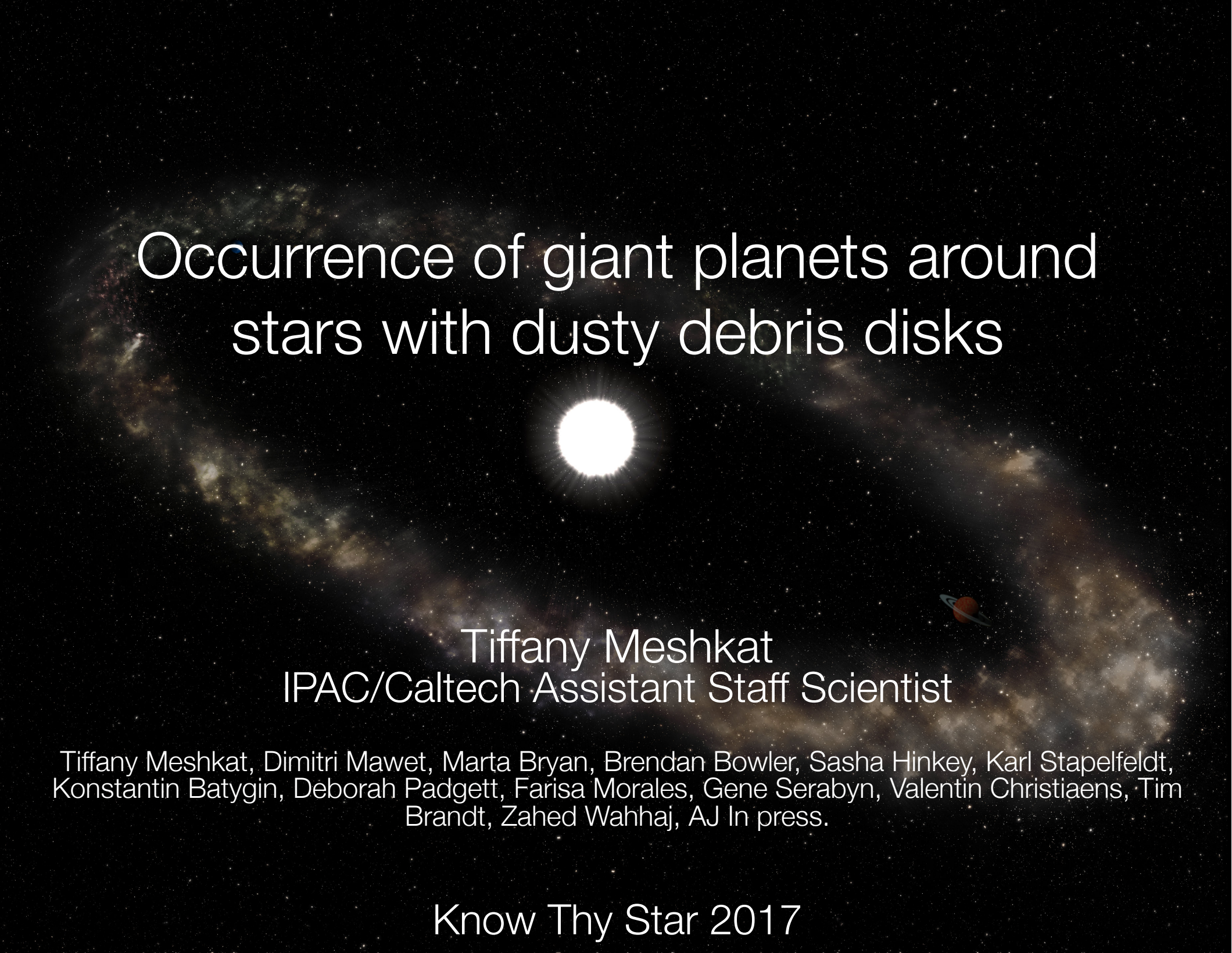
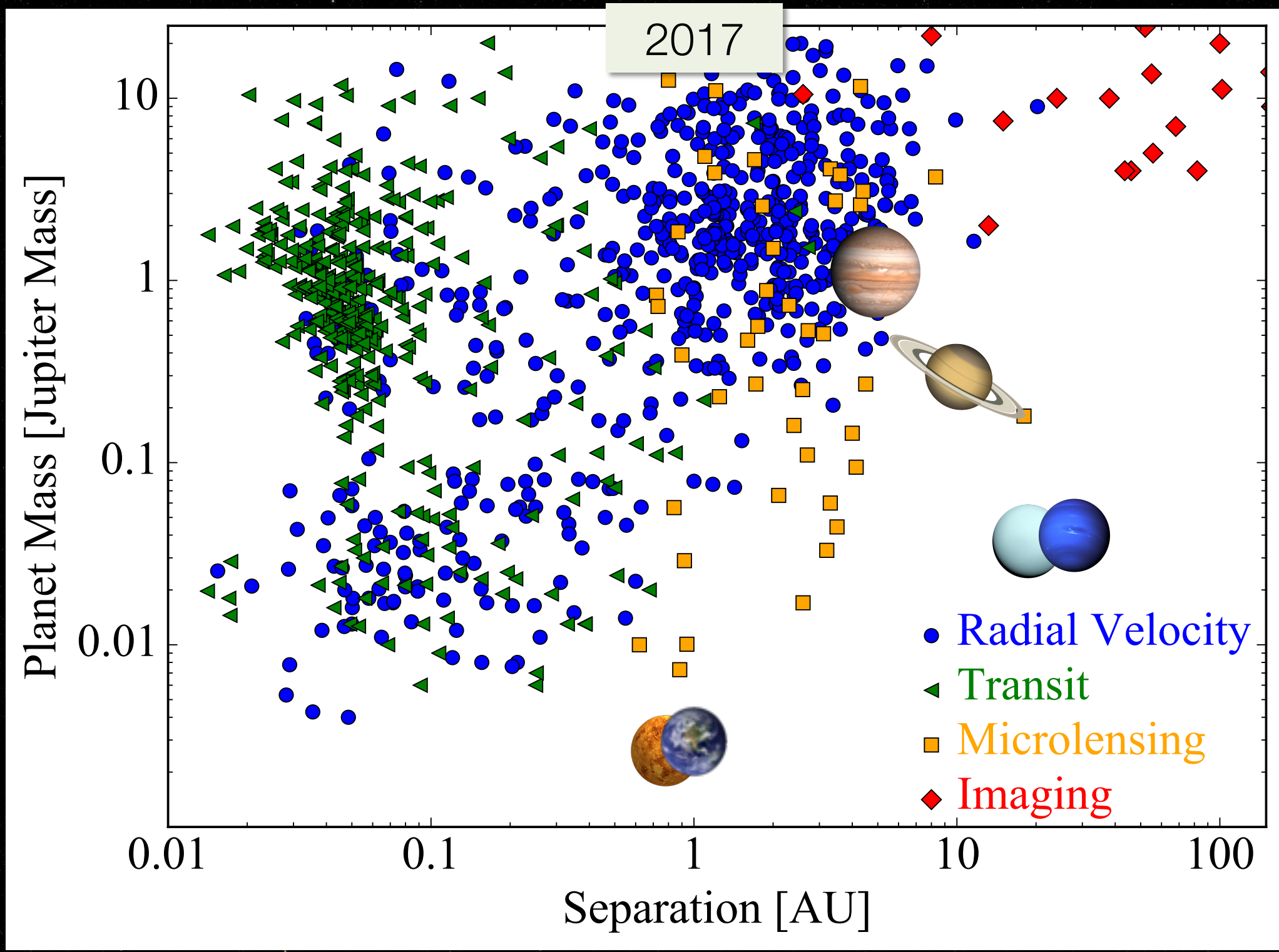
Occurrence of giant planets around stars with dusty debris disks



Tiffany Meshkat
IPAC/Caltech Assistant Staff Scientist

Tiffany Meshkat, Dimitri Mawet, Marta Bryan, Brendan Bowler, Sasha Hinkey, Karl Stapelfeldt, Konstantin Batygin, Deborah Padgett, Farisa Morales, Gene Serabyn, Valentin Christiaens, Tim Brandt, Zahed Wahhaj, AJ In press.

Know Thy Star 2017

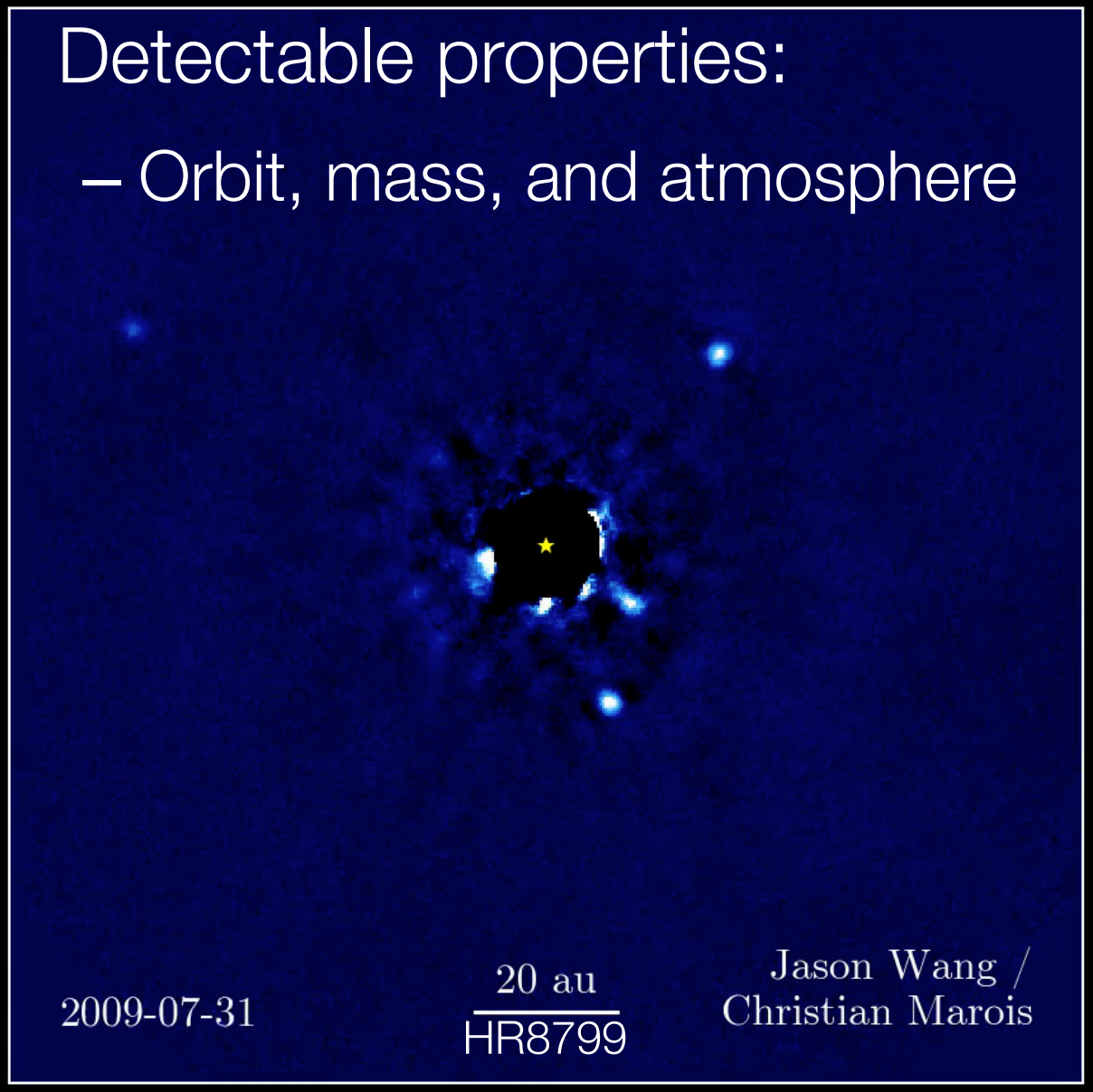


Data from NASA Exoplanet Archive

Direct Imaging

Detectable properties:

– Orbit, mass, and atmosphere



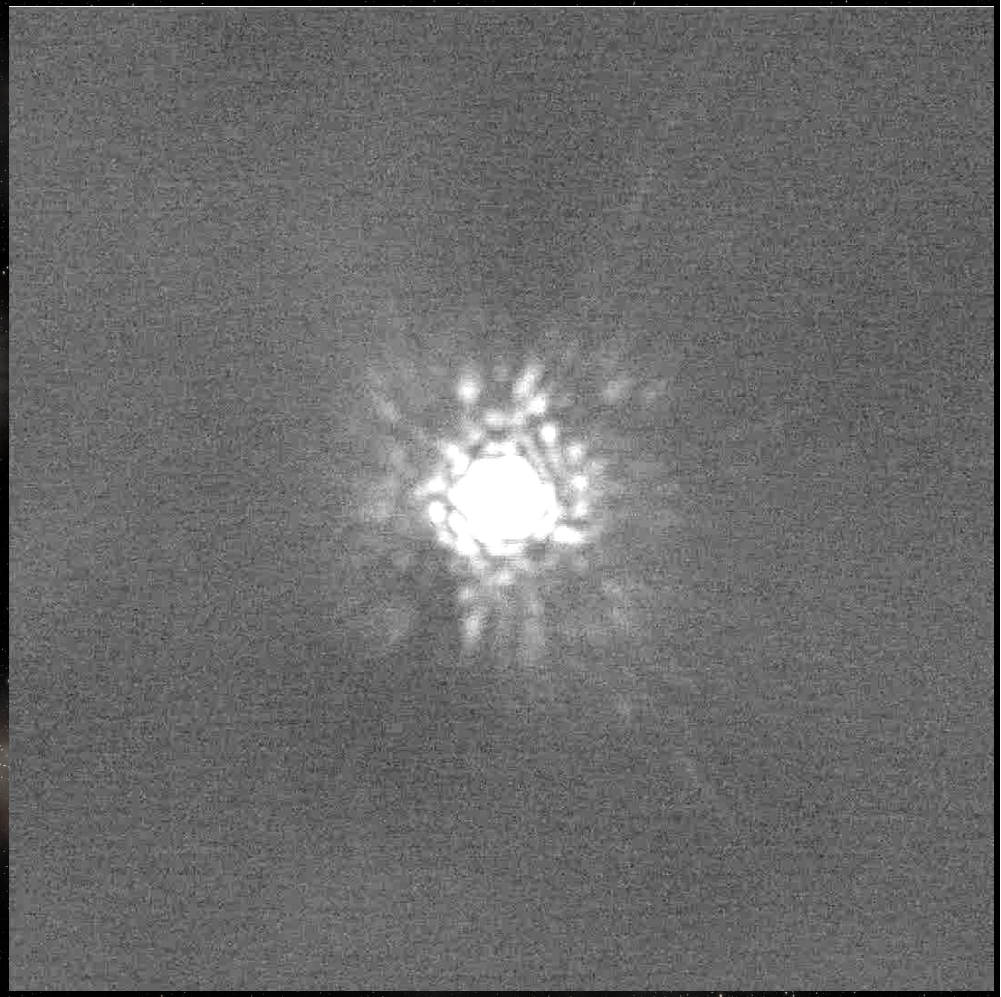
Completed direct imaging surveys

Reference	Telescope	Instr.	Mode	Filter	FoV (″×″)	#	SpT	Age (Myr)
Chauvin et al. (2003)	ESO3.6m	ADONIS	Cor-I	H, K	13 × 13	29	GKM	≲50
Neuhäuser et al. (2003)	NTT	Sharp	Sat-I	K	11 × 11	23	AFGKM	≲50
	NTT	Sofi	Sat-I	H	13 × 13	10	AFGKM	≲50
Lowrance et al. (2005)	HST	NICMOS	Cor-I	H	19 × 19	45	AFGKM	10–600
Masciadri et al. (2005)	VLT	NaCo	Sat-I	H, K	14 × 14	28	KM	≲200
Biller et al. (2007)	VLT	NaCo	SDI	H	5 × 5	45	GKM	≲300
	MMT		SDI	H	5 × 5	–	–	–
Kasper et al. (2007)	VLT	NaCo	Sat-I	L'	28 × 28	22	GKM	≲50
Lafrenière et al. (2007)	Gemini-N	NIRI	ADI	H	22 × 22	85		10–5000
Apai et al. (2008)[a]	VLT	NaCo	SDI	H	3 × 3	8	FG	12–500
Chauvin et al. (2010)	VLT	NaCo	Cor-I	H, K	28 × 28	88	BAFGKM	≲100
Heinze et al. (2010a,b)	MMT	Clio	ADI	L', M	15.5 × 12.4	54	FGK	100–5000
Janson et al. (2011)	Gemini-N	NIRI	ADI	H, K	22 × 22	15	BA	20–700
Vigan et al. (2012)	Gemini-N	NIRI	ADI	H, K	22 × 22	42	AF	10–400
	VLT	NaCo	ADI	H, K	14 × 14	–	–	–
Delorme et al. (2012)	VLT	NaCo	ADI	L'	28 × 28	16	M	≲200
Rameau et al. (2013c)	VLT	NaCo	ADI	L'	28 × 28	59	AF	≲200
Yamamoto et al. (2013)	Subaru	HiCIAO	ADI	H, K	20 × 20	20	FG	125 ± 8
Biller et al. (2013)	Gemini-S	NICI	Cor-ASDI	H	18 × 18	80	BAFGKM	≲200
Brandt et al. (2013)	Subaru	HiCIAO	ADI	H	20 × 20	63	AFGKM	≲500
Nielsen et al. (2013)	Gemini-S	NICI	Cor-ASDI	H	18 × 18	70	BA	50–500
Wahhaj et al. (2013)[a]	Gemini-S	NICI	Cor-ASDI	H	18 × 18	57	AFGKM	~100
Janson et al. (2013)[a]	Subaru	HiCIAO	ADI	H	20 × 20	50	AFGKM	≲1000

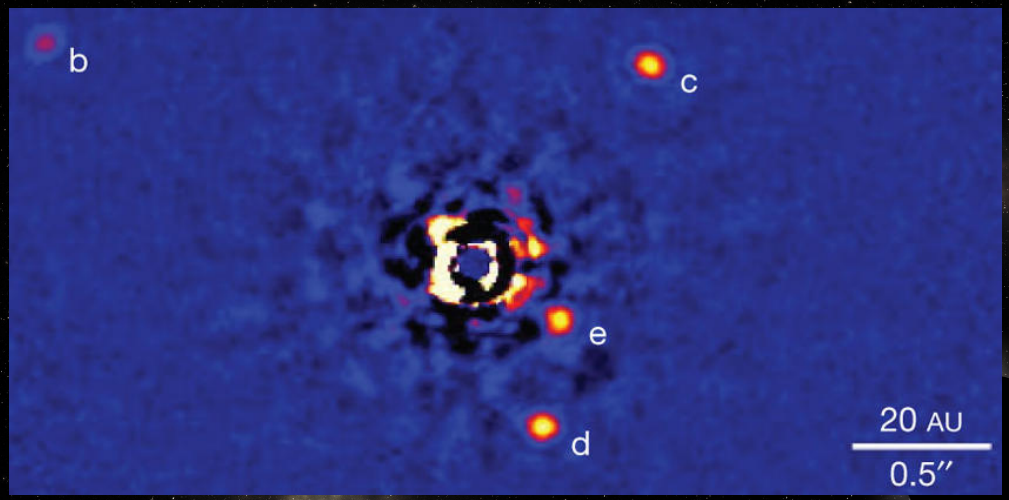
Chauvin et al. 2015

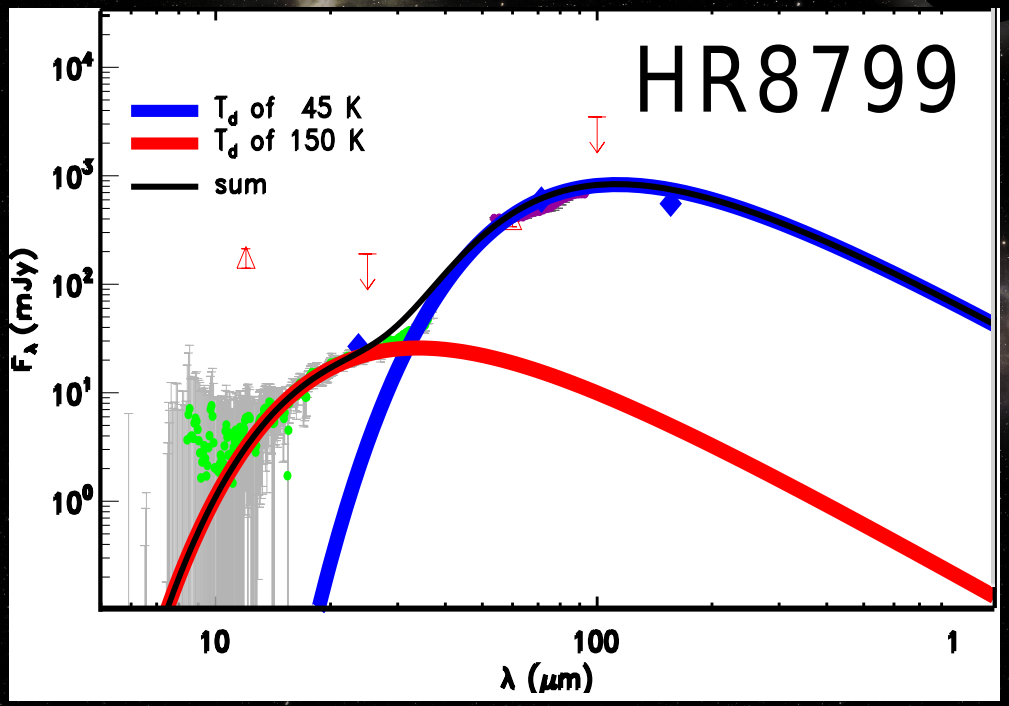
Why so few?

1. Challenging observations
2. These planets seem to be less common



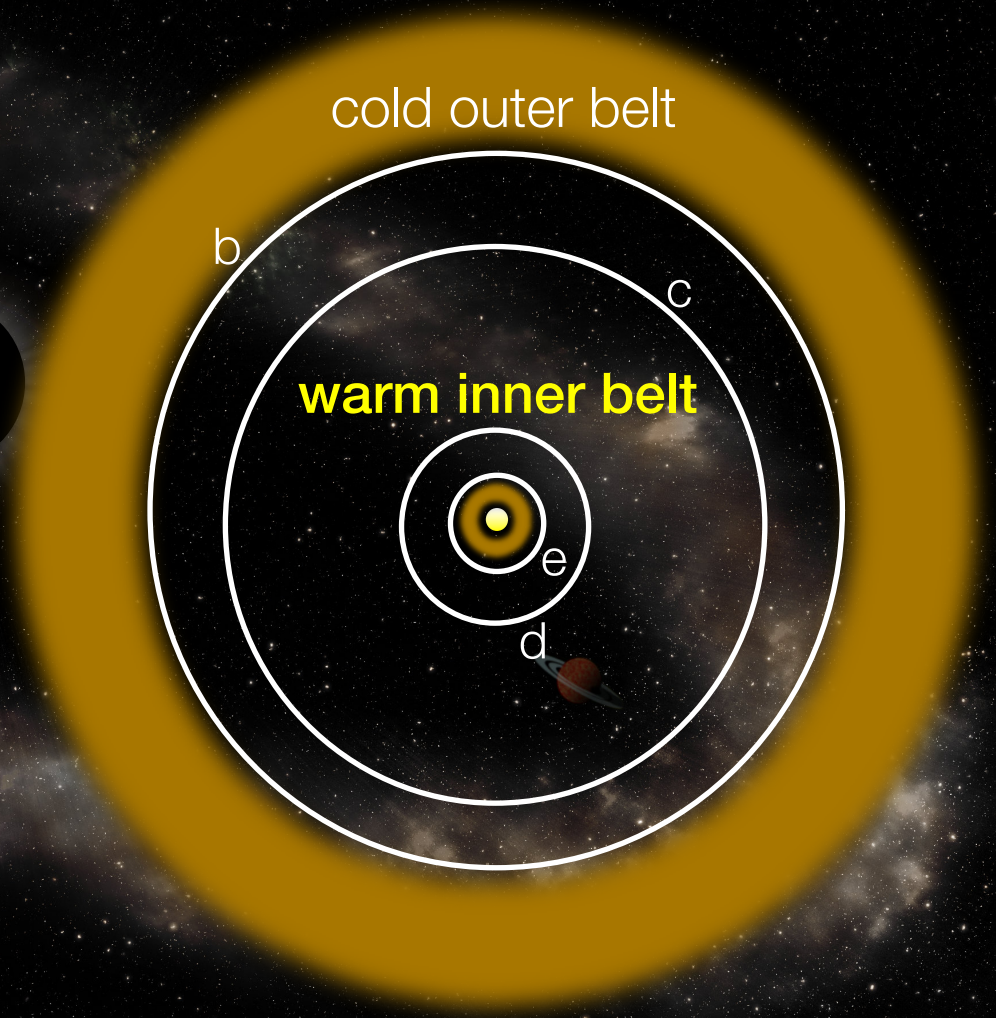
Motivation for finding planets in debris disks

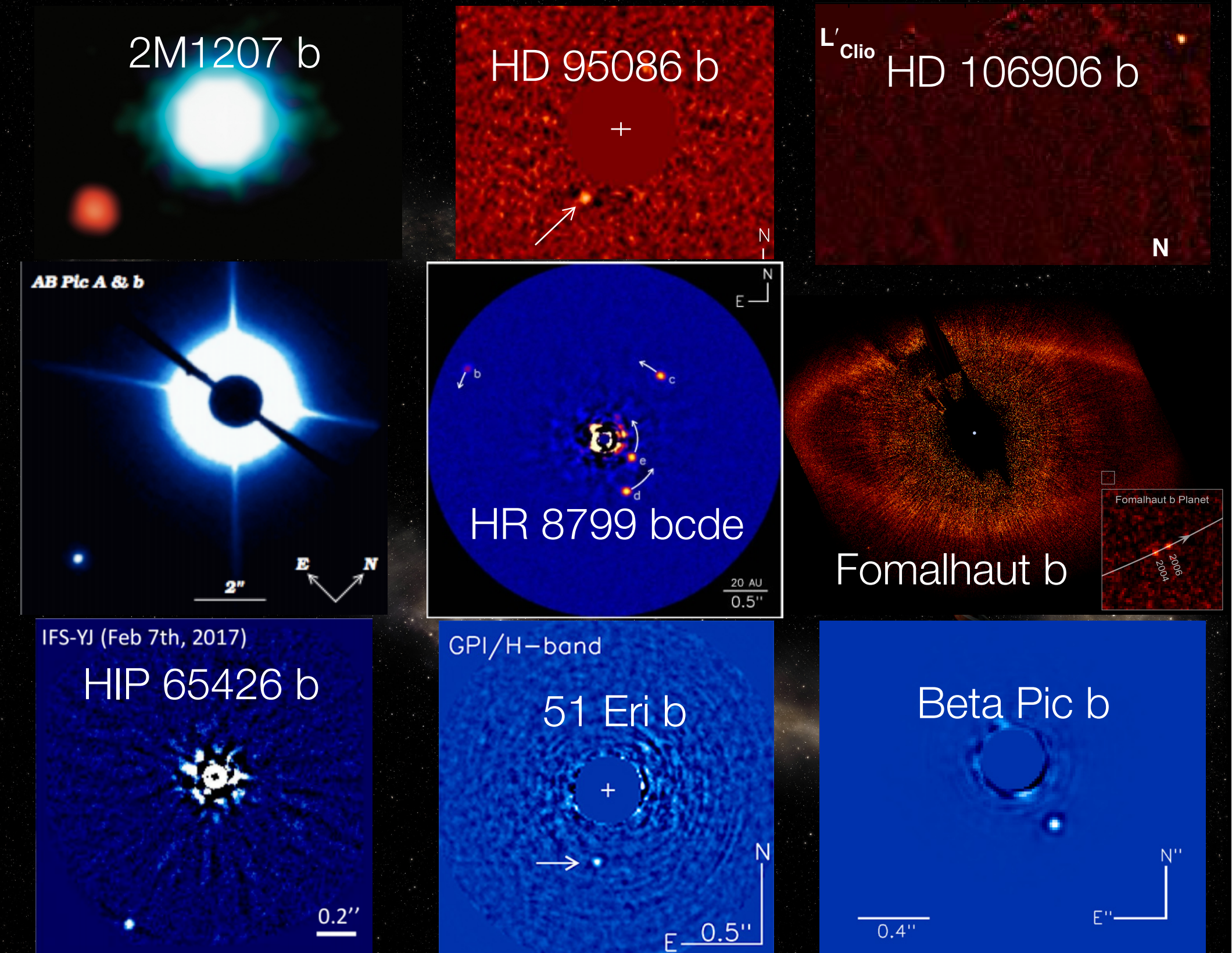




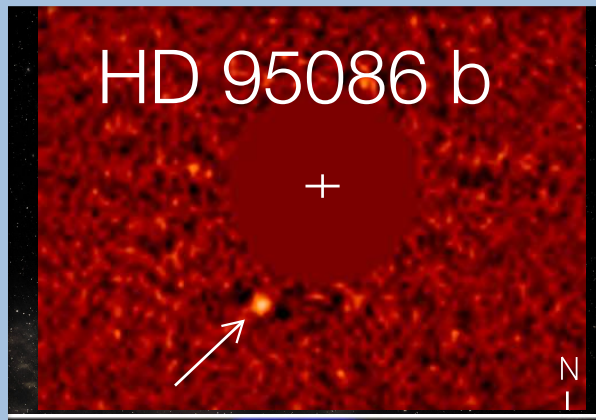
Su et al. 2013

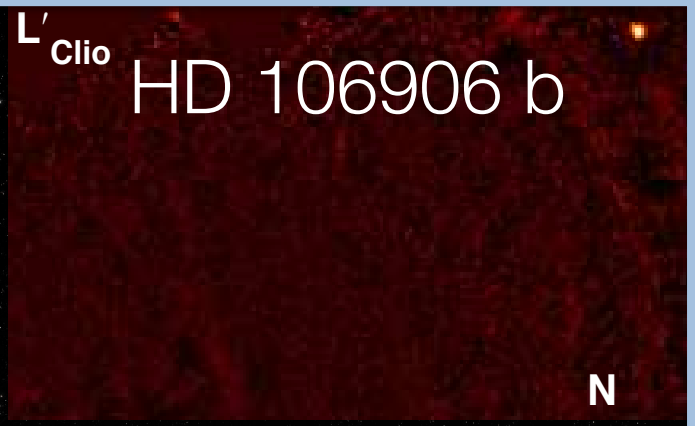
HR 8799

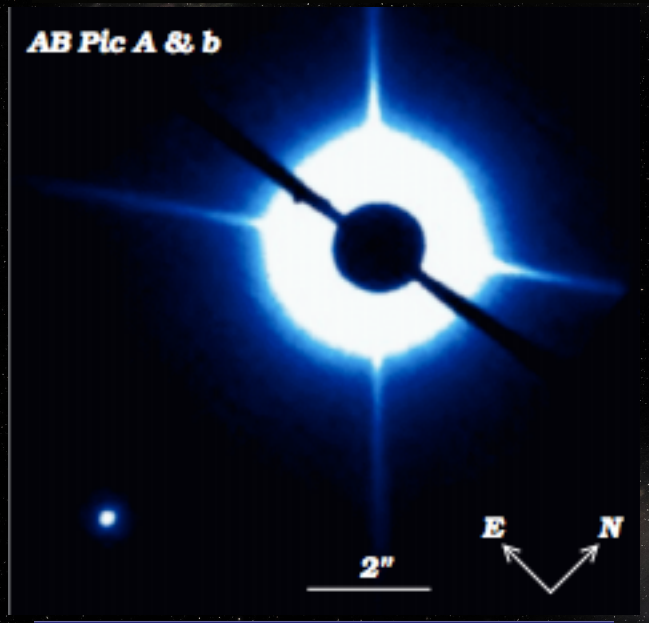


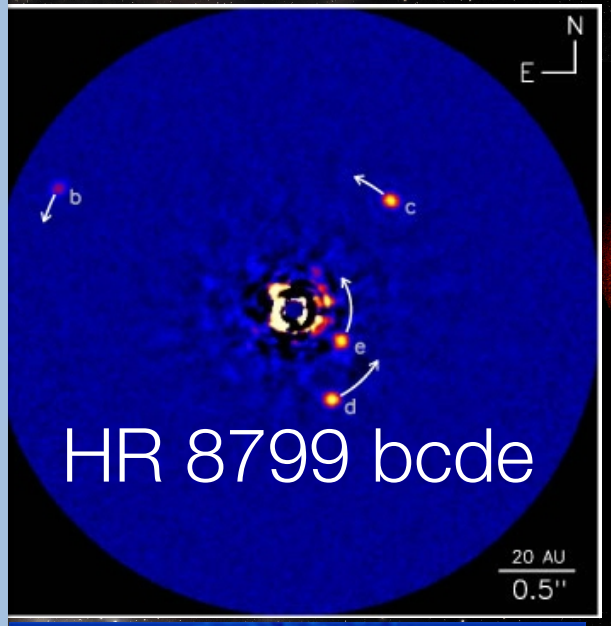

2M1207 b
HD 95086 b
N
L′ Clio
HD 106906 b
N
AB Pic A & b
2″
E
N
N
E
b
c
e
d
HR 8799 bcde
20 AU
0.5″
Fomalhaut b
Fomalhaut b Planet
2006
2004
IFS-YJ (Feb 7th, 2017)
HIP 65426 b
0.2″
GPI/H−band
51 Eri b
N
E
0.5″
Beta Pic b
N″
E″
0.4″

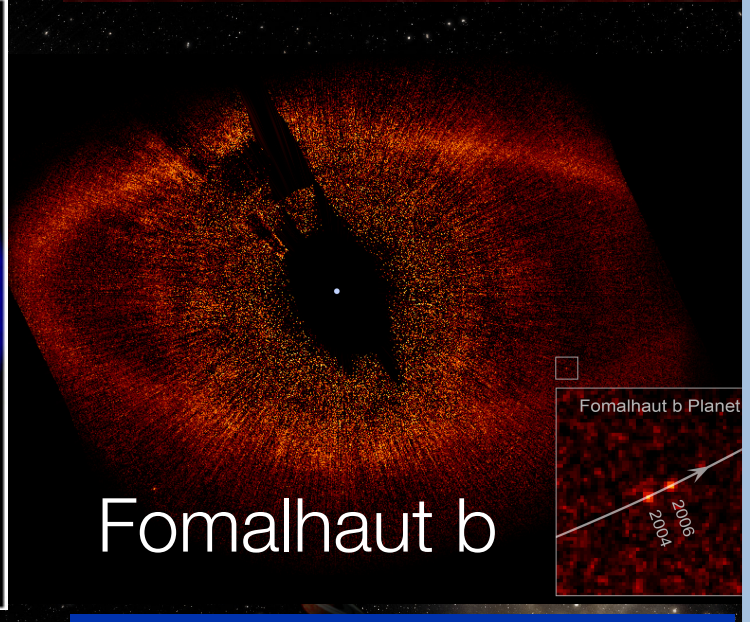

2M1207 b

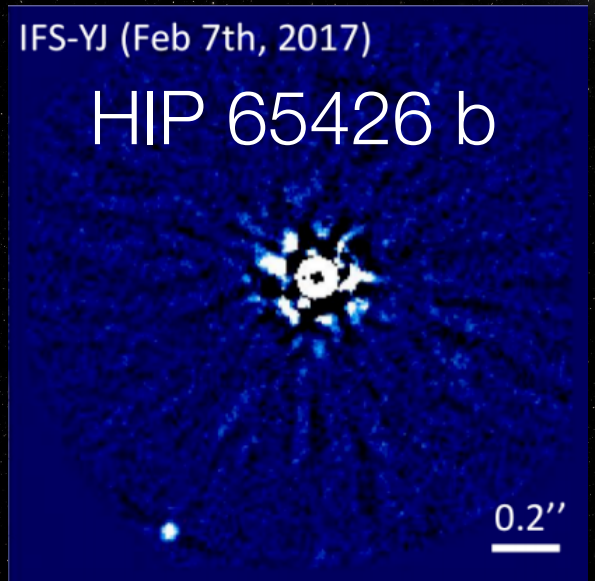

HD 95086 b
N

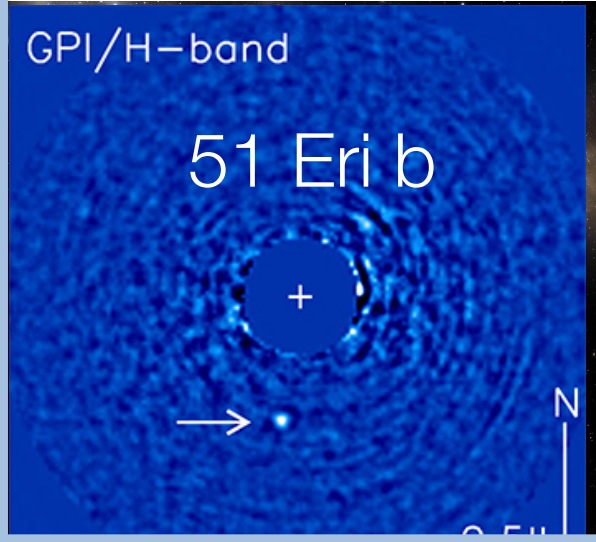

L′ Clio
HD 106906 b
N

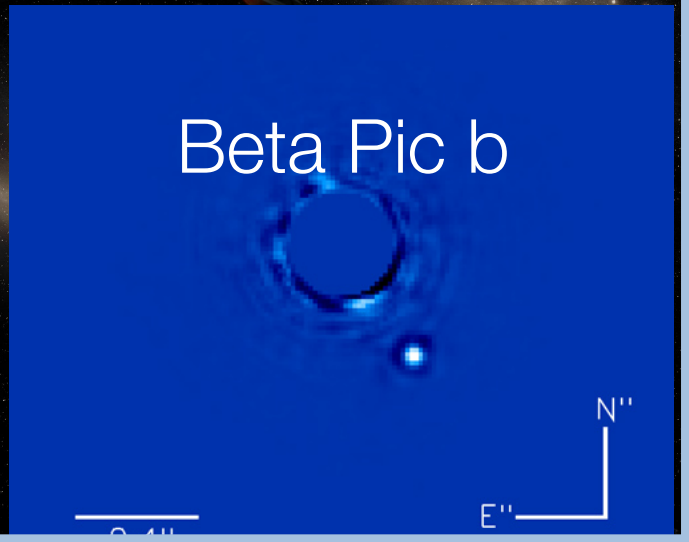

AB Pic A & b
2″
E
N


N
E
b
c
e
d
HR 8799 bcde
20 AU
0.5″


Fomalhaut b
Fomalhaut b Planet
2004
2006


IFS-YJ (Feb 7th, 2017)
HIP 65426 b
0.2″


GPI/H−band
51 Eri b
N

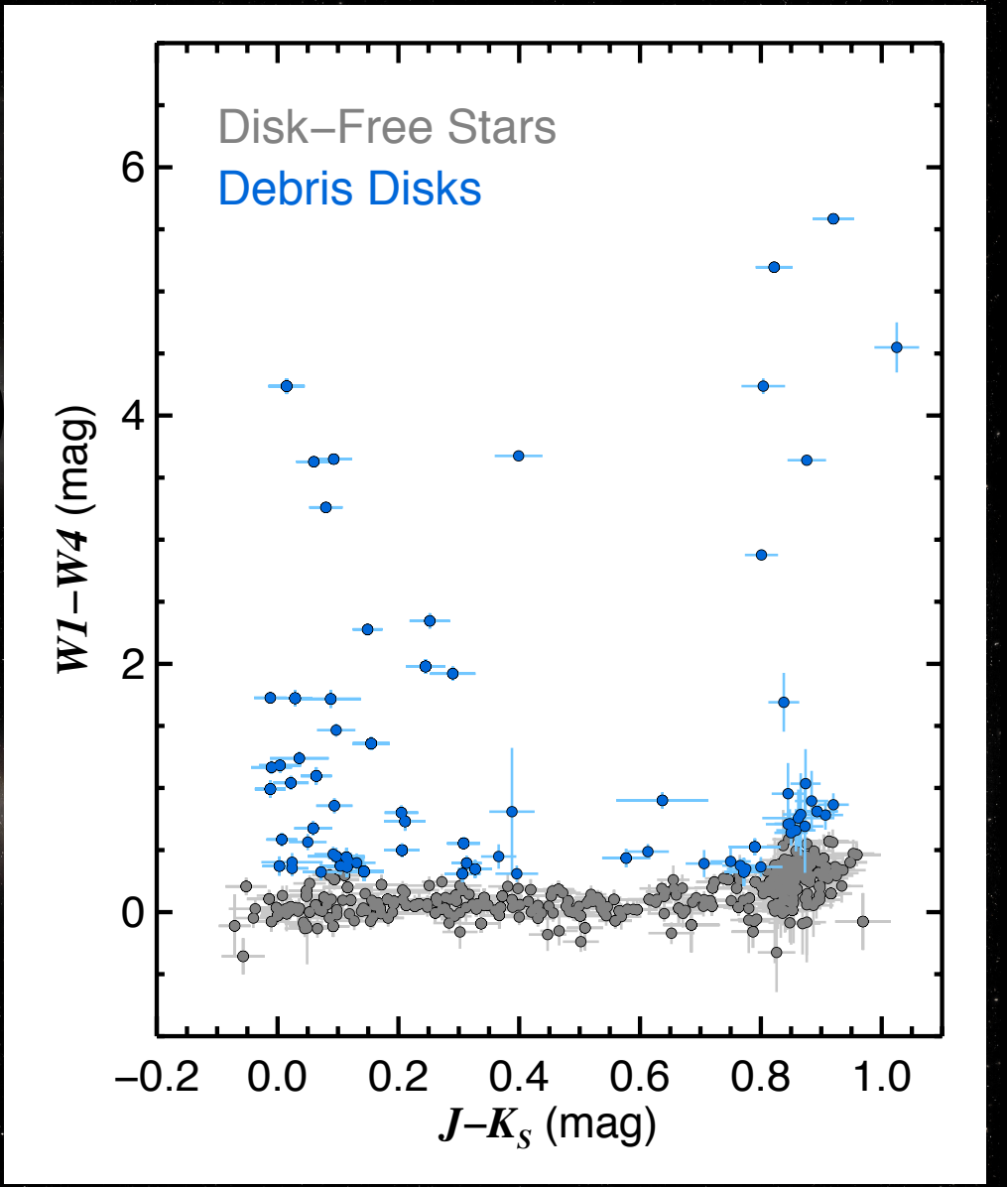

Beta Pic b
N″
E″


Are debris disks signposts
for planets?

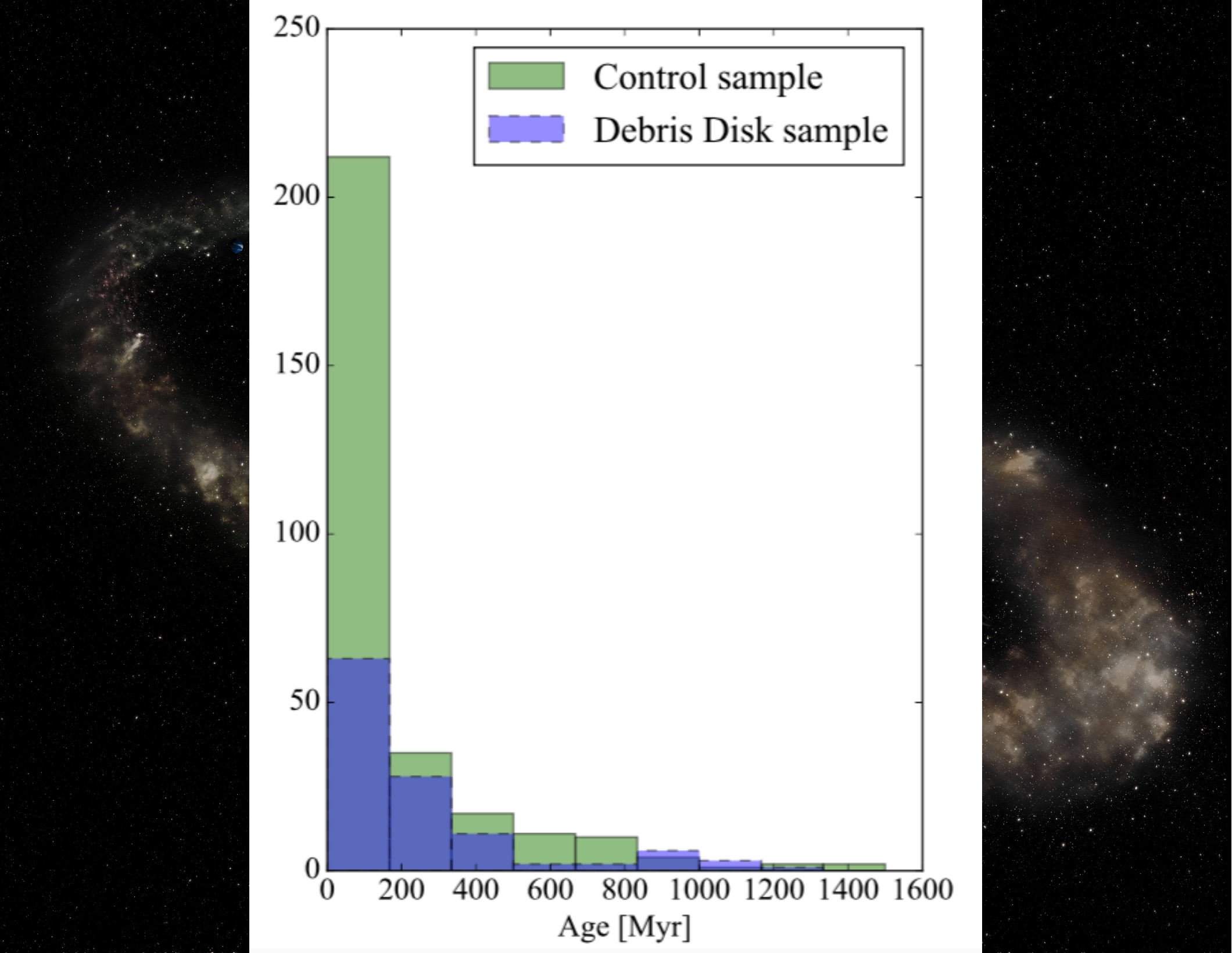
Debris disk sample and control sample

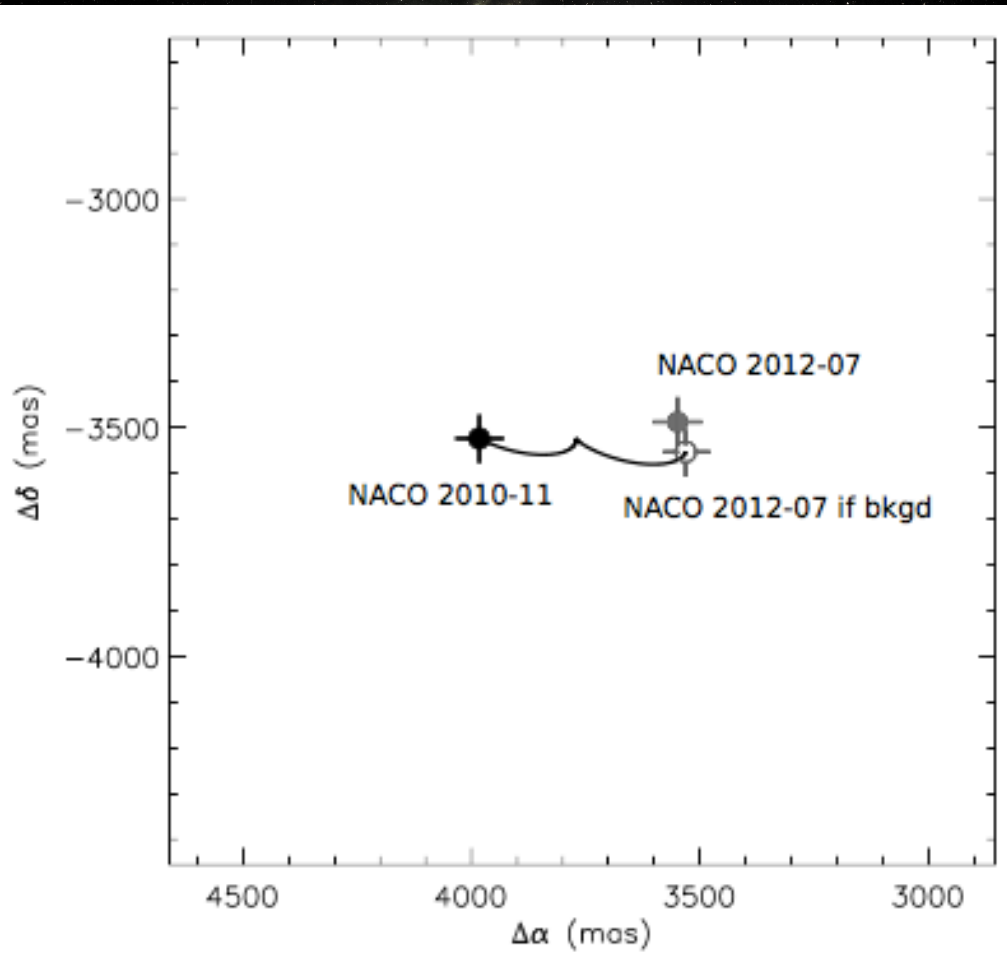
- 130 debris disk stars
  (including new data from 30 Spitzer targets and Wahhaj et al. 2013, Rameau et al. 2013, Janson et al. 2013)

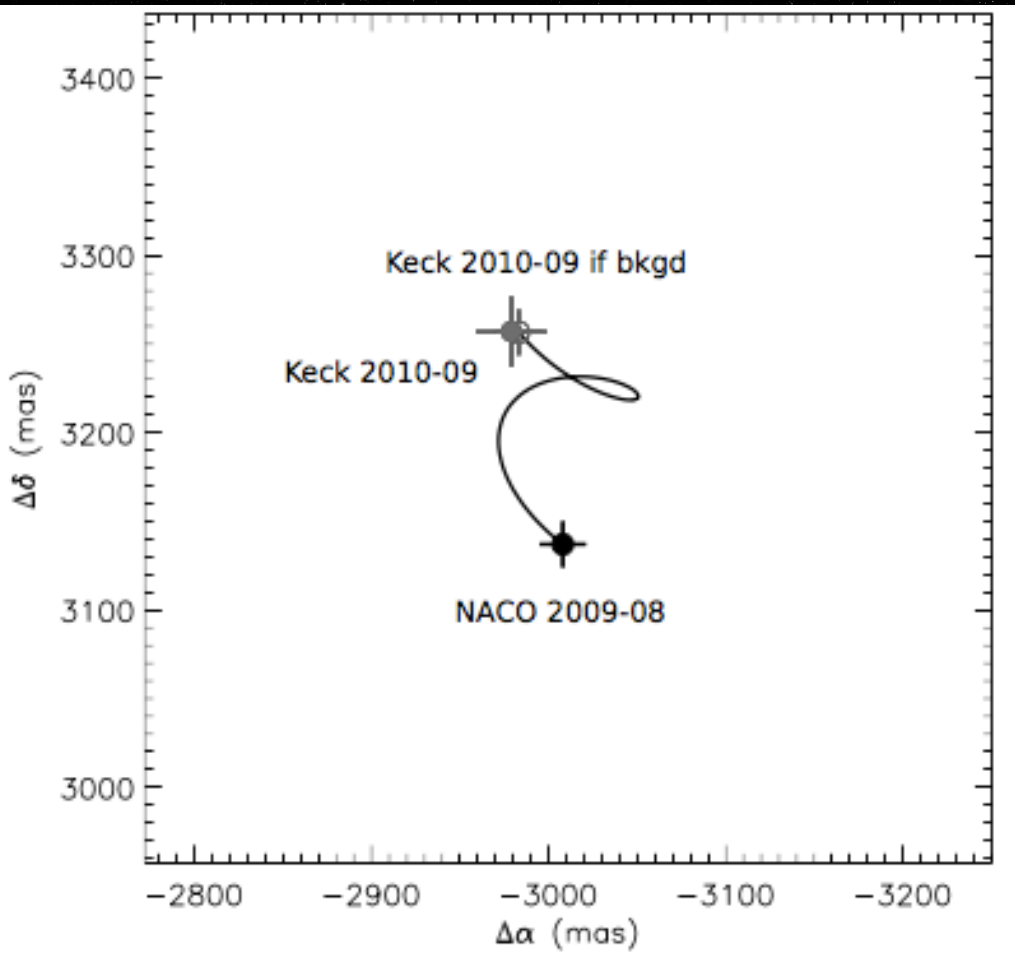
- 277 control sample stars
  (data from Biller et al. 2013, Bowler et al. 2015, Brandt et al. 2014, Galicher et al. 2016, Lafreniere et al, 2007, Nielsen et al. 2013, Vigan et al. 2012)



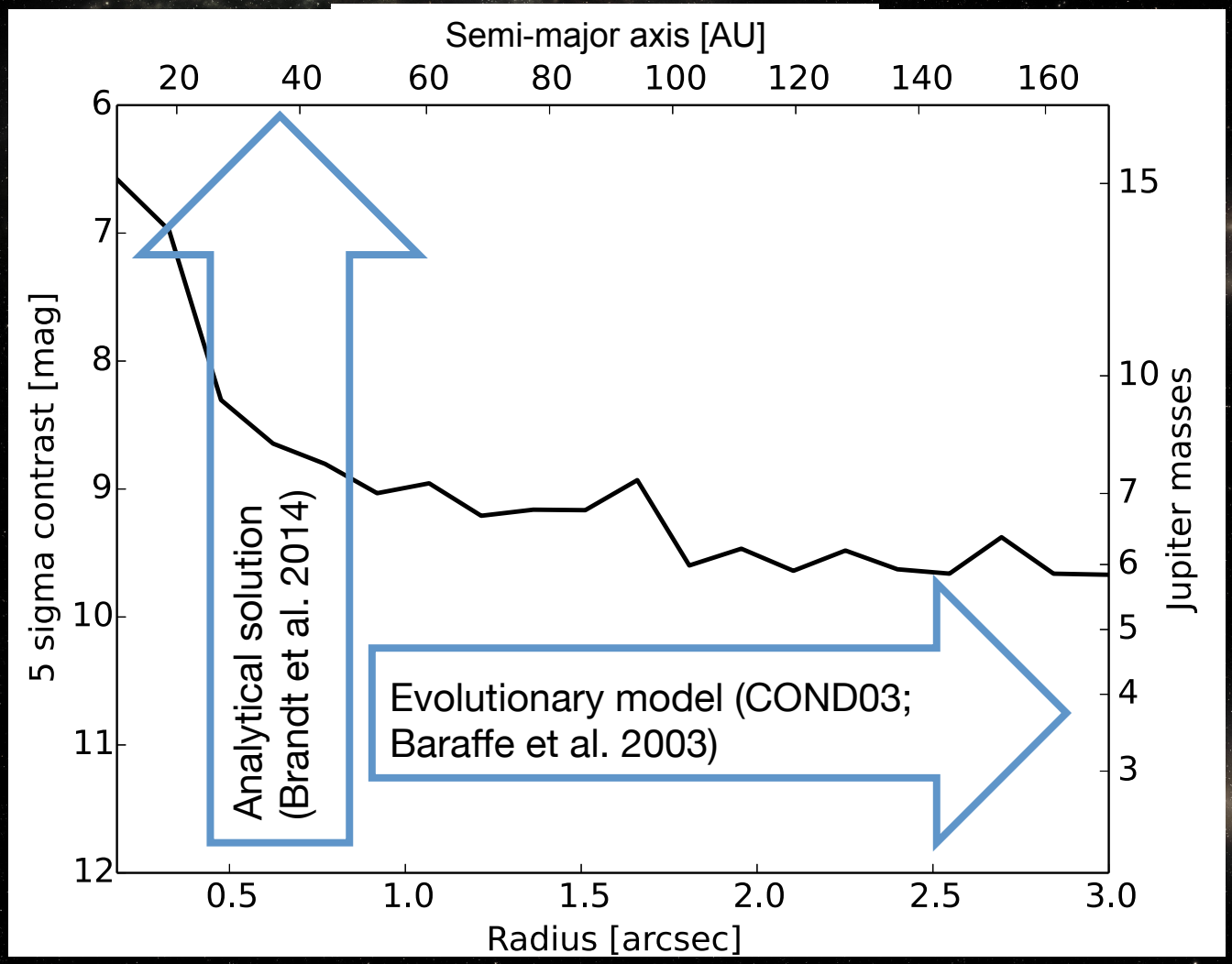
Meshkat et al. 2017 in press

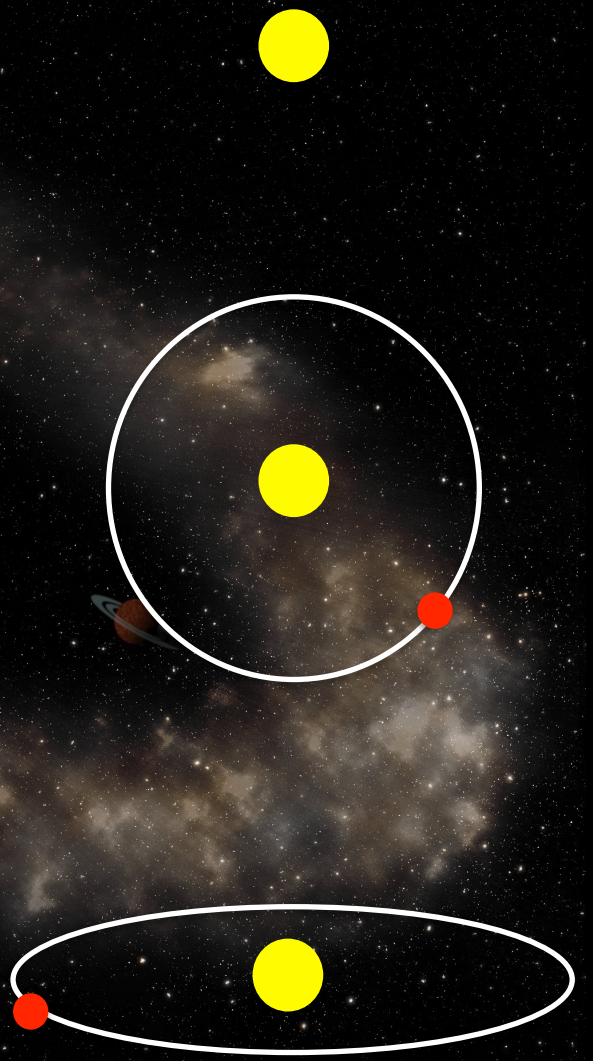

Control sample
Debris Disk sample
250
200
150
100
50
0
0
200
400
600
800
1000
1200
1400
1600
Age [Myr]


−3000
−3500
−4000
Δδ (mas)
NACO 2012-07
NACO 2010-11
NACO 2012-07 if bkgd
4500
4000
3500
3000
Δα (mas)

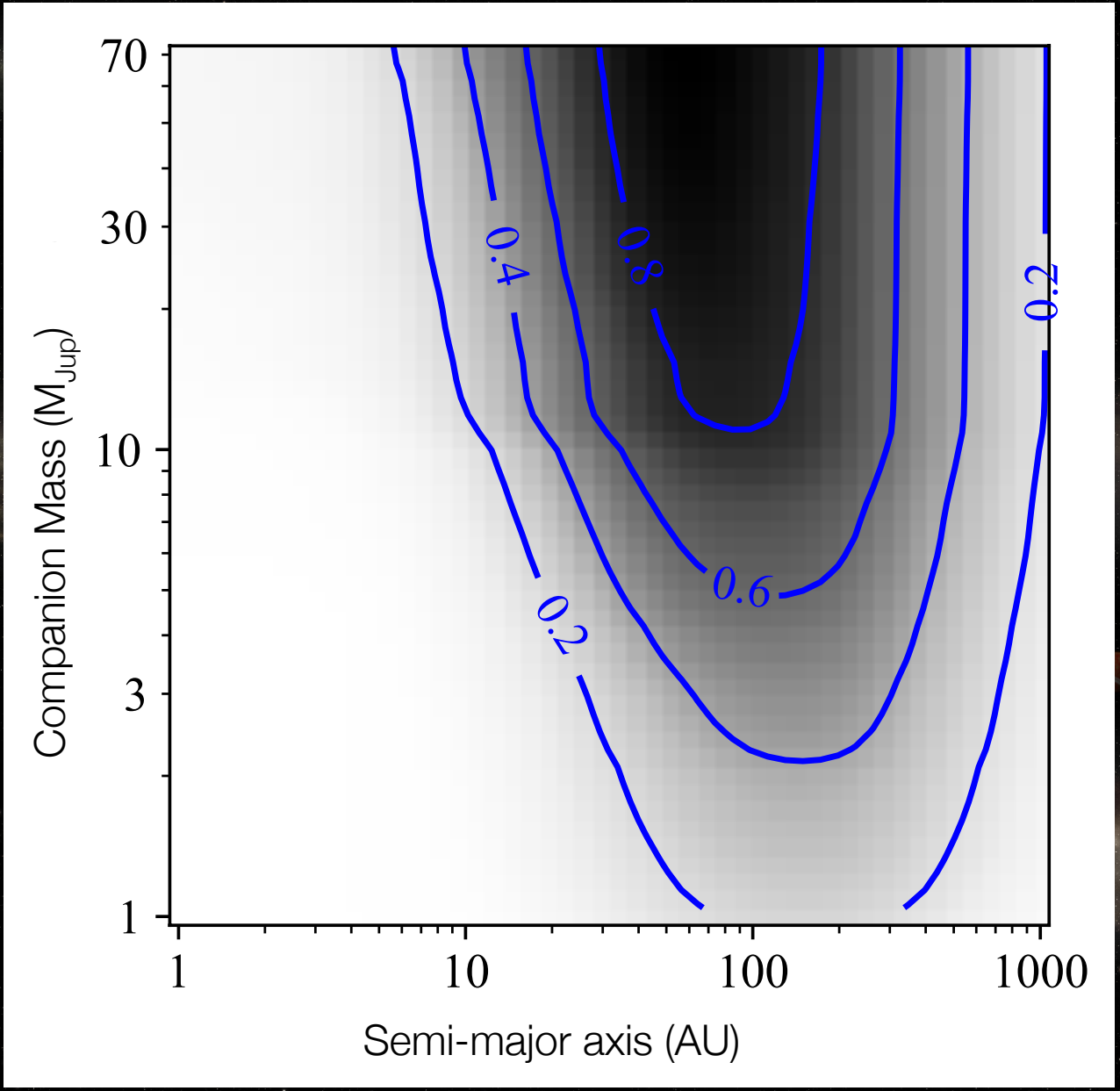

3400
3300
3200
3100
3000
Δδ (mas)
Keck 2010-09 if bkgd
Keck 2010-09
NACO 2009-08
−2800
−2900
−3000
−3100
−3200
Δα (mas)

Convert from contrast curves to detection probability maps





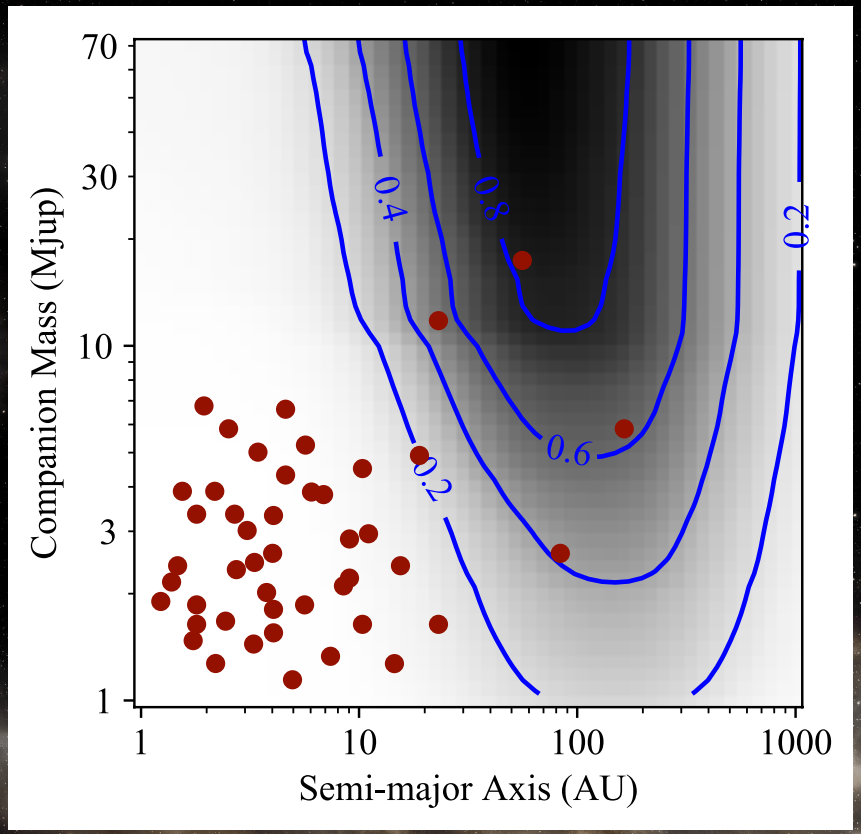
Average detection probability maps



Meshkat et al. 2017 in press

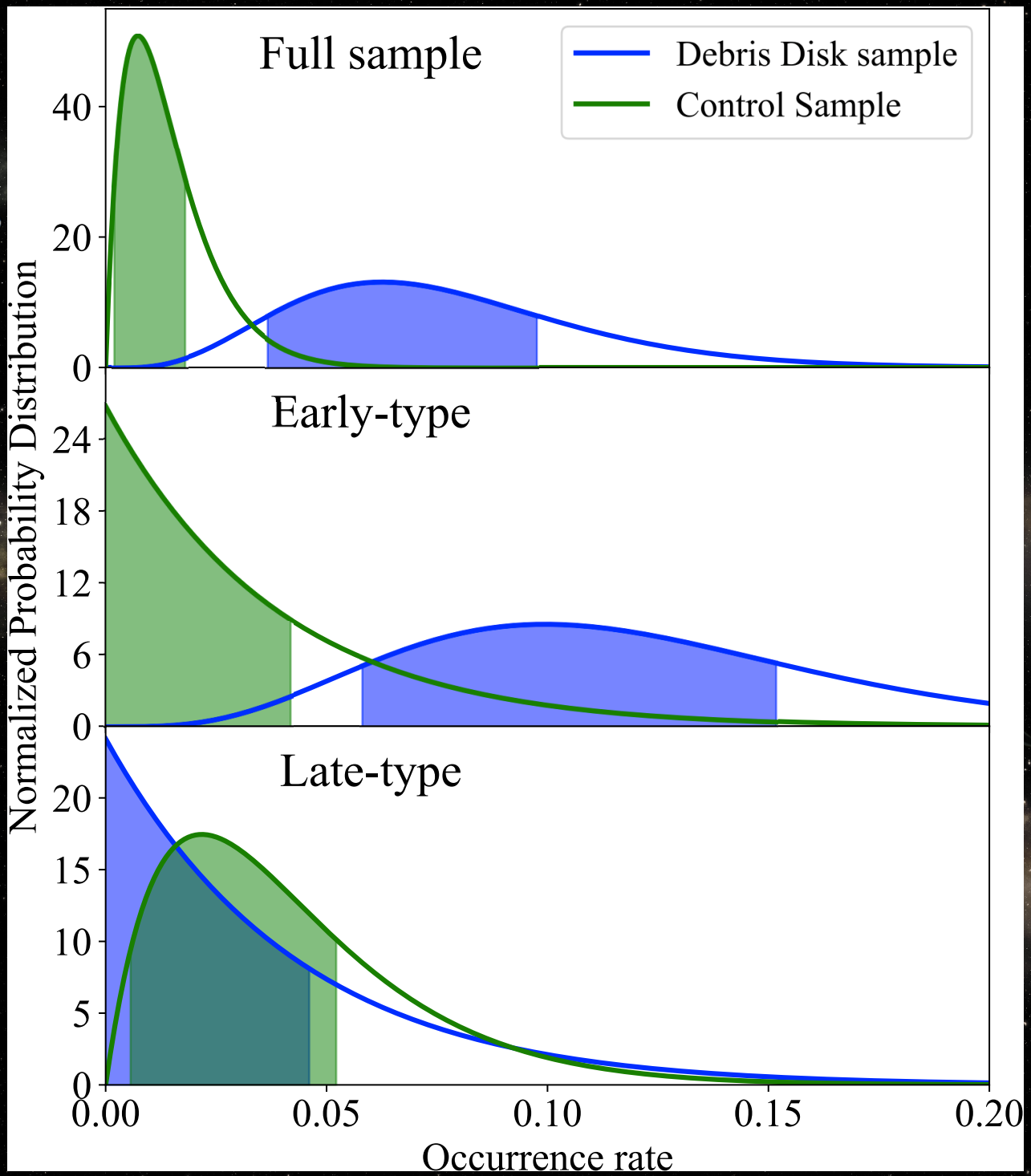
Calculating occurrence rates requires a lot of assumptions

$$f(m,a) = C\, m^{\alpha}\, a^{\beta}$$



$$\text{occurrence rate} = \frac{\text{(planets you detect + planets you miss)}}{\text{all stars surveyed}}$$

Occurrence Rates



Occurrence Rates

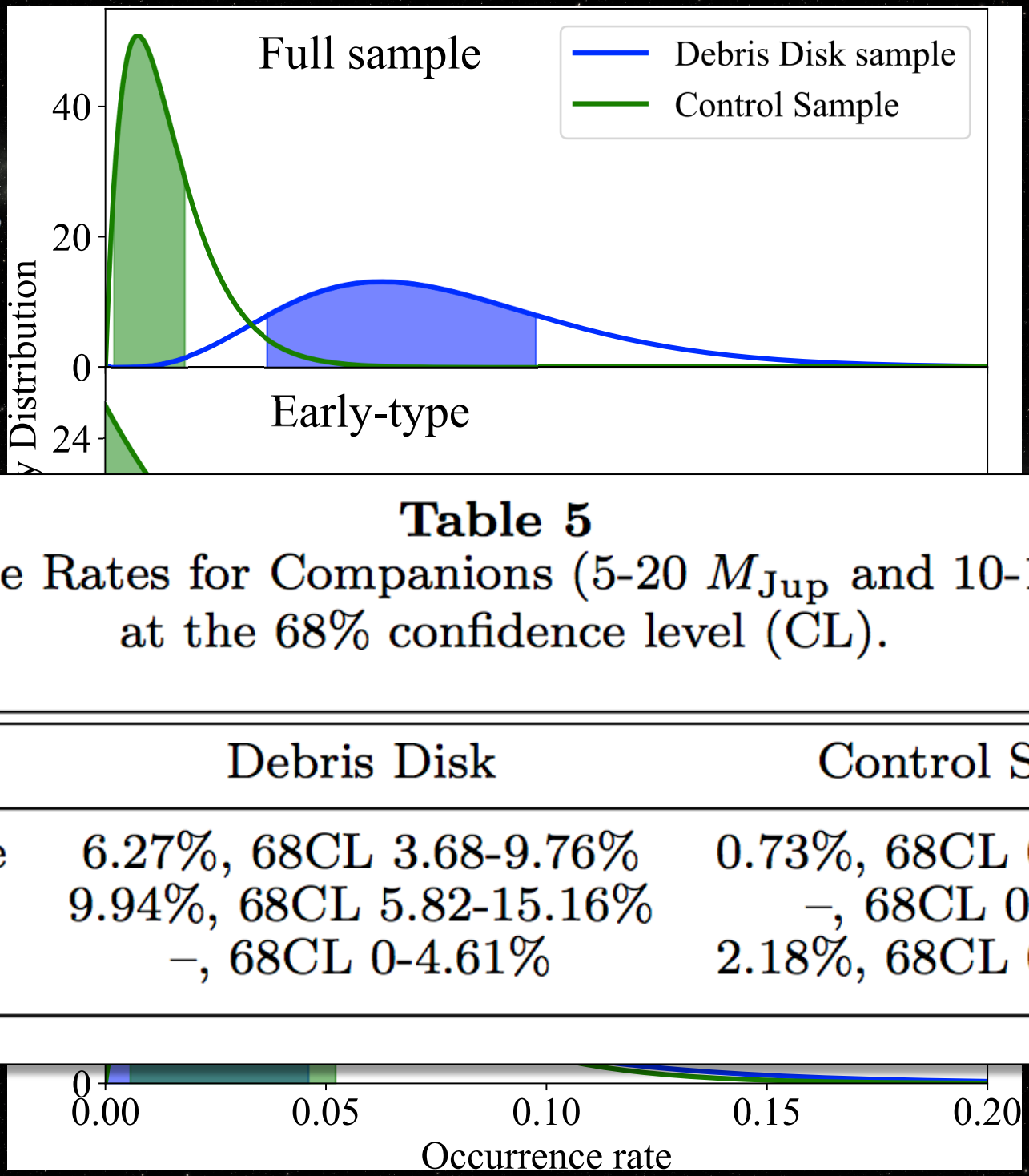


Table 5
Occurrence Rates for Companions (5-20 $M_{\rm Jup}$ and 10-1000 AU) at the 68% confidence level (CL).

	Debris Disk	Control Sample
Full Sample	6.27%, 68CL 3.68-9.76%	0.73%, 68CL 0.20-1.80%
Early-type	9.94%, 68CL 5.82-15.16%	–, 68CL 0-4.17%
Late-type	–, 68CL 0-4.61%	2.18%, 68CL 0.57-5.22%

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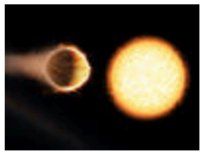
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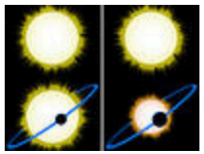
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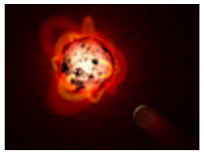
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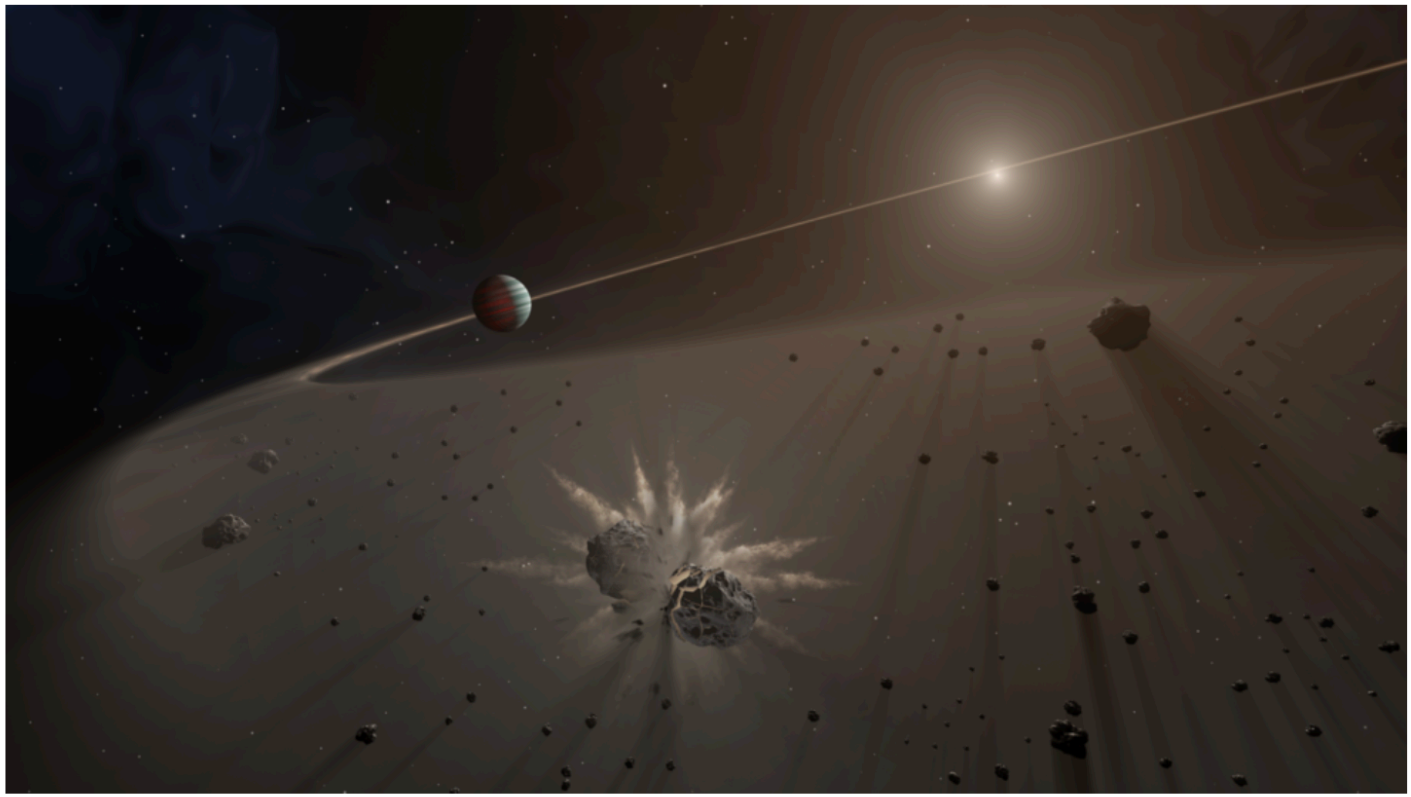
Oct. 11, 2017

Giant Exoplanet Hunters: Look for Debris Disks

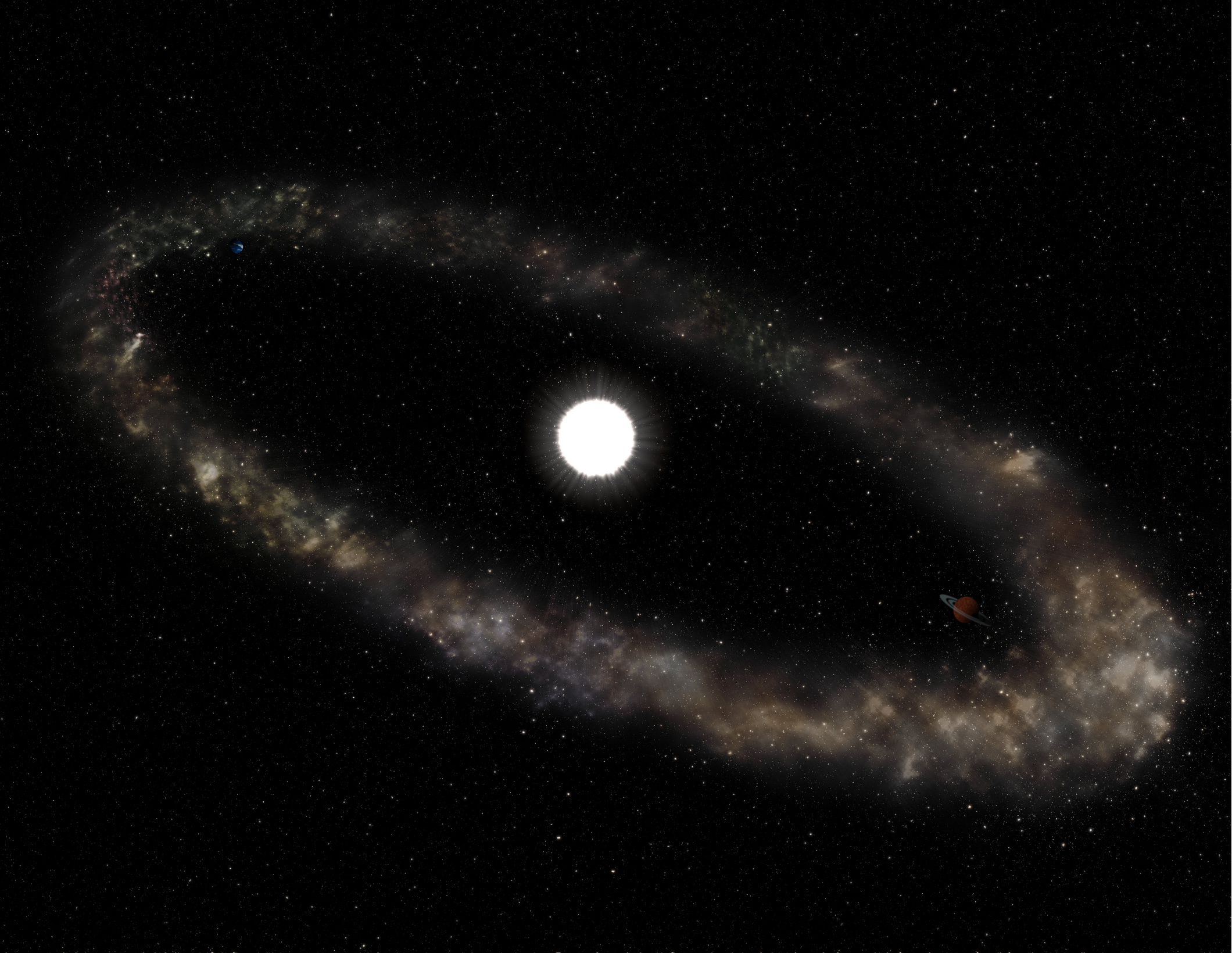


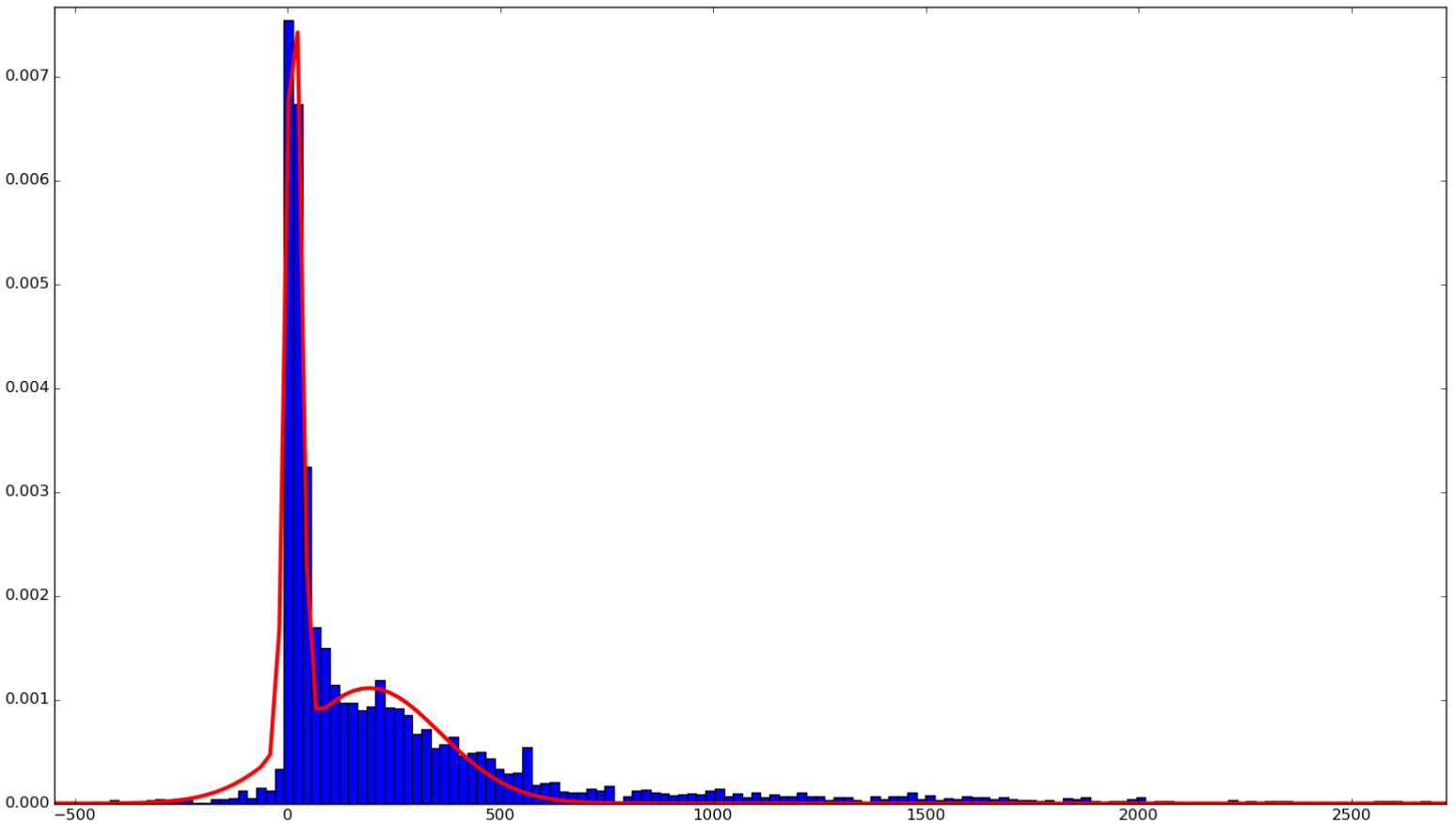
This artist's rendering shows a large exoplanet causing small bodies to collide in a disk of dust.
Credits: NASA/JPL-Caltech
Full image and caption

There's no map showing all the billions of exoplanets hiding in our galaxy -- they're so distant and faint compared

Conclusions

- Stars with debris disks are promising targets to search for planets
- We have shown that the occurrence of young giant planets around stars with debris disks is higher than those without debris disks (88%CL)
- Progress in the coming years will inform future planet searches




0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
−500
0
500
1000
1500
2000
2500