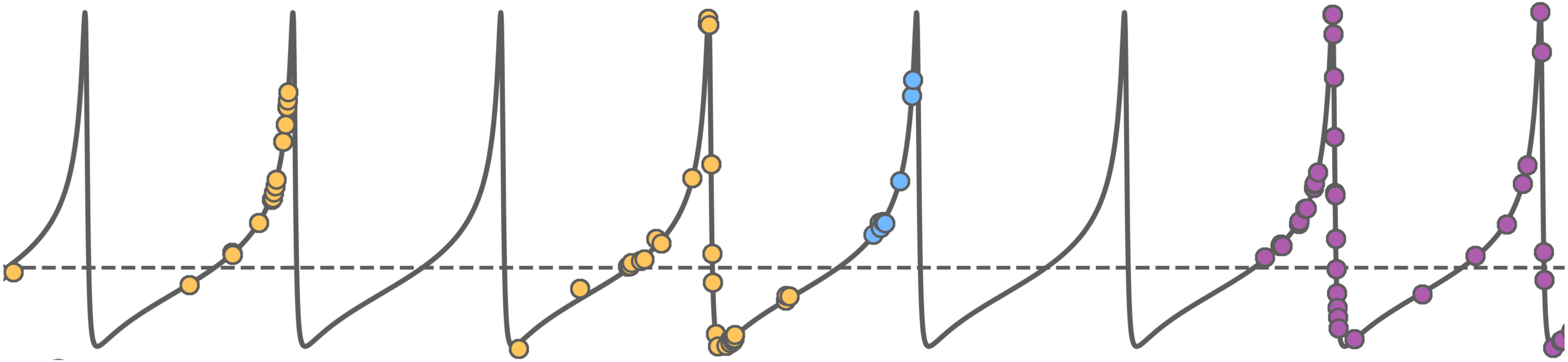
Testing the Origins of Close-in Giant Planets with Population-Level Eccentricities



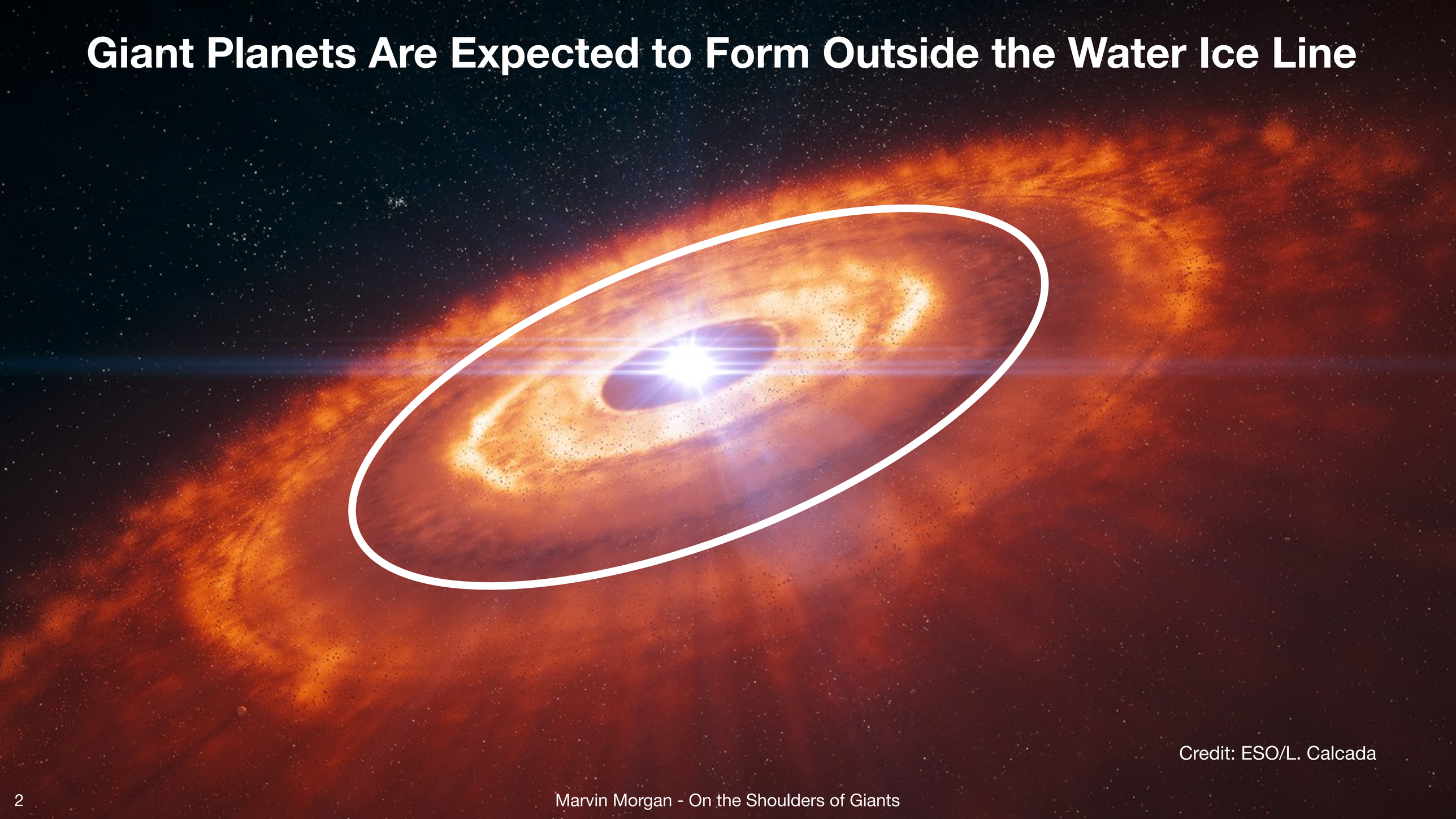
Marvin Morgan

PhD Candidate

University of California, Santa Barbara

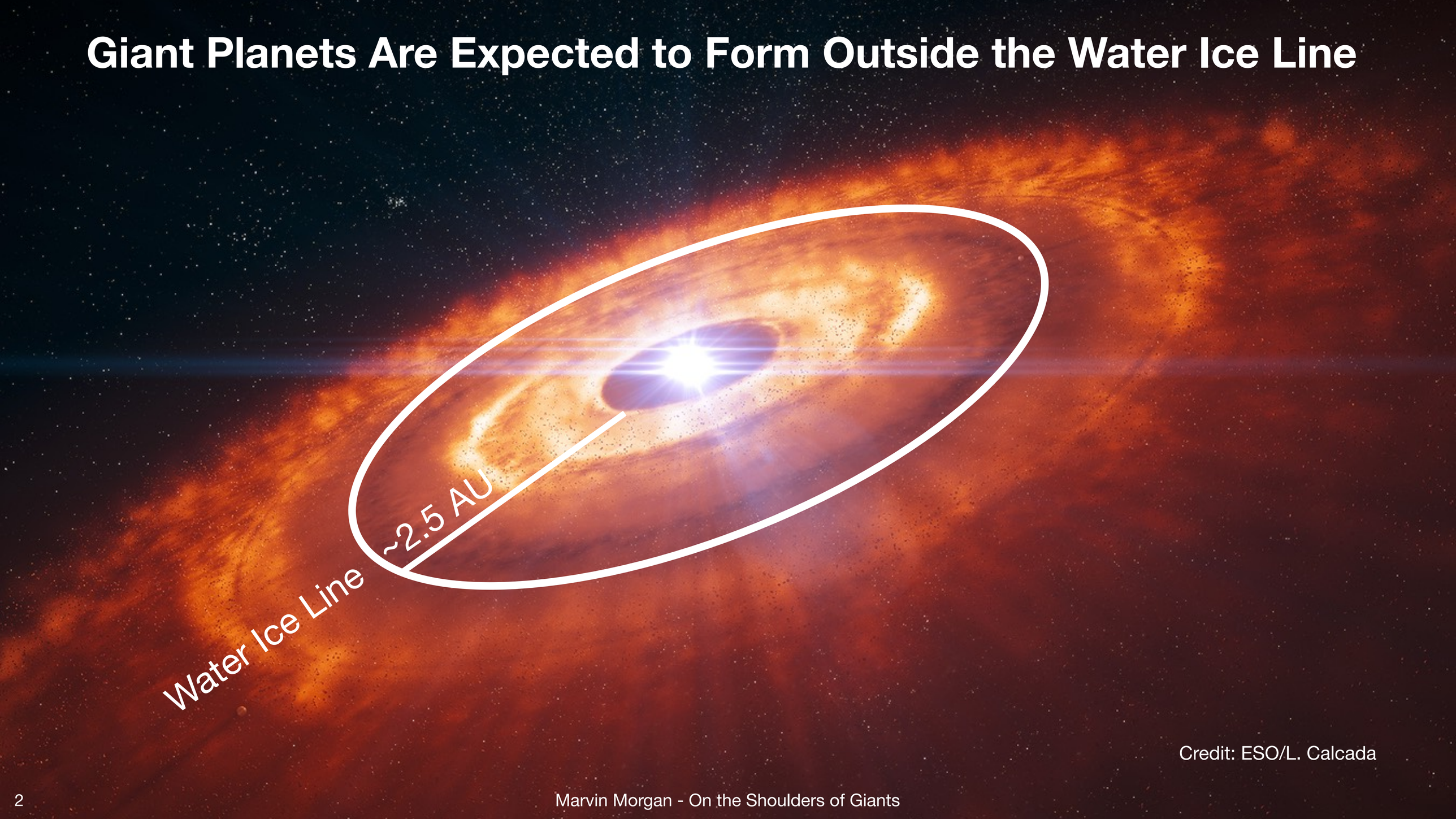
Advisor: Brendan Bowler

Giant Planets Are Expected to Form Outside the Water Ice Line



Credit: ESO/L. Calcada

Giant Planets Are Expected to Form Outside the Water Ice Line



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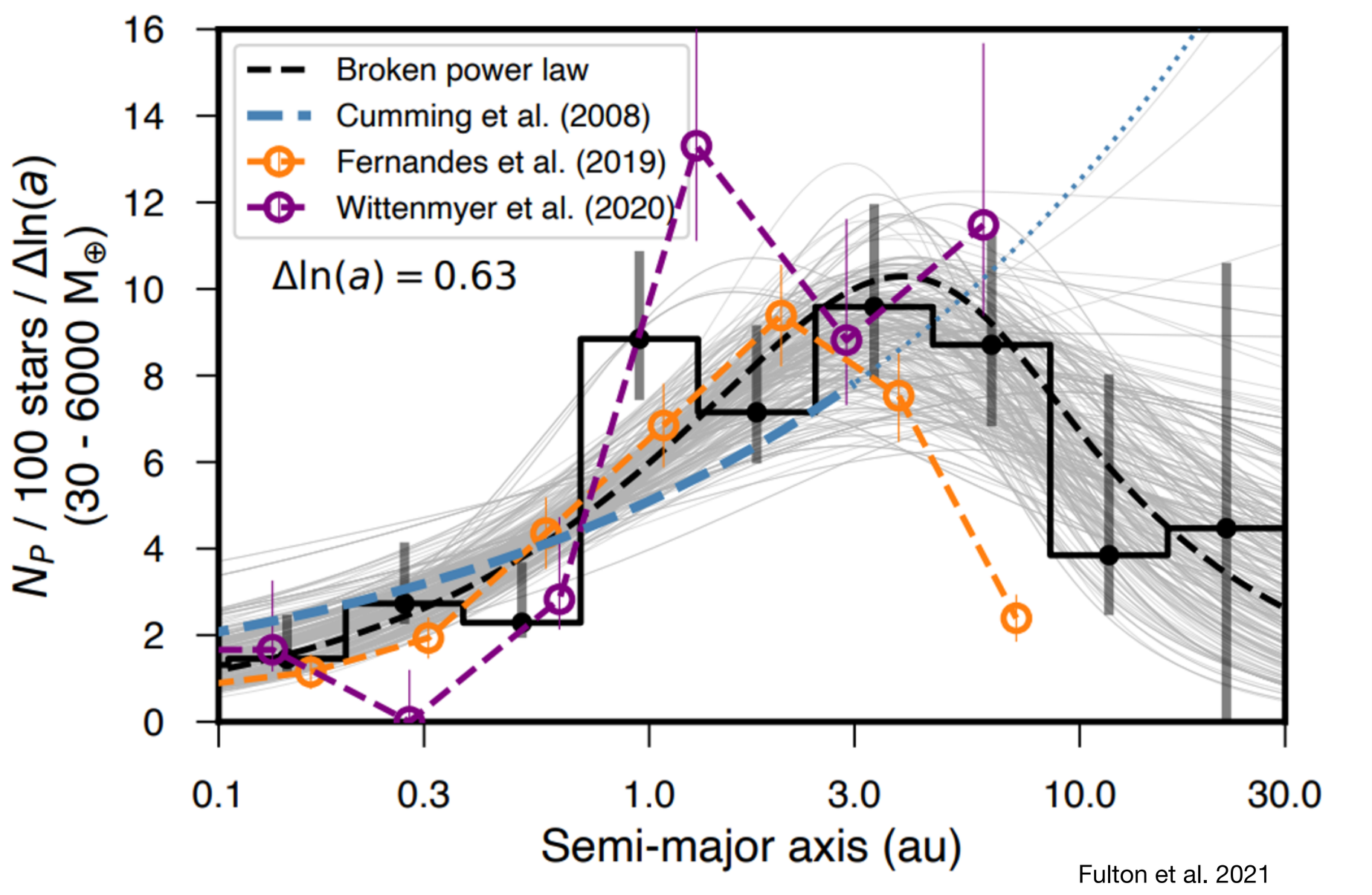
Giant Planet Occurrence Peaks Past the Water Ice Line



Fulton et al. 2021

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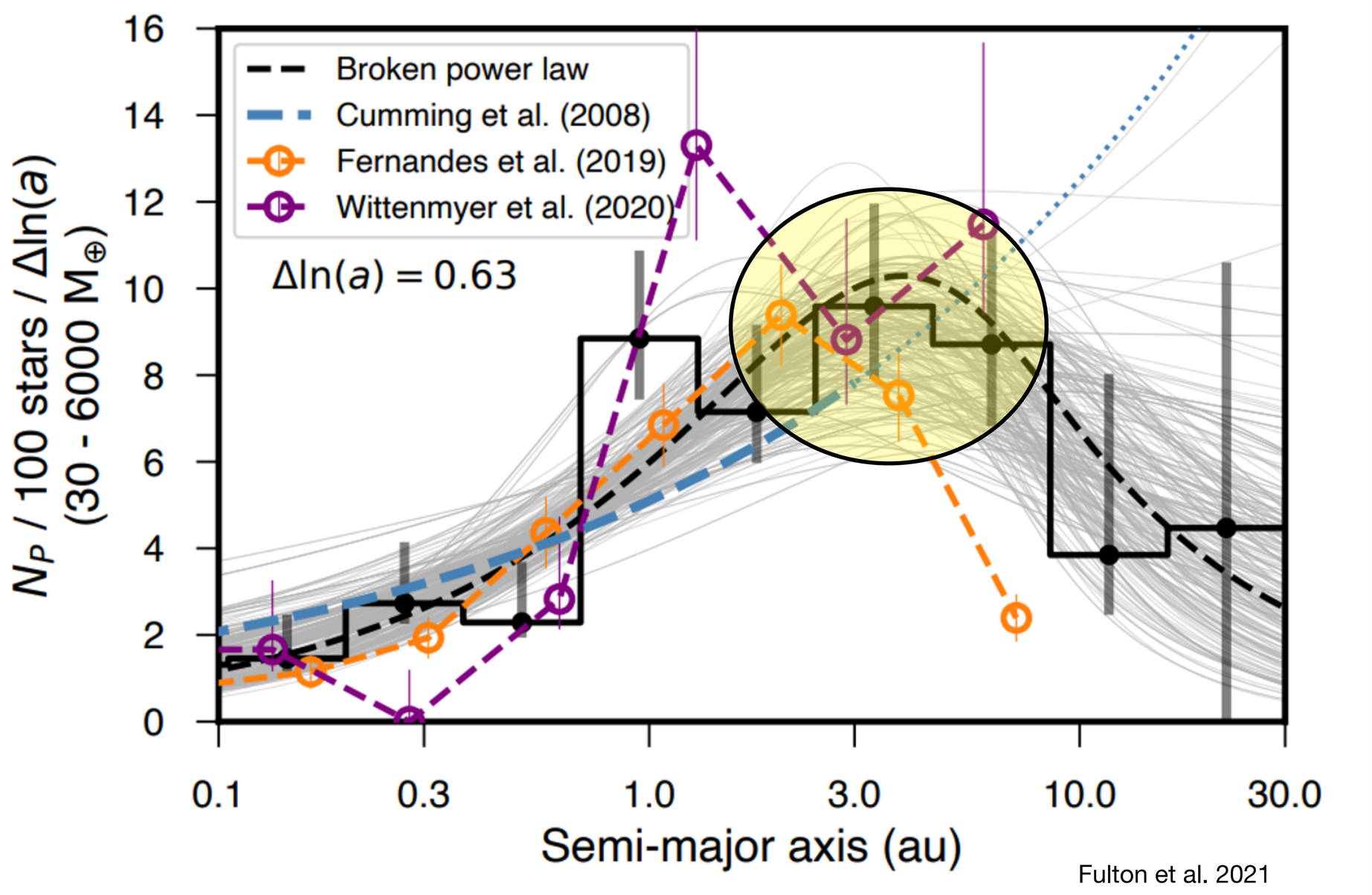

Fulton et al. 2021

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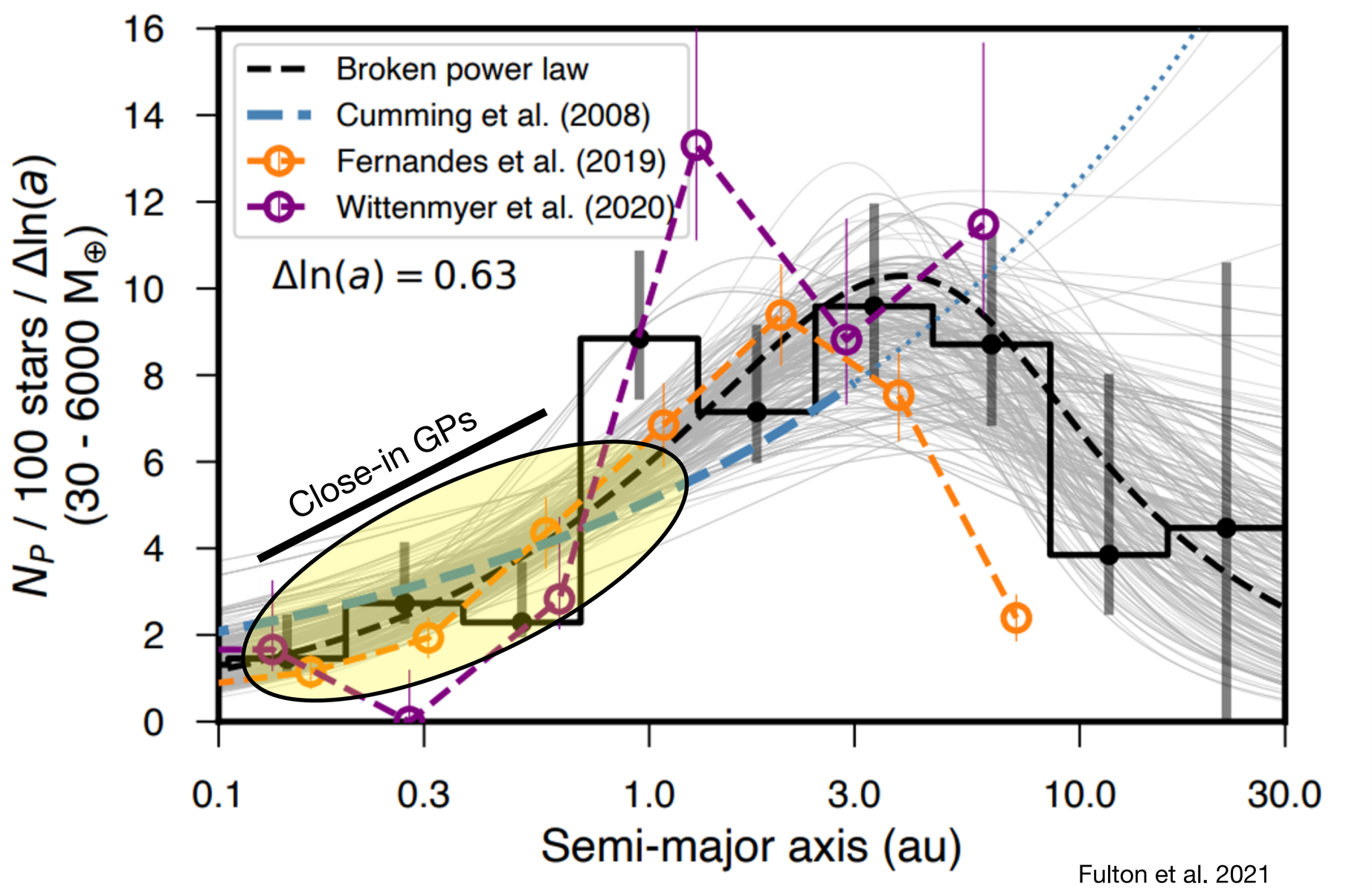
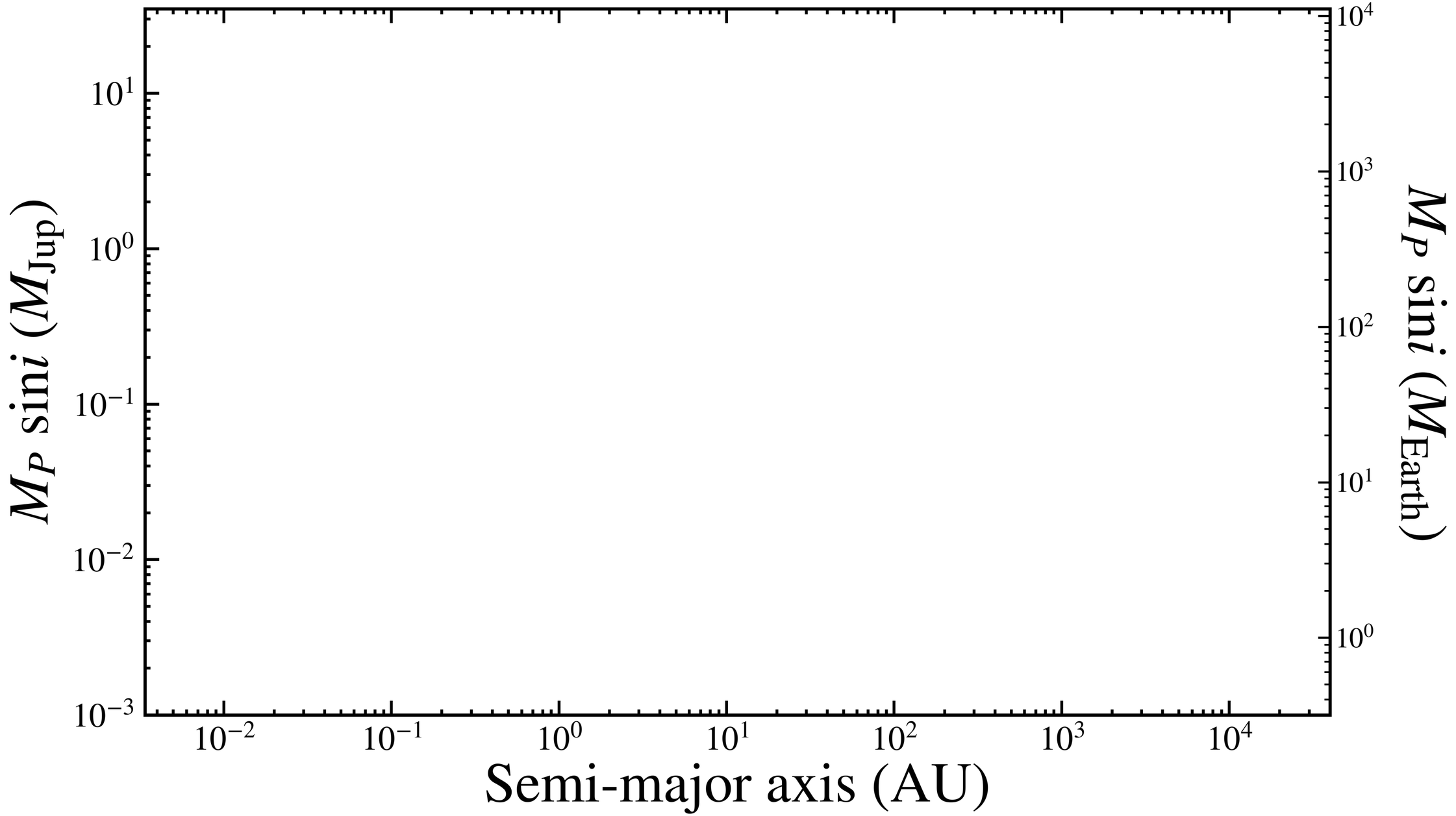


Fulton et al. 2021

Significant Population of Giant Planets Interior to 1AU



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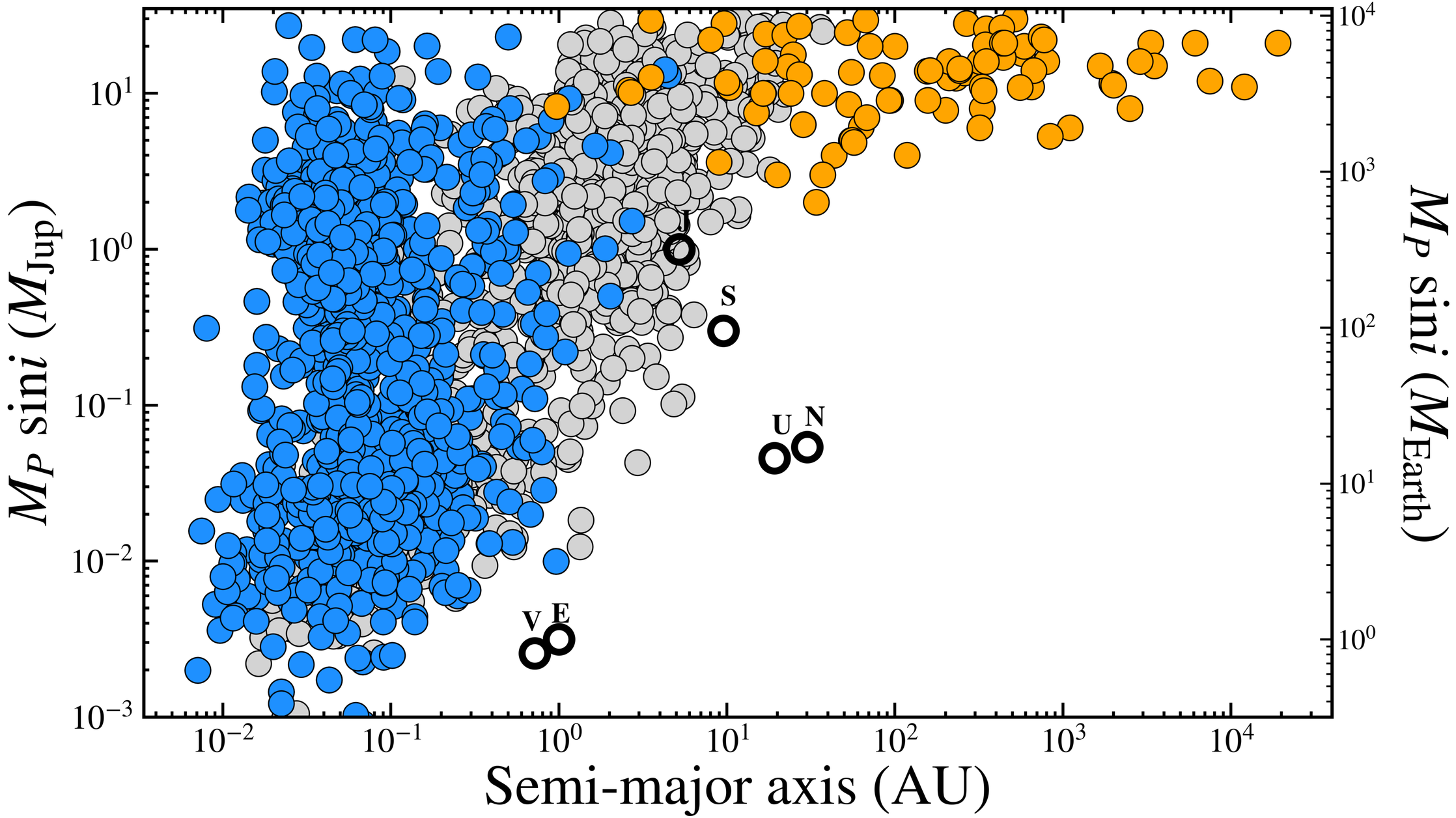

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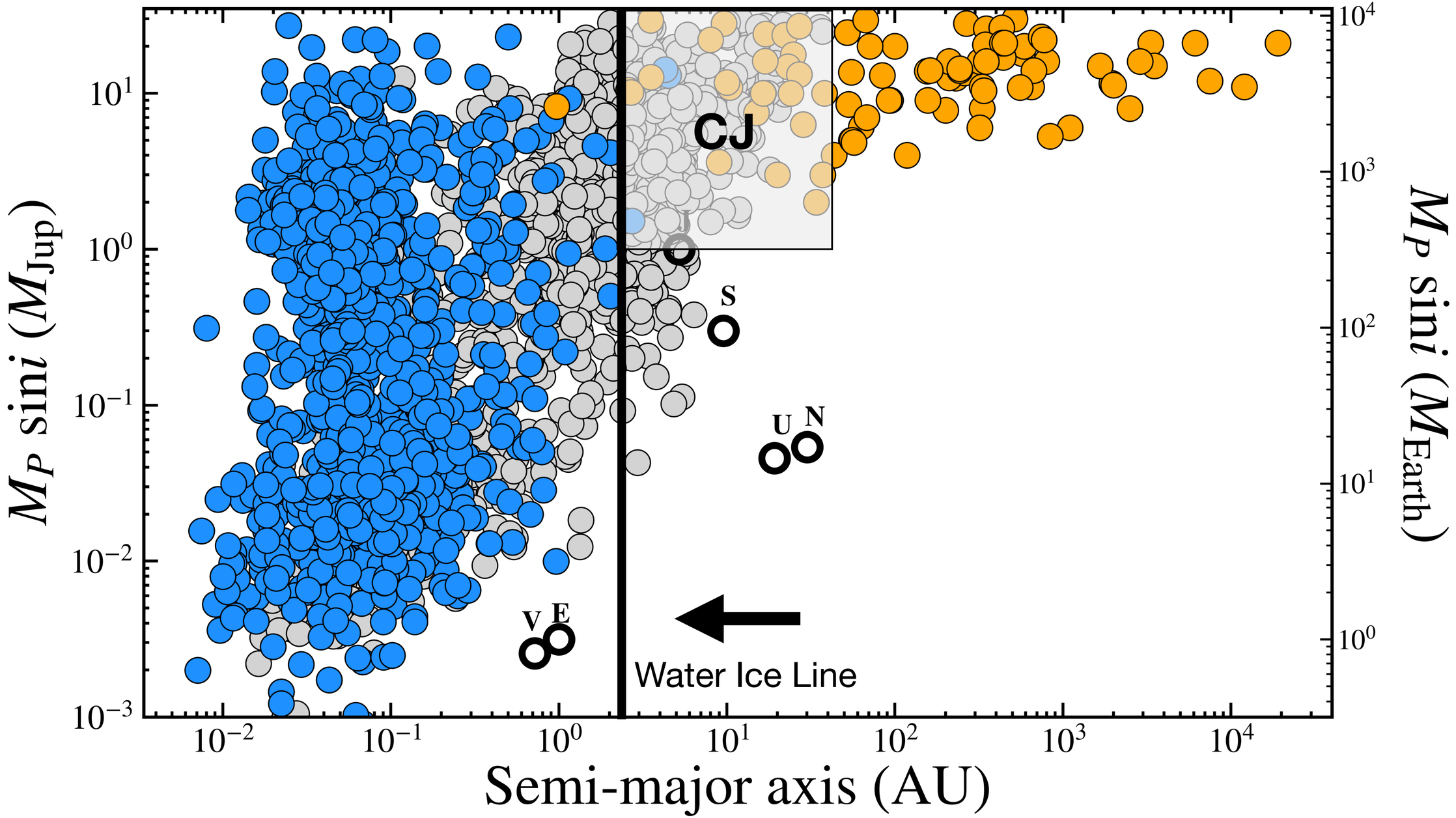

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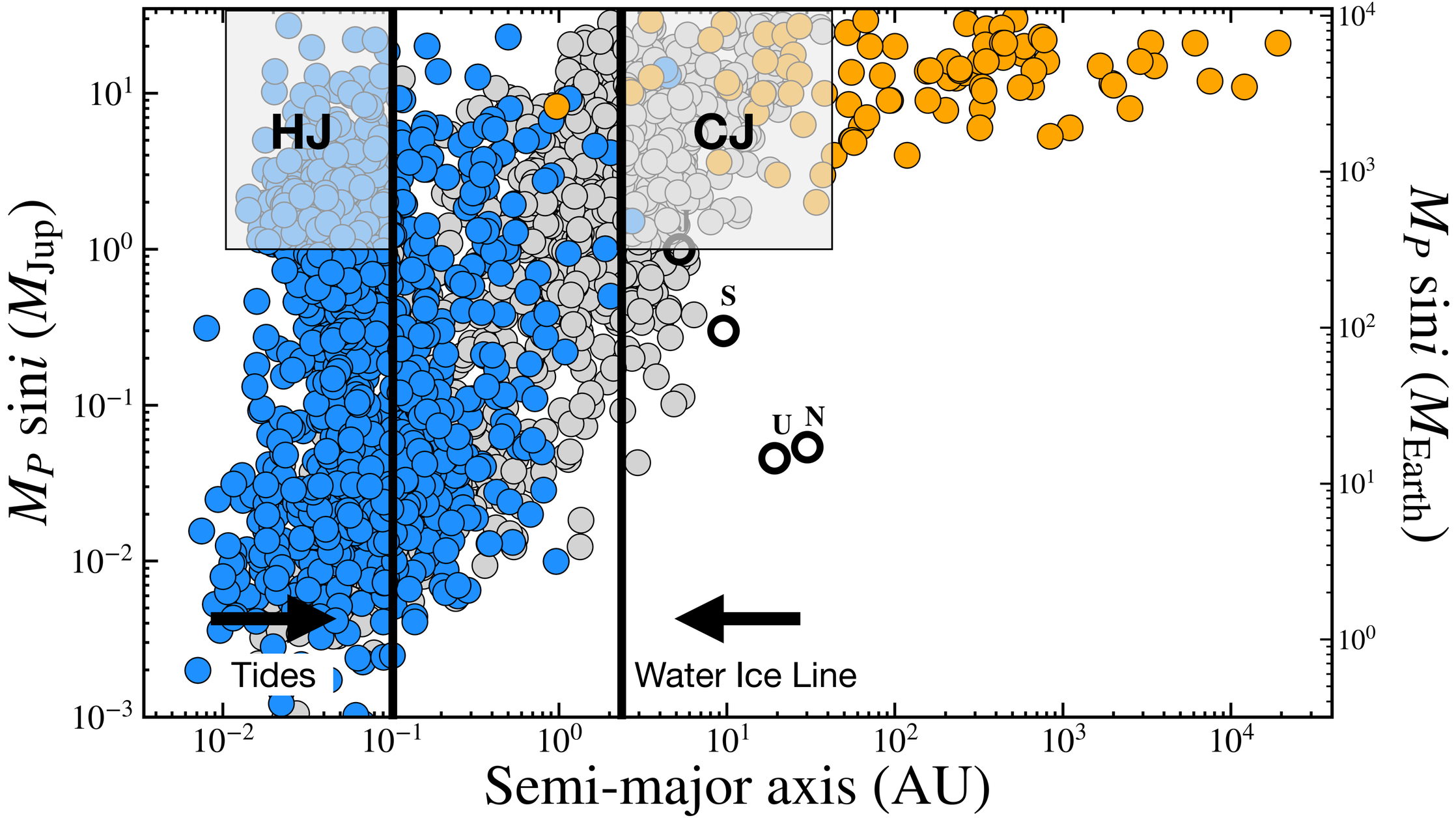

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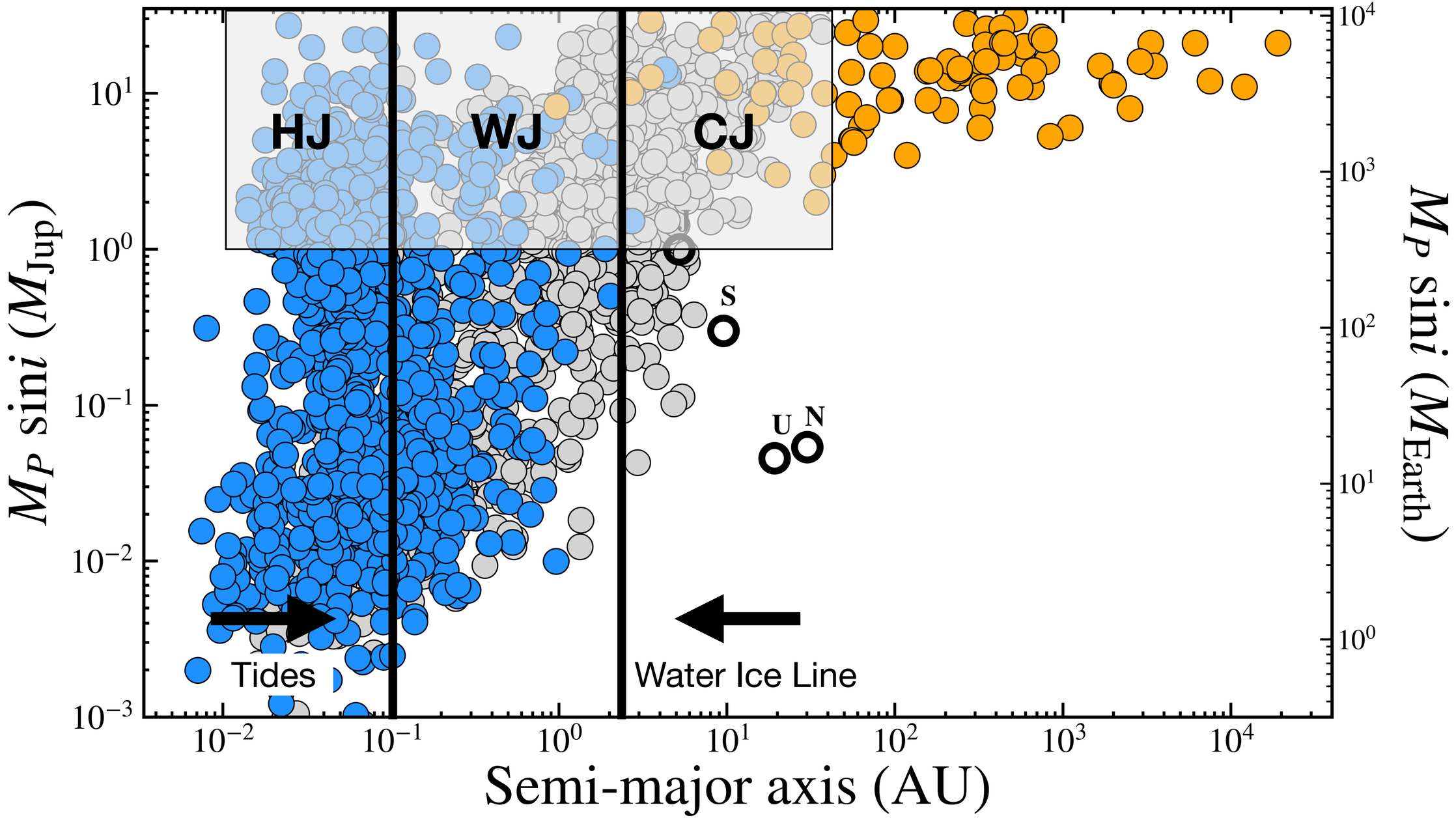
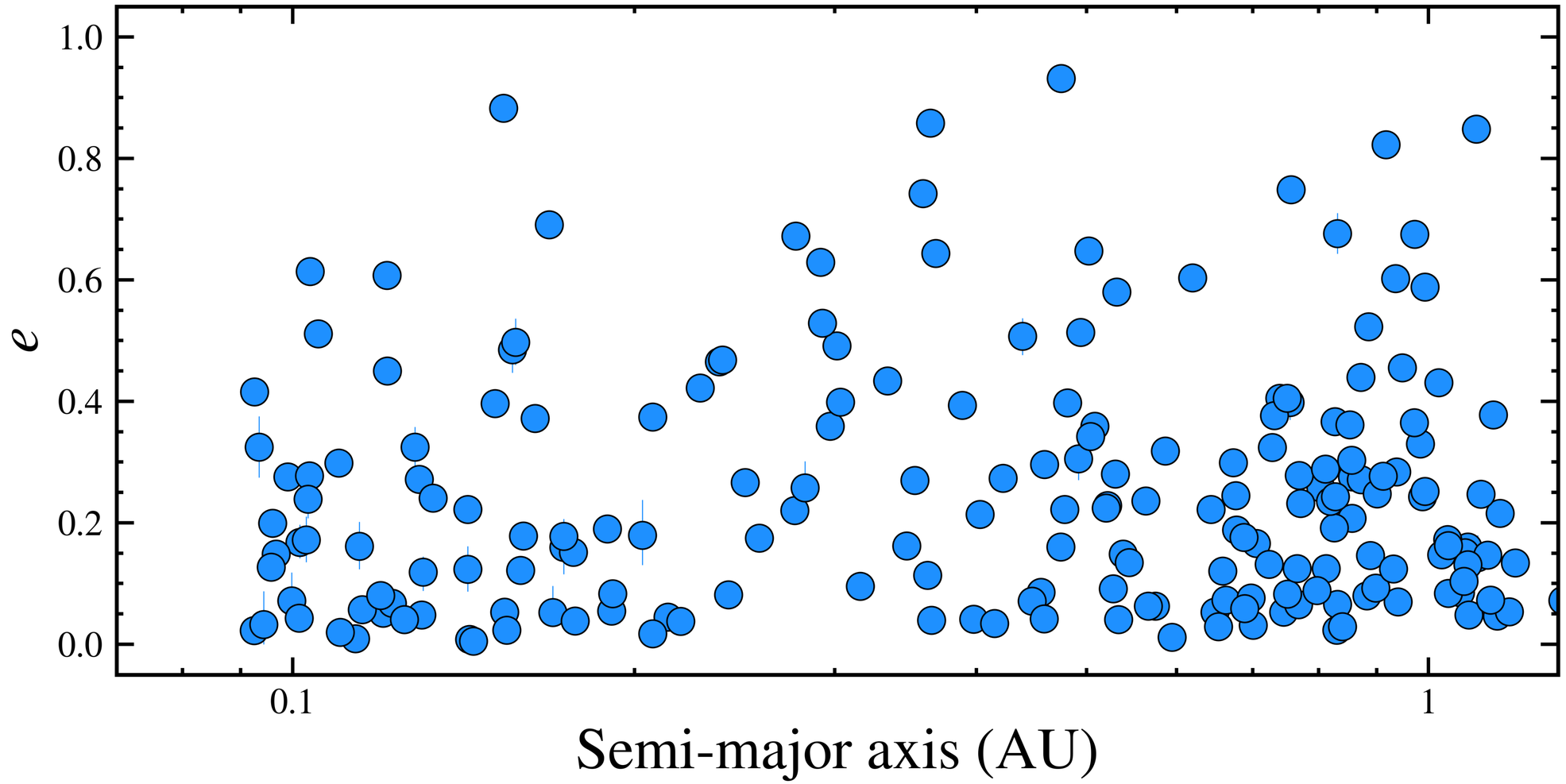


Eccentricities of Warm Jupiters Provide Migration Clues



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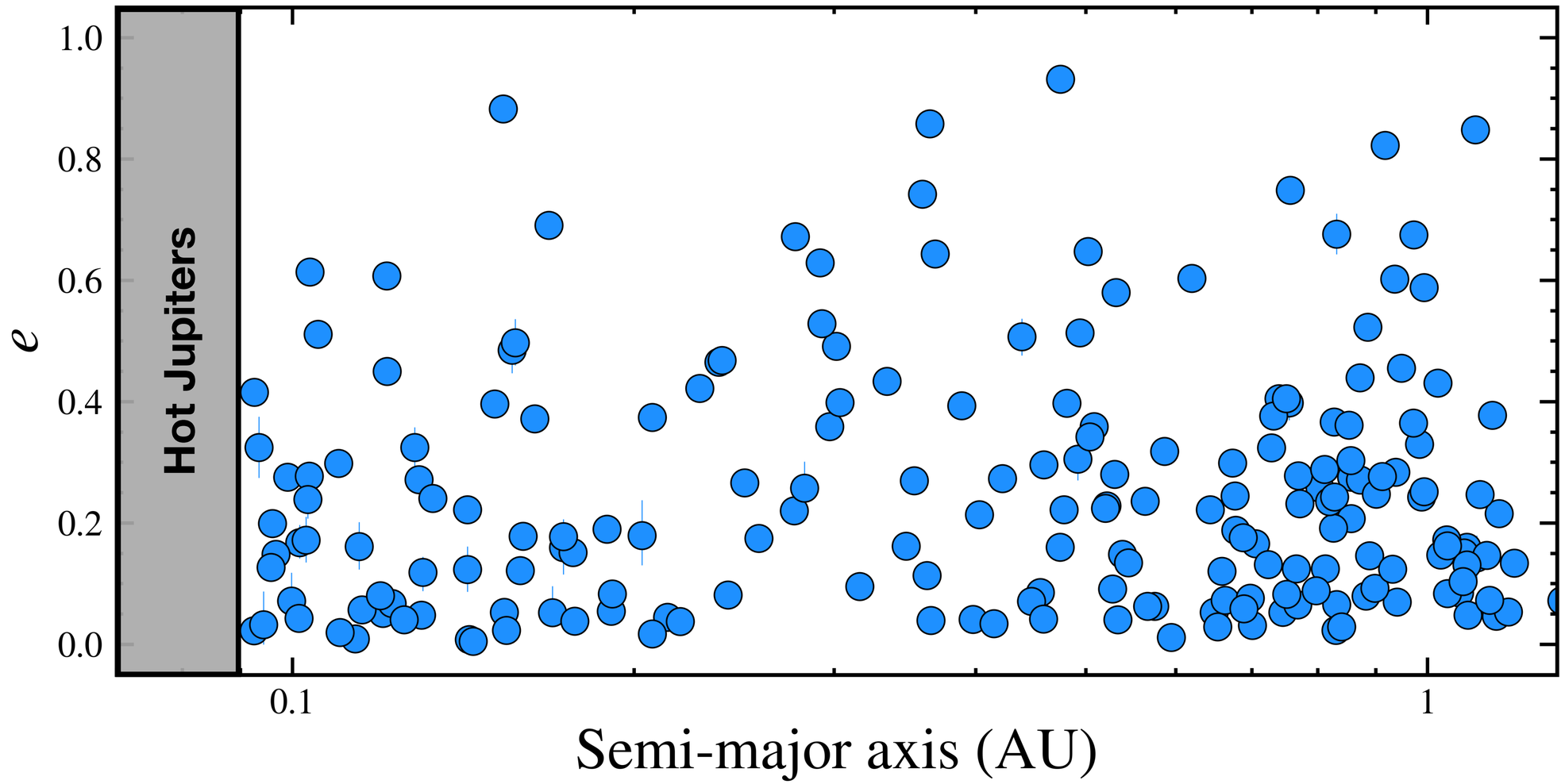

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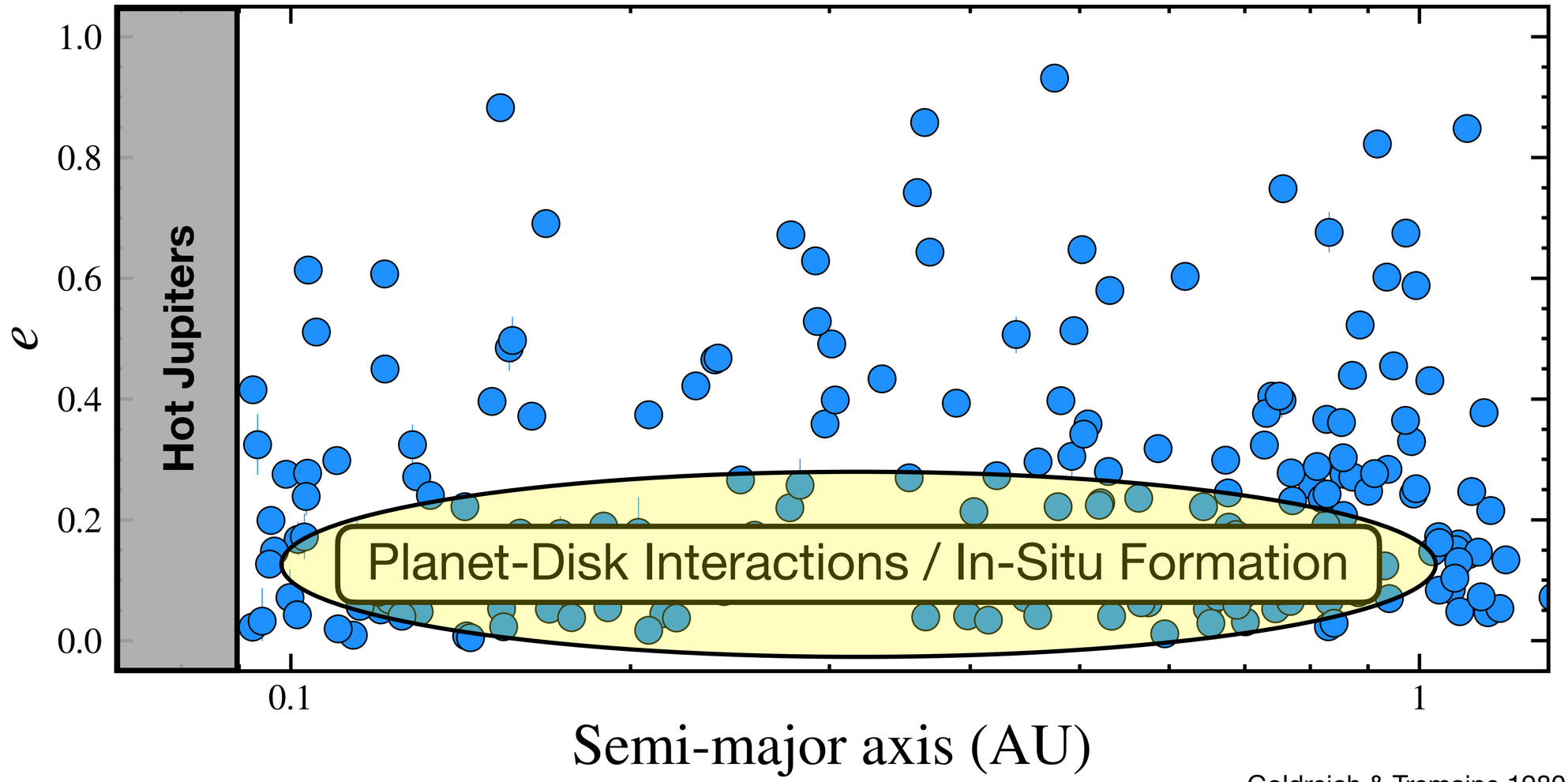

Goldreich & Tremaine 1980
Lin & Bodenheimer 1996
Kley & Nelson 2012

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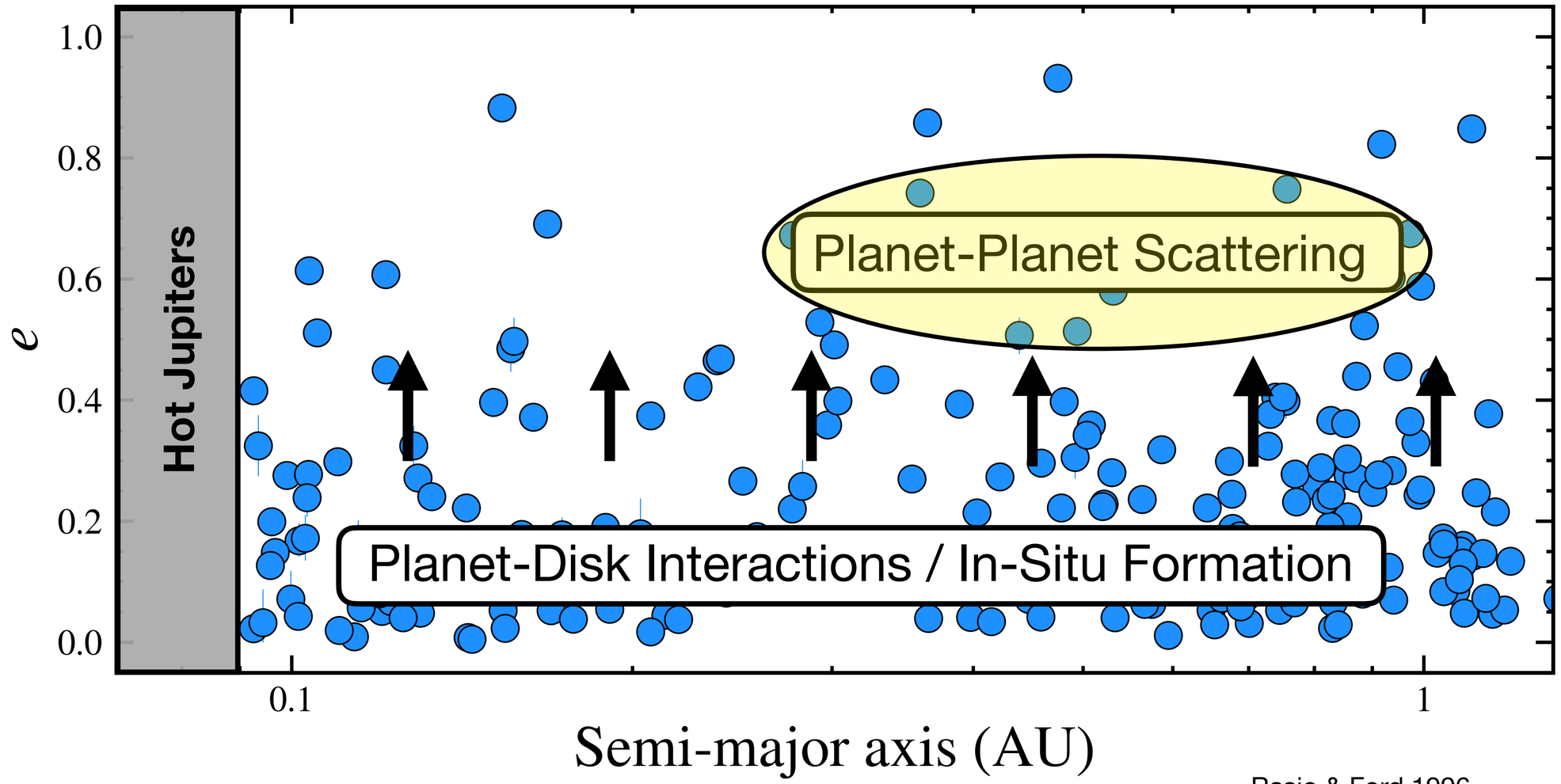

Rasio & Ford 1996
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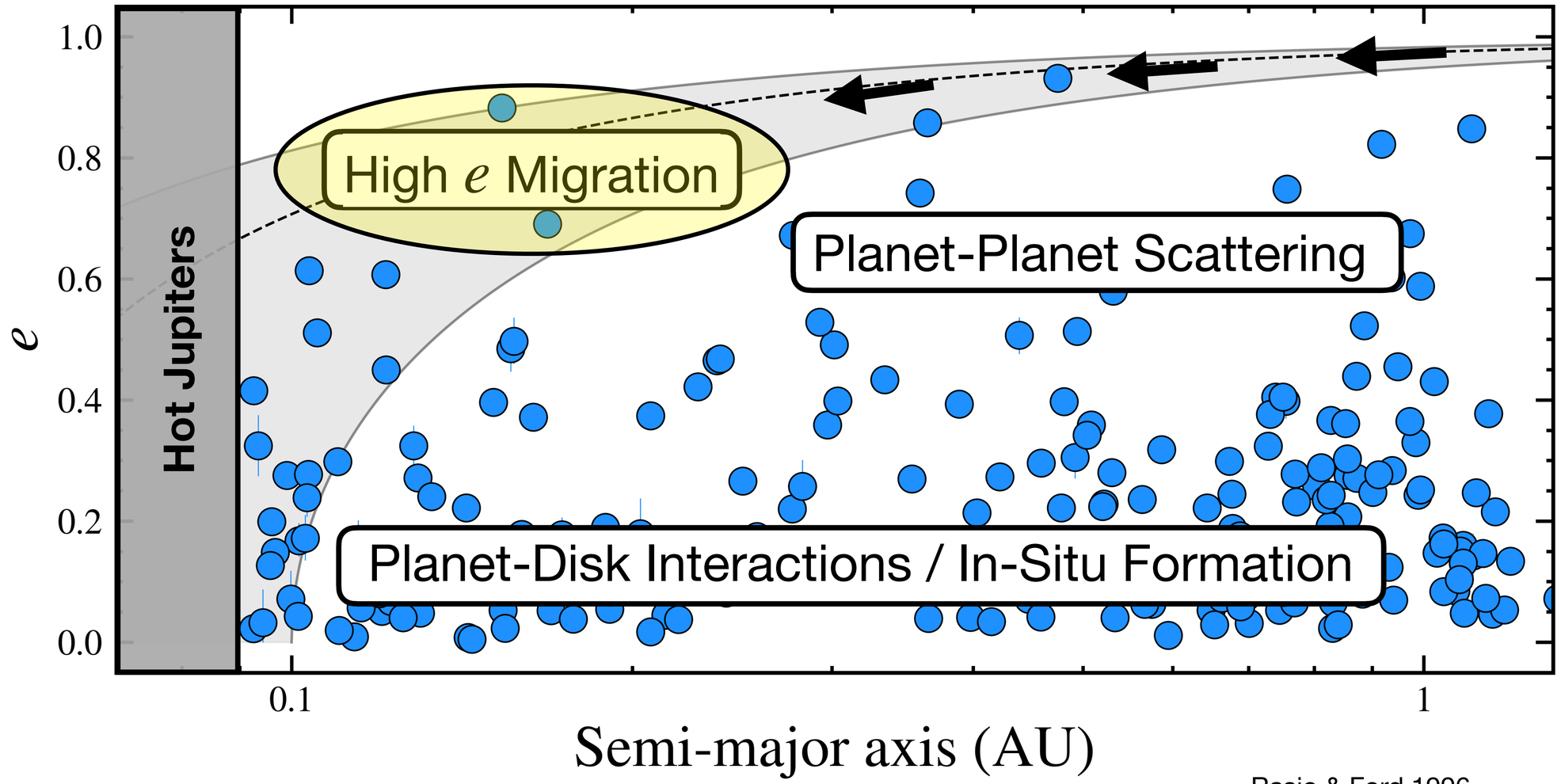

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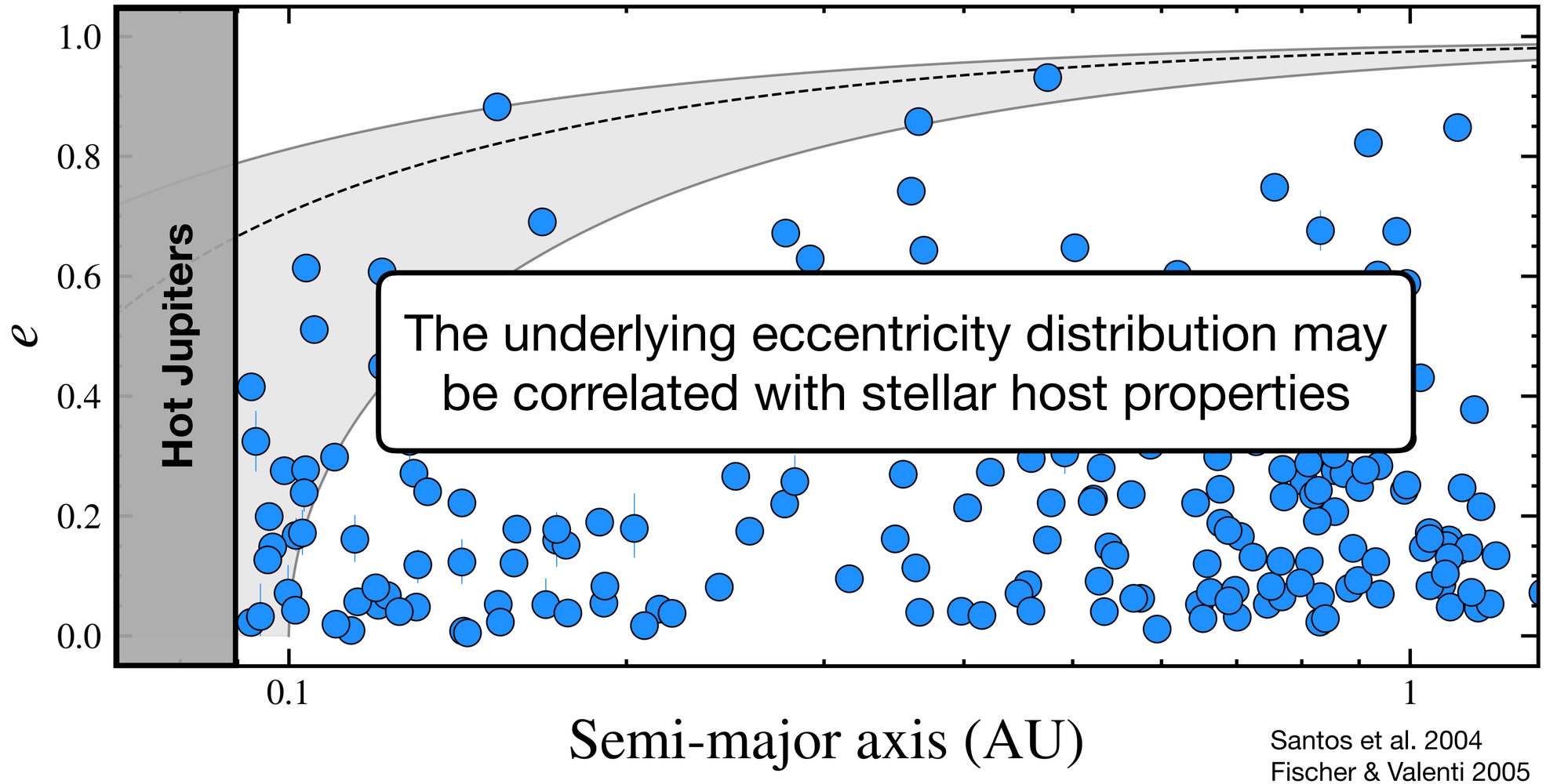
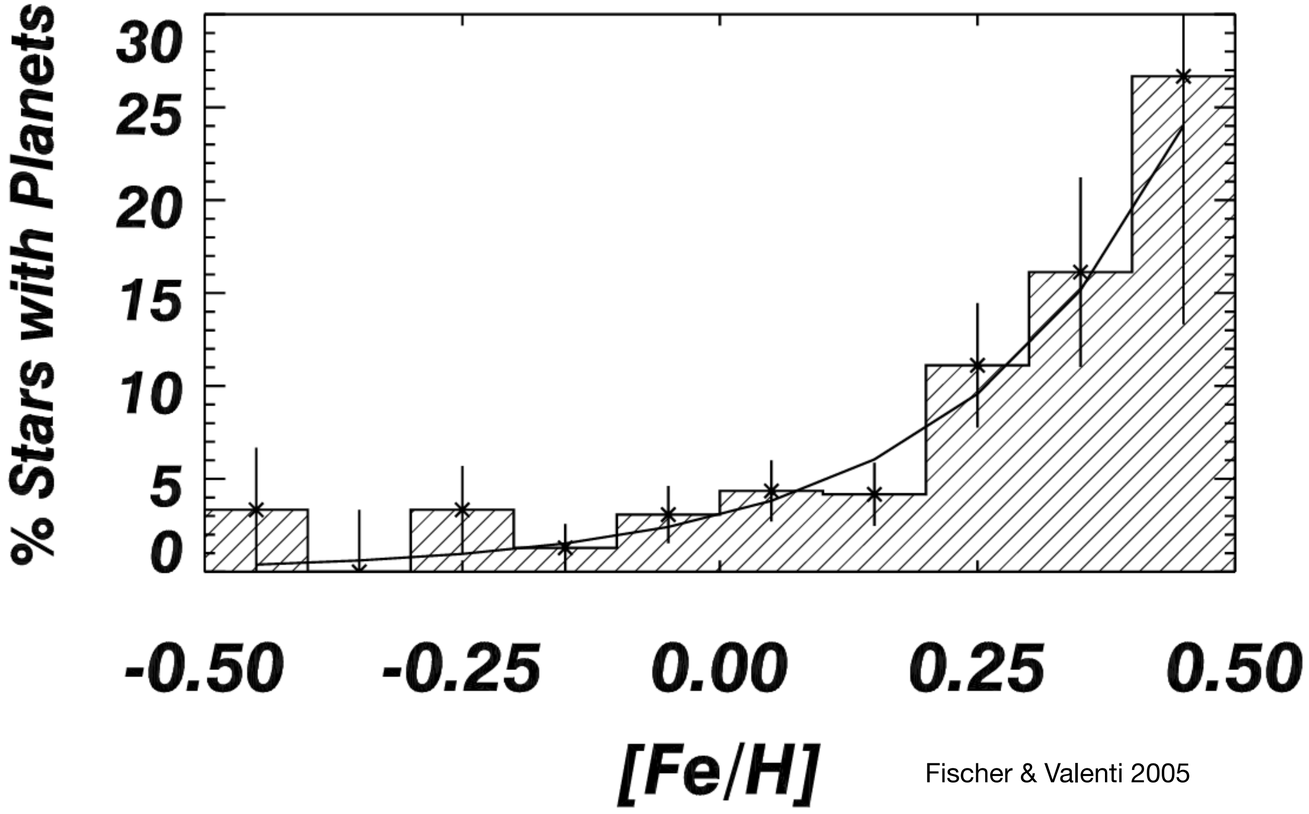


Santos et al. 2004
Fischer & Valenti 2005
Endl et al. 2006
Johnson et al. 2010
Bowler et al. 2015
Pass et. al 2023

Eccentricities May be Correlated With Host Star Properties



Fischer & Valenti 2005

Also see:
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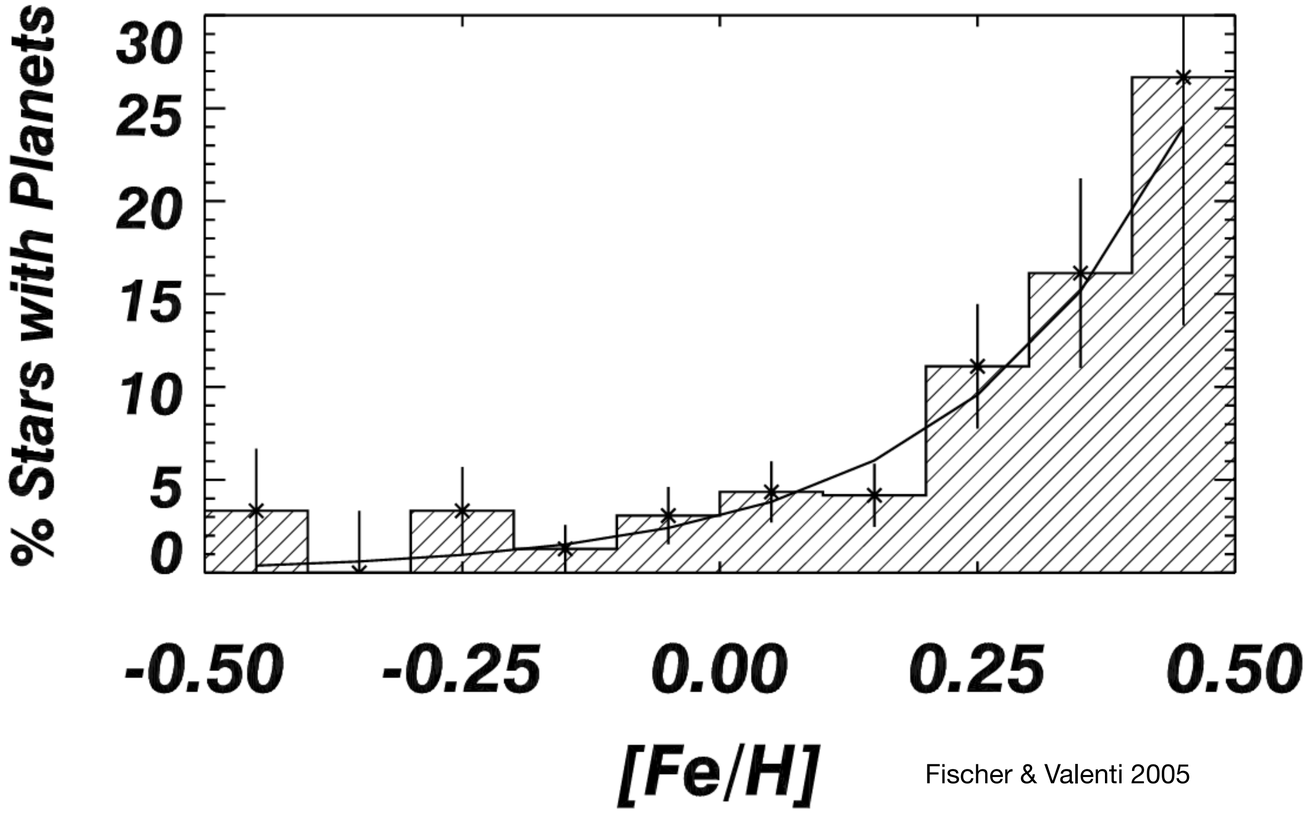

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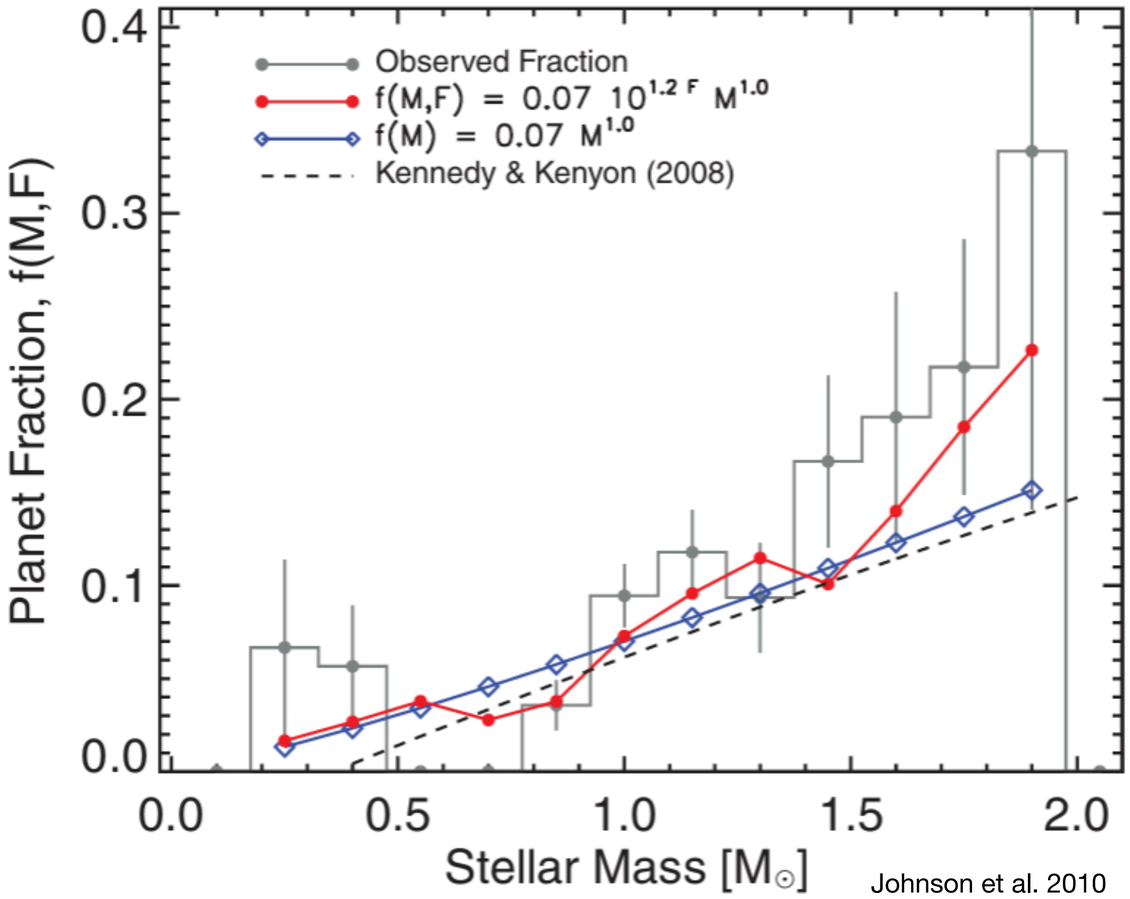

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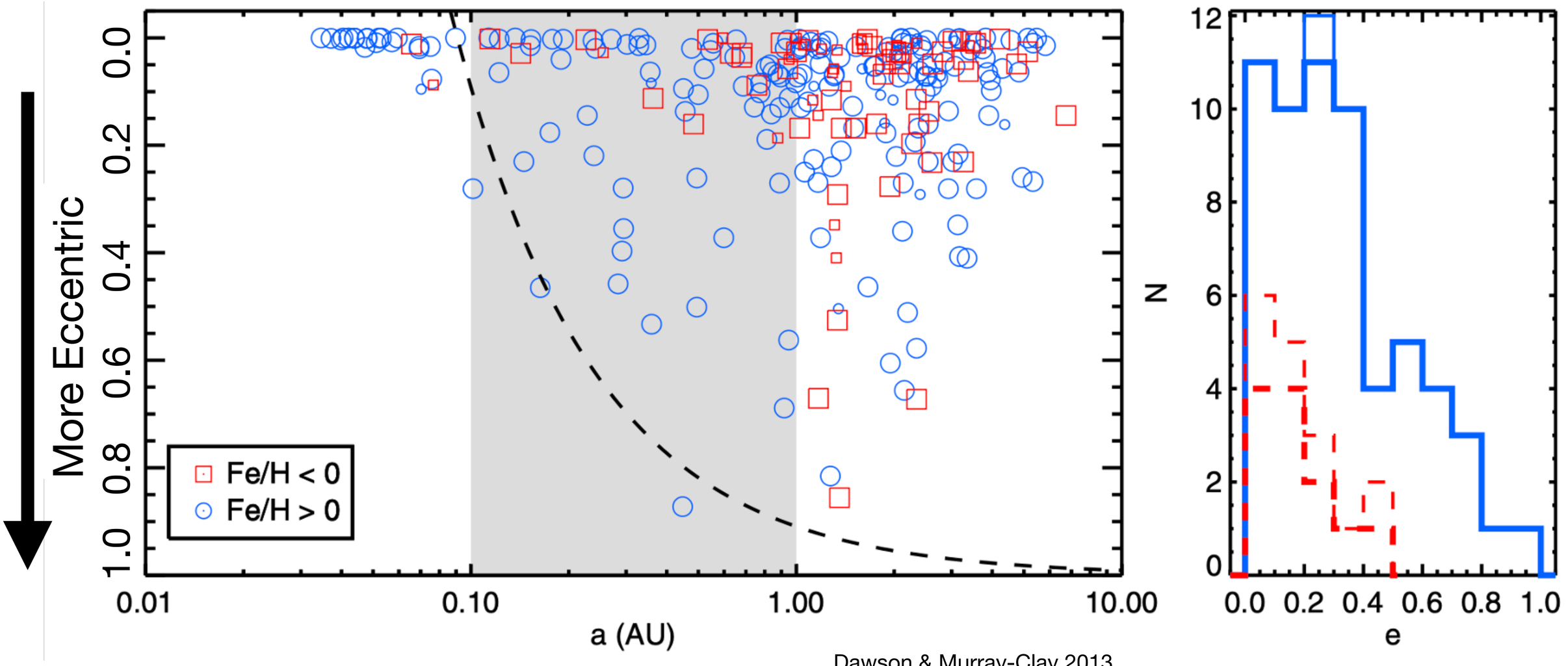

Dawson & Murray-Clay 2013

Exploring Warm Jupiter Migration Pathways with Eccentricities

Survey Goals:

- Uniform meta-analysis of WJ eccentricities.
- Eccentricity as a function of M_*, [Fe/H], and orbital separation.

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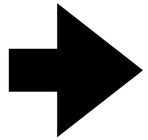
Morgan et al. 2025, 2026a

- ~18,500 RV measurements
- 40 spectrographs
- 30+ years of RVs
- 194 host stars harboring 200 planets
- Average of 70 RVs per system
- Average baseline of 8 years



Refit Orbits

Exploring Warm Jupiter Migration Pathways with Eccentricities

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Table 1. Spectrographs used to collect RV data for warm Jupiters

Telescope	Instrument	# RVs	λ (nm)	Reference
Whippie 1.5-m	AFOE	78	450–700	1
Lick/Levy 2.4-m	APF	444	374–970	2
Fairborn AST 2-m	AST	136	492–710	3
BOAO 1.8-m	BOES	165	350–1050	4,5
Calar Alto 2.2-m	CAFE	28	365–980	6
Calar Alto/CAHA 3.5-m	CARMENES	368	550–1700	7,8
ESO CAT 1.4-M	CES	95	360–1100	9,10
CTIO 1.5-m	CHIRON	262	410–870	11,12
ESO Euler 1.2-m	CORALIE	1817	381–681	13
Tautenburg 2-m	COUDE	212	463–737	14
ESO Paranal VLT 8-m	CRIRES	4	1000–5000	15,16
OHP 1.9-m	ELODIE	396	390–681	17,18
CFHT 3.6-m	ESPaDOnS	29	370–1050	19
MPG 2.2-m	FEROS	438	360–920	20,21
ESO LA Silla 1-m	FIDEOS	34	400–680	22,23
NOT 2.5-m	FIES	52	370–730	24
TNG 3.6-m	GIANO	7	950–2500	25,26
Lick/Shane 3-m	HAMILTON	1620	340–1100	27,28
ESO LA Silla 3.6-m	HARPS	1261	380–690	29,30
TNG 3.6-m	HARPS-N	301	378–691	31
Subaru 8.2-m	HDS	35	300–1000	32
OAO 1.9-m	HIDES	1690	500–620	33
Keck-I 10-m	HIRES	4547	300–1100	34,35
McDonald HET 9.2-m	HPF	195	810–1270	36,37
McDonald HET 9.2-m	HRS	1134	390–1100	38
Sloan 2.5-m	KeckET	16	500–590	39
KPNO 2.1-m	KPNO ET	40	500–564	40,41,42
Sloan 2.5-m	MARVELS	25	500–570	43,44,45
Magellan II 6.5-m	MIKE	48	320–1000	46,47,48
Mount Kent Obs./ 4×0.7-m	MINERVA-Australis	539	500–630	49,50
LCOGT/ 6 × 1-m	NRES	33	390–860	51
Magellan II 6.5-m	PFS	48	390–620	52,53
TNG 3.6-m	SARG	29	370–1000	54,55
SONG 1-m	SONG	40	440–690	56
OHP 1.9-m	SOPHIE/SOPHIE+	1460	387–694	57,58
Tillinghast 1.5-m	TRES	106	385–910	59
McDonald 2.7-m	Tull	313	387–1045	60,61
AAT 3.9-m	UCLES	451	300–1100	62,63,64
Xinglong 2.2-m	XSCES	31	330–1100	65,66
Xinglong 2.2-m	XSHRS	60	330–1100	66

NOTE—Telescopes and instruments used to discover and characterize warm Jupiters in our sample. Listings are ordered by instrument name.

Exploring Warm Jupiter Migration Pathways with Eccentricities

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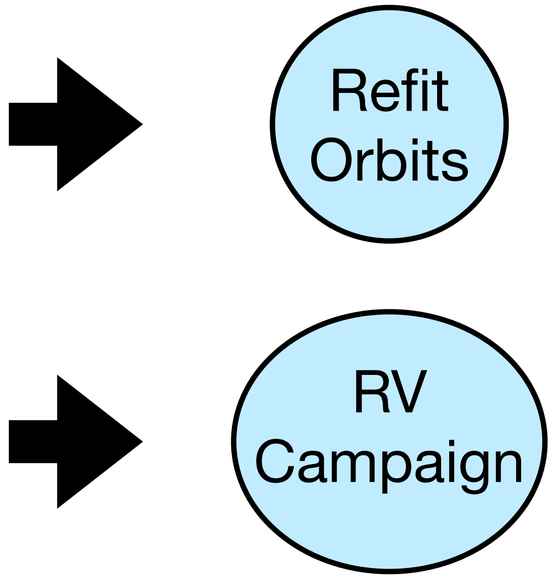
Morgan et al. 2025, 2026a

- Multi-hemisphere campaign
- Habitable-Zone Planet Finder (HPF)
- MINERVA-Australis
- 540 new observations
- Target planets near periapsis



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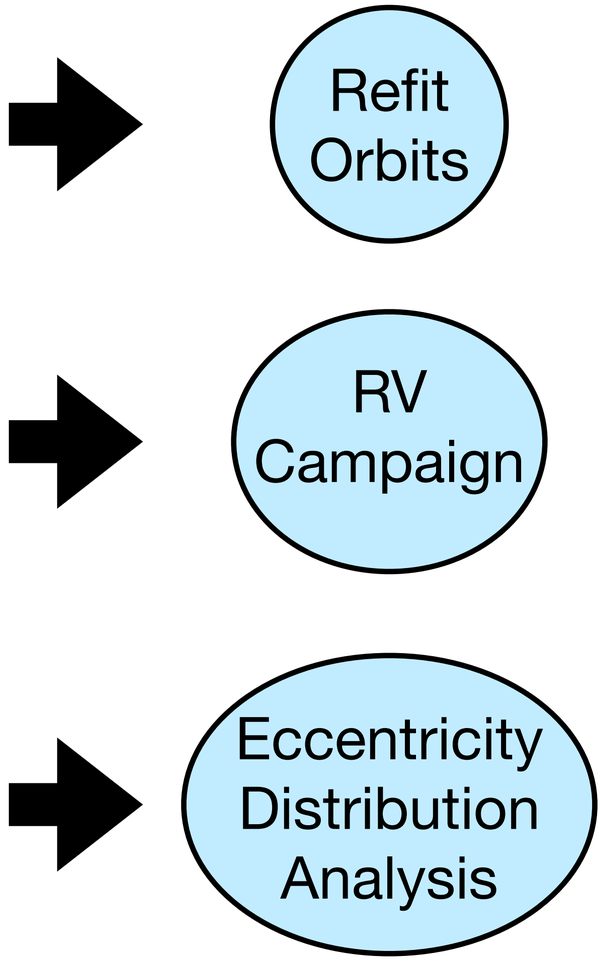
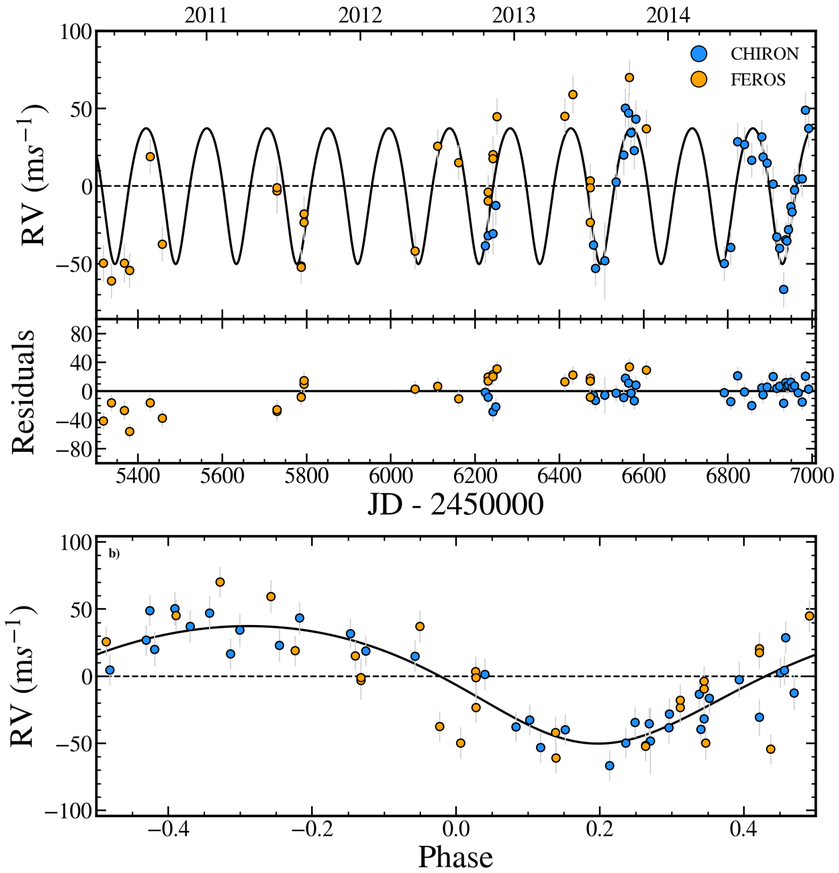
Morgan et al. 2025, 2026a

- Sample eccentricity posteriors
- Hierarchical Bayesian Modeling
- M_*, [Fe/H], and orbital separation



Orbit Fit and Model Selection

Keplerian



Radvel; Fulton et al. 2018

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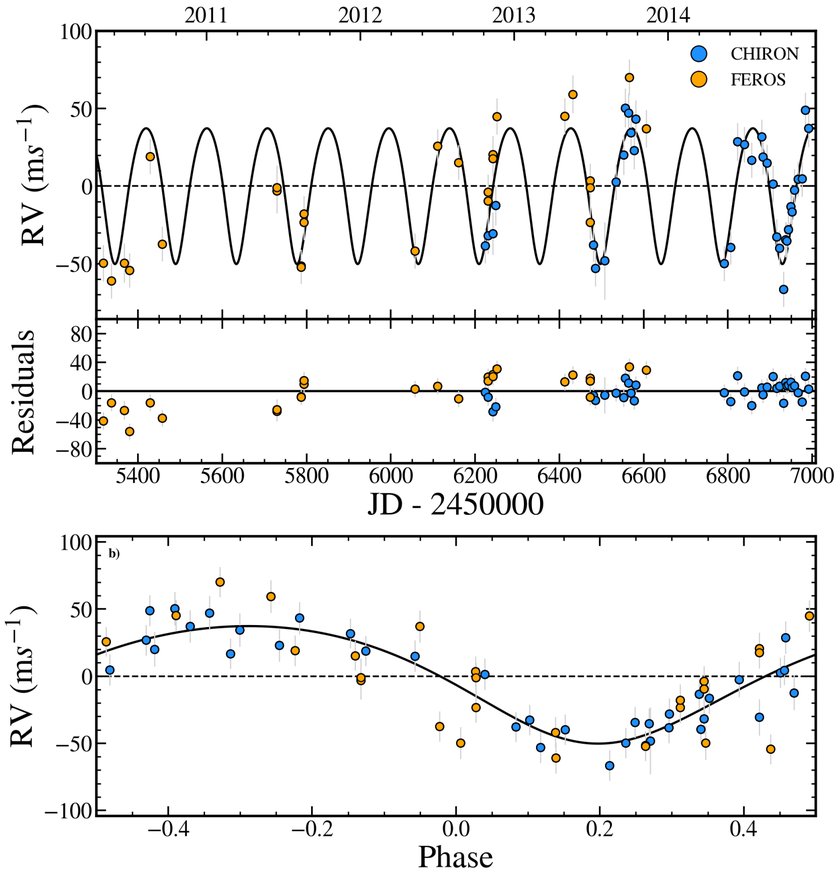
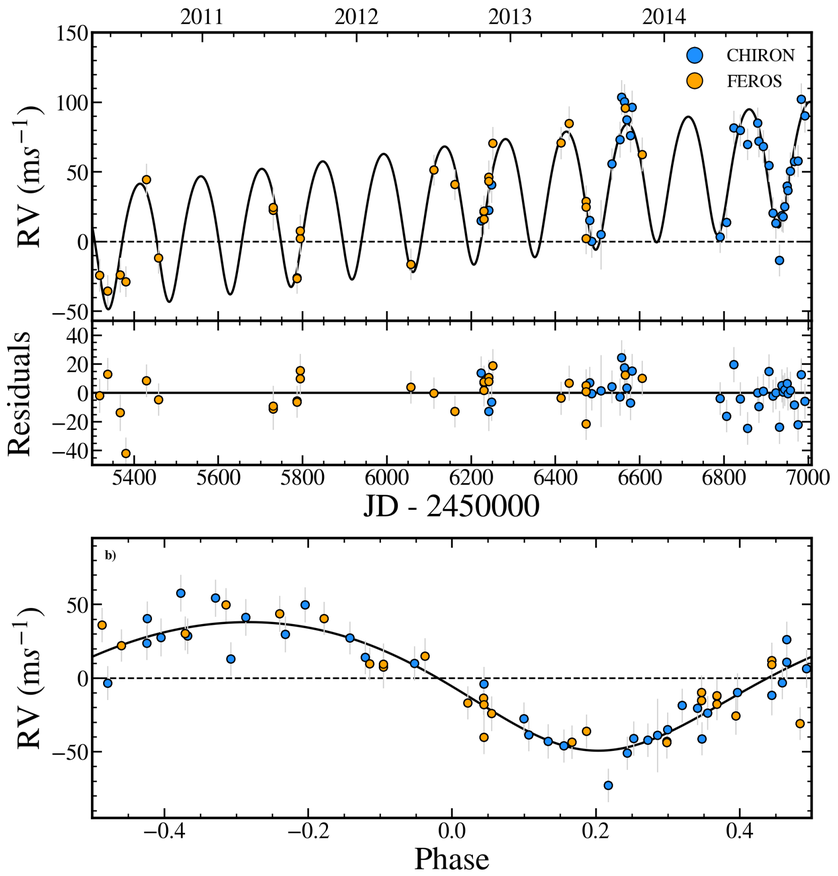


Keplerian + Linear Trend



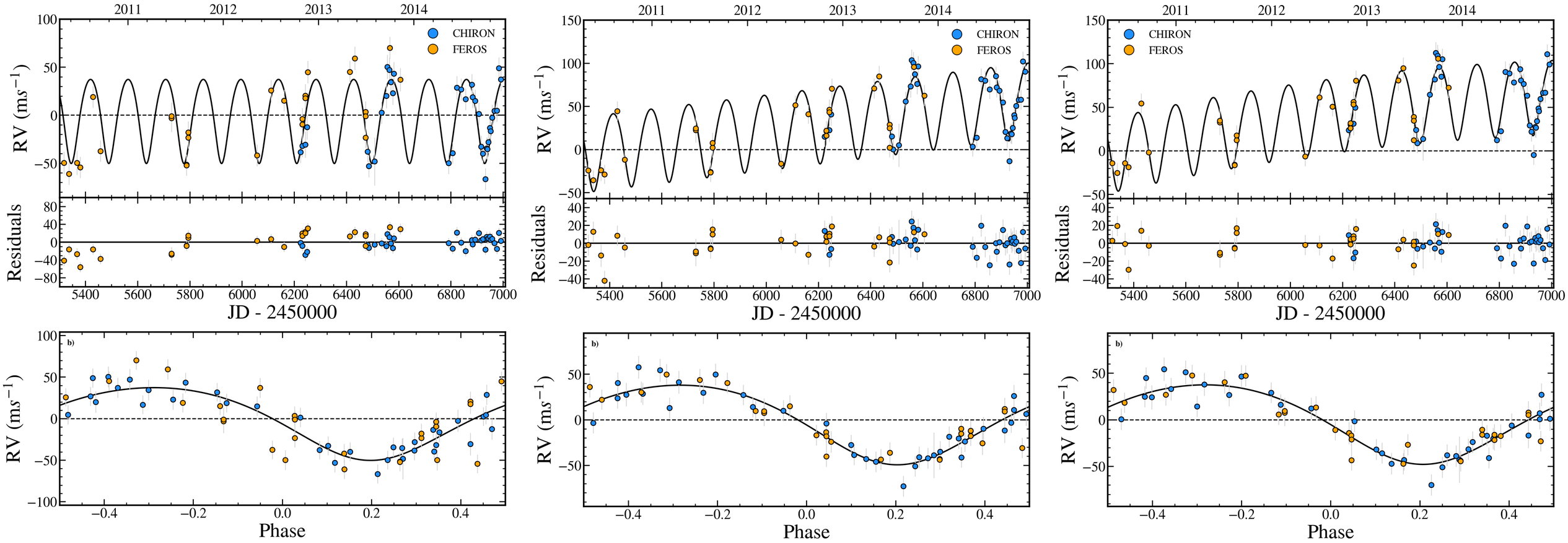
Radvel; Fulton et al. 2018

Orbit Fit and Model Selection

Keplerian

Keplerian + Linear Trend

Keplerian + Curvature



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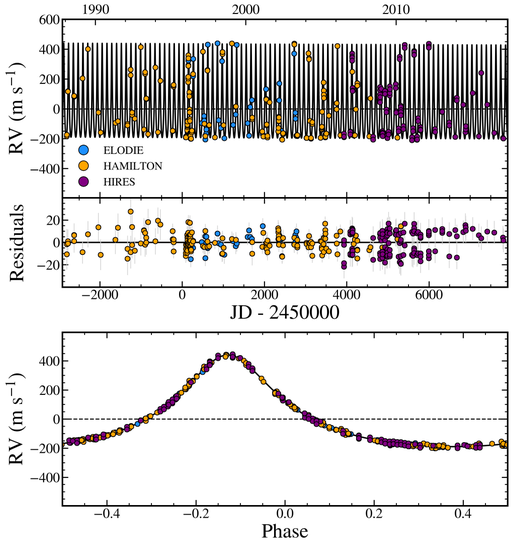
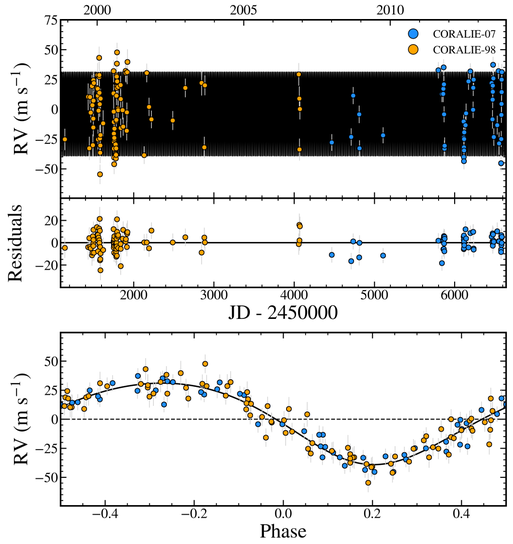
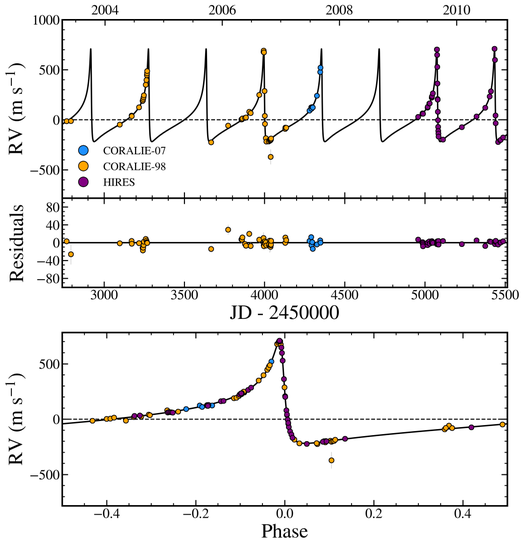
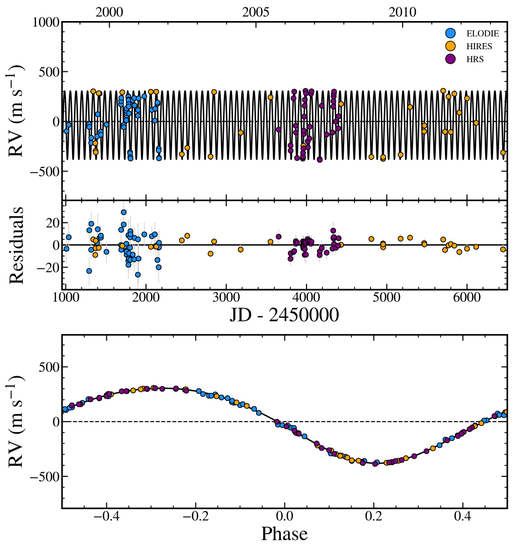
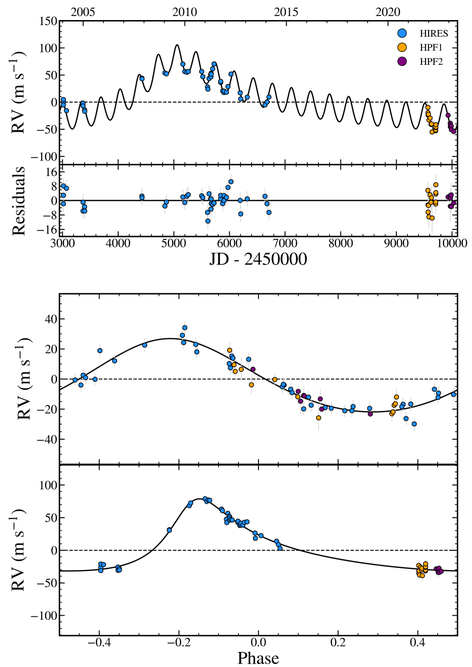
Uniformly Refit Warm Jupiter Orbits

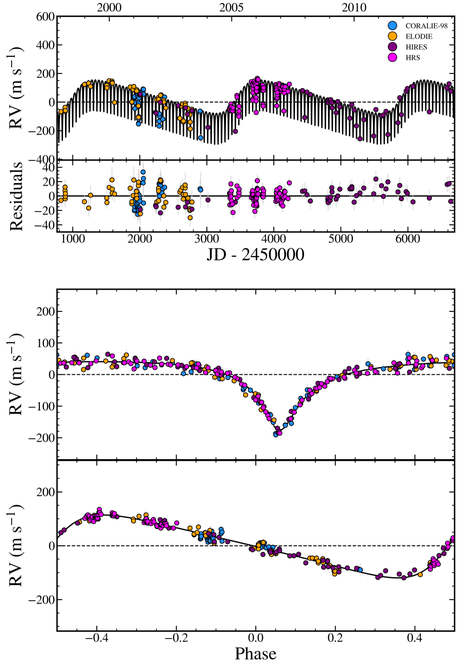


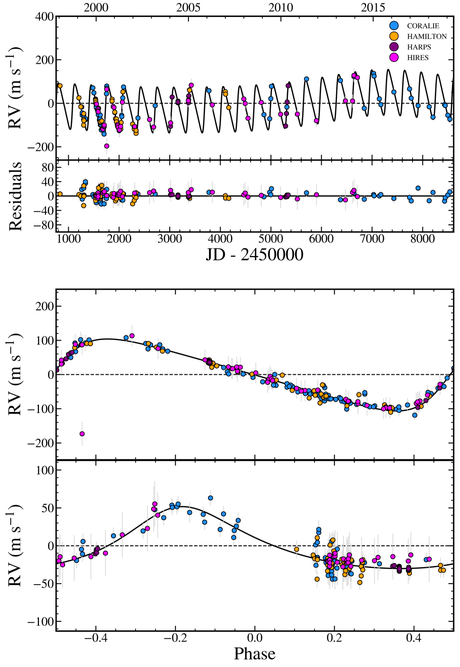


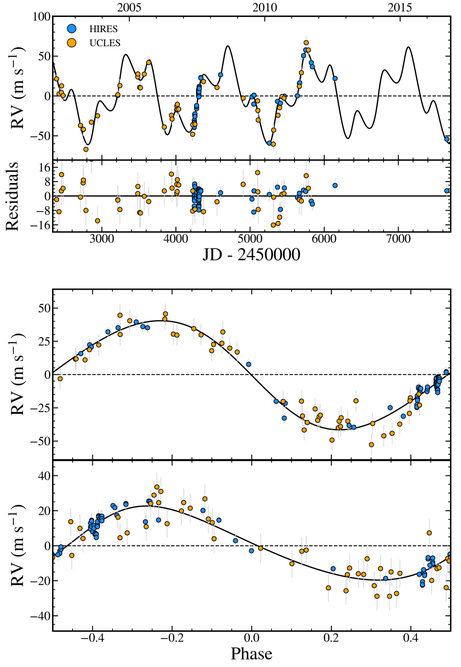


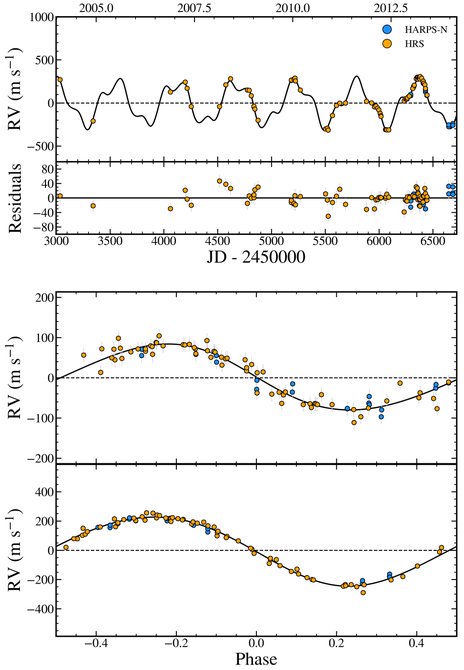






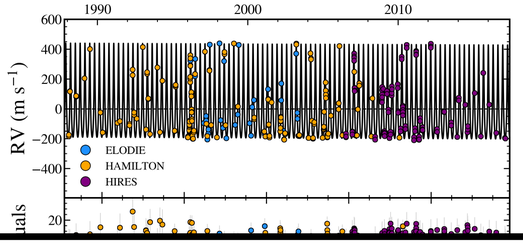


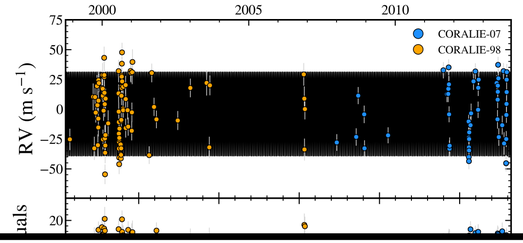


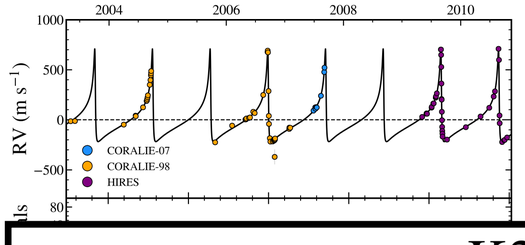


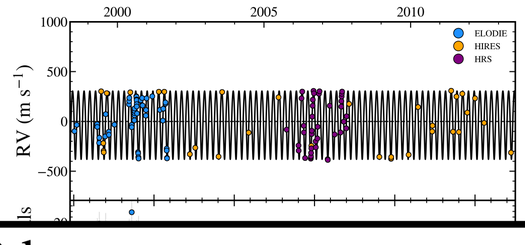
Morgan et al. 2025, 2026a

Uniformly Refit Warm Jupiter Orbits

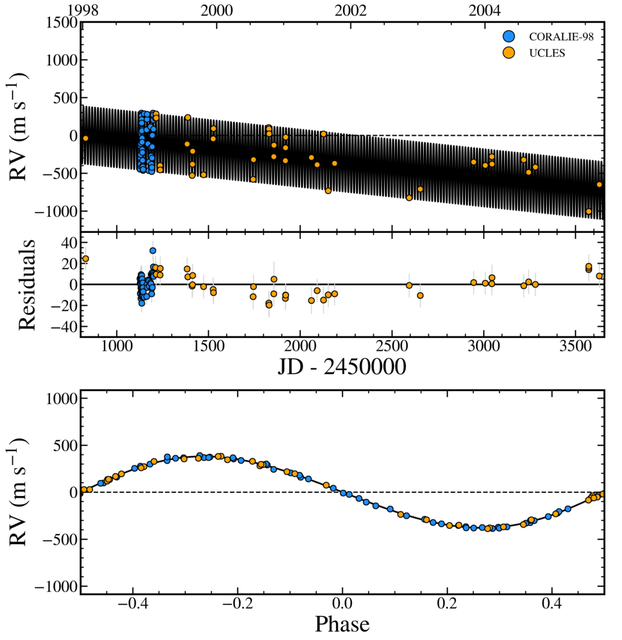


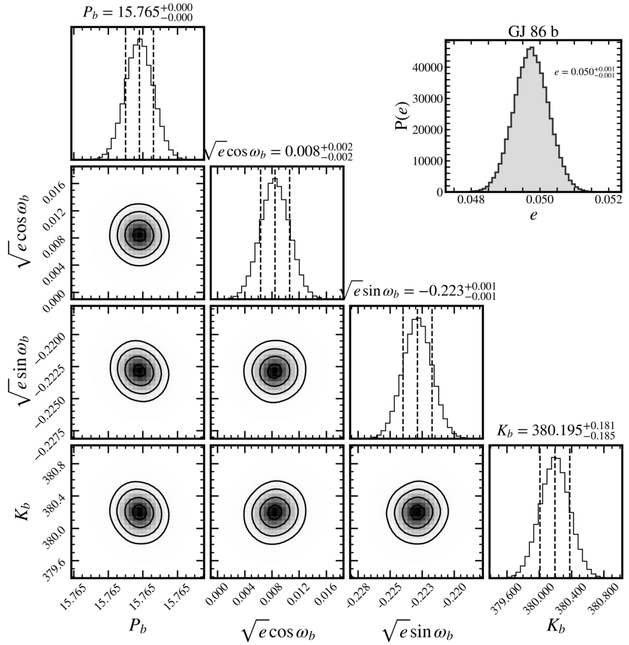




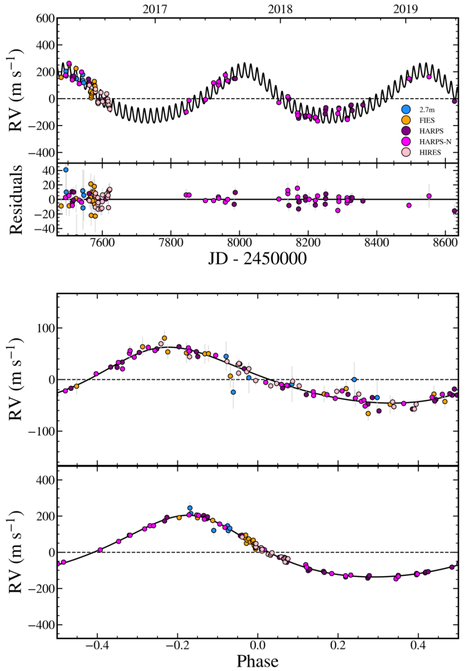


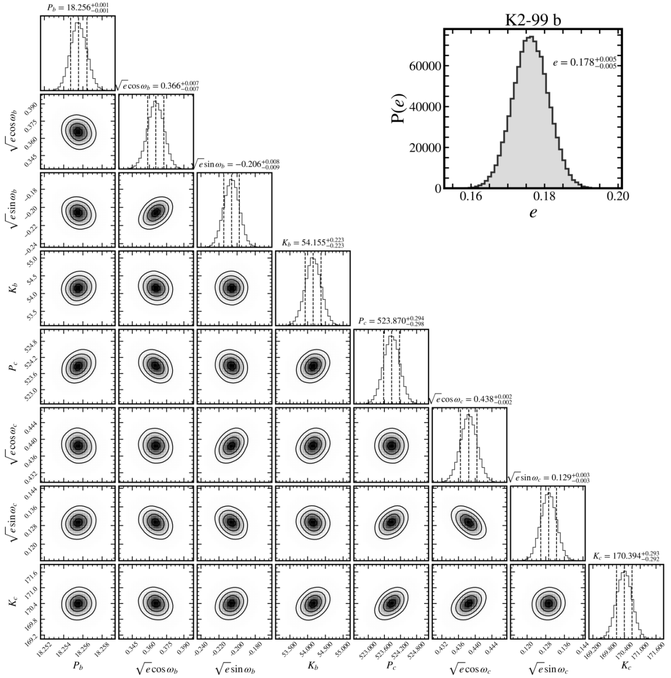
GJ 86 b

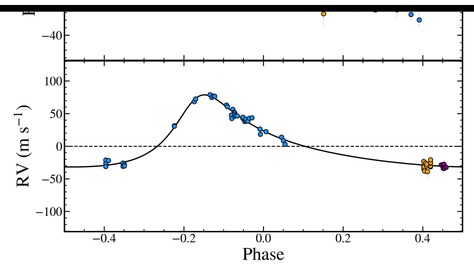


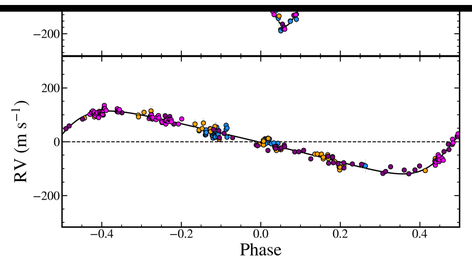


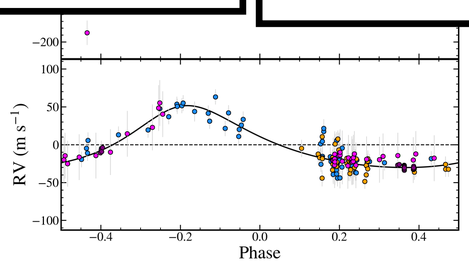
K2-99 b

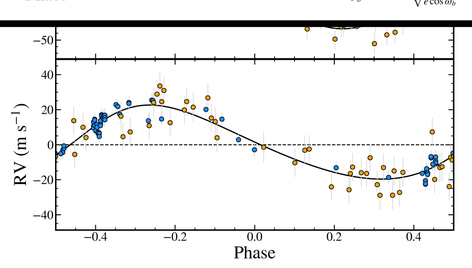


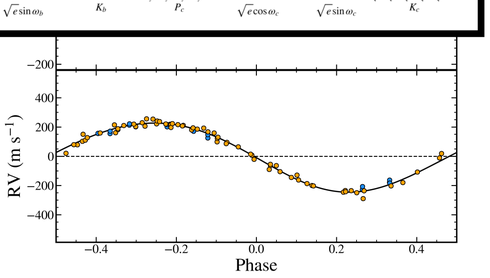








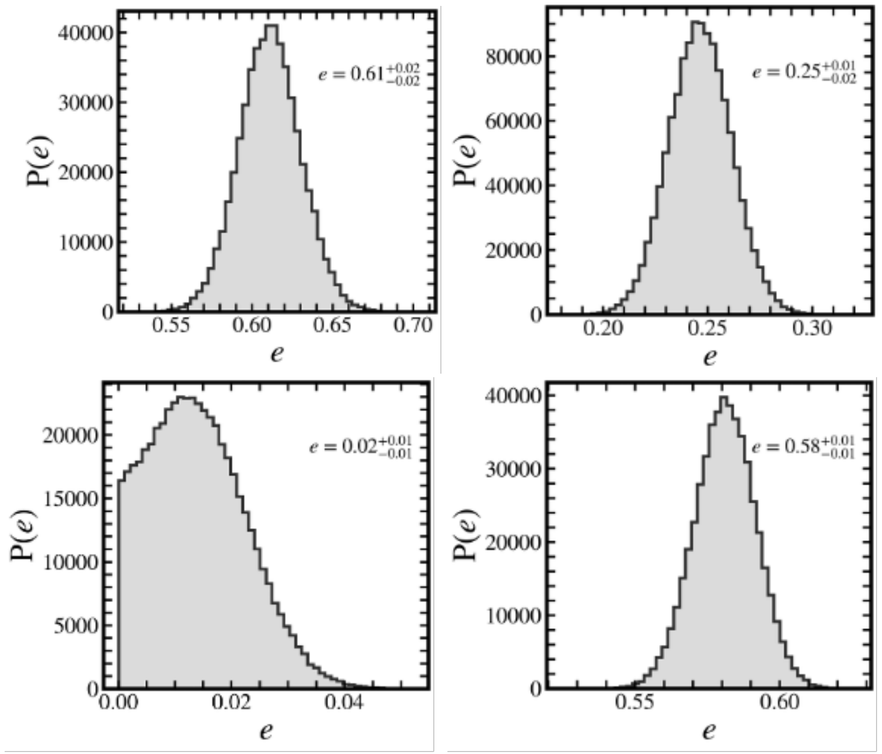




Morgan et al. 2025, 2026a

Recovering Underlying Distributions with HBM

1. Constrain individual eccentricities for each warm Jupiter in the sample.



Radvel ; Fulton et al. 2018

Recovering Underlying Distributions with HBM

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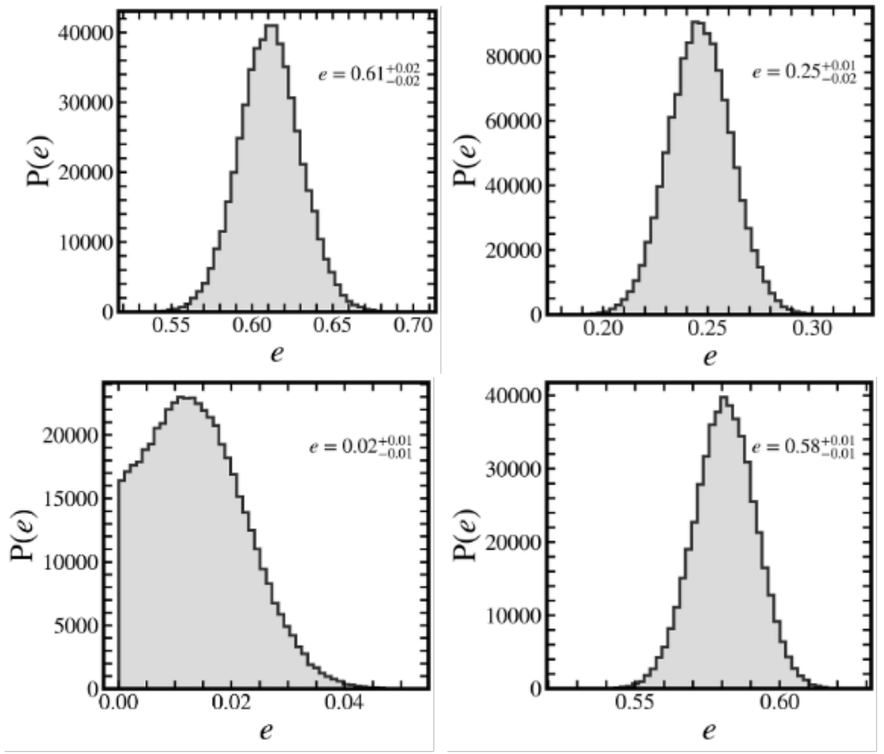
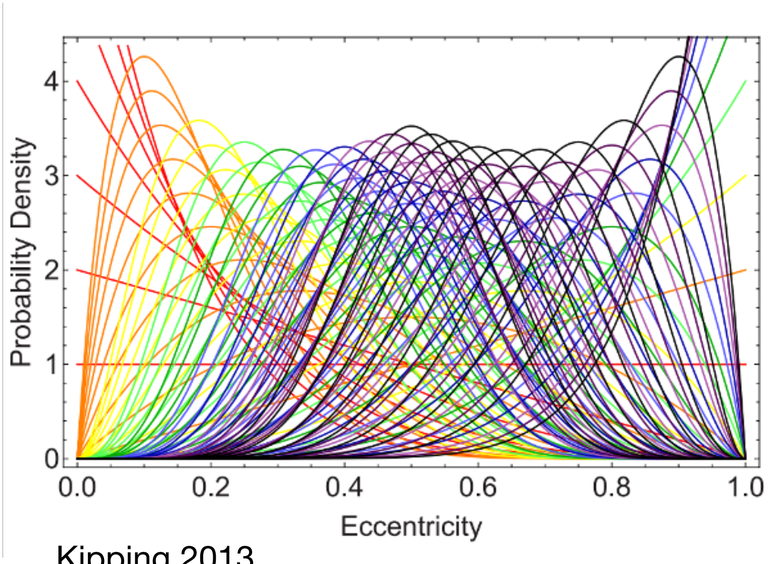
2. Select underlying model (Beta Distribution)



Radvel ; Fulton et al. 2018



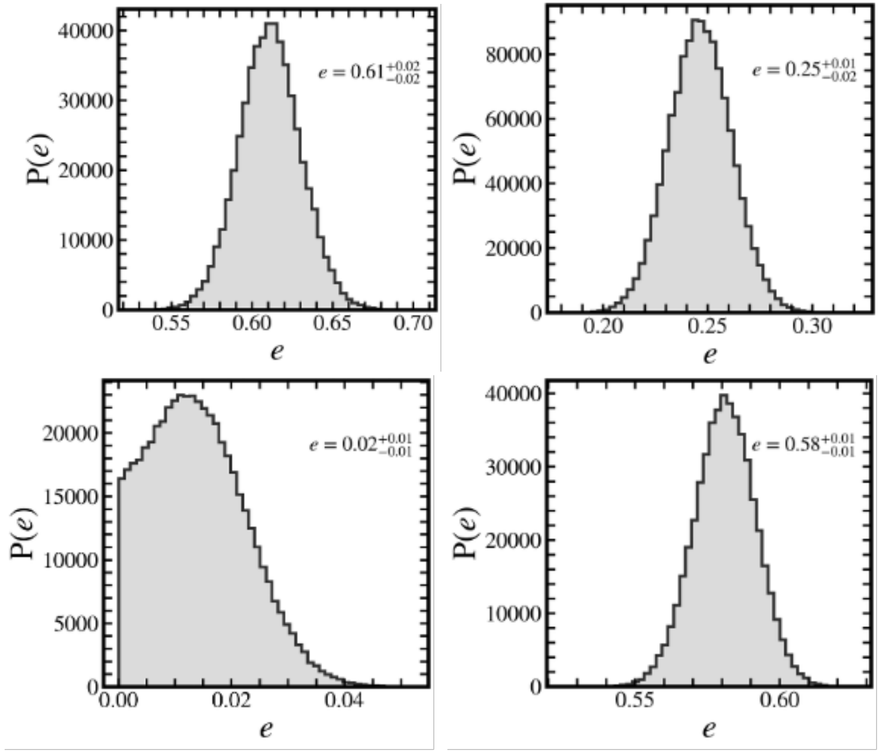
Kipping 2013

Recovering Underlying Distributions with HBM

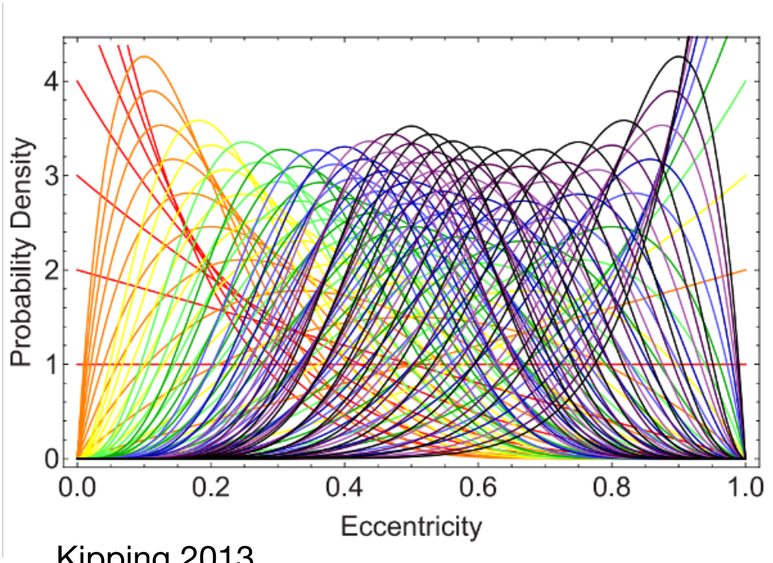
1. Constrain individual eccentricities for each warm Jupiter in the sample.

2. Select underlying model (Beta Distribution)

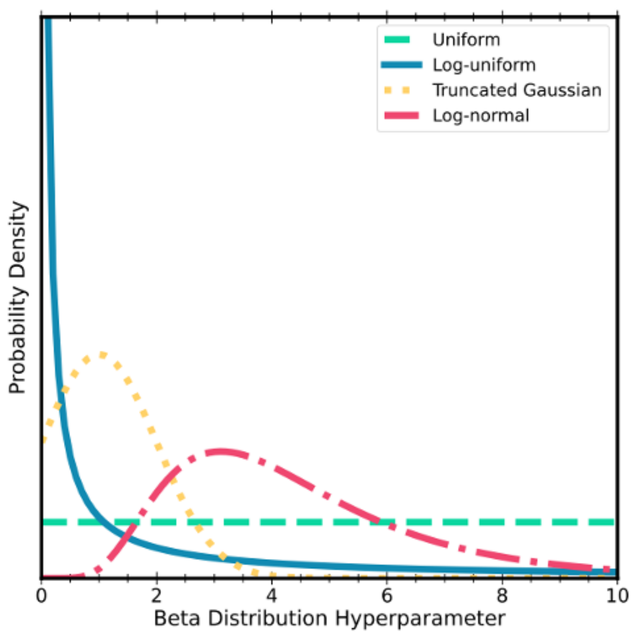
3. Adopt hyperpriors on the model



Radvel ; Fulton et al. 2018



Kipping 2013

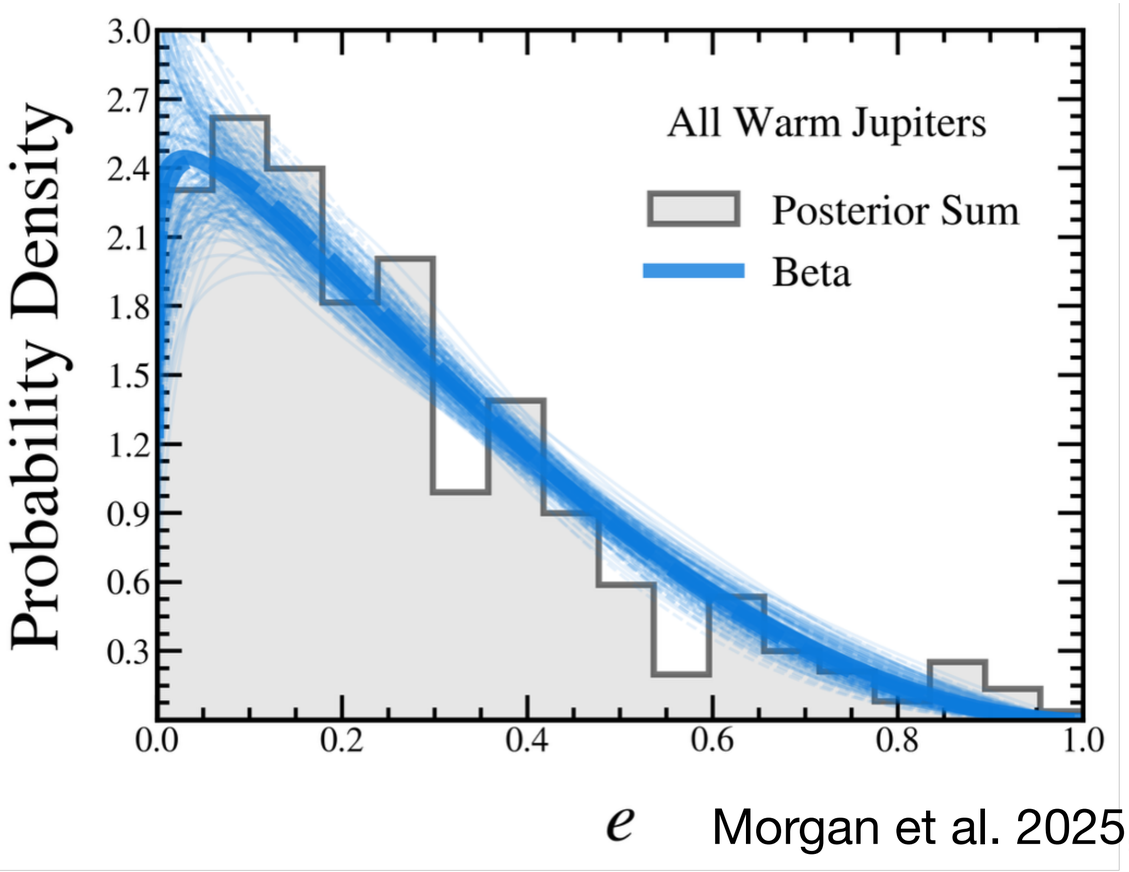


ePop! ; Nagpal et al. 2024

Key Results from Exploring Warm Jupiter Migration with Eccentricities

Key Results from Exploring Warm Jupiter Migration with Eccentricities

Warm Jupiters are a Dynamically Hot Population



Morgan et al. 2025, 2026a

Key Results from Exploring Warm Jupiter Migration with Eccentricities

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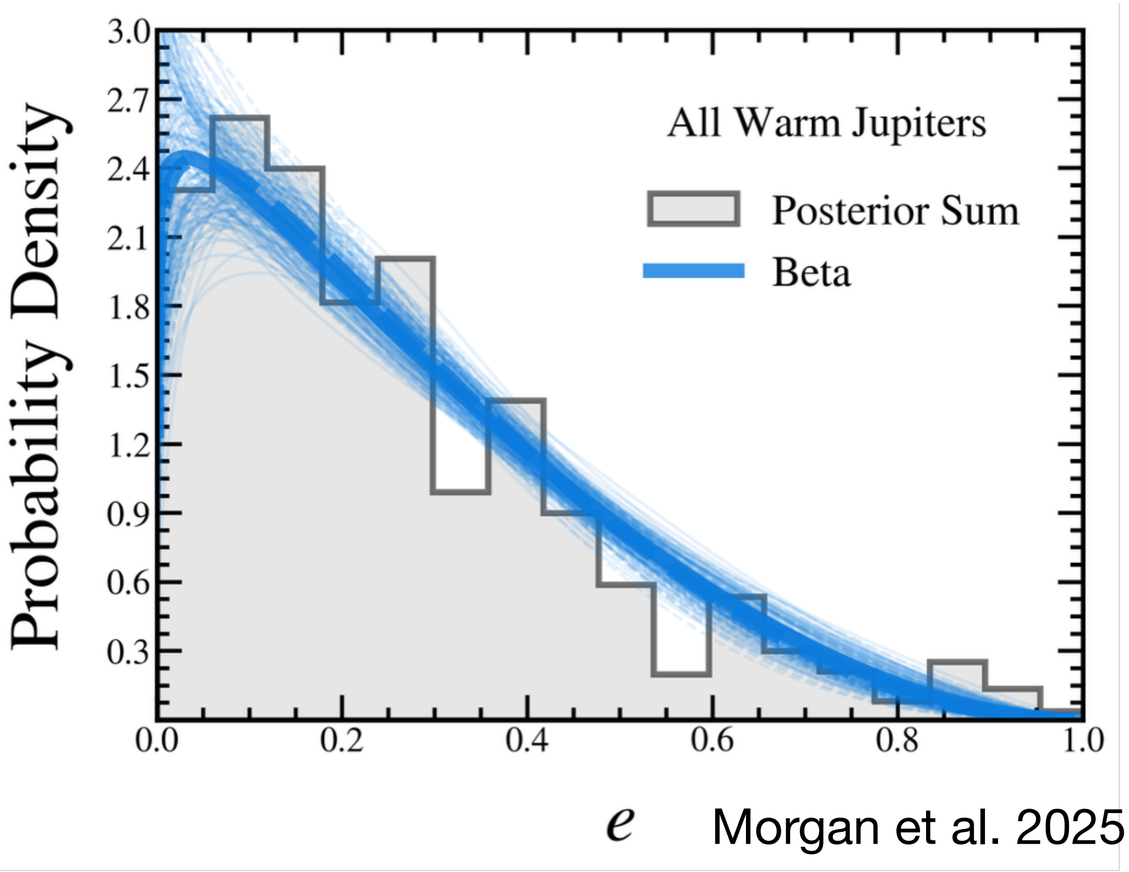
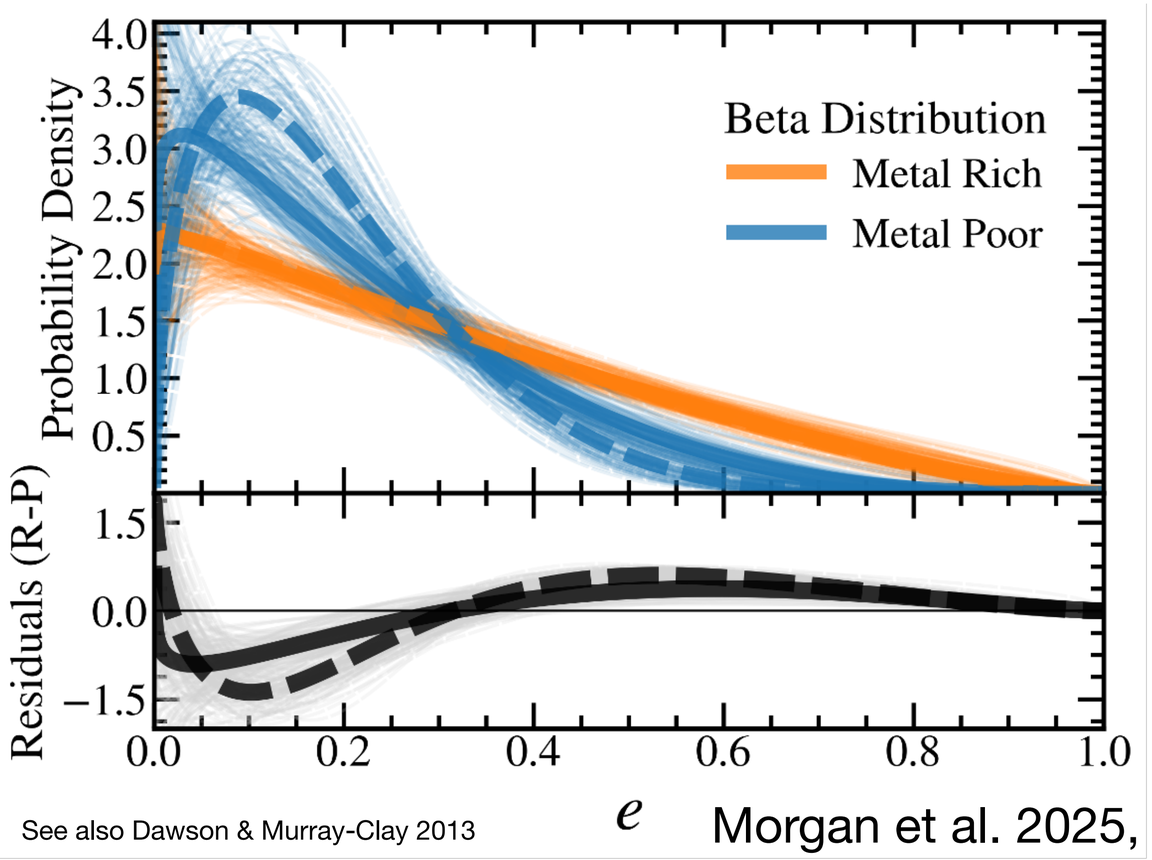


Morgan et al. 2025, 2026a

- $73^{+3}_{-3}\,\%$ of warm Jupiters have excited eccentricities ($e > 0.1$).
- $27^{+3}_{-4}\,\%$ of warm Jupiters have eccentricities consistent with near-circular orbits ($e < 0.1$).

Key Results from Exploring Warm Jupiter Migration with Eccentricities

Metal-Rich Host Stars Harbor the Most Eccentric Warm Jupiters



See also Dawson & Murray-Clay 2013

Morgan et al. 2025, 2026a

Key Results from Exploring Warm Jupiter Migration with Eccentricities

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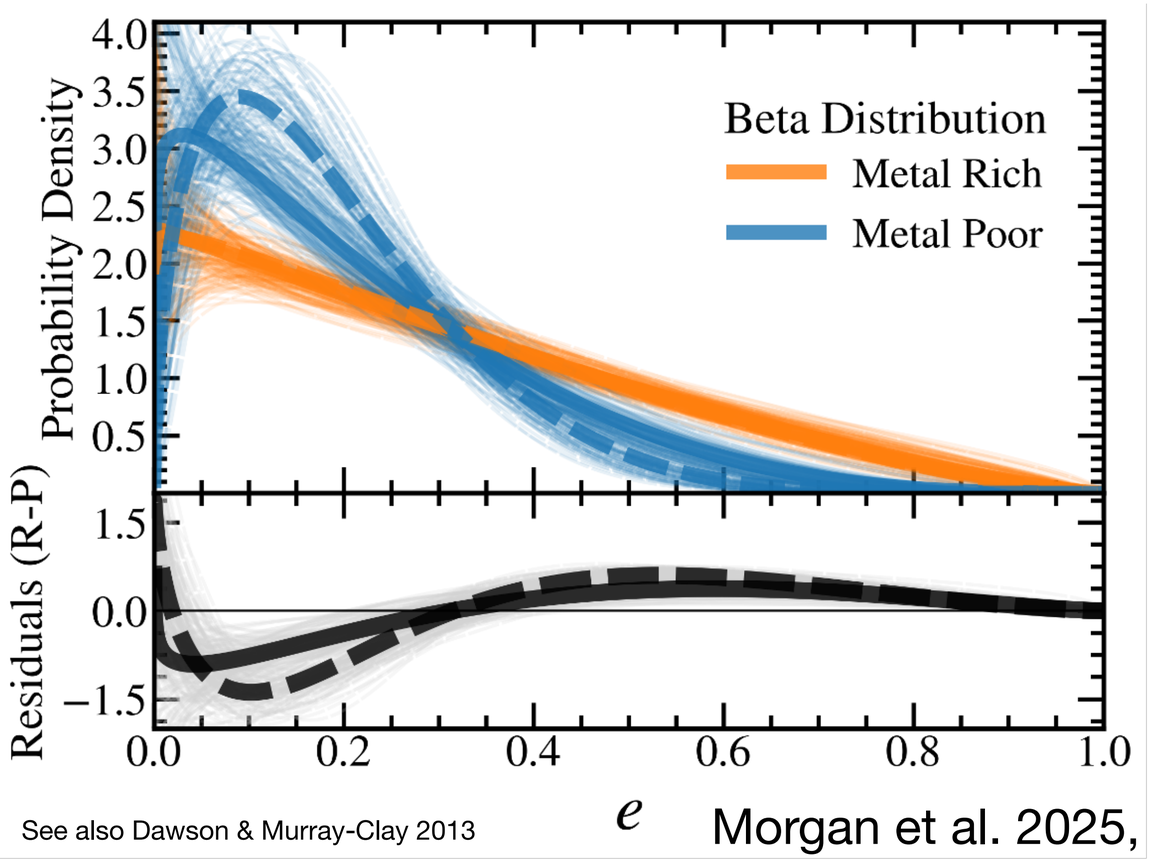


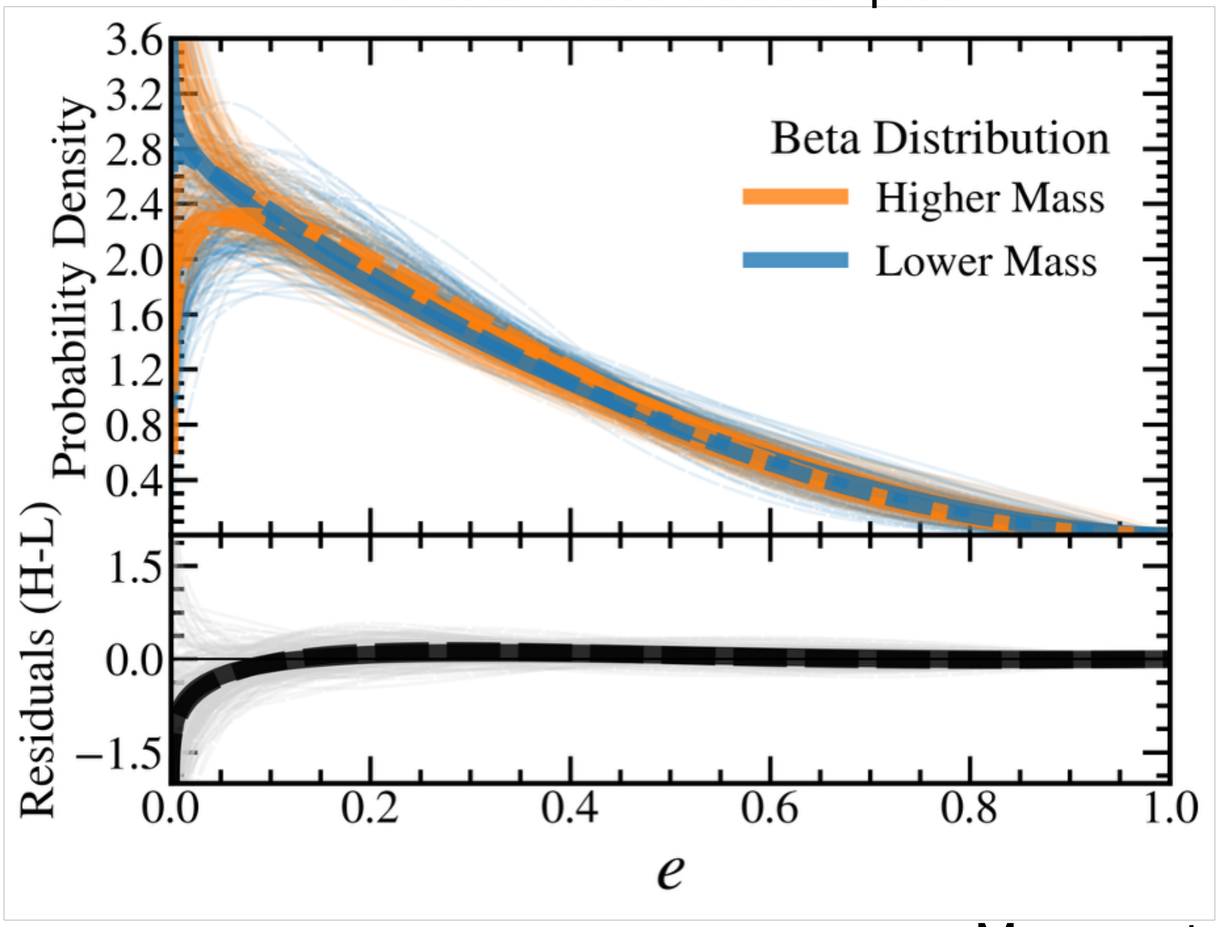
See also Dawson & Murray-Clay 2013

Morgan et al. 2025, 2026a

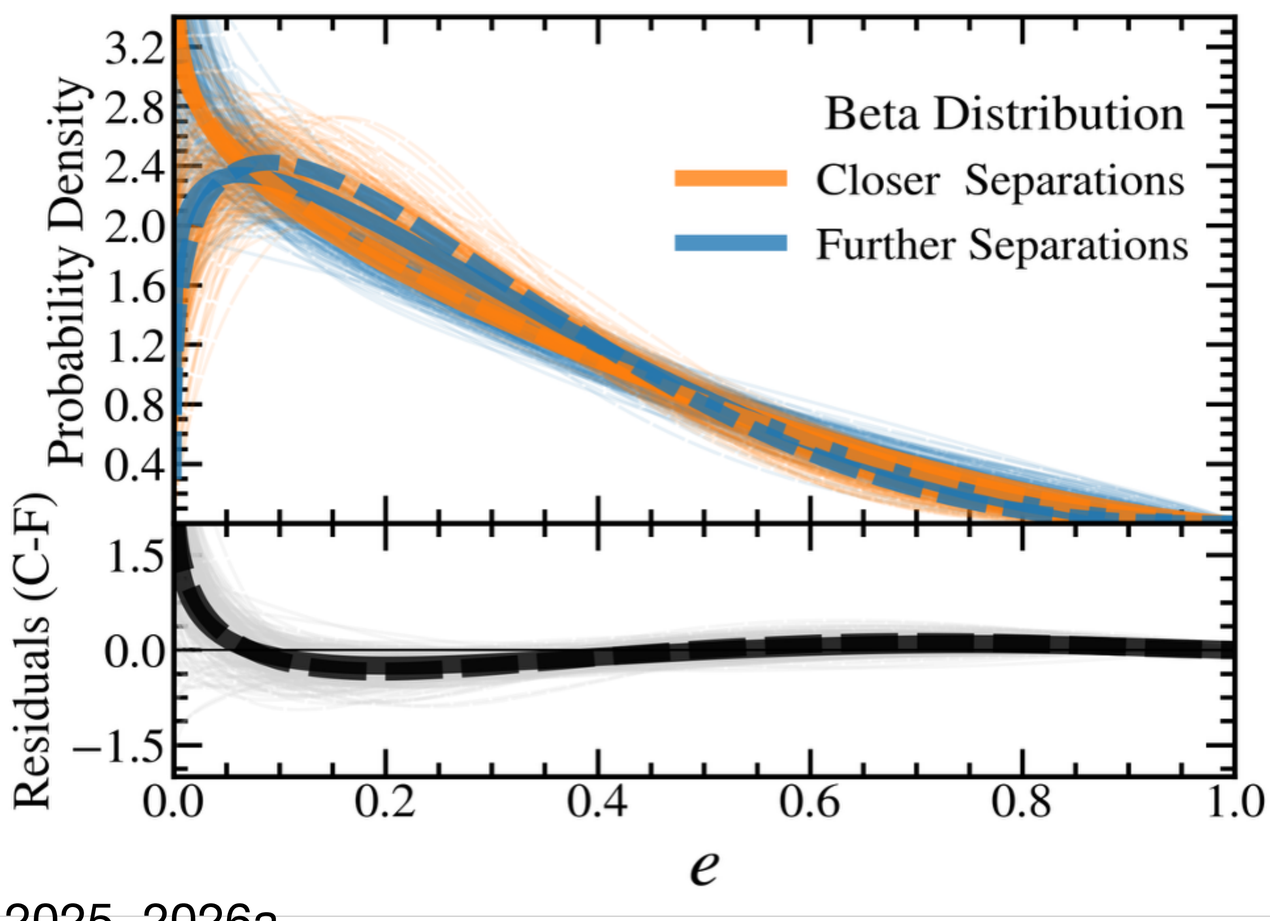
- Clear distinction with [Fe/H]
- Insensitive to M_* and orbital separation

Key Results from Exploring Warm Jupiter Migration with Eccentricities

Stellar Mass Subsamples



Orbital Separation Subsamples



Morgan et al. 2025, 2026a

Dynamical Influence of Companions on Warm Jupiter Evolution

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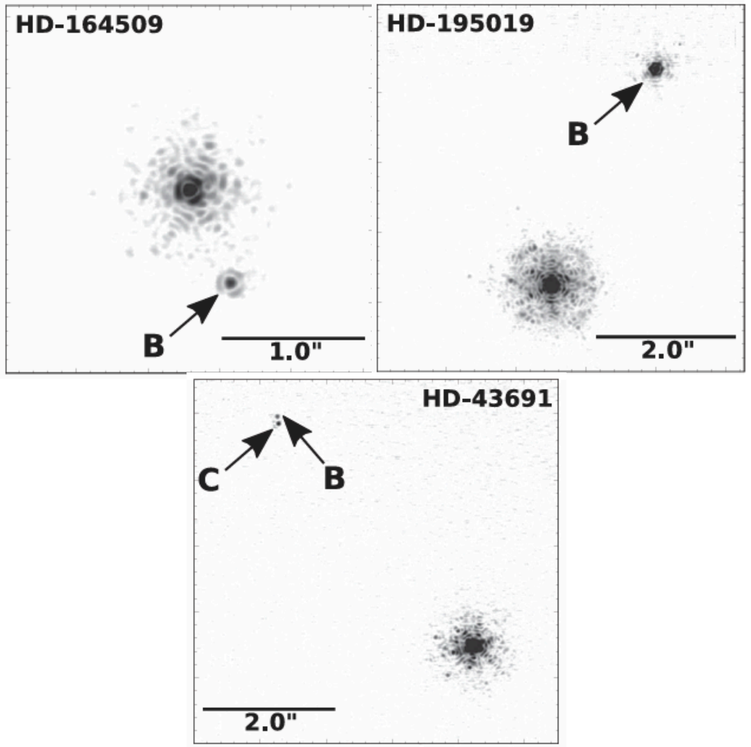
Stellar Multiplicity



Ngo et al. 2017

Dynamical Influence of Companions on Warm Jupiter Evolution

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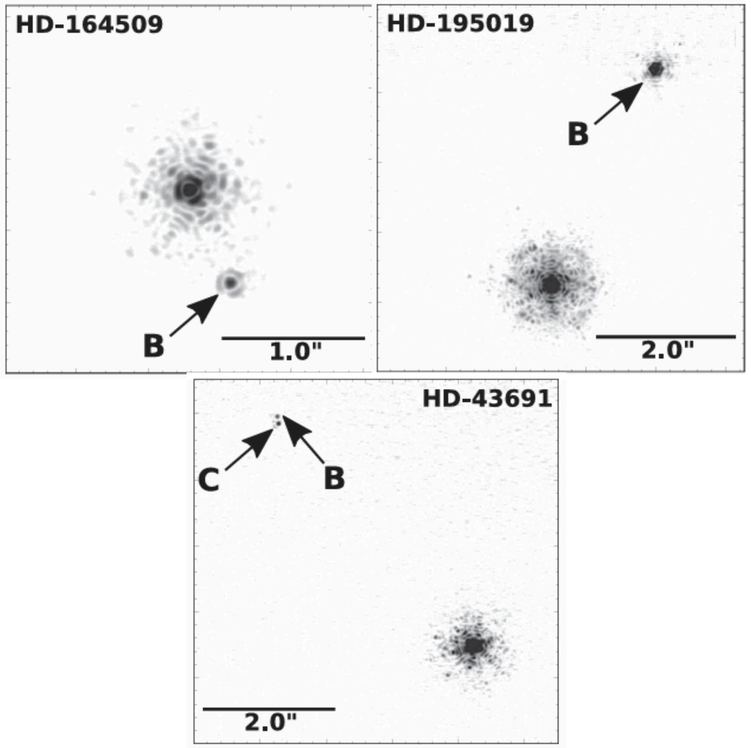
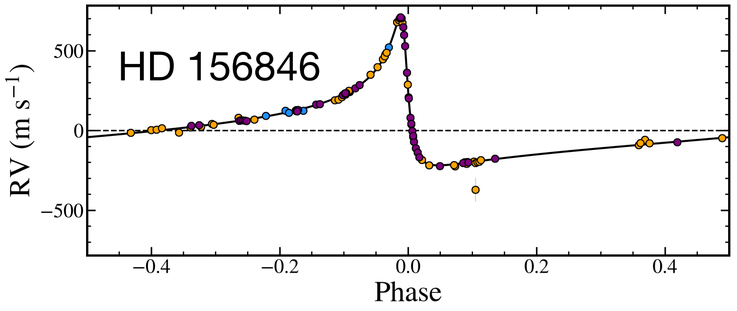
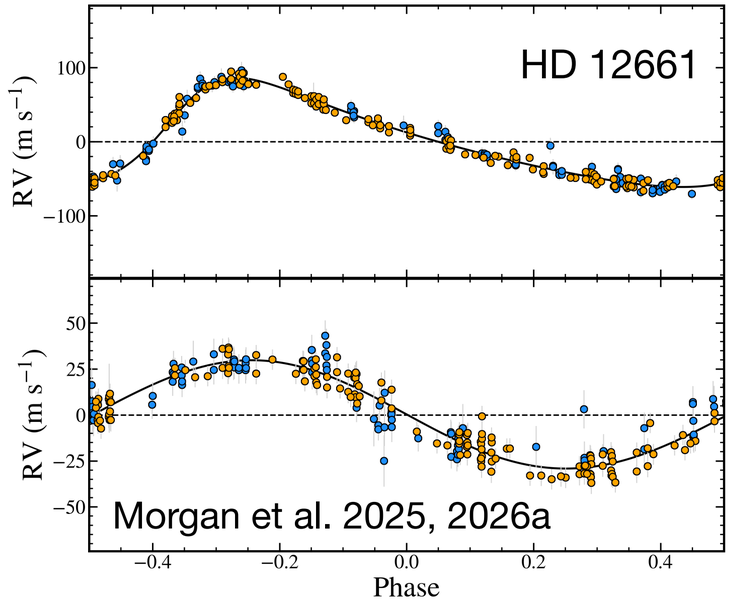


Ngo et al. 2017

Giant Planet Multiplicity





Dynamical Influence of Companions on Warm Jupiter Evolution

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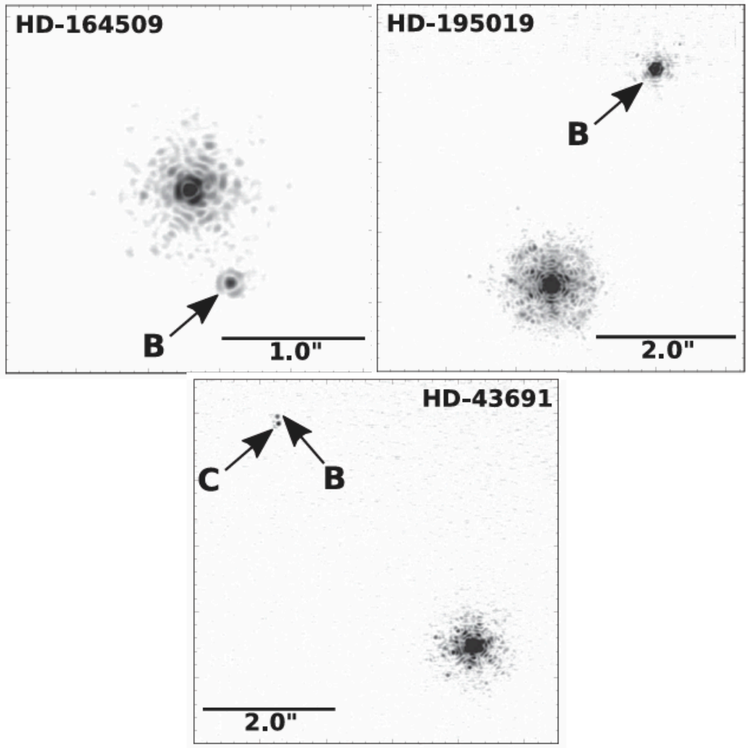

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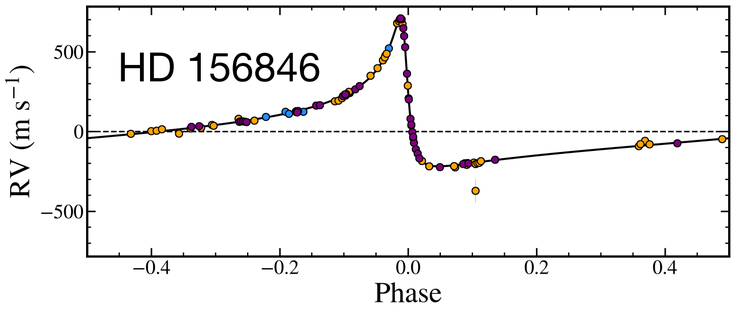
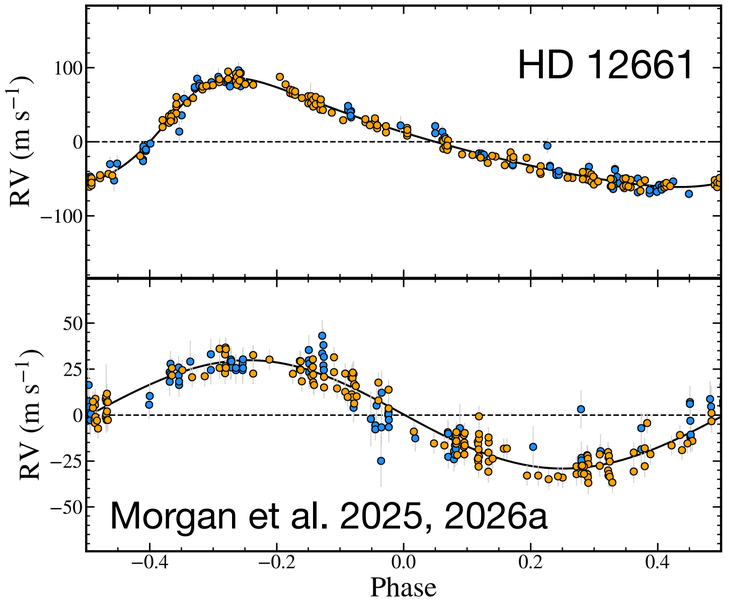
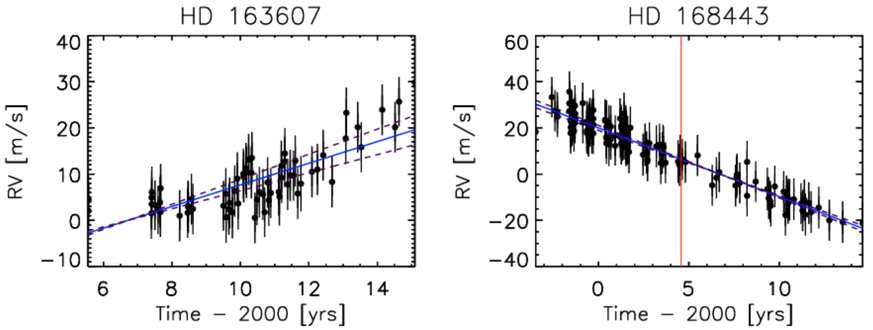
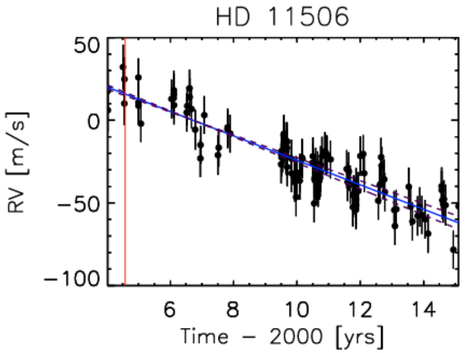




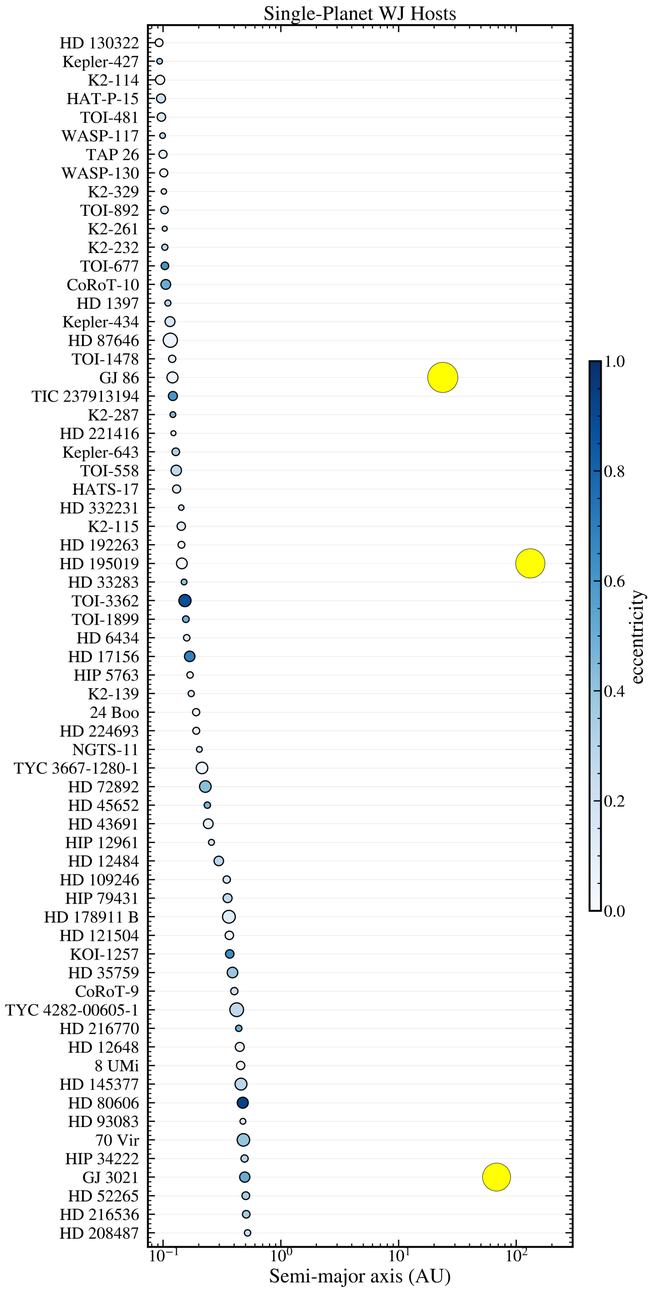
RV Trends

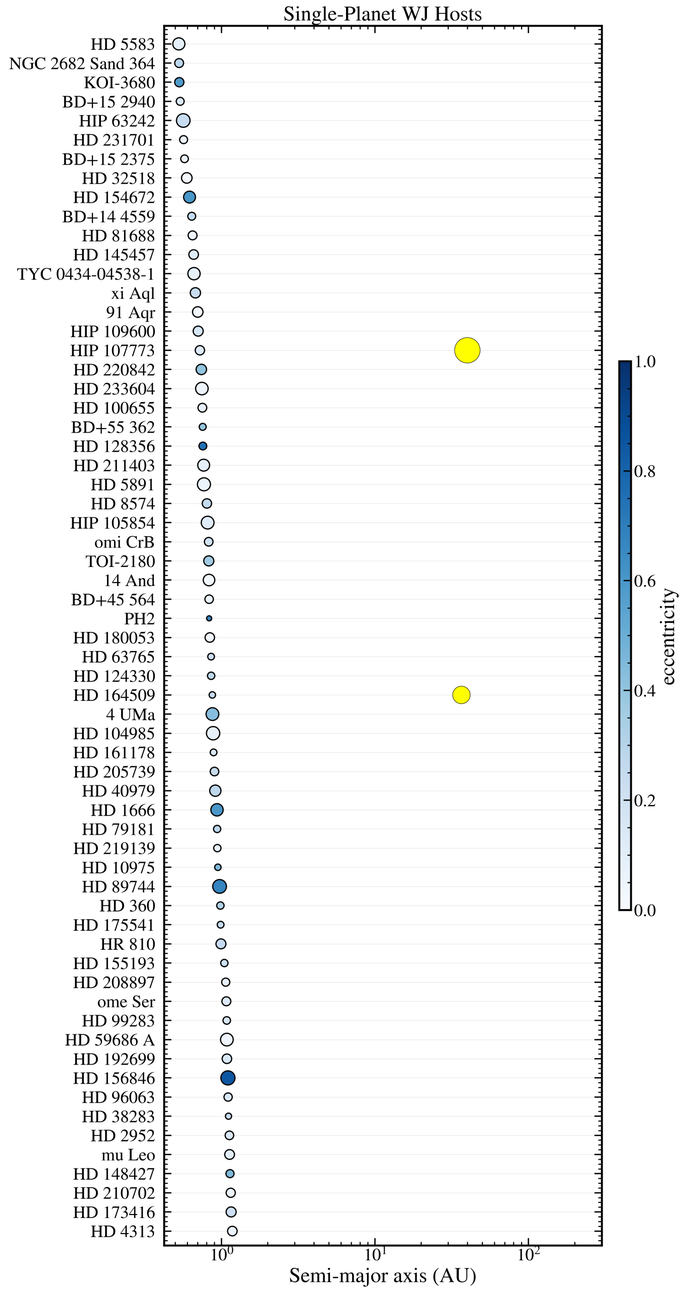




Bryan et al. 2016

Dynamical Influence of Companions on Warm Jupiter Evolution





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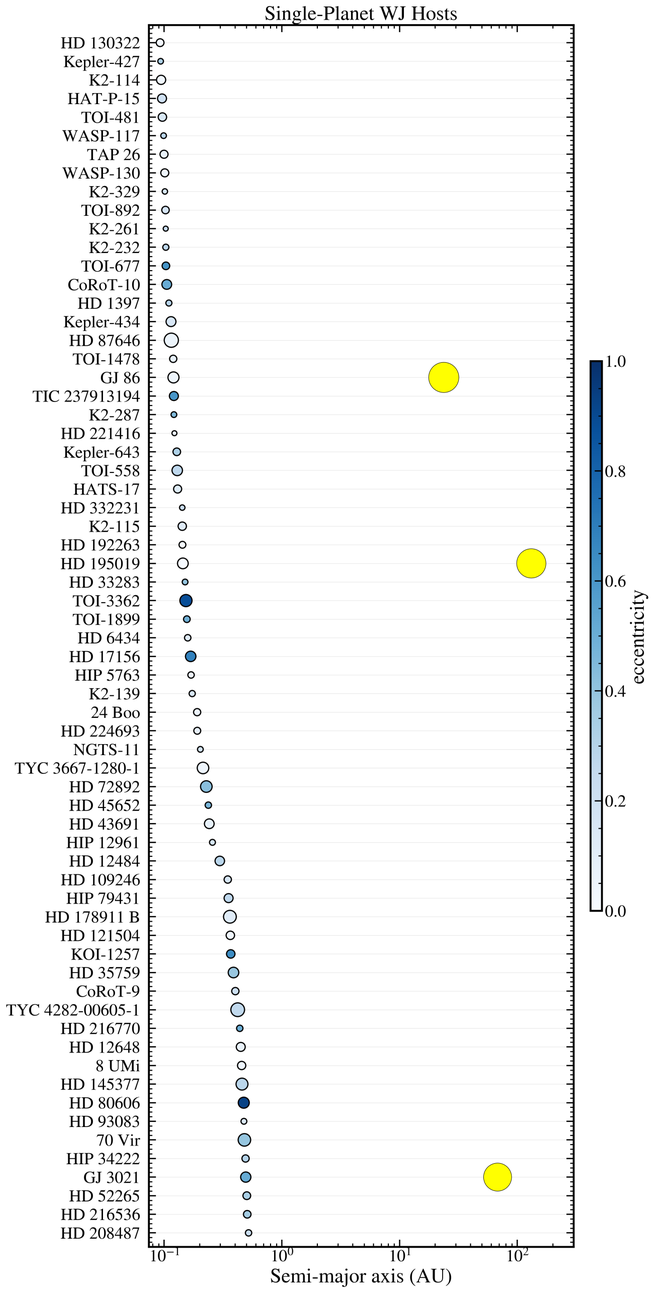
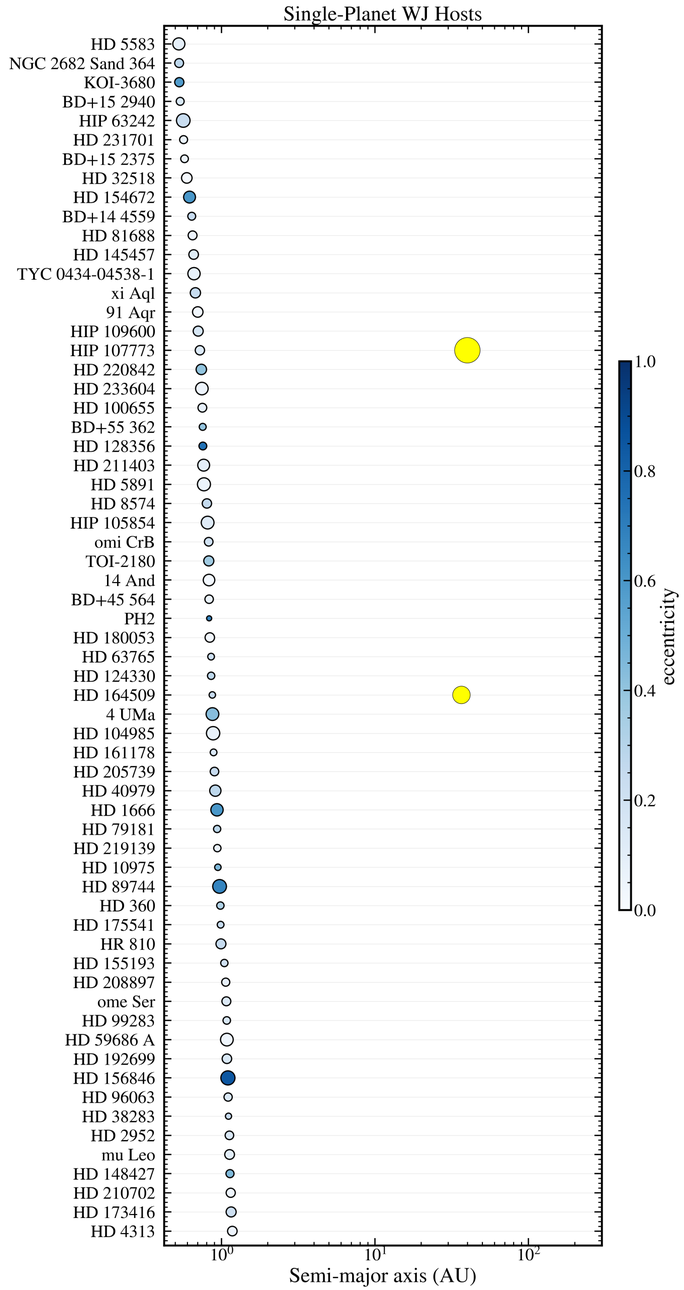
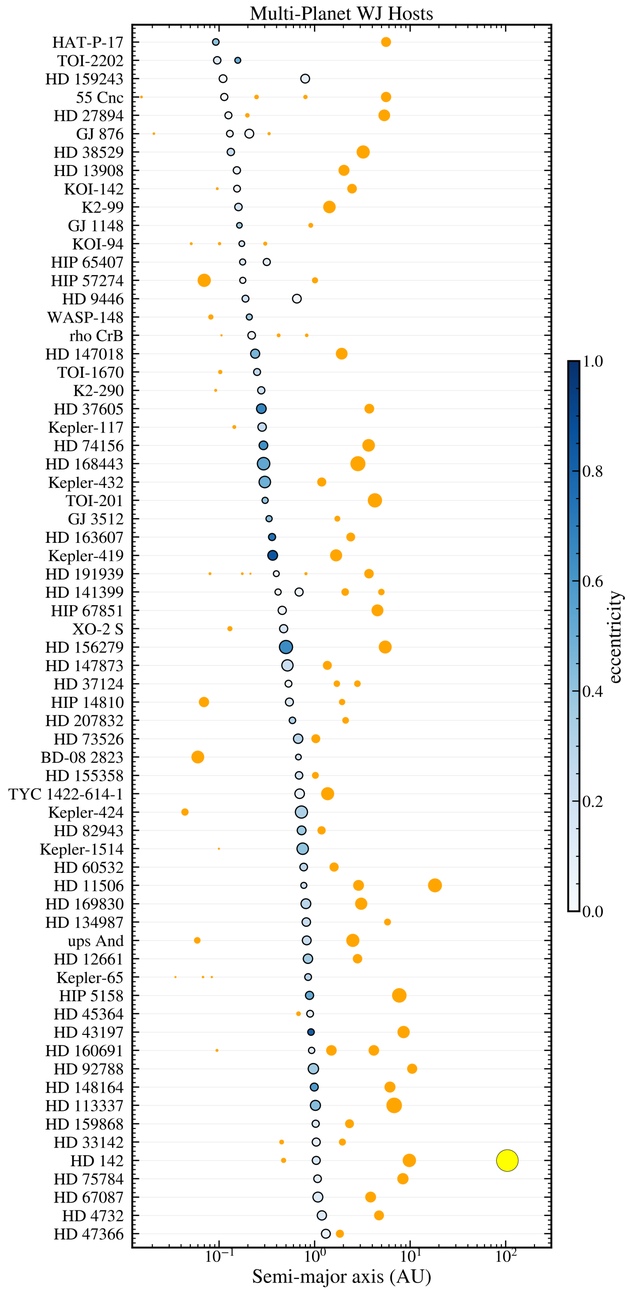
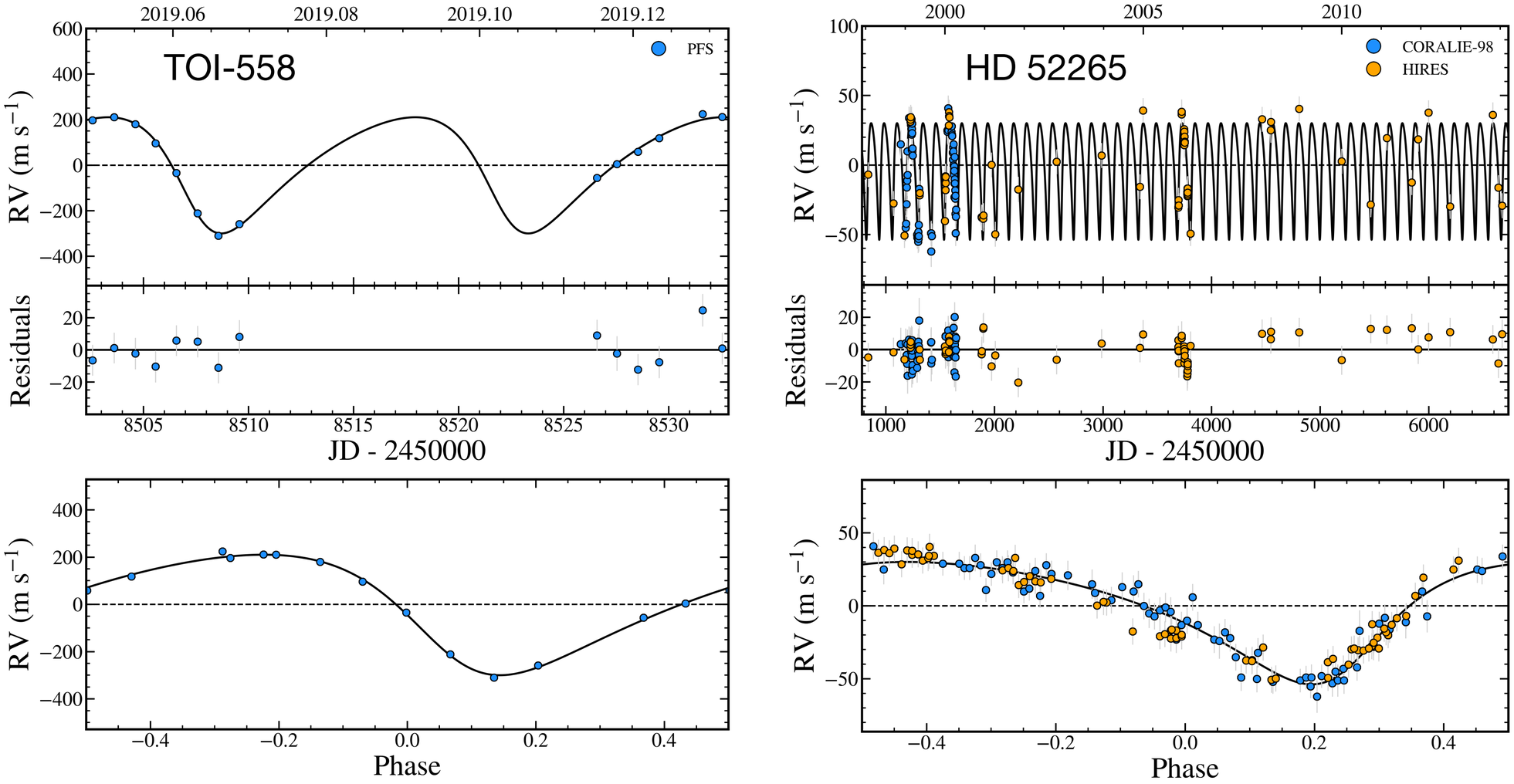






Influence of Giant Planet Companions on Warm Jupiter Evolution

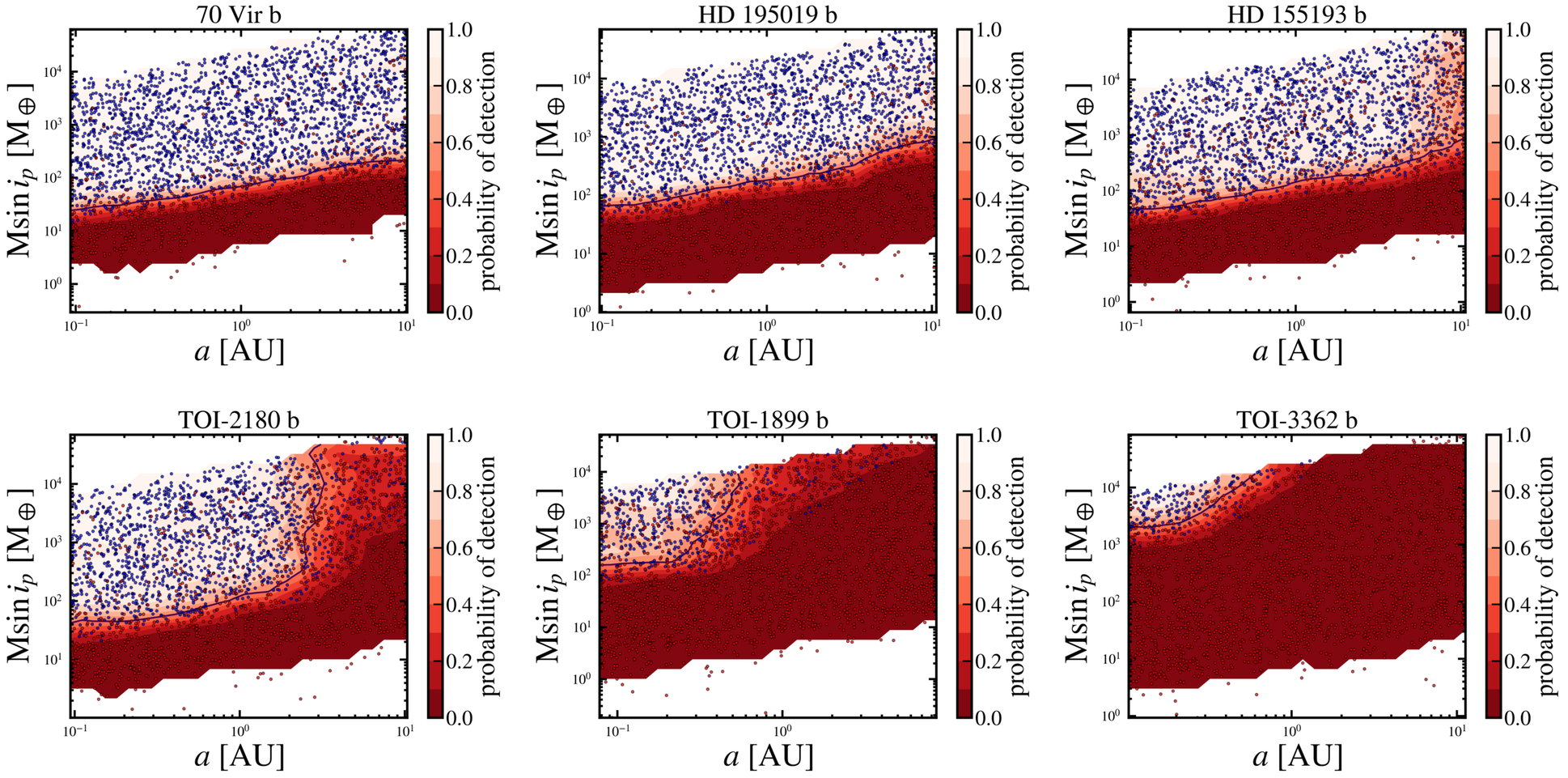
Δt : 30 days — 30 years



Influence of Giant Planet Companions on Warm Jupiter Evolution

Longer Baseline
More Sensitive

Shorter Baseline
Less Sensitive



Morgan et al. in prep

RVSearch Rosenthal et al. 2021

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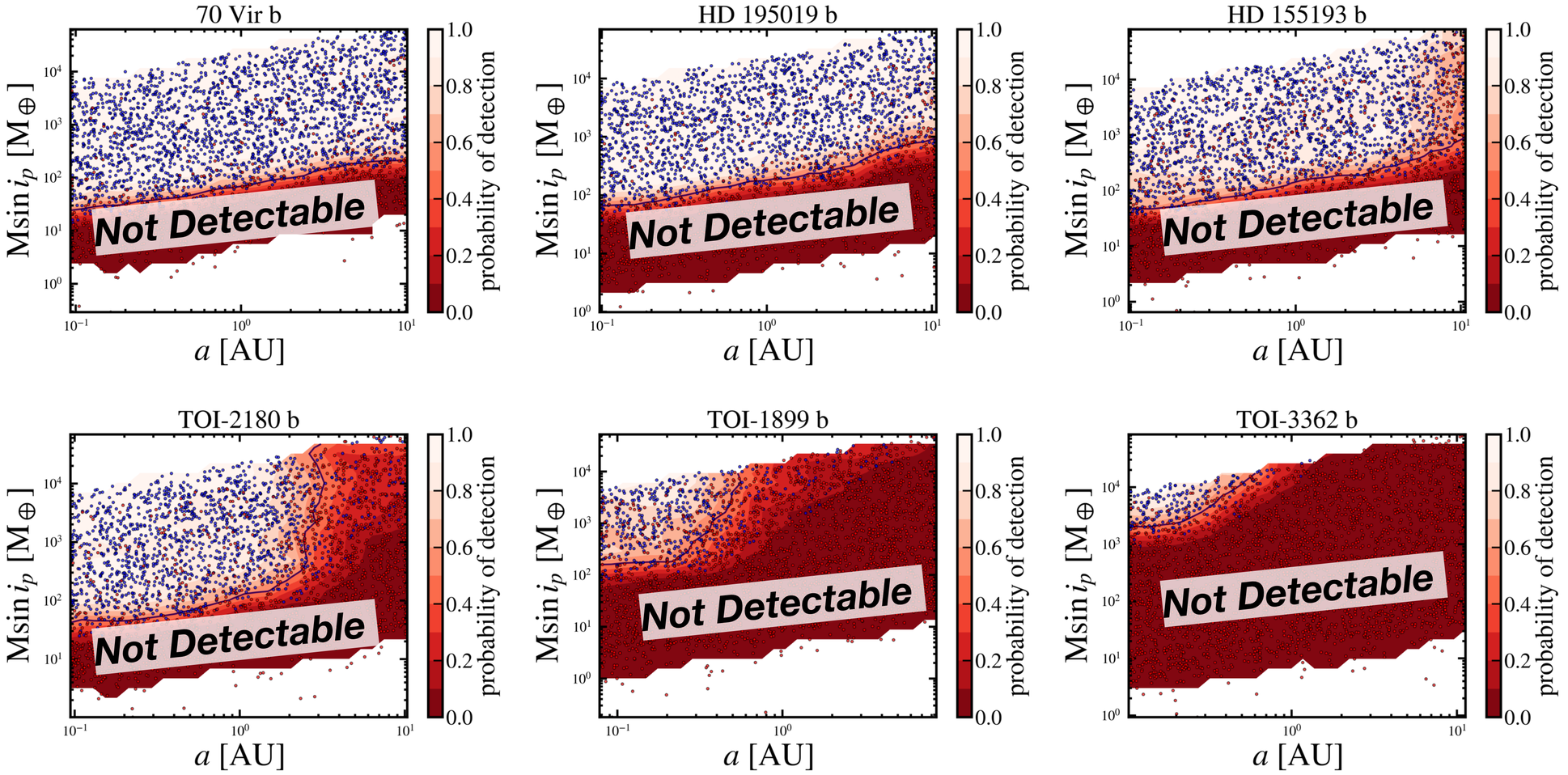

Morgan et al. in prep

RVSearch Rosenthal et al. 2021

Attempt 1: Not Accounting for Sensitivity to an Additional Giant Planet

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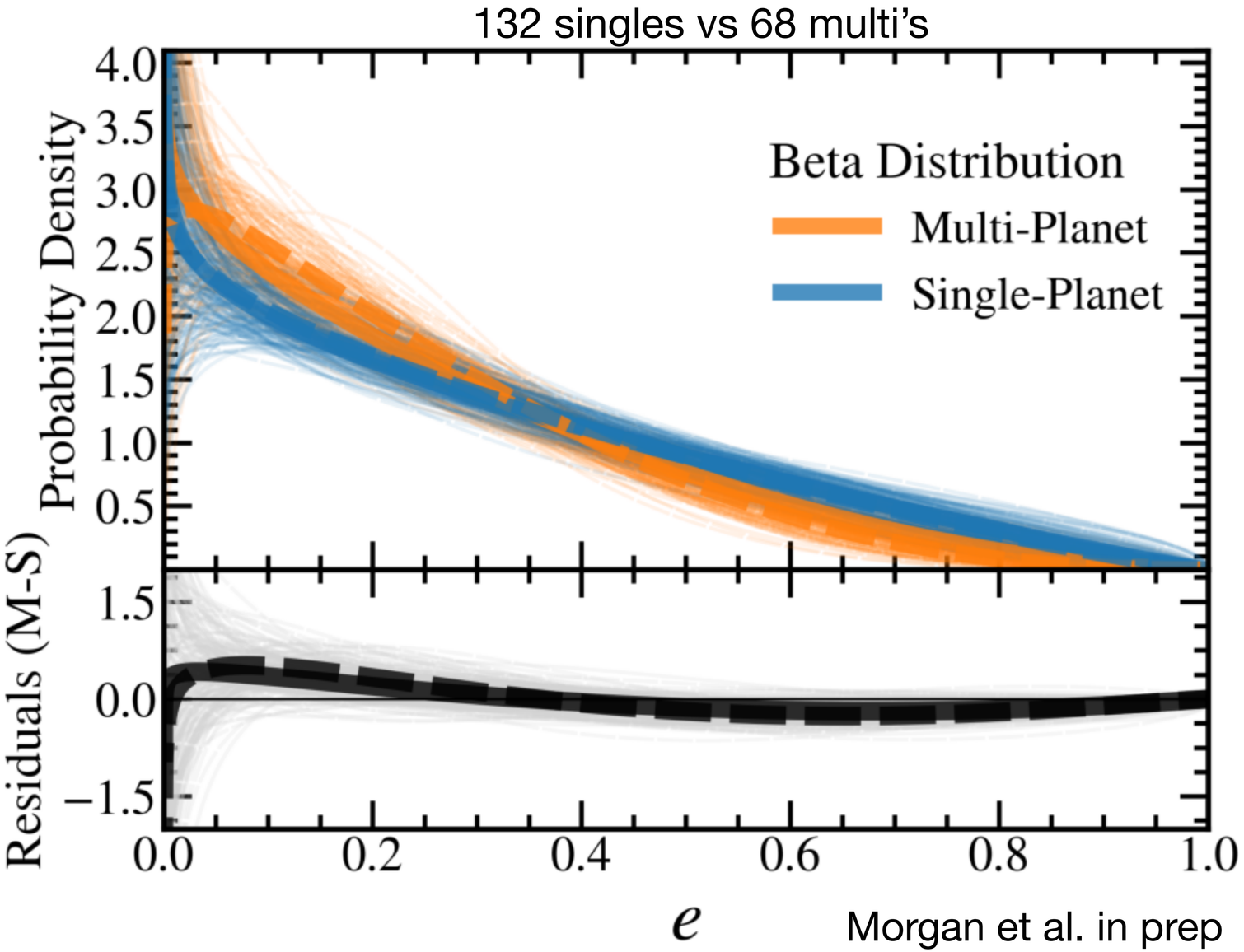
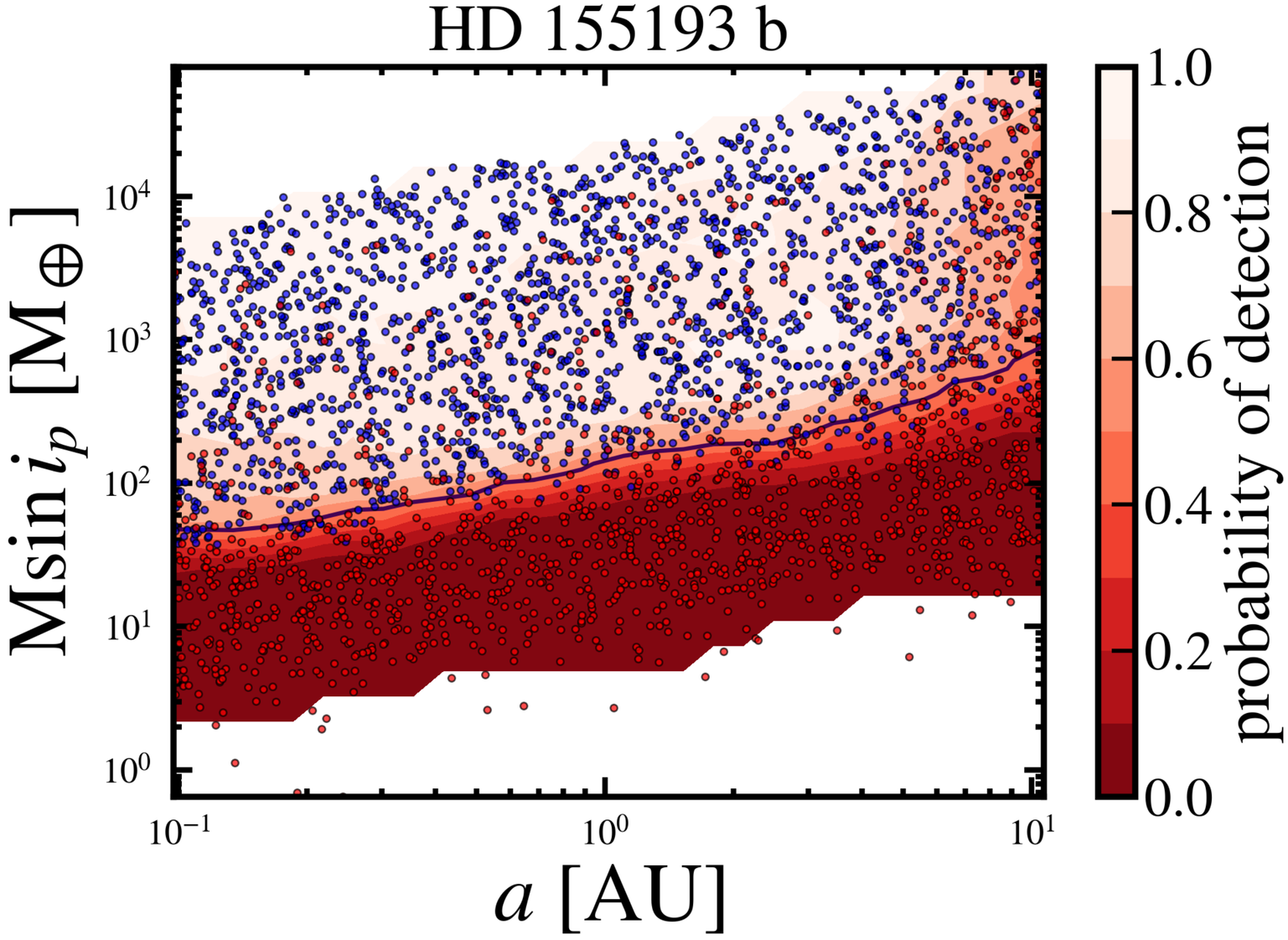


Attempt 2: Accounting for Sensitivity to an Additional Giant Planet



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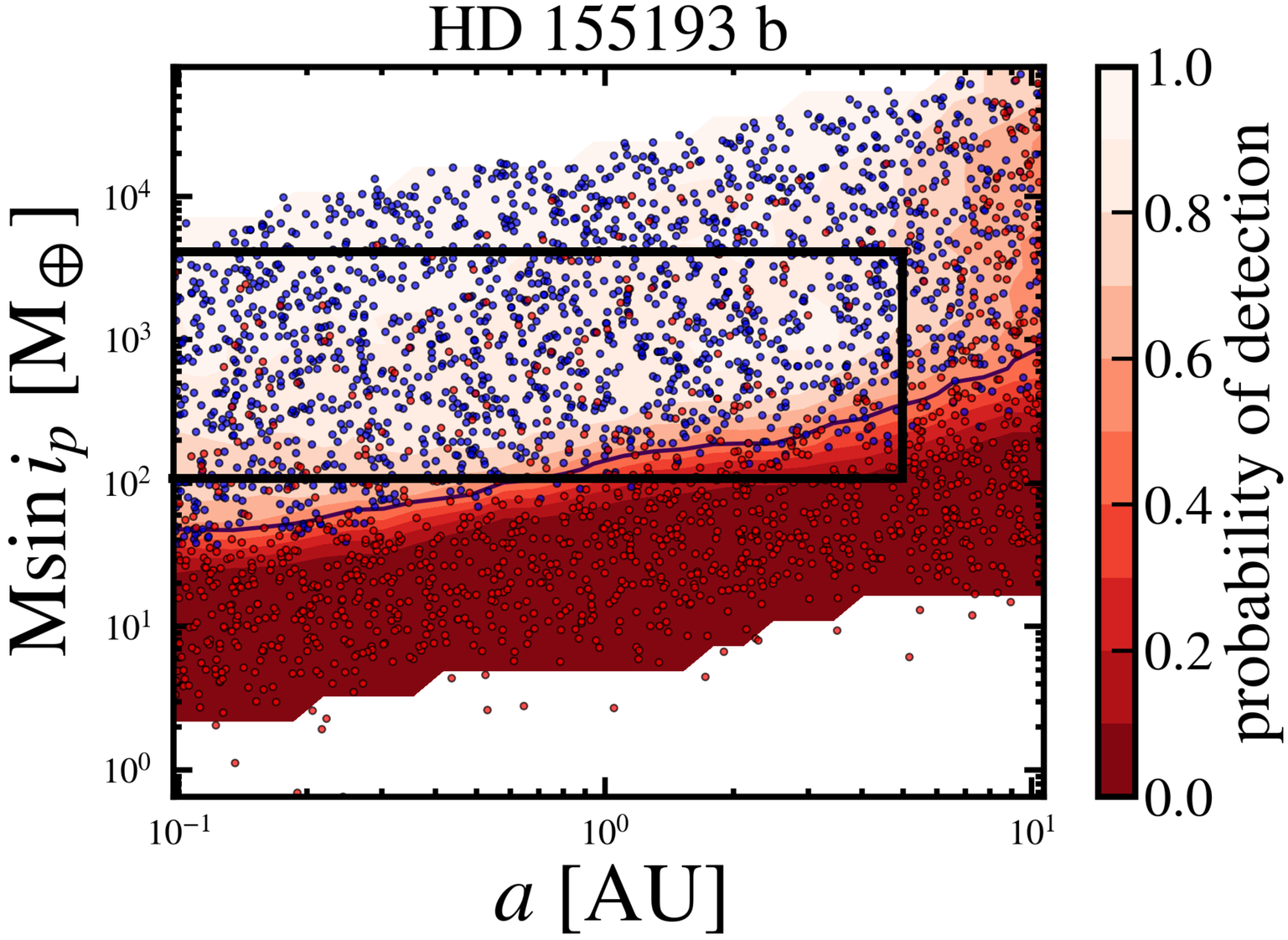

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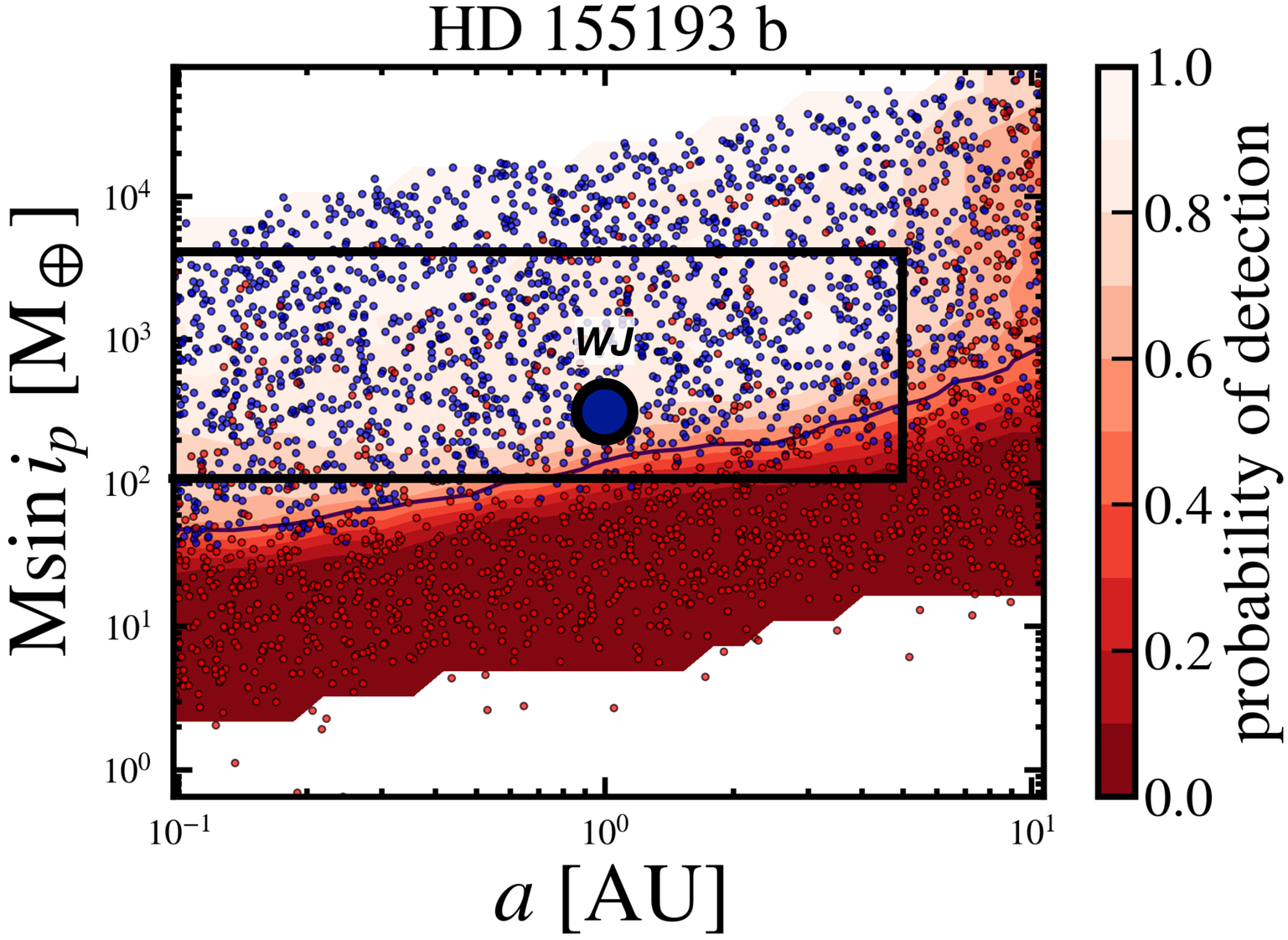

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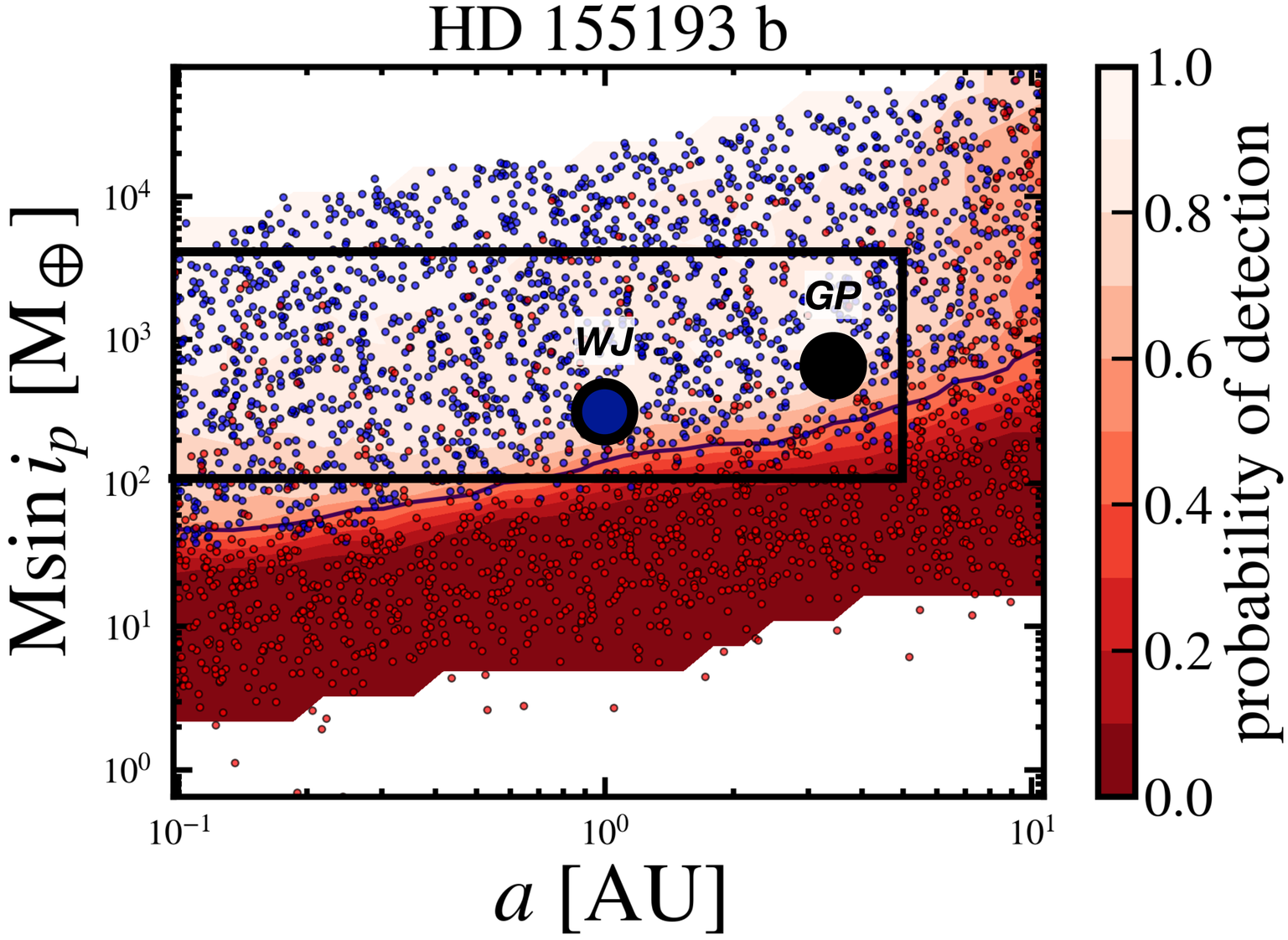

Attempt 2: Accounting for Sensitivity to an Additional Giant Planet

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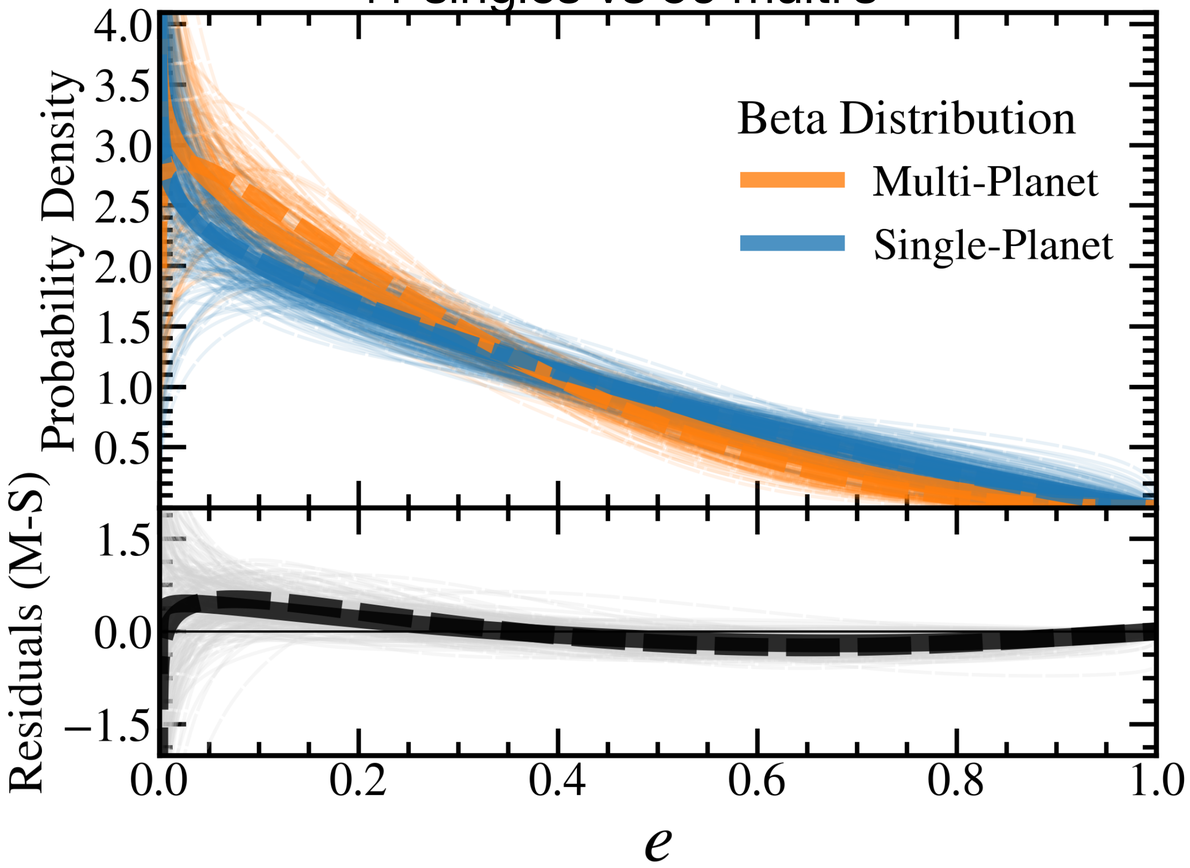
Sensitivity 0.1—1AU

41 singles vs 56 multi's



Morgan et al. in prep

Attempt 2: Accounting for Sensitivity to an Additional Giant Planet

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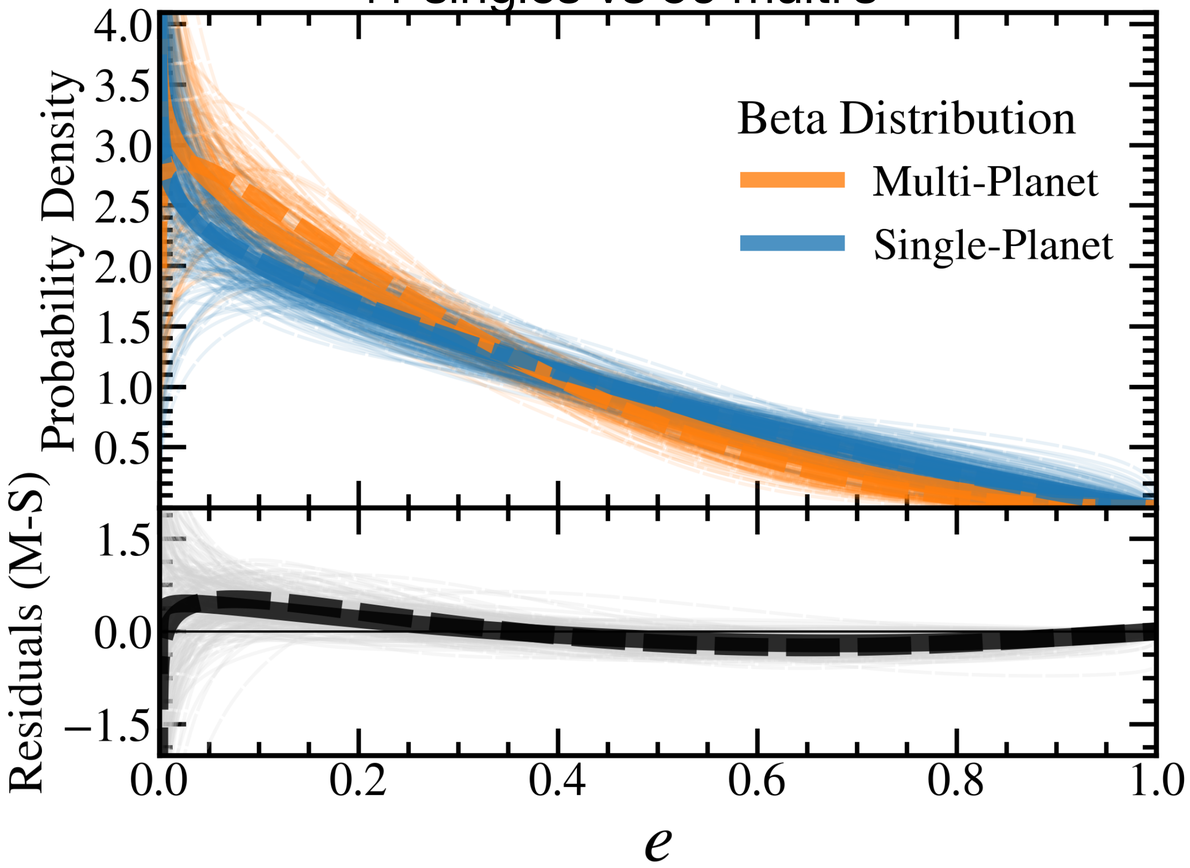
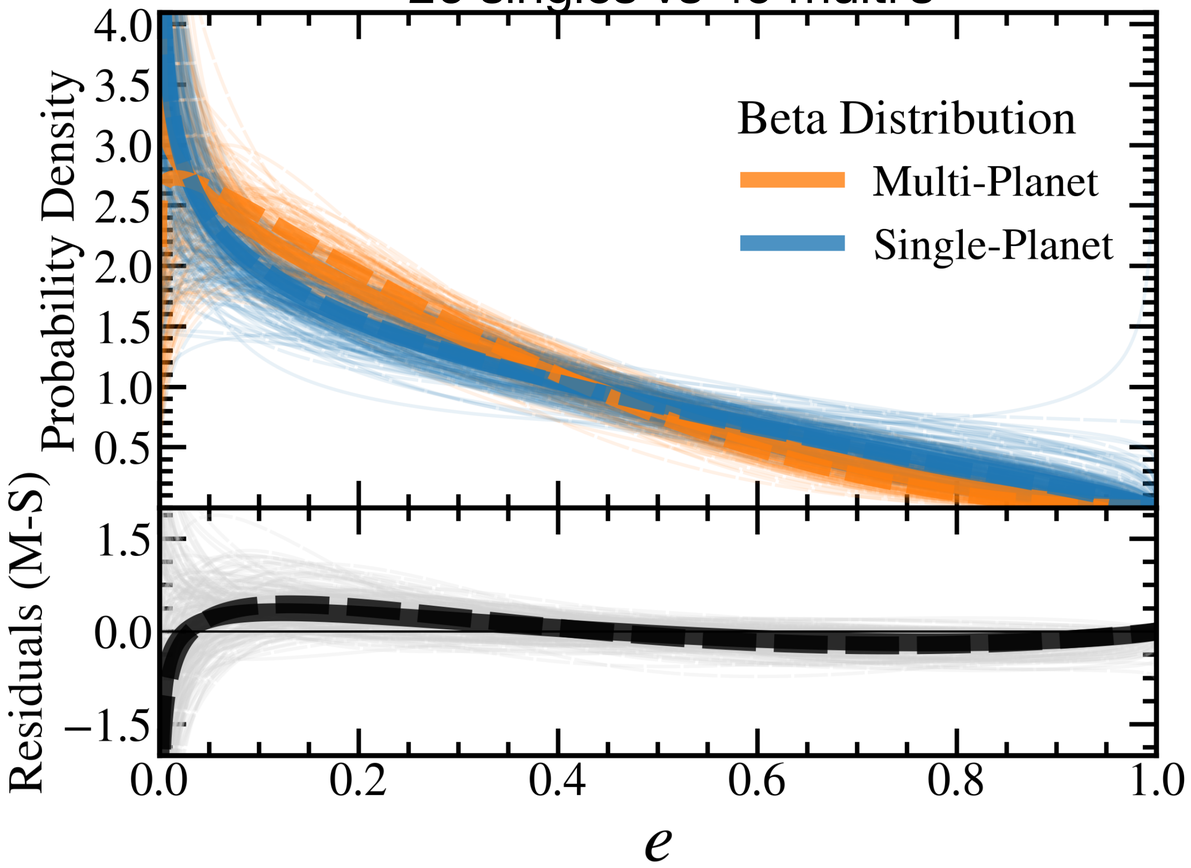


Sensitivity 0.1—5AU

26 singles vs 49 multi's



Morgan et al. in prep

Influence of Stellar Companions on Warm Jupiter Evolution

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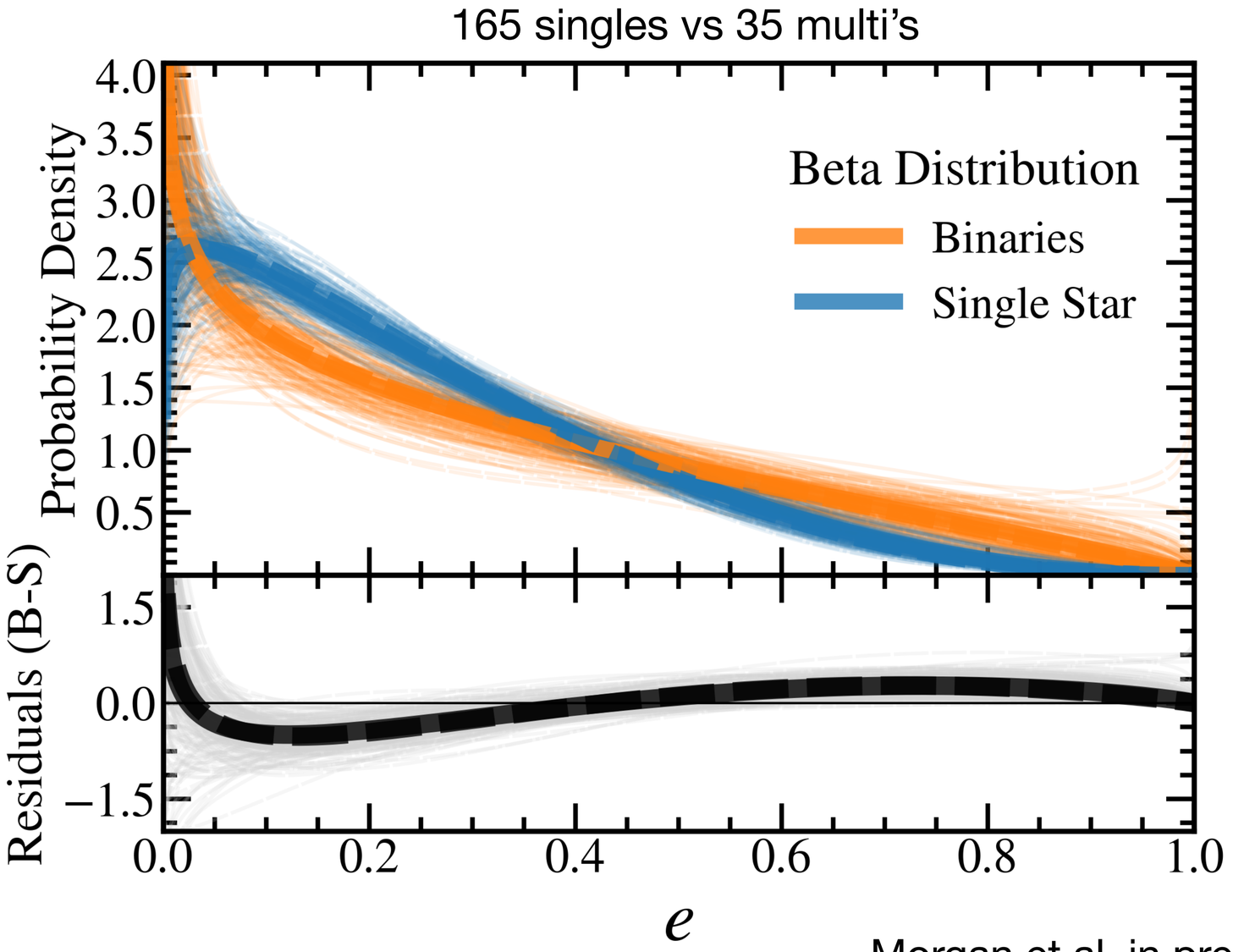
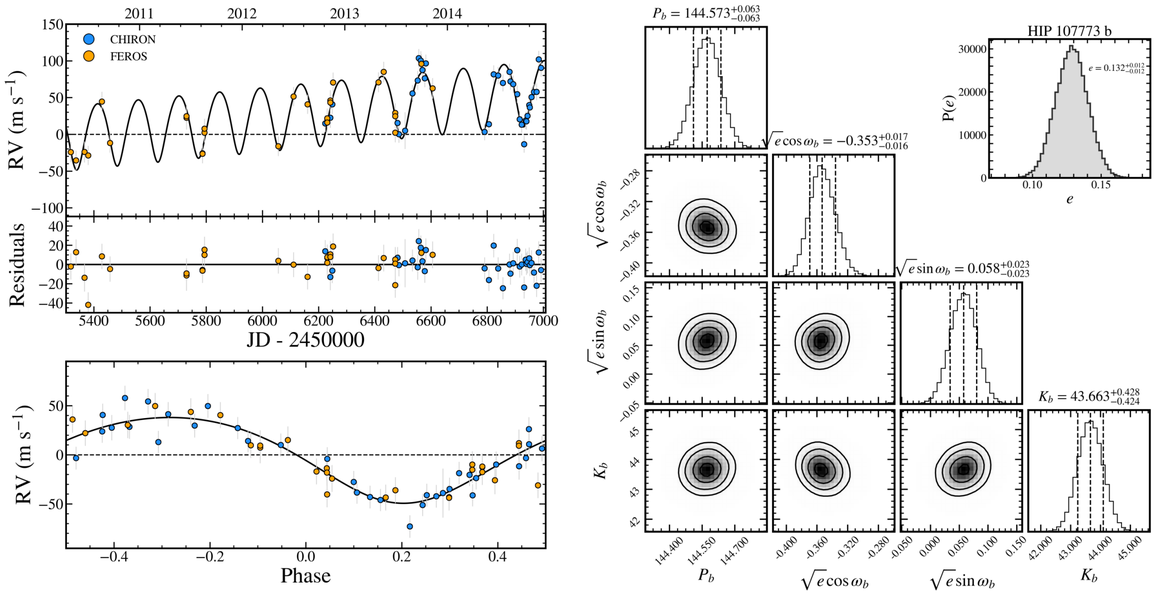


Morgan et al. in prep

Distant Long-Period Planets and Stellar Companions to Warm Jupiters

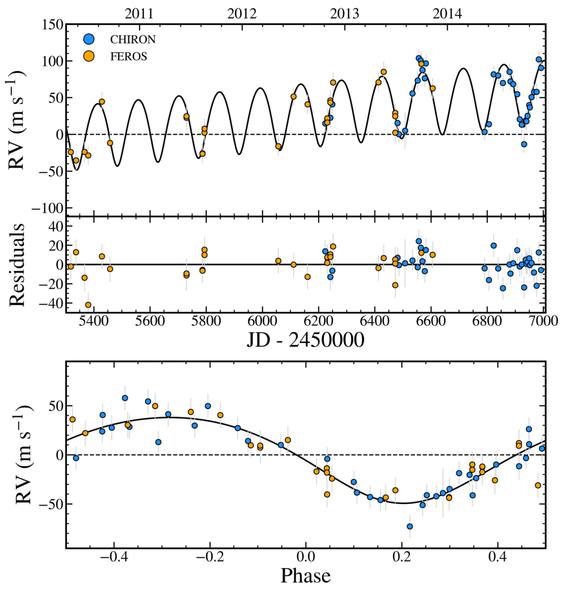
Distant Long-Period Planets and Stellar Companions to Warm Jupiters

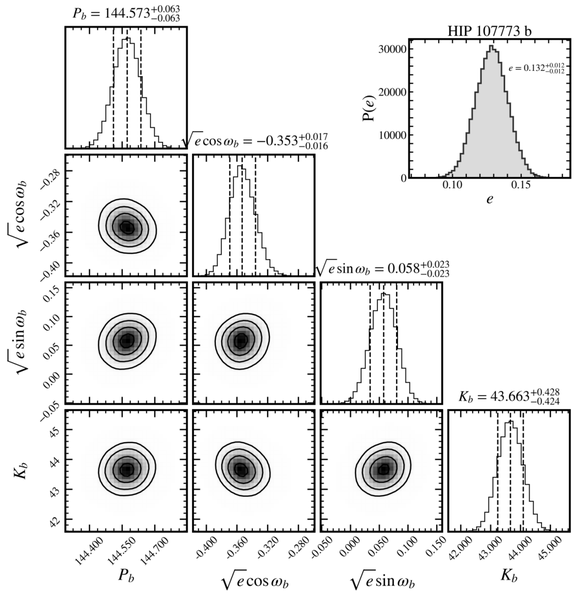
HIP 107773 b



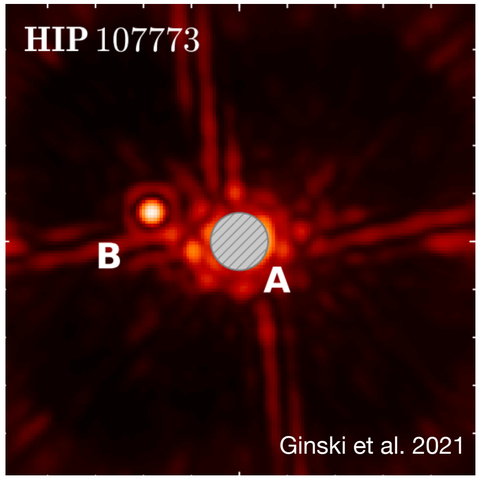
Distant Long-Period Planets and Stellar Companions to Warm Jupiters

HIP 107773 b





VLT/SPHERE

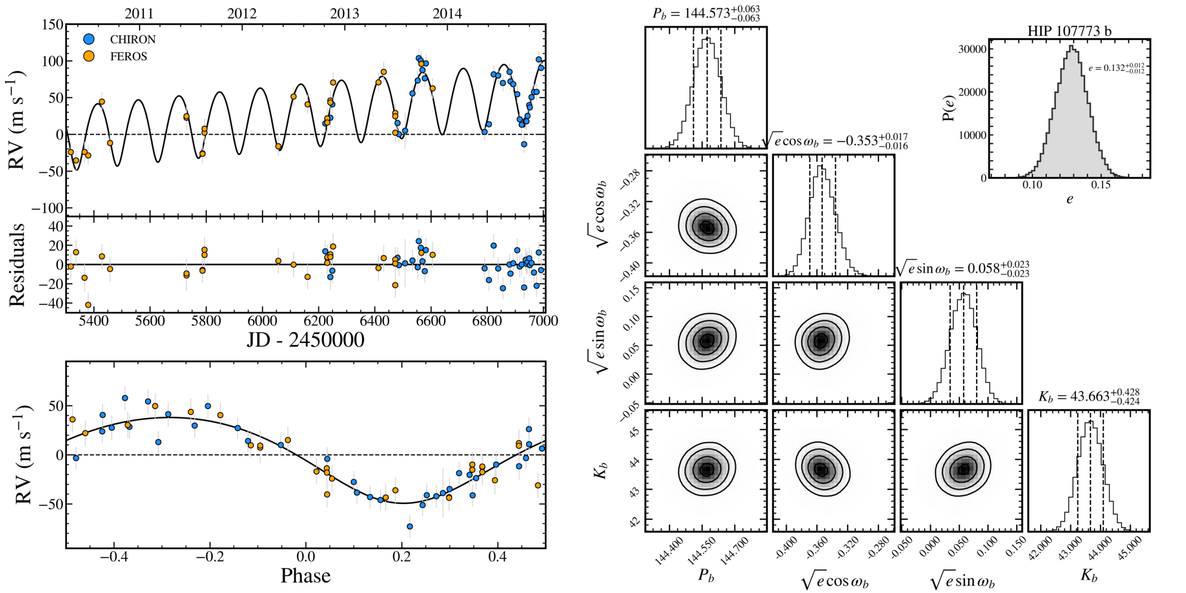


$\dot{\gamma} = 13.49^{+0.35}_{-0.36}\,\mathrm{m\,s^{-1}\,yr^{-1}}$

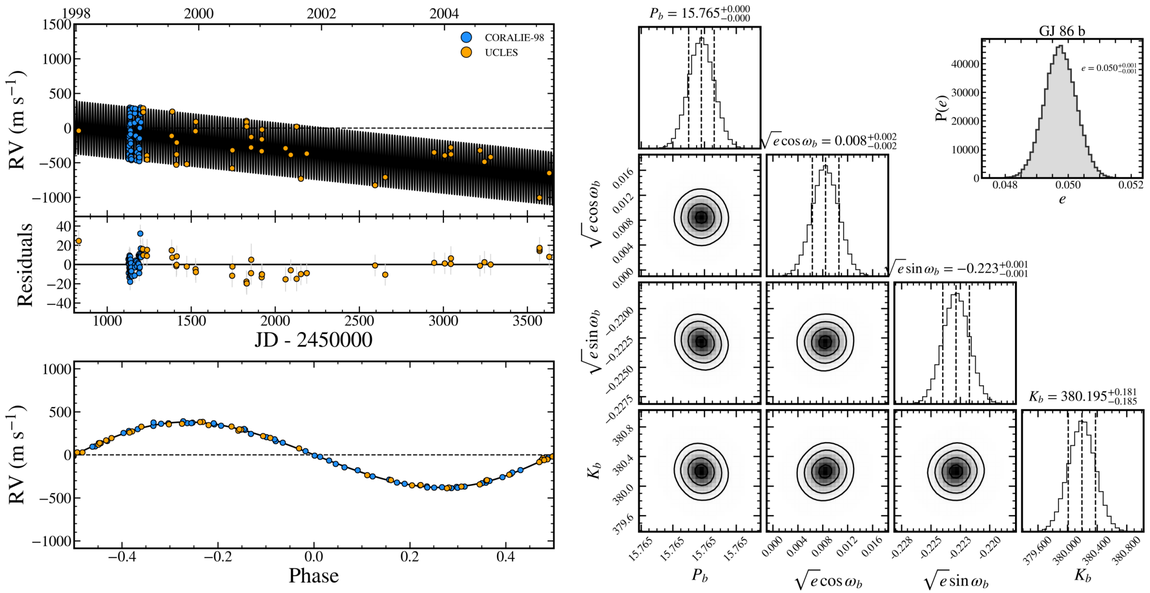
0.63 $M_\odot$ at 40 AU

Distant Long-Period Planets and Stellar Companions to Warm Jupiters

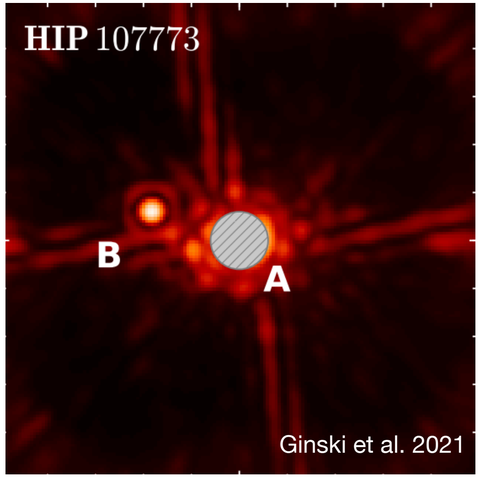
HIP 107773 b



GJ 86 b



VLT/SPHERE



$$\dot{\gamma} = 13.49^{+0.35}_{-0.36}\,\mathrm{m\,s^{-1}\,yr^{-1}}$$

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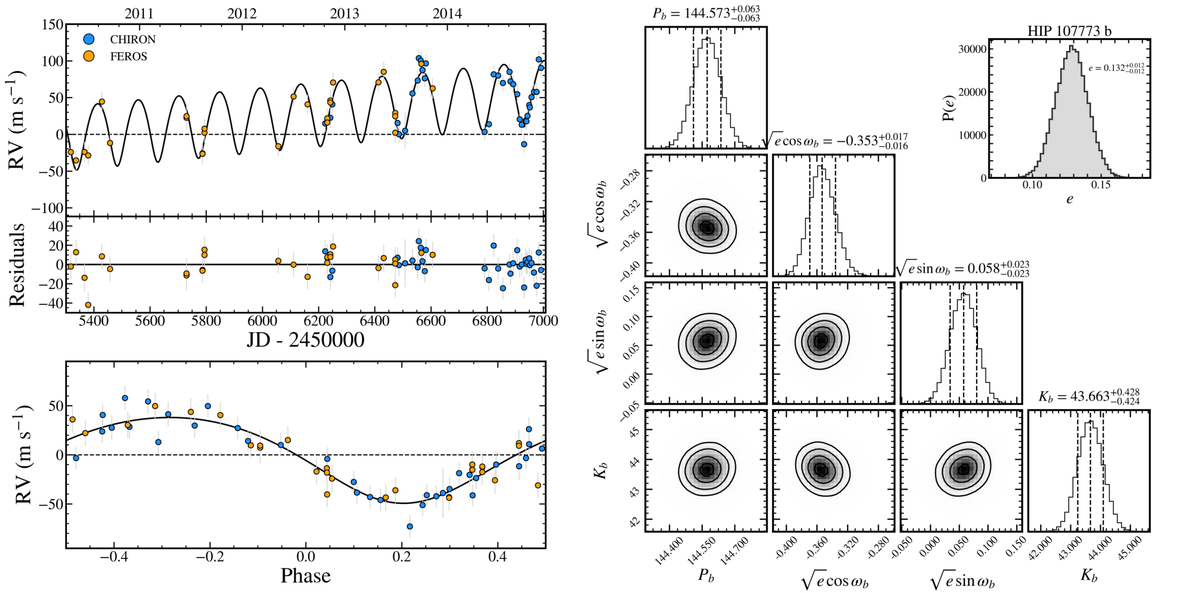
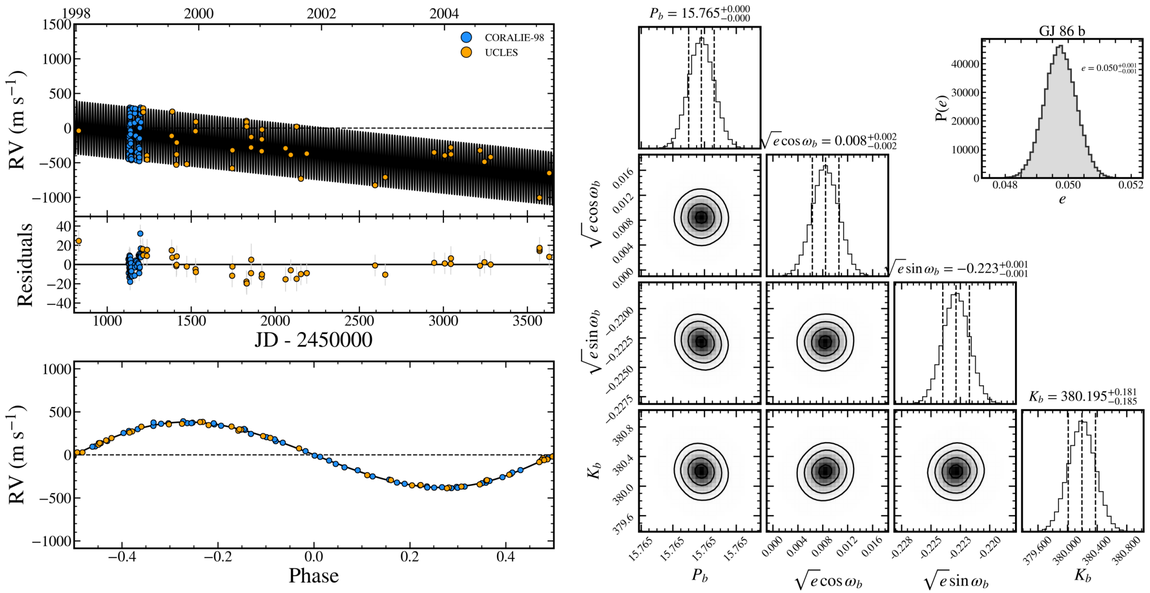
Distant Long-Period Planets and Stellar Companions to Warm Jupiters

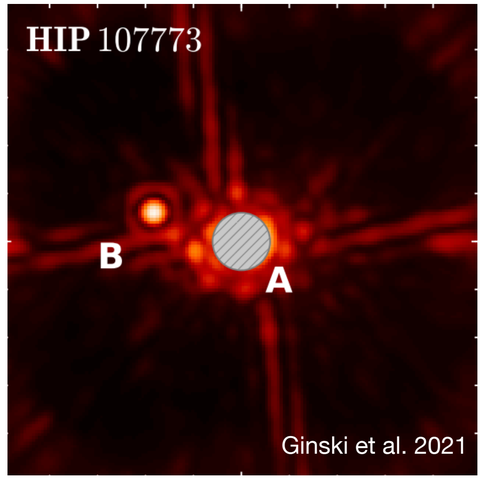
HIP 107773 b



GJ 86 b



VLT/SPHERE



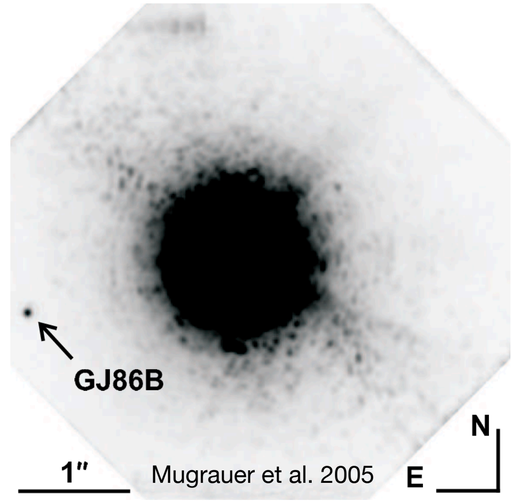
$$\dot{\gamma} = 13.49^{+0.35}_{-0.36}\,\mathrm{m\,s^{-1}\,yr^{-1}}$$

0.63 $M_\odot$ at 40 AU

$$\dot{\gamma} = -113.77^{+0.23}_{-0.22}\,\mathrm{m\,s^{-1}\,yr^{-1}}$$

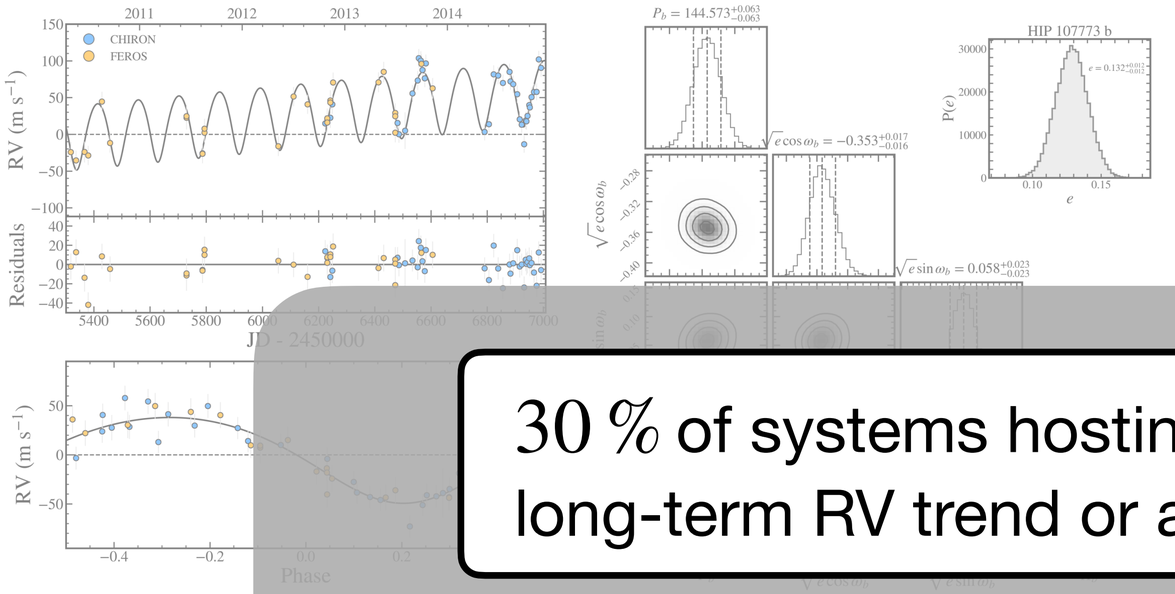
0.54 $M_\odot$ at 24 AU

VLT/SDI

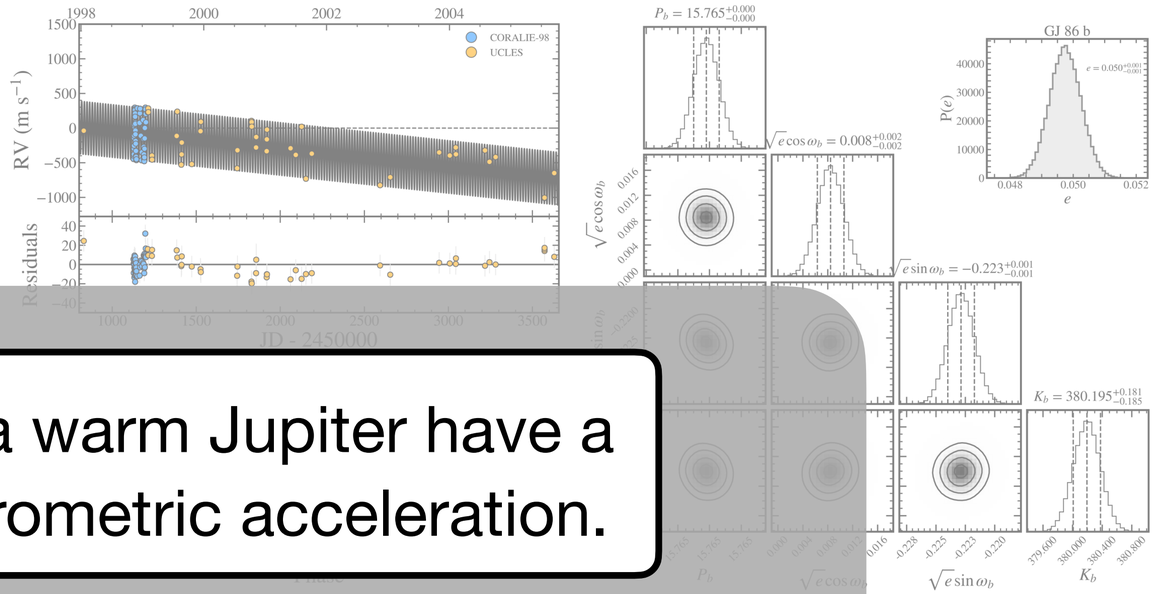


Distant Long-Period Planets and Stellar Companions to Warm Jupiters

HIP 107773 b



GJ 86 b

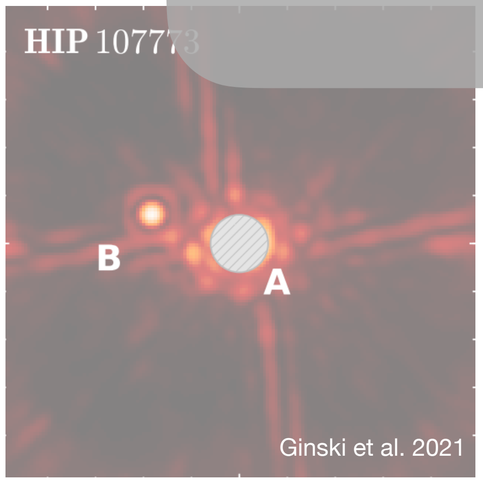


30 % of systems hosting a warm Jupiter have a long-term RV trend or astrometric acceleration.

Morgan et al. in prep

VLT/SPHERE

VLT/SDI



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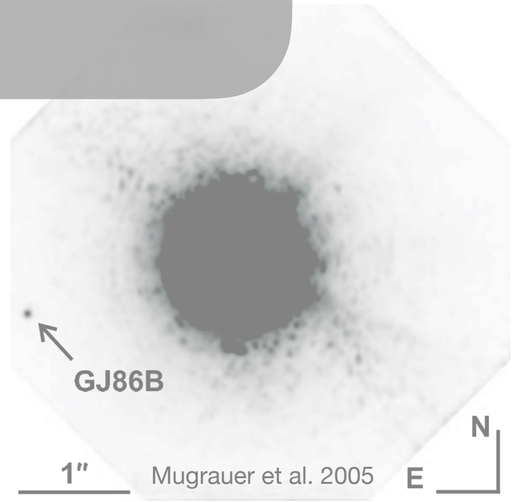
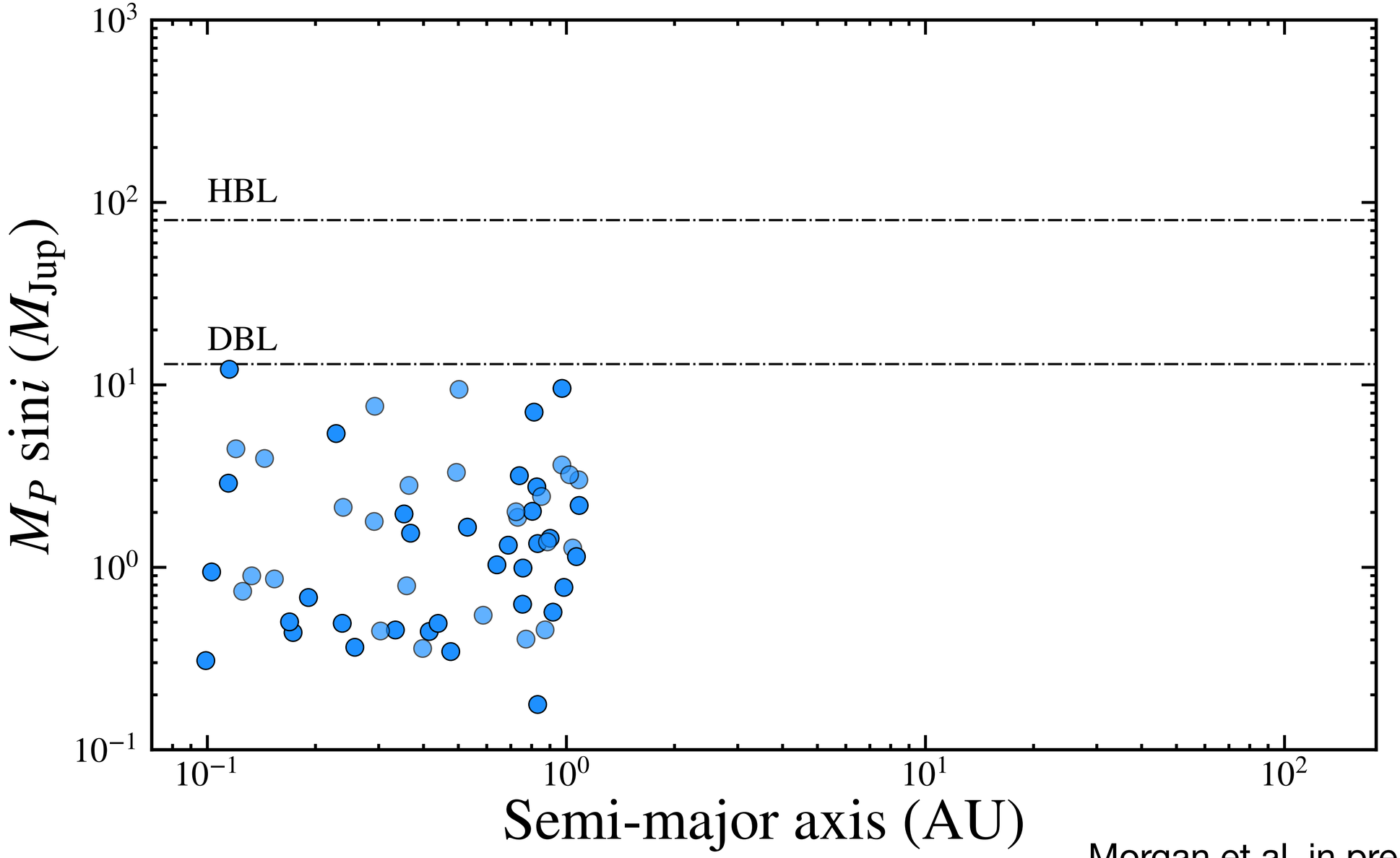
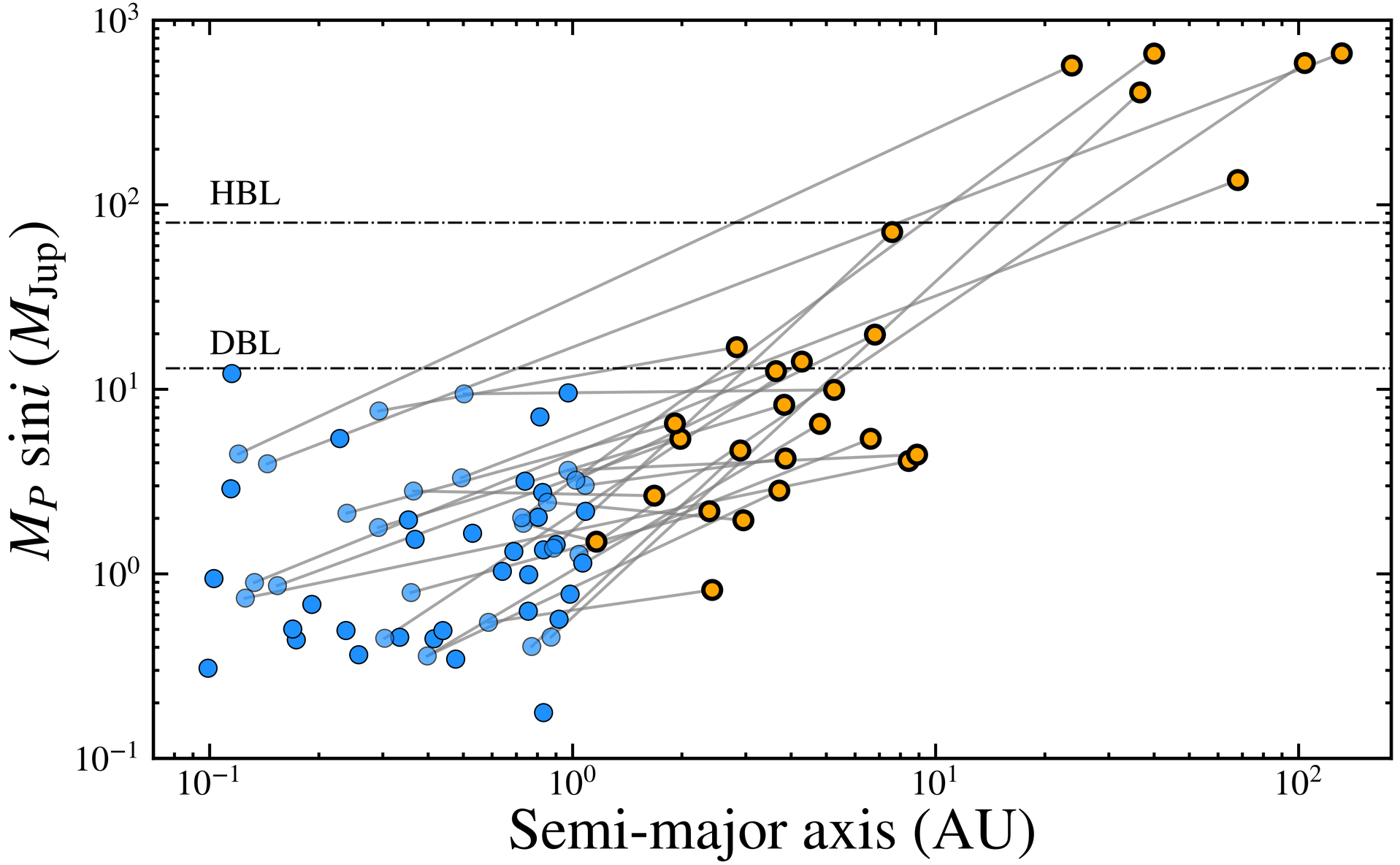


Accelerating Warm Jupiter Host Stars

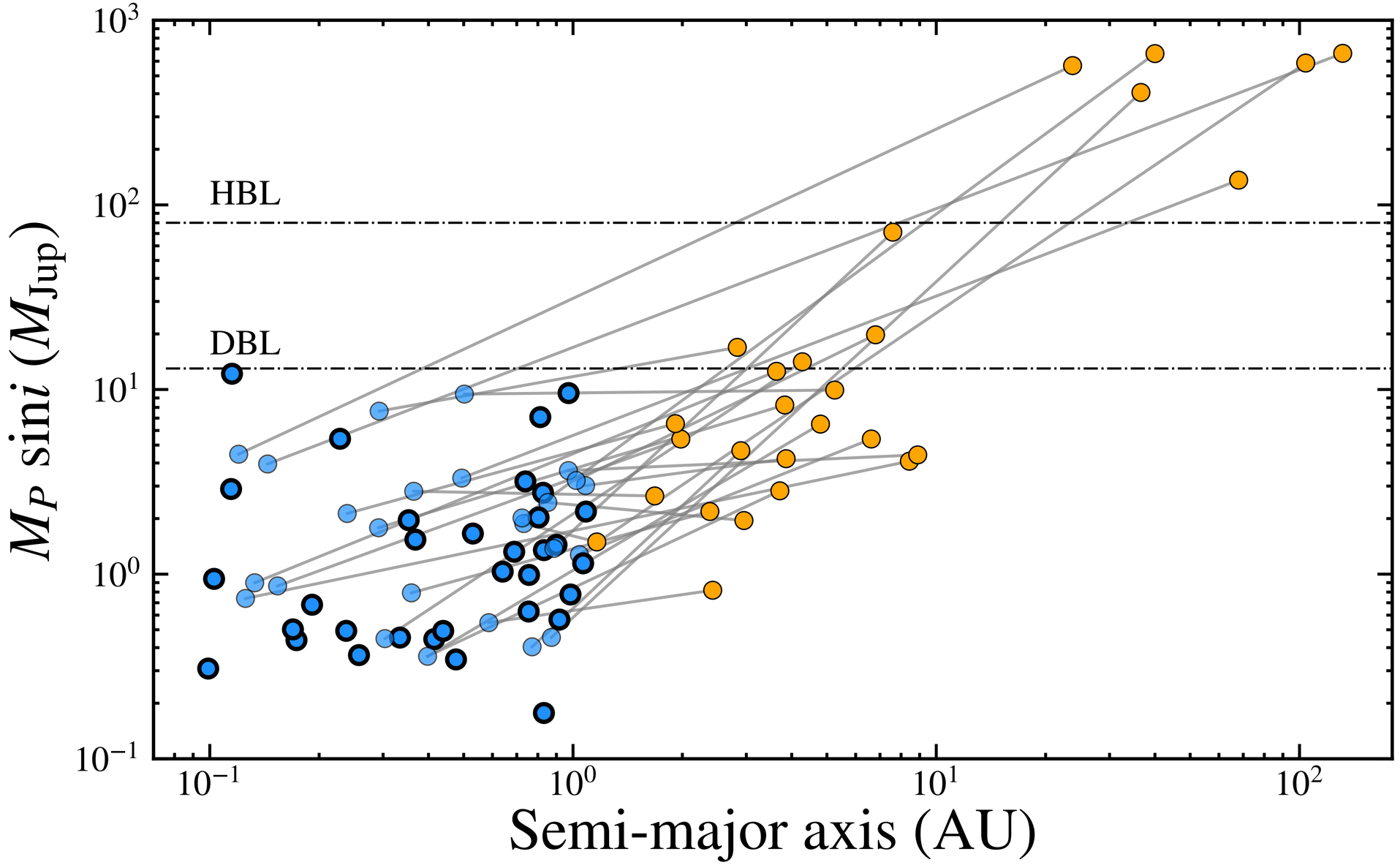


Morgan et al. in prep

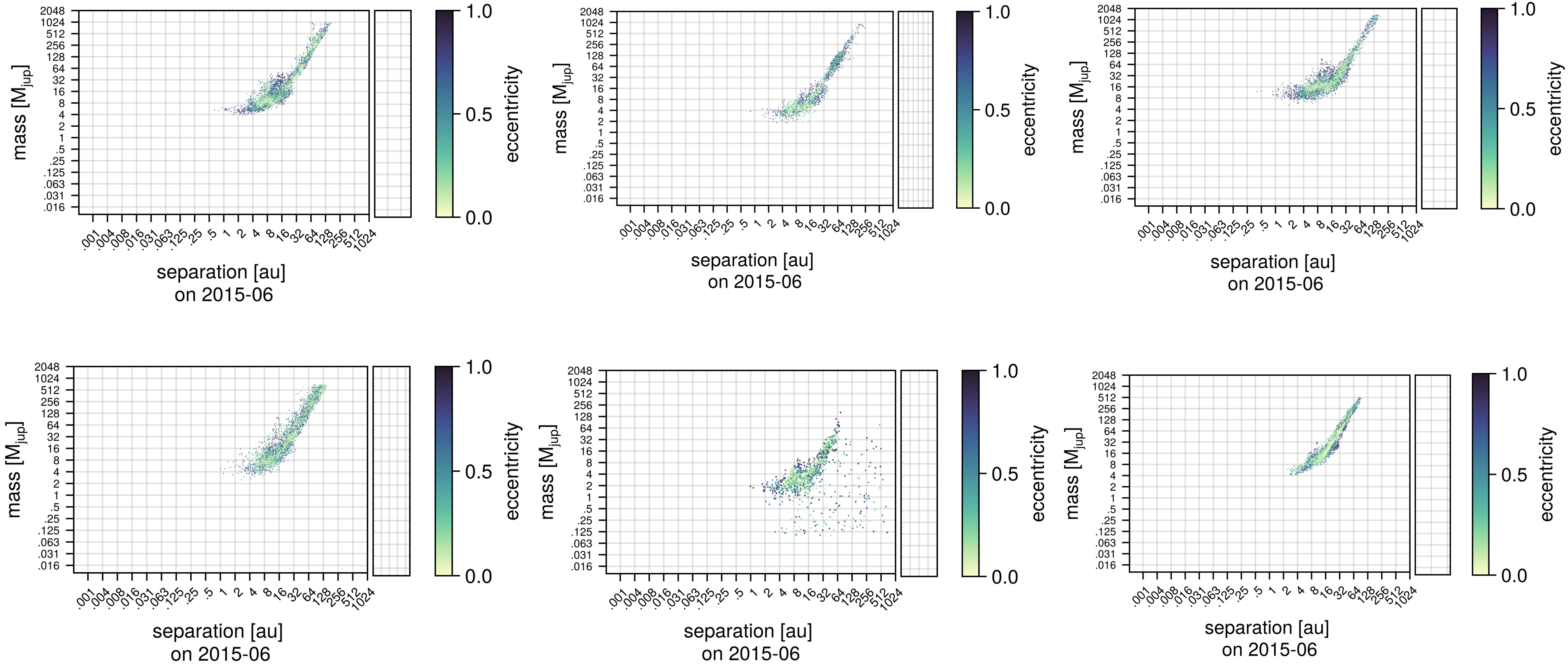
Accelerating Warm Jupiter Host Stars



Accelerating Warm Jupiter Host Stars

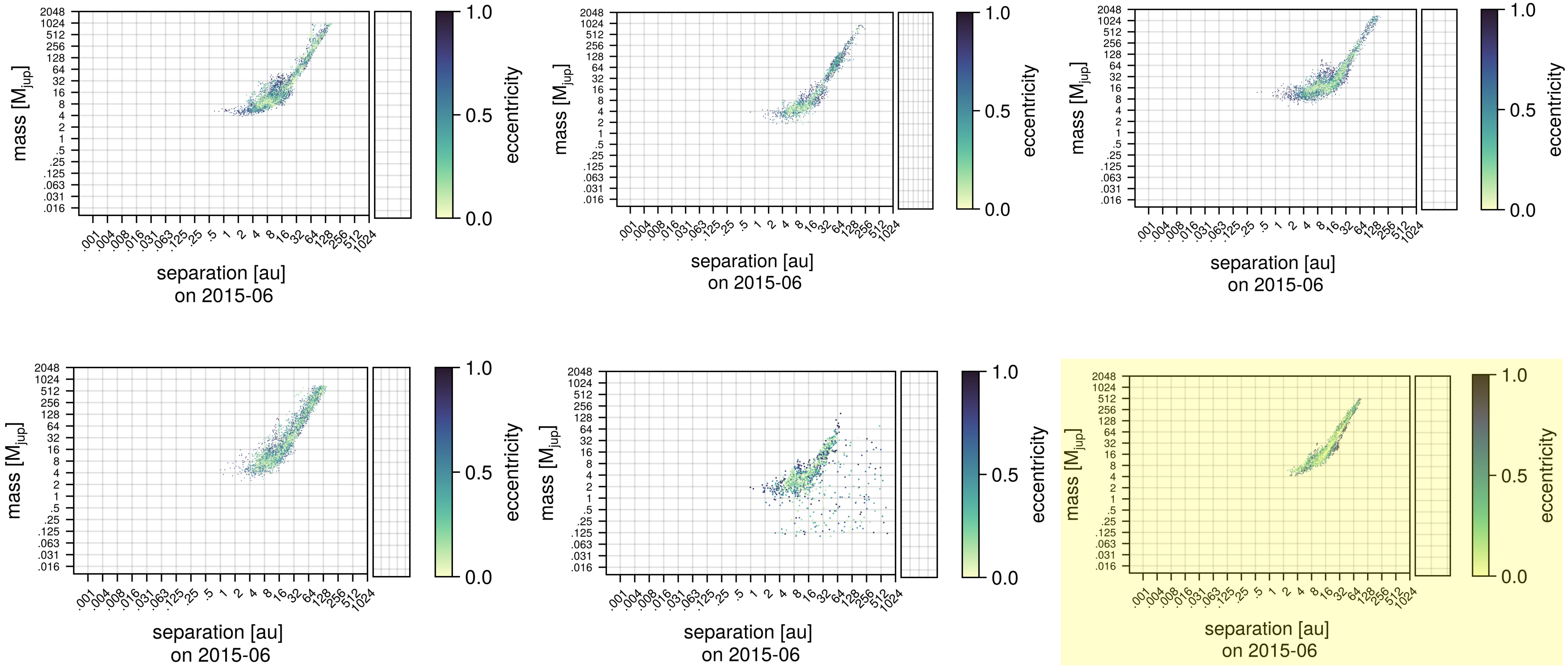


Constraining Mass and Separations of Companions to Warm Jupiters



Octofitter G23H ; Thompson, Blakely et al. 2026

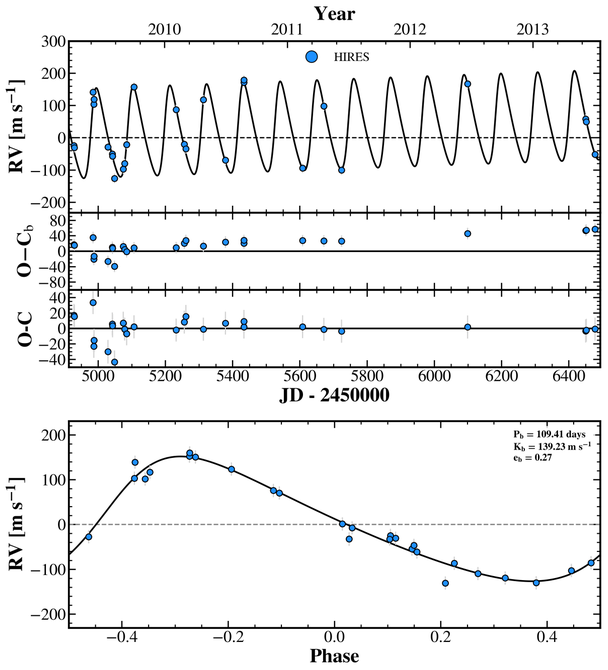
Constraining Mass and Separations of Companions to Warm Jupiters

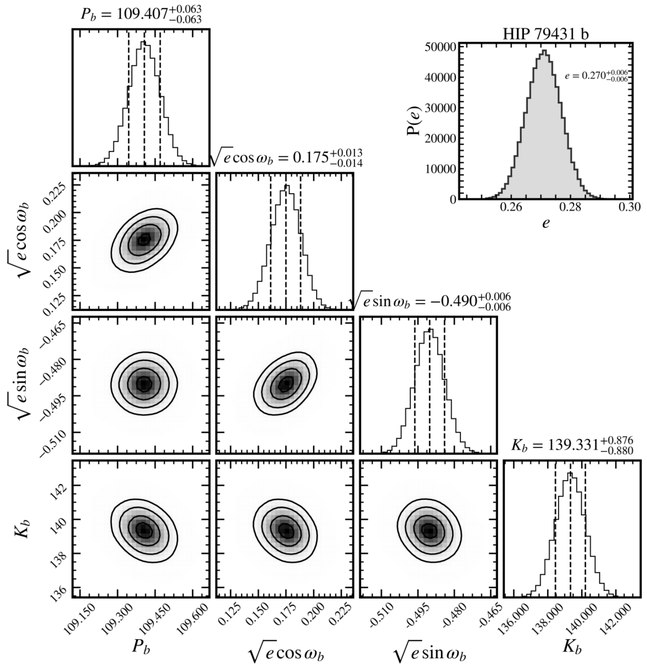


Octofitter G23H ; Thompson, Blakely et al. 2026

Imaging a Hidden Super-Jupiter Accelerating HIP 79431

HIP 79431 b





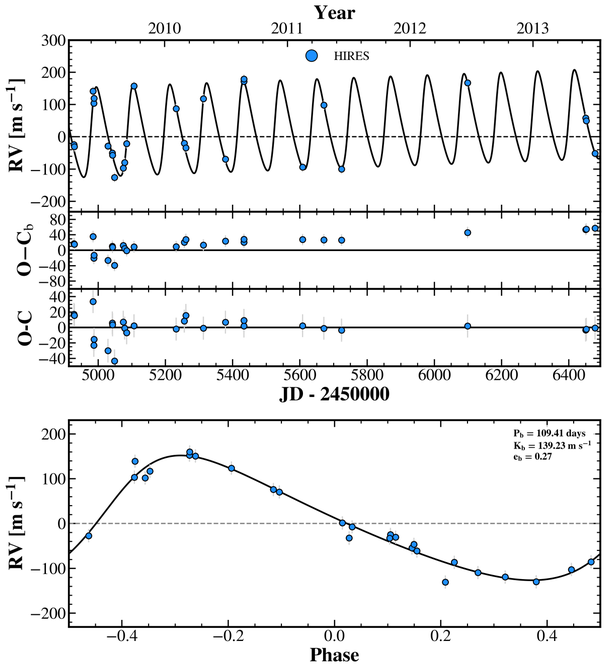
$$\dot{\gamma} = 13.67^{+0.89}_{-0.91}\ \mathrm{m\,s^{-1}\,yr^{-1}}$$

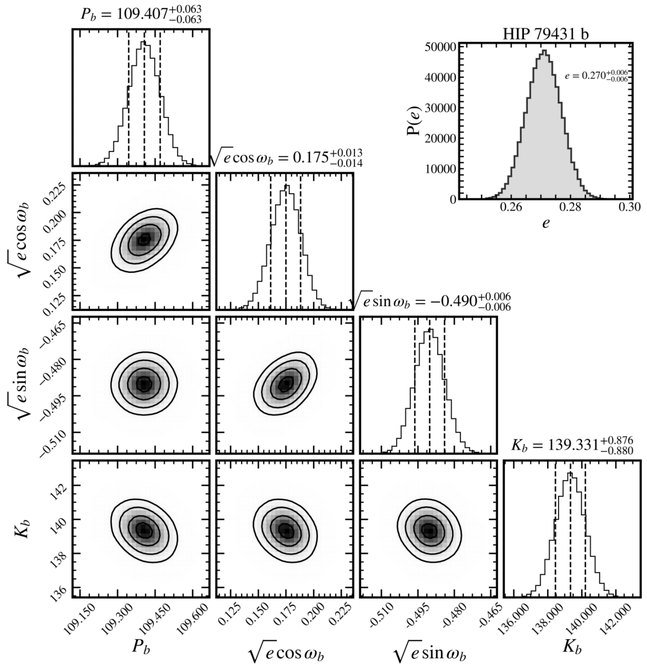
HGCA = $9.89^{+0.52}_{-0.52}\ \mathrm{m\,s^{-1}\,yr^{-1}}$

- [Fe/H] = 0.4 dex
- 0.49 $M_\odot$; M3V
- 14.56 pc

Imaging a Hidden Super-Jupiter Accelerating HIP 79431

HIP 79431 b





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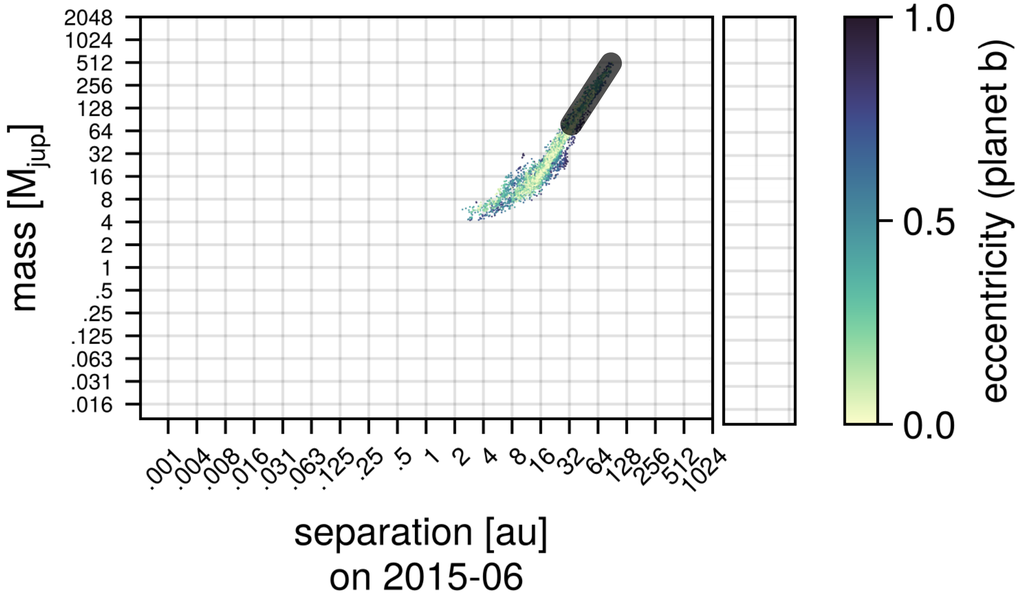
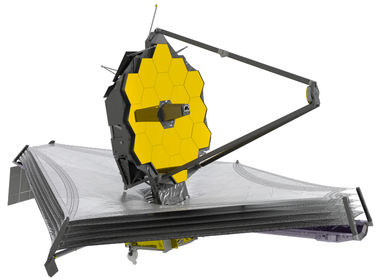
JWST MIRI C4 GO 9091 PI: Morgan

$$a = 14^{+22}_{-8}\,\mathrm{AU} \quad m_p \sin i = 13^{+29}_{-6}\,\mathrm{M_{Jup}}$$





Imaging a Hidden Super-Jupiter Accelerating HIP 79431

HIP 79431 b

JWST MIRI C4 GO 9091 PI: Morgan

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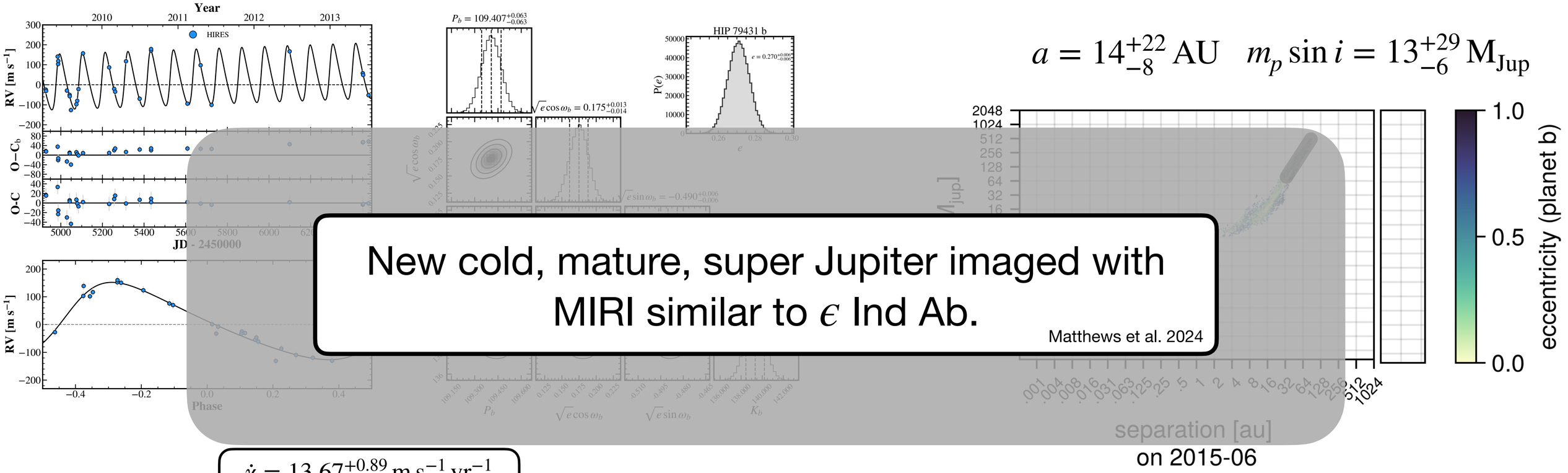

New cold, mature, super Jupiter imaged with MIRI similar to ϵ Ind Ab.

Matthews et al. 2024

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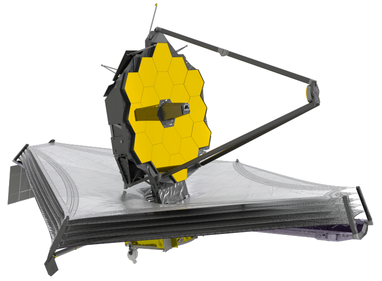

Conclusions

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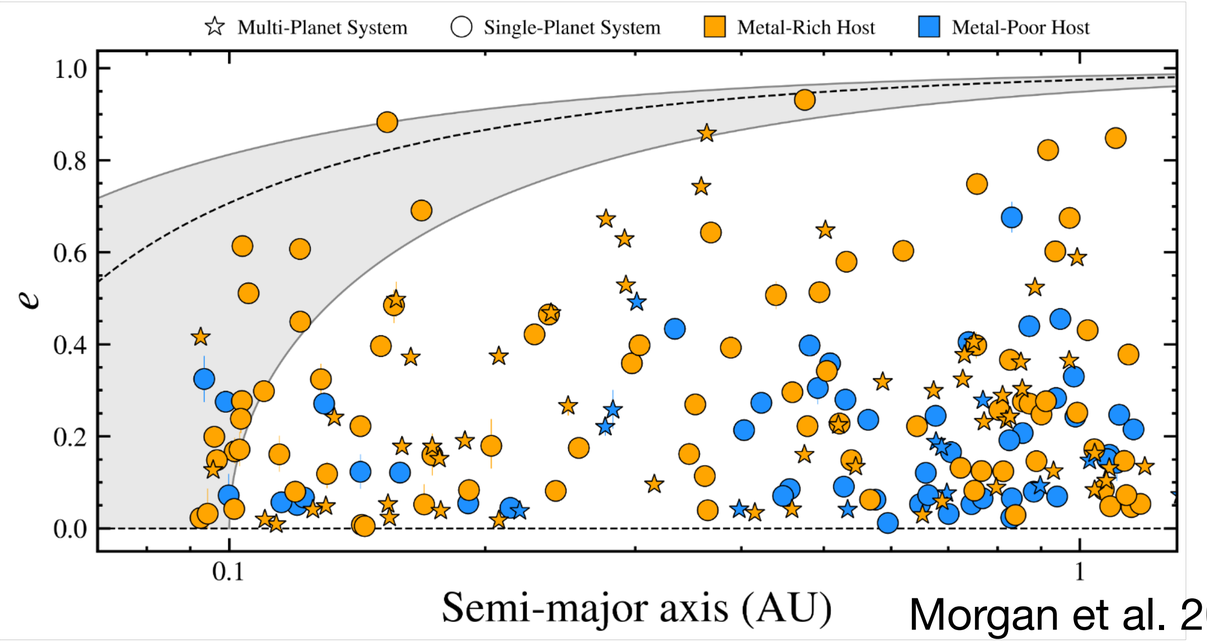
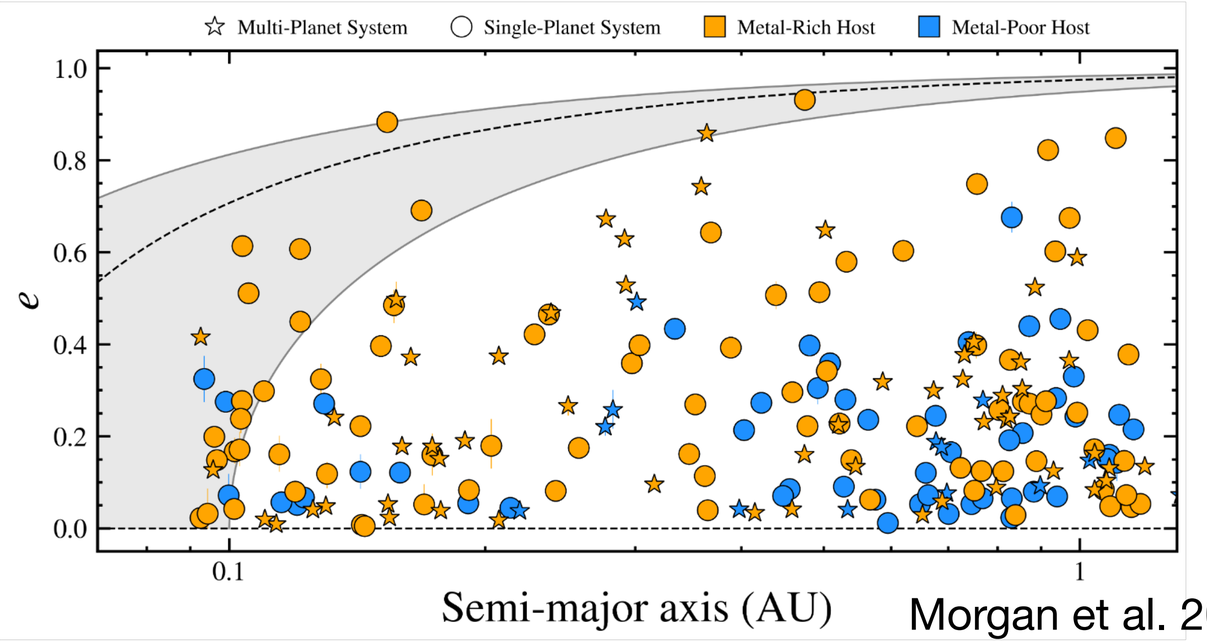
- Scattering plays a dominant role in shaping the orbits of most warm Jupiters.



Morgan et al. 2025, 2026a

Conclusions

- Scattering plays a dominant role in shaping the orbits of most warm Jupiters.
- [Fe/H] plays a more dominant role than M_* or orbital separation.



Morgan et al. 2025, 2026a

Conclusions

- Scattering plays a dominant role in shaping the orbits of most warm Jupiters.
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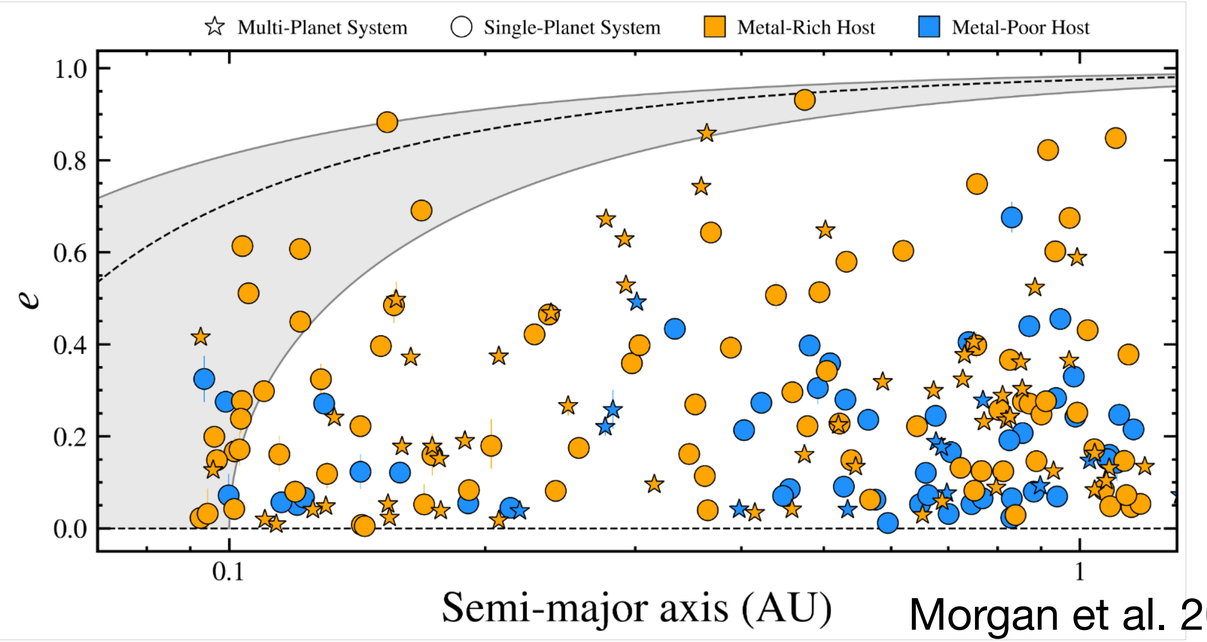

Morgan et al. 2025, 2026a

Conclusions

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- [Fe/H] plays a more dominant role than M_* or orbital separation.
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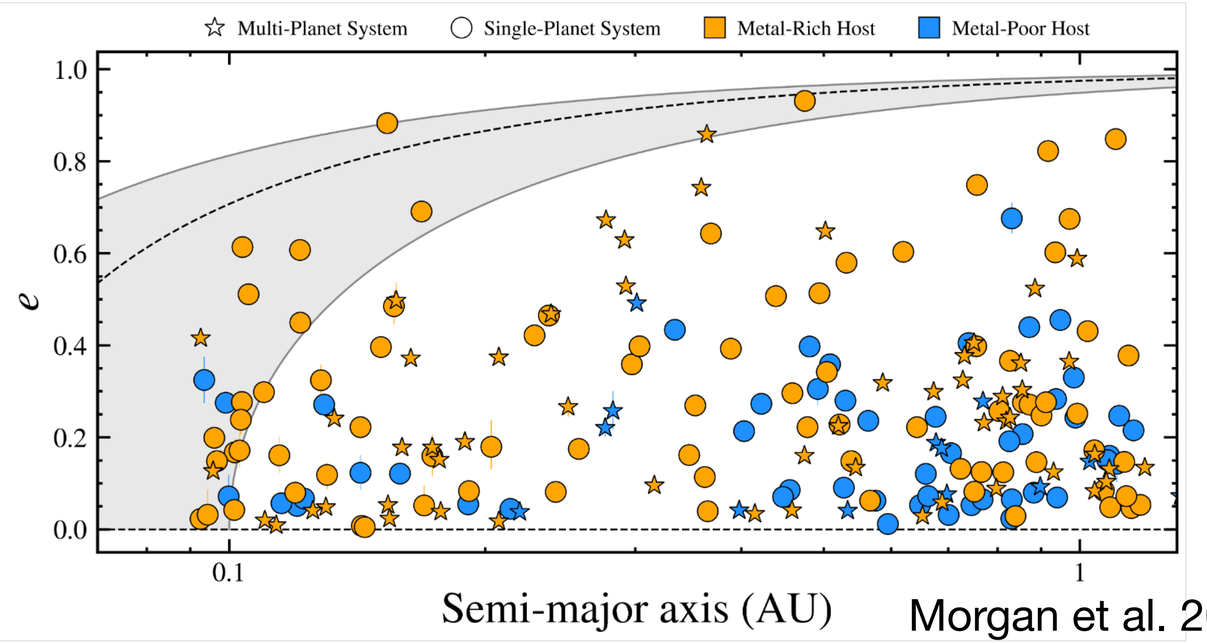
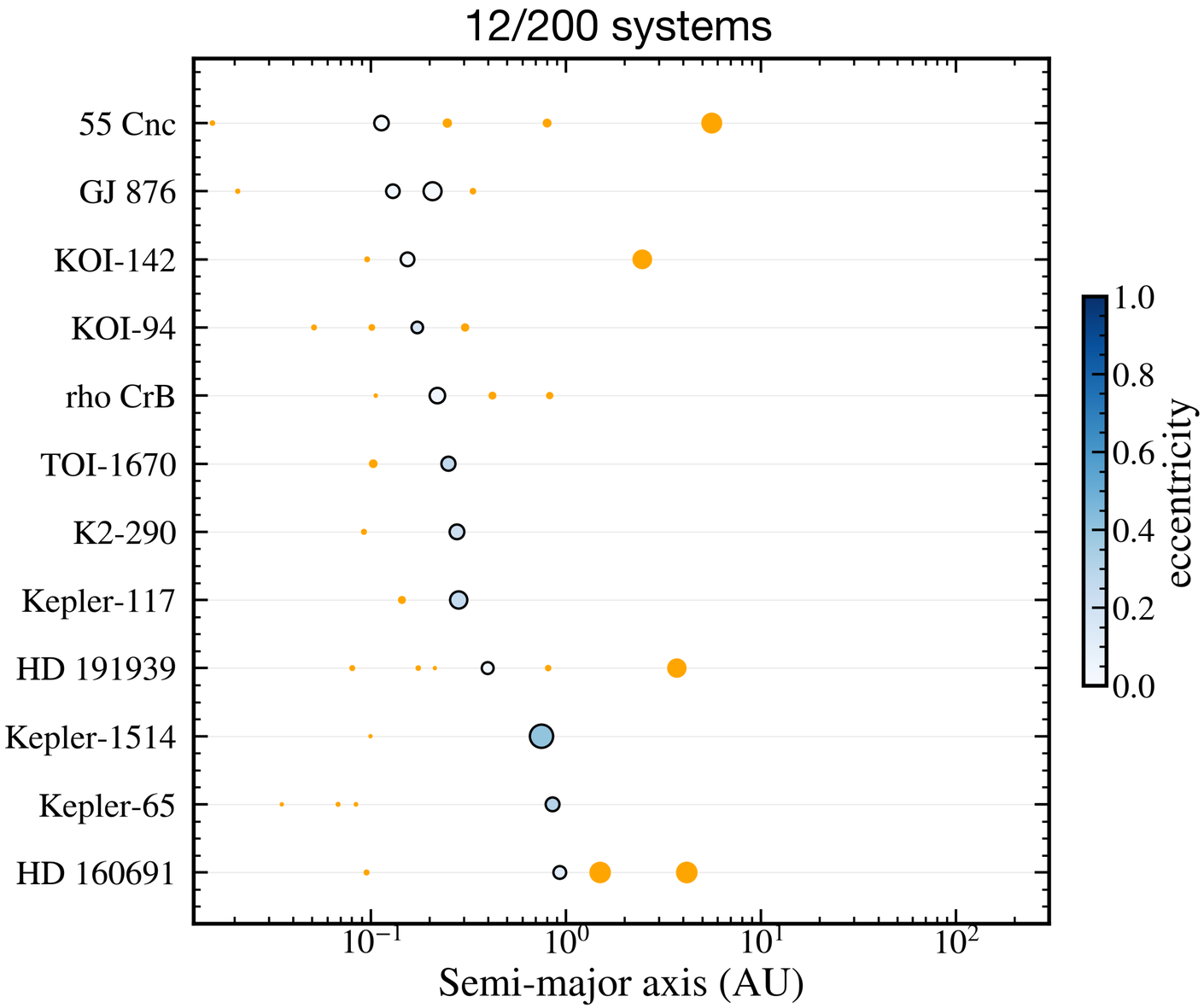
- Analyzing new substellar companions to accelerating WJ host stars.



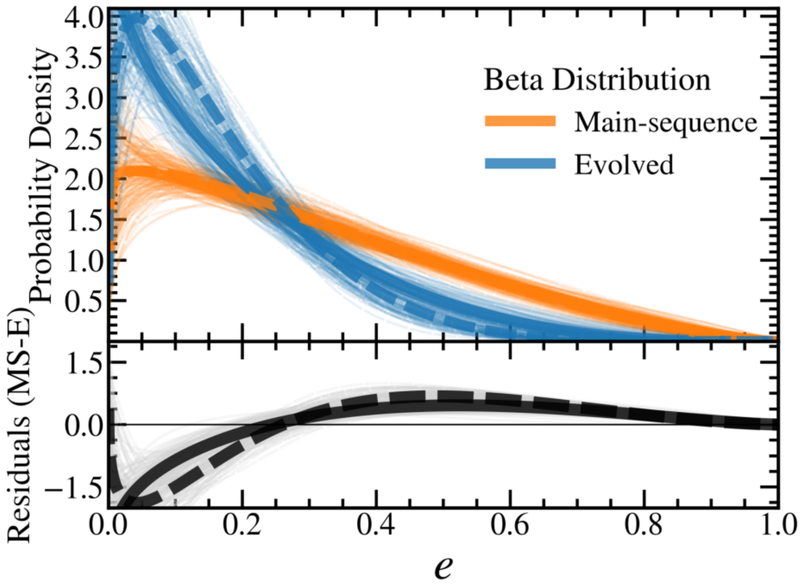
Morgan et al. 2025, 2026a

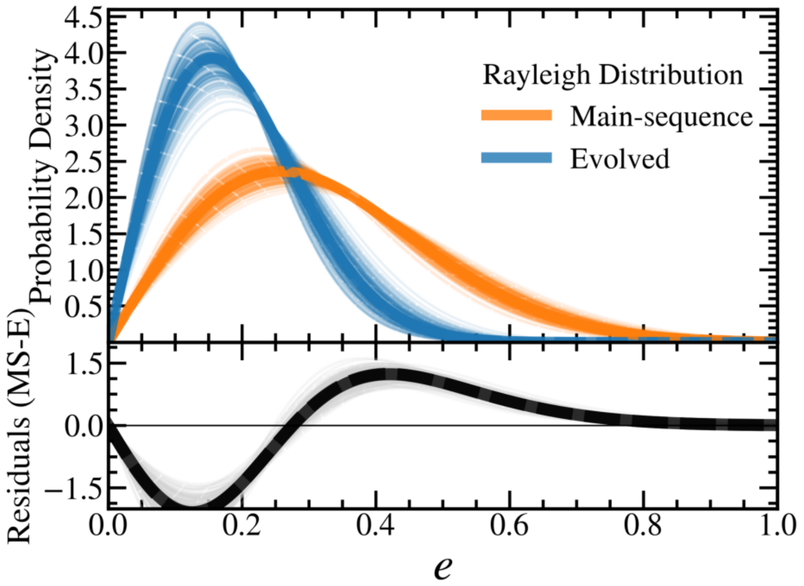
Influence of Warm Jupiters on Inner SuperEarths and SubNeptunes

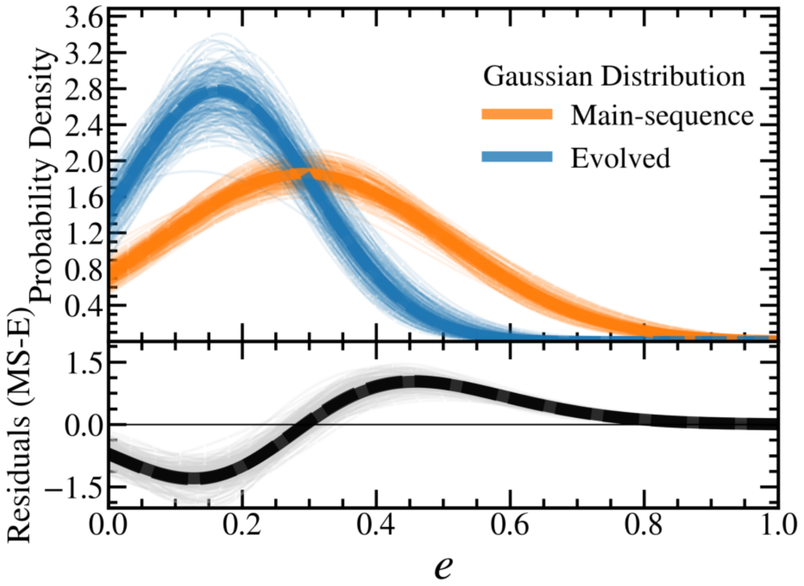


Key Results from Exploring Warm Jupiter Migration with Eccentricities

Evolutionary Phase Comparison







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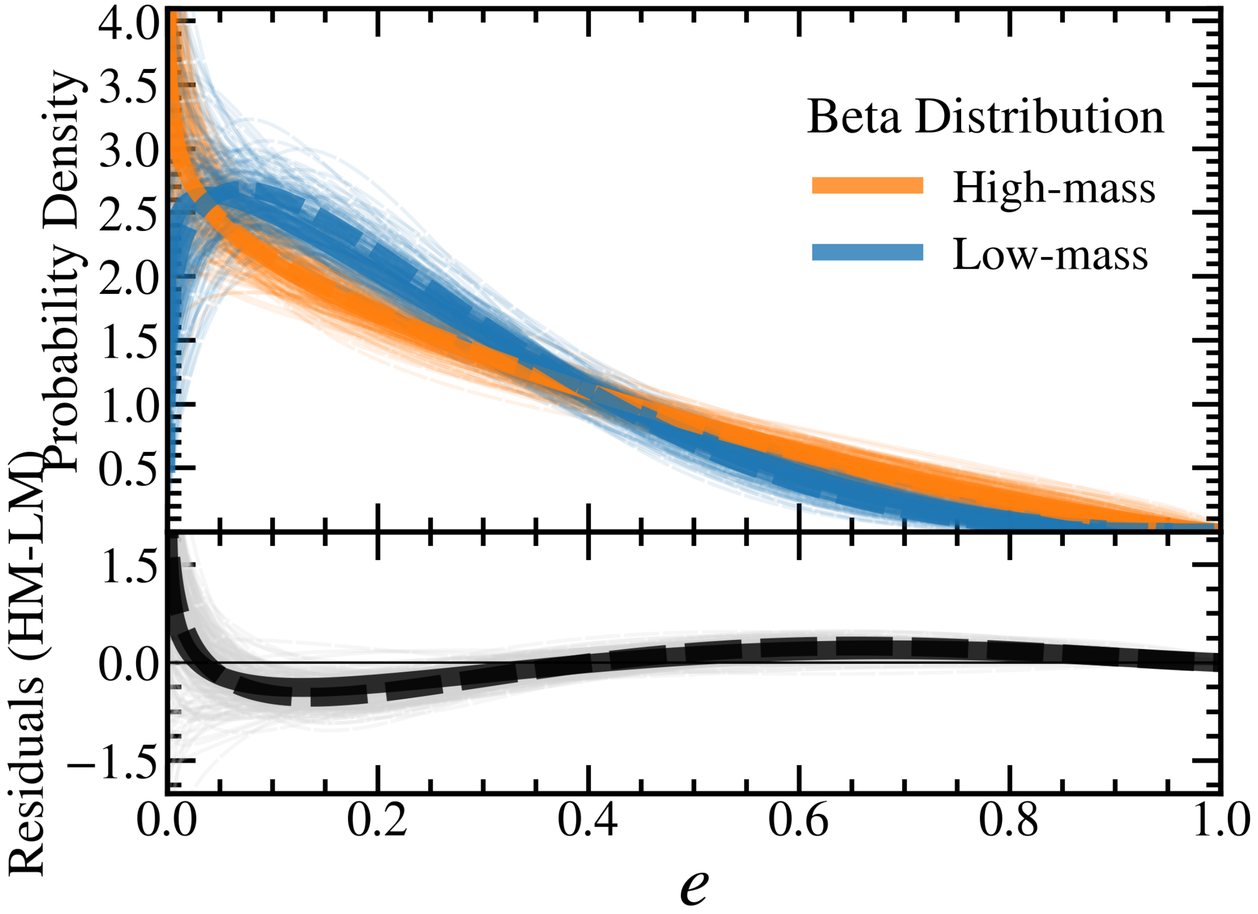
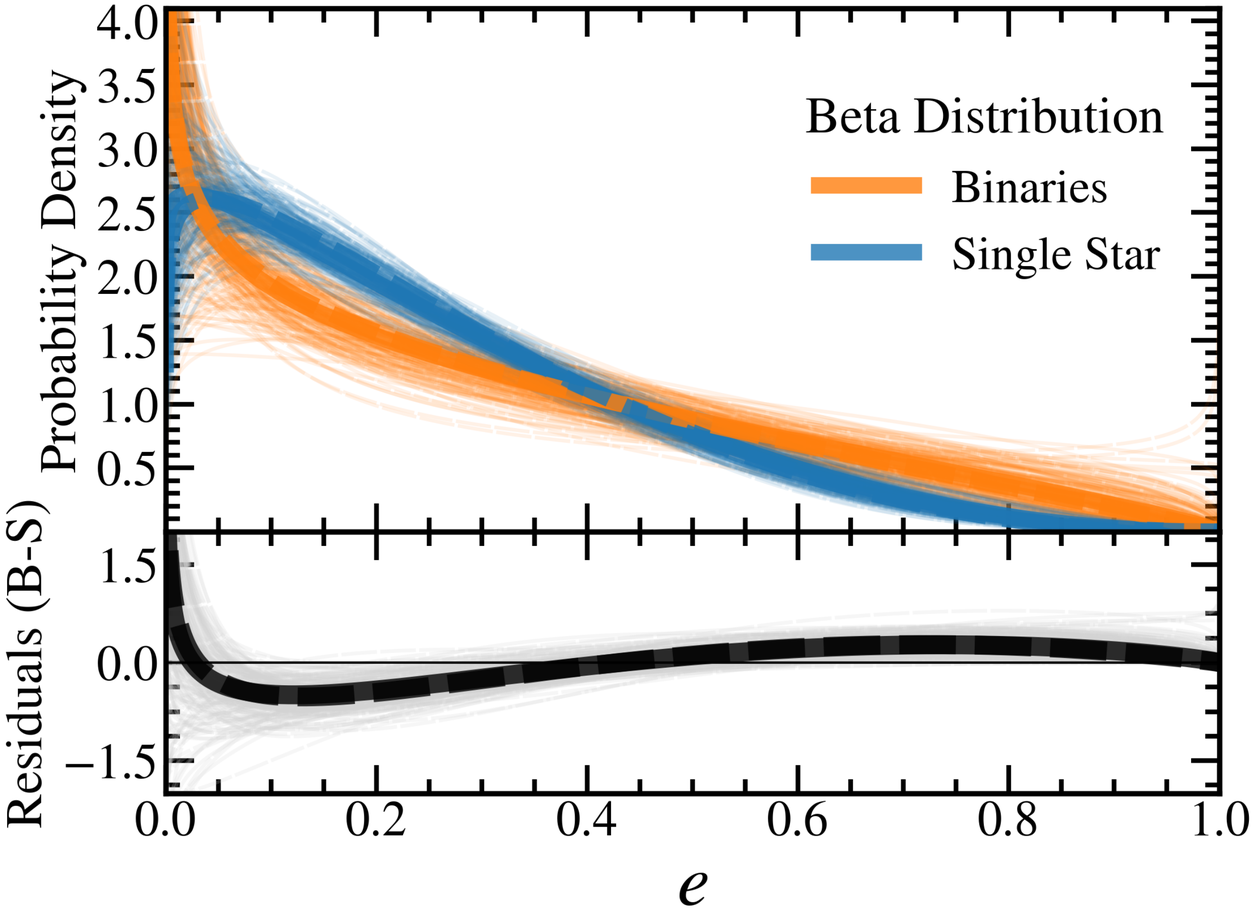
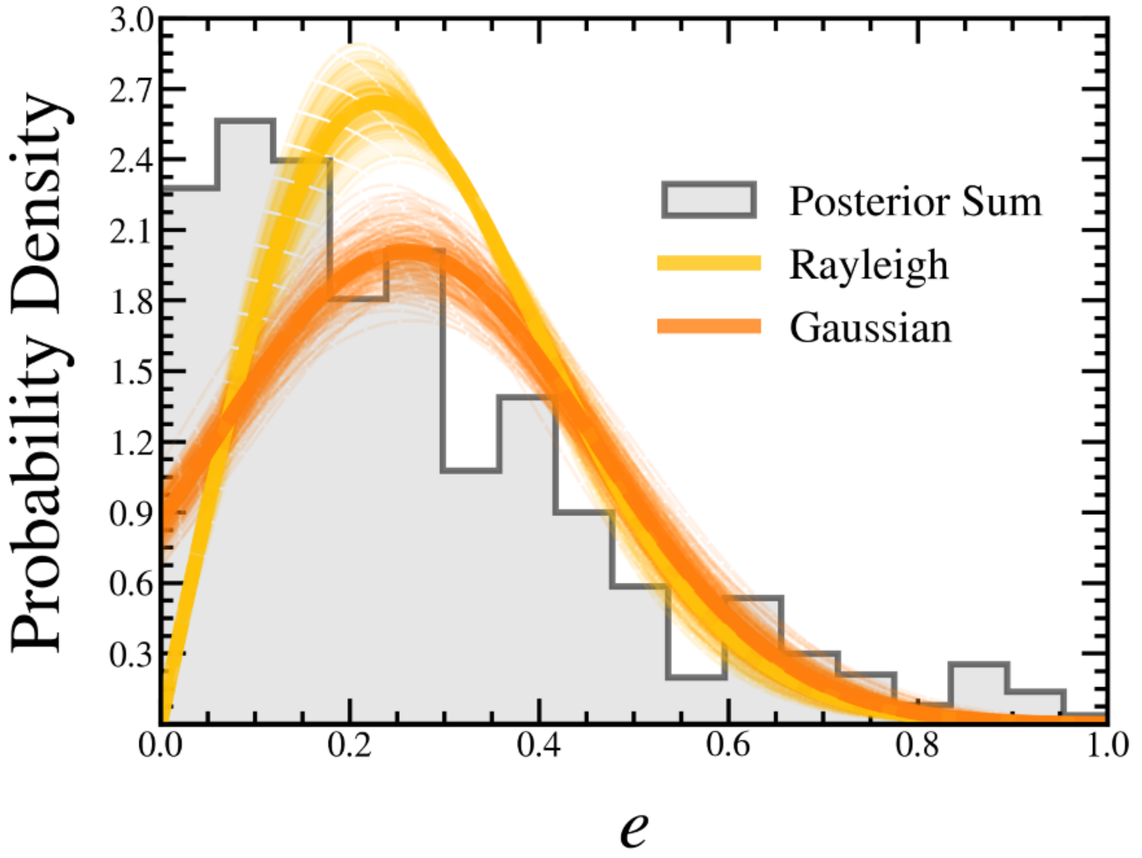
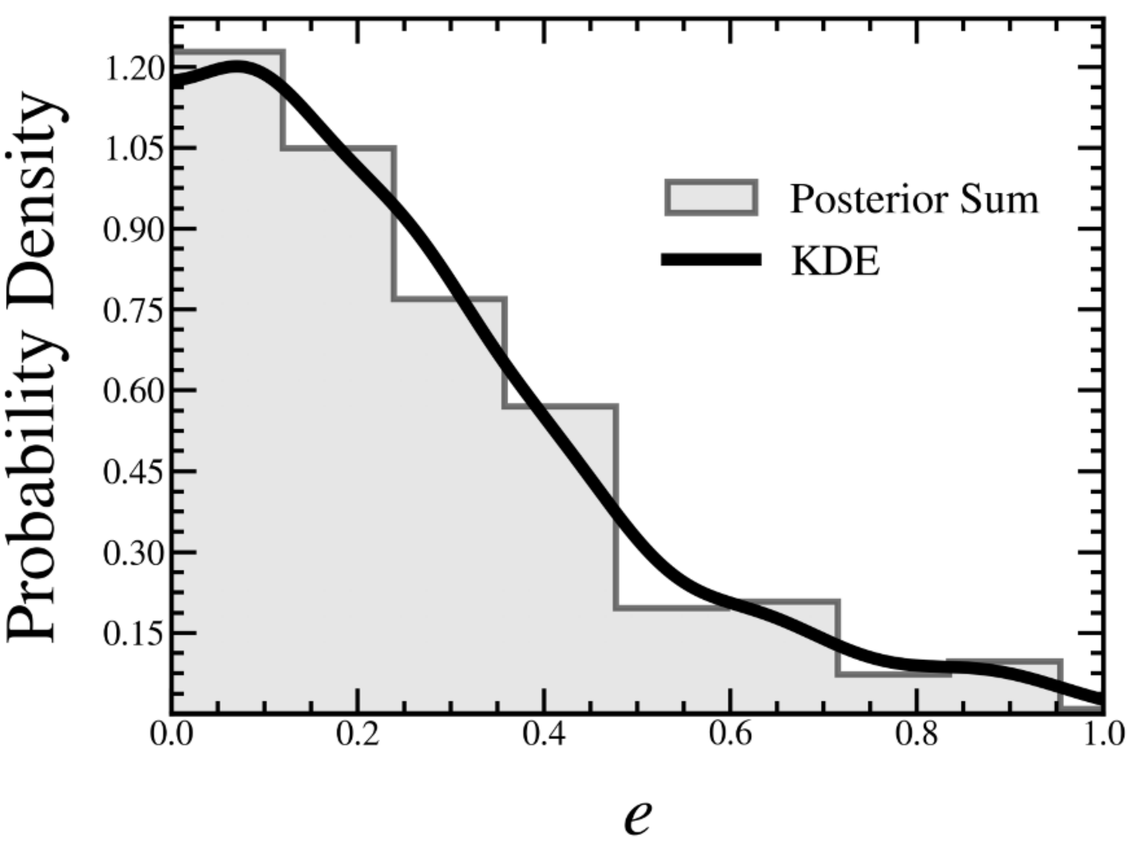




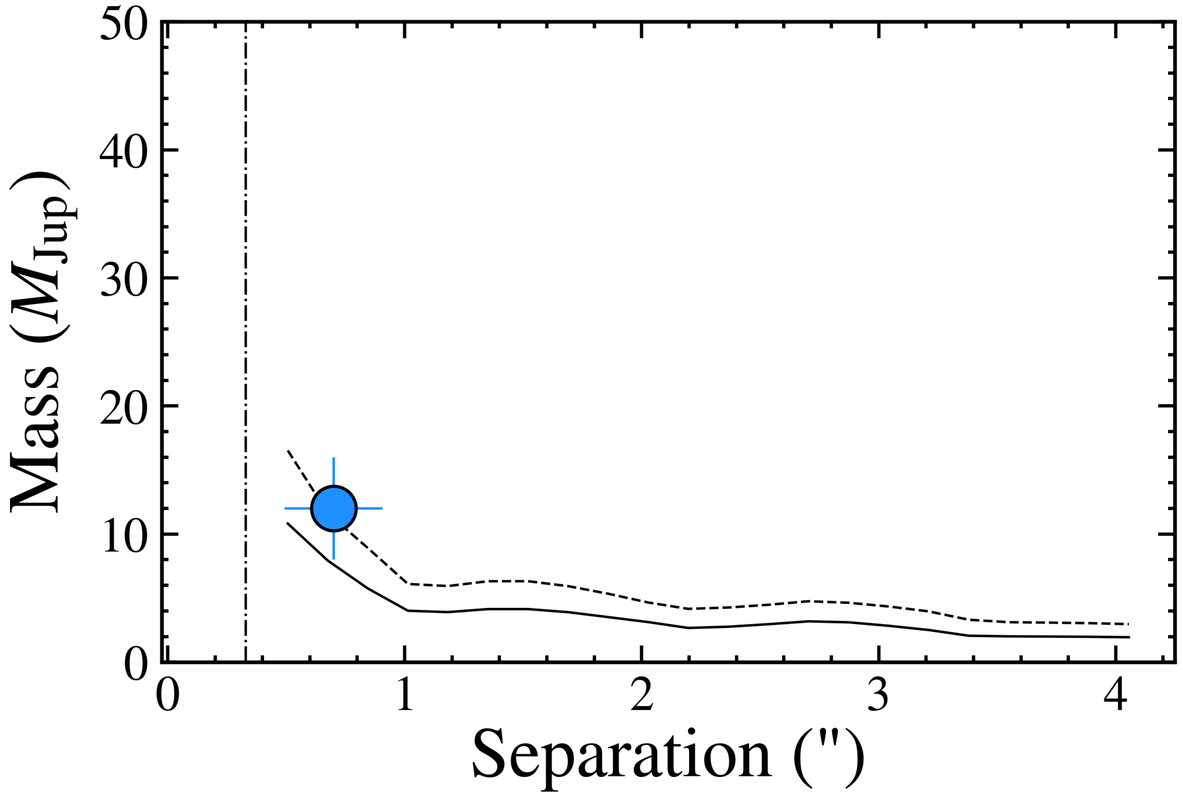
All Warm Jupiters





Imaging a Hidden Super-Jupiter Accelerating HIP 79431

F1065C



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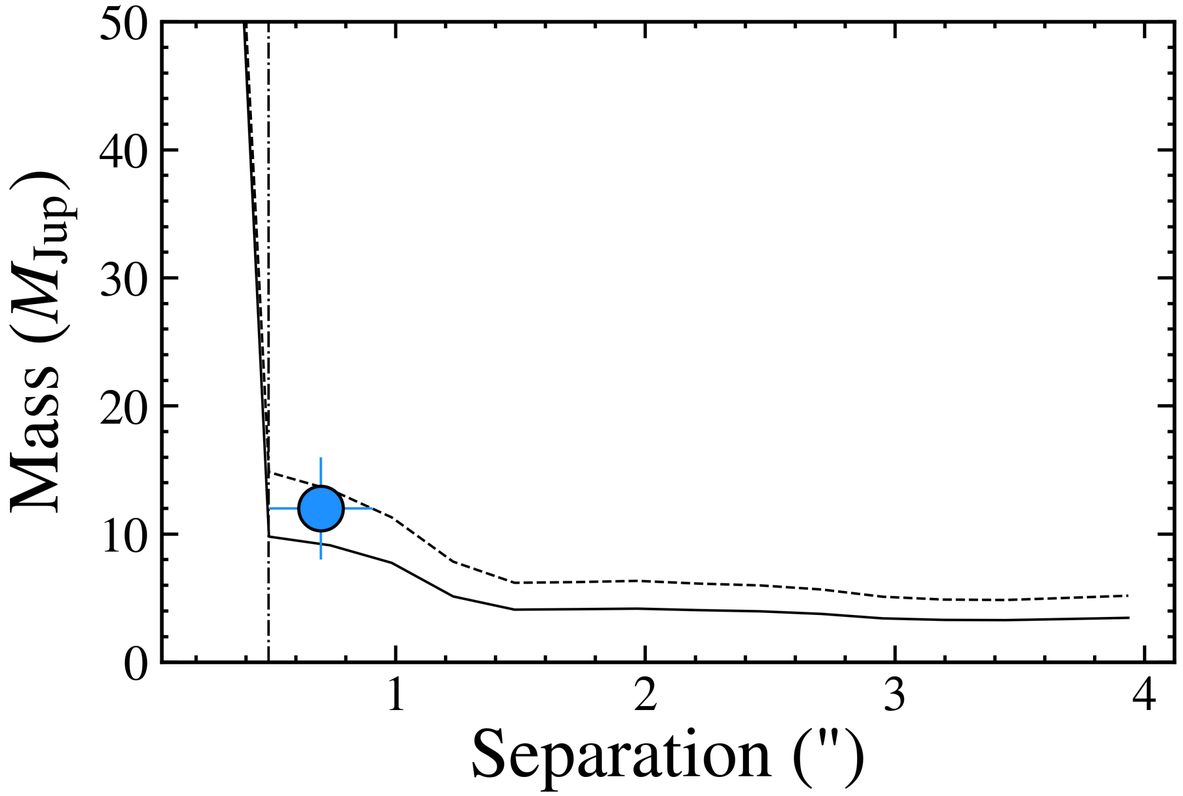
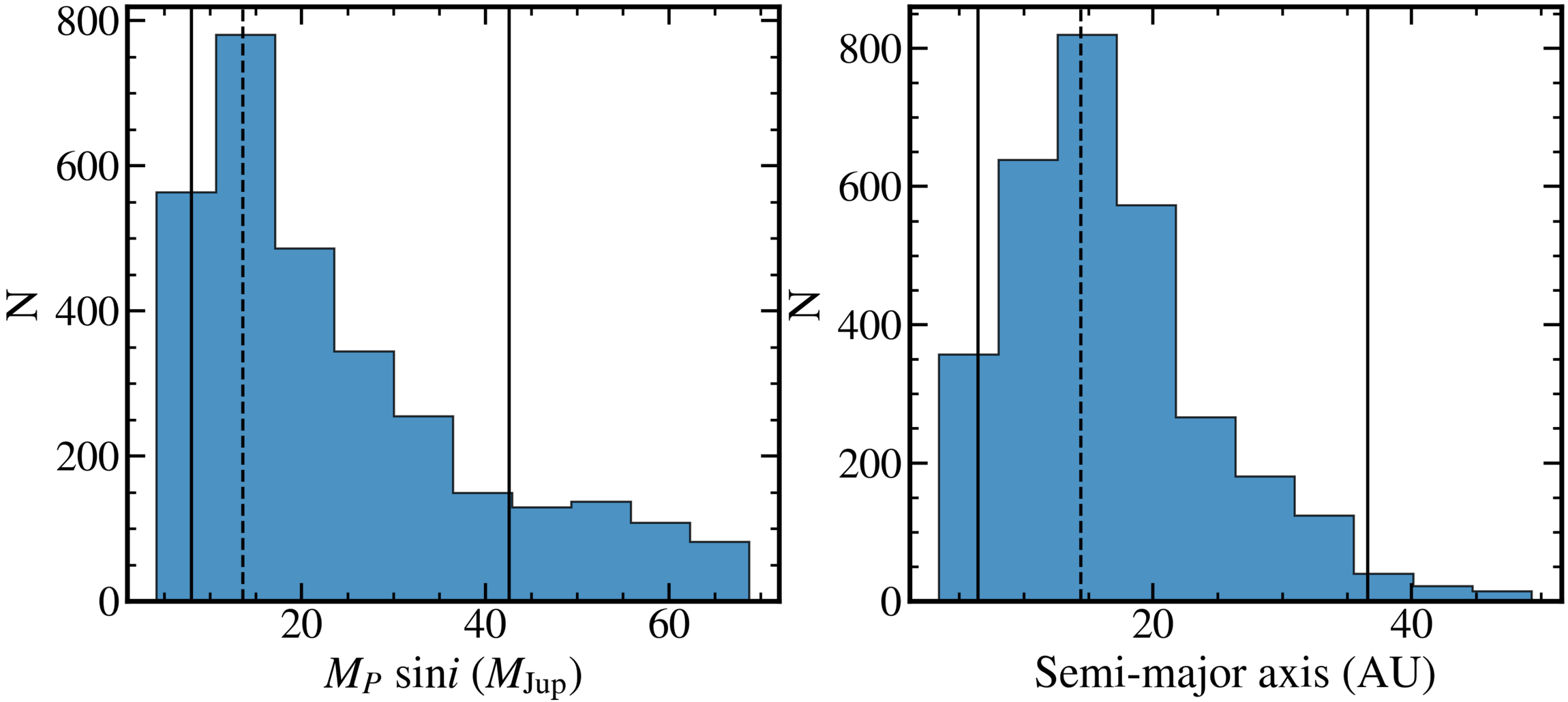


Imaging a Hidden Super-Jupiter Accelerating HIP 79431



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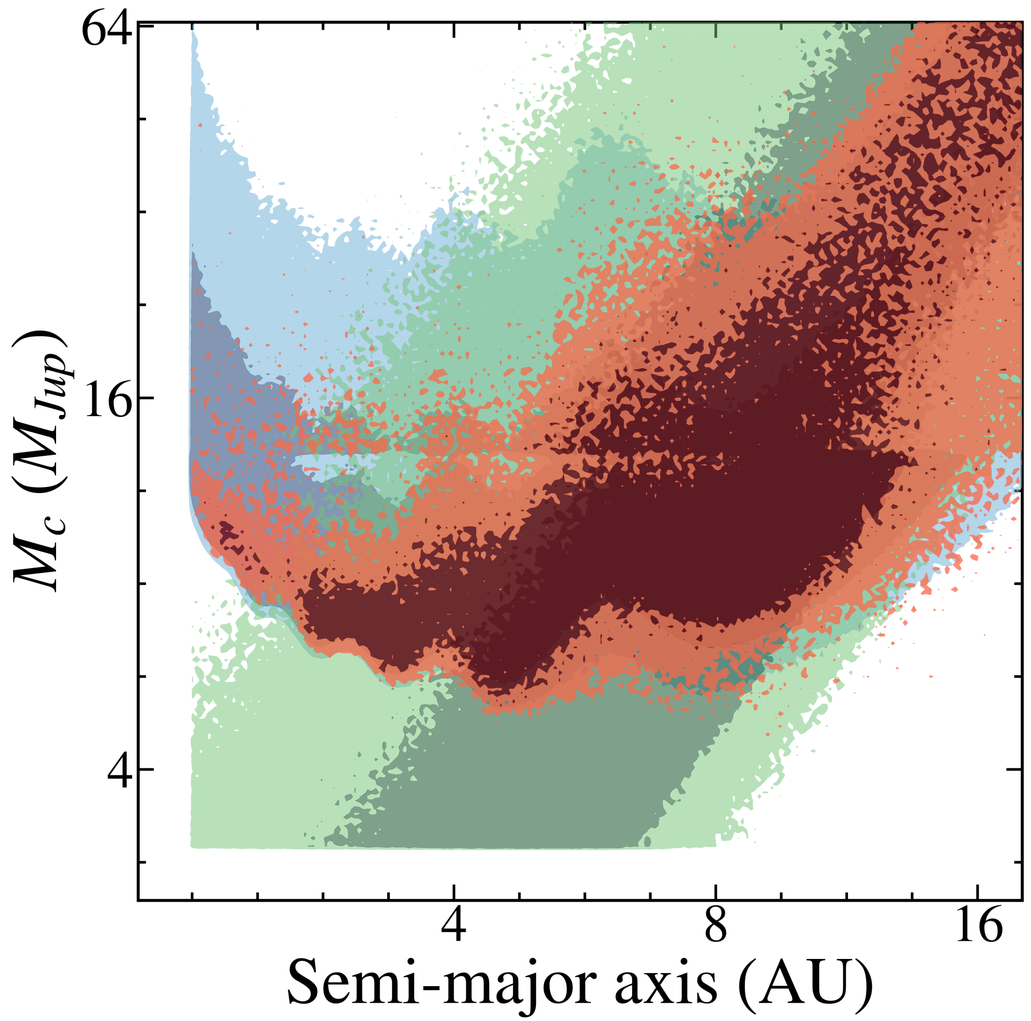
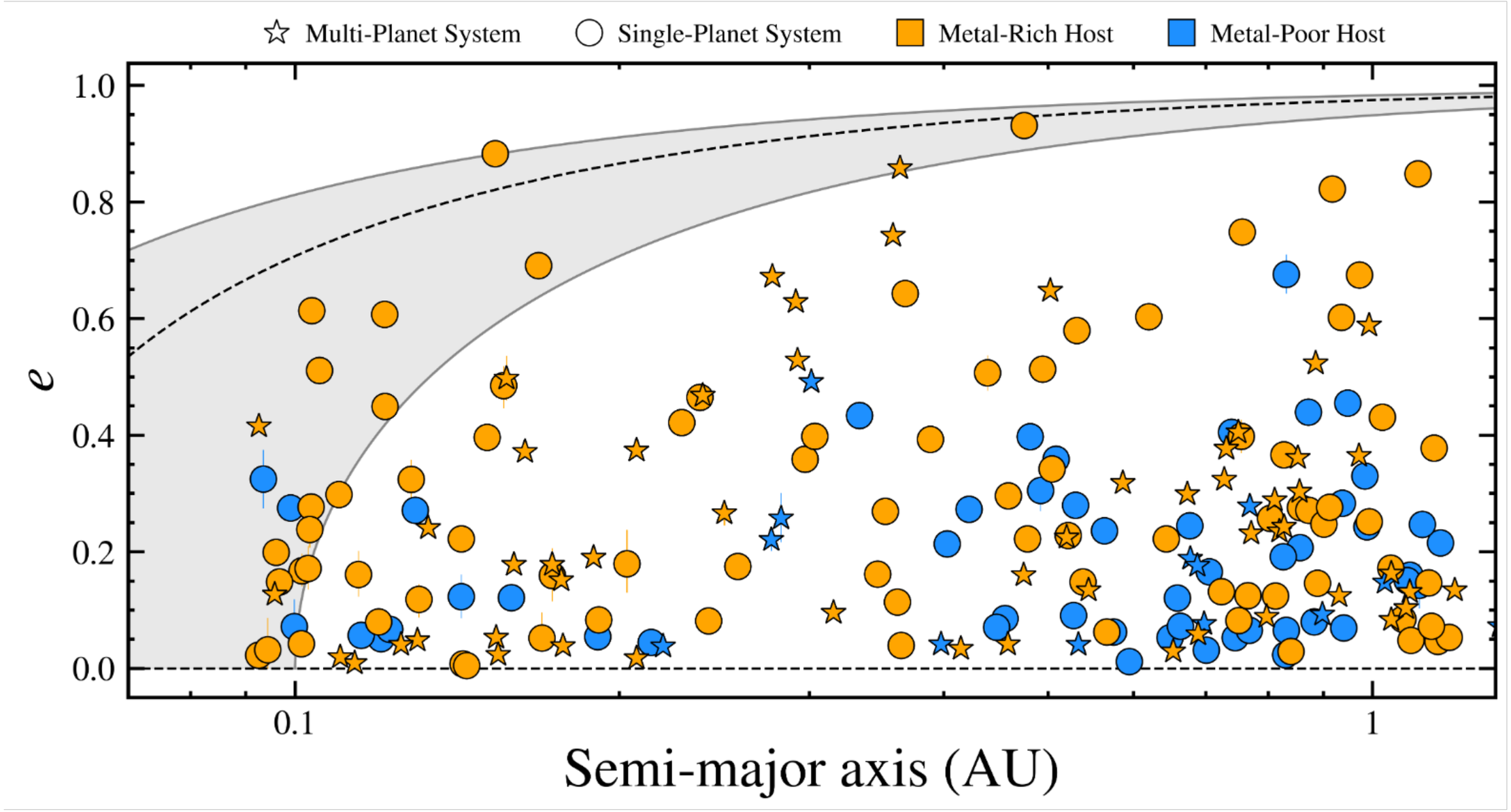
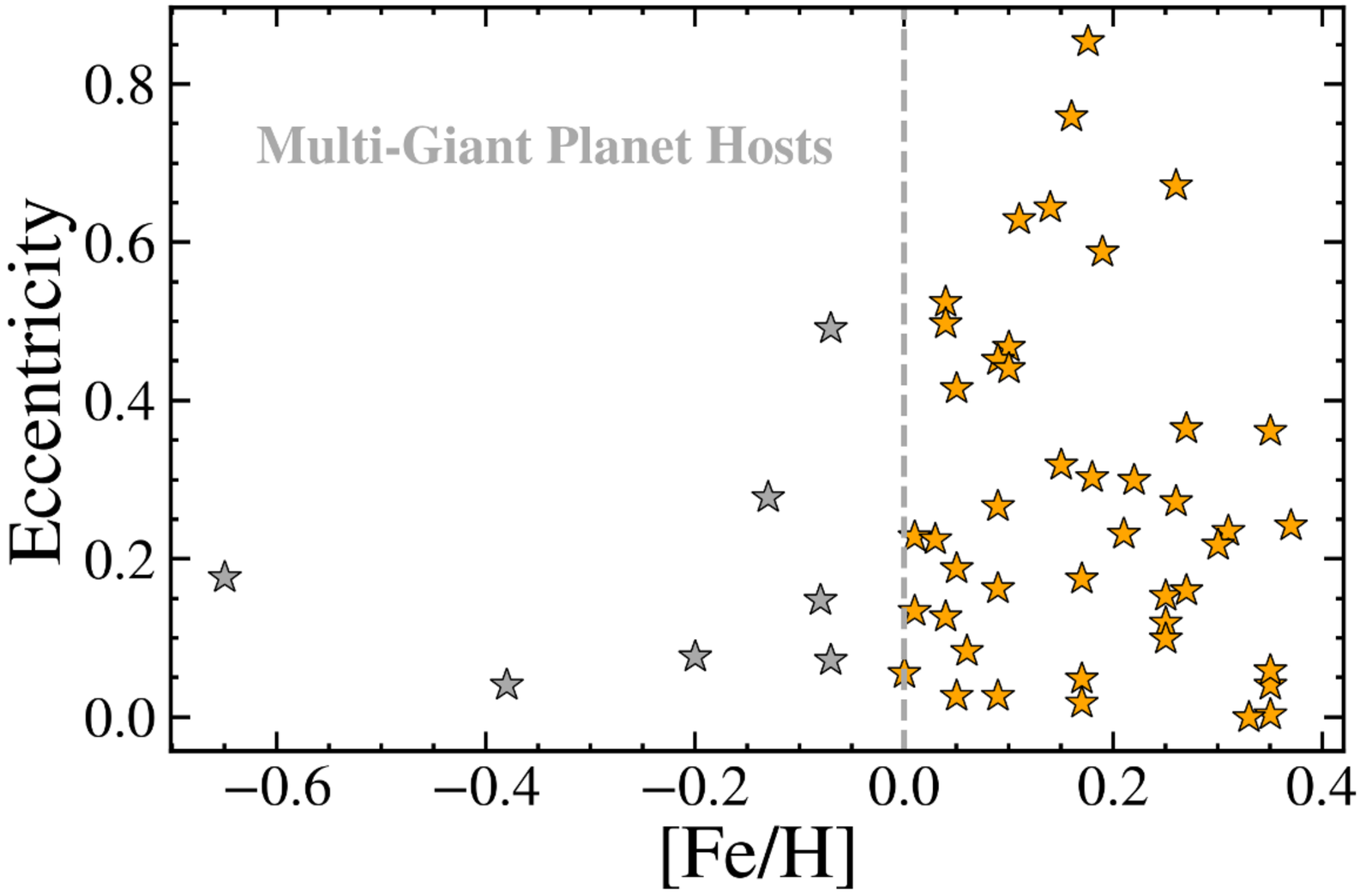
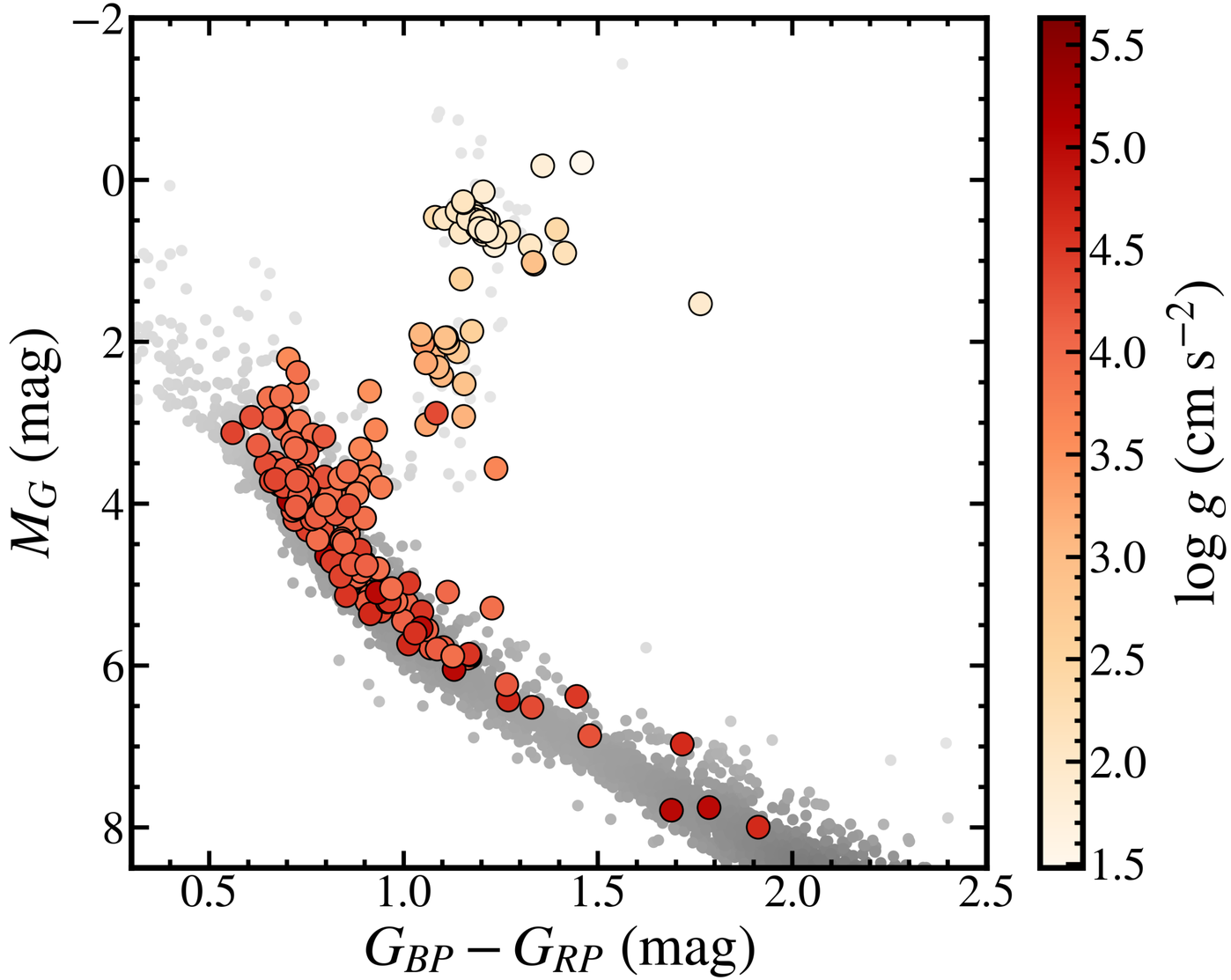


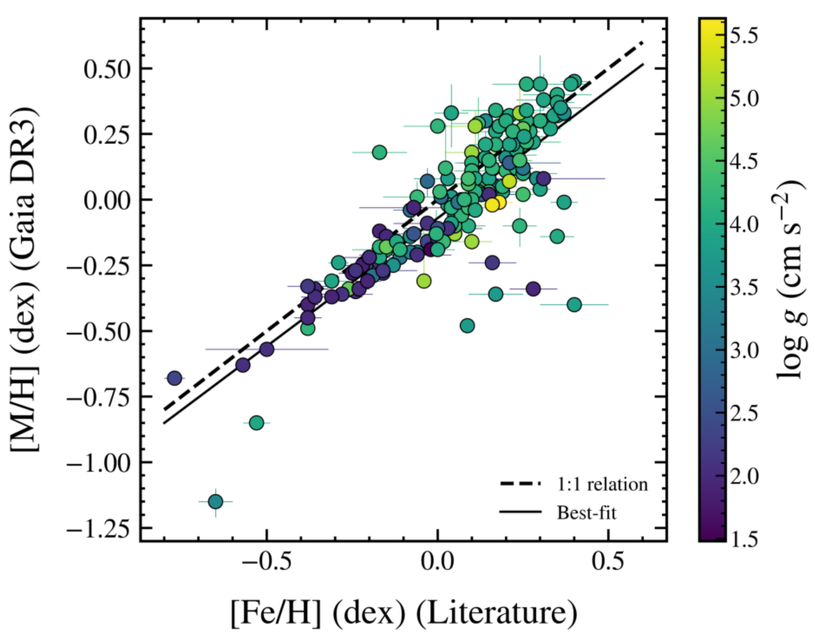
Key Results from Exploring Warm Jupiter Migration with Eccentricities

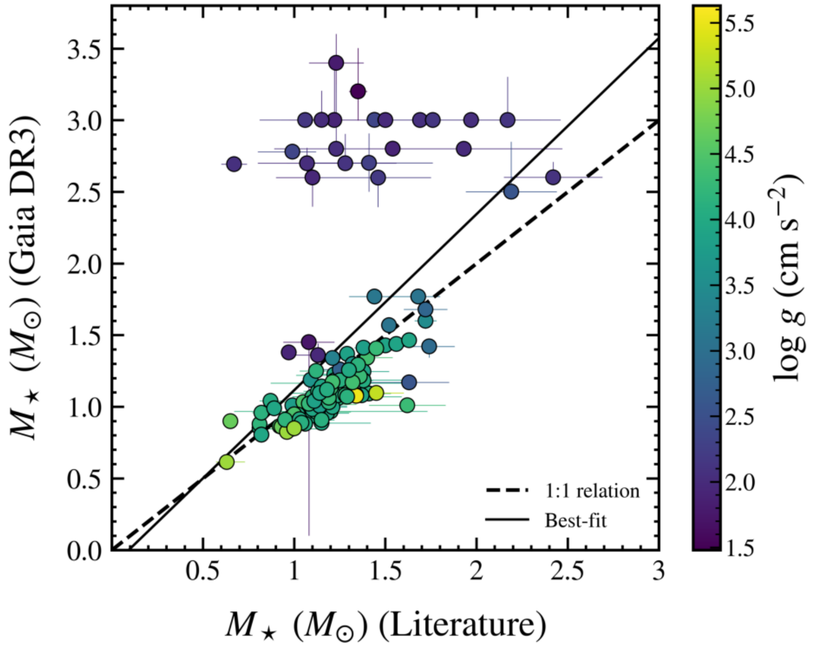


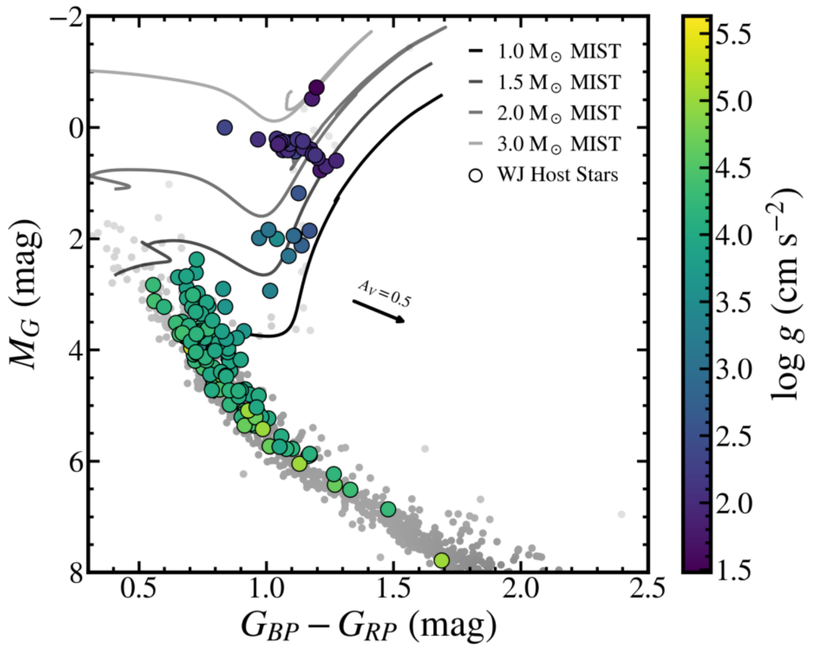

Multi-Giant Planet Hosts
Eccentricity
0.0
0.2
0.4
0.6
0.8
−0.6
−0.4
−0.2
0.0
0.2
0.4
[Fe/H]

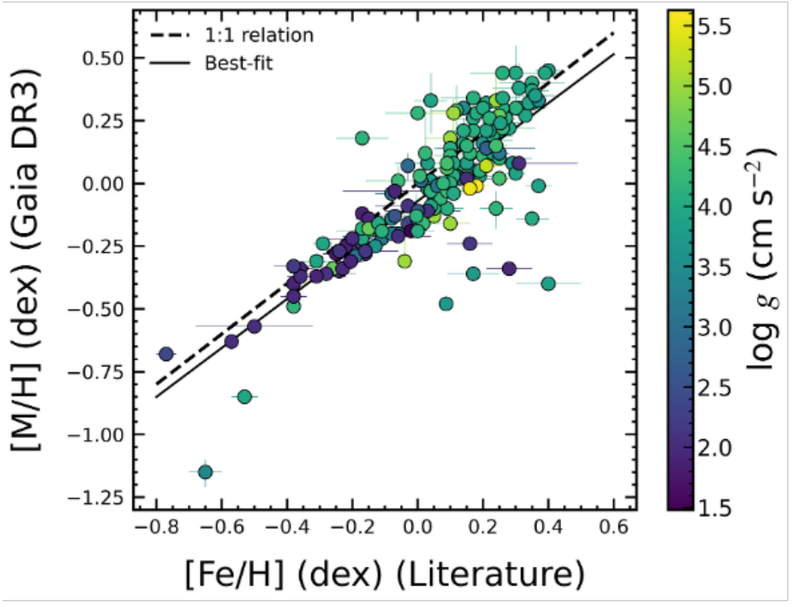
Key Results from Exploring Warm Jupiter Migration with Eccentricities

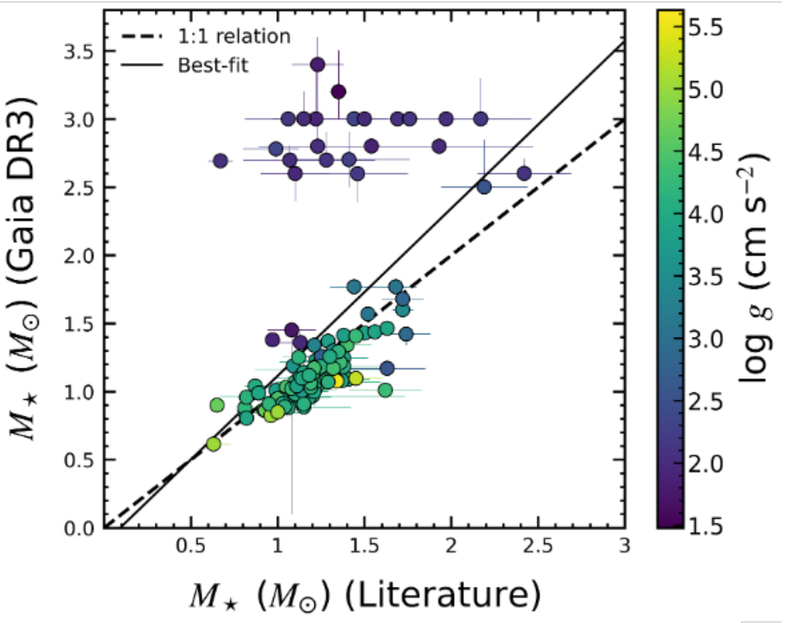


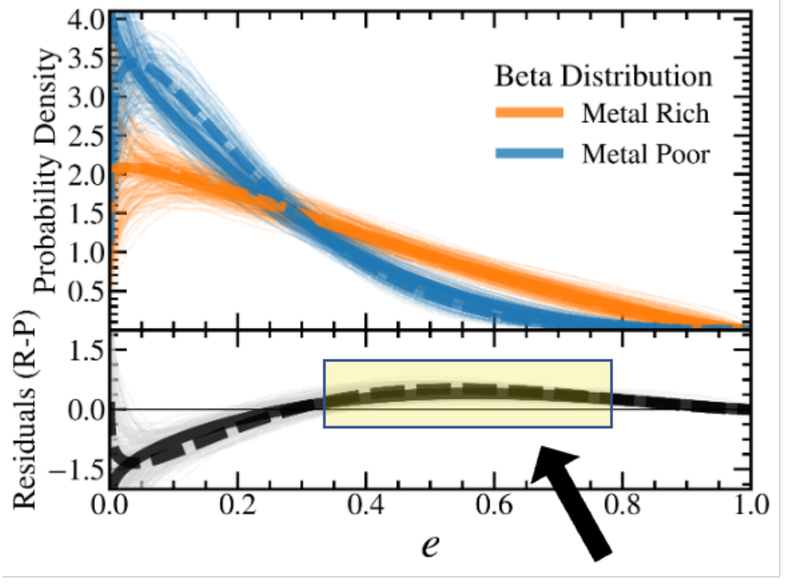

[M/H] (dex) (Gaia DR3)
[Fe/H] (dex) (Literature)
1:1 relation
Best-fit
log g (cm s^{-2})

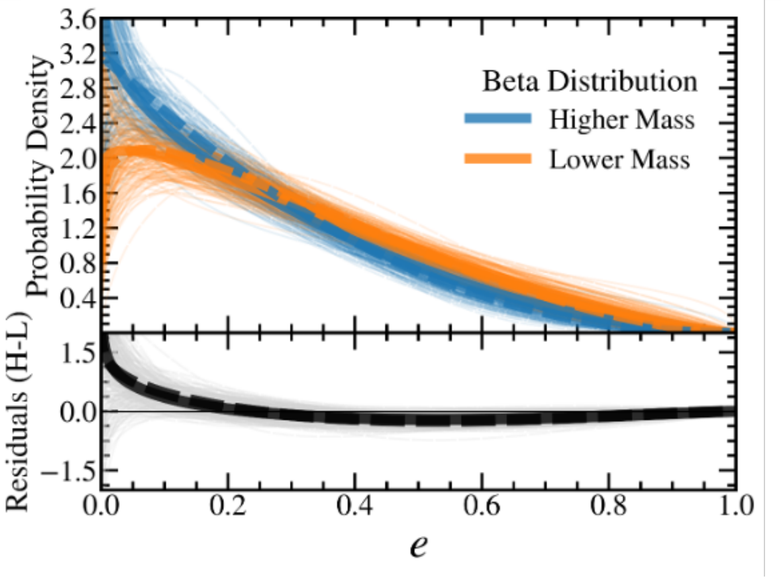

$M_\star$ ($M_\odot$) (Gaia DR3)
$M_\star$ ($M_\odot$) (Literature)
1:1 relation
Best-fit
log g (cm s^{-2})

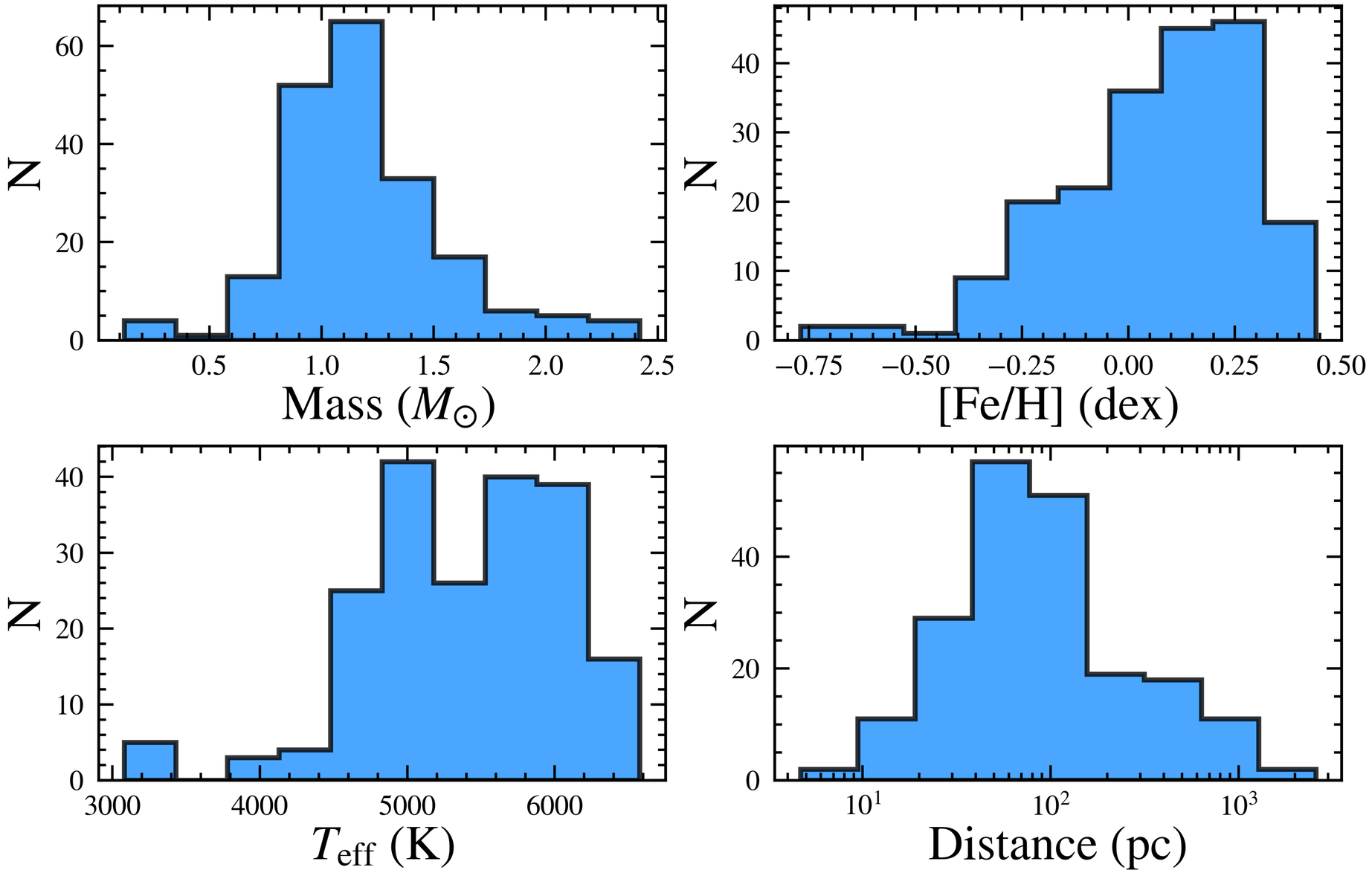

1.0 M$_\odot$ MIST
1.5 M$_\odot$ MIST
2.0 M$_\odot$ MIST
3.0 M$_\odot$ MIST
WJ Host Stars
$A_V = 0.5$
M_G (mag)
$G_{BP} - G_{RP}$ (mag)
log g (cm s^{-2})

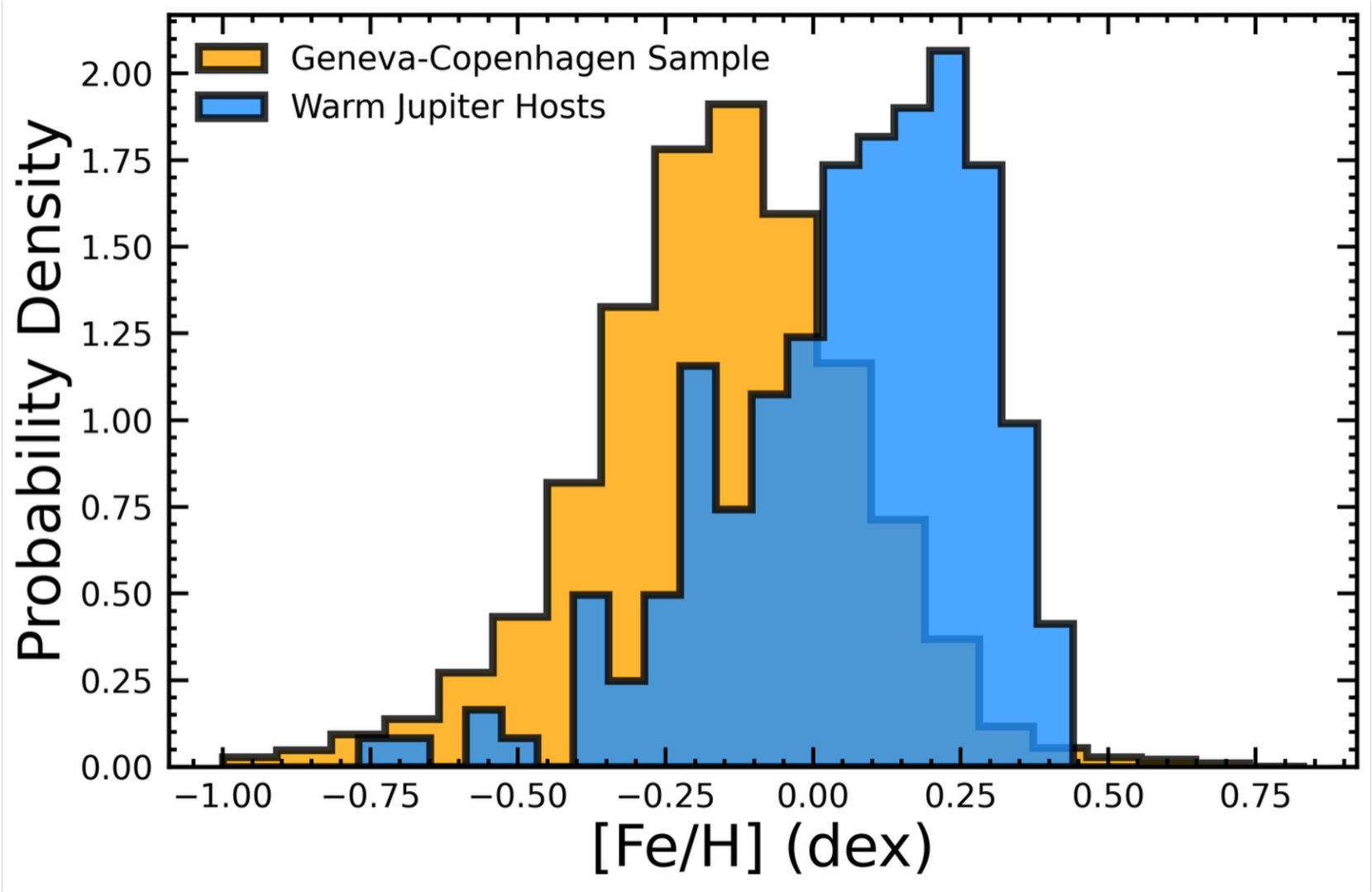

1:1 relation
Best-fit
[M/H] (dex) (Gaia DR3)
[Fe/H] (dex) (Literature)
log g (cm s^{-2})

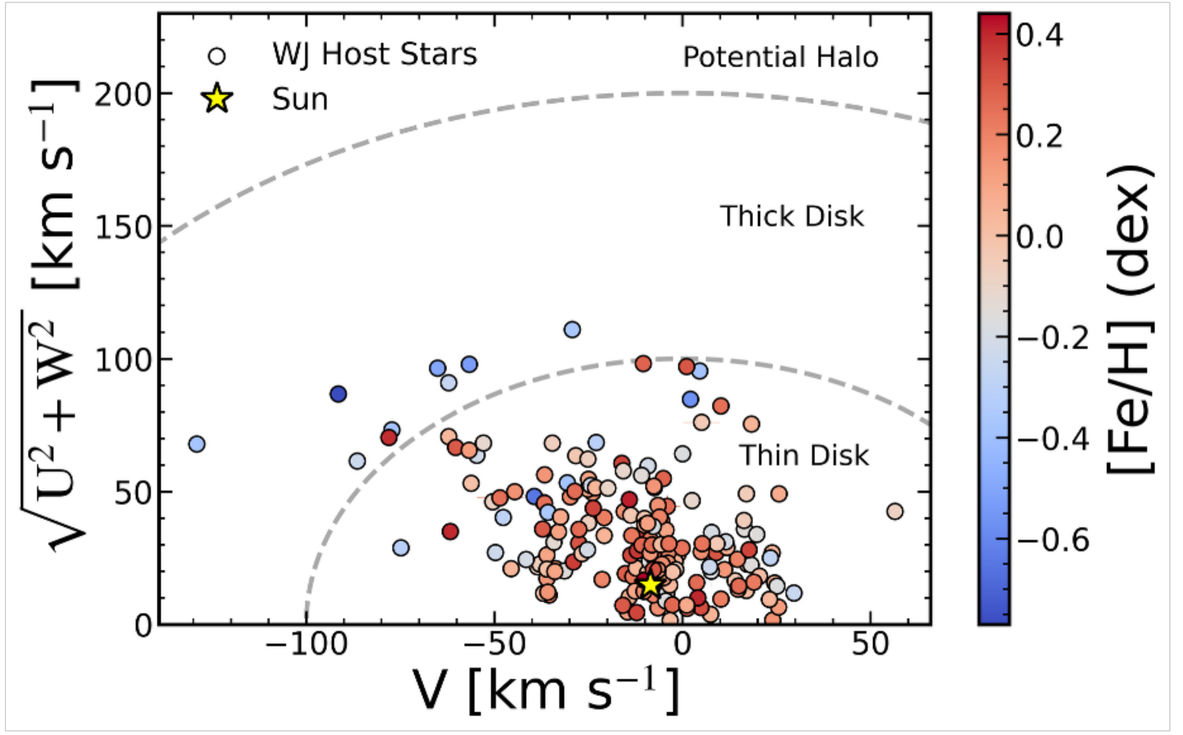

1:1 relation
Best-fit
$M_\star$ ($M_\odot$) (Gaia DR3)
$M_\star$ ($M_\odot$) (Literature)
log g (cm s^{-2})

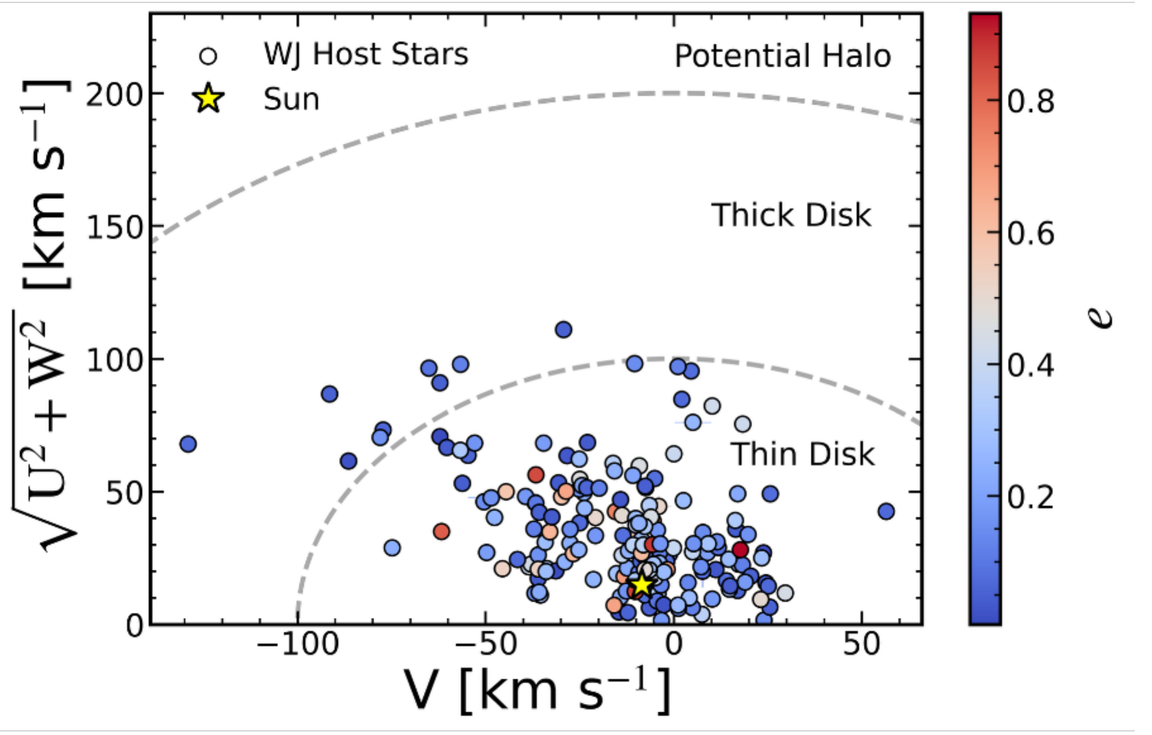

Beta Distribution
Metal Rich
Metal Poor
Probability Density
Residuals (R-P)
e


Beta Distribution
Higher Mass
Lower Mass
Probability Density
Residuals (H-L)
e


N
Mass ($M_\odot$)
[Fe/H] (dex)
$T_{\rm eff}$ (K)
Distance (pc)


Geneva-Copenhagen Sample
Warm Jupiter Hosts
Probability Density
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0.00
−1.00
−0.75
−0.50
−0.25
0.00
0.25
0.50
0.75
[Fe/H] (dex)


WJ Host Stars
Sun
Potential Halo
Thick Disk
Thin Disk
$\sqrt{U^2+W^2}$ [km s^{-1}]
V [km s^{-1}]
[Fe/H] (dex)
0.4
0.2
0.0
−0.2
−0.4
−0.6
200
150
100
50
0
−100
−50
0
50


WJ Host Stars
Sun
Potential Halo
Thick Disk
Thin Disk
$\sqrt{U^2+W^2}$ [km s^{-1}]
V [km s^{-1}]
e
0.8
0.6
0.4
0.2
200
150
100
50
0
−100
−50
0
50