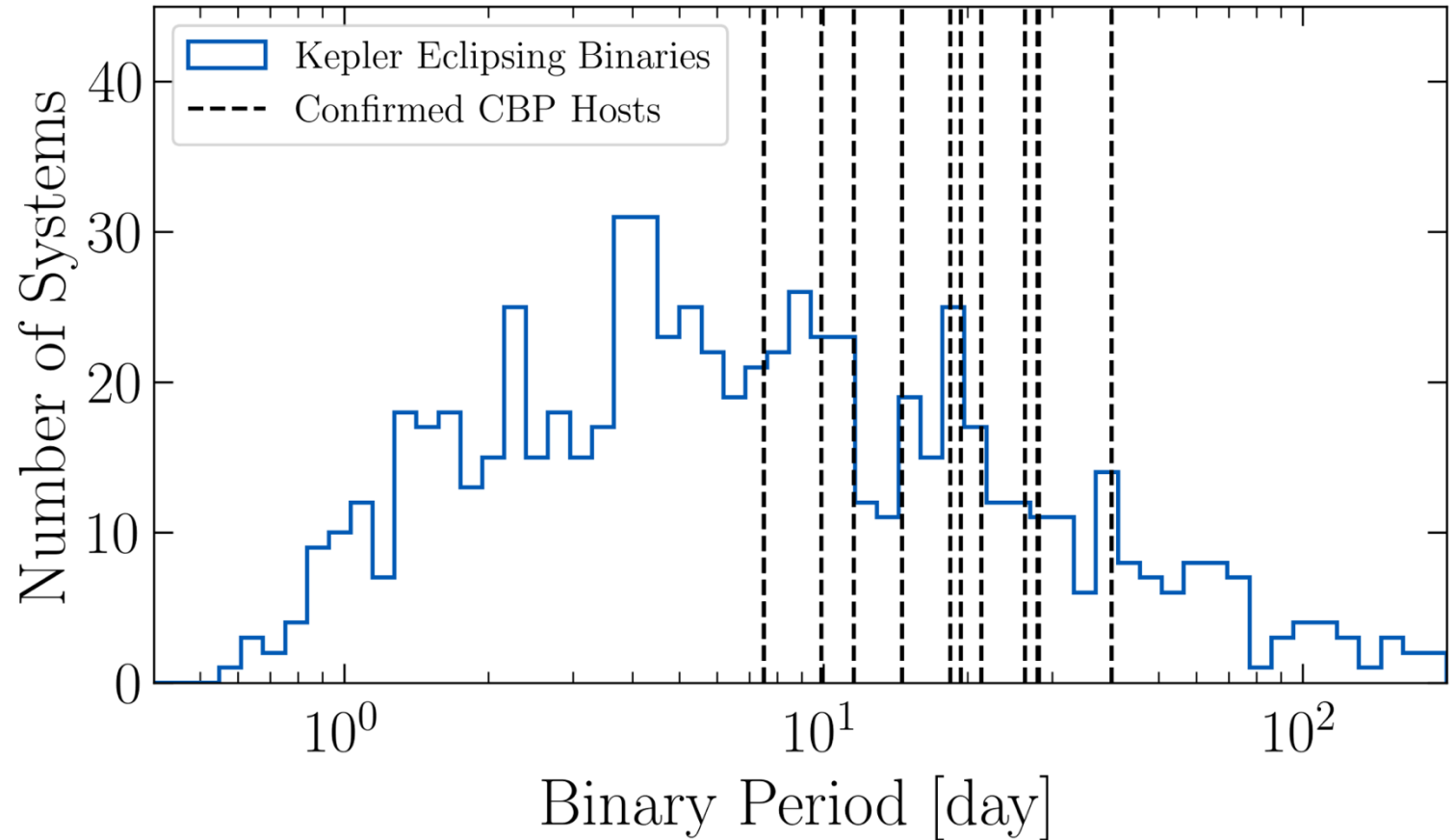


See also Martin & Triaud 2014

Where are the Circumbinary Planets?

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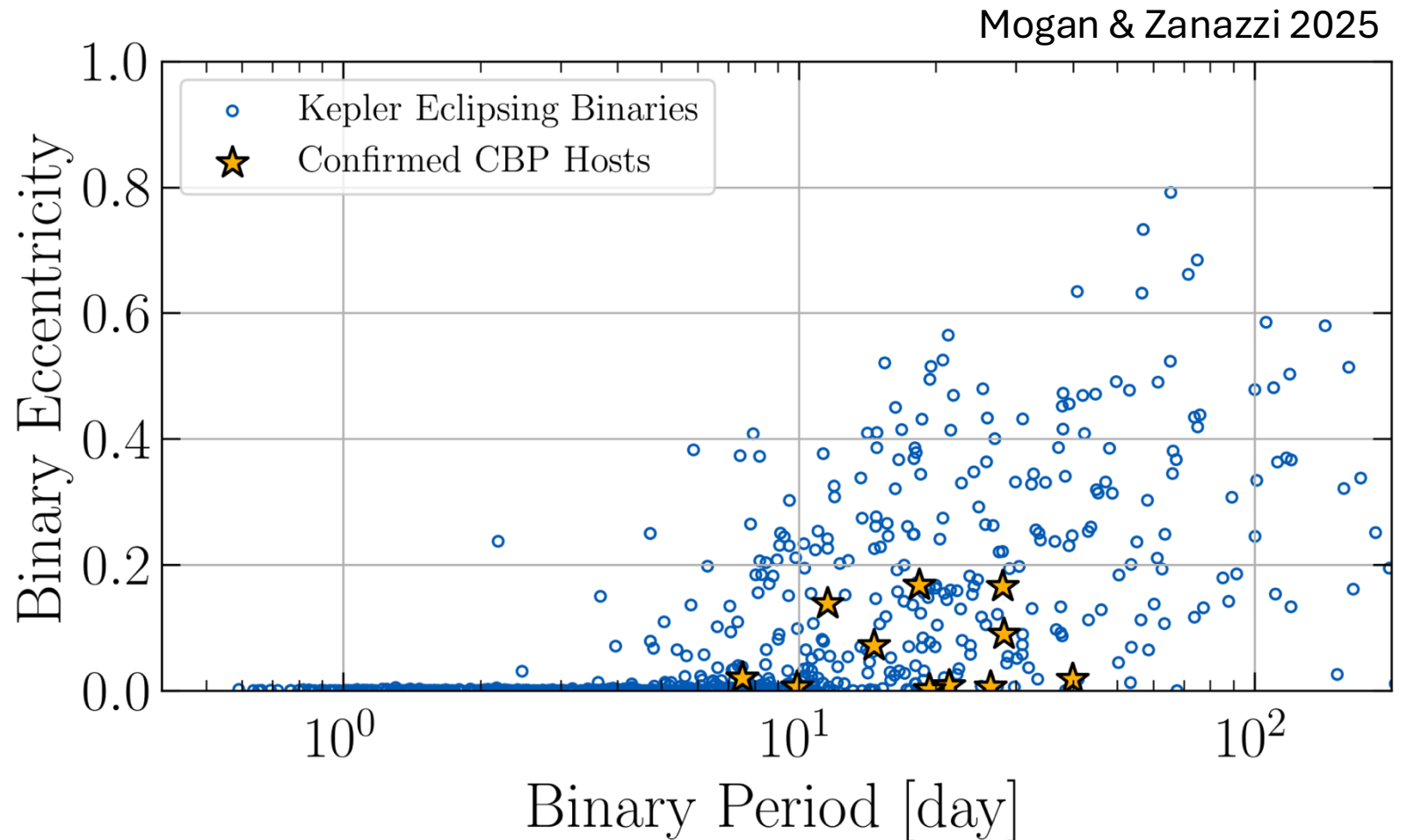
- Median EB $P_b \sim 7$ days
- CBP hosts $P_b > 7$ days
- Where are the short-period binaries with transiting planets?



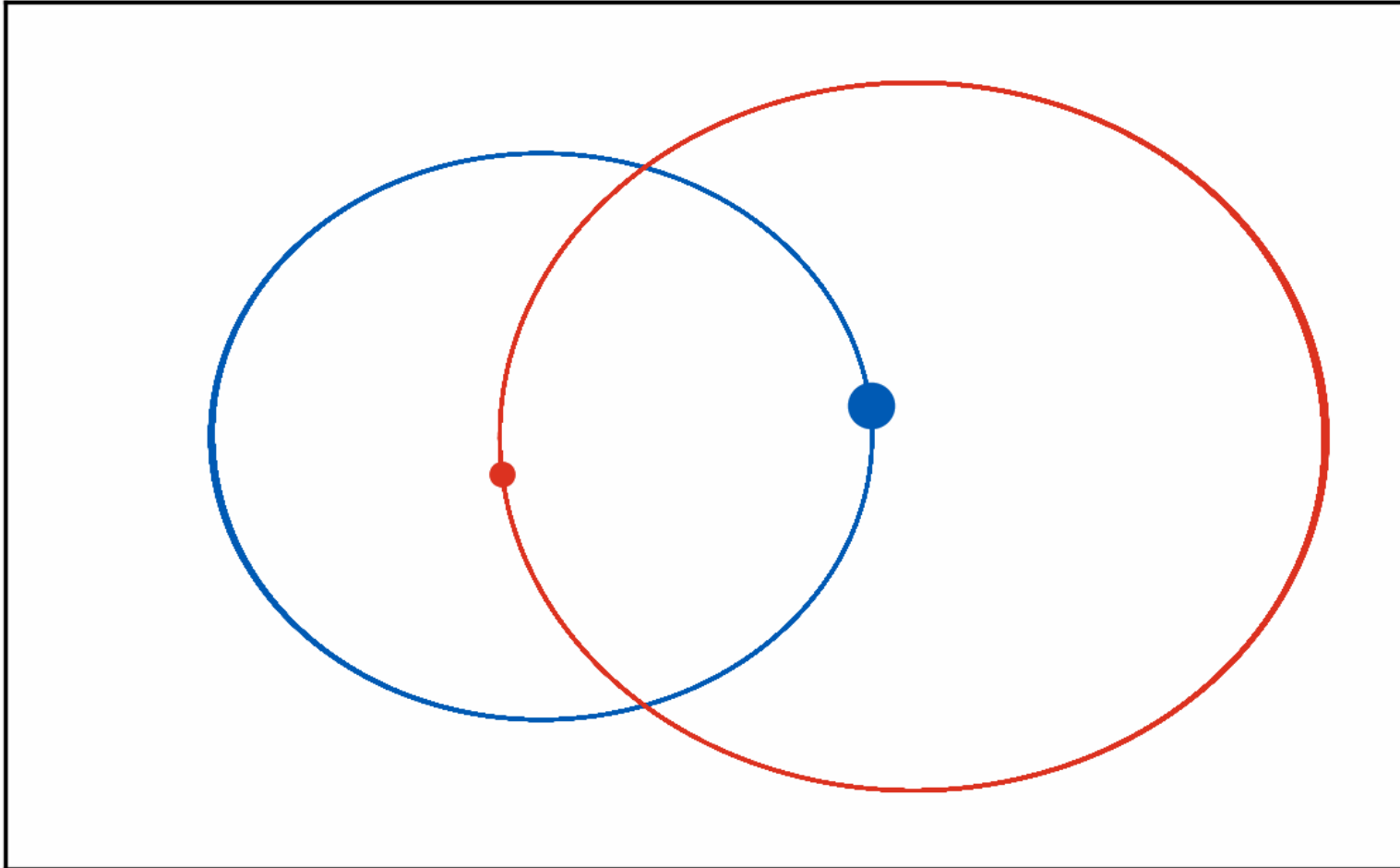
see talk by:
Mohammad Farhat

Could tides **hide** the planets?

- Almost all EBs are circular when $P_b < 7$ days
- Tight, circular orbits \rightarrow tidal dissipation

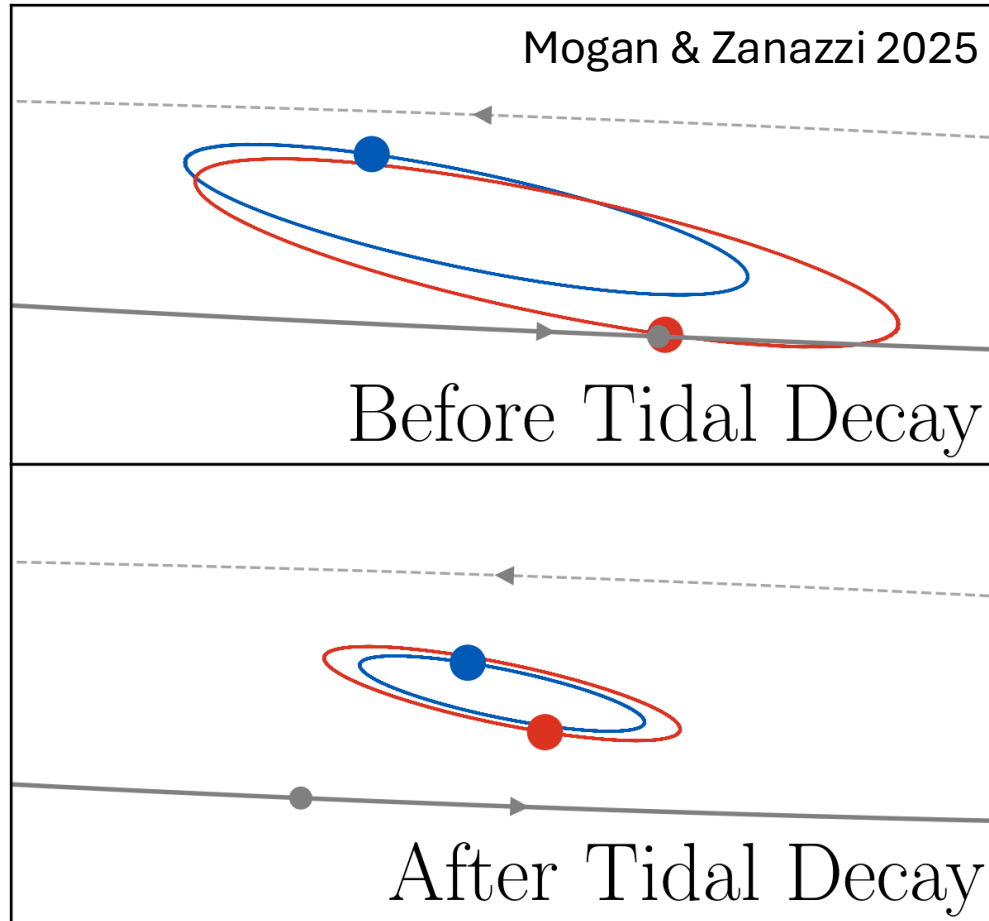


Tidal Dissipation and Shrinkage



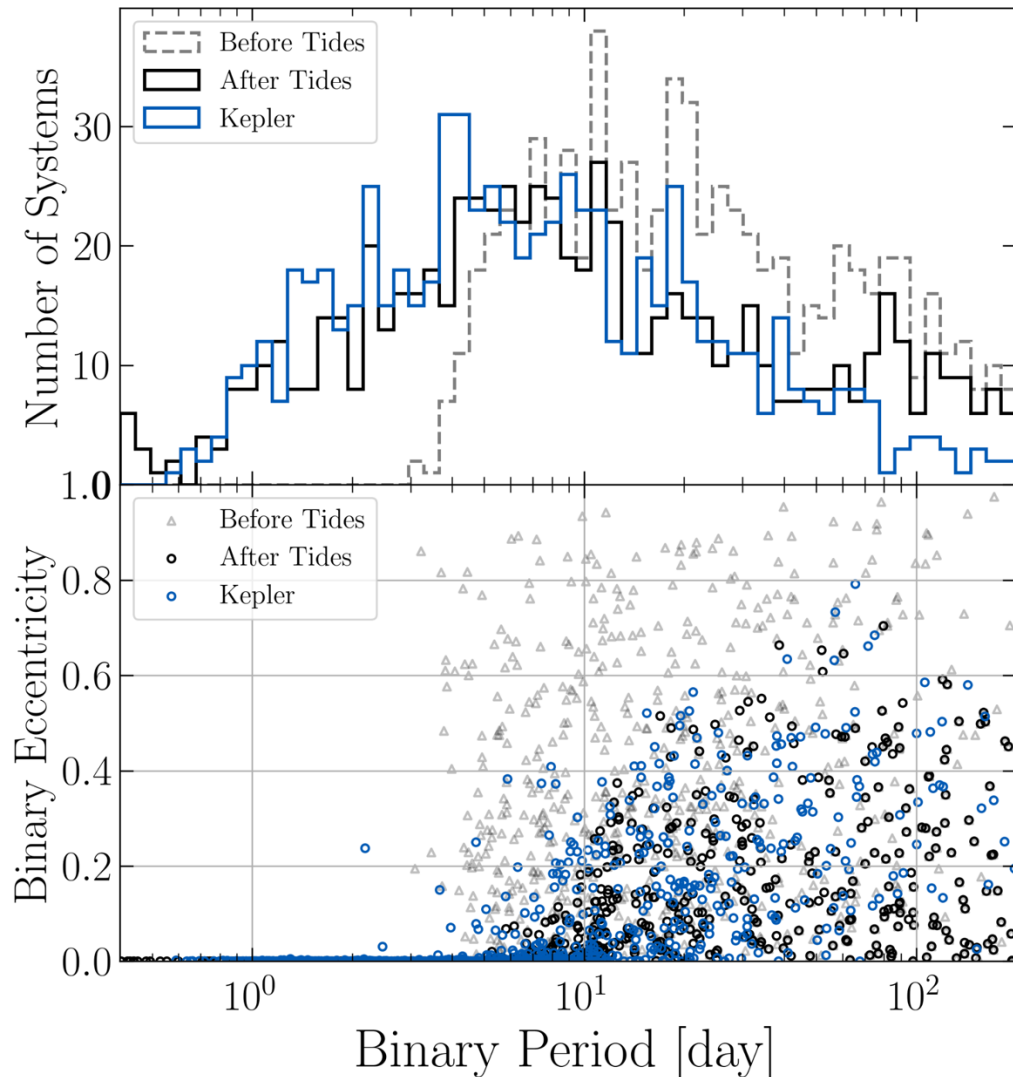
- **Friction from gravitational interactions**
- Decrease in energy \rightarrow Decrease in P_b and e

Concealing Circumbinary Planets with Tidal Shrinkage



Tidal shrinkage decreases the cross-sectional area across which a planet can transit

Simulating a Population of CBPs with Tides



- Binaries populated with initial P_b , e_b , and q with **empirical distributions**
- Planets populated outside **initial stability limit** (Holman & Wiegert 1999)

see talk by:
Nikolaos Georgakarakos

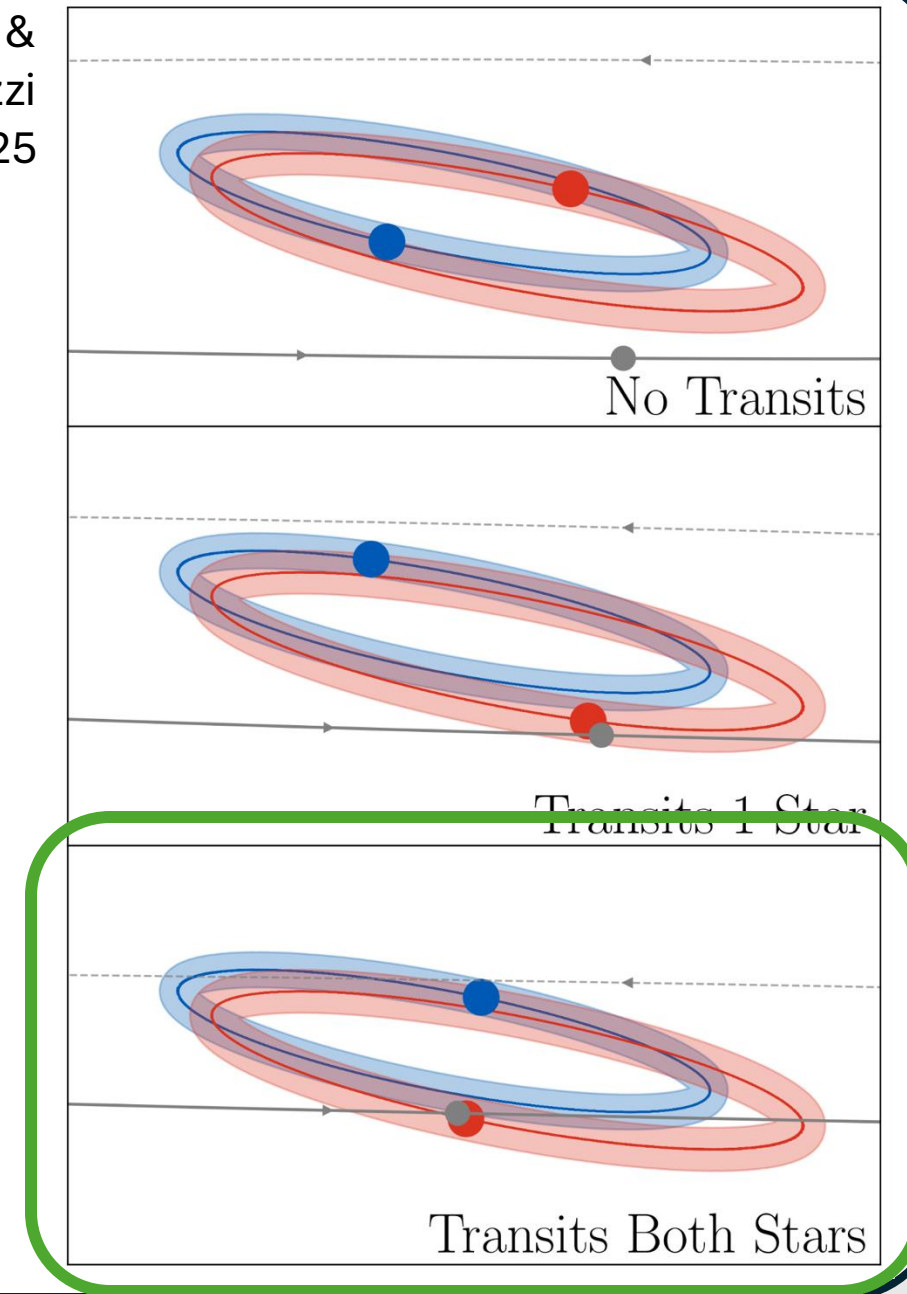
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Integrate!

Check for Transits

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- Period-averaged transit detection model
 - Binaries are “smeared” over their periods, projected → “transit rings”
 - Intersection of planet orbit with both “rings” = transit



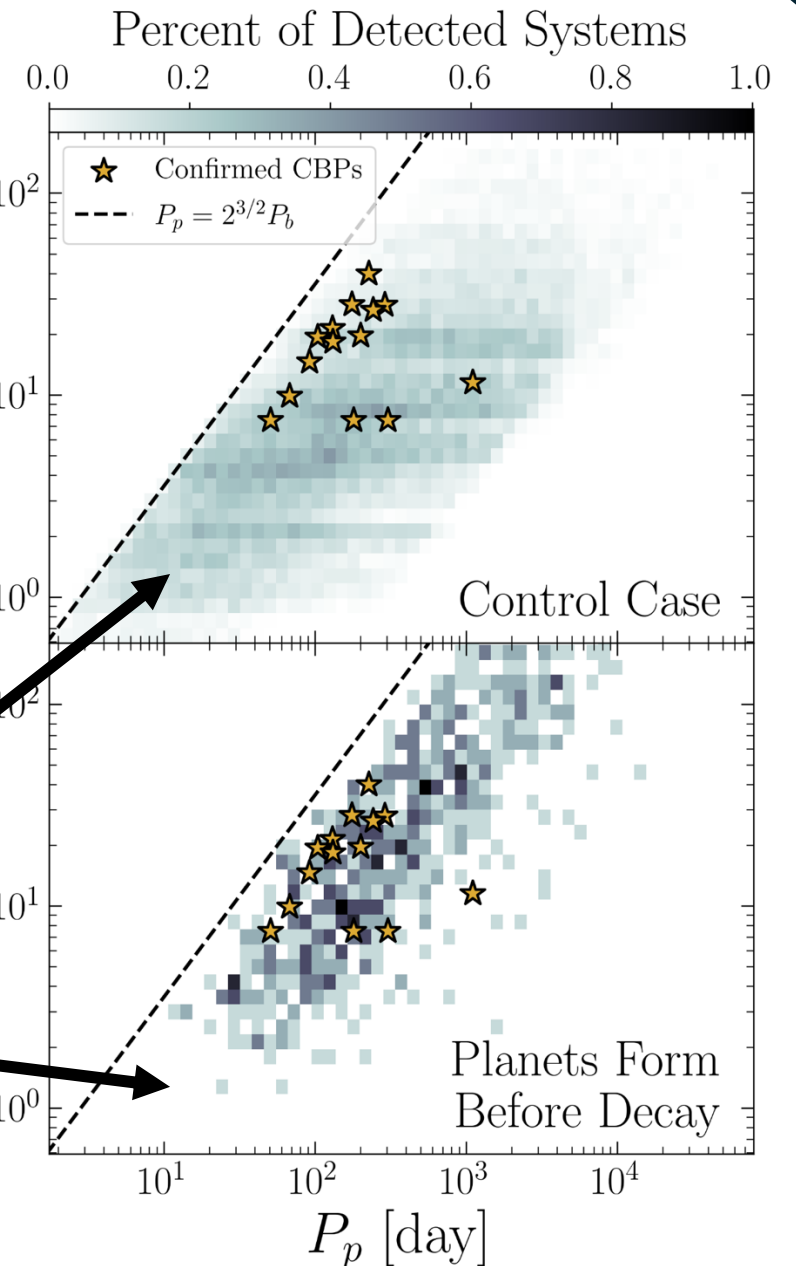
Tides do hide the planets!

- Statistical Significance:
 - 2 sample KS test, marginalized over P_p
 - **Control:** $p = 5.6 \times 10^{-4} \ll 0.05$
 - **Our Model:** $p = 0.19 > 0.05$

Compare!

Control: binary parameters drawn from Kepler with **no** tidal evolution

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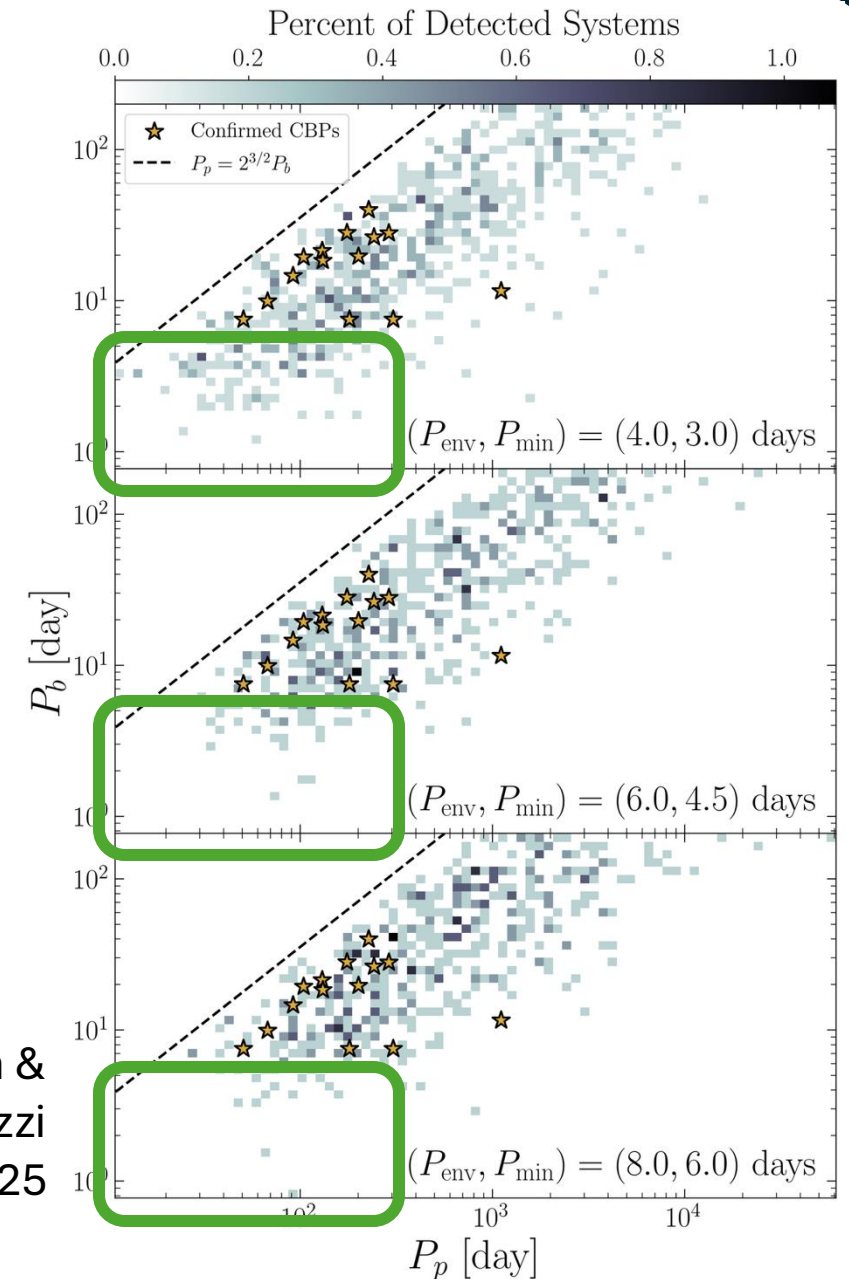


Effect of Simulation Parameters

- Most parameters tested have little effect:
 - Initial orbital parameters
 - Tidal parameters
- Most significant: P_{env} (Zanazzi 2022)
 - **Limits the minimum detected P_b**

Circularization Timescale: $\dot{e} \propto t_c^{-1} \propto \left(\frac{P_{\text{env}}}{P_b}\right)^\eta$

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Predictions

- Hidden to transit \nRightarrow hidden completely
 - Detectable by other methods
- Implies a population of wide-separation, non-transiting planets orbiting tight binaries, like **KIC 3853259 (AB)b** (Borkovits et al. 2015)
- Hides nearly co-planar planets, unlike the von Zipel-Lidov-Kozai mechanism (Muñoz & Lai 2015)

Conclusions

- Tidal shrinkage can partially explain the CBP deficit
 - Requires planet formation prior to circularization
- **Predictive:** implies a population of wide-separation, non-transiting, nearly coplanar planets orbiting short-period binaries
- Pairing this with other observational biases and dynamical reasons can help explain the discrepancy

Mogan, S. & Zanazzi, J. J.
2025, Accepted in ApJ, doi:
10.3847/1538-4357/ade2e8

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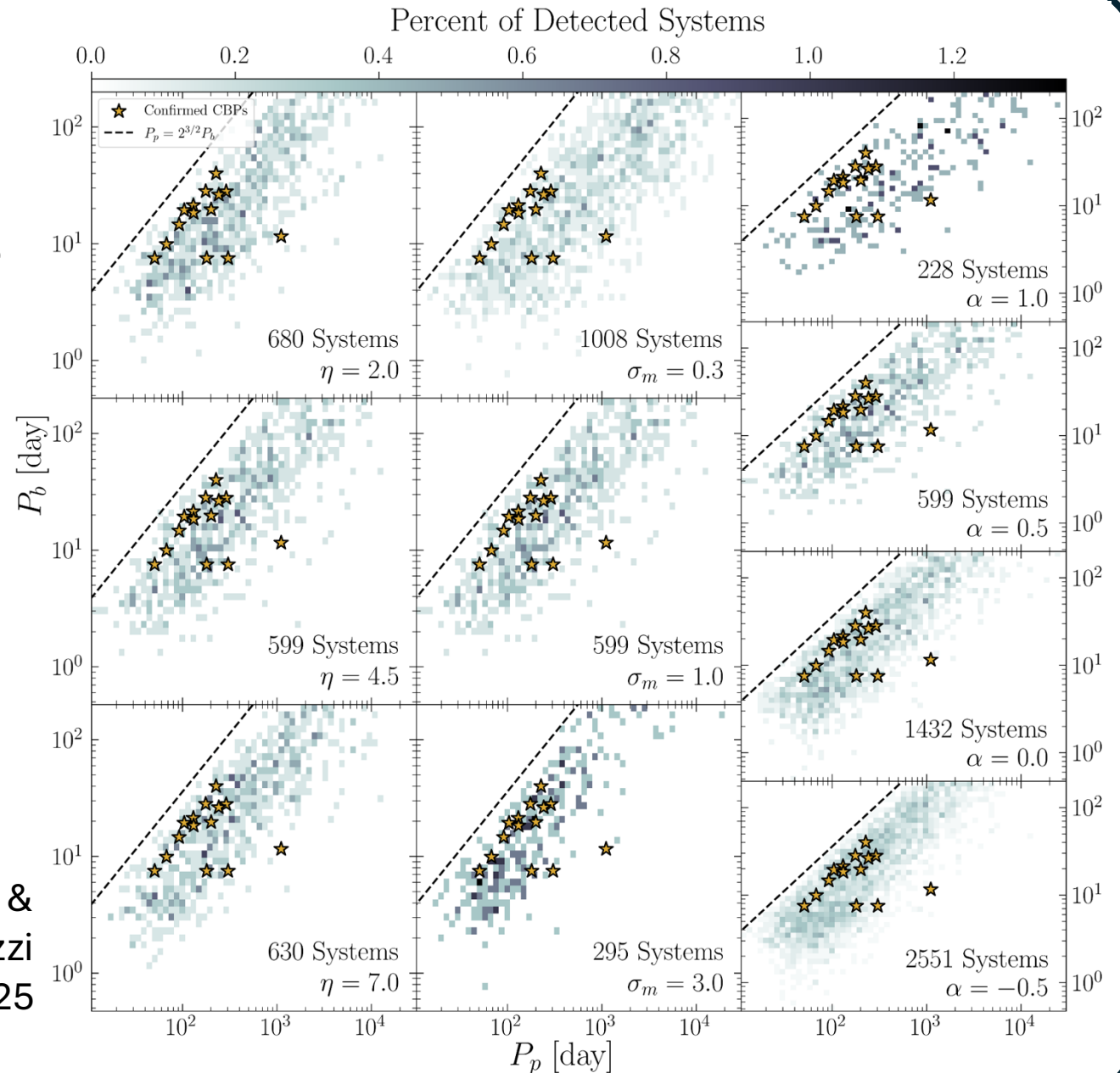


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Sensitivity to Other Simulation Parameters

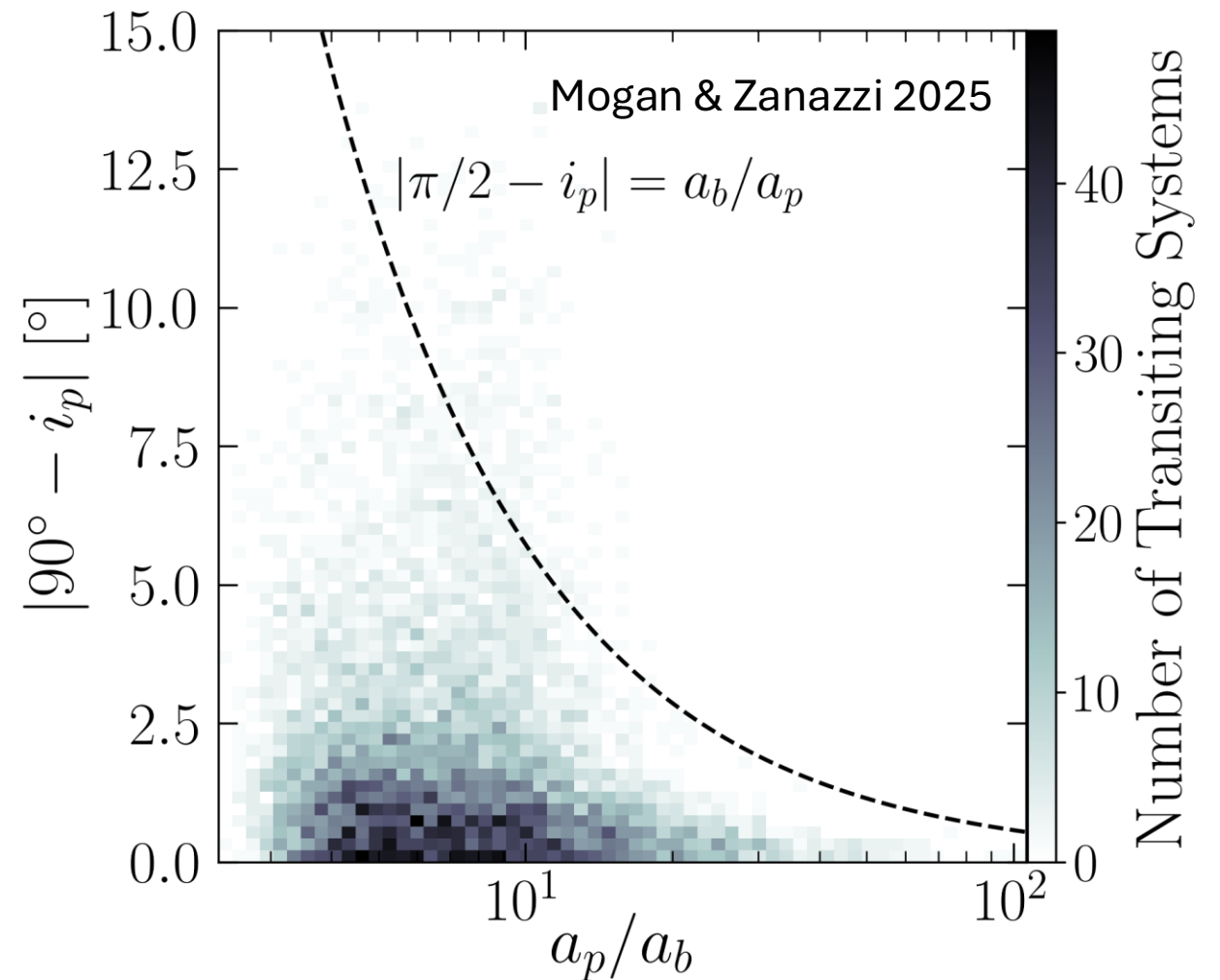
- η : Tidal Efficiency
- σ_m : Scale parameter for mutual inclination distribution
- α : Planet separation power law

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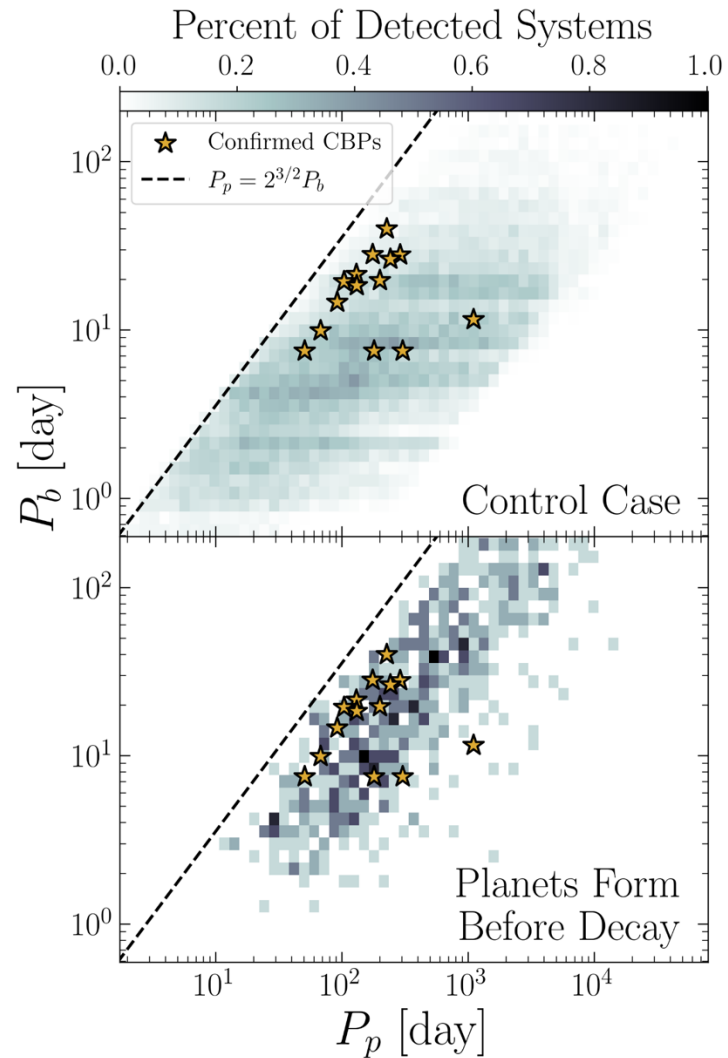


Transit Checker Validation

- Obeys geometric transit limit
- Leakage due to apsidal precession



Kolmogorov–Smirnov Test



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