STELLAR COMPANIONS AND PLANET PROPERTIES WITH HIGH RESOLUTION IMAGING

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CALTECH/IPAC-NEXSCI

KNOW THY STAR – KNOW THY PLANET

2017 OCTOBER 11

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NExScI Caltech

Imaging-Related Presentations

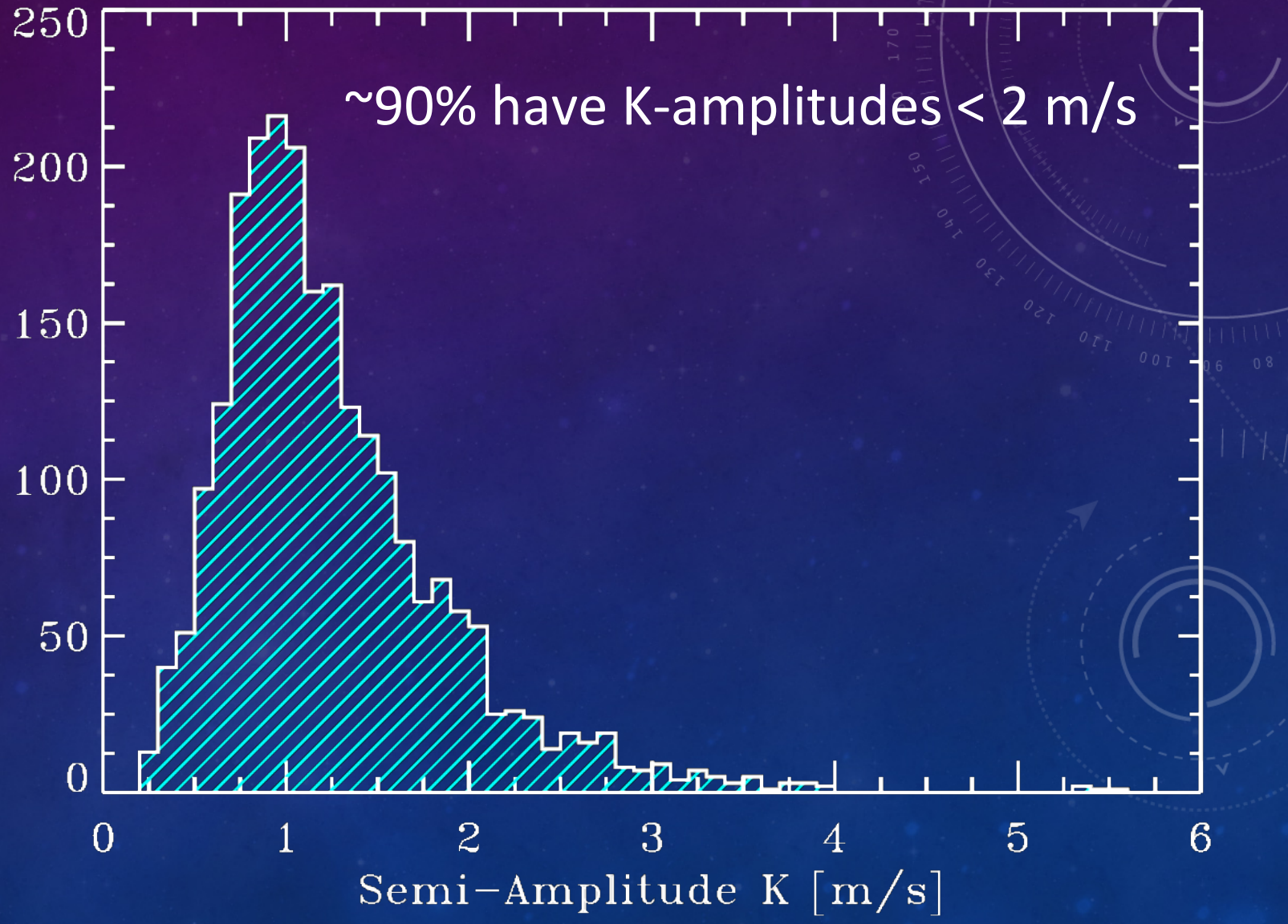
- Tuesday
  - Christiansen, Horch, Morton, Neilson, Hirsch
- Wednesday
  - Sozzetti, Henry, Kraus, Matson, Ziegler, Furlan
- Thursday – direct imaging of planets session
  - Kalas, Bonavita, Lawler, Meshkat, Wang
- Posters
  - Baranec, Everett, Fess, Furlan, Gonzales, Howell, Kwon, Law, Nusdeo, Scott, Wang, Winters

Why We Image Planet-Host Stars?

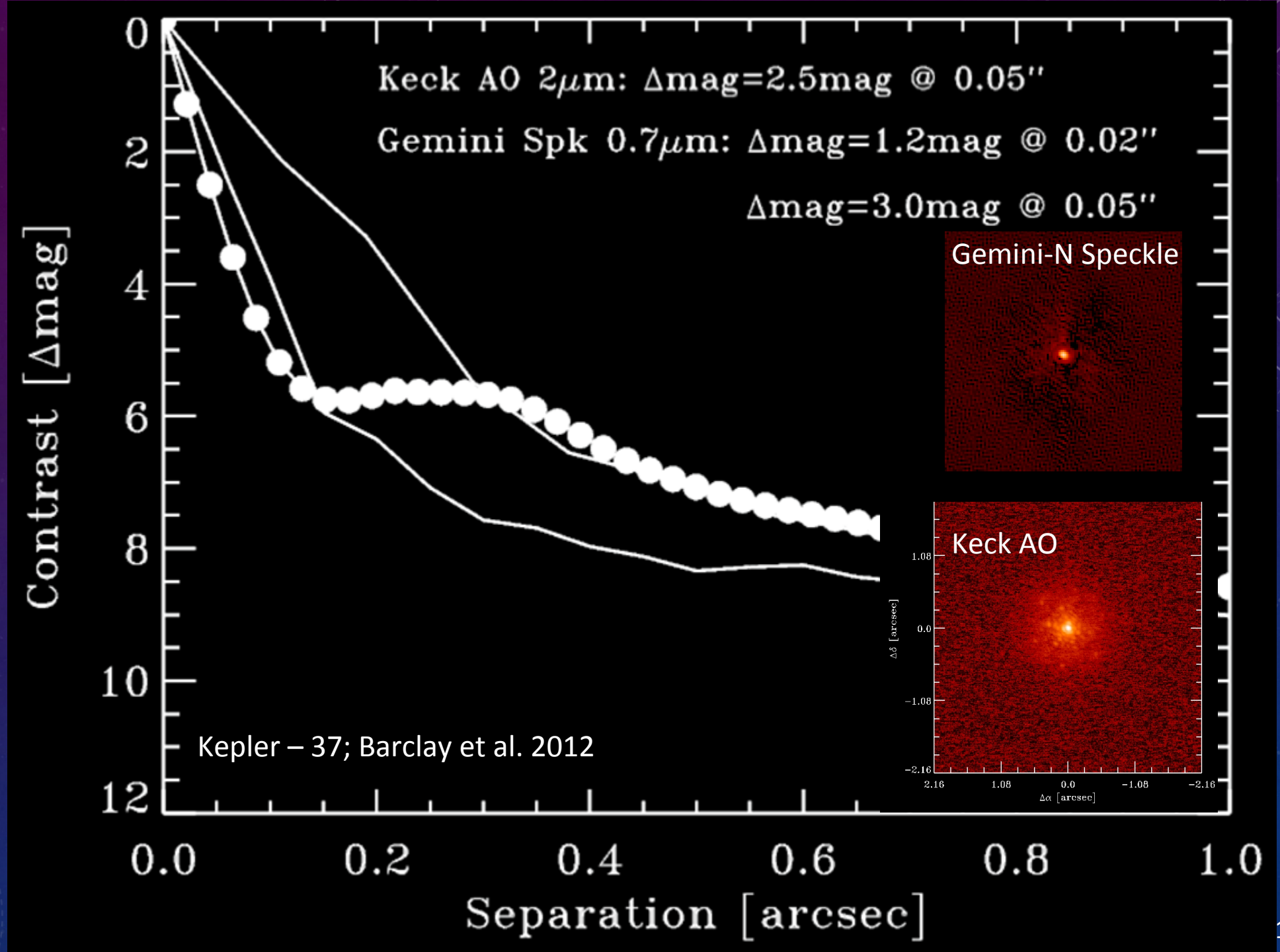
- Provide clean samples
  - Avoid binaries … or … select binaries
- Directly image planets
  - See talks later in the week
- Validate transiting planets
- Characterize the stellar host systems
- And lots of other science …

As We Push to Smaller and Smaller

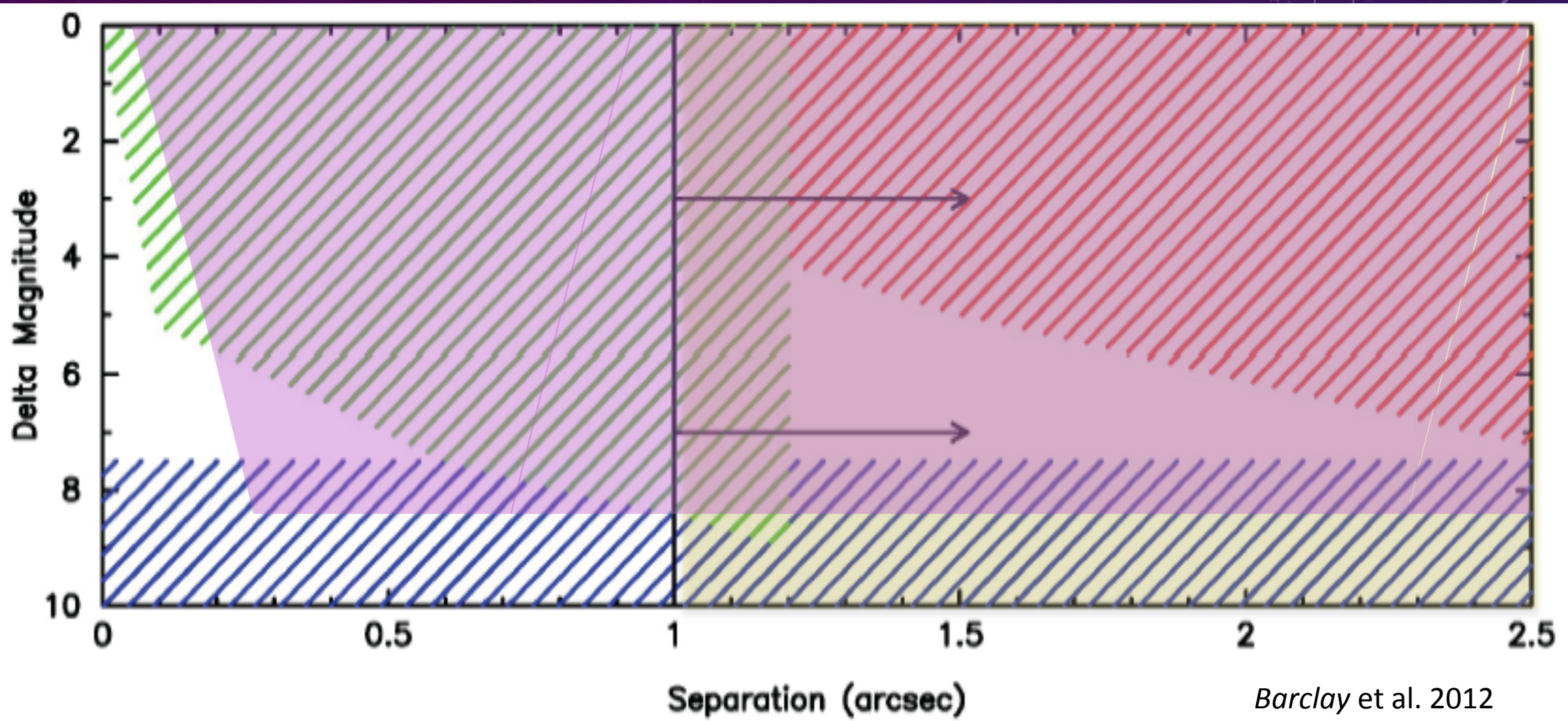
- Kepler: ~4500 transiting candidates
- K2: ~500 transiting candidates
- TESS: similar numbers to Kepler in postage stamps*



Validating Transiting Planets

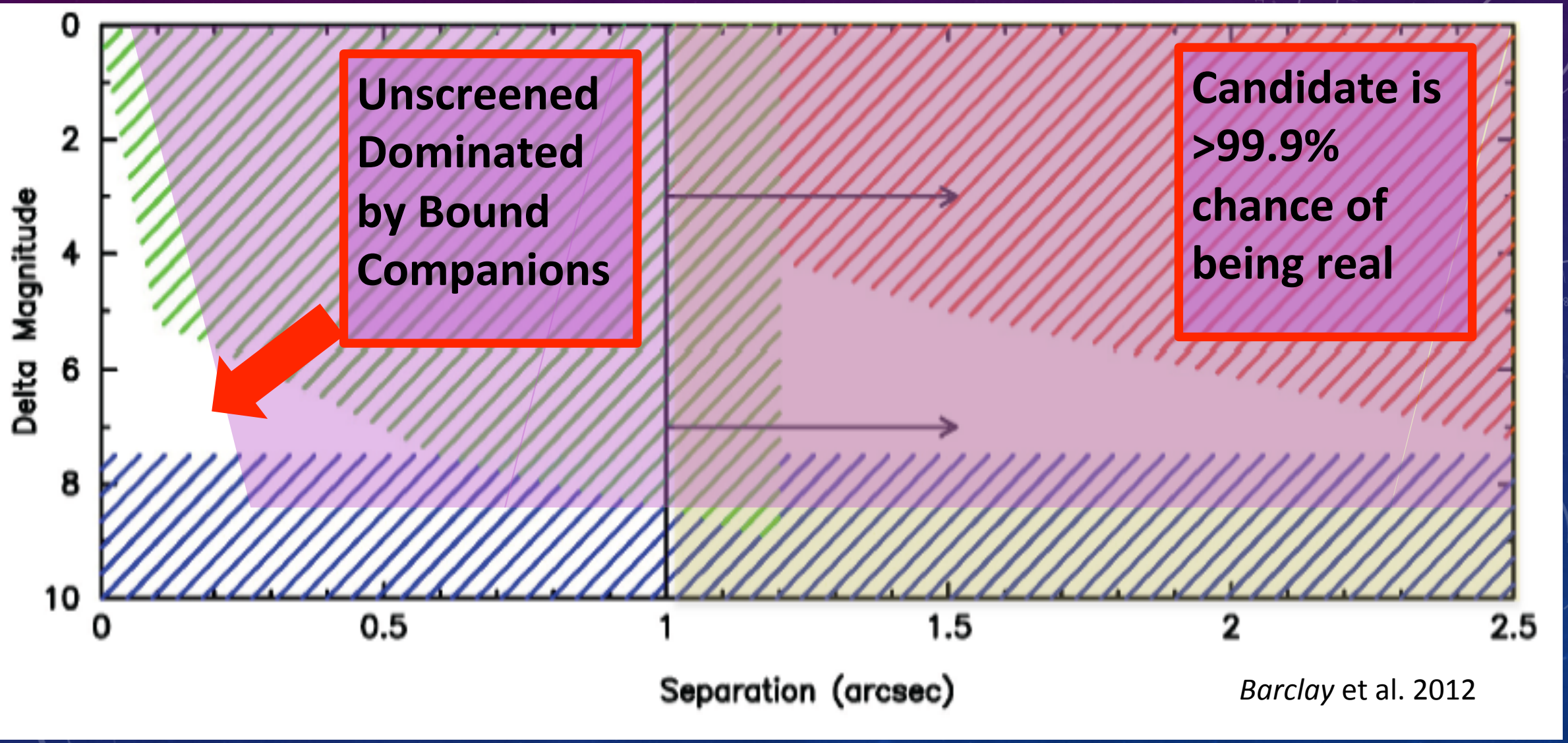

Keck AO 2μm: Δmag=2.5mag @ 0.05"
Gemini Spk 0.7μm: Δmag=1.2mag @ 0.02"
Δmag=3.0mag @ 0.05"
Gemini-N Speckle
Keck AO
Kepler – 37; Barclay et al. 2012
Contrast [Δmag]
Separation [arcsec]
0
2
4
6
8
10
12
0.0
0.2
0.4
0.6
0.8
1.0
1.08
0.0
−1.08
−2.16
Δδ [arcsec]
Δα [arcsec]

Build-Up the "Imaging Scene"



Barclay et al. 2012

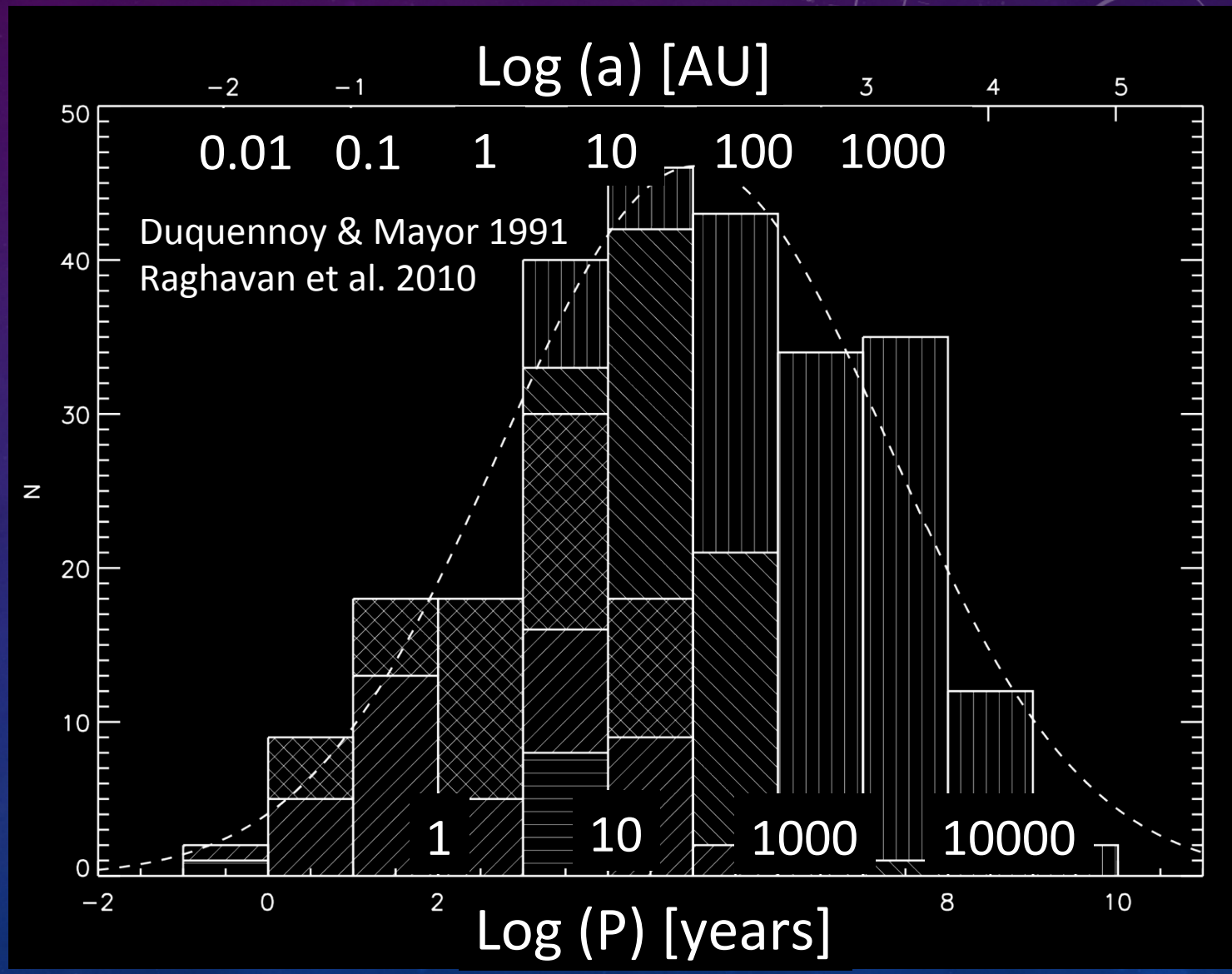
Build-Up and "Imaging Scene"



Barclay et al. 2012

Stars Can Have Stellar Companions

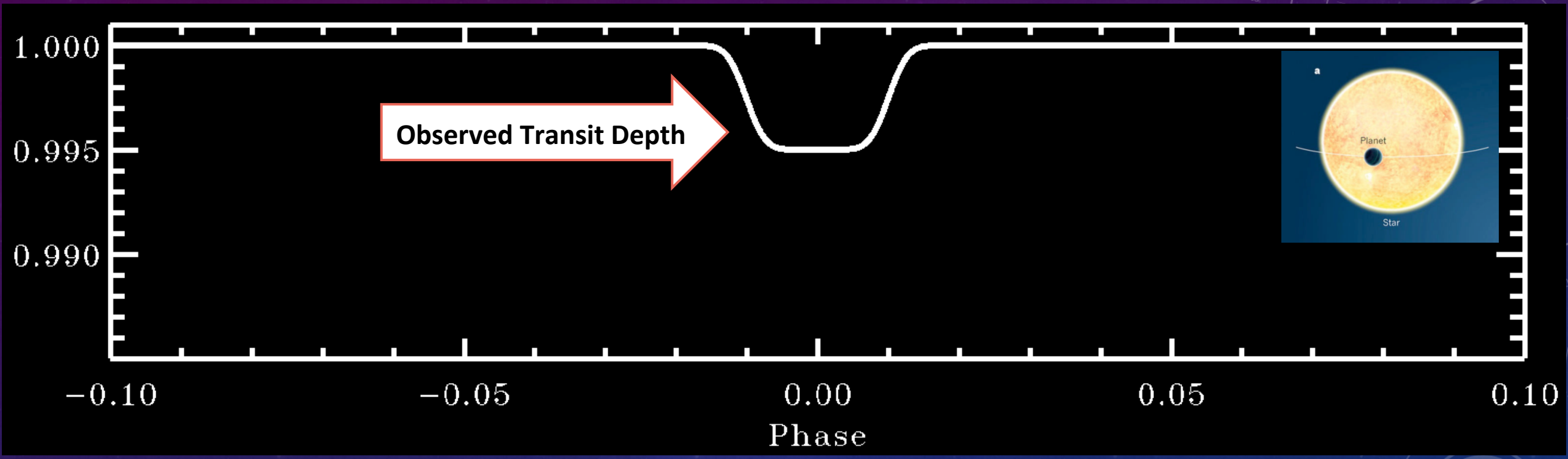
- Multiplicity fraction for field stars is 40 – 50%
- Multiplicity fraction may correlate with stellar mass
- Planet host stars may have different companion distributions than the field (see talks that follow)



So … Why Does This Matter?

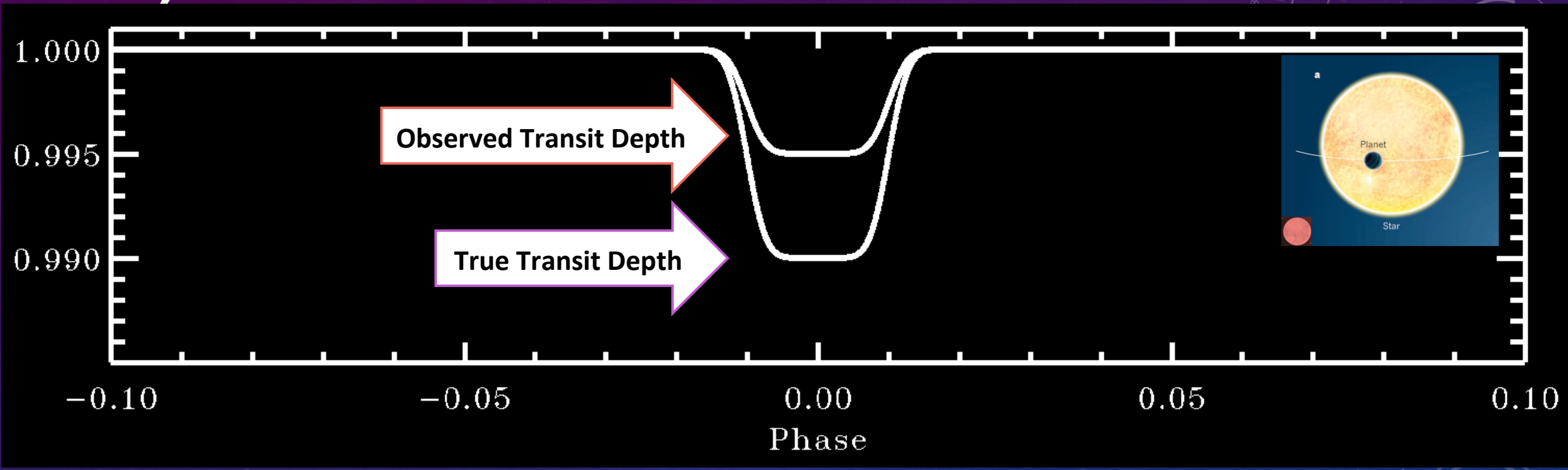
- Presence (or absence of companions) can greatly affect the derived properties of the planets (e.g., Know Thy Star)
- Understand the planetary occurrence rates
  - Planets In multiple star systems
  - Or … Multiple stars in planetary systems

Planet Radii From Transit Depths



$$\delta_o = \left(\frac{R_p}{R_{t\star}} \right)^2$$

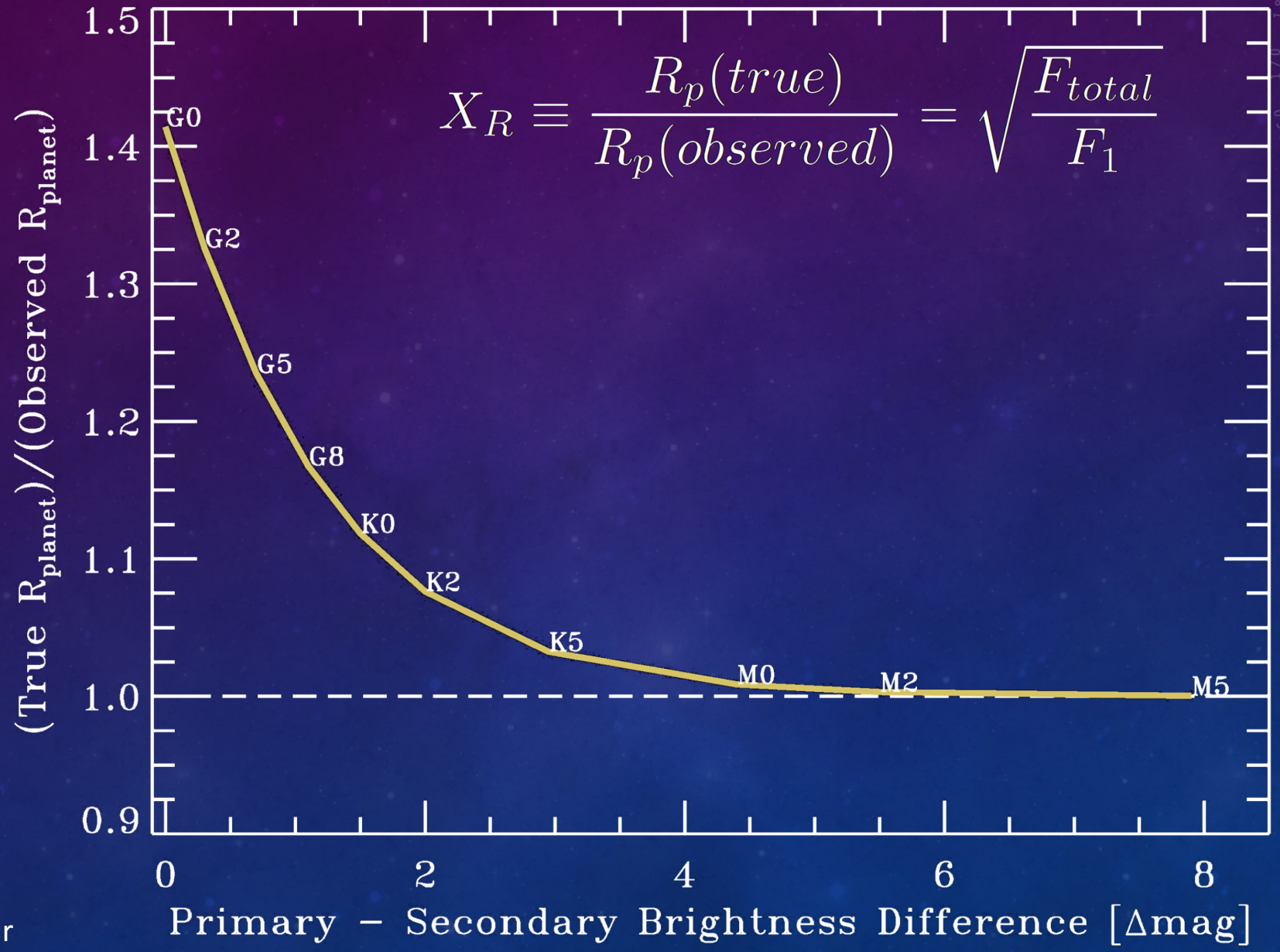
But, It's More Complicated ...



$$\delta_o = \left(\frac{F_t}{F_{total}}\right)\left(\frac{R_p}{R_{t\star}}\right)^2$$

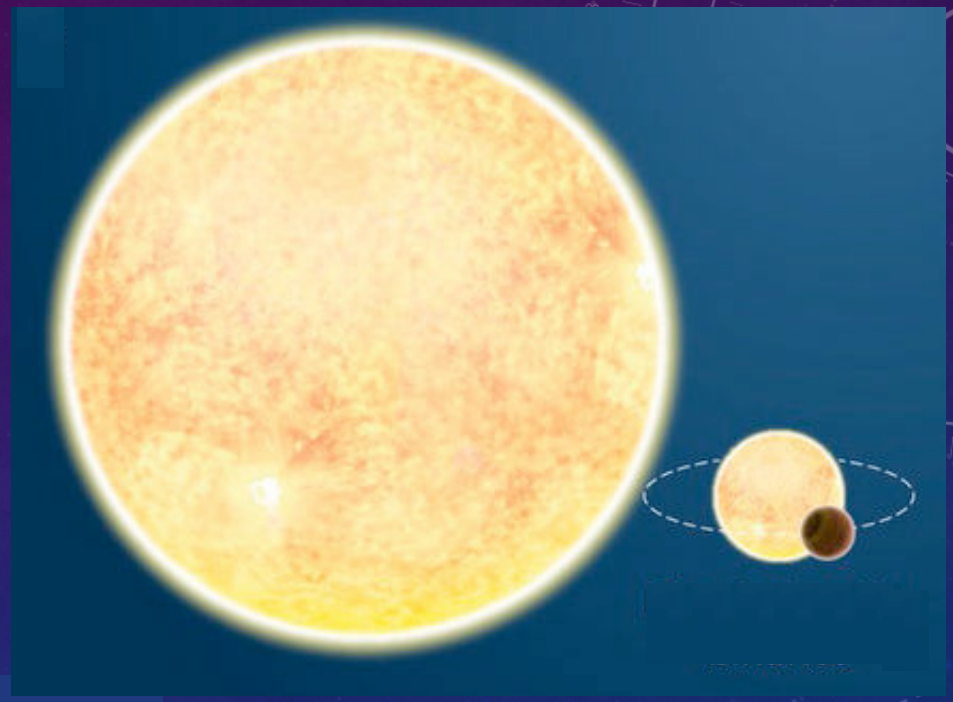
Underestimate Rp From Blends

$$X_R \equiv \frac{R_p(true)}{R_p(observed)} = \sqrt{\frac{F_{total}}{F_1}}$$



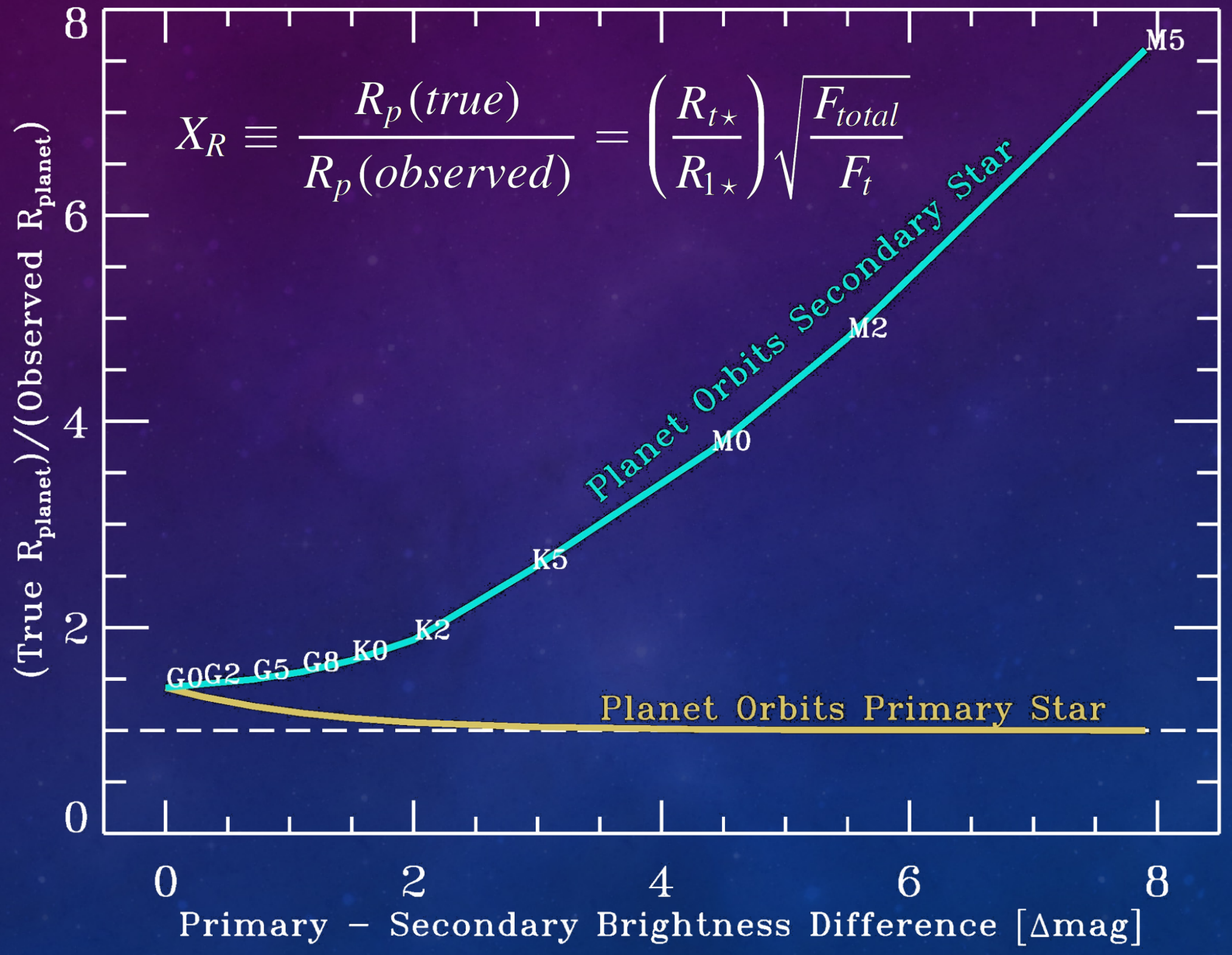
IF THE PLANET ORBITS THE COMPANION ?

- Need to take into account the photometric blending AND the radius of the secondary star



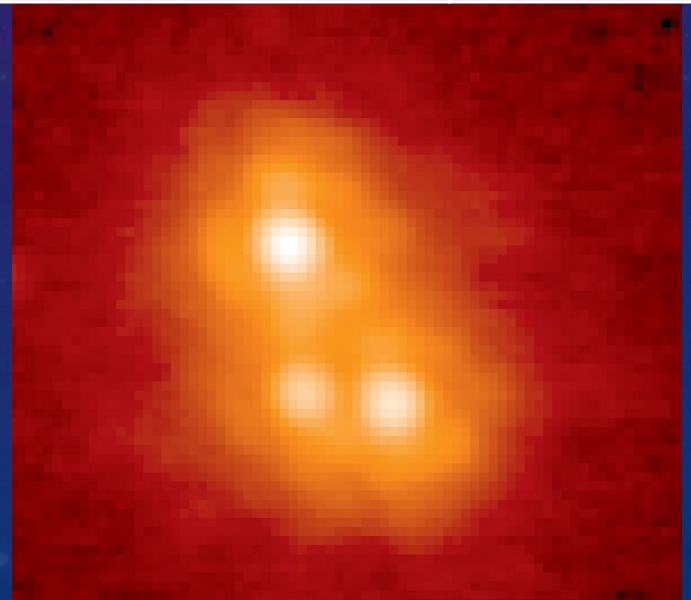
$$\delta_o = \left(\frac{F_t}{F_{total}}\right)\left(\frac{R_p}{R_{t\star}}\right)^2$$

IF THE PLANET ORBITS THE COMPANION ?



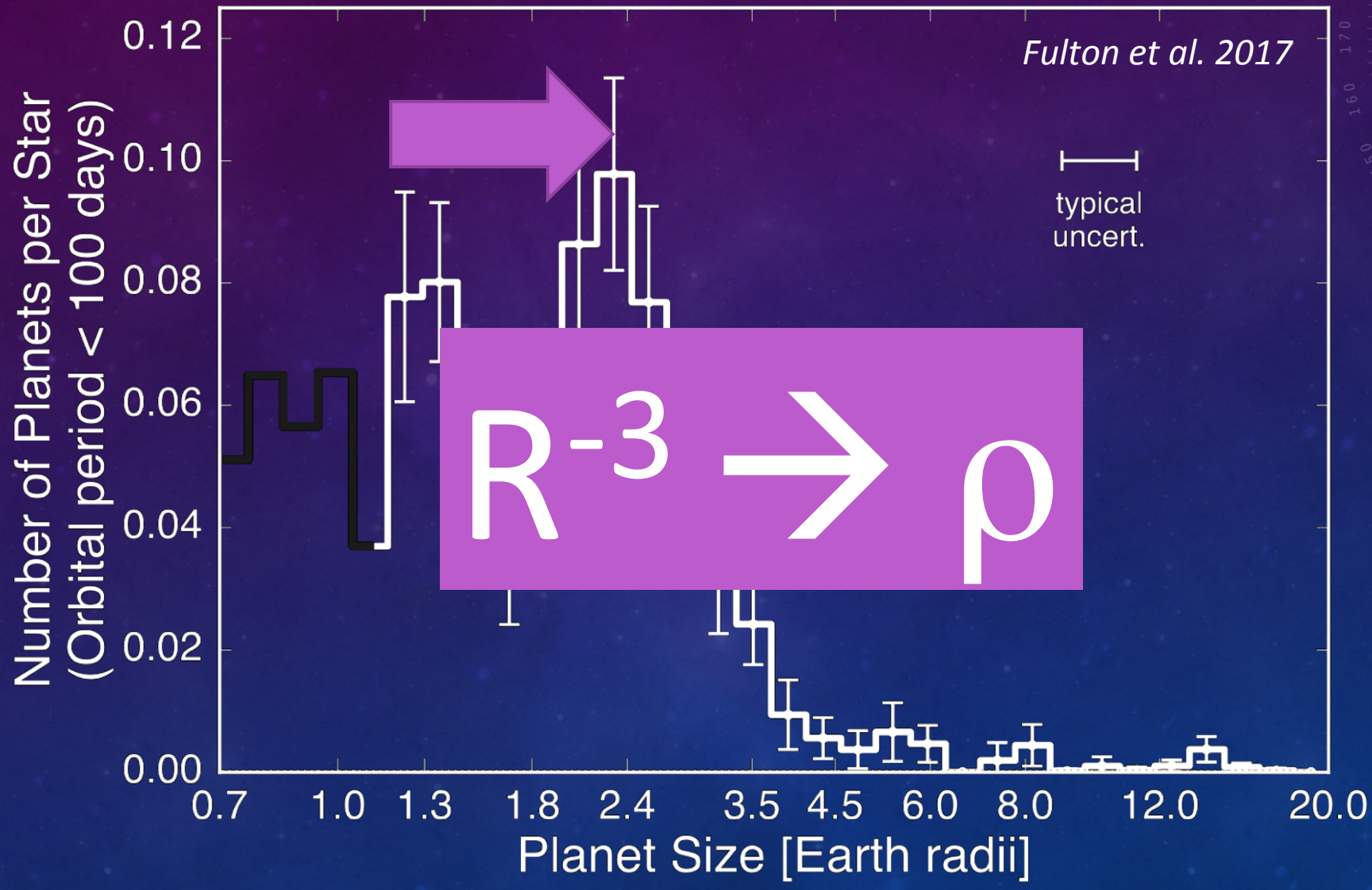
KOI2626: HZ Earth-sized Planet to Not

	Stellar Temperature and Radius	Planet Radius	Equilibrium Temperature
KOI List: Single Star	3480 K 0.35 R_{Sun}	1.12+/-0.16 Re	229 K (0.7 S_0)
Component A	3650 K 0.48 R_{sun}	2.04+/-0.33 Re	265 K (1.17 S_0)
Component B	3520 K 0.42 R_{sun}	2.37+/-0.44 Re	244 K (0.84 S_0)
Component C	3400 K 0.32 R_{Sun}	2.58+/-0.62 Re	217 K (0.52 S_0)



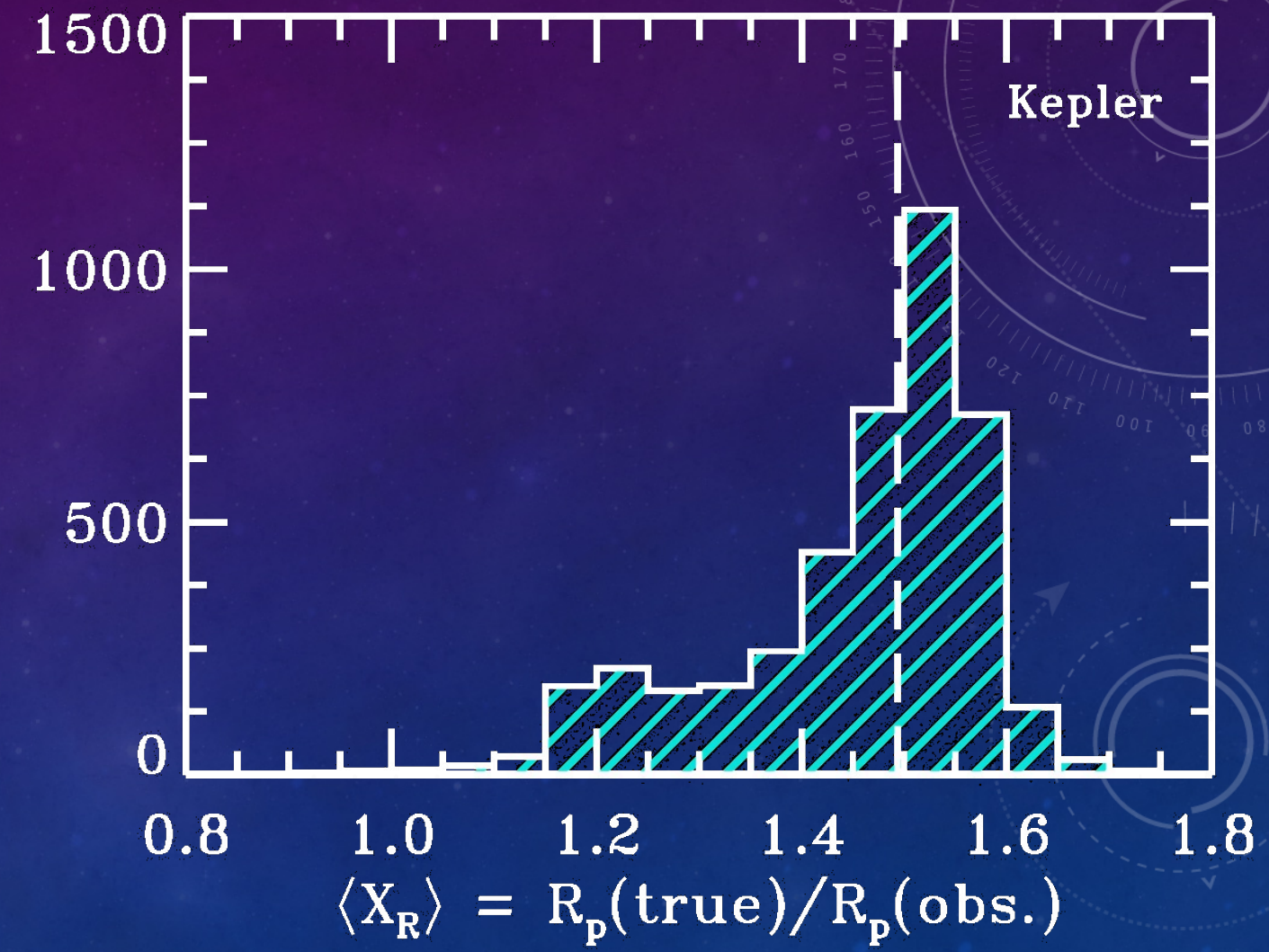
Cartier et al. 2015

KOI2626: Rocky vs Non-Rocky …



On Average …

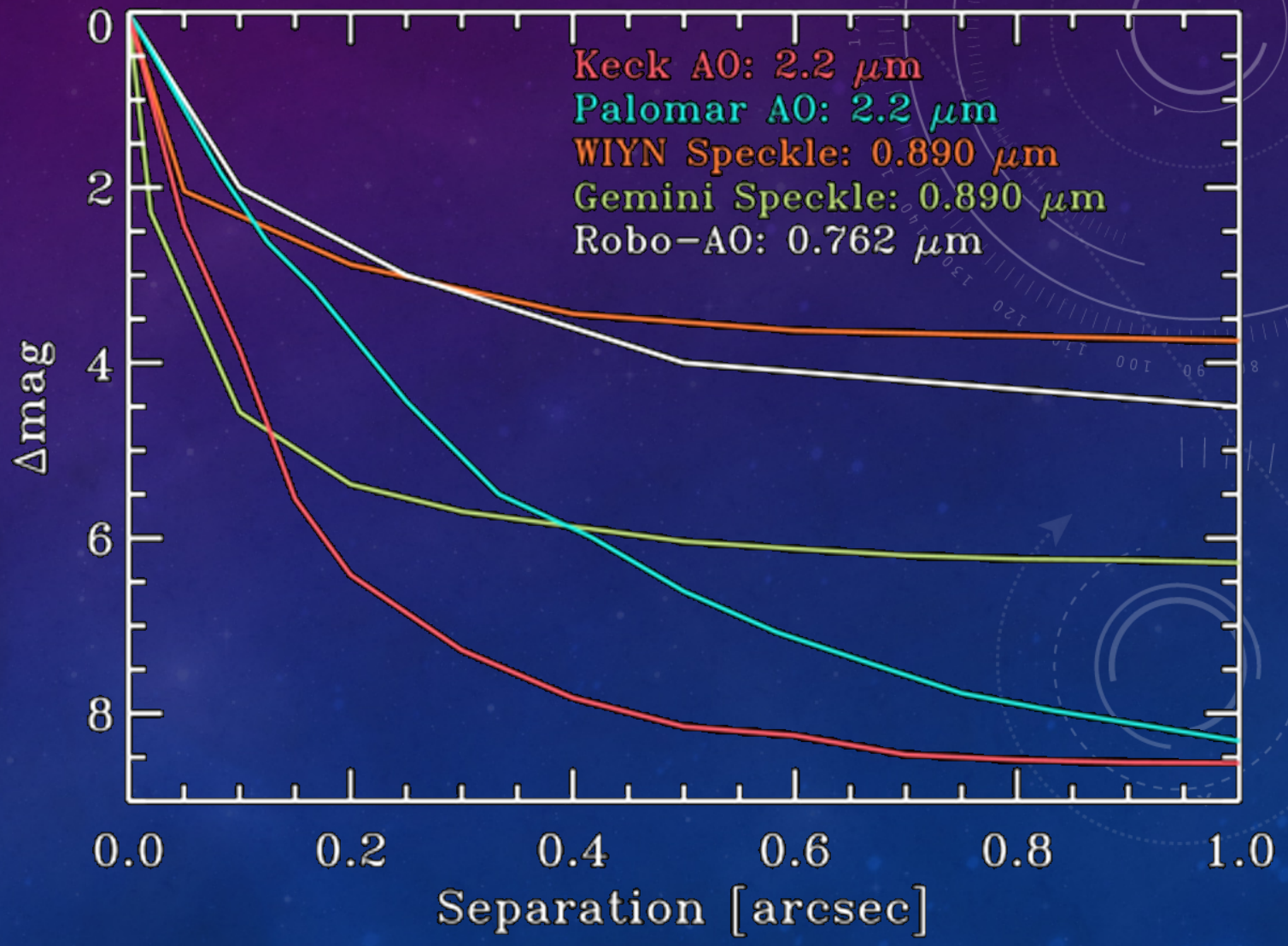
- If you know nothing about the multiplicity of a star and assume it is a single star, then the planet radii are underestimated by a factor of X_R=1.5
  - F and G stars: X_R=1.6
  - K and M Stars: X_R=1.2



Ciardi et al. 2015

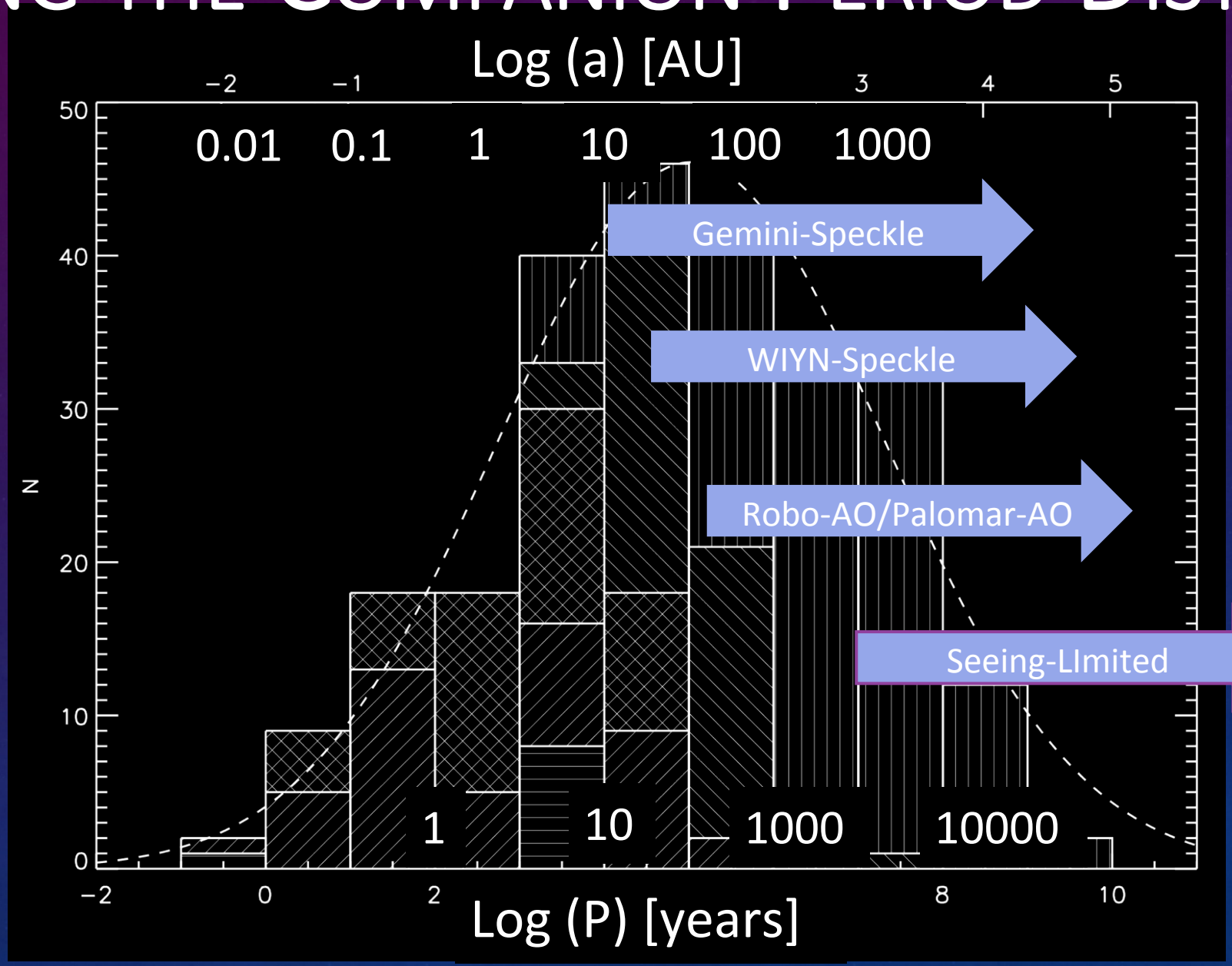
Complementary Techniques

- Seeing limited imaging (~1”)
- Optical and NIR Adaptive Optics (0.05” – 0.2”)
- Optical speckle (0.02” – 0.1”)
- Long-baseline interferometry (~1 mas)



Sampling the Companion Period Distribution

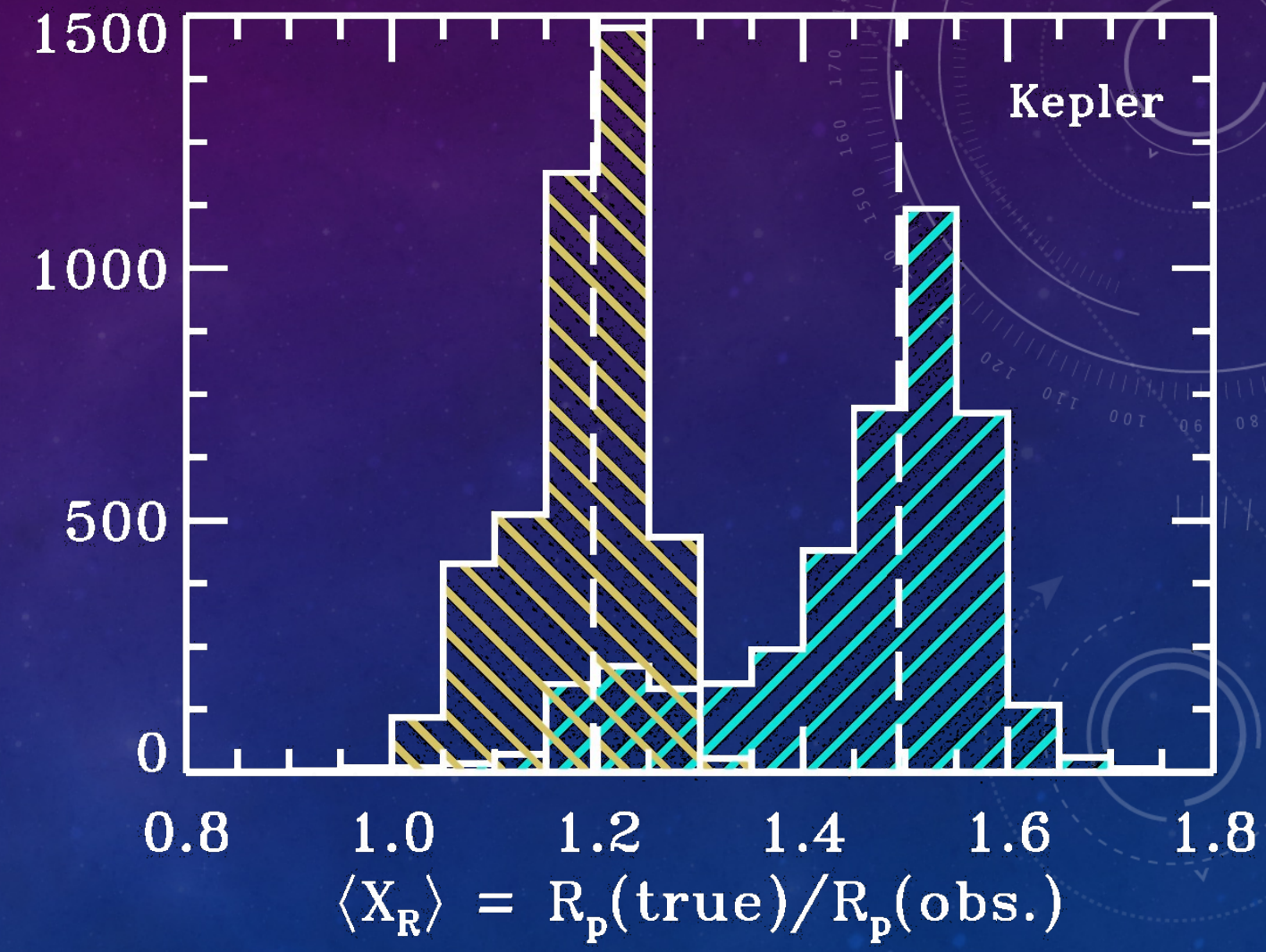
Kepler
~1000 pc



Unvetted Companions

- Vetting decreases the amplitude of the radii underestimation but does not remove it completely

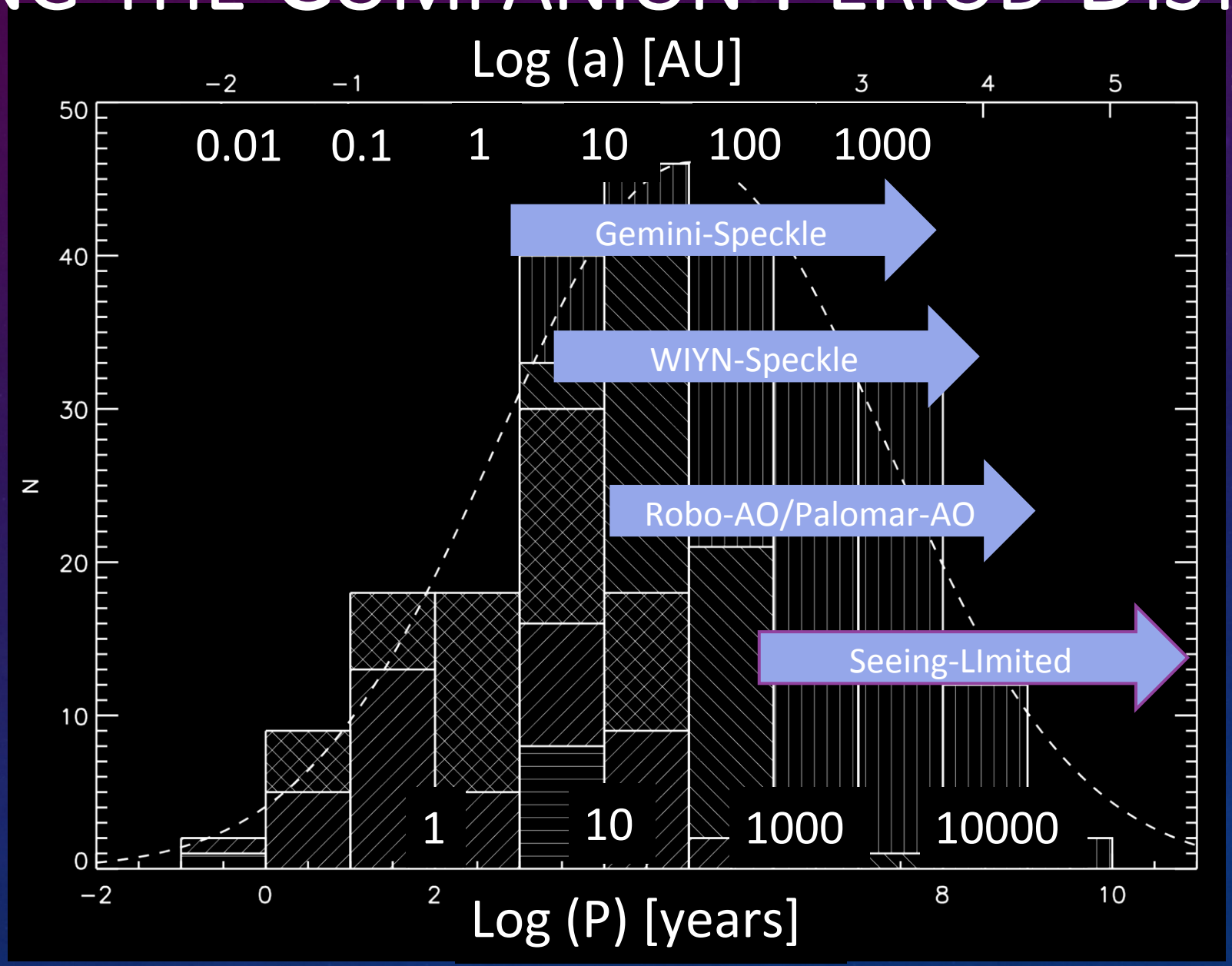
Average: X_R=1.2
F and G stars: X_R=1.3
K and M Stars: X_R=1.1



Ciardi et al. 2015

Sampling the Companion Period Distribution

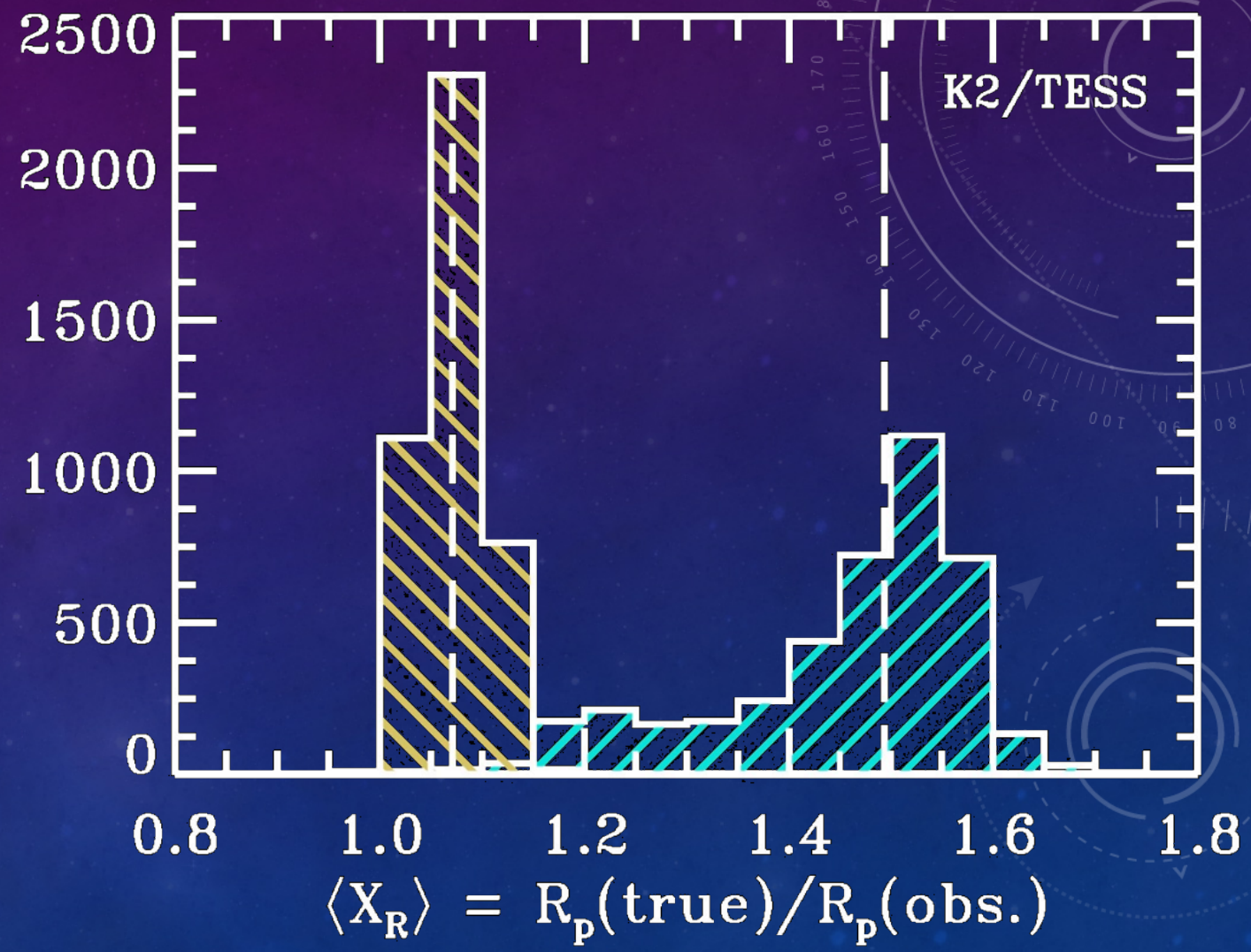
K2/TESS
~100 pc



K2/TESS → Closer Stars for the Win!

- Imaging becomes even more powerful

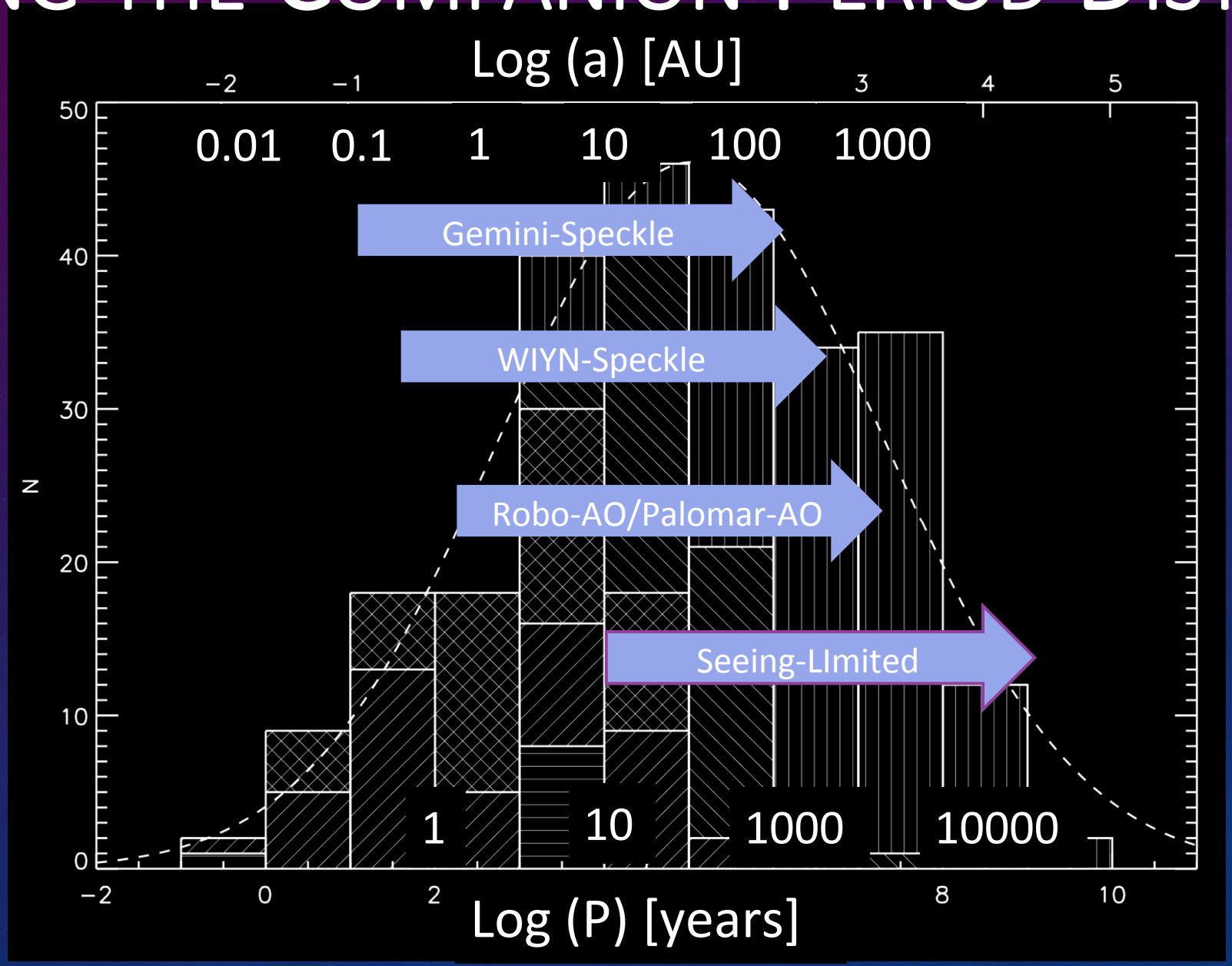
Average: X_R=1.1
Significantly more complete for all stars



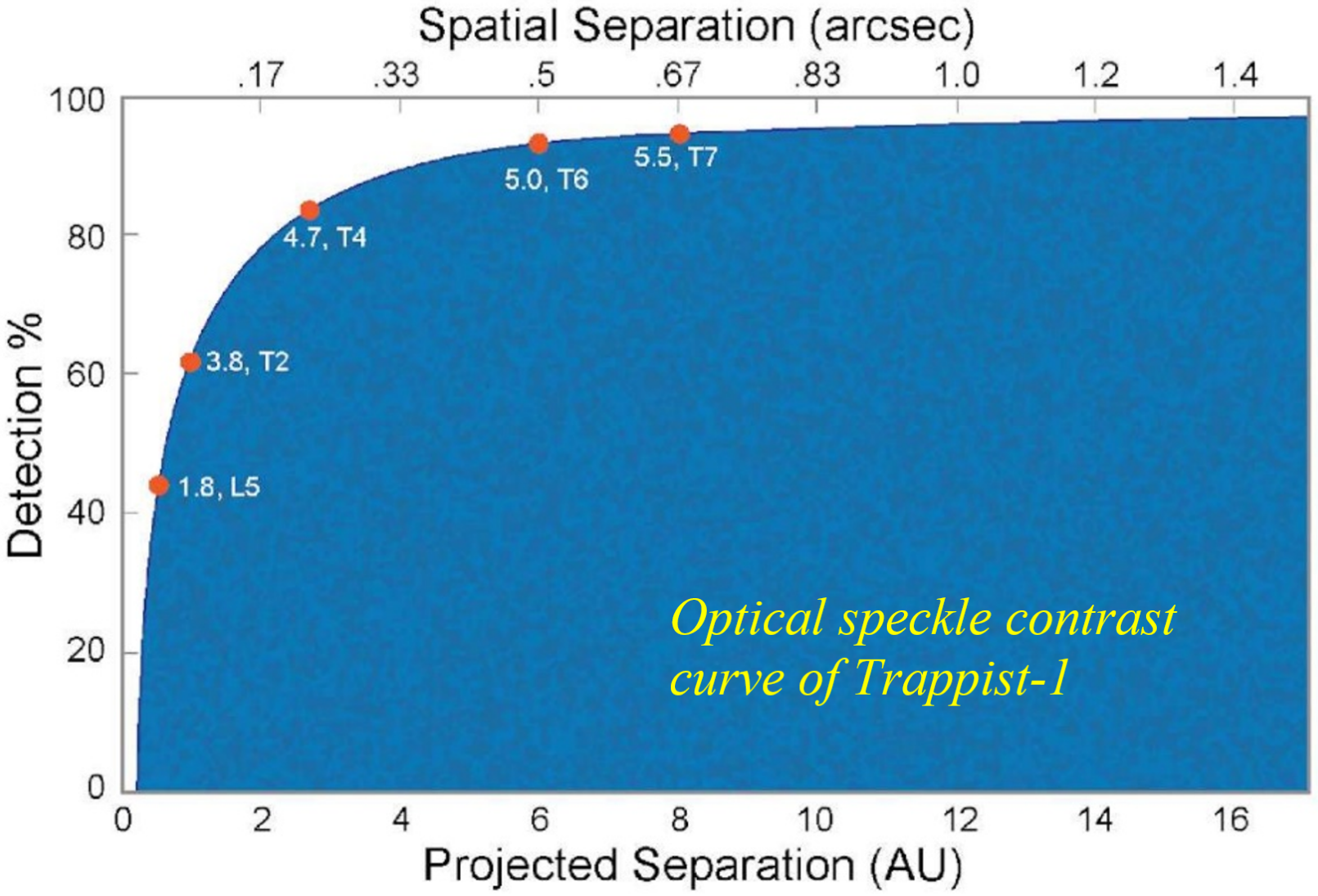
Ciardi et al. 2015

Sampling the Companion Period Distribution

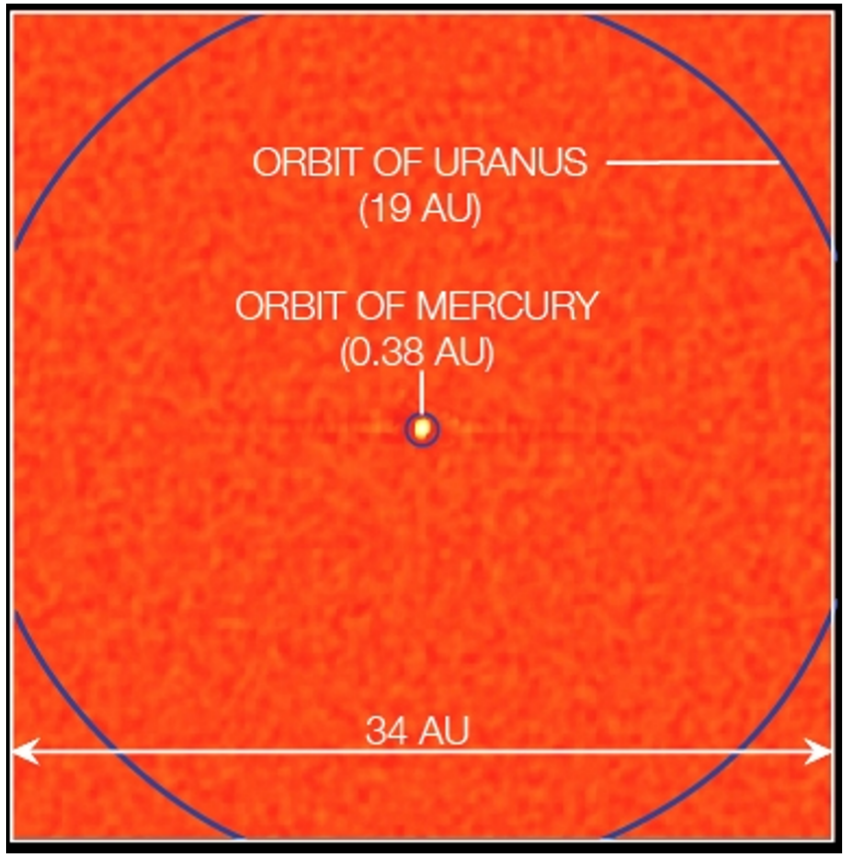
Very Near Stars ~10 pc



TRAPPIST - 1



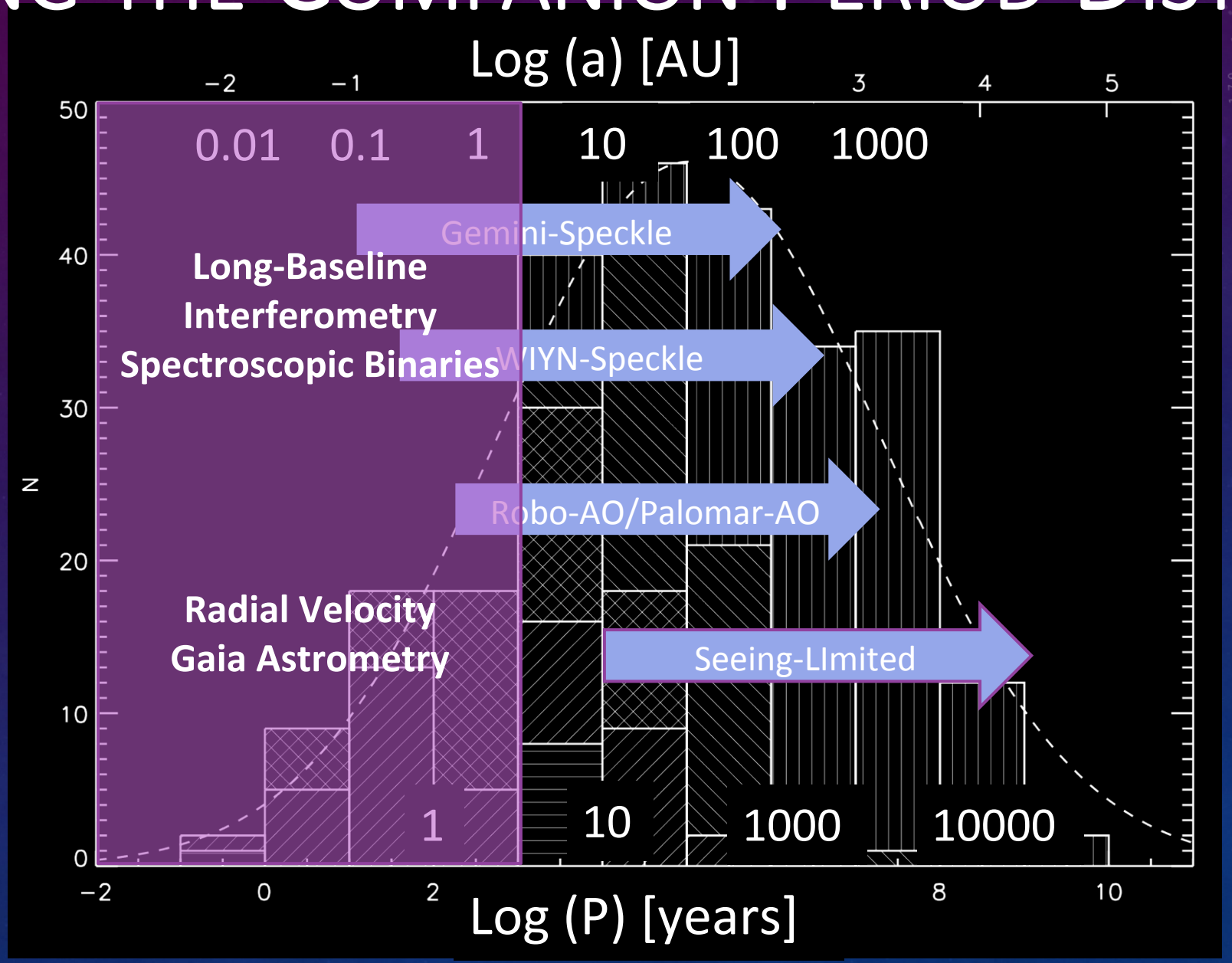
Optical speckle contrast curve of Trappist-1



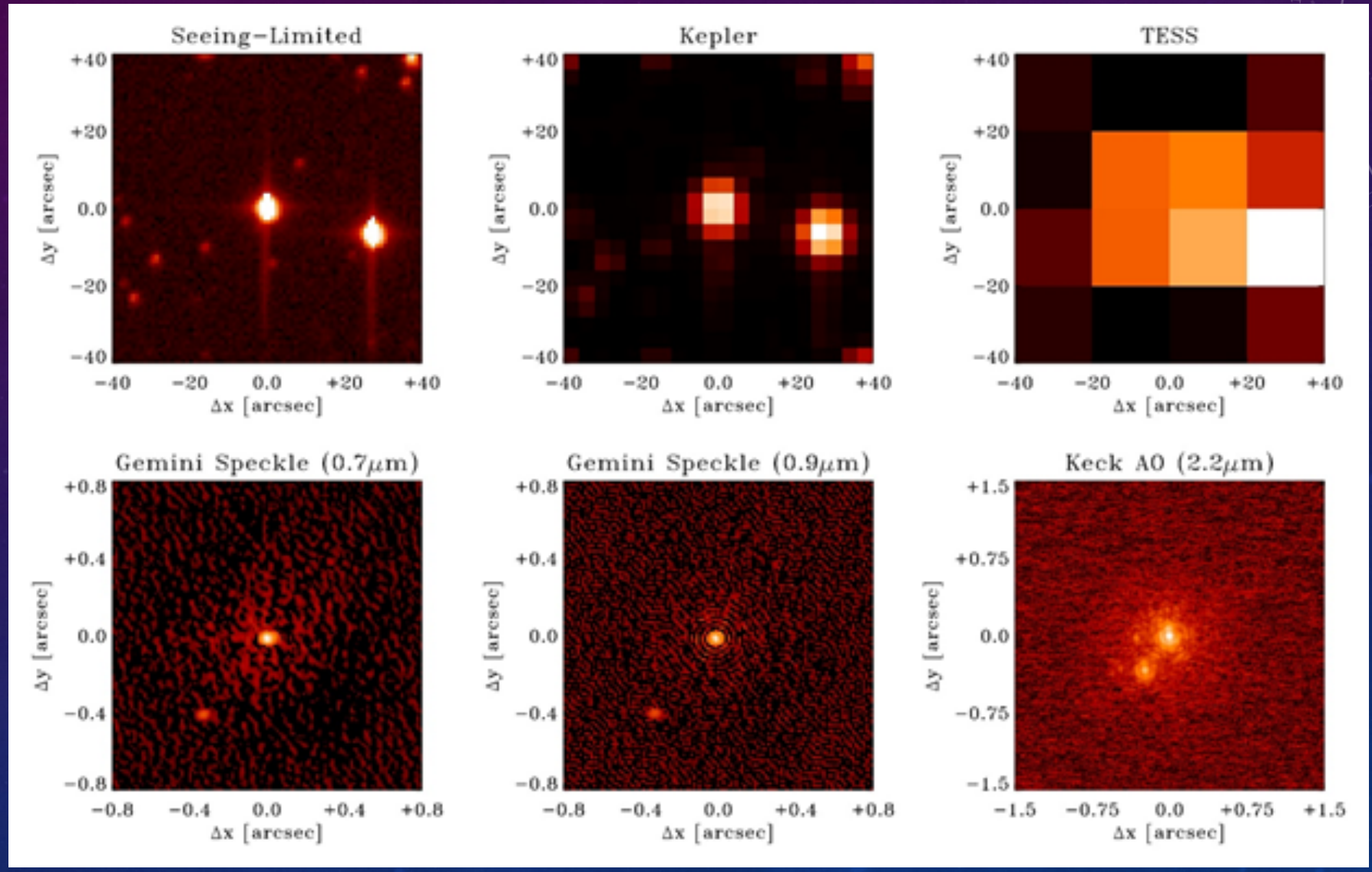
Howell et al. 2016

Sampling the Companion Period Distribution

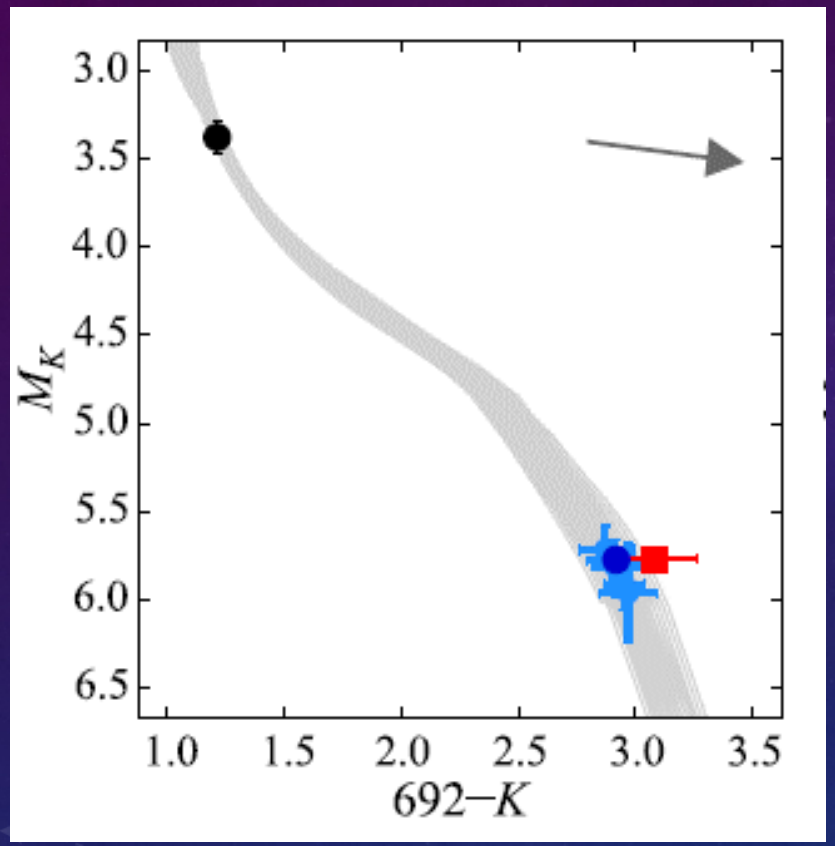
~10 pc



Need Imaging at ALL Scales

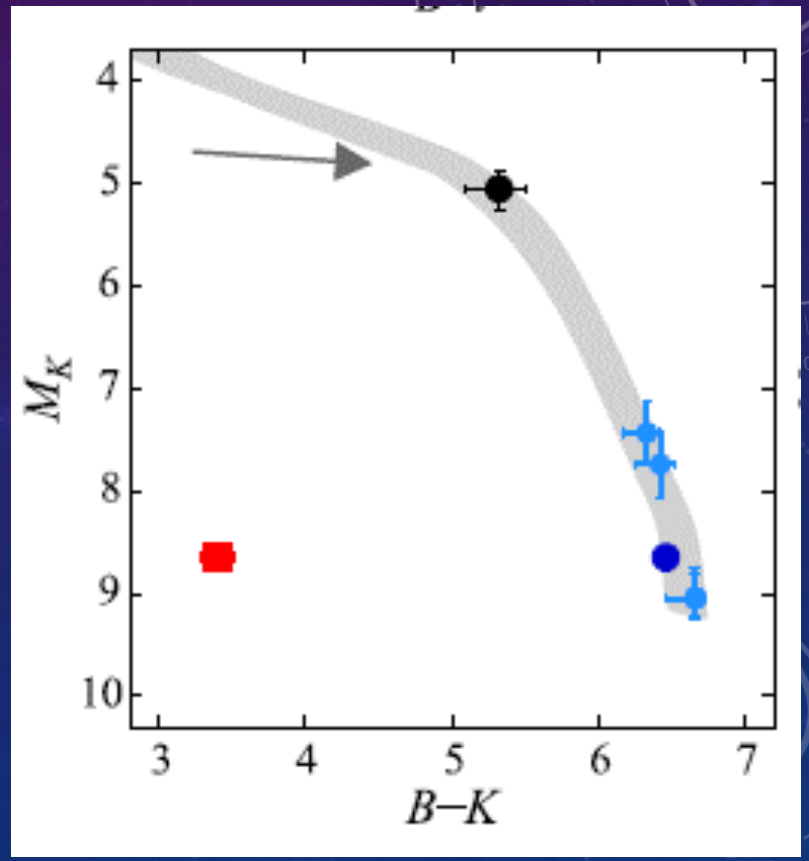


Need Imaging at Multiple Wavelengths



Multiple Wavelengths enable assessment of "boundness" and stellar parameters of companions

Hirsch et al. 2017

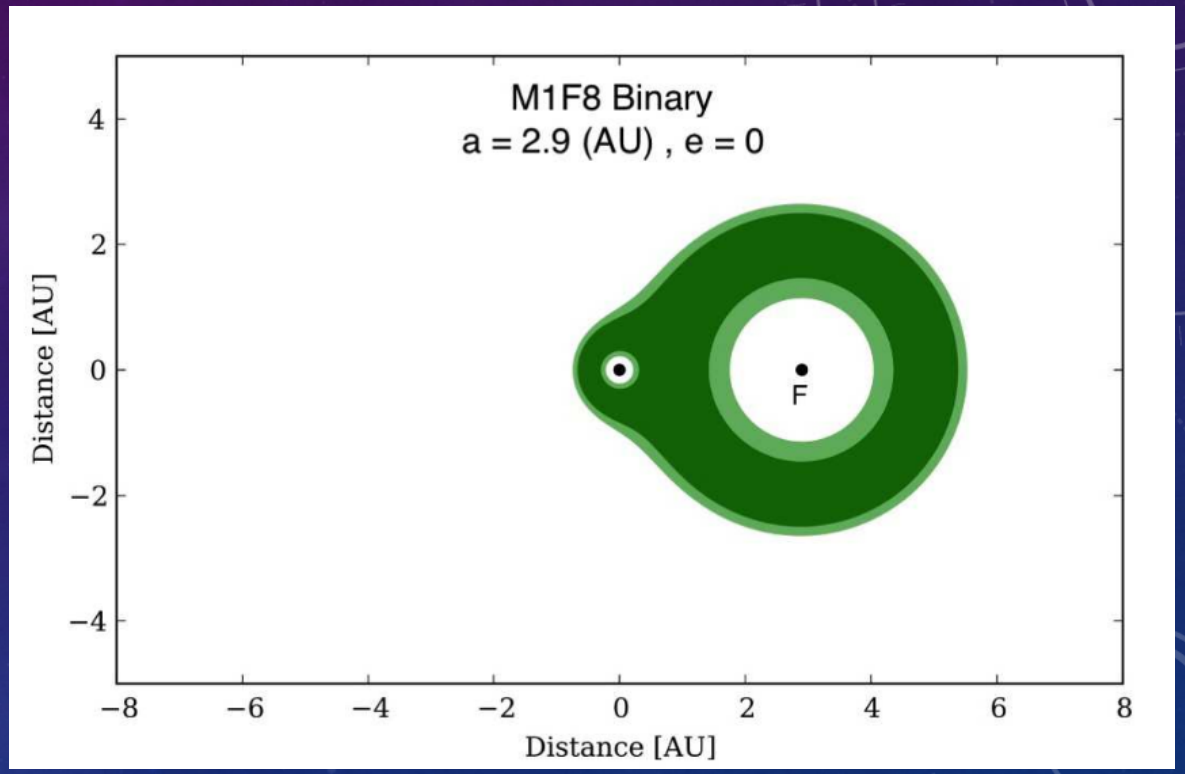


Bound

Unbound

Other Science Enabled by Imaging …

- Binary star habitable zones
  - Secondary star affects size and orientation of HZs
  - Time dependence
  - S and P Type binaries

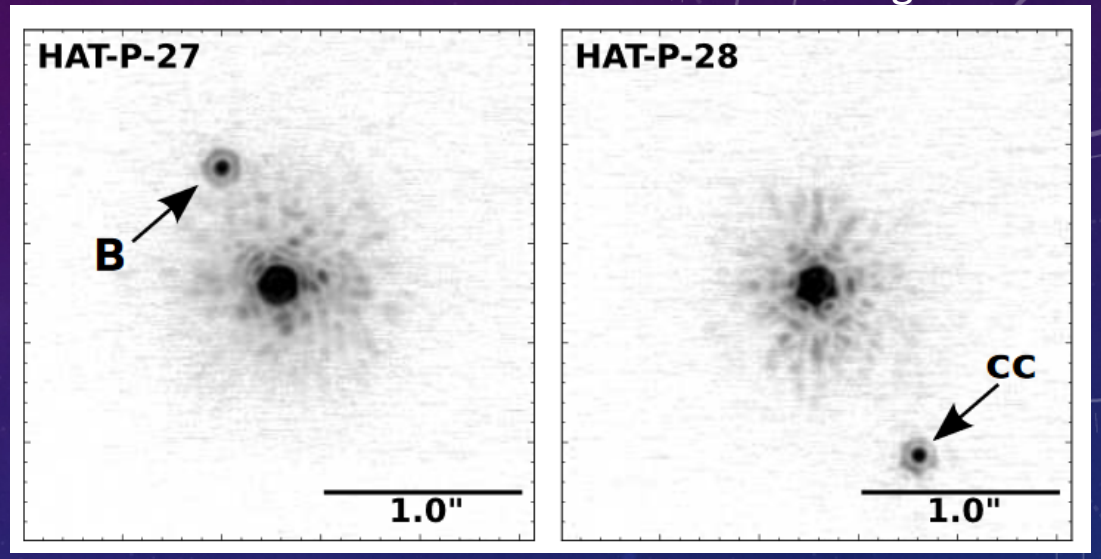


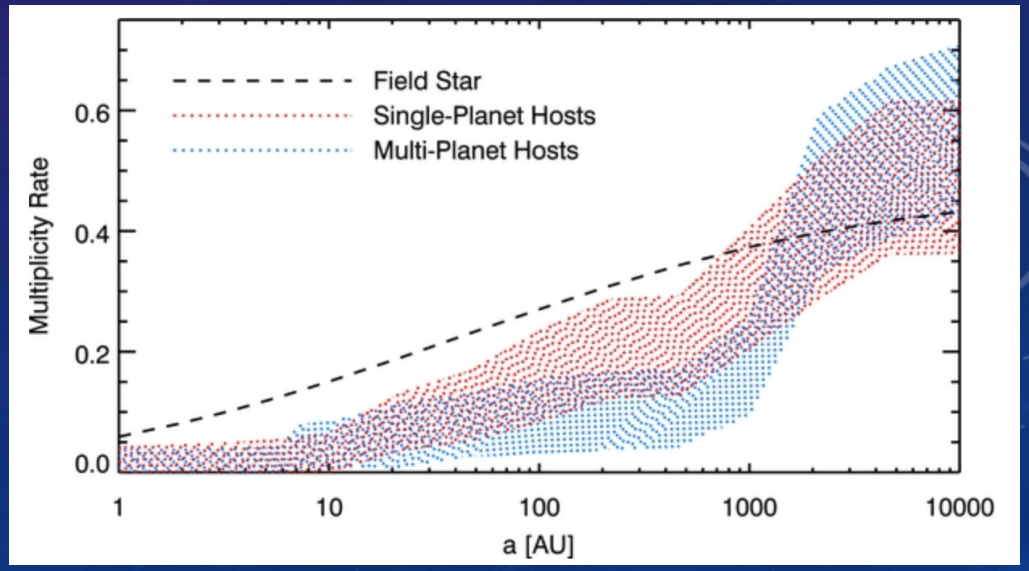
Kaltenegger & Haghighipour 2013
Haghighipour & Kaltenegger 2013

Other Science Enabled by Imaging …

- System Architectures
  - >45% of HJ systems have stellar companion at >50AU (3σ greater than field stars)
  - Hints that stellar companions may be less common in planet hosting stars … or not … upcoming talks

Ngo et al. 2016





Wang et al. 2014

Love Thy Imaging …

- Validate planets beyond the reach of RV
- Obtain accurate planetary radii – or, at least, understand better the uncertainties
- Supporting a variety of science questions
  - Occurrence rates
  - System architectures
  - Mulitiplicity in (non-)planet hosting stars
  - And on and on …