Studying the three-dimensional architecture of transiting planets and their outer companions in the era of Gaia

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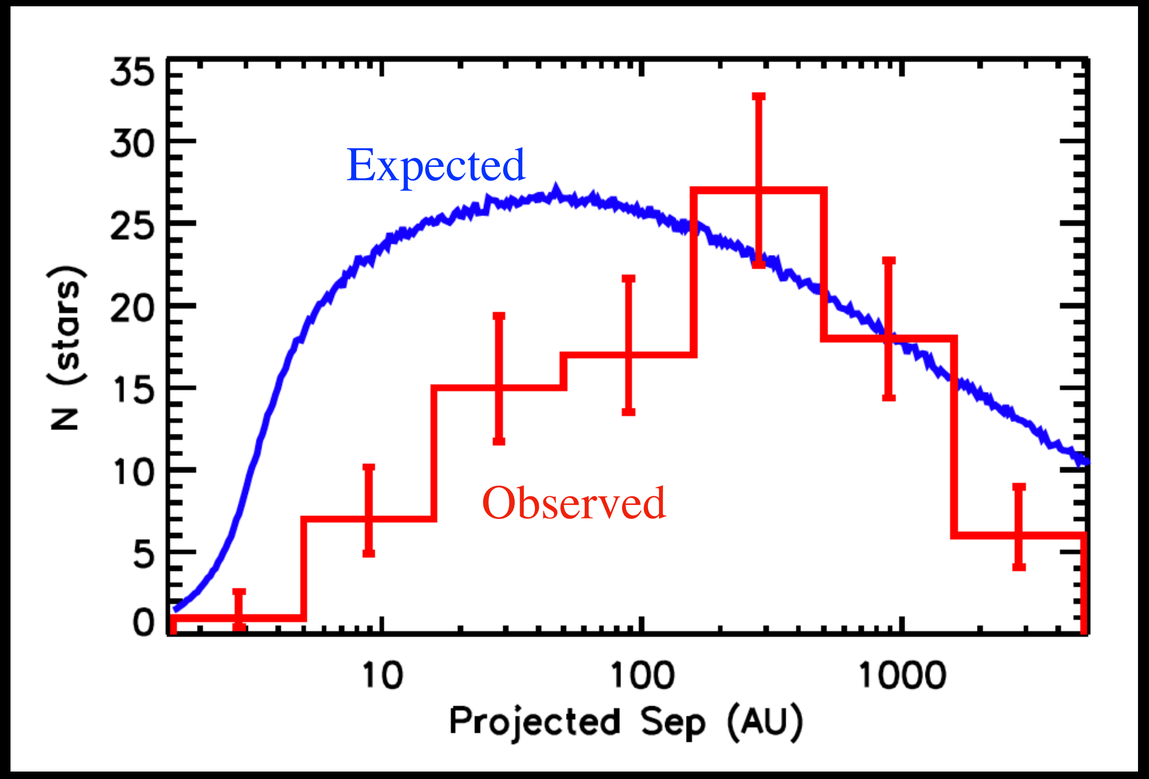
ExSoCal 2025

Close stellar companions as disruptors of planet formation

Number of Kepler Objects of Interest (KOIs) with stellar companions



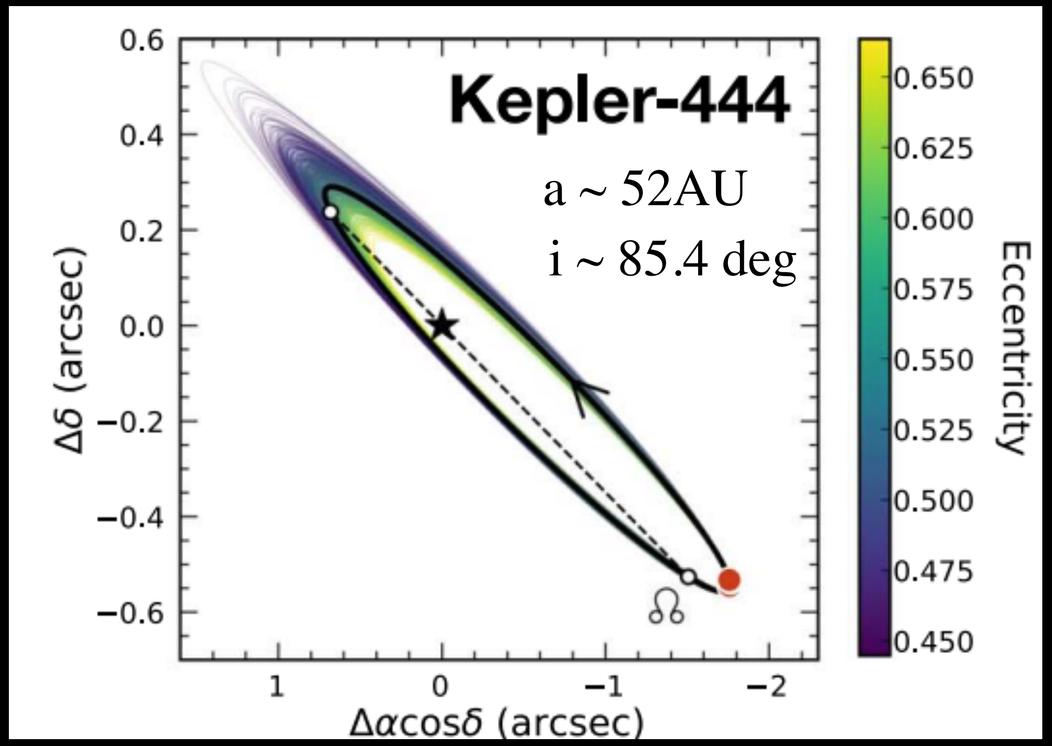
Kraus+2016

- Truncating disks (Jang-Condell 2015)
- Dynamically stirring planetesimals (Silsbee & Rafikov 2015)
- Enhancing accretion and photoevaporation (Alexander 2012)

See also in Hirsh+2021, Ziegler+2020, 2021, Clark+2022

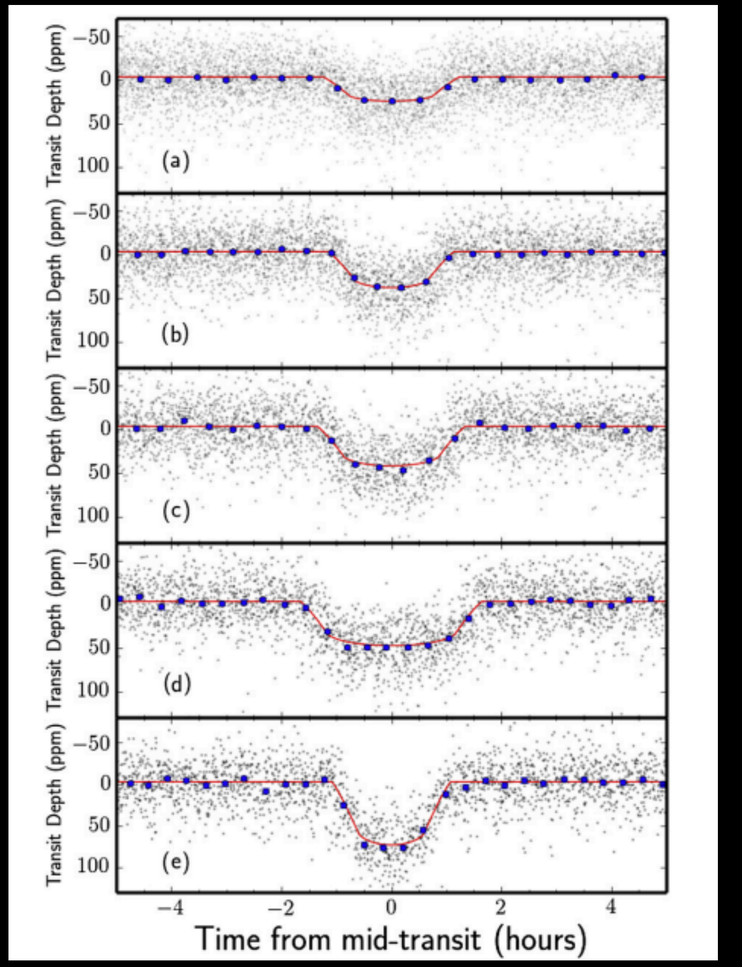
But, some planets survive in such an hostile environment

A K dwarf primary around by
a pair of M dwarf binary



Dupuy et al. 2016, ZJ. Zhang+2023

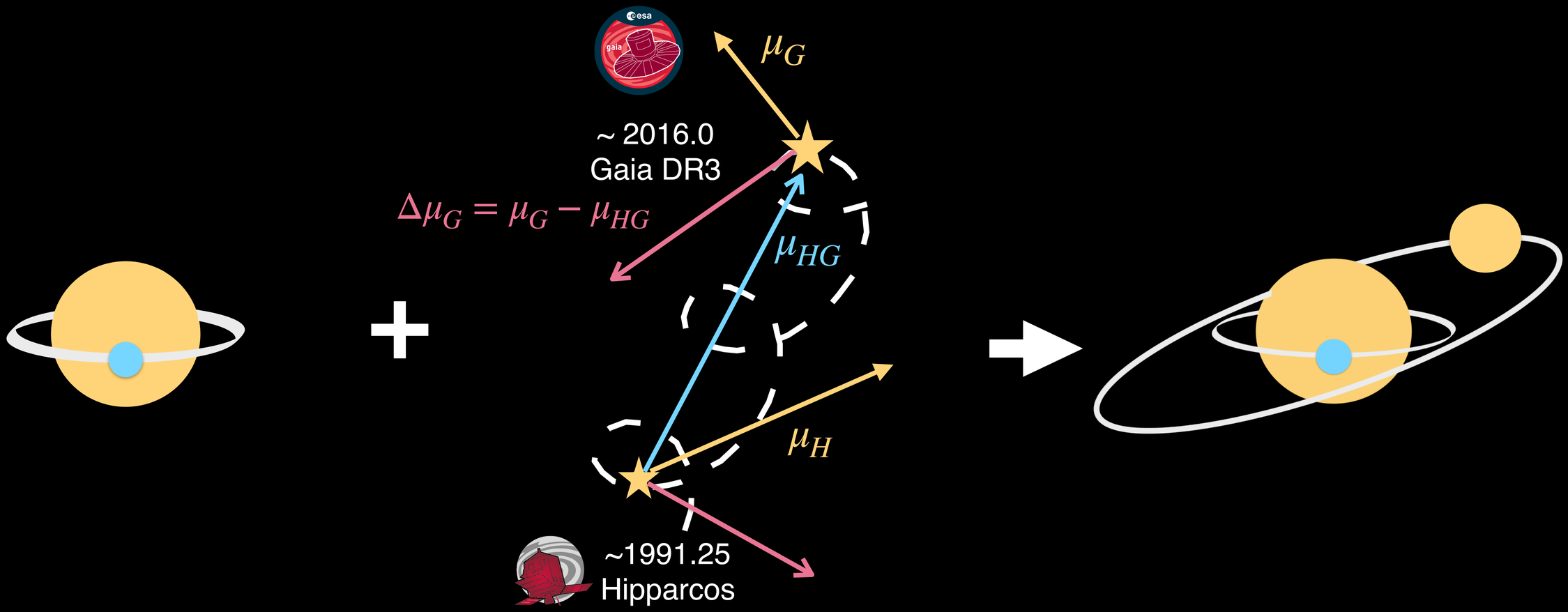
Five Mars sized planets around primary



Campante
et al. 2015

Survey Design: Cross-match TESS Object of Interest (TOI) list with Hipparcos Gaia Catalog of Acceleration

Kervella+2019; Brandt 2021

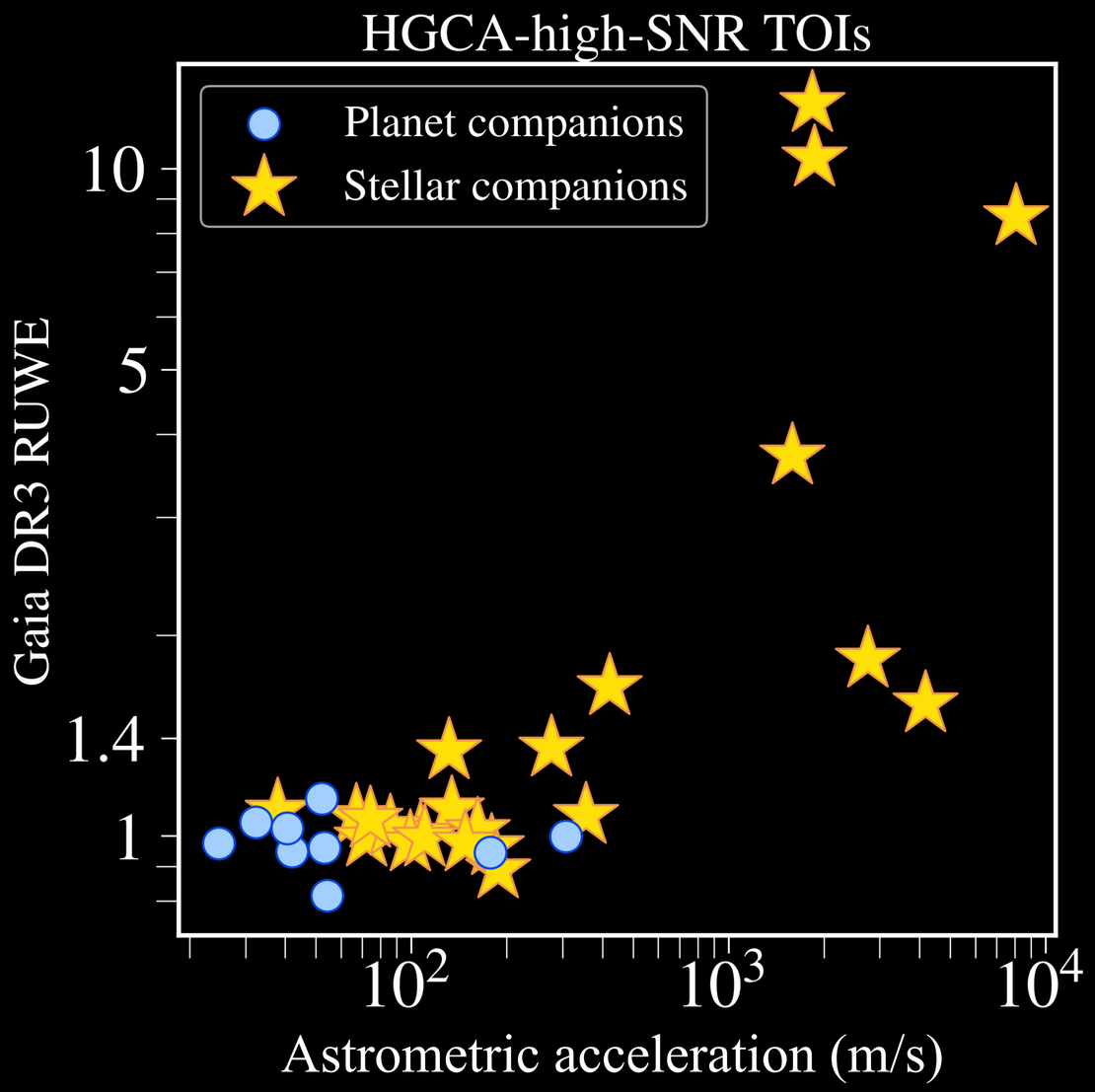


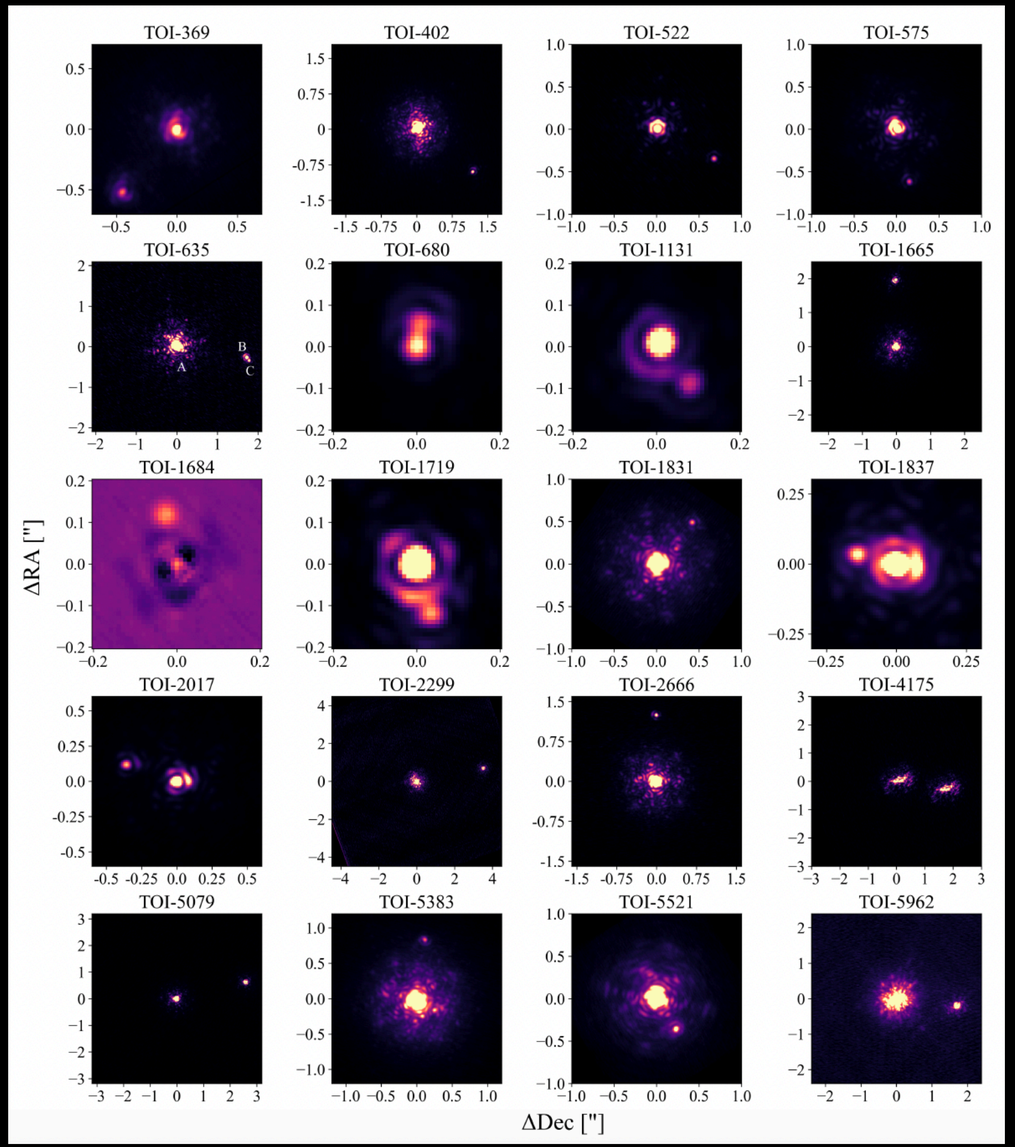
TOIs

SNR_astrometric acceleration >3

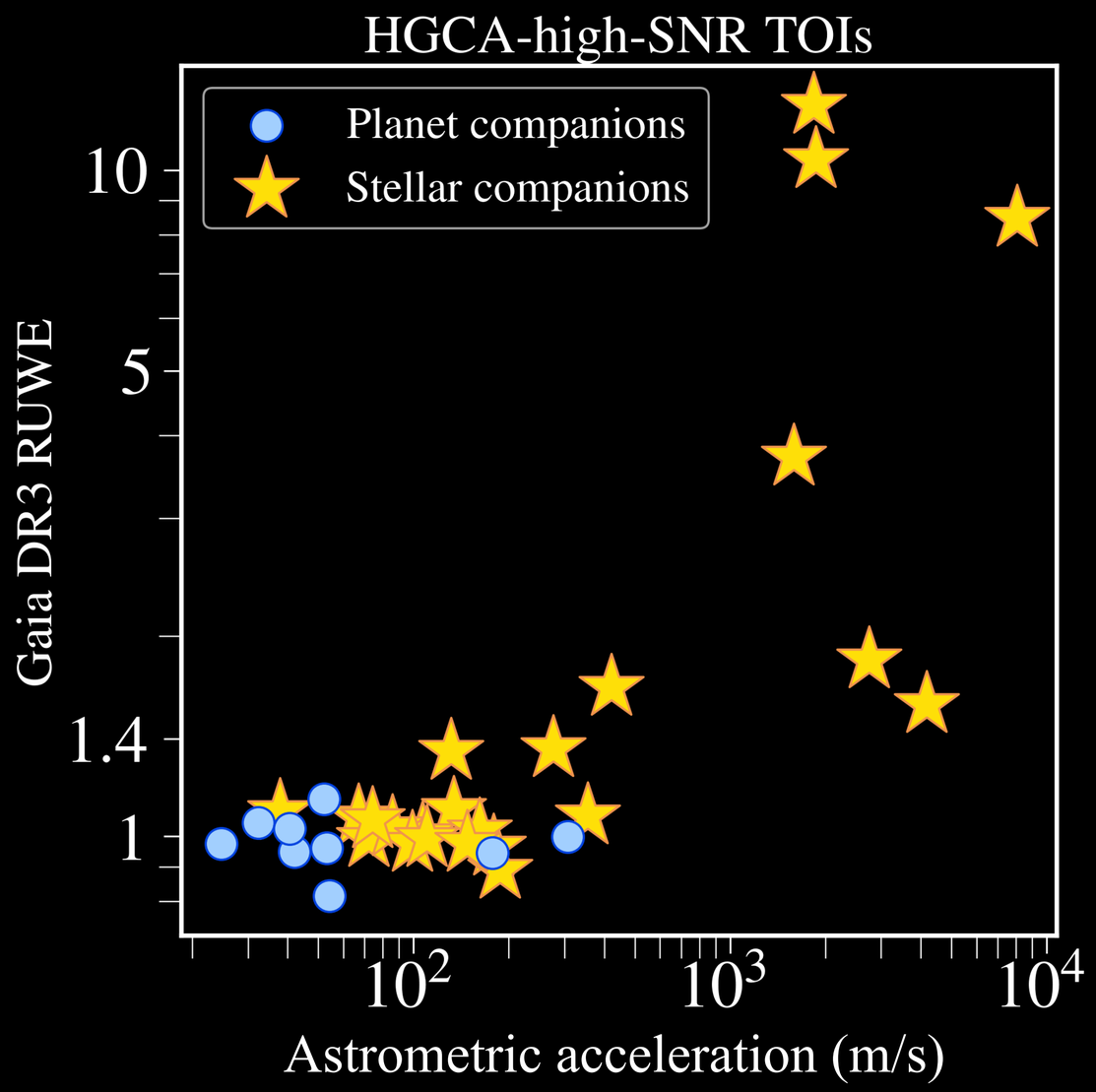
Survey Results： Stellar Companions

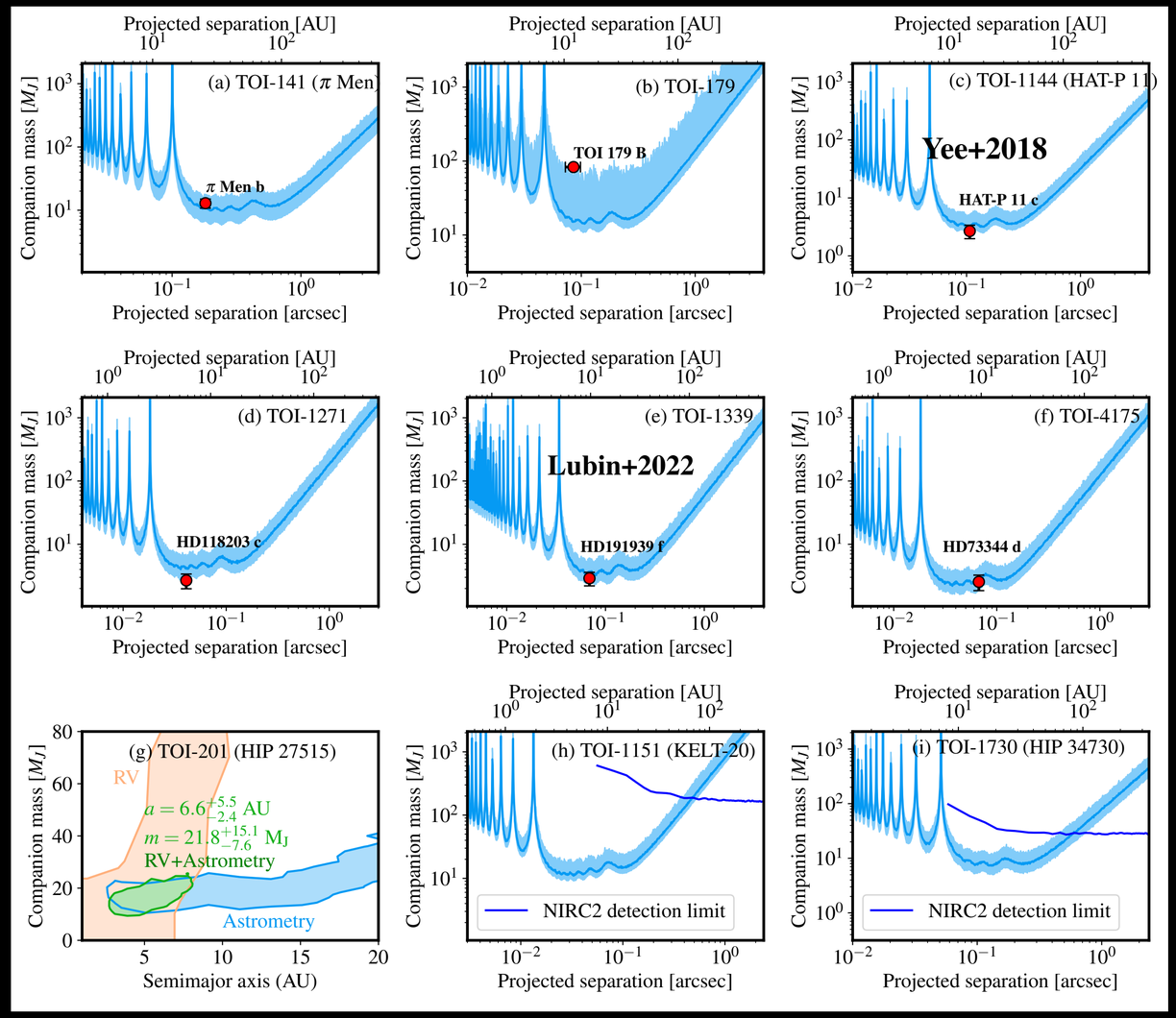
NICR2 on W.M.Keck Observatory





Survey Results： Planet Companions

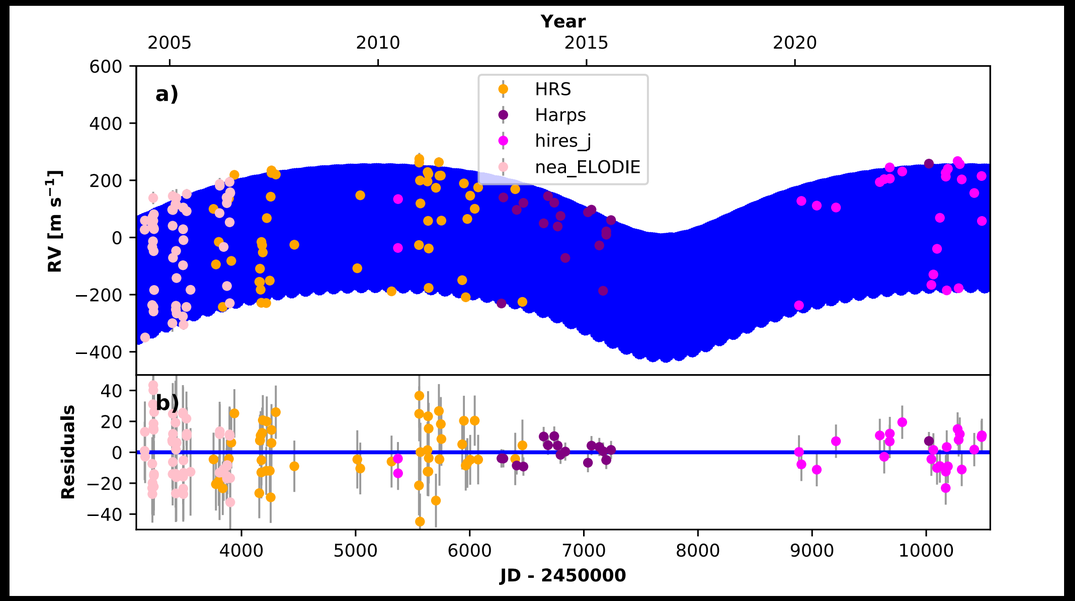




Survey Results： Planet Companions

HD118203: an eccentric hot Jupiter with an aligned outer planet companion

Zhang+2024c

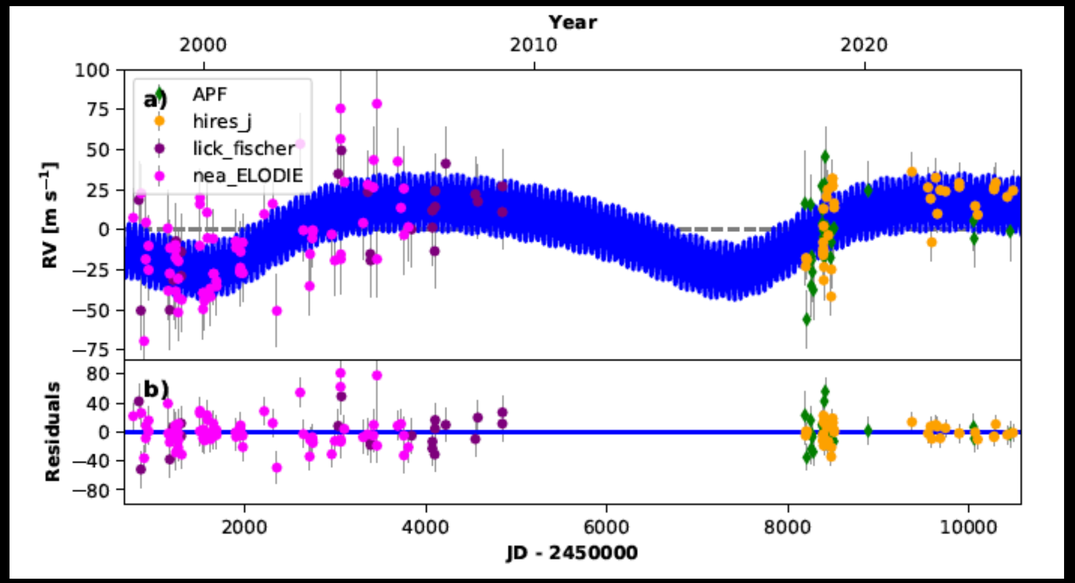


$a_c = 6.3$ AU

$m_c = 11.8\ M_J$

HD 73344: Discovery of a Jupiter Analog Misaligned to the Inner Planetary System

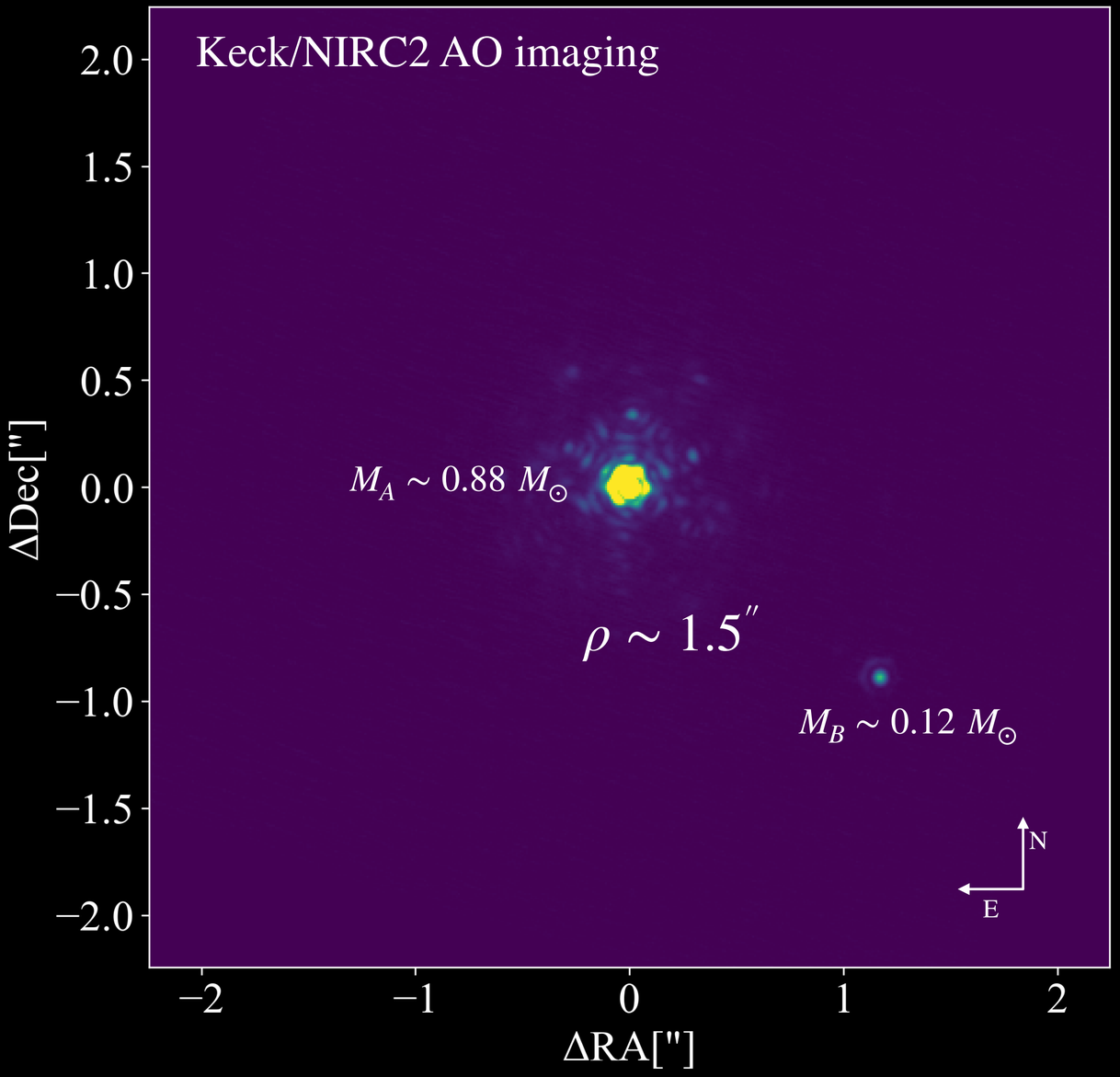
Zhang+2025a



$a_d = 6.7$ AU

$m_d = 2.6\ M_J$

HIP11433 system (TOI-402)



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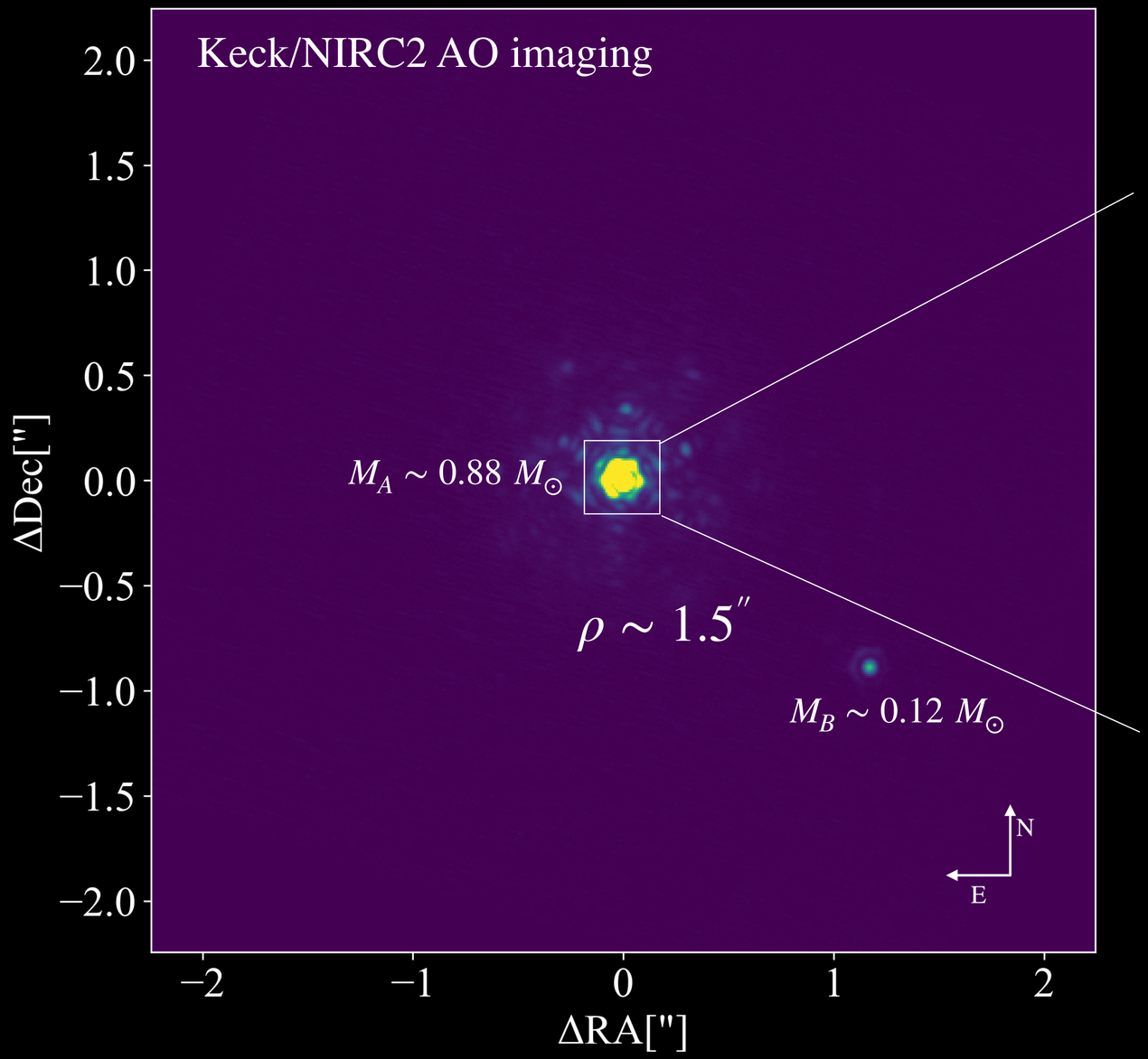
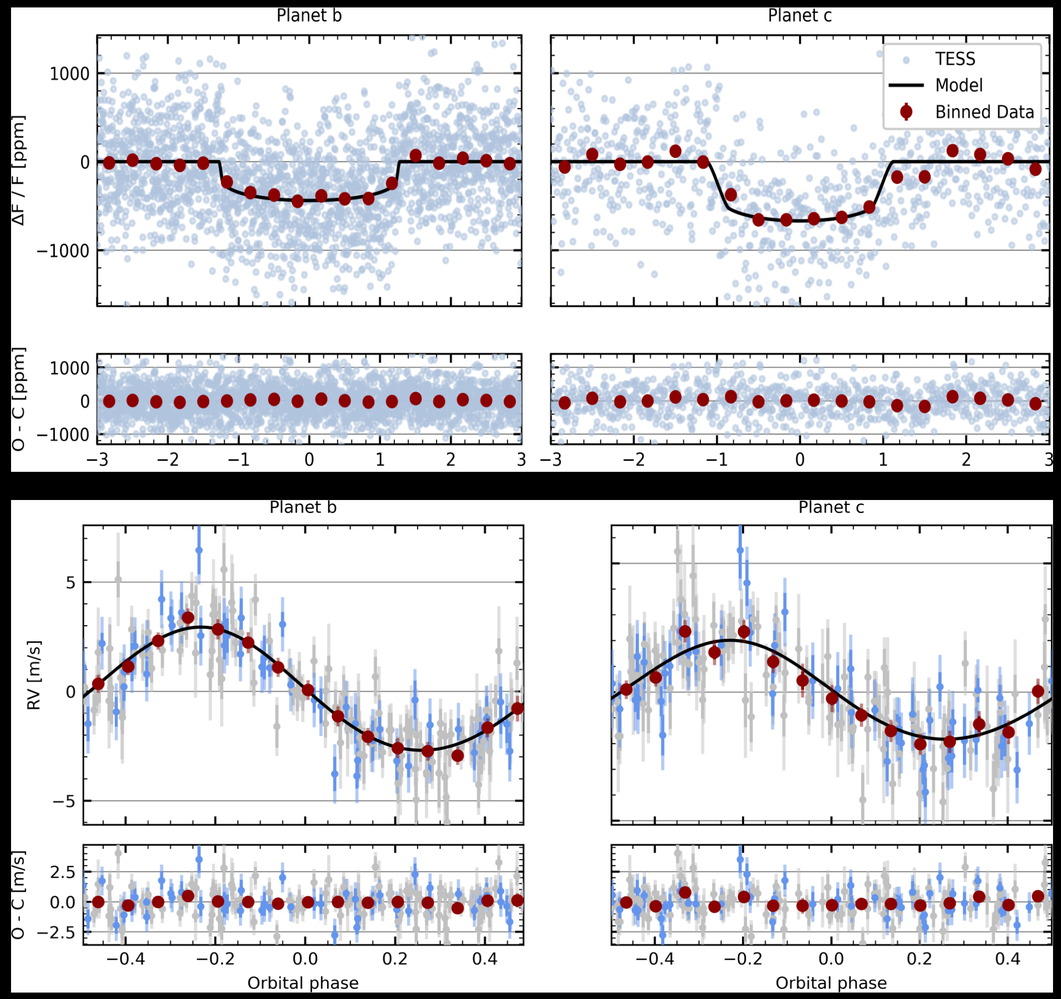
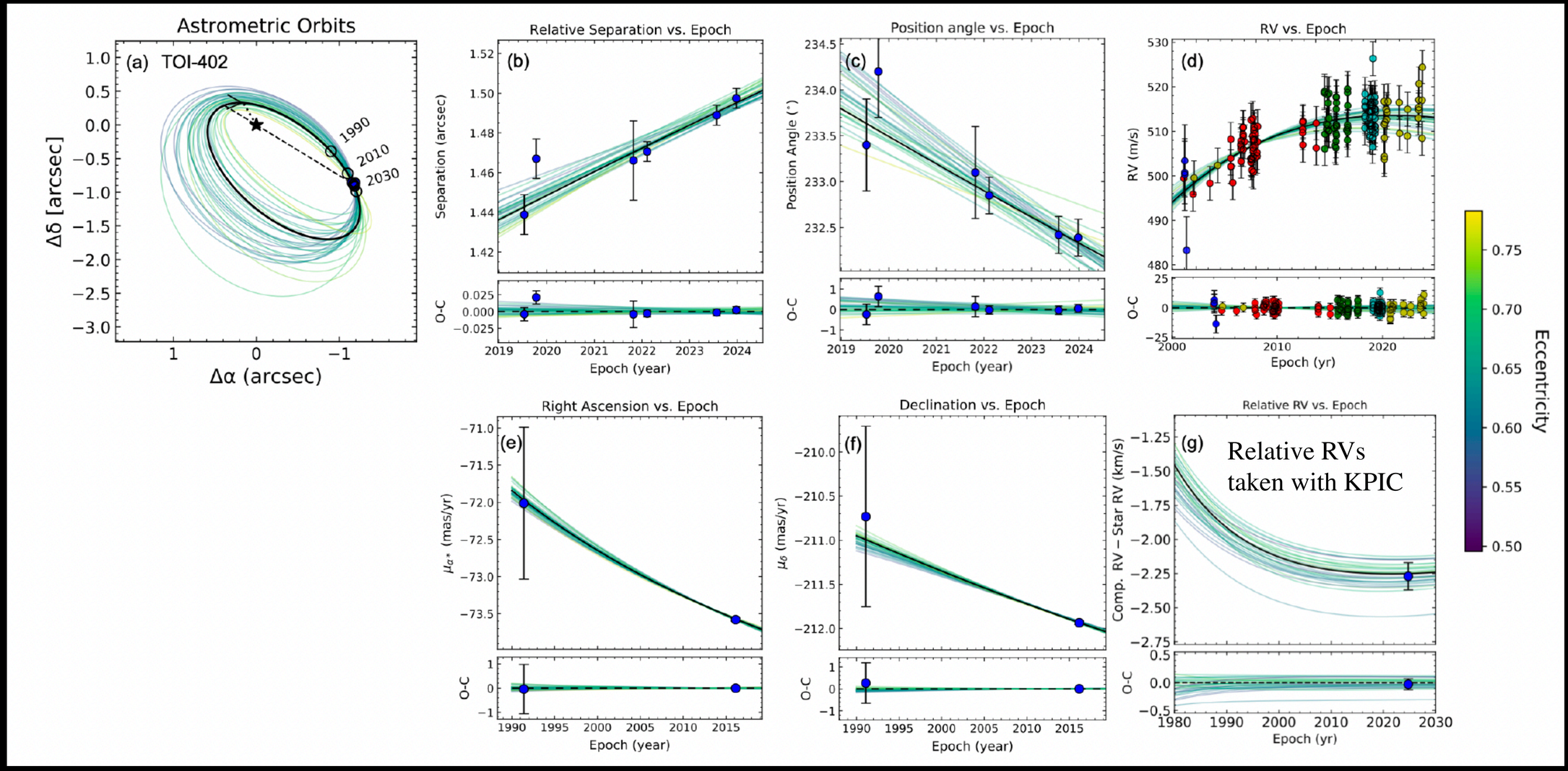


$P_b = 4.76d, r_b = 1.8\ R_\oplus, m_b = 6.5\ M_\oplus$ $P_c = 17.1d, r_c = 2.5\ R_\oplus, m_c = 6.8\ M_\oplus$



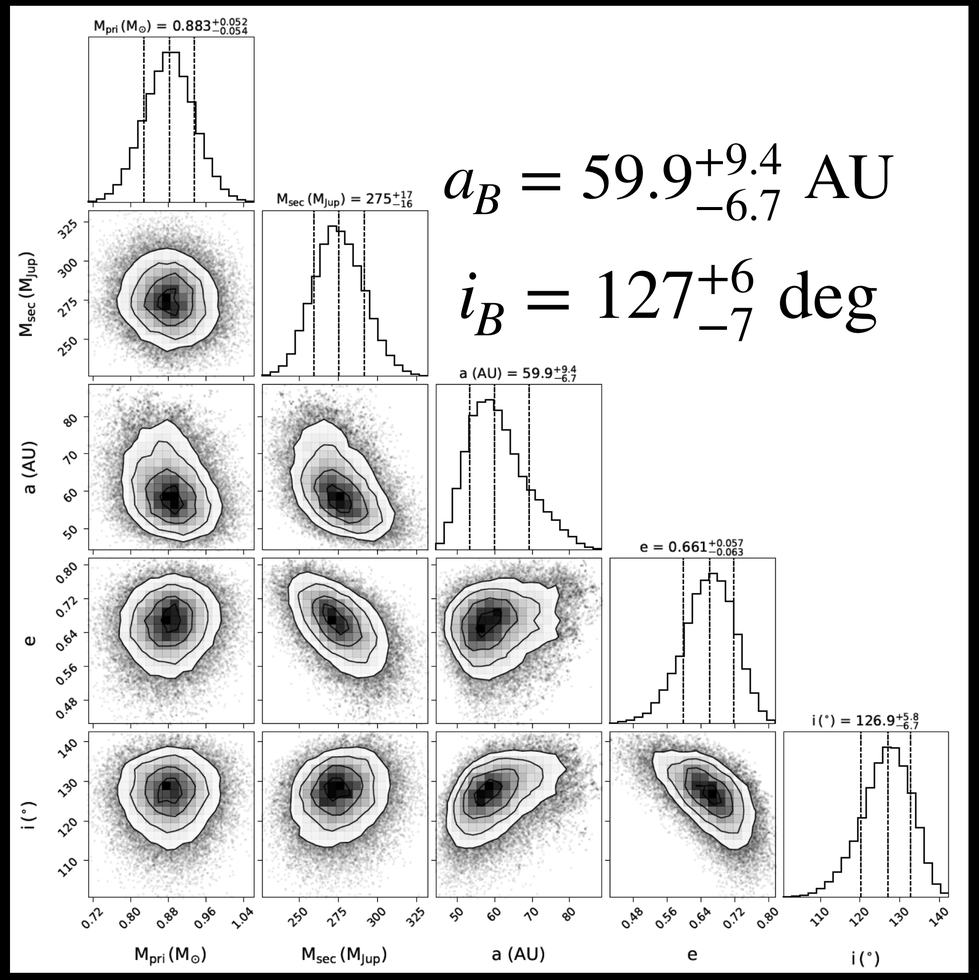
Dumusque+2019,Gandolf+2019, Rosário+2024

3D orbital fitting of the stellar companion



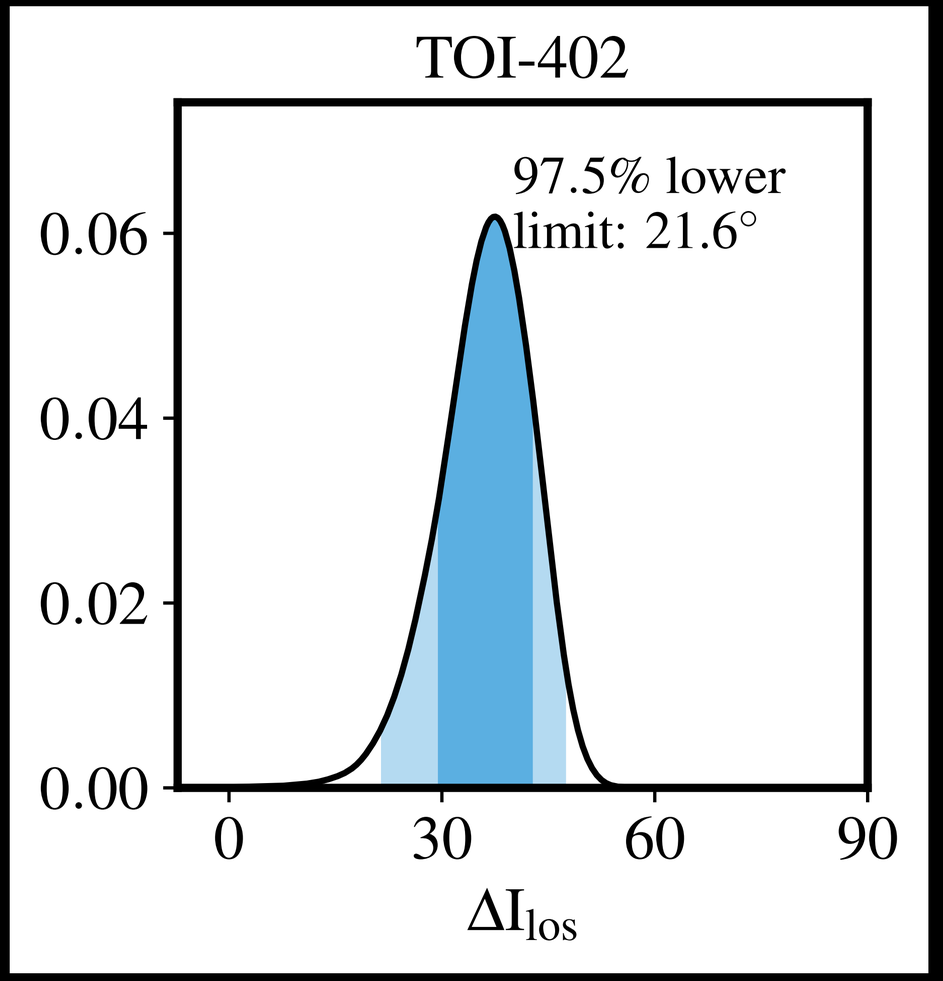
Zhang+2025b

Constraint on line-of-sight mutual inclination: $|I_{comp} - I_p|$



$$a_B = 59.9^{+9.4}_{-6.7}\ \text{AU}$$

$$i_B = 127^{+6}_{-7}\ \text{deg}$$



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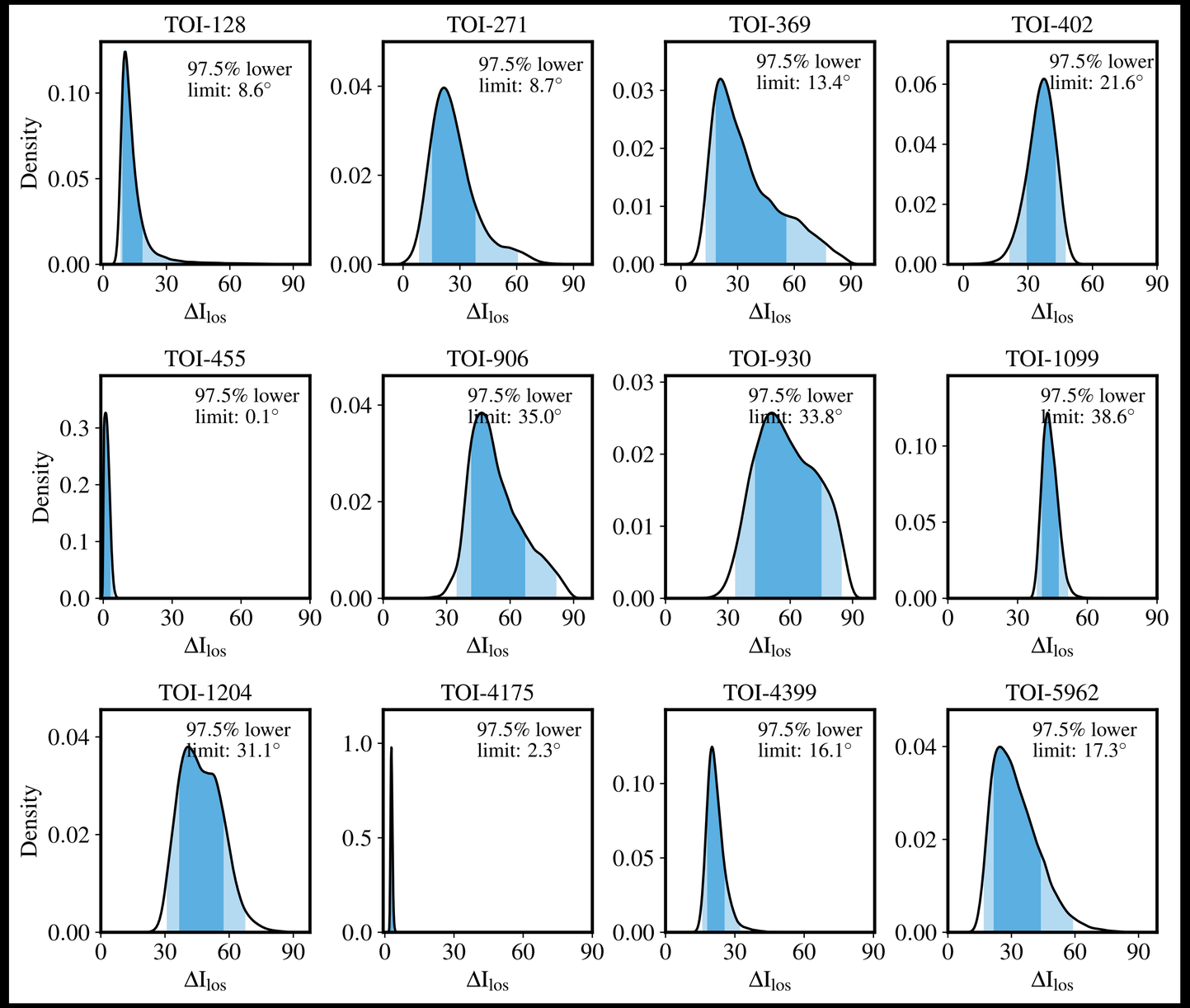
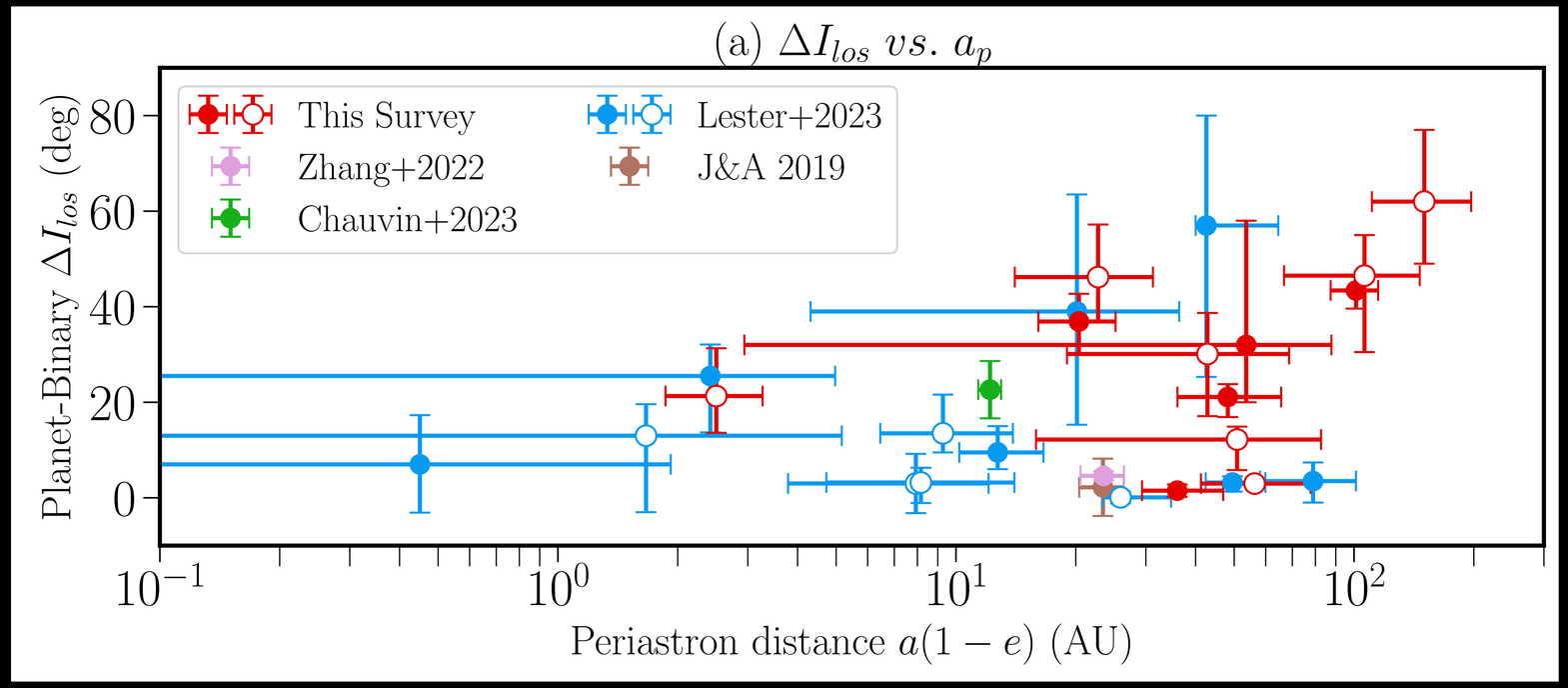
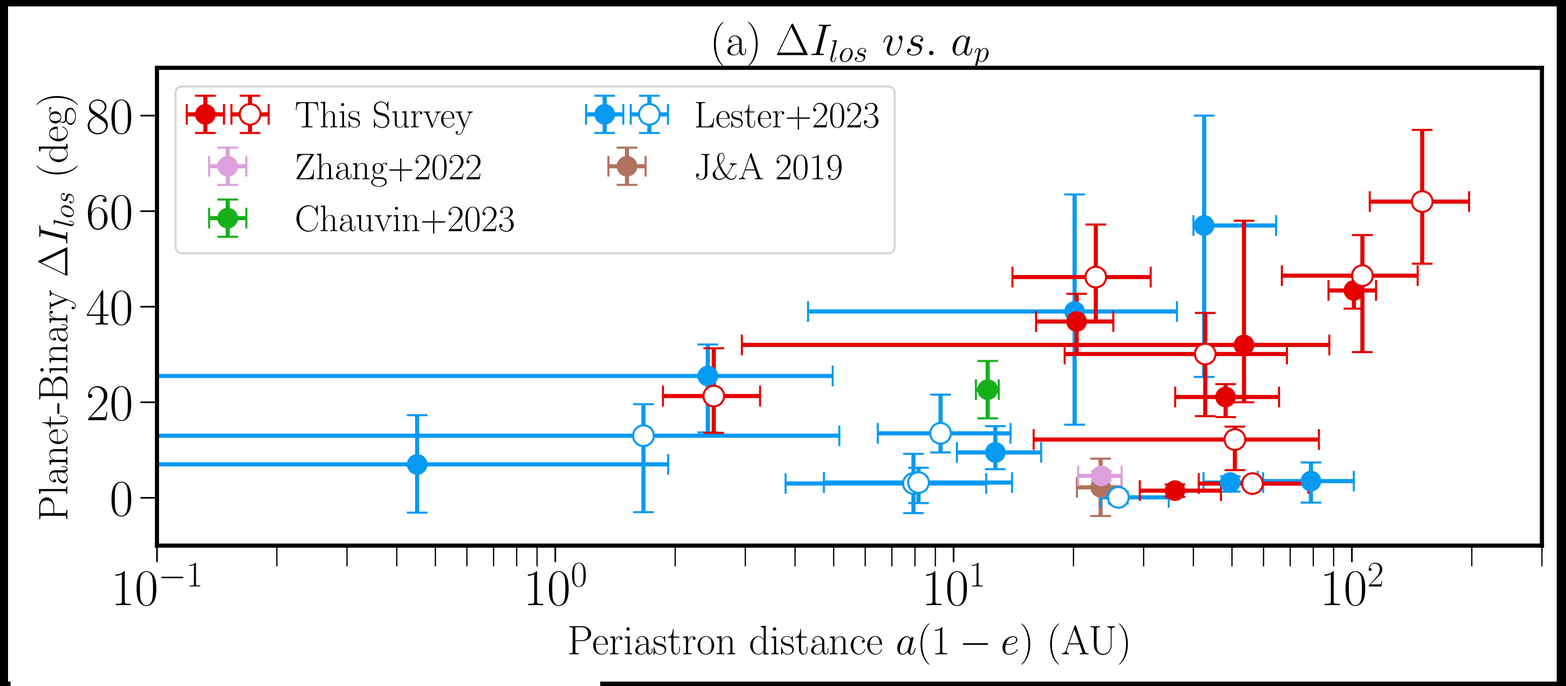


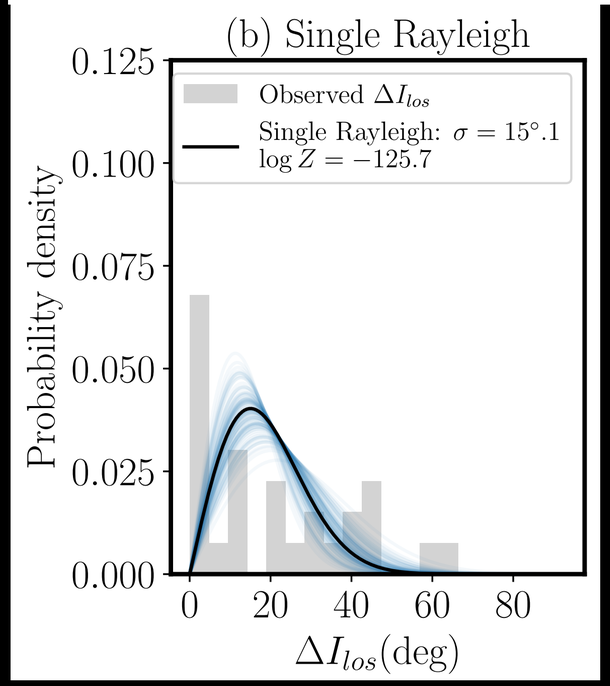
Zhang+2025b



Line-of-sight mutual inclination vs. semi-major axis

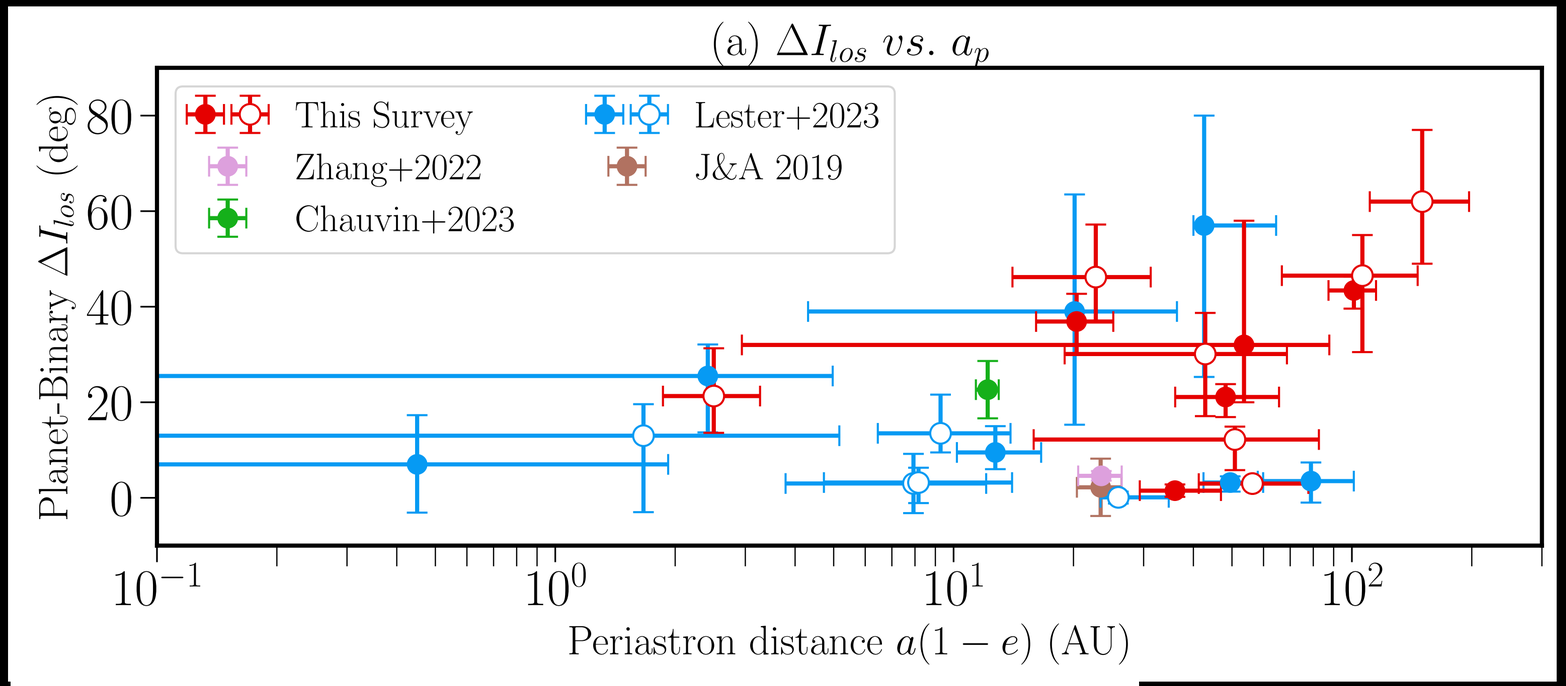
Zhang+2025b



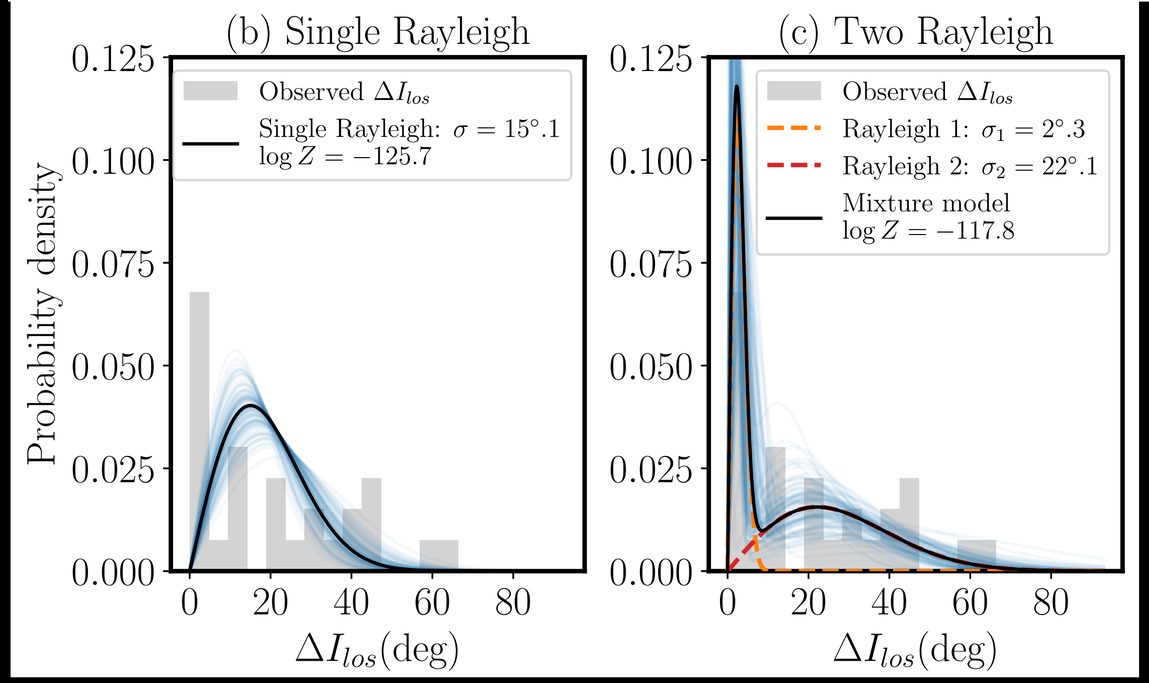


Line-of-sight mutual inclination vs. semi-major axis

Zhang+2025b



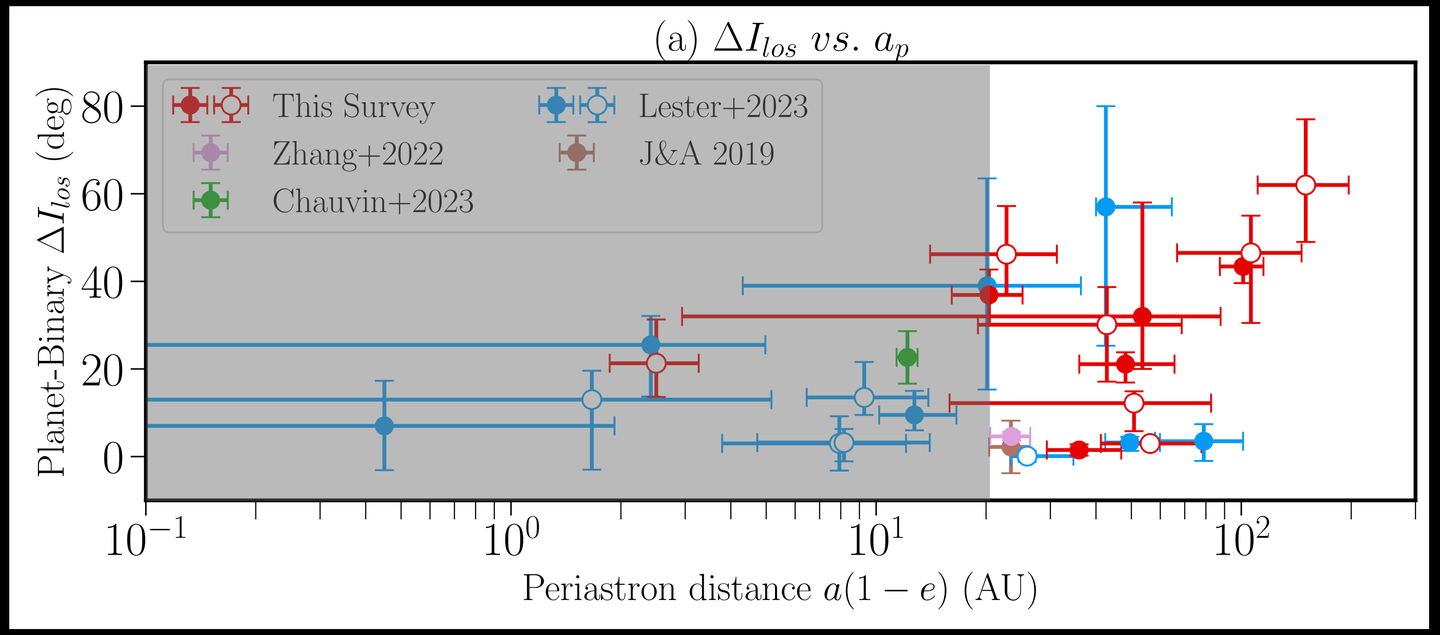
Line-of-sight mutual inclination vs. semi-major axis

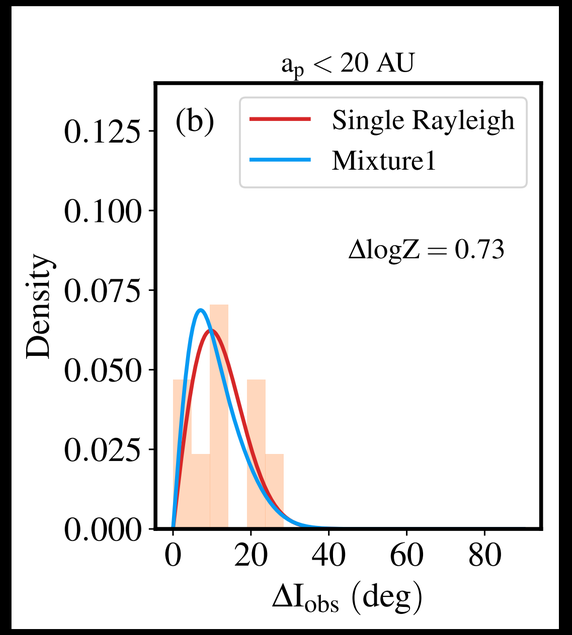


Mixture model is strongly favored over single model for the distribution of the mutual inclination

Zhang+2025b

A transition in planet alignment for binaries from 20 to 100 AU





Zhang+2025b

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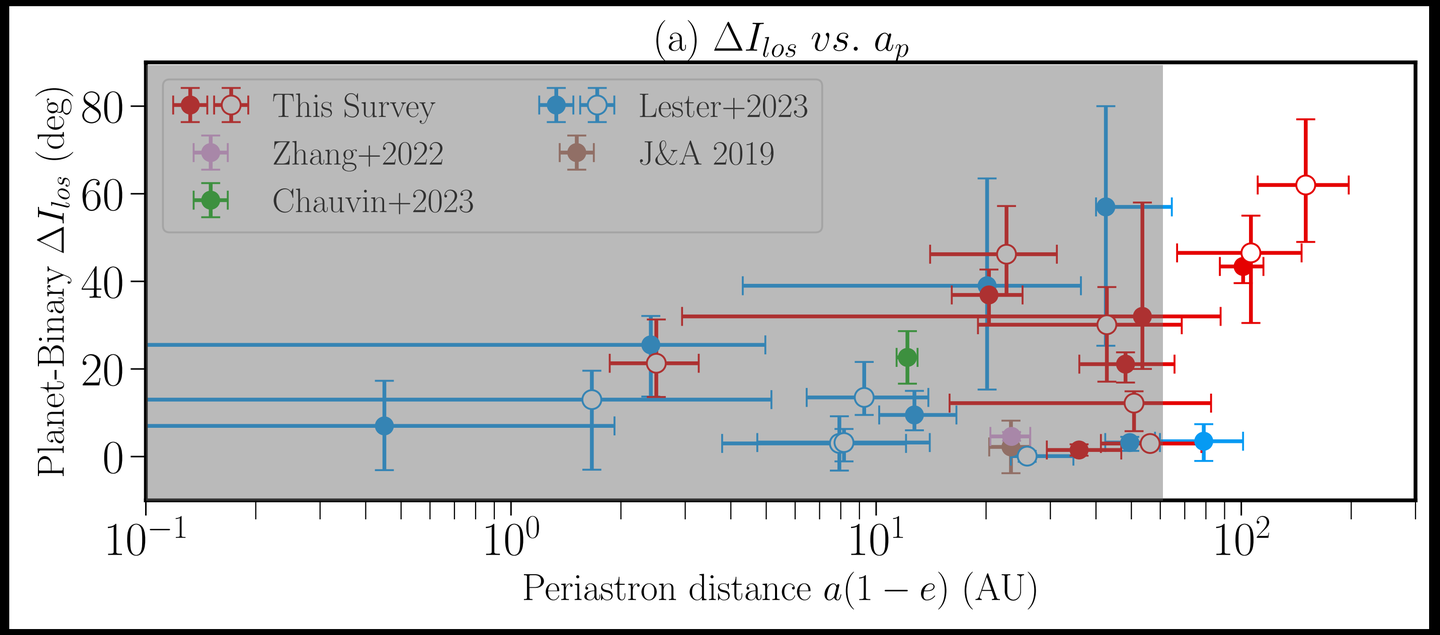

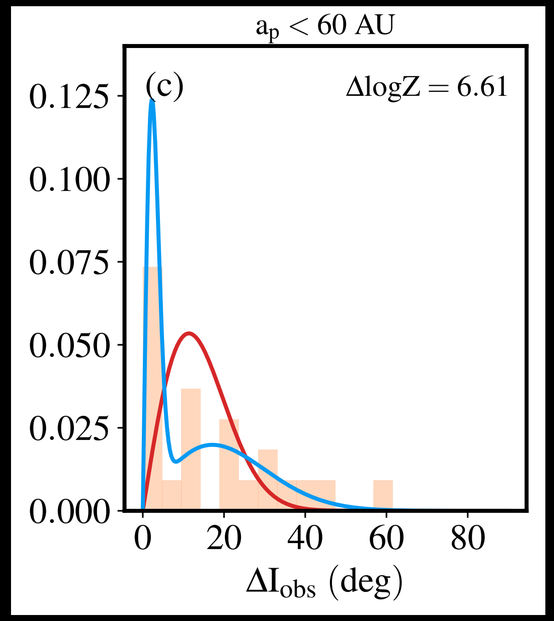

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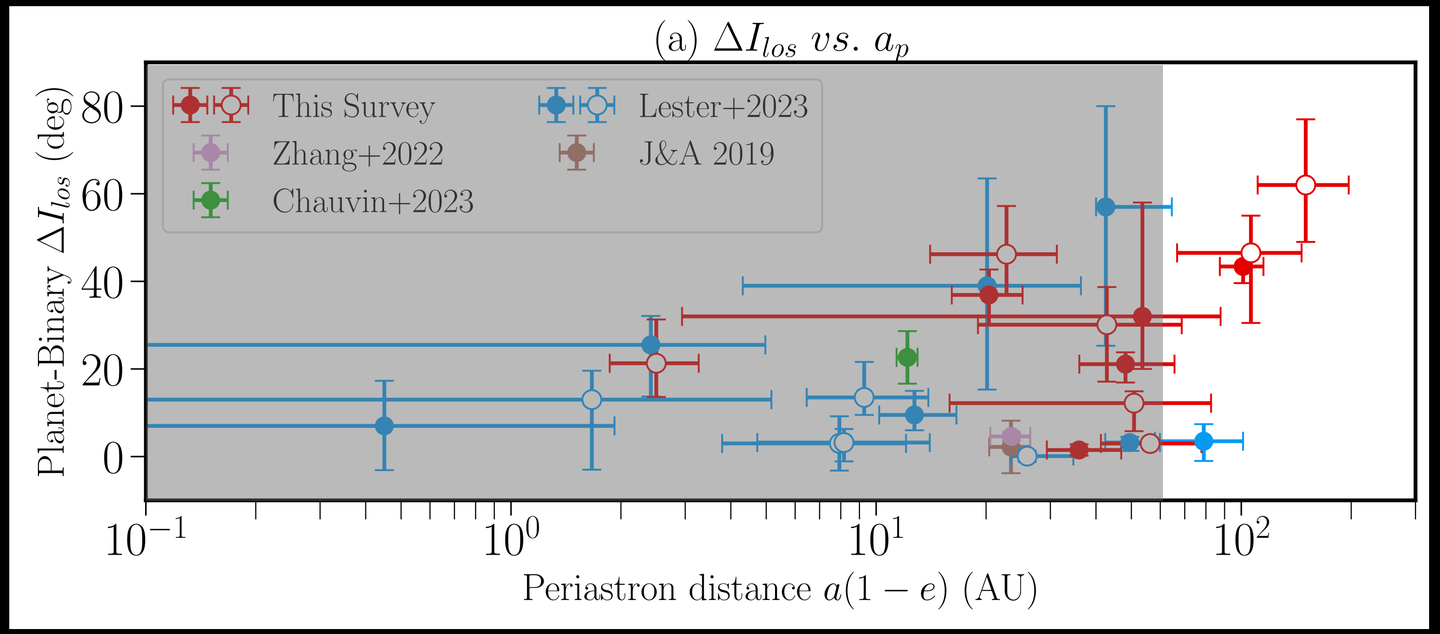
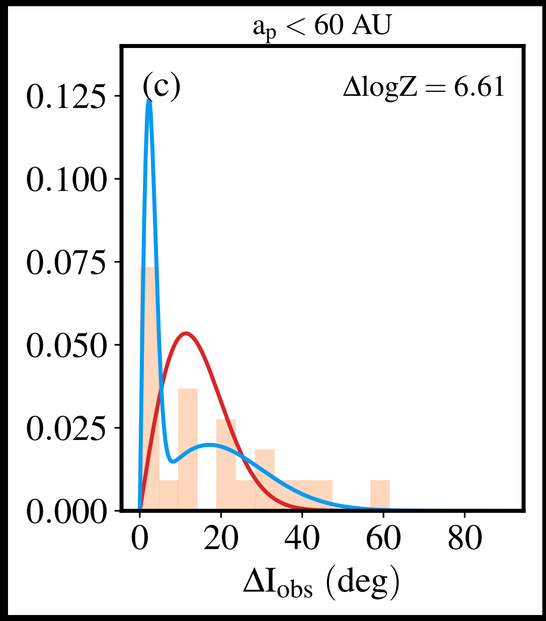
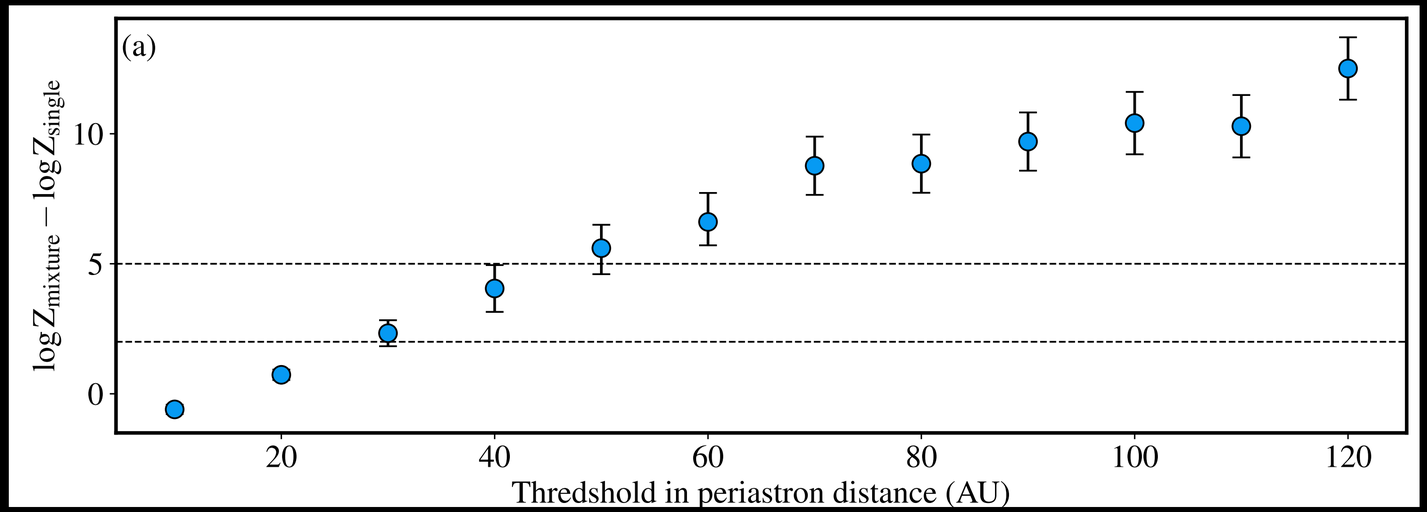




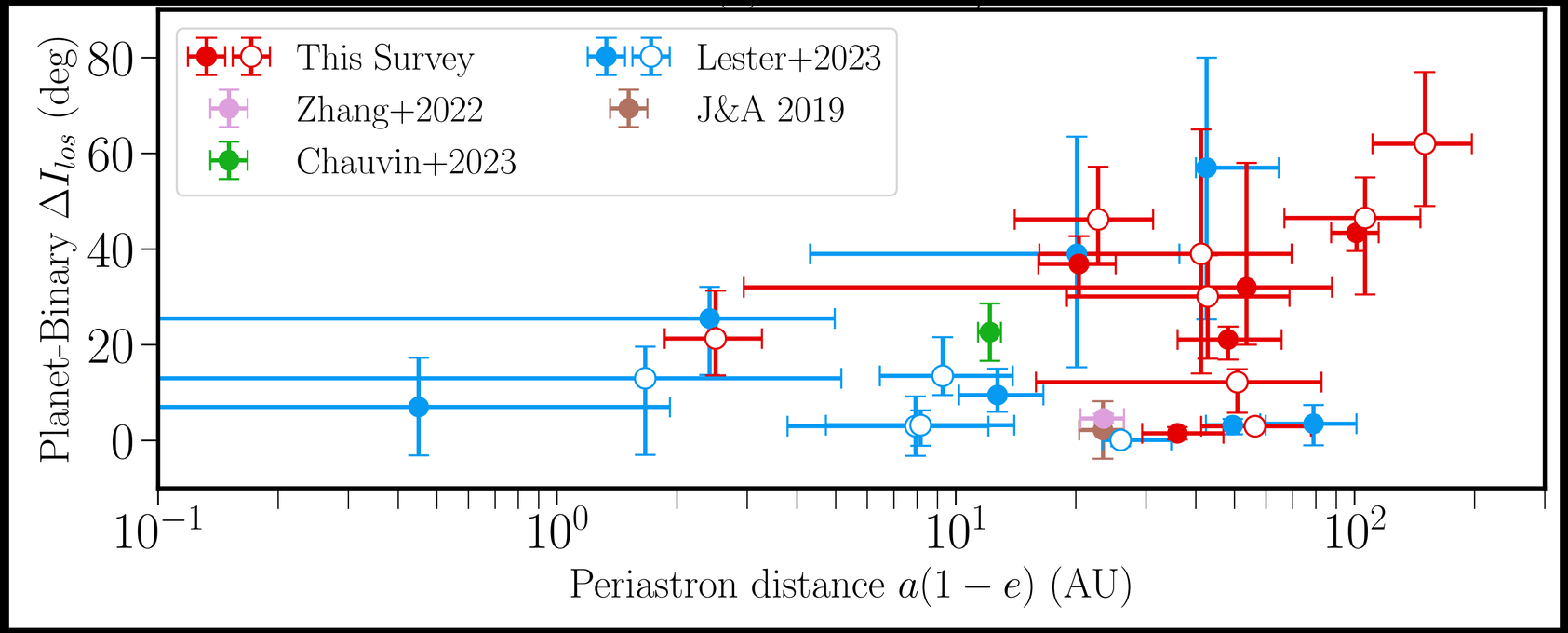


Zhang+2025b

Conclusions

Build up a catalog of transiting planet hosts with significant proper motion anomaly and constrain the mutual inclination between inner planets and outer companions:

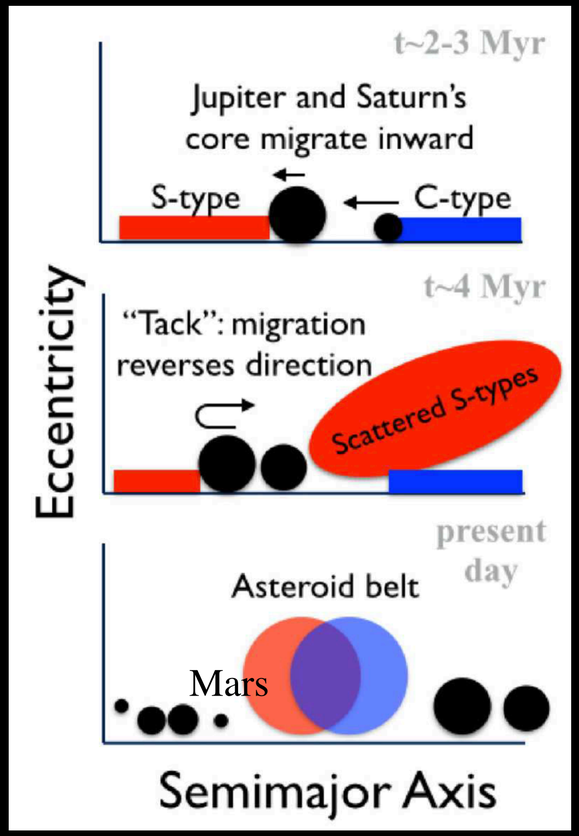
A Dichotomy in Orbital Alignment of Small Planets in Close Binary Systems



Thanks

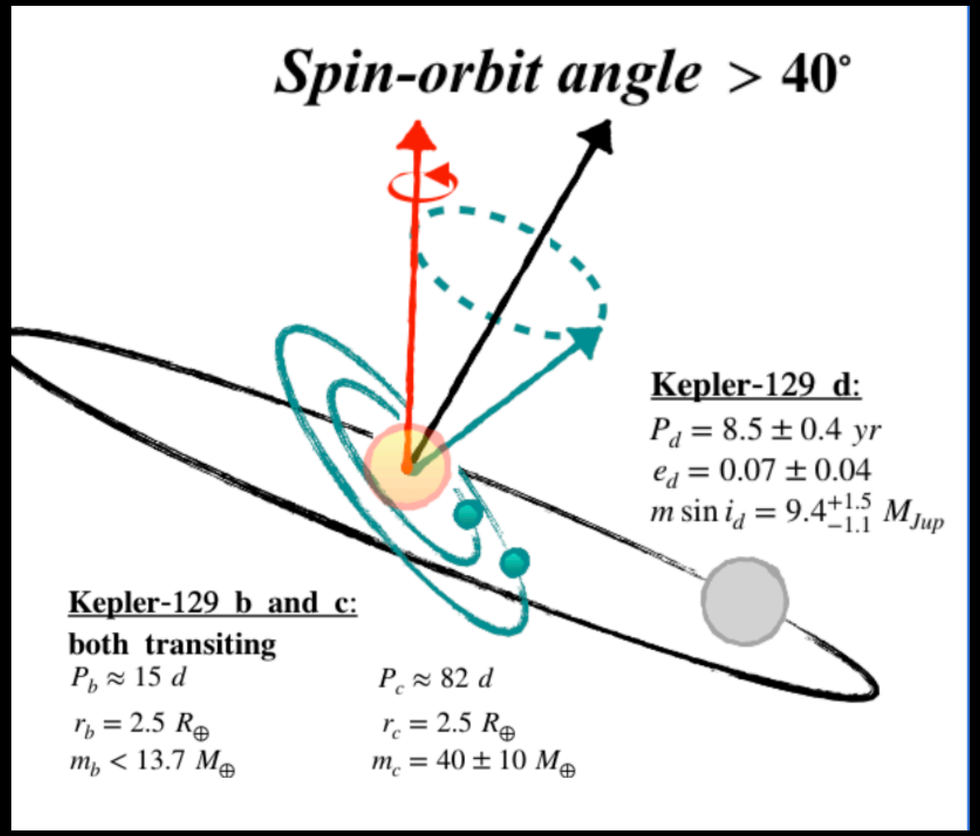
Orbital dynamics of transiting planets with outer companions

In-and-out migration of Jupiter and Saturn result in low mass of Mars



Raymond+2018

In-and-out migration of Jupiter and Saturn result in low mass of Mars



Zhang+2021