Hot Jupiters. Are They Alone?

Jon Zink

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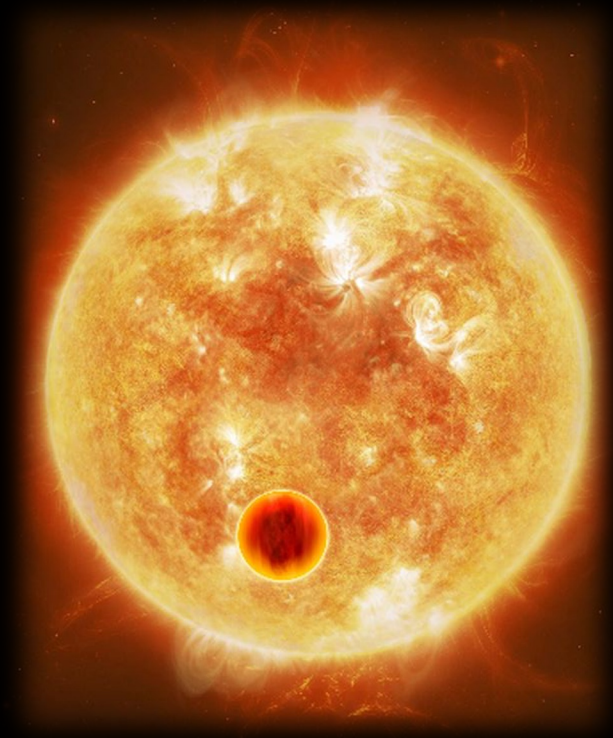
Hot Jupiter Are Strange

- Orbital Periods between 1 and 10 days

  (less than 25% the orbital radius of Mercury)

- Dayside temperature ~2700K

  (hotter than many late M-dwarfs)



Hot Jupiter Are Strange

- Orbital Periods between 1 and 10 days

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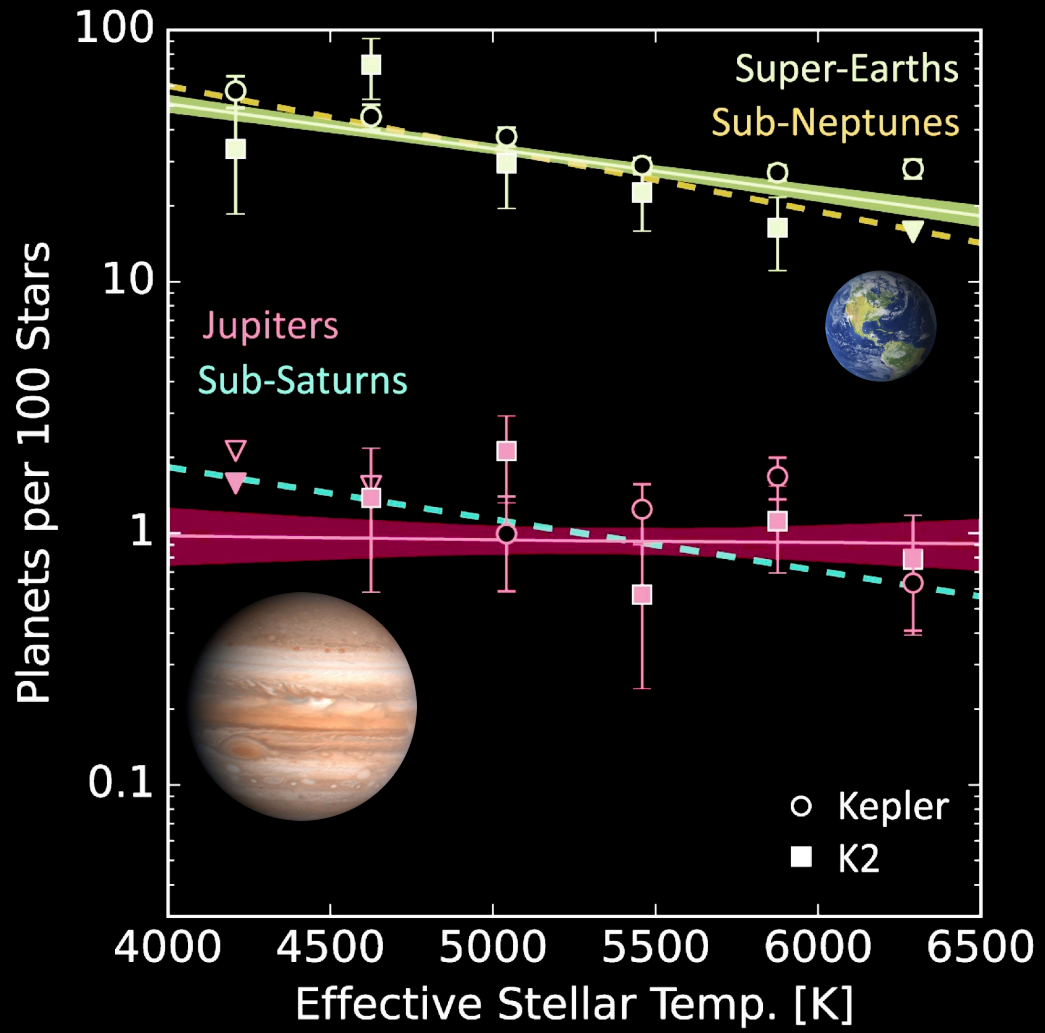
- Dayside temperature ~2700K

  (hotter than many late M-dwarfs)

- Appear to have no FGK preference

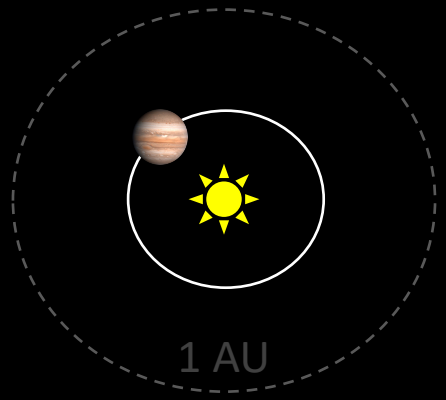


(Zink et al. 2023)

Formation Pathways:

In-Situ (Batygin et al. 2016)

HJs form within 1 AU and undergo minimal migration.



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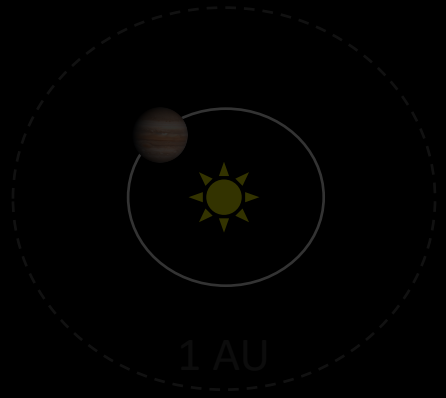
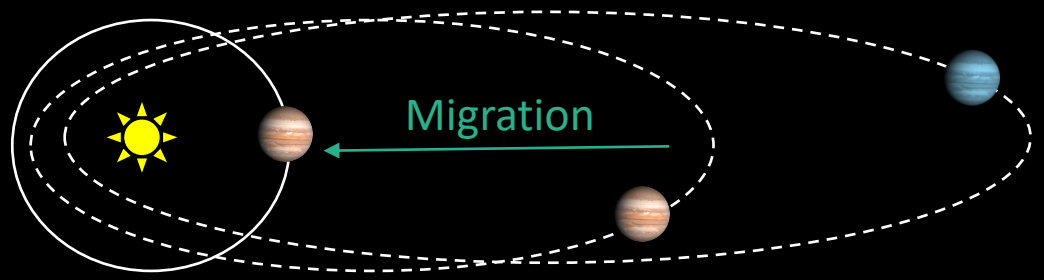


Coplanar High-Eccentricity Migration (Petrovich 2015)

Two cold giants exchange angular momentum and tidally interact with the host star, culminating in a HJ.



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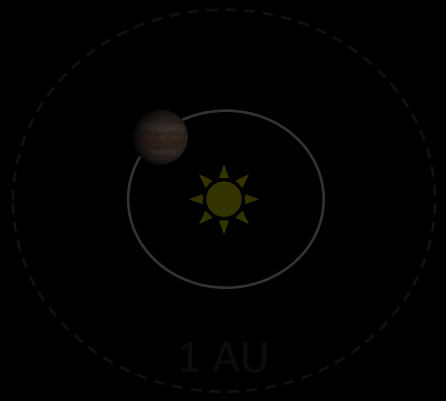

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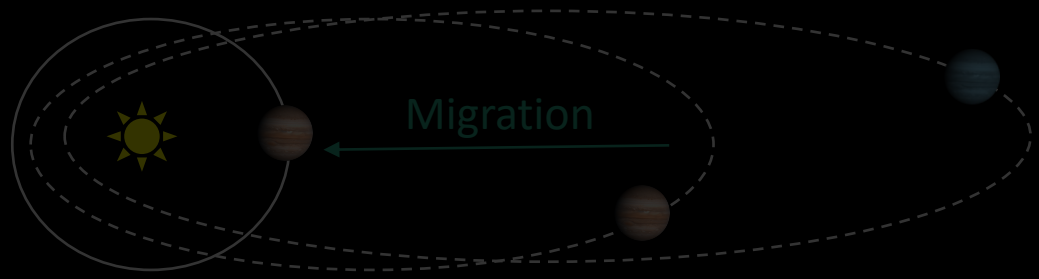
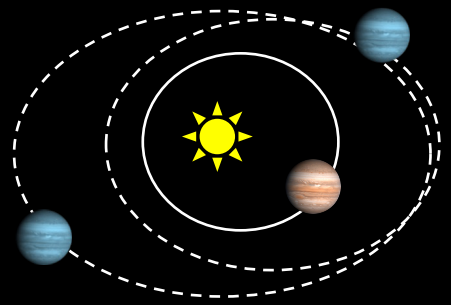


Secular Chaos (Wu & Lithwick 2011)

Three or more cold giants dynamically interact to produce a HJ.



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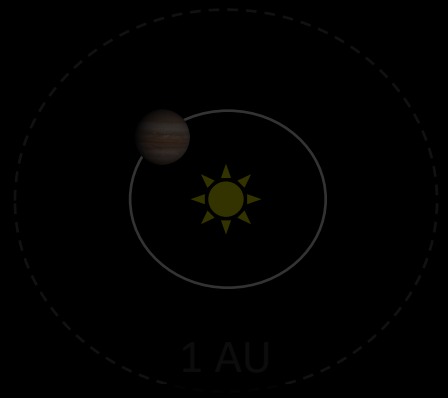

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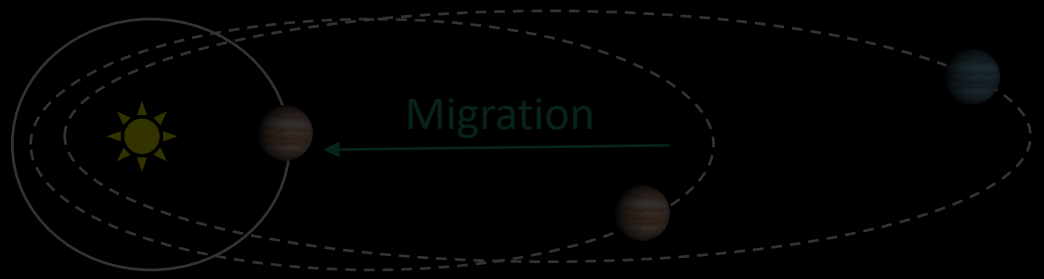

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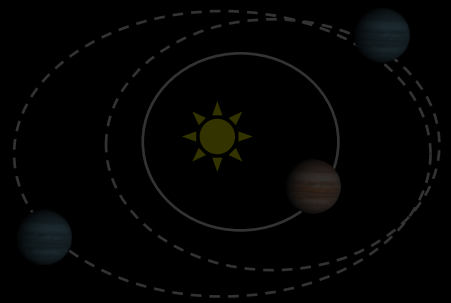
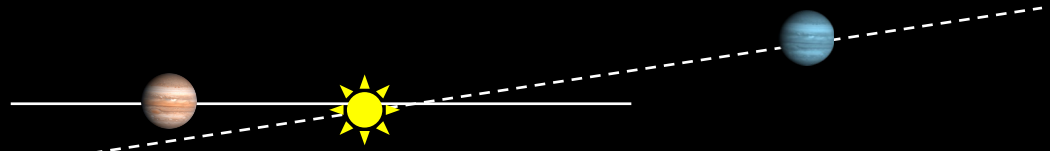


Lidov-Kozai Cycling (Wu & Murry 2003)

Two cold giants with high initial mutual inclination undergo oscillations in eccentricity and inclination, yielding a HJ.

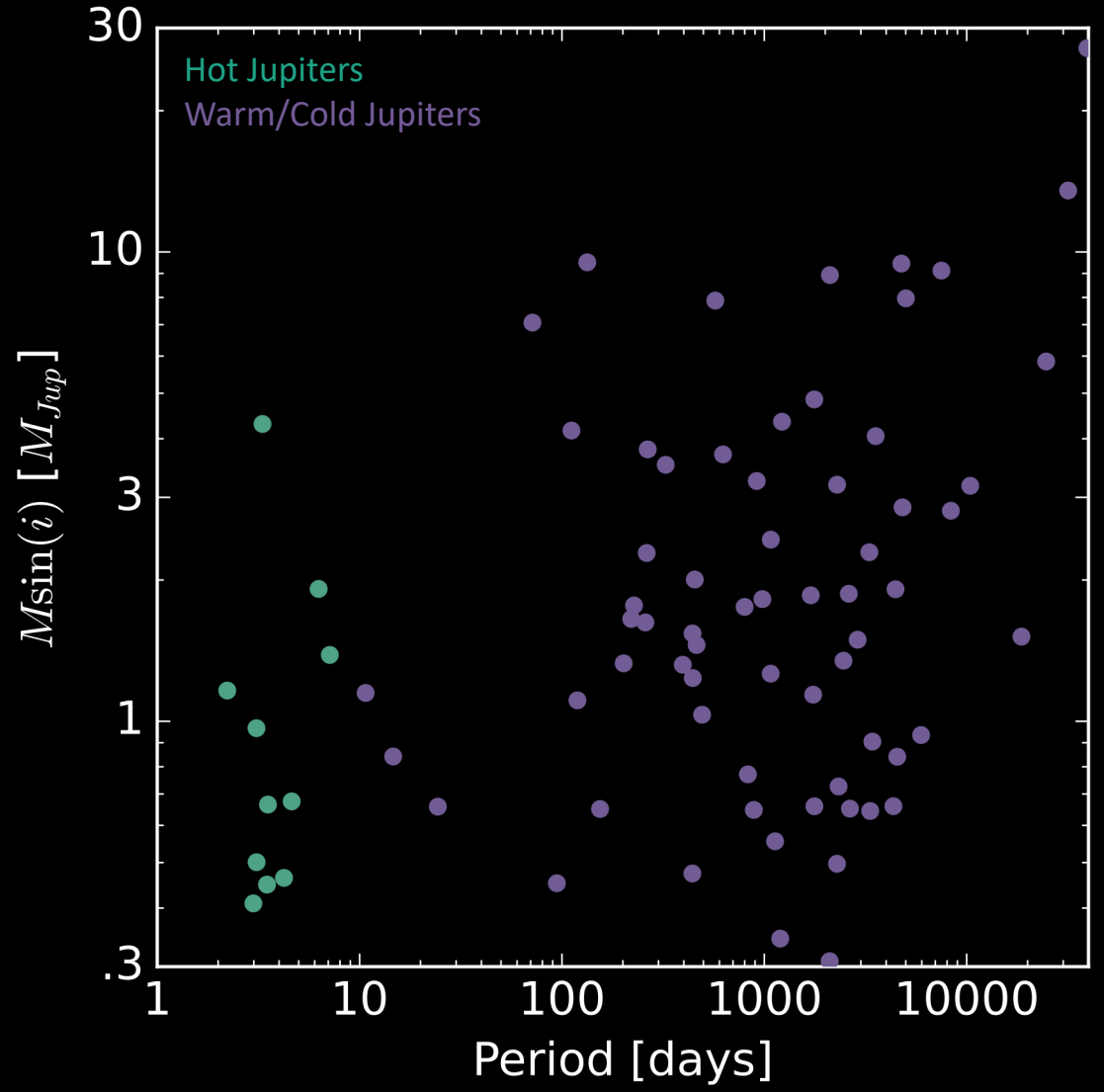


A Homogenous RV Sample

- The California Legacy Survey (CLS) monitored the radial velocities of 719 stars over 30 years. (Rosenthal et al. 2021)

Identified 127 Planets

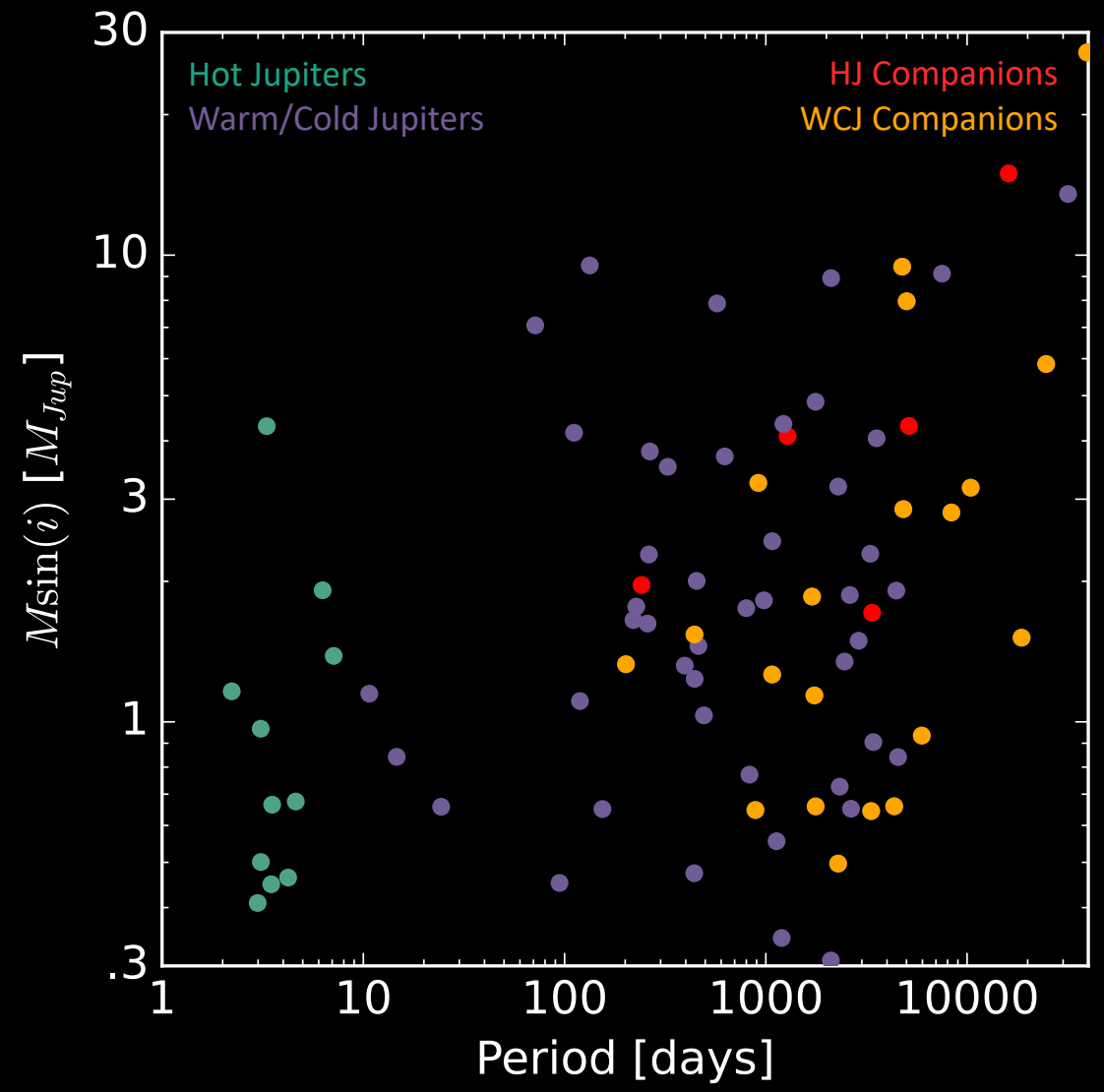
- 11 Hot Jupiter systems
- 46 Warm/Cold Jupiter systems



Zink & Howard Submitted

OUTER COMPANION SAMPLE

- 5 Hot Jupiter Companions
- 11 Warm/Cold Jupiter Companions



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Giant Multiplicity Is Ubiquitous

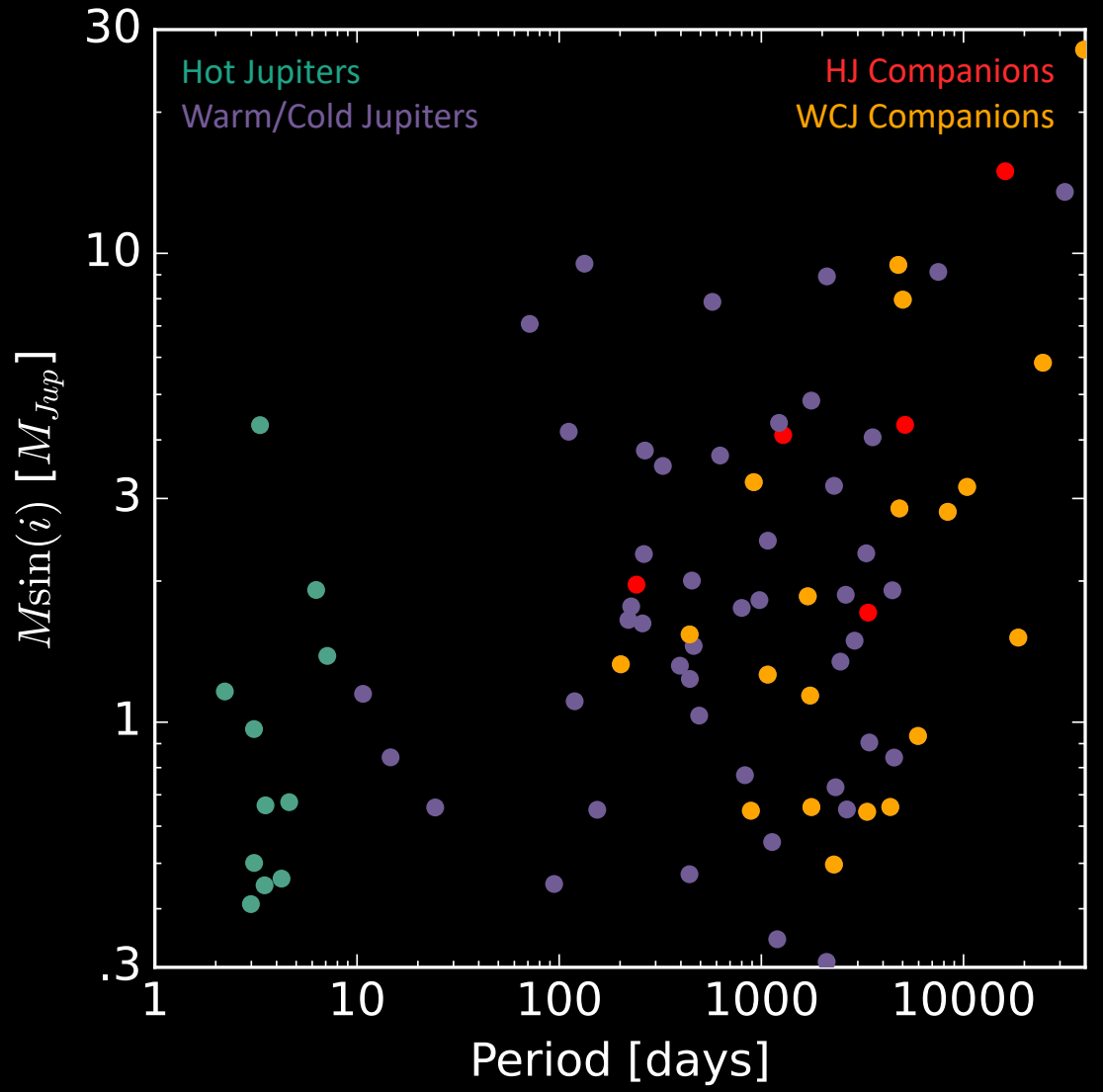
OUTER COMPANION SAMPLE

- 5 Hot Jupiter Companions
- 11 Warm/Cold Jupiter Companions

COMPANIONSHIP STATISTICS

$1.3 \pm^{1.0}_{0.6}$ Companions per HJ

1.0 ± 0.3 Companions per WCJ



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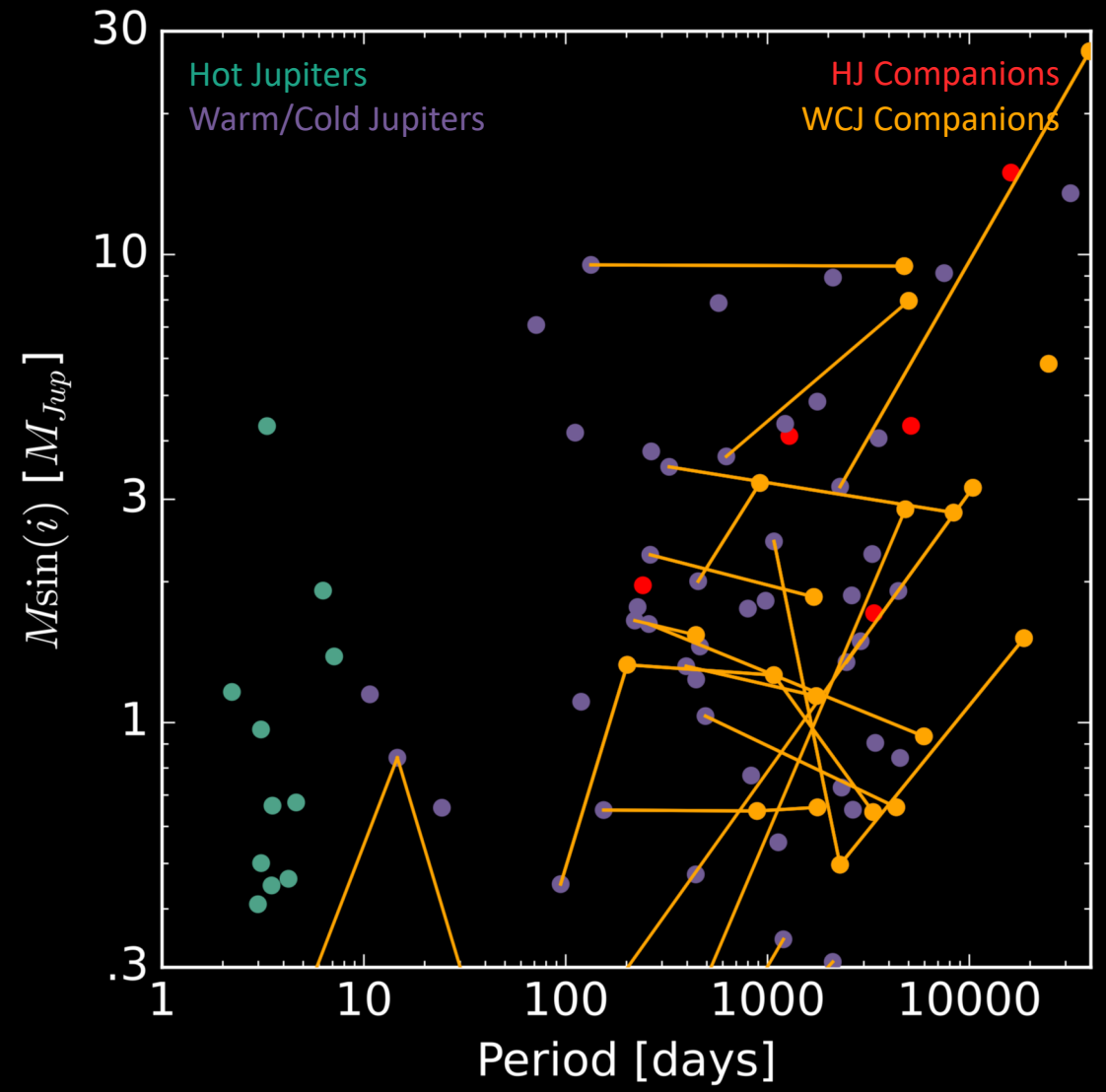
AVERAGE MASS RATIO FOR EACH ARCHITECTURE

Warm/Cold Jupiter Systems

$$\frac{M_{Outer}}{M_{Inner}} \sim 1$$

Random Draw



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HJs Require 3X Mass Companions

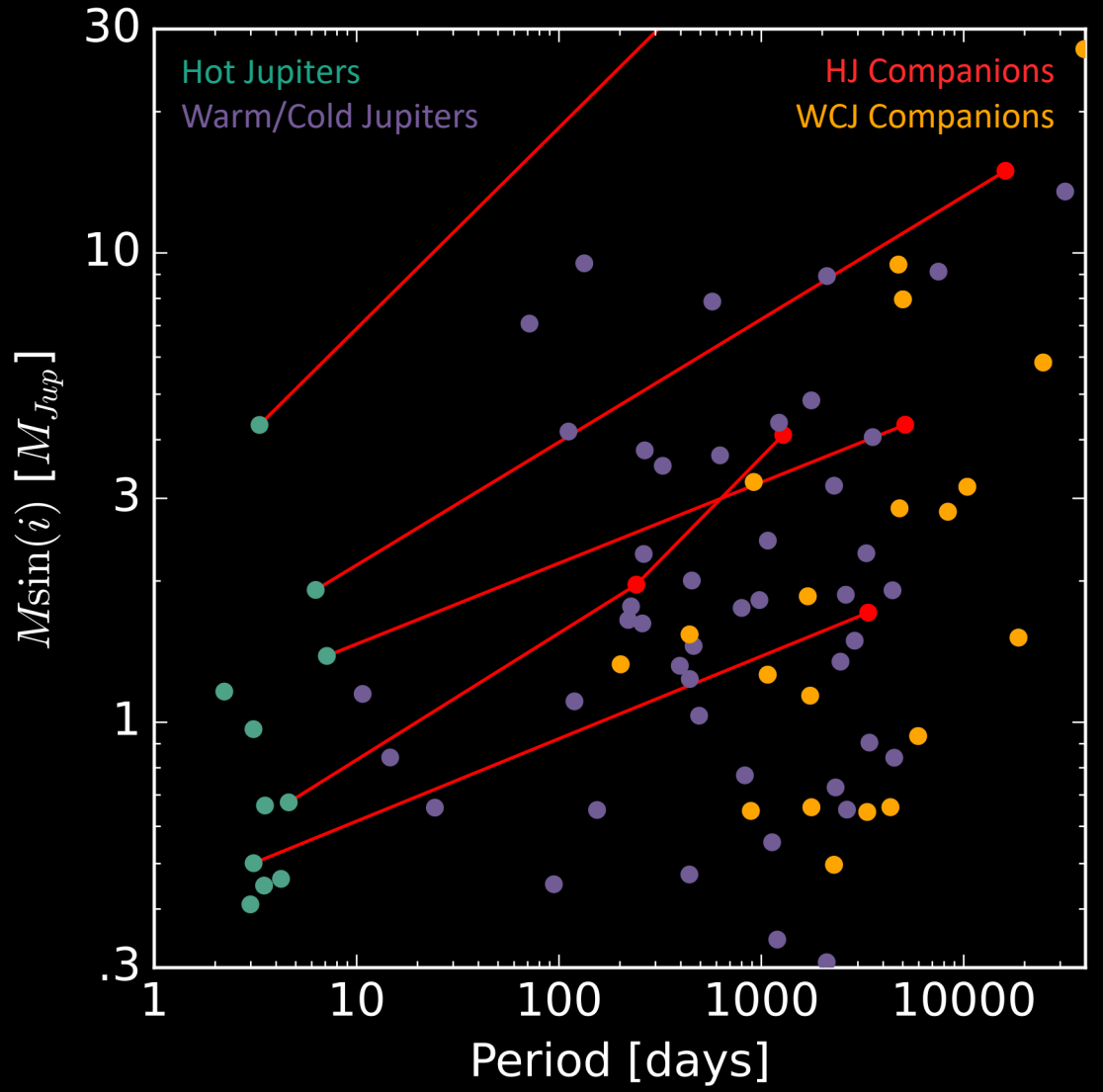
AVERAGE MASS RATIO
FOR EACH ARCHITECTURE

Warm/Cold Jupiter Systems

$$\frac{M_{Outer}}{M_{Inner}} \sim 1$$ Random Draw

Hot Jupiter Systems

$$\frac{M_{Outer}}{M_{Inner}} > 3$$ Highly Order



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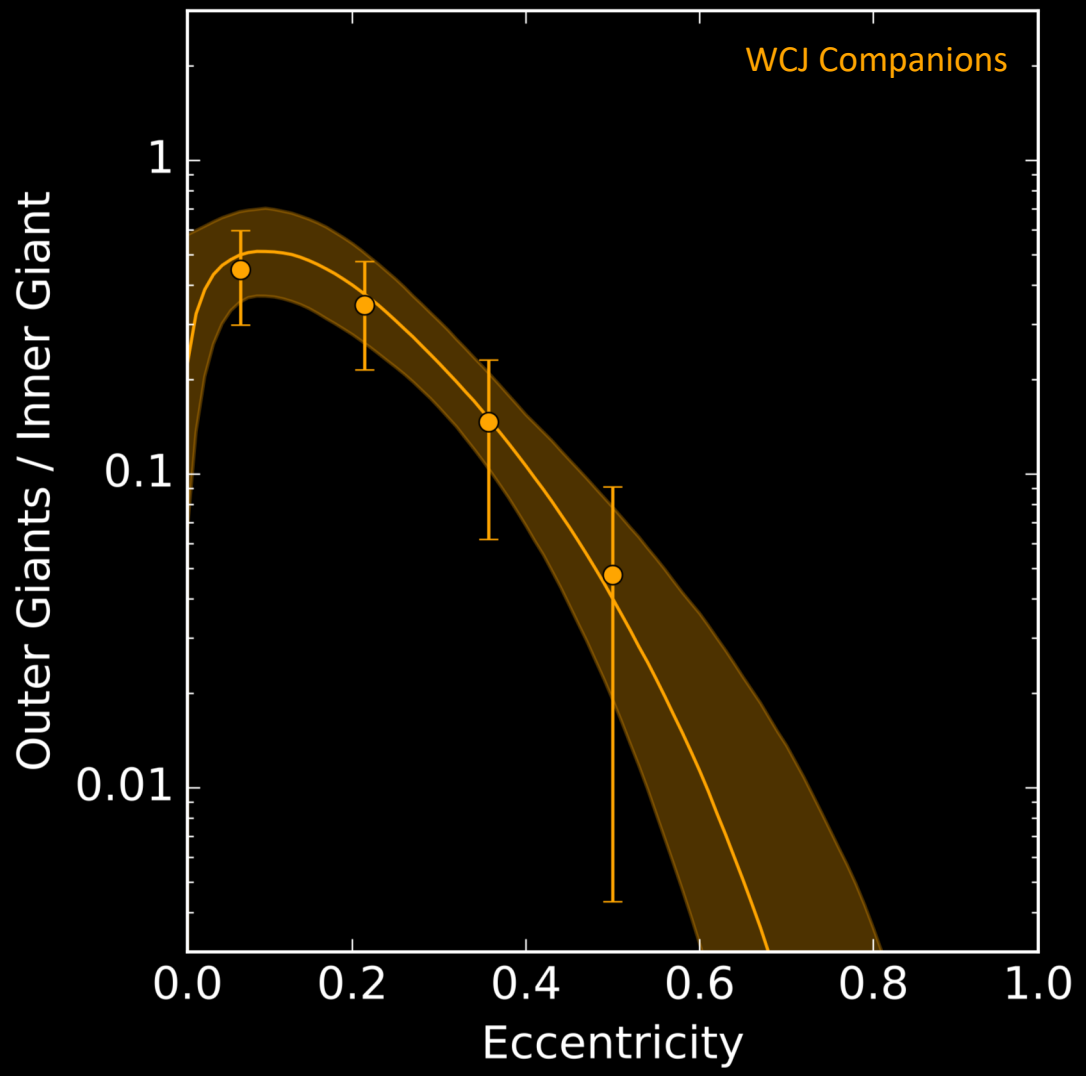
AVERAGE ECCENTRICITY FOR EACH ARCHITECTURE

Warm/Cold Jupiter Companions

$$\langle e \rangle = 0.19 \pm 0.02$$



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HJs Companions Are More Eccentric

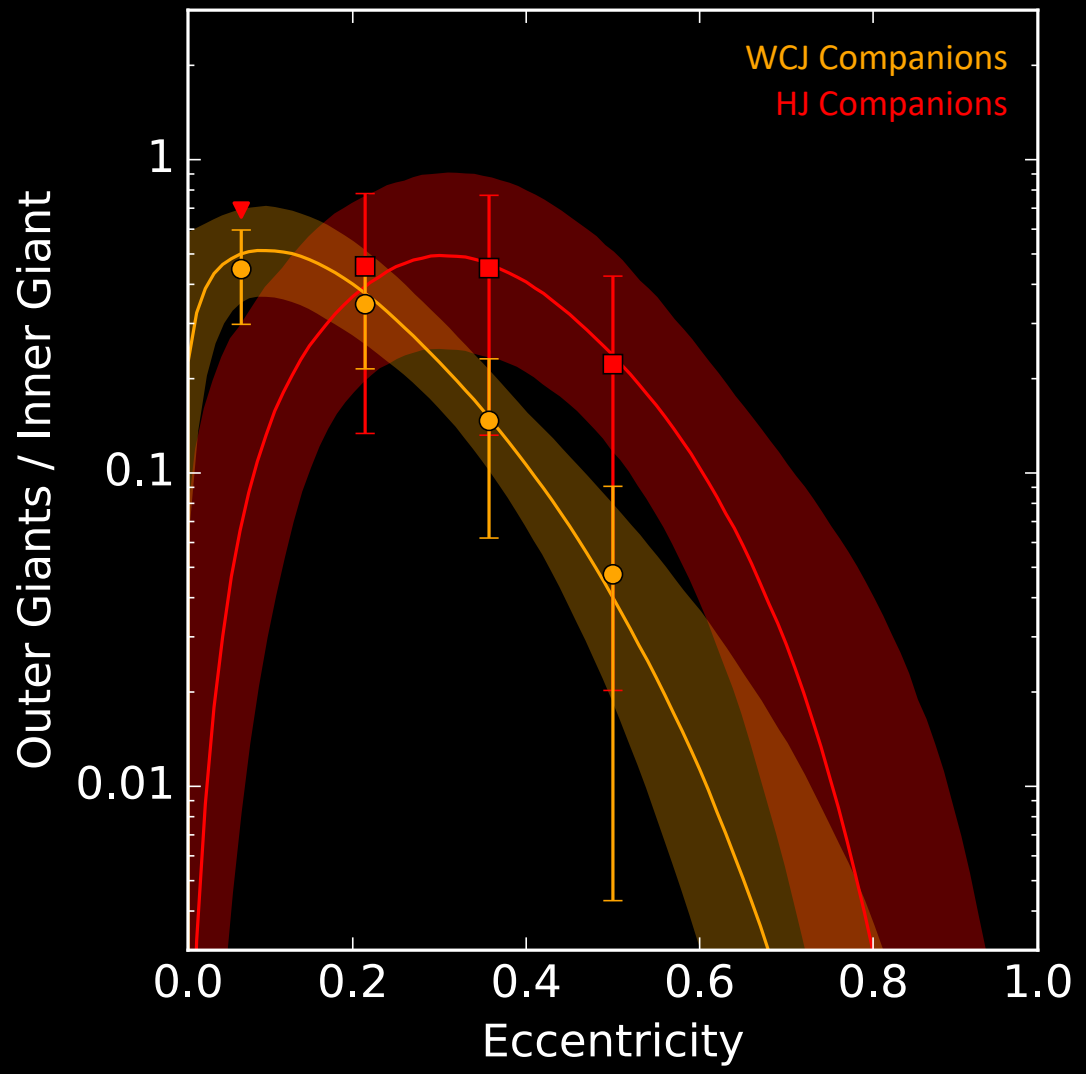
AVERAGE ECCENTRICITY
FOR EACH ARCHITECTURE

Warm/Cold Jupiter Companions

$$\langle e \rangle = 0.19 \pm 0.02$$

Hot Jupiter Companions

$$\langle e \rangle = 0.34 \pm 0.05$$ 3σ Higher



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Formation Pathways

Mechanism:	2 Giant Multiplicity:	3X Mass Companion:	Enhanced E. Companion:	Obliquity Distribution:
In-Situ				
Coplanar High-E.				
Secular Chaos				
Kozai Oscillations				

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Mechanism:	2 Giant Multiplicity:	3X Mass Companion:	Enhanced E. Companion:	Obliquity Distribution:
In-Situ	X	X	X	O
Coplanar High-E.	O	O	O	O
Secular Chaos	X	O	O	X
Kozai Oscillations	O	X	O	X

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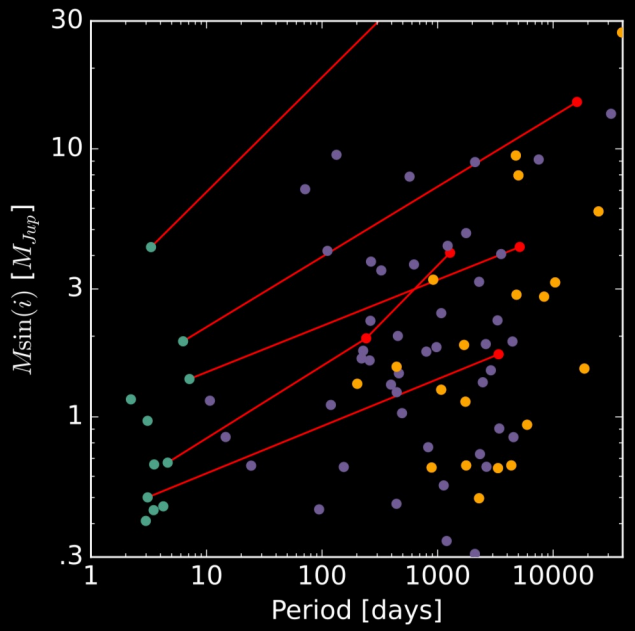
Summary

Hot Jupiters Have 3x Mass Outer Companions



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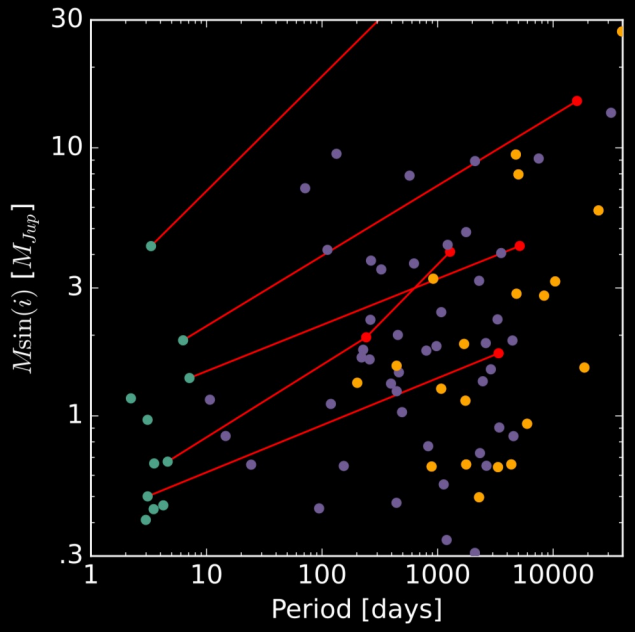
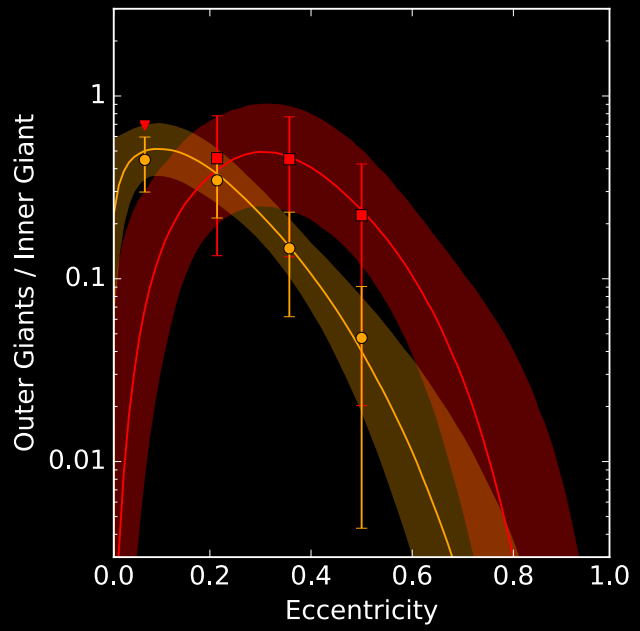


Hot Jupiter Companions are More Eccentric



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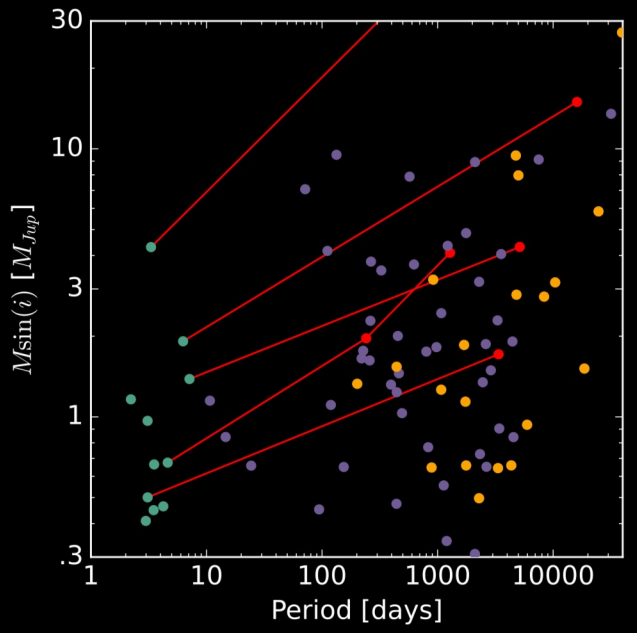

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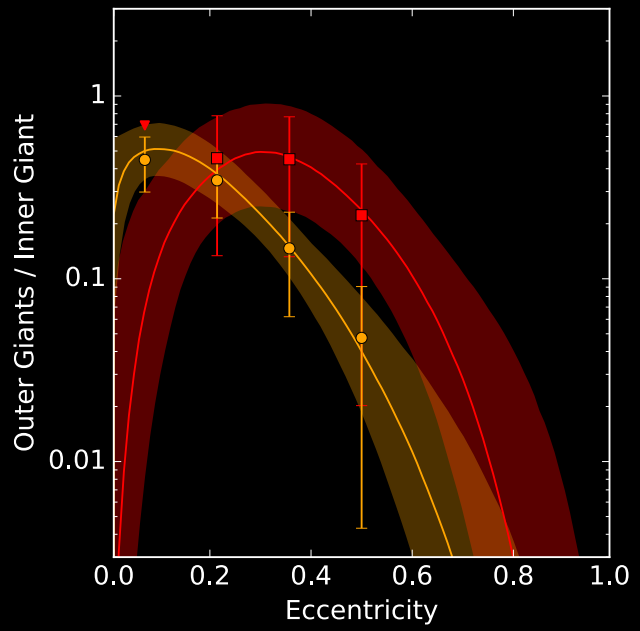

We Favor a Coplanar High-Eccentricity Migration Mechanism