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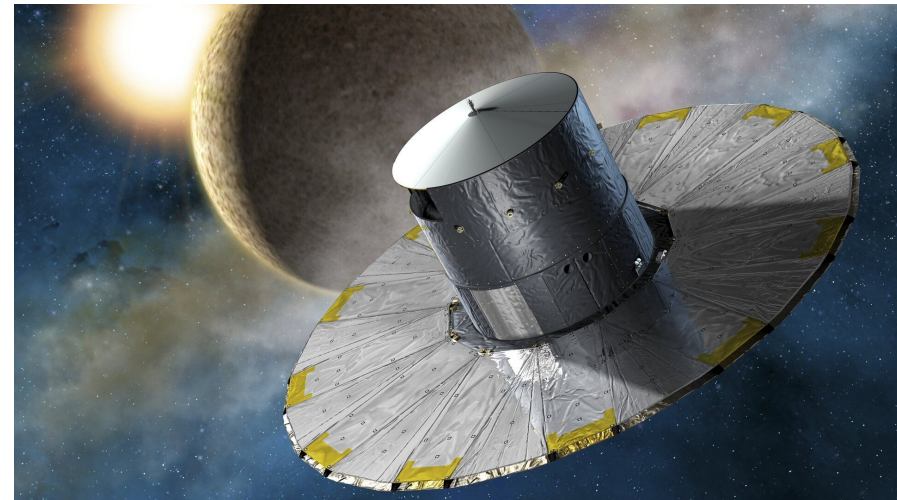


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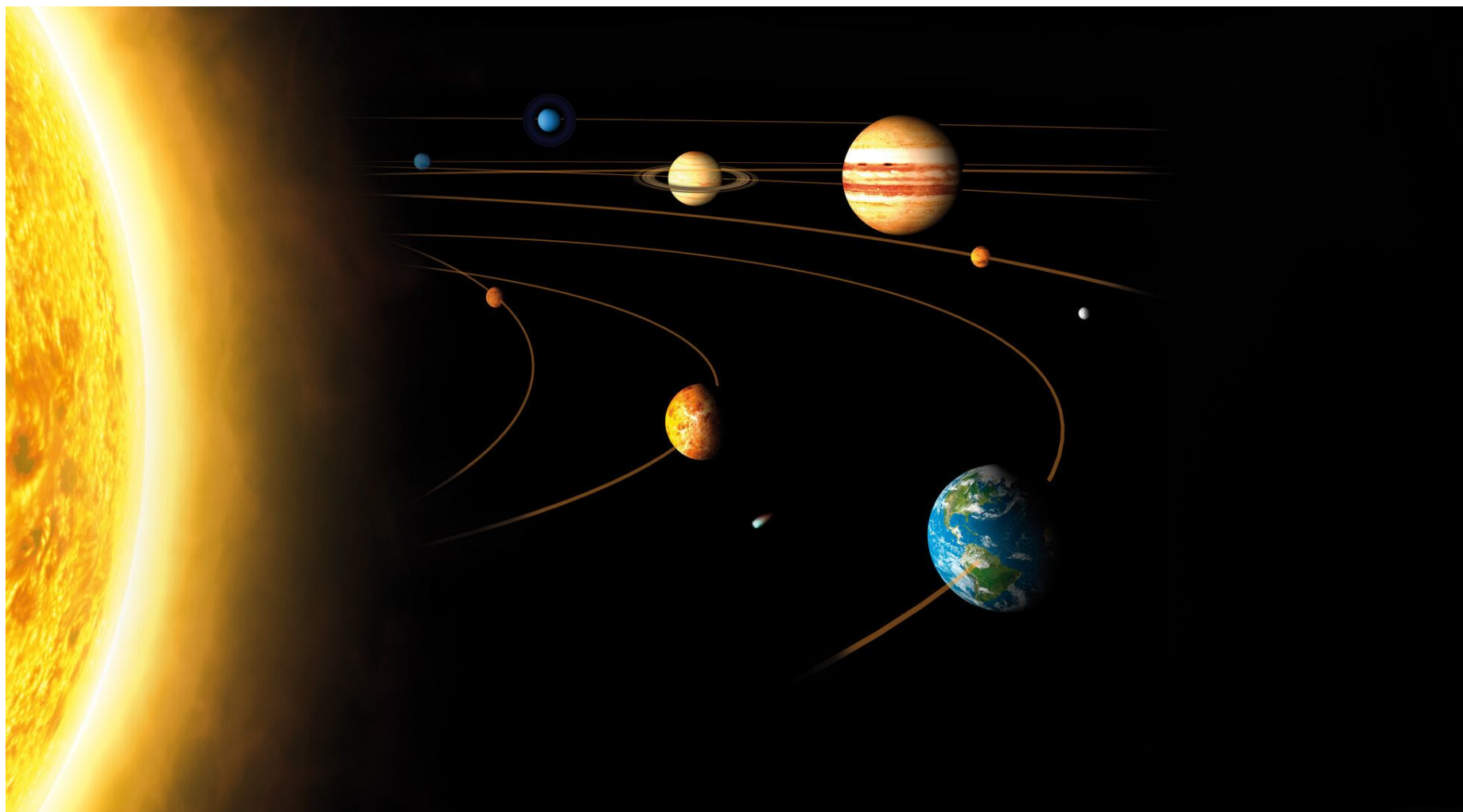
Astrometric constraints on long-period planetary companions: present and DR4 perspectives

M. Pinamonti [[observer](#)]

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Solar-system-like architectures?



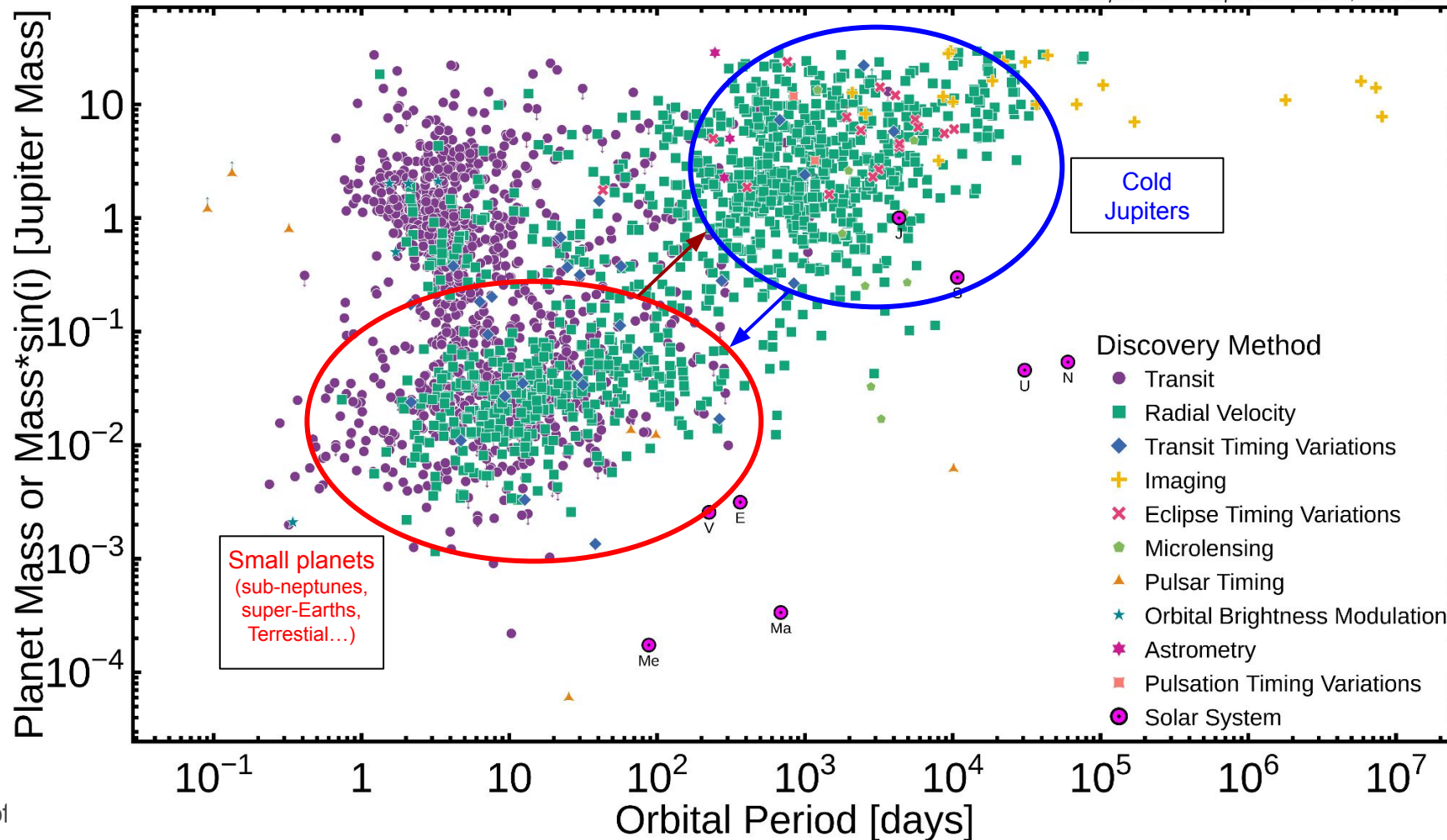


Hierarchical Systems

(not really Solar-System-like)

Planet Mass or Mass* $\sin(i)$ vs Orbital Period

exoplanetarchive.ipac.caltech.edu, 2025-01-31



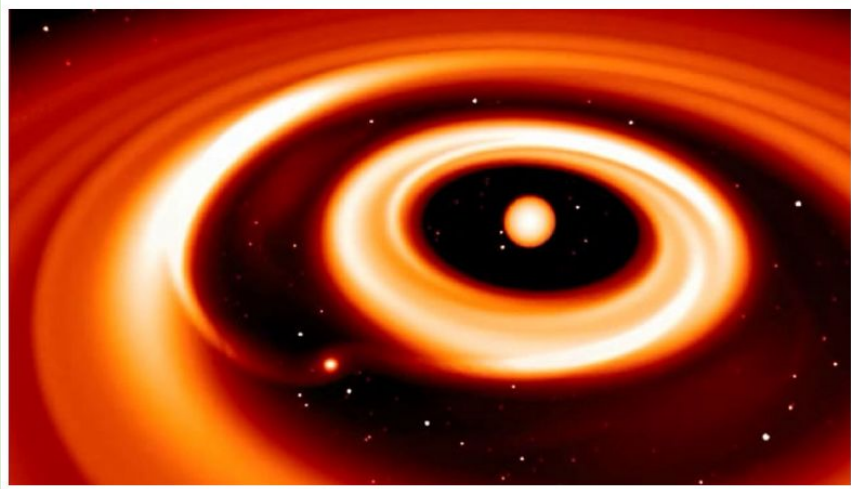


Hierarchical Systems: formation scenarios

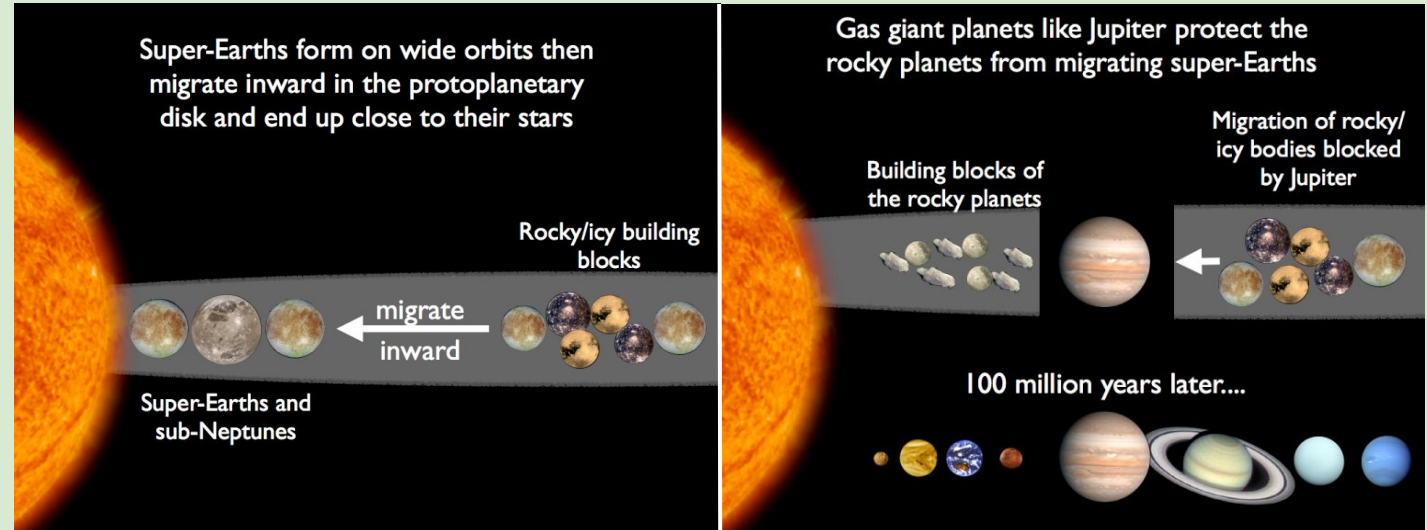
(not really Solar-System-like)

Cold Jupiters open gaps in the disk, reduce inward pebble flux

=> lower occurrence of small planets



Lambrechts et al. 2019



Izidoro et al. 2022

Cold Jupiters prevent migration of outer planetary cores

=> no formation of inner super-Earths and sub-Neptunes

But other models make different predictions: no correlation (e.g. Schlecker et al. 2021); positive correlation SP-CJ (e.g. Chiang & Laughlin 2013)...

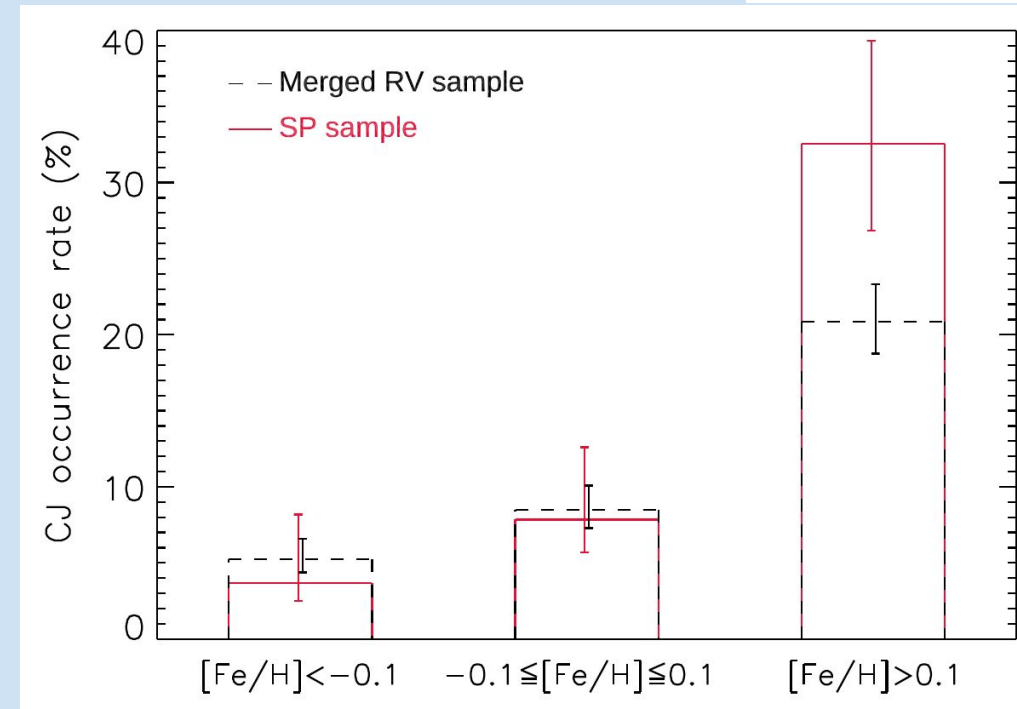
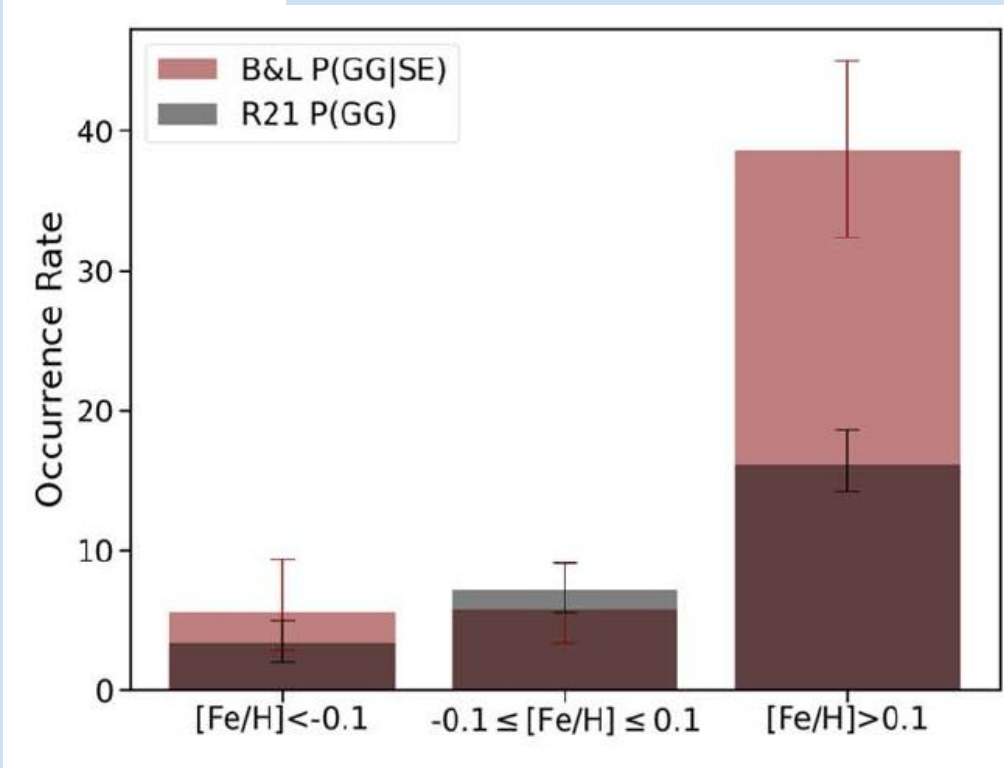


Hierarchical Systems: observational constraints

Occurrence rates of outer giant companions (GG/CJ) in systems with know transiting/RV inner small planets (SE/SP)

Bonomo et al. 2025

Bryan & Lee 2024



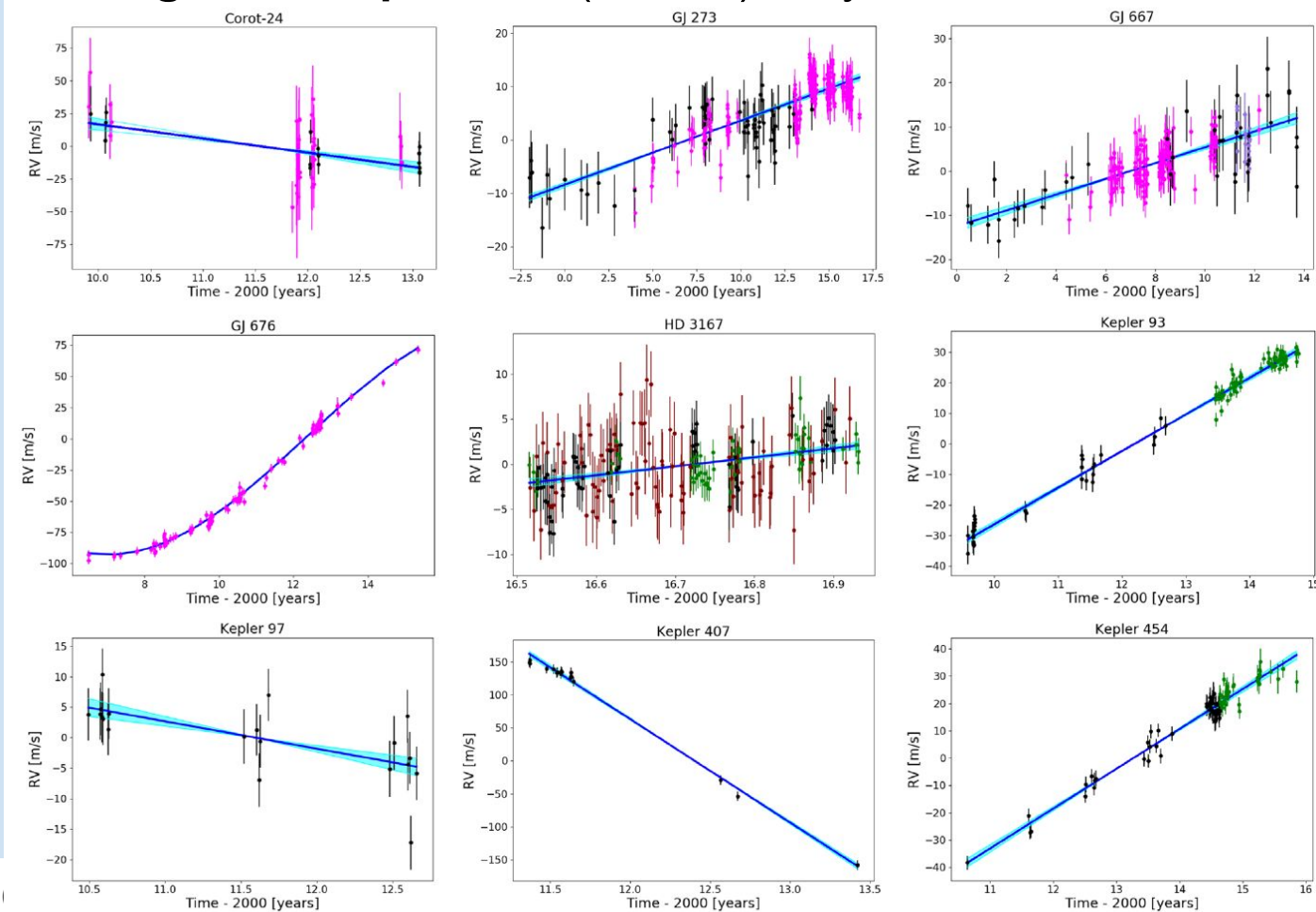
Claims the giant planets are more common in systems with inner super-Earths, not confirmed by other studies.

Unresolved topic!



Hierarchical Systems: observational constraints

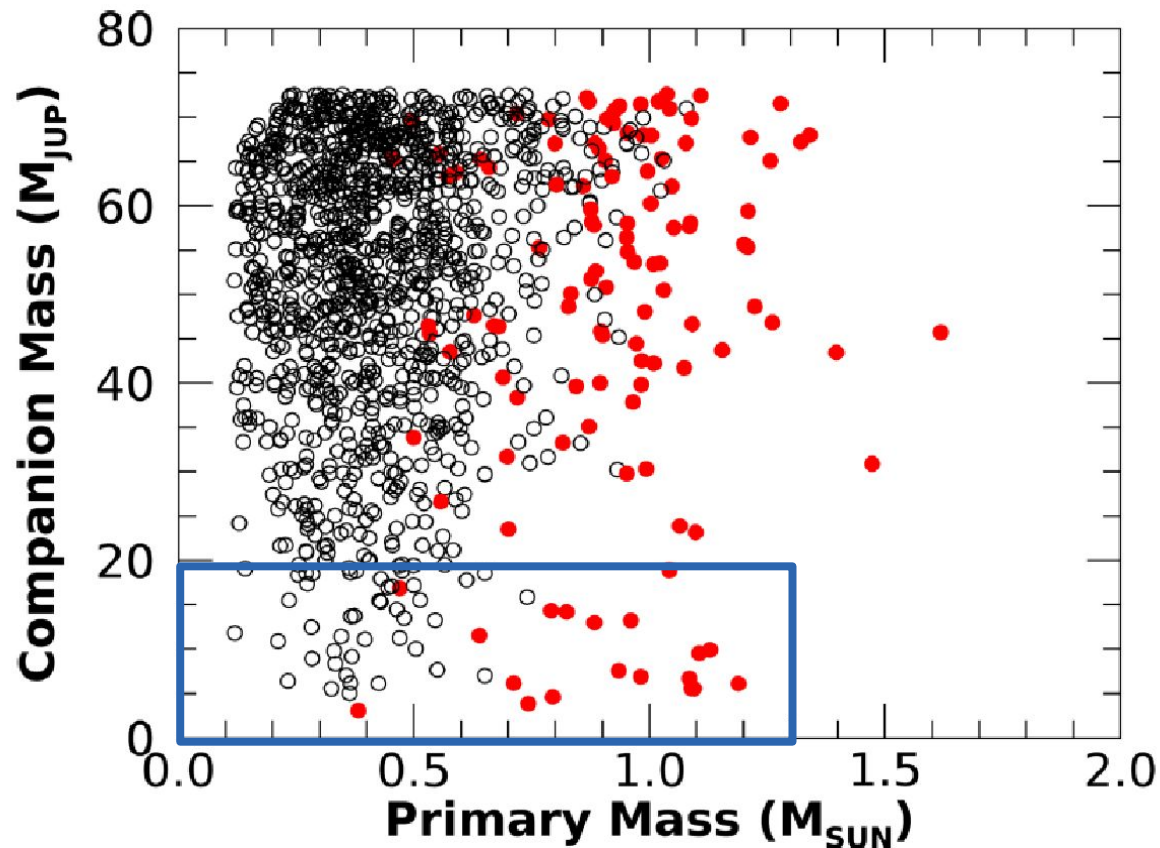
Occurrence rates of outer giant companions (GG/CJ) in systems with know transiting/RV inner small planets (SE/SP)



Bryan et al. 2019



Gaia DR3 Astrometry & Exoplanets



≈ 1800 orbits



$\approx 5\%$ with $M_2 < 20 M_{\text{Jup}}$



$\approx 30\%$ with $G < 12$ mag

Typically:

- $P < 1000$ days
- $a_0 \approx 100\text{-}400 \mu\text{as}$

Gaia DR3: outer companions to known SP?

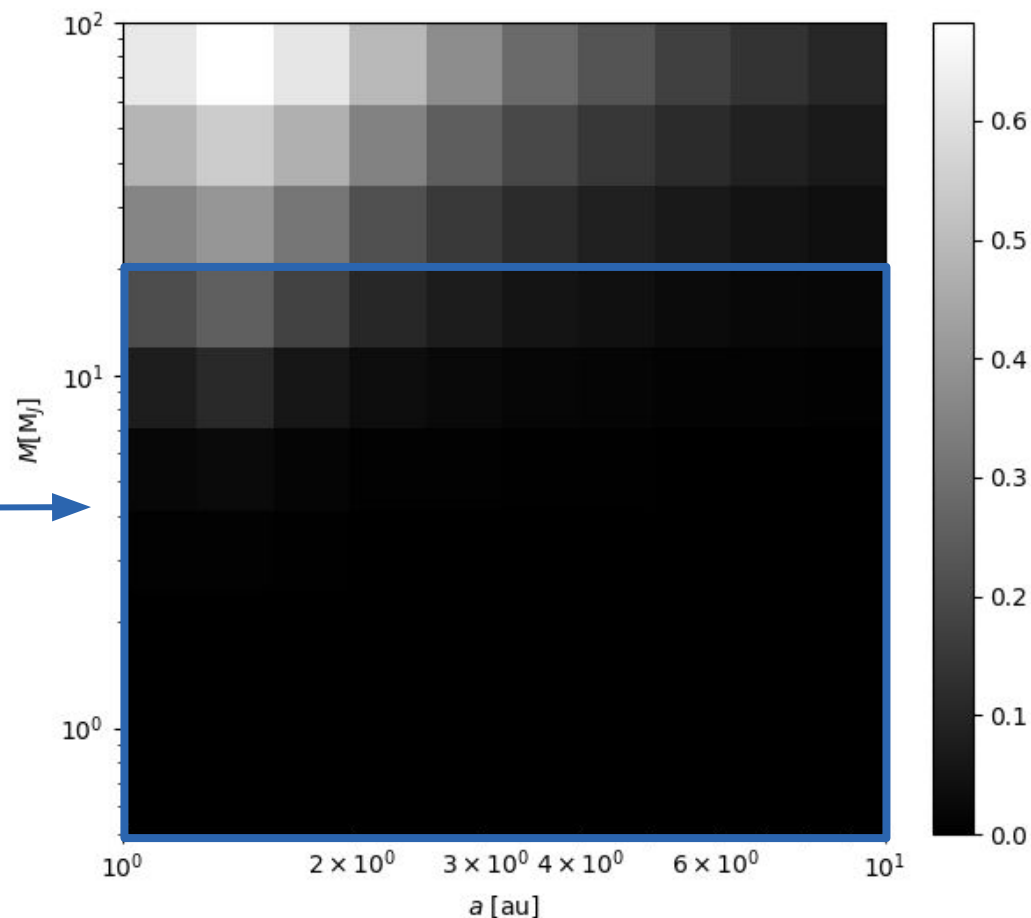
SP: $P \lesssim 100$ d, $1 < M_p < 20 M_{\oplus}$

CJ: $1 < a < 10$ AU, $0.5 < M_p < 20 M_{\text{Jup}}$

(Bonomo et al. 2025)

Detection MAP on SP sample from Bonomo et al. 2025: **240 systems** with detection transit/RV SP

Completeness to CJ = 2.1%



What can we expect from DR4?

Gaia DR4: outer companions to known SP?

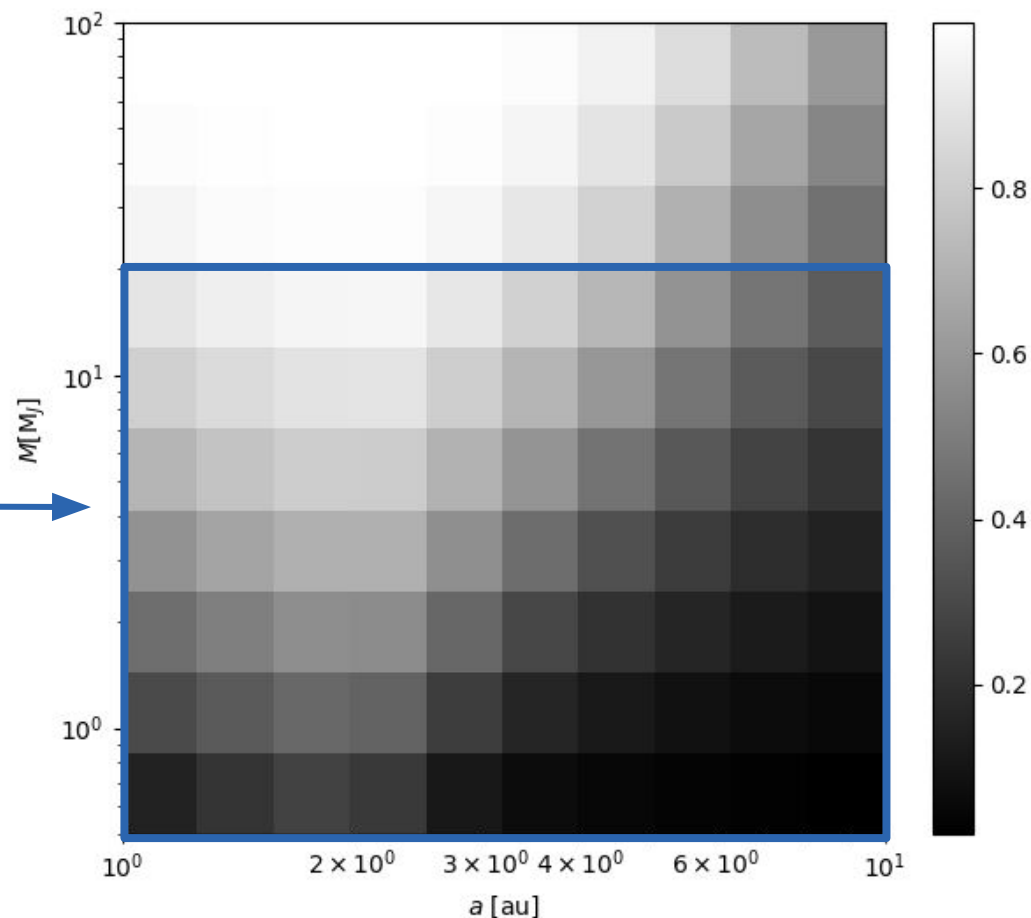
SP: $P \lesssim 100$ d, $1 < M_p < 20 M_{\oplus}$

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(Bonomo et al. 2025)

Detection MAP on SP sample from Bonomo et al. 2025: **240 systems** with detected transit/RV SP

Completeness to CJ = 44.9%



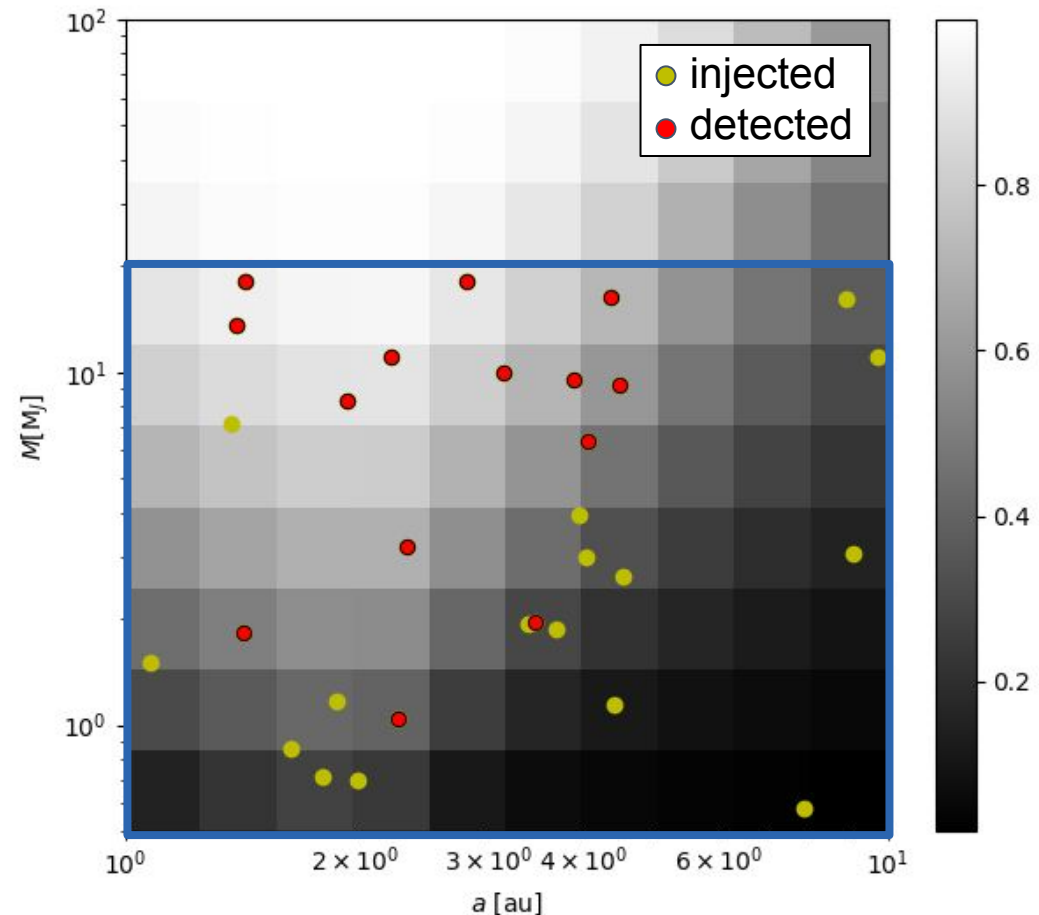


Gaia DR4: expected CJ detections

SP sample from Bonomo et al. 2025
(B25): **240 systems** with detected
transit/RV SP

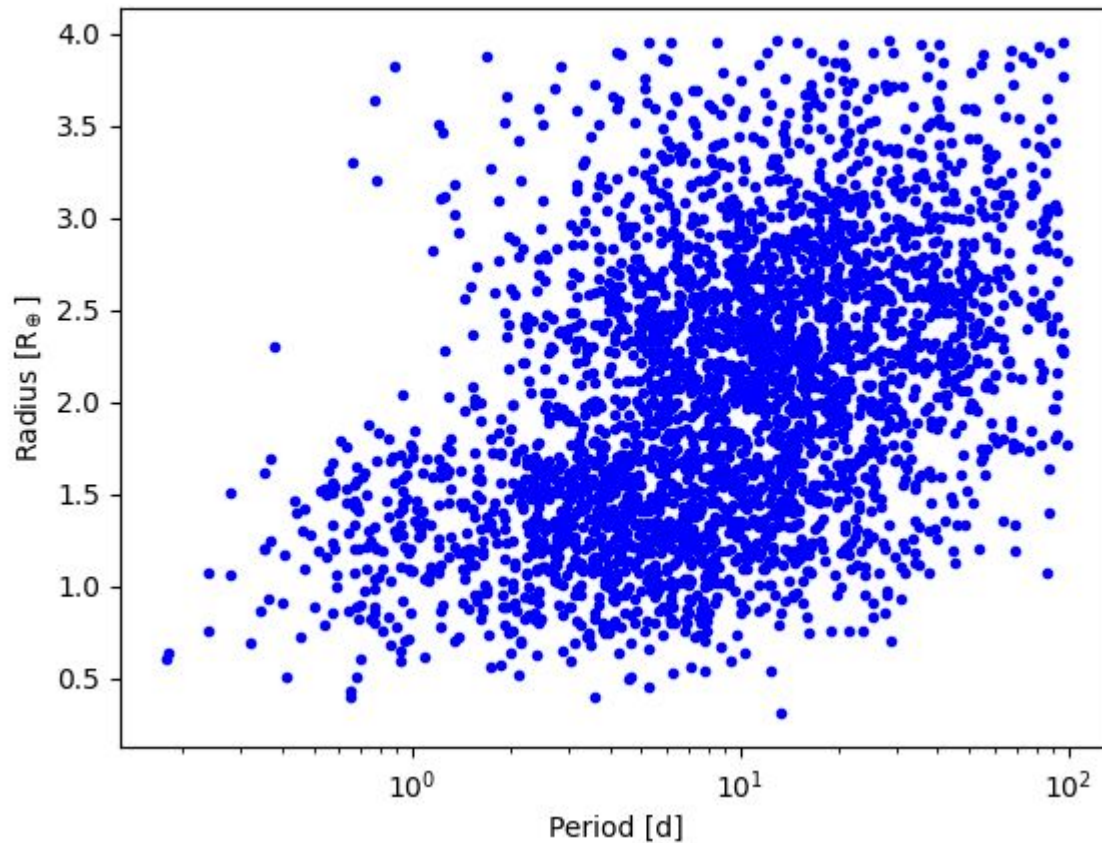
$$f_{\text{CJ}|\text{SP+Mixed}} = 12.5^{+2.5}_{-1.8} \%$$

$$f_{\text{CJ}|\text{SP+DR4}} = 15.8^{+4.8}_{-2.9} \%$$





Gaia DR4: outer companions to known SP?



Larger sample:

all SP ($P > 100$, $R_p > 4 R_{\oplus}$)

from NASAExoplanetArchive:

=> 2437 systems



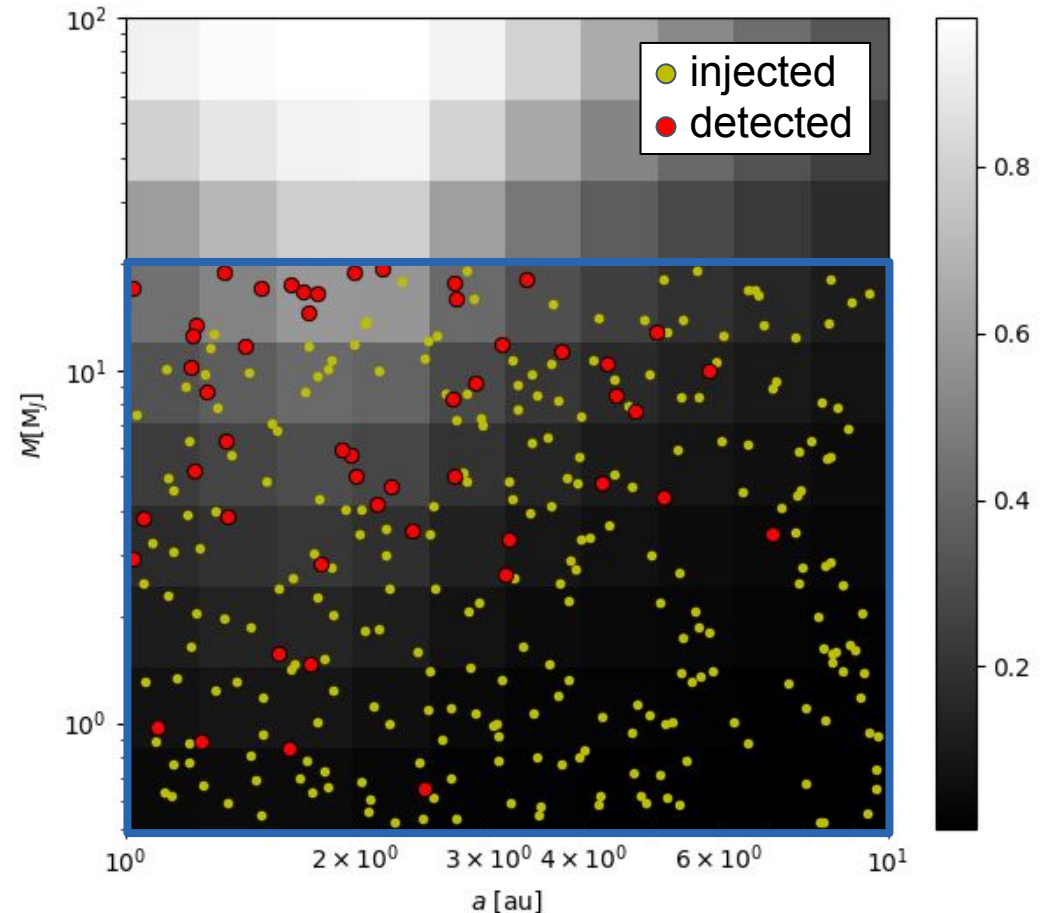
Gaia DR4: expected CJ detections

SP sample from NASAExoplanets:
2437 systems with detected transit/RV
SP

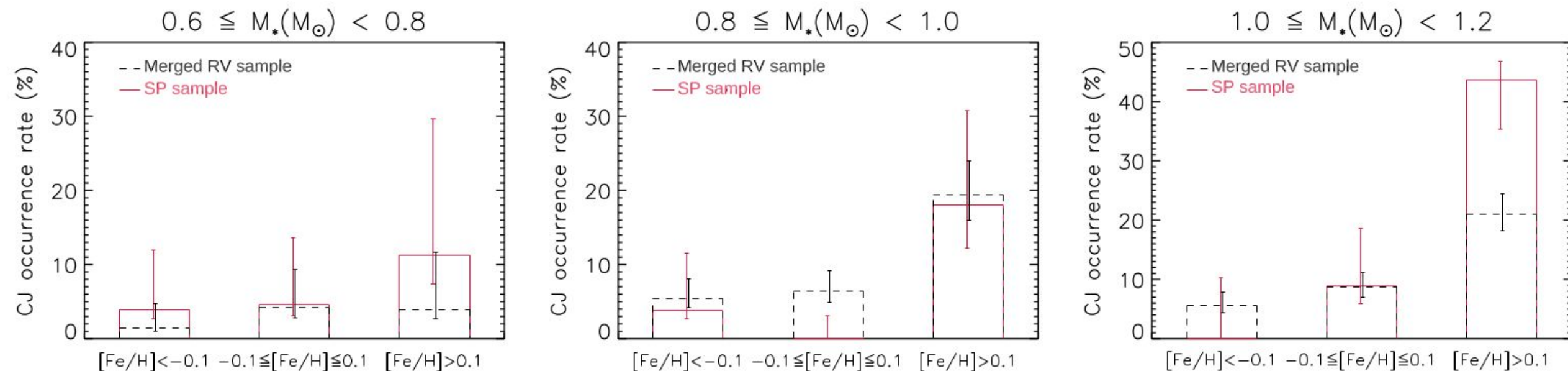
$$f_{\text{CJ}|\text{SP+Mixed}} = 12.5^{+2.5}_{-1.8} \%$$

Completeness to CJ = 15.3%

$$f_{\text{CJ}|\text{SP+DR4}} = 13.2^{+2.2}_{-1.6} \%$$



Hierarchical Systems: observational constraints



Bonomo et al. 2025

No very strong additional constraints on $f_{(CJ|SP)}$



Gaia DR4: huge statistical samples!

(Bonomo et al. 2025)

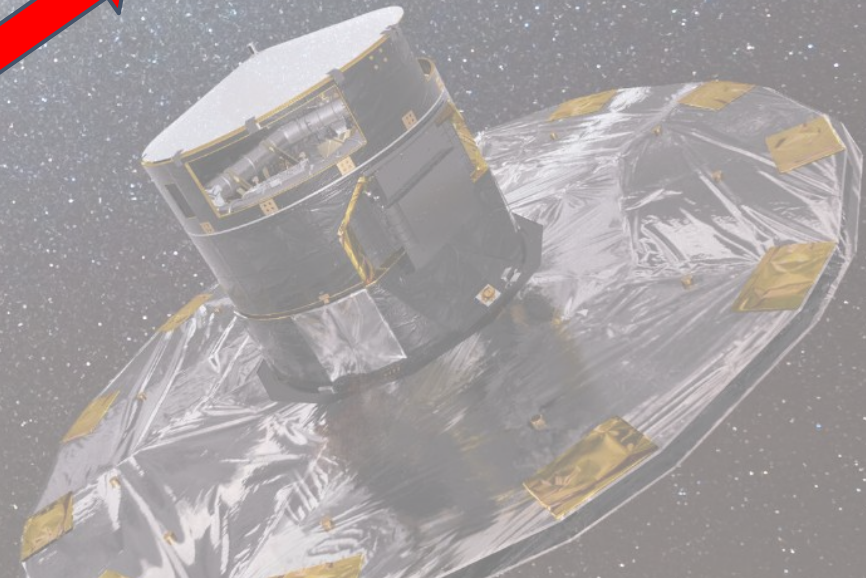
[Fe/H]	$M_p = 0.3 - 13 M_{Jup}$			$M_p = 0.5 - 20 M_{Jup}$		
	$N_\star d$	C	$f_{CI} [\%]$	$N_\star d$	C	$f_{CI} [\%]$
Small planet (transit+radial velocity) sample						
$\overline{[Fe/H]} = -0.011 \pm 0.005$	217 27	0.928	$13.4^{+2.8}_{-2.0}$	217 23	0.958	$11.1^{+2.5}_{-1.8}$
$[Fe/H] < -0.1$	64 2	0.943	$3.3^{+4.1}_{-1.1}$	64 2	0.969	$3.2^{+4.0}_{-1.0}$
$-0.1 \leq [Fe/H] \leq +0.1$	86 6	0.918	$7.6^{+4.1}_{-2.0}$	86 3	0.952	$3.7^{+3.3}_{-1.1}$
$[Fe/H] > +0.1$	67 19	0.923	$30.7^{+6.4}_{-5.2}$	67 18	0.954	$28.2^{+6.2}_{-4.9}$
$[Fe/H] \leq 0$	102 3	0.932	$3.2^{+2.9}_{-1.0}$	102 3	0.961	$3.1^{+2.8}_{-0.9}$
$[Fe/H] > 0$	115 24	0.923	$22.6^{+4.5}_{-3.5}$	115 20	0.954	$18.2^{+4.2}_{-3.1}$

Merged (AAT+CLS+HARPS) radial velocity comparison sample

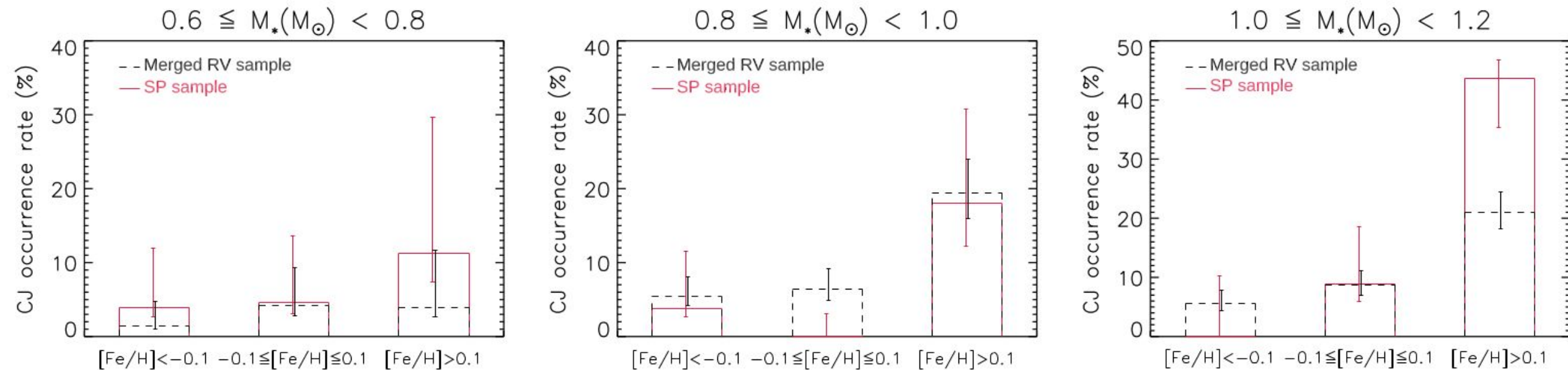
$\overline{[Fe/H]} = -0.072 \pm 0.009$	1167 118	0.974	$10.4^{+1.0}_{-0.8}$	1167 113	0.988	$9.8^{+0.9}_{-0.8}$
$[Fe/H] < -0.1$	430 22	0.974	$5.2^{+1.3}_{-0.9}$	430 21	0.988	$4.9^{+1.3}_{-0.8}$
$-0.1 \leq [Fe/H] \leq +0.1$	413 31	0.971	$7.7^{+1.5}_{-1.1}$	413 31	0.986	$7.6^{+1.5}_{-1.1}$
$[Fe/H] > +0.1$	324 65	0.977	$20.5^{+2.4}_{-2.1}$	324 61	0.990	$19.0^{+2.4}_{-2.0}$
$[Fe/H] \leq 0$	624 33	0.973	$5.4^{+1.1}_{-0.8}$	624 32	0.988	$5.2^{+1.0}_{-0.7}$
$[Fe/H] > 0$	543 85	0.974	$16.1^{+1.7}_{-1.5}$	543 81	0.988	$15.1^{+1.7}_{-1.4}$

$d < 200$ pc, DR3 Mass, [Fe/H]

$[Fe/H] = -0.077$	220 000
$[Fe/H] < -0.1$	88 000
$-0.1 < [Fe/H] < 0.1$	70 000
$[Fe/H] > 0.1$	58 000



Hierarchical Systems: observational constraints



Bonomo et al. 2025

Very strong additional constraints on $f(\text{CJ})$



Takeaway messages:

- Currently difficult to constrain relative frequency of SP and CJ from RV alone;
- Gaia DR3 does not help the search for CJ companions (other astrometric constraints: P_{Ma}, ruwe...);
- Gaia DR4:
 - small improvements in $f_{(CJ|SP)}$: some new detections (limited by number of known SP);
 - large improvement to $f_{(CJ)}$: all-sky constraint on the presence of Cold Jupiters around stars of different Mass, [Fe/H];
 - improvements to $f_{(SP|CJ)}$: new CJ systems around which to search for inner companions!