The Celestial Movers and Shakers: How Outer Gas Giants Shape Inner Extrasolar Systems

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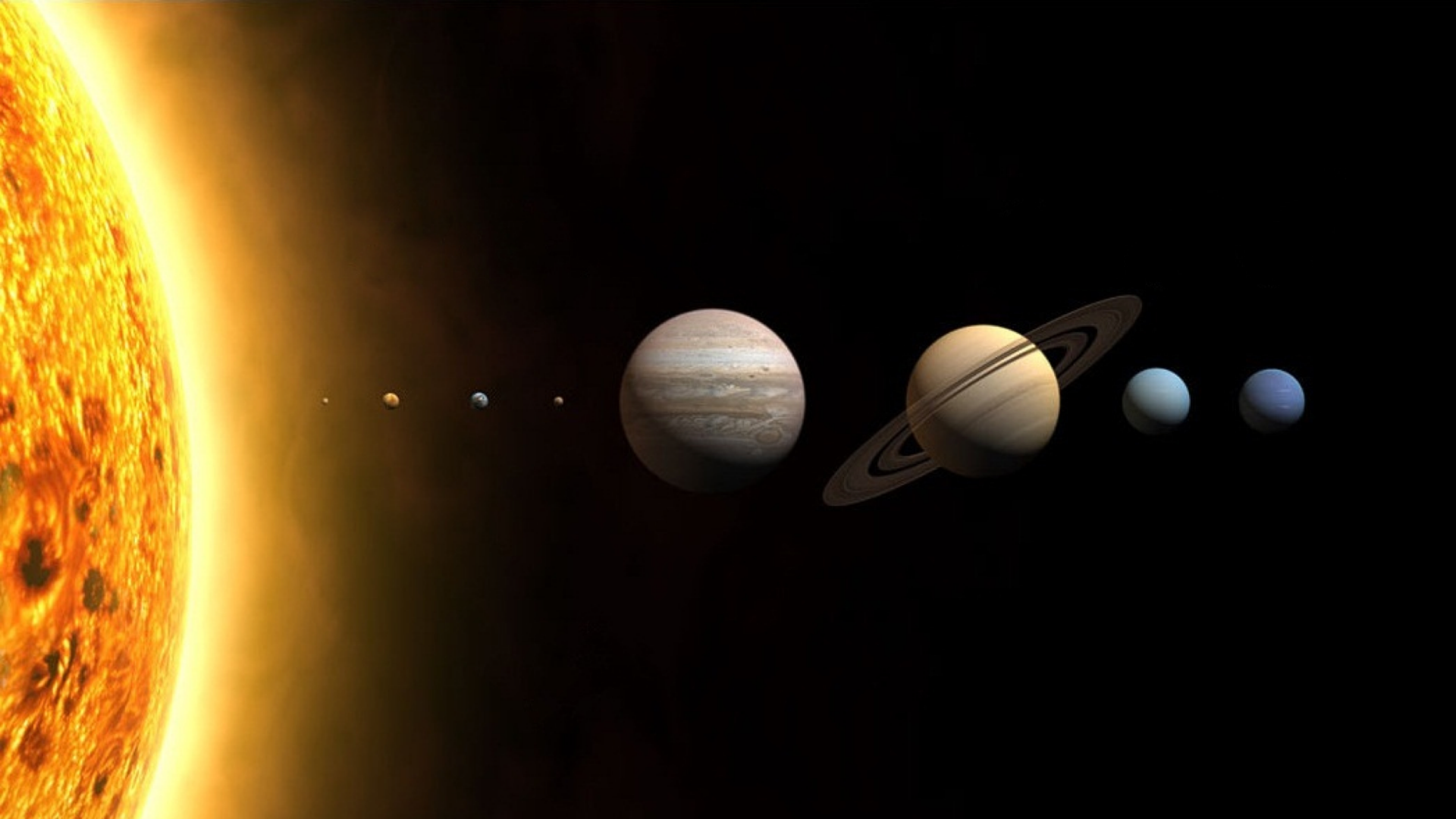
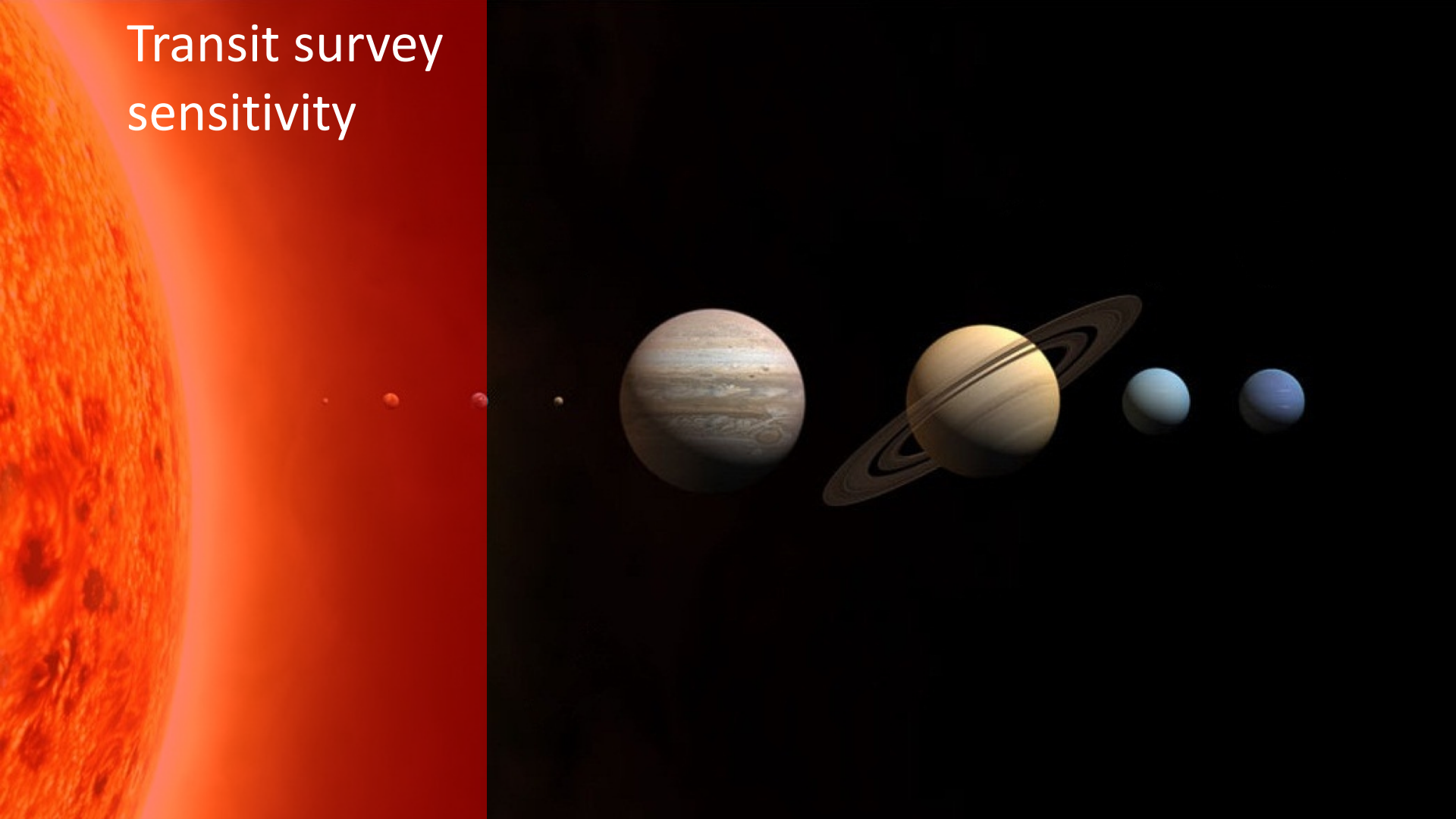
51 Pegasi b Fellow
University of California Berkeley

ExoPAG 21

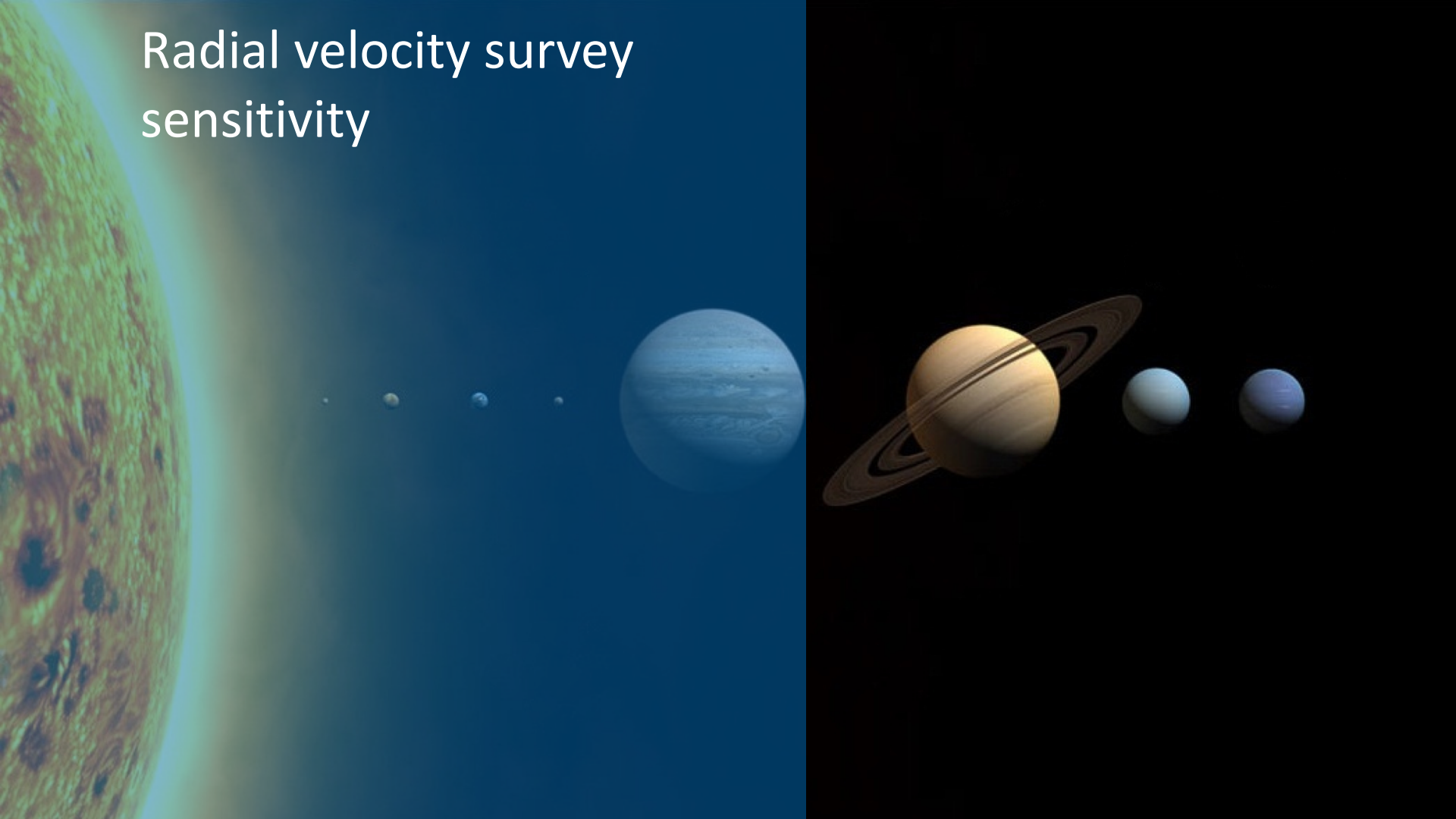
Friday January 3, 2020

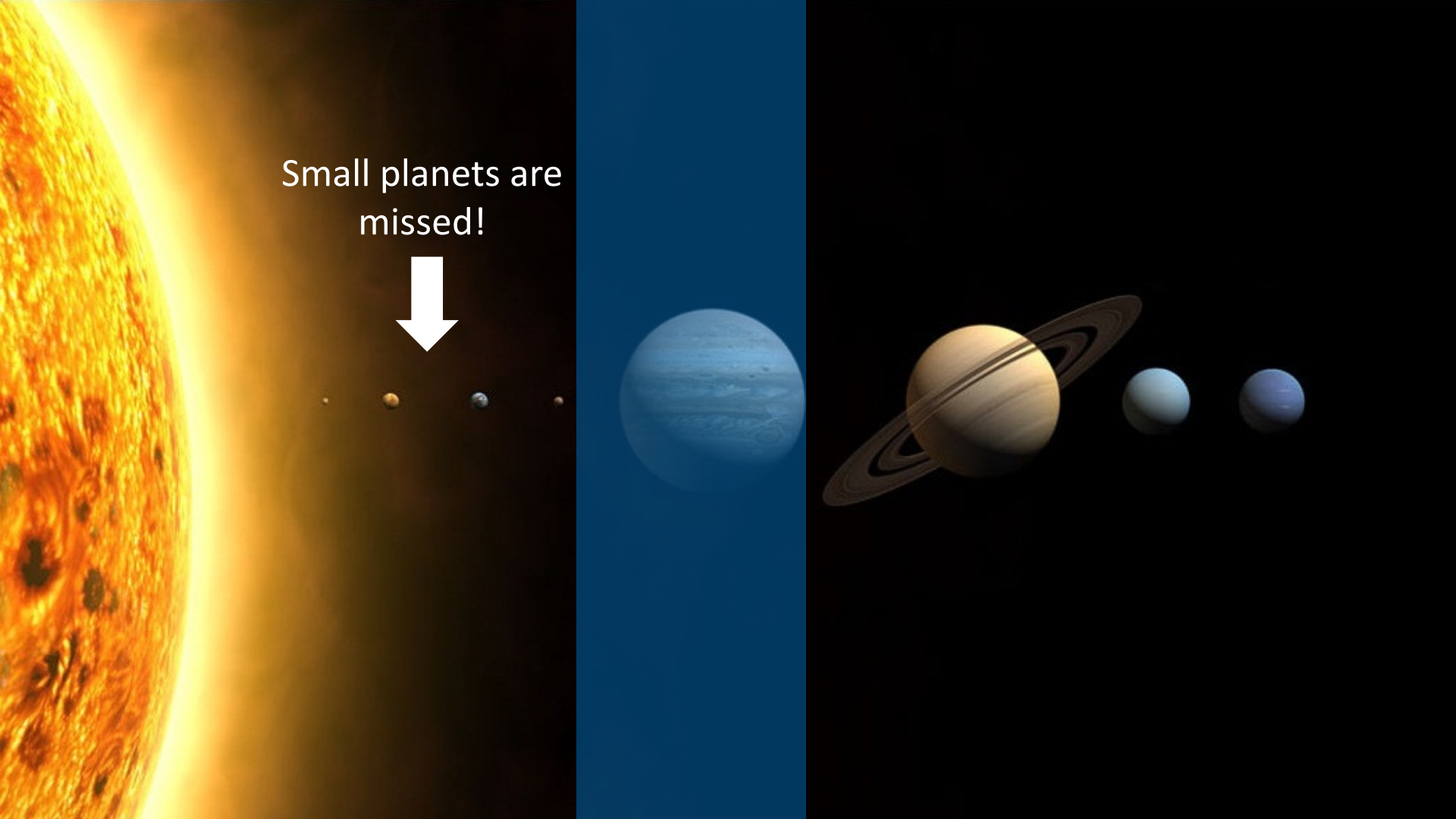


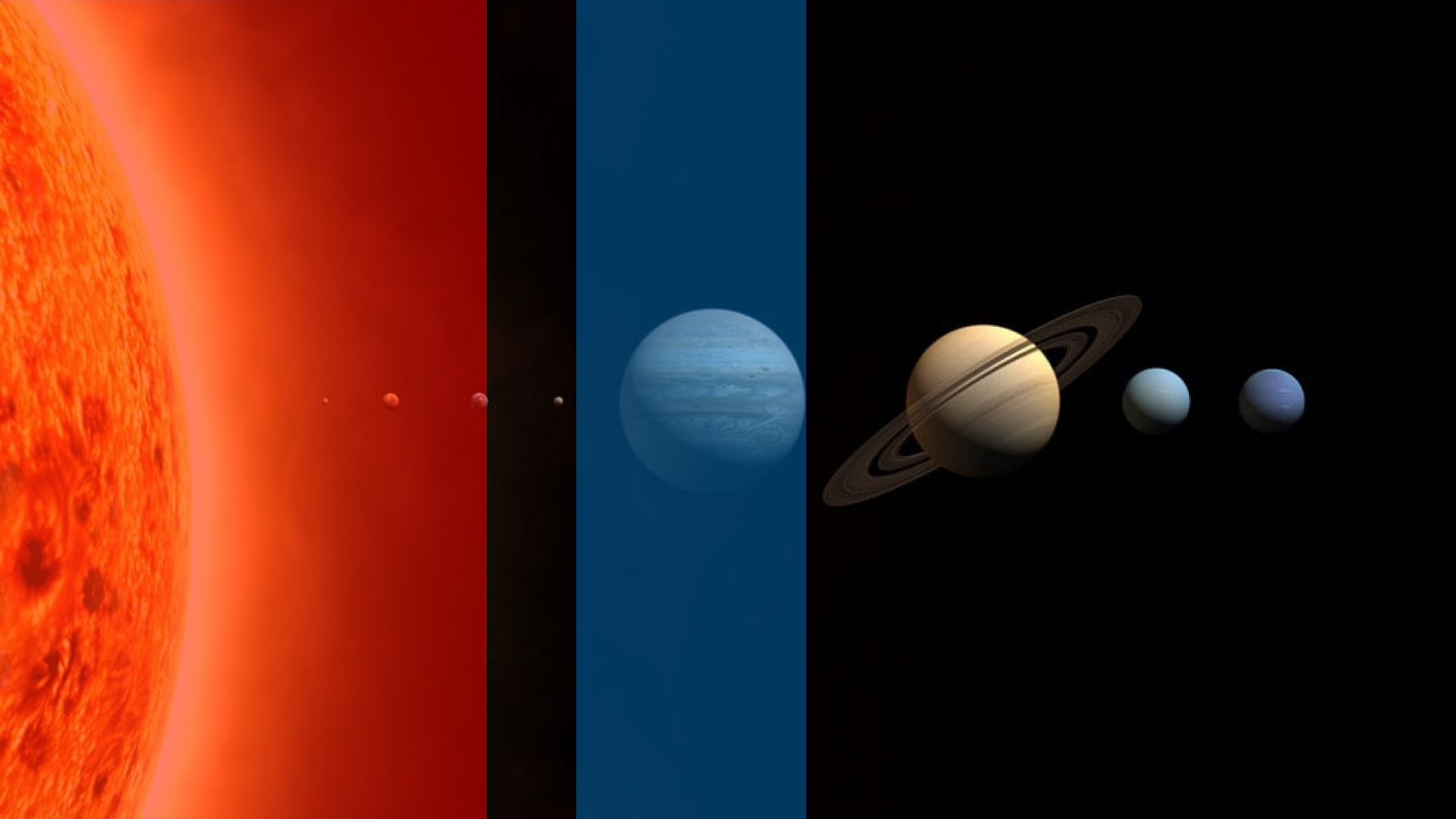
Transit survey sensitivity

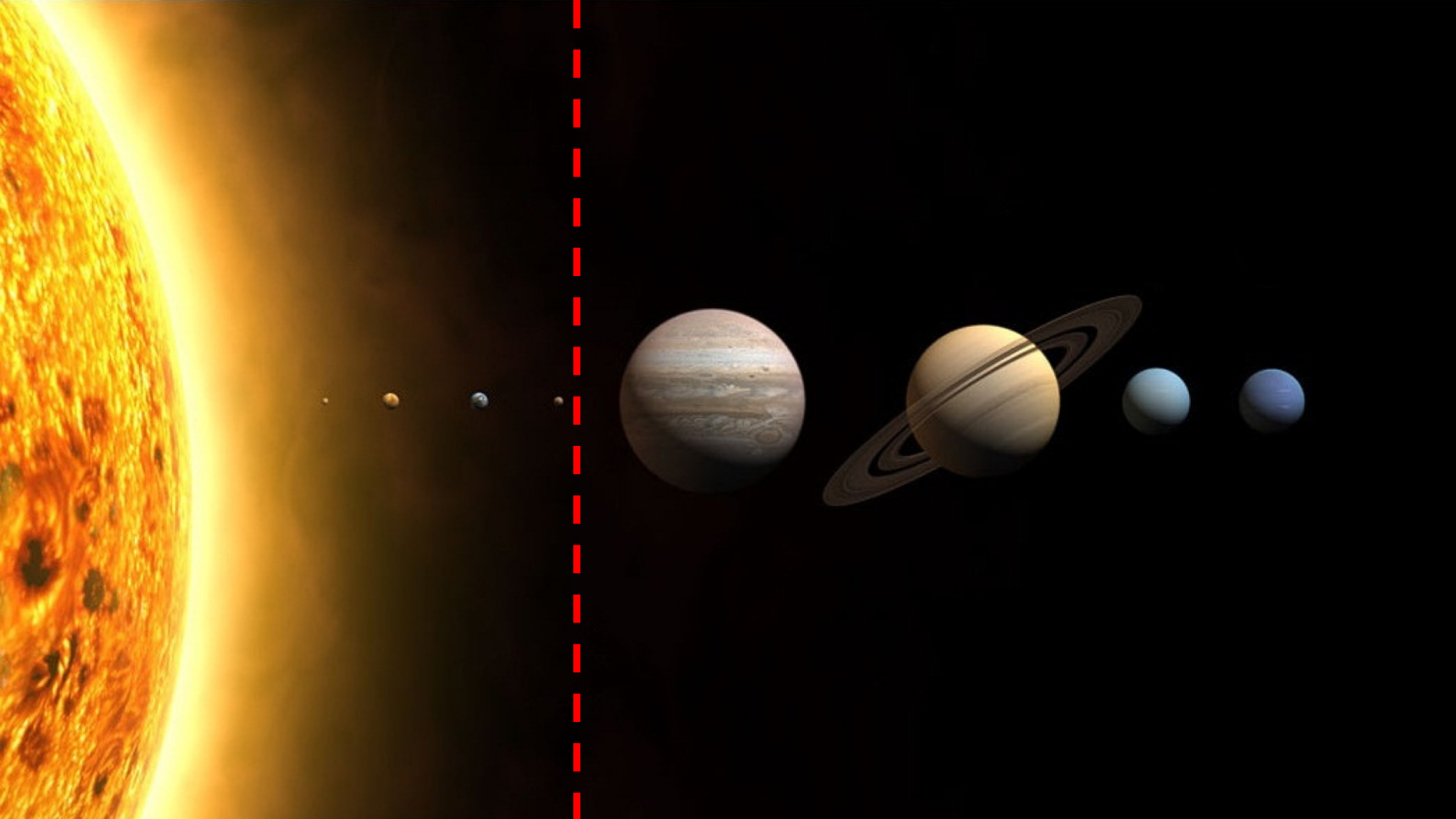


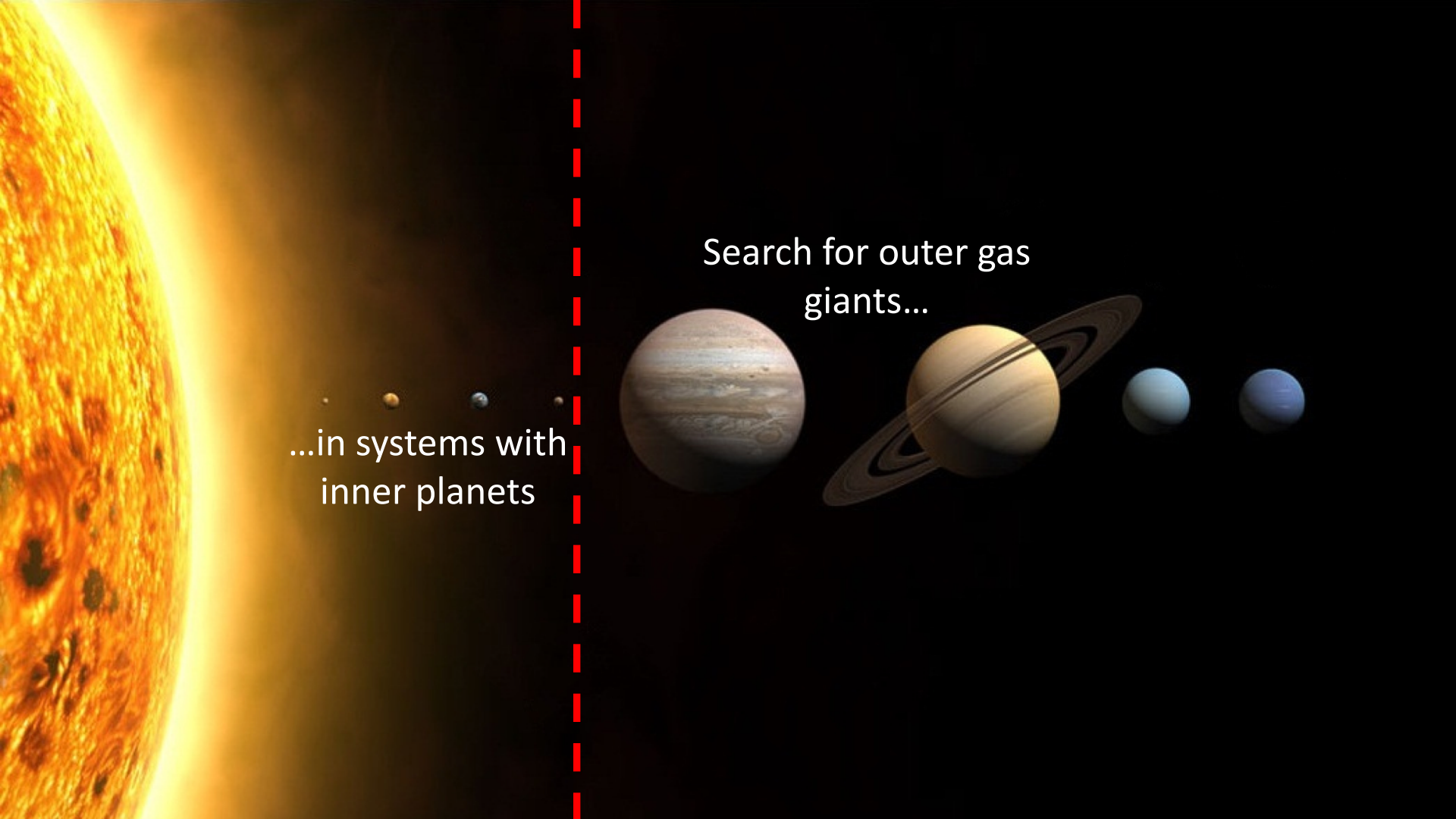
Radial velocity survey sensitivity

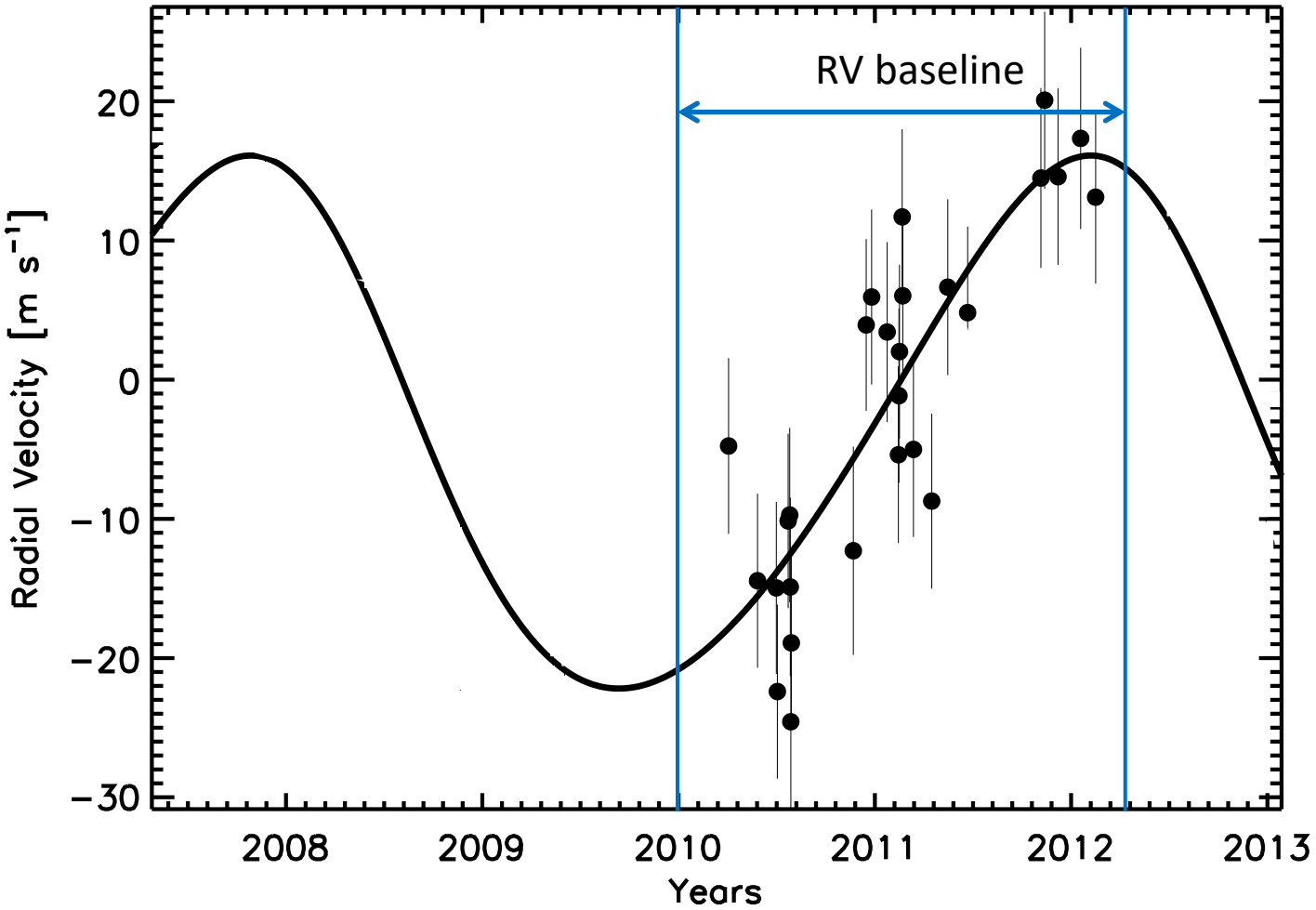



Small planets are missed!






Search for outer gas giants…
…in systems with inner planets


RV baseline
Radial Velocity [m s^{-1}]
20
10
0
−10
−20
−30
2008
2009
2010
2011
2012
2013
Years

FRIENDS OF HOT JUPITERS. I. A RADIAL VELOCITY SEARCH FOR MASSIVE, LONG-PERIOD COMPANIONS TO CLOSE-IN GAS GIANT PLANETS

Heather A. Knutson, Benjamin J. Fulton, Benjamin T. Montet et al 2014

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Are gas giant companions common or rare in super-Earth systems?

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Almenara et al 2015
Alonso et al 2014
Anglada-Escude et al 2012
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Astudillo-Defru et al 2015
Astudillo-Defru et al 2017
Berta-Thompson et al 2015
Borucki et al 2012
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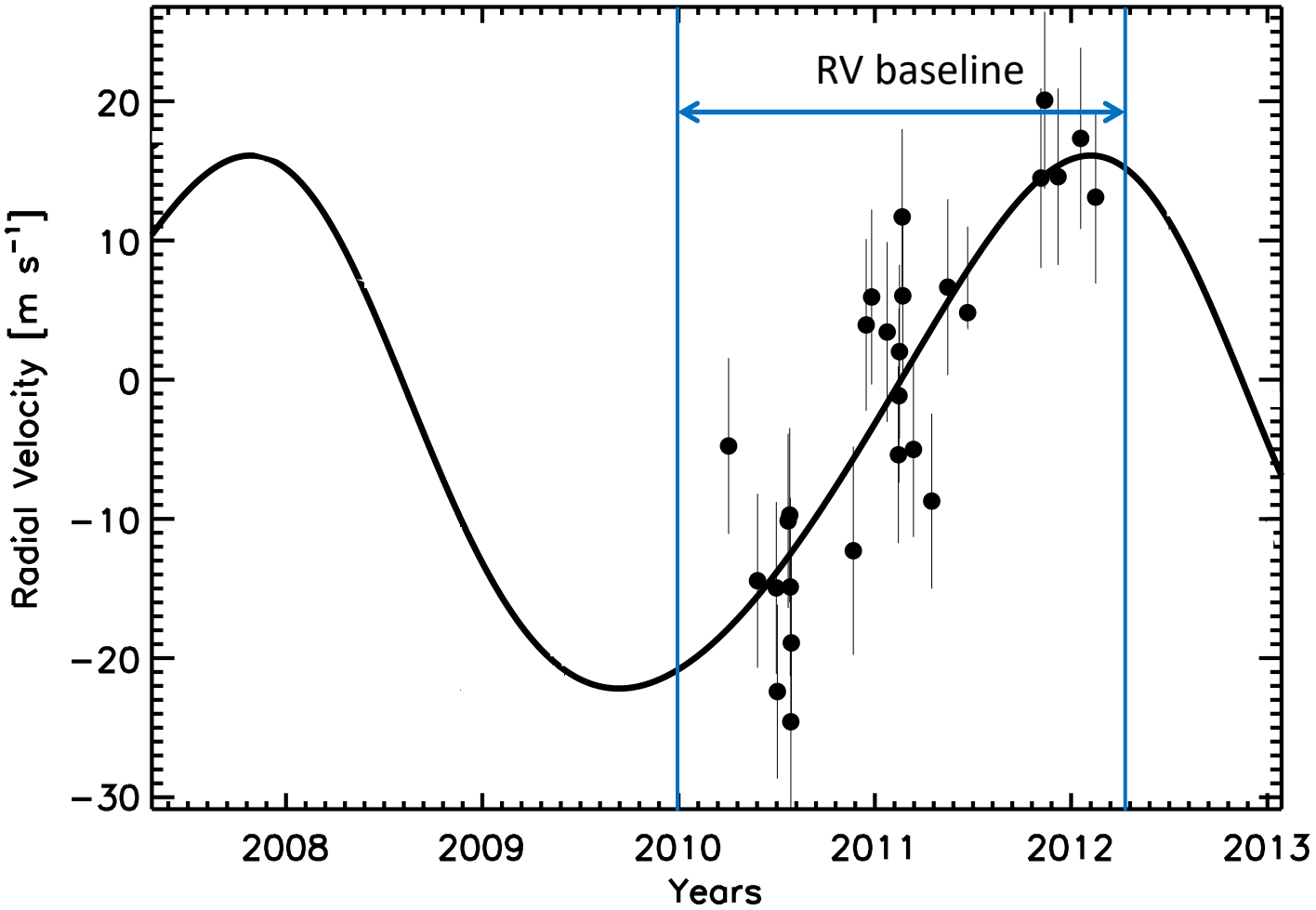
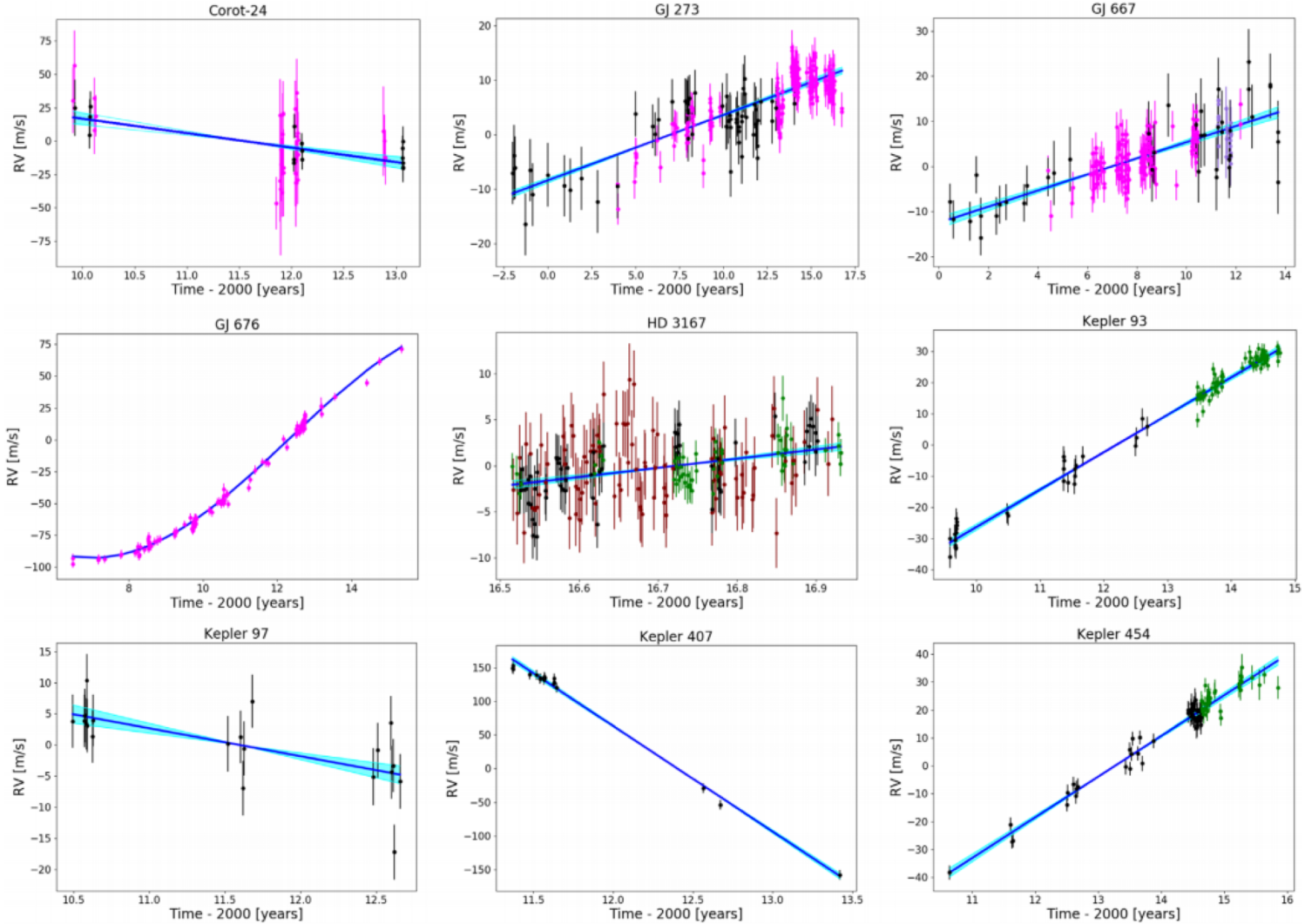
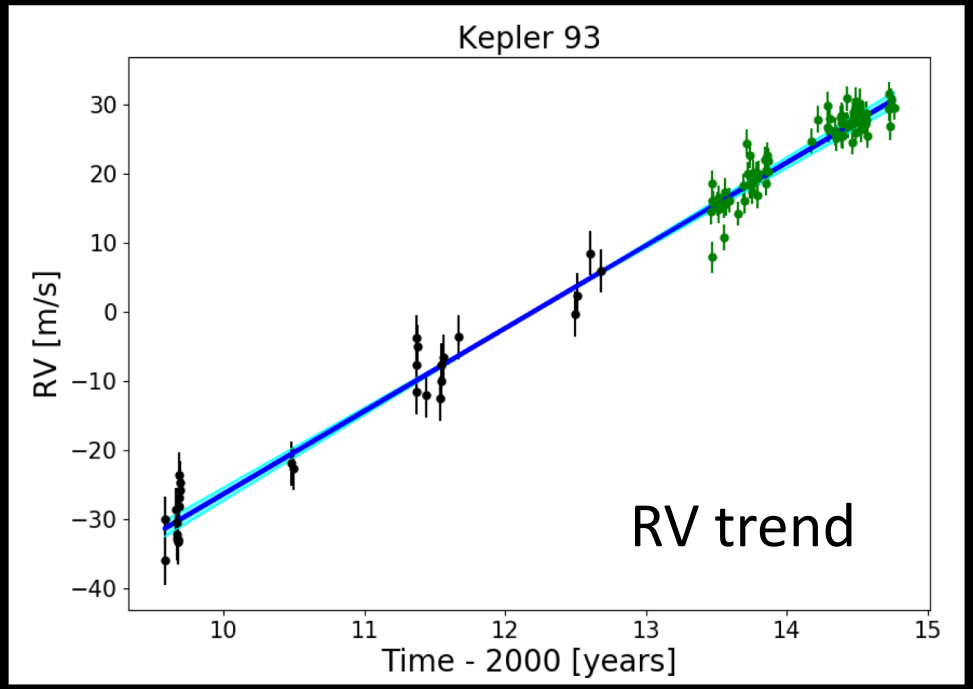
Bryan et al 2016
Delfosse et al 2013
Dittmann et al 2017
Dressing et al 2015
Dumusque et al 2014
Endl et al 2017
Forveille et al 2009
Gautier et al 2012
Gettel et al 2016
Howard et al 2014
Howell et al 2012
Lo Curto et al 2010
Lopez-Morales et al 2016
Mayor et al 2009
Pepe et al 2011
Petigura et al 2017
Queloz et al 2009
Suarez Mascareno et al 2017
Wittenmyer et al 2014


RV baseline
Radial Velocity [m s^{-1}]
20
10
0
−10
−20
−30
2008
2009
2010
2011
2012
2013
Years

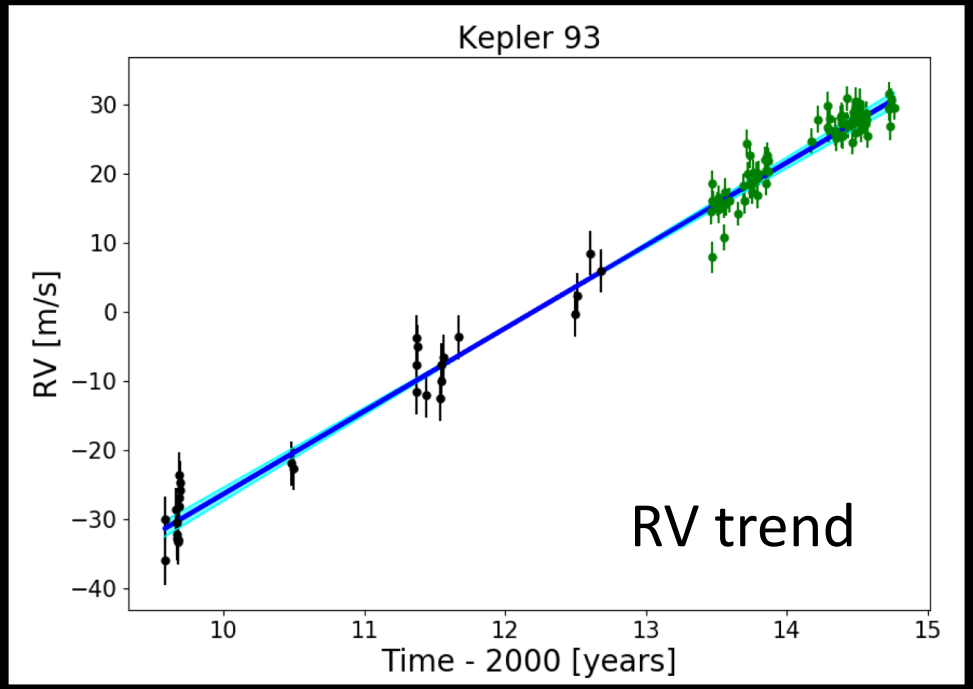

Corot-24
GJ 273
GJ 667
GJ 676
HD 3167
Kepler 93
Kepler 97
Kepler 407
Kepler 454
RV [m/s]
Time - 2000 [years]

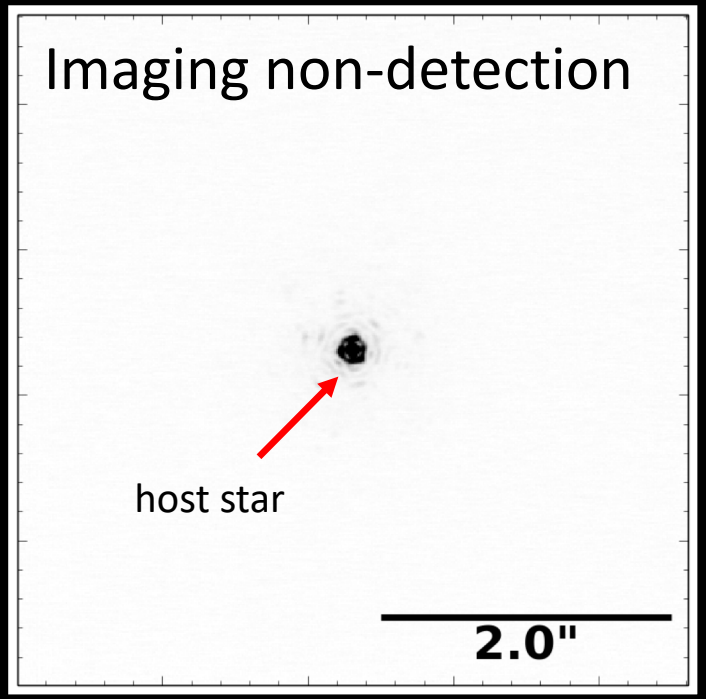
Companion probability distributions



Bryan et al 2019

Companion probability distributions



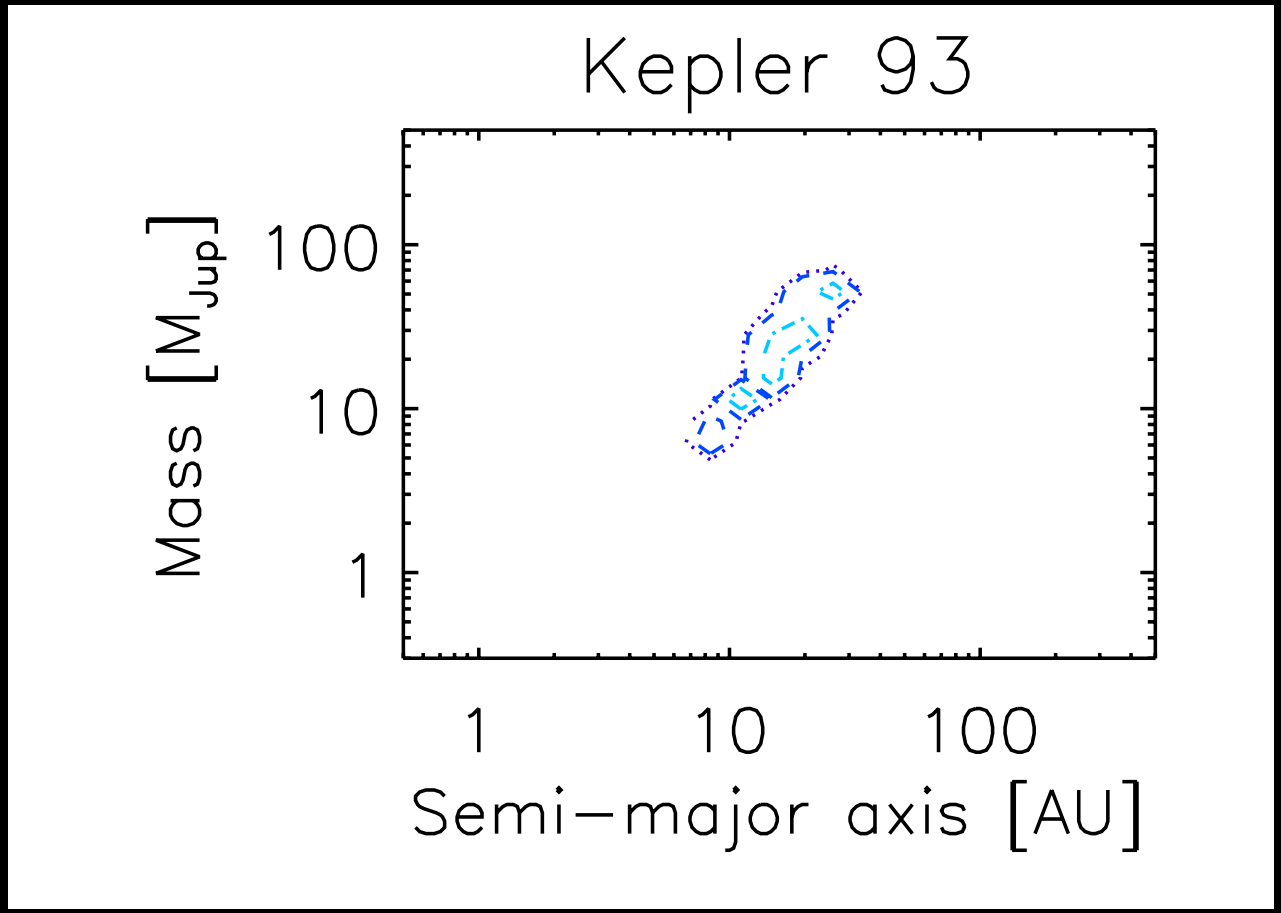


lower limit

upper limit

Bryan et al 2019

Companion probability distributions



Bryan et al 2019

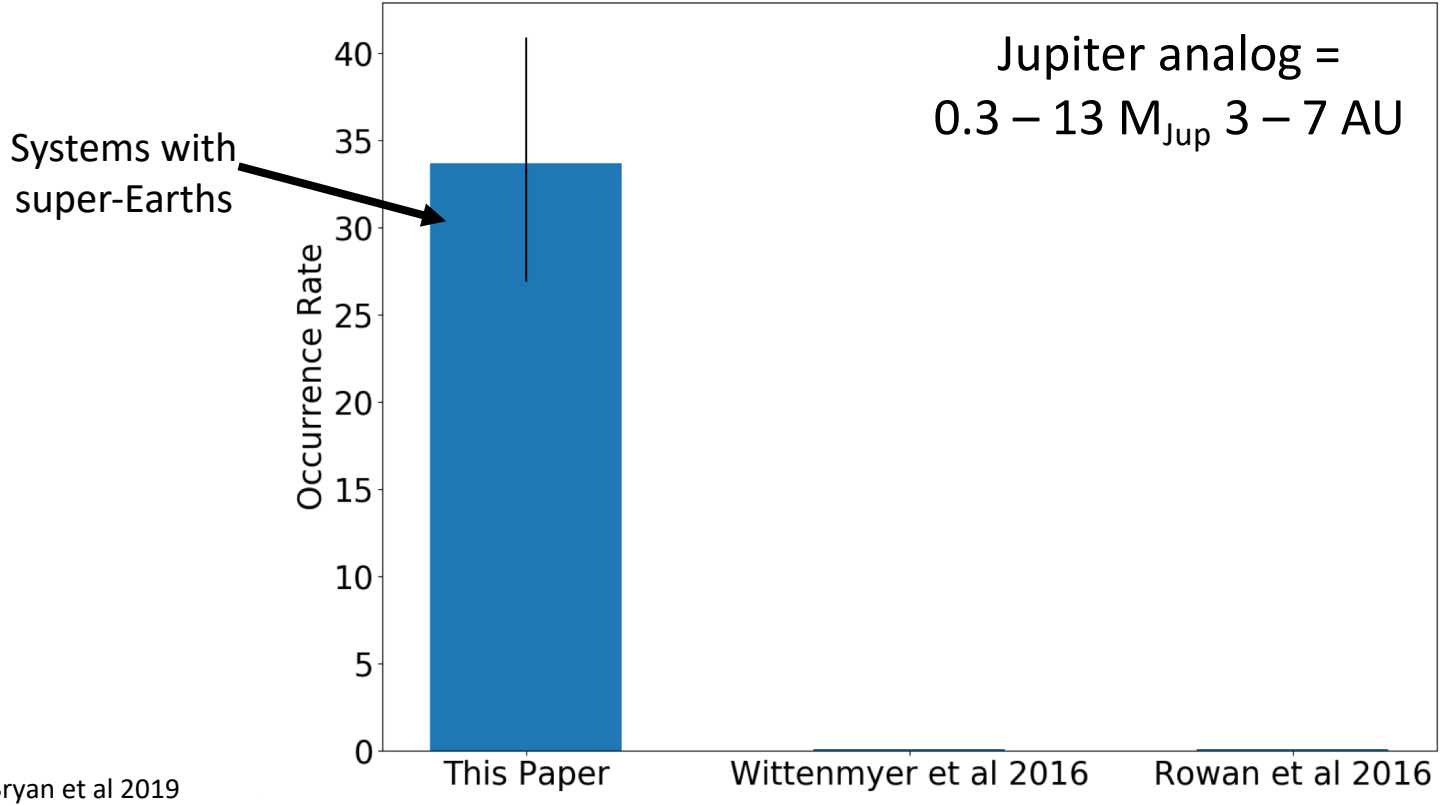
Gas giant companion occurrence rate

$$\text{Occurrence rate} = \frac{\text{Number of long-period gas giants}}{\text{Number of systems searched}}$$

39 +/- 7% of super-Earth systems host an outer gas giant companion

outer gas giant companion = 0.5 – 20 M_{Jup}, 1-20 AU

Are gas giant companions common or rare in super-Earth systems?



Bryan et al 2019

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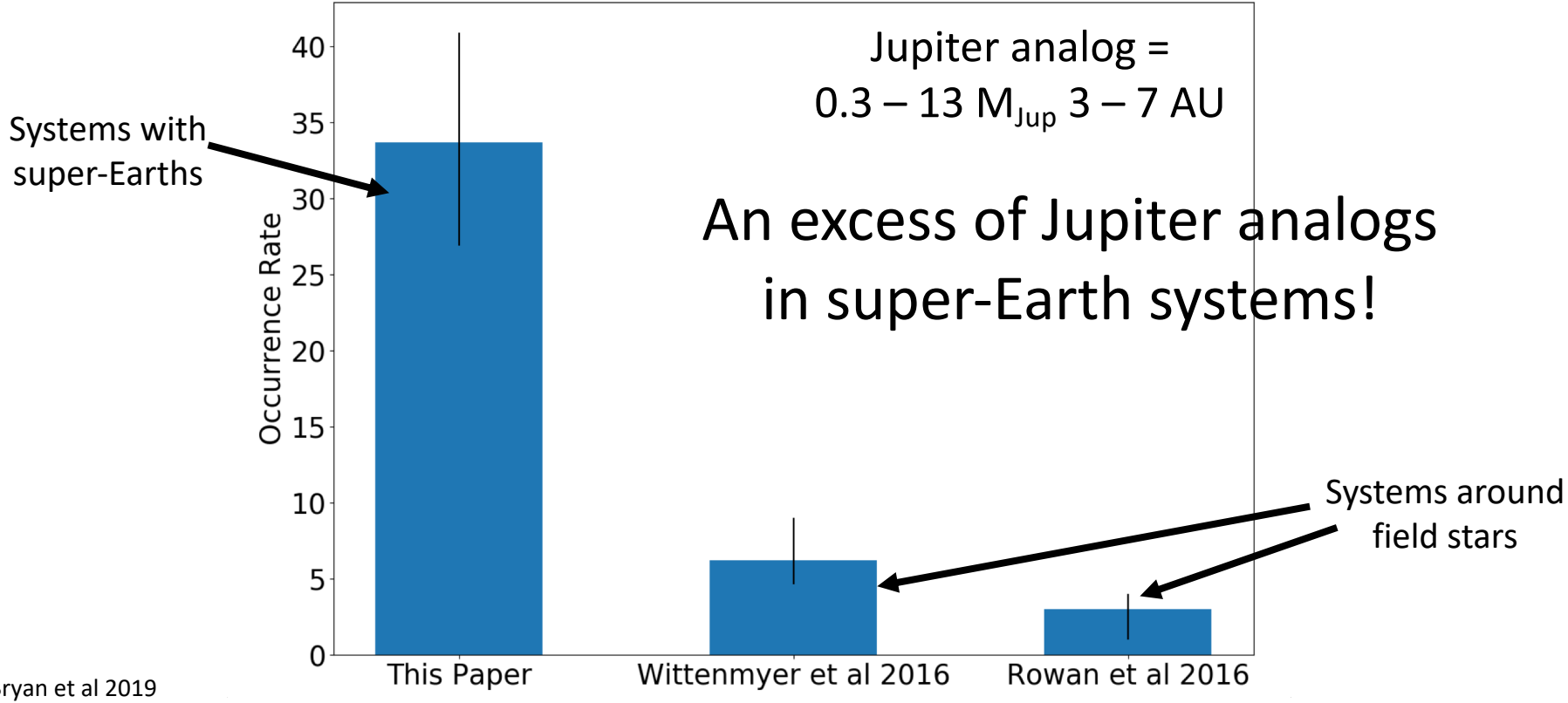

Bryan et al 2019

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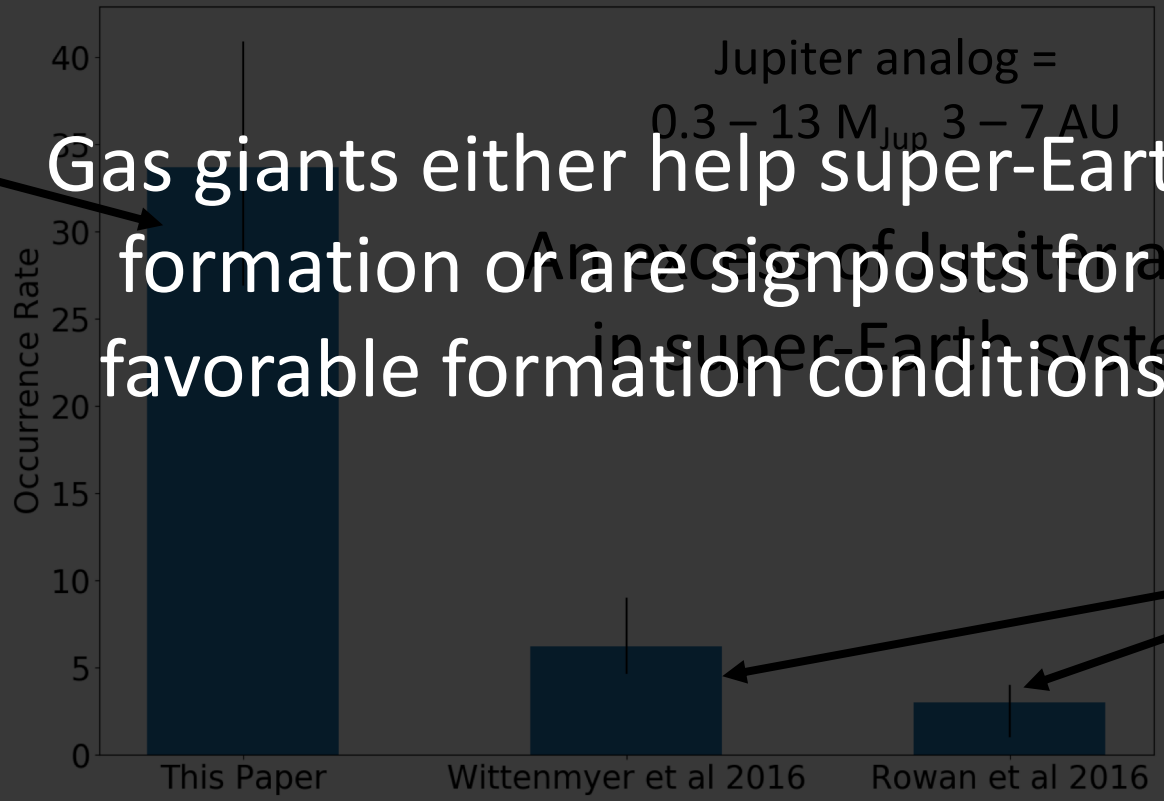


Systems with super-Earths

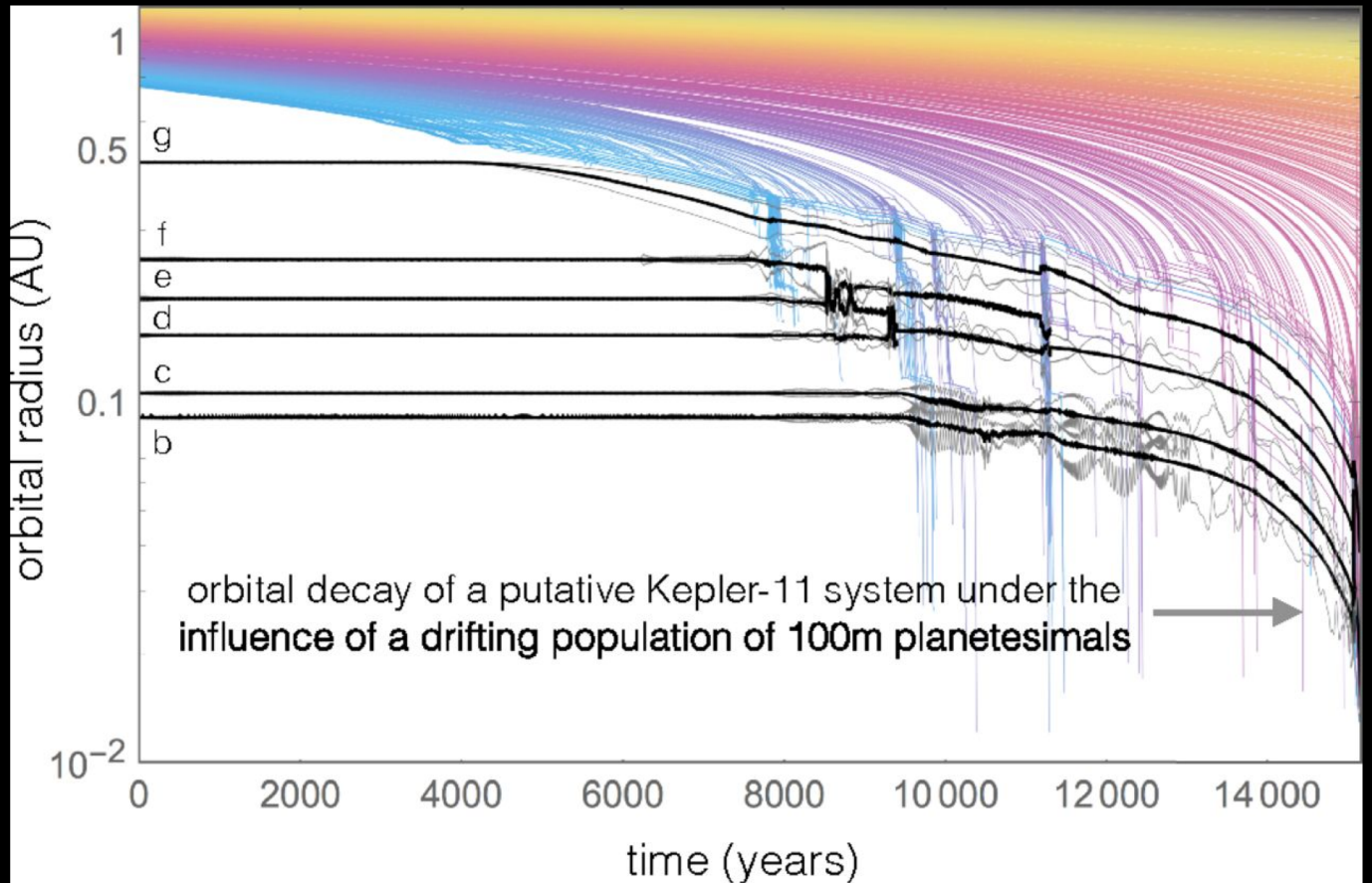
Systems around field stars

Gas giants either help super-Earth formation or are signposts for favorable formation conditions

An excess of Jupiter analogs in super-Earth systems!

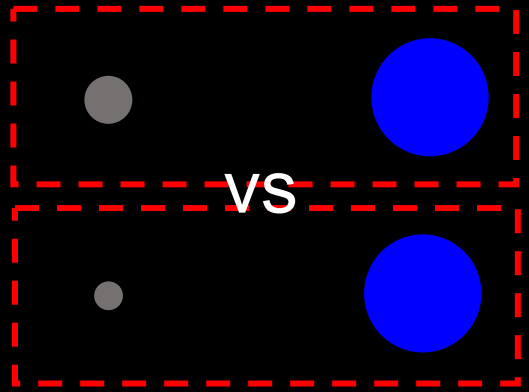
Bryan et al 2019

Gas giant companions in super-Earth systems do not undergo long-range migration

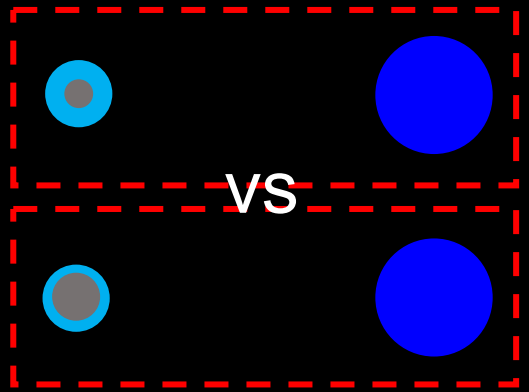


Batygin & Laughlin 2015

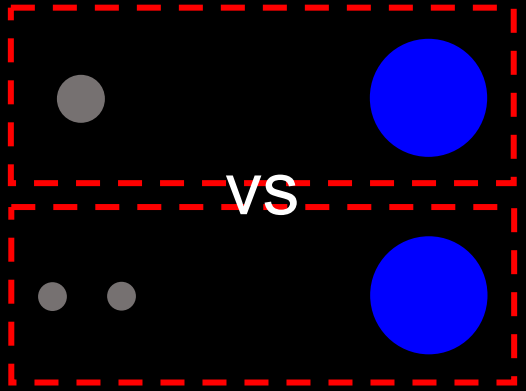
inner planet masses



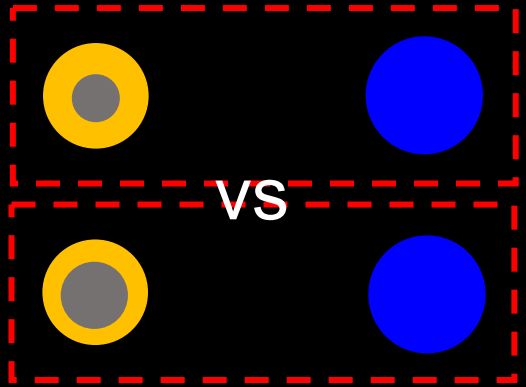
low density/ volatile rich or rocky



mass distribution



gas giant core mass fraction



Current precision RV instruments:

- HIRES
- HARPS
- HARPS-N
- PFS
- APF
- HPF
- SPIRou

Keck

Future precision RV instruments:

- Neid
- MAROON-X
- NIRPS
- KPF
- ESPRESSO

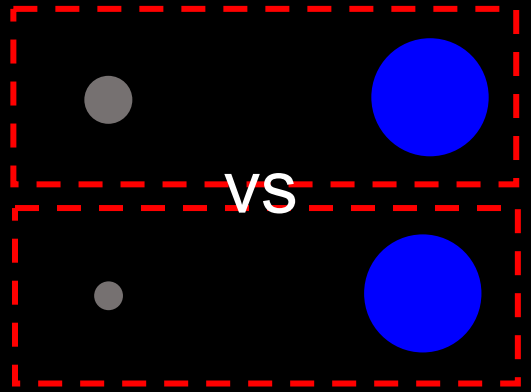
Gemini-N

New targets from TESS (Transiting Exoplanet Survey Satellite)

TESS

Lots of targets and lots of RV data

inner planet masses



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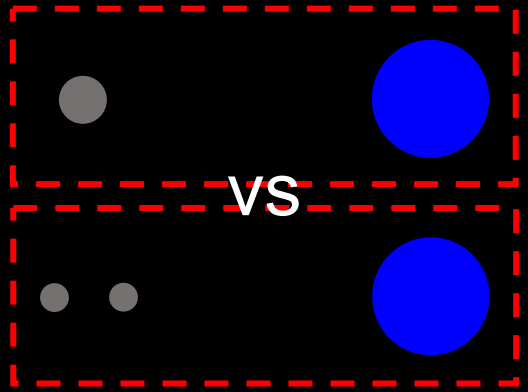

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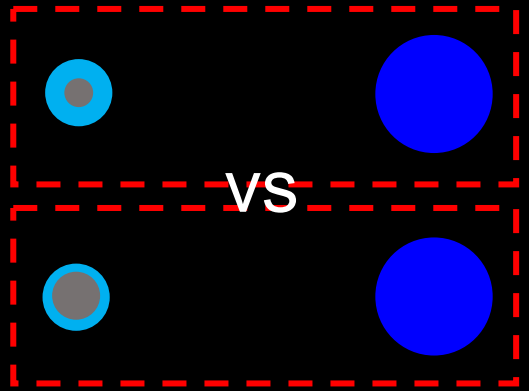

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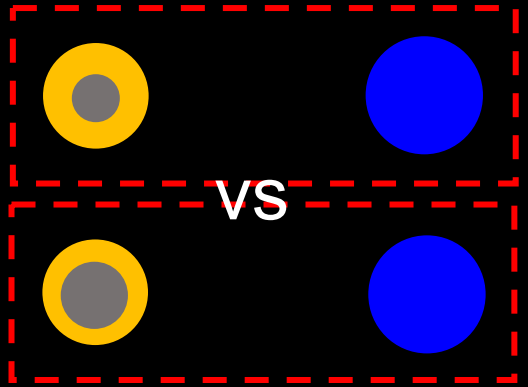

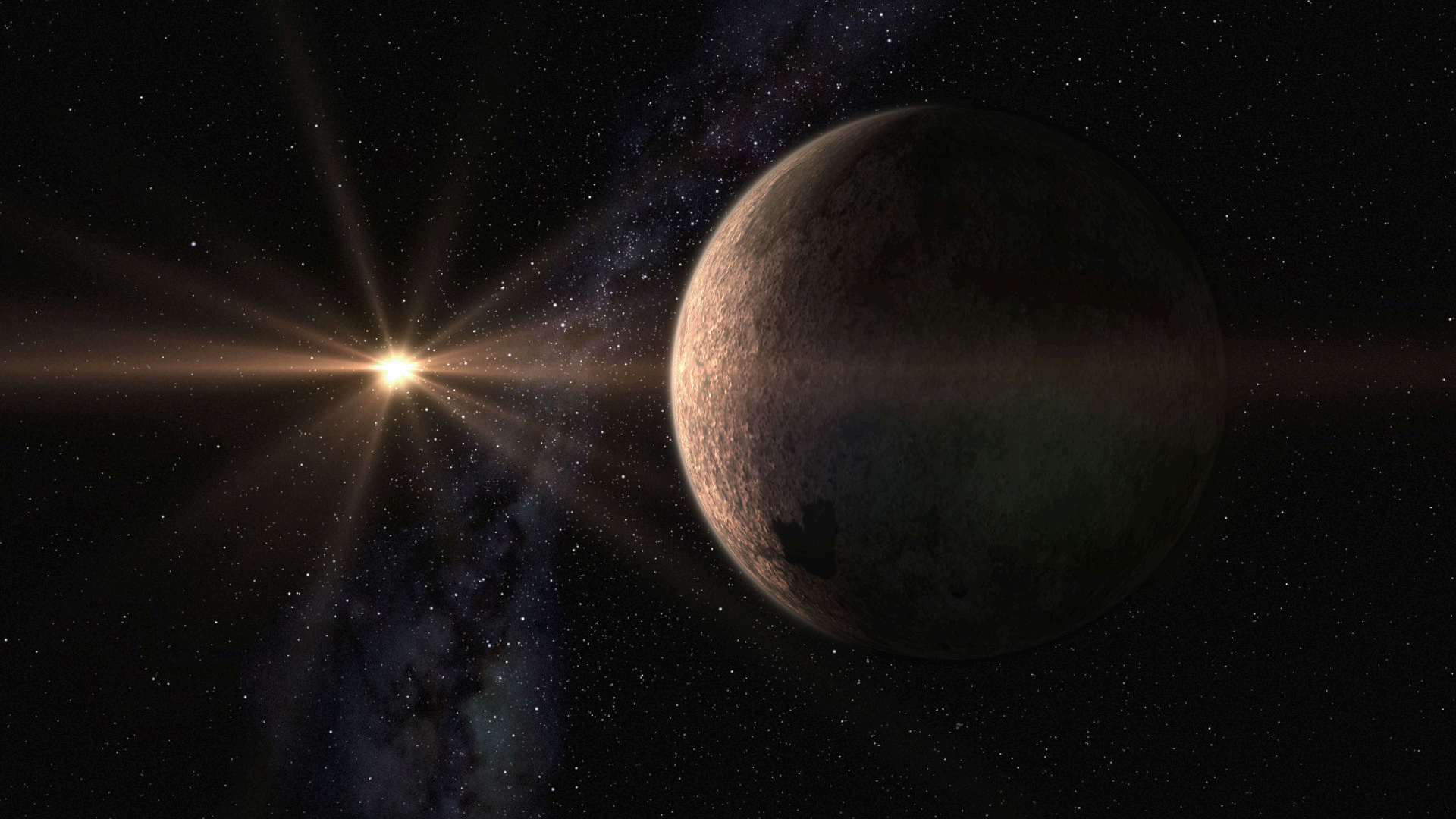

Gas giant friends are common

Companion distribution: $$\frac{dN}{d\ln a\, d\ln m} = Cm^{\alpha}a^{\beta}$$

Gas giant friends are common

Companion distribution: $$\frac{dN}{d\ln a\ d\ln m} = Cm^{\alpha}a^{\beta}$$

Occurrence rate: $$\int\int Cm^{\alpha}a^{\beta}d\ln a\ d\ln m$$

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Companion distribution: $$\frac{dN}{d\ln a\, d\ln m} = Cm^{\alpha}a^{\beta}$$

Occurrence rate: $$\int\int Cm^{\alpha}a^{\beta} d\ln a\, d\ln m$$

Integration range: 0.5 – 20 M_{Jup}, 1 – 20 AU

Occurrence rate of gas giant companions in known planetary systems is:

39 +/- 7%