

Searching for cold Jupiters with VLT/SPHERE in systems hosting close-in, low-mass planets



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On the shoulders of giants, Torino, 26/03/2026

Context and motivation of the survey

Close-in, low-mass exoplanets:

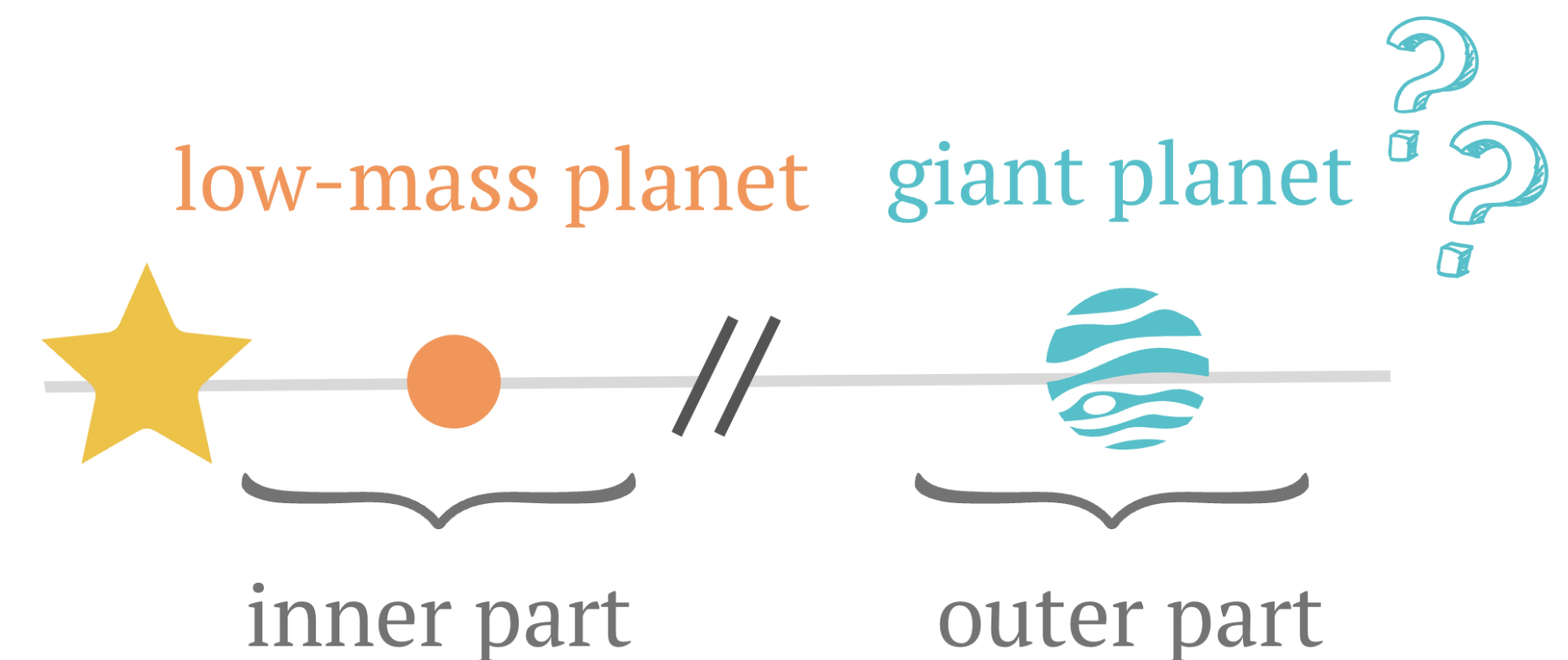
extremely abundant type of exoplanets (~50 % single G stars may host one, *Mayor et al. 2011*), but how they form remains an open question.

Two possibilities:

Could close-in low-mass planets have formed in-situ at typically less than 1 au?

or Did they form further out in the planet-forming disk and migrated inwards?

Could there be a correlation between the presence of close-in low-mass planets and outer giant planets?



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**Astronomy
&
Astrophysics**

Planetary system architectures with low-mass inner planets

Direct imaging exploration of mature systems beyond 1 au★

C. Desgrange^{1,2}, J. Milli¹, G. Chauvin³, Th. Henning², A. Luashvili⁴, M. Read⁵, M. Wyatt⁶, G. Kennedy^{7,8},
R. Burn², M. Schlecker⁹, F. Kiefer¹⁰, V. D'Orazi^{11,12}, S. Messina¹³, P. Rubini¹⁴, A.-M. Lagrange¹⁰, C. Babusiaux¹,
L. Matrà¹⁵, B. Bitsch², M. Bonavita^{12,16}, P. Delorme¹, E. Matthews², P. Palma-Bifani³, and A. Vigan¹⁷

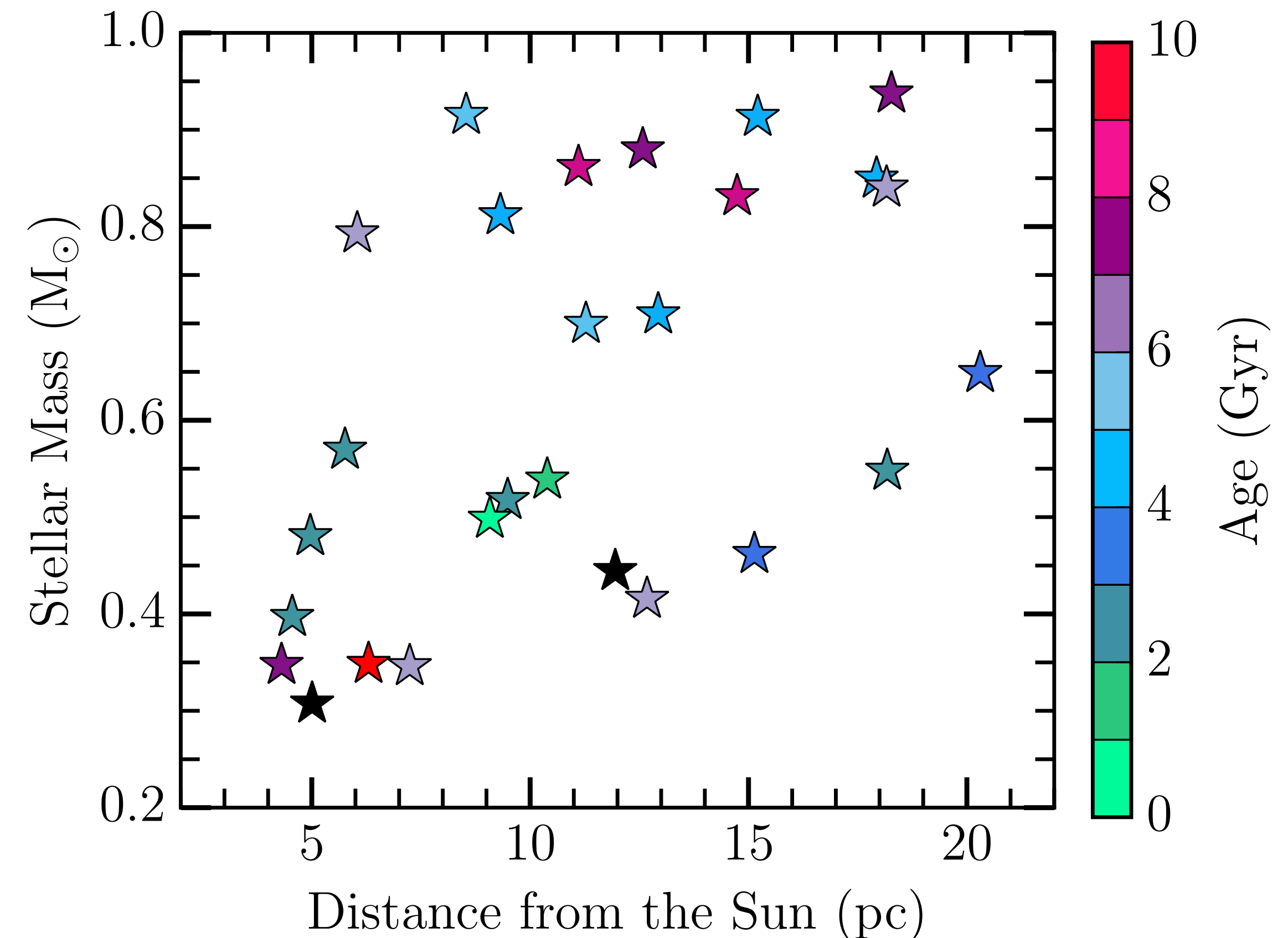
Sample

Sample = **27 systems**

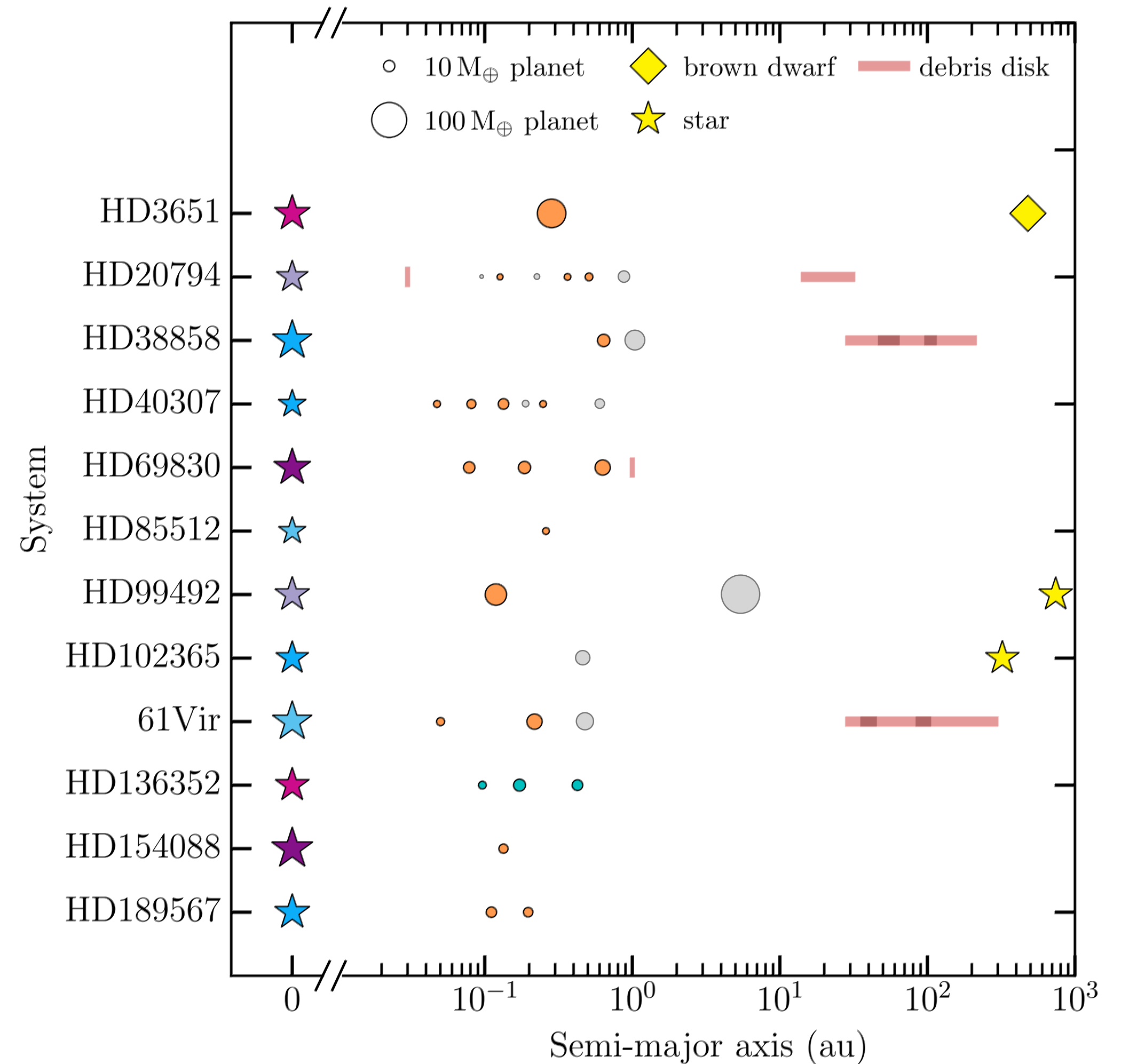
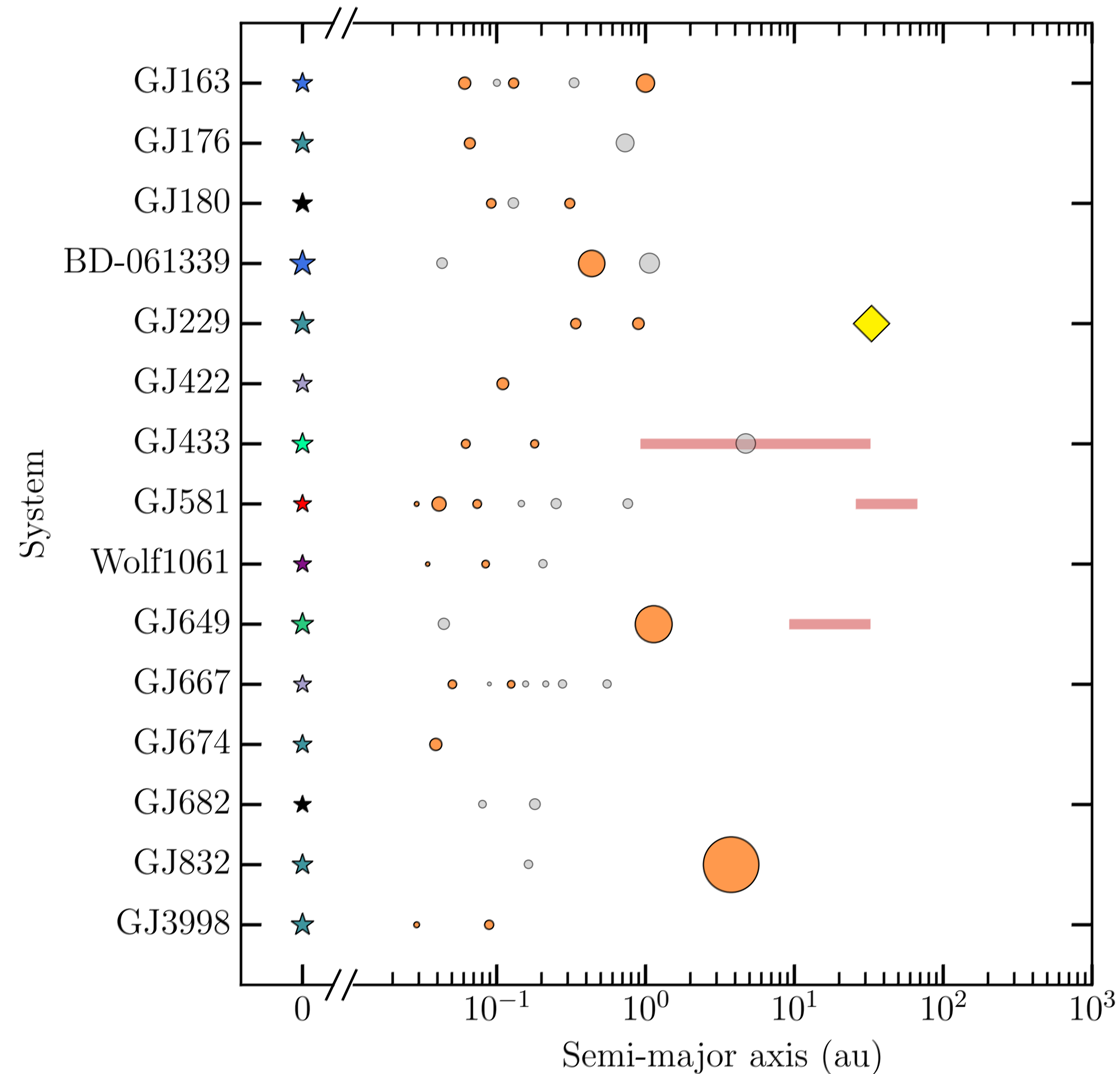
- hosting suggested close-in ($\lesssim 1$ au) low-mass ($\lesssim 95 M_{\oplus}$) planets already detected by radial velocities
- within 20 pc of about 500 Myr – 10 Gyr and around G, K, M stars

Note: The sample was designed in 2016, first observation in 2017, last observation in July 2022.

We look for giant planets located at a few au from their host star.

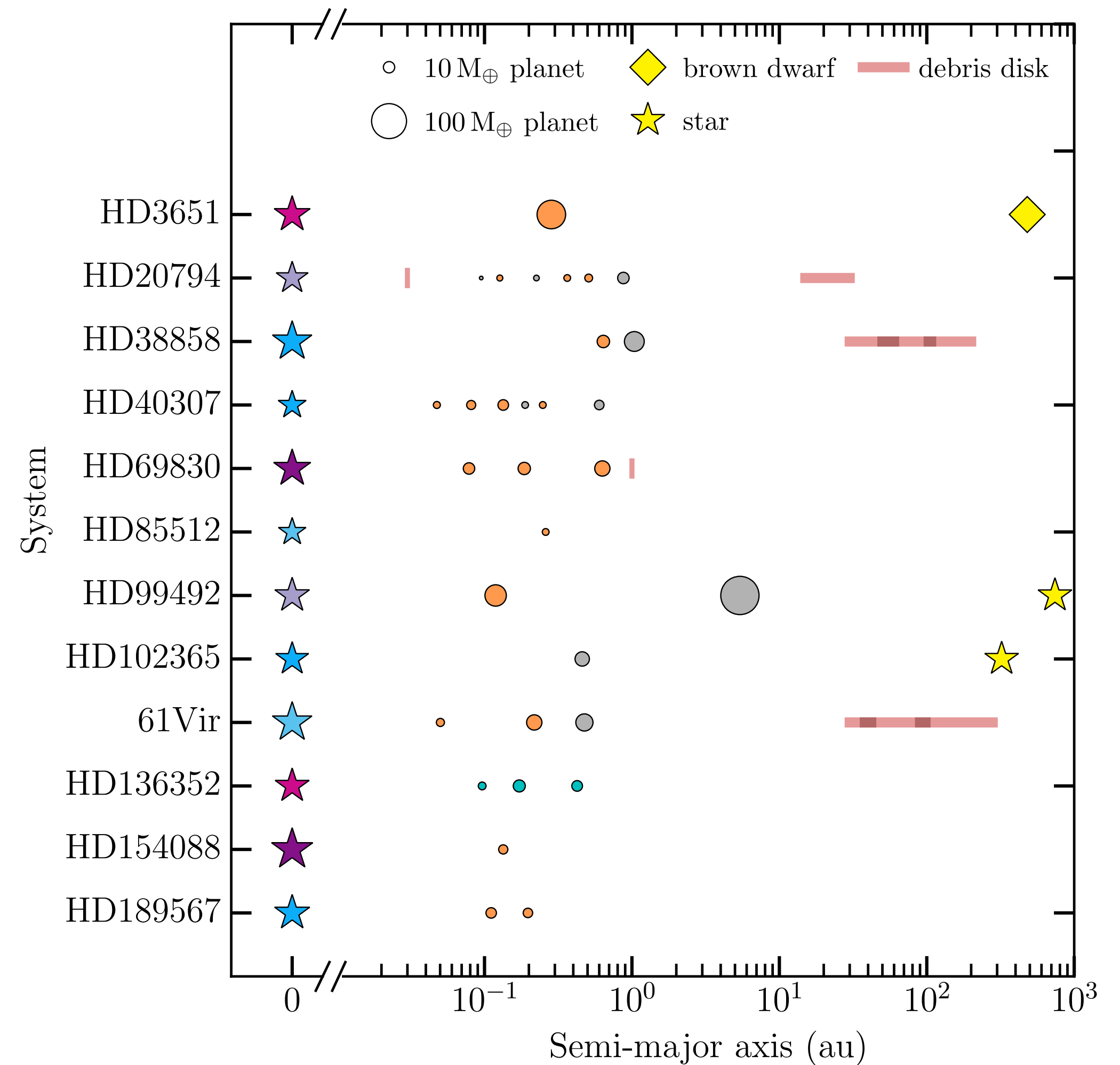
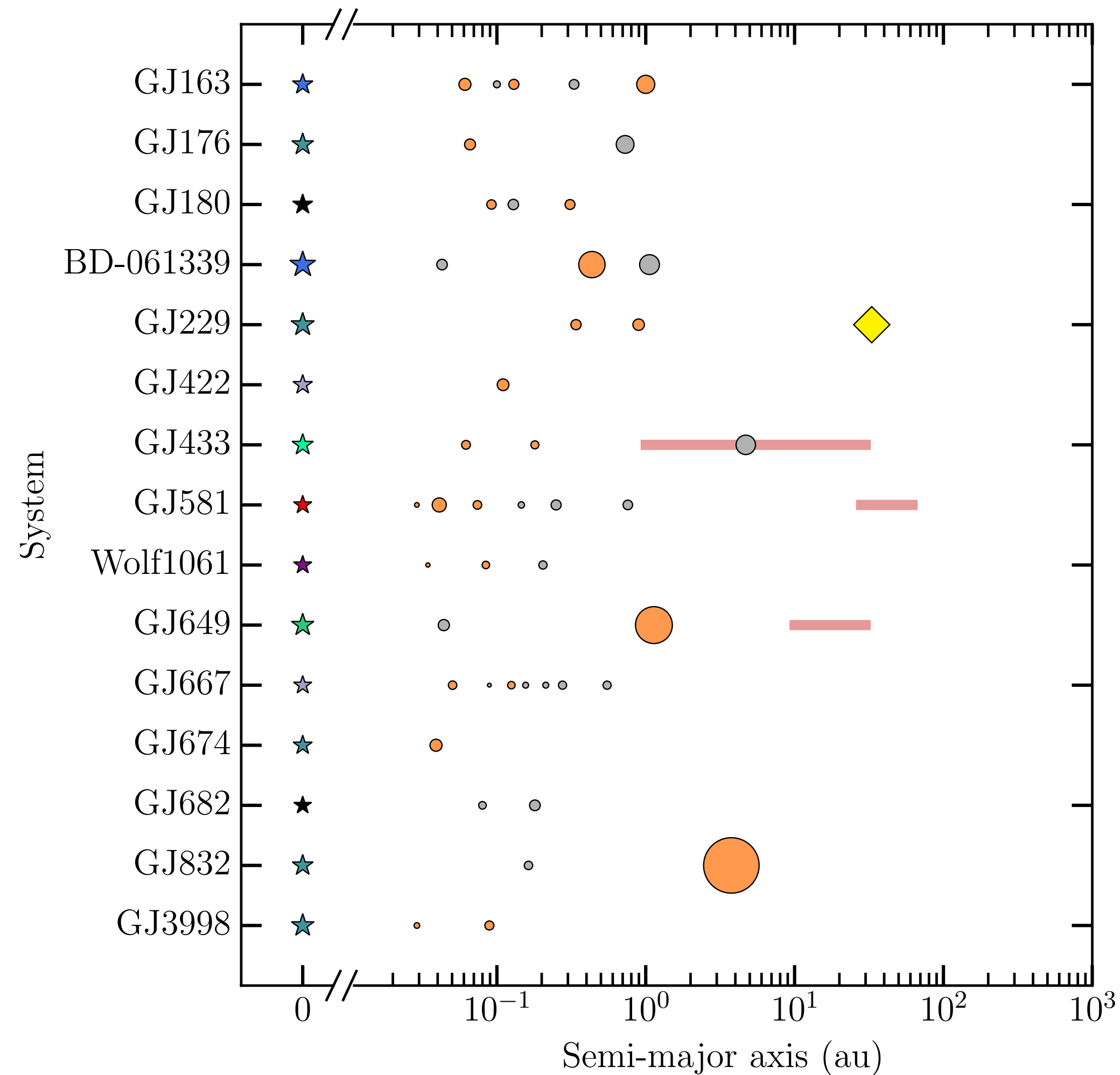


Architecture of the studied systems



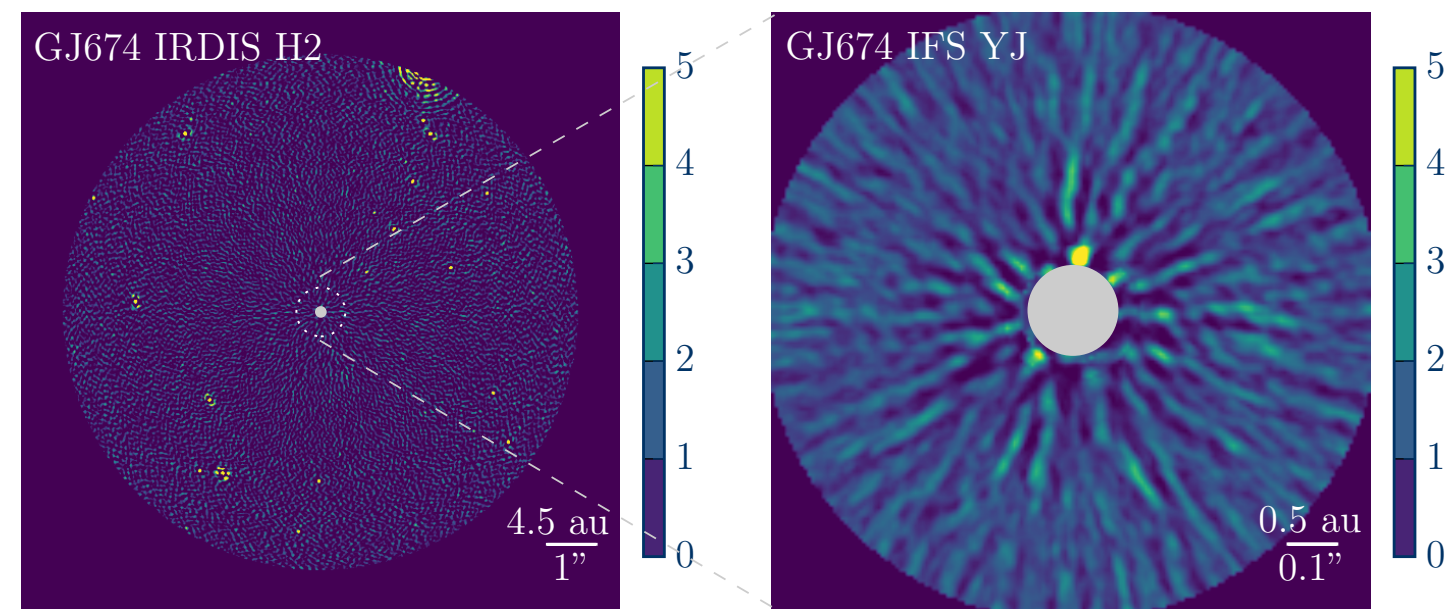
Legend: orange = confirmed planets, blue = transiting planets, grey = unconfirmed planets

Architecture of the studied systems



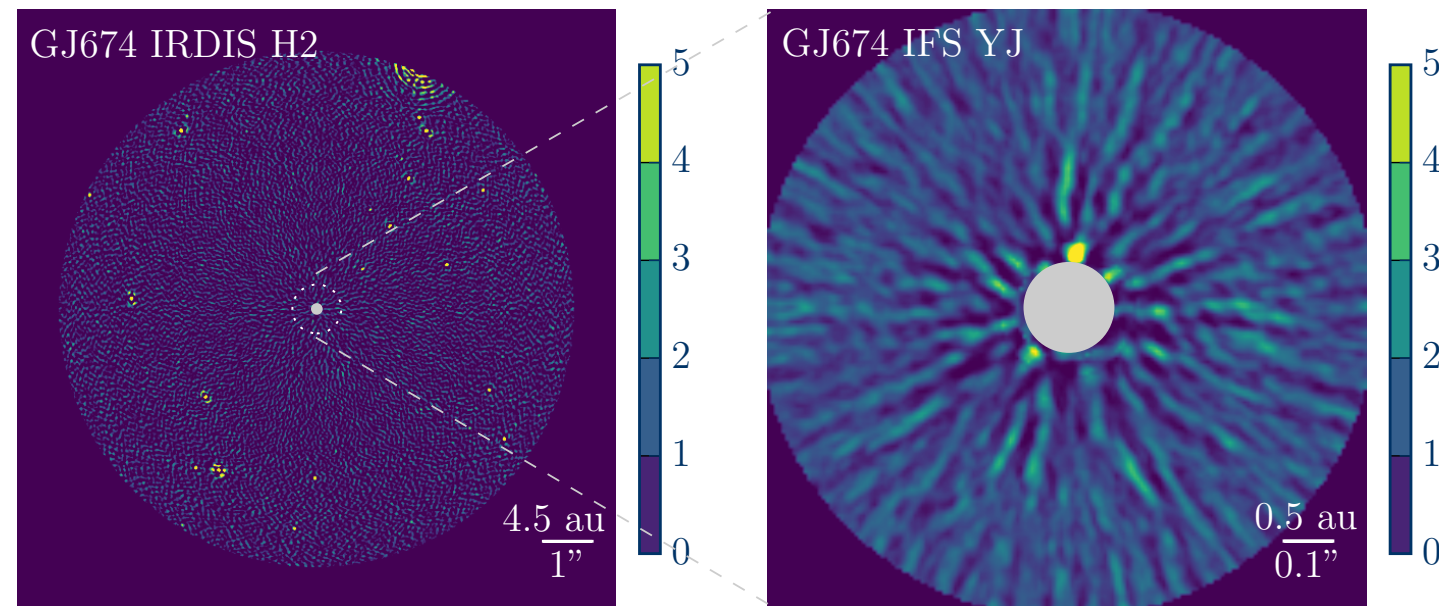
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Observations and point-source detections



47 SPHERE observations

Observations and point-source detections



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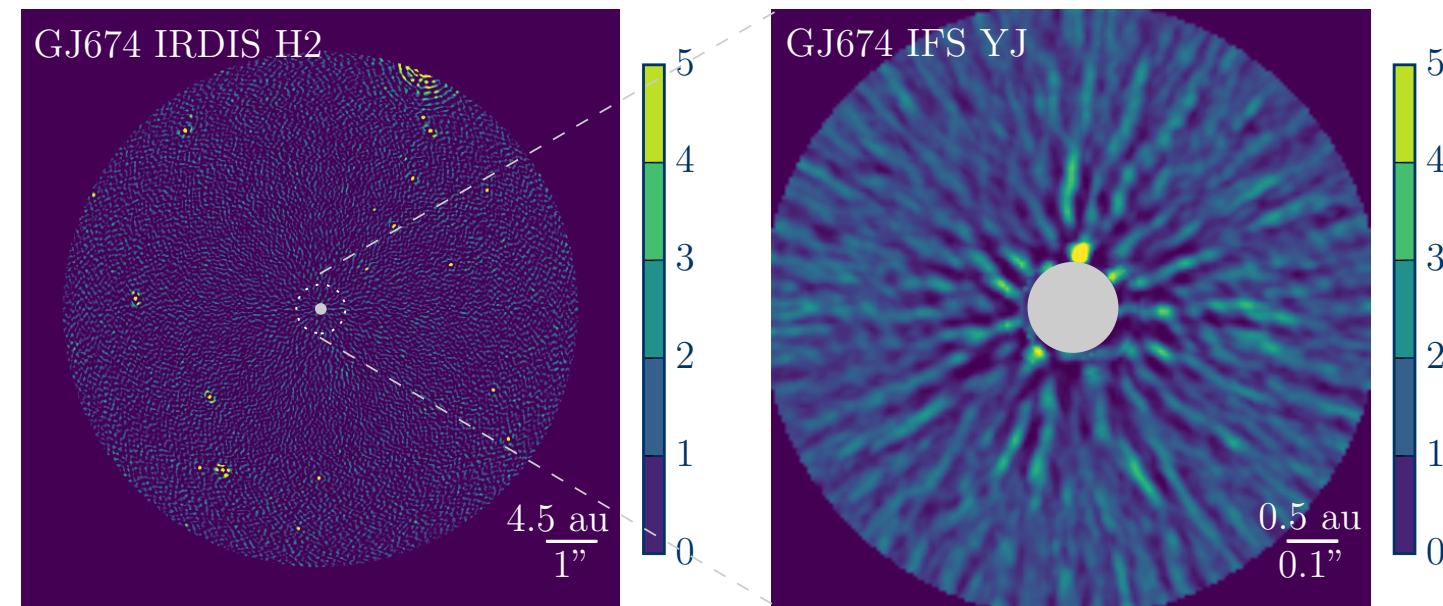


Status of the companion candidates:

Confirmed bound companions?

Or background stars, or instrumental artifacts?

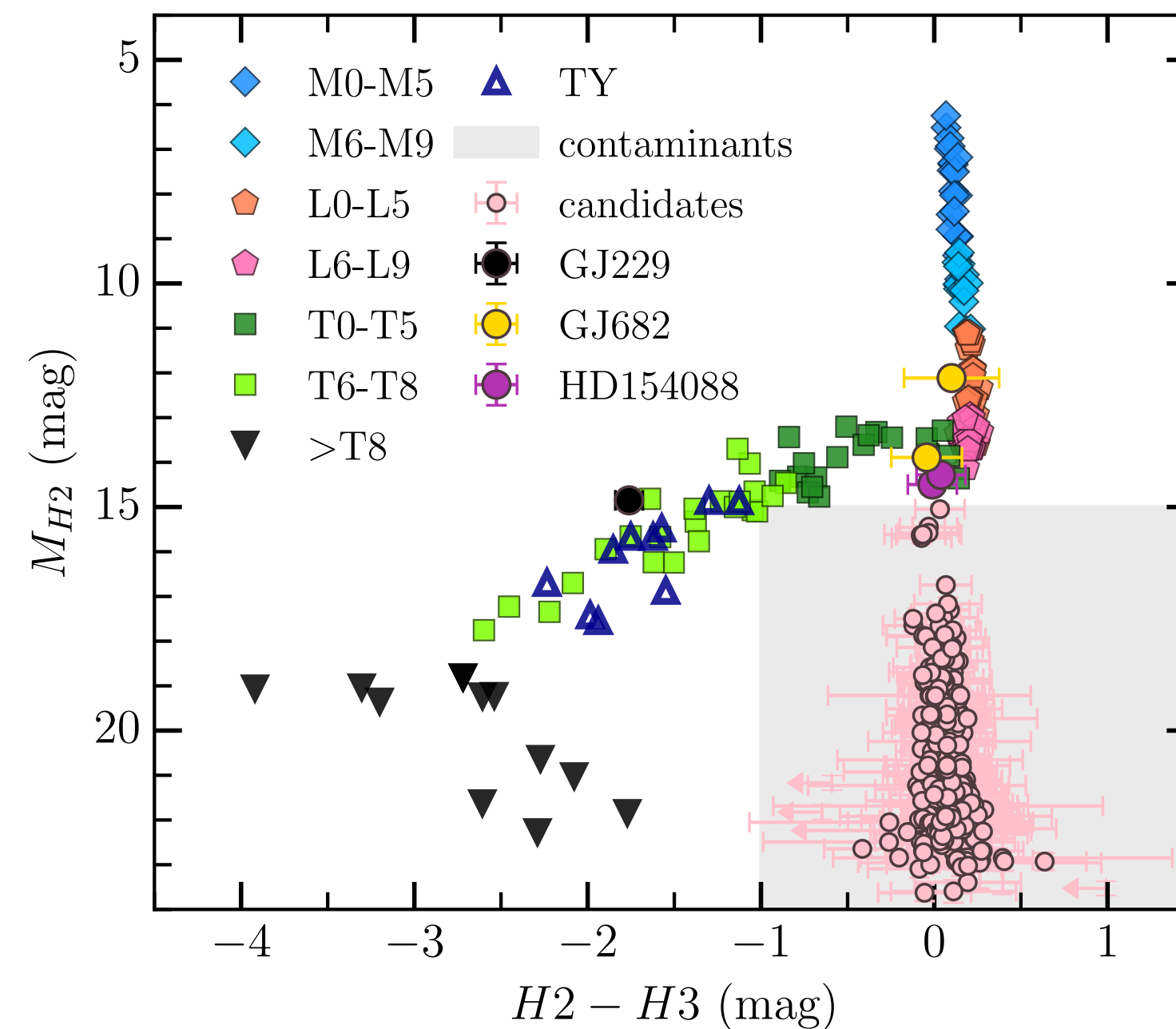
Observations and point-source detections



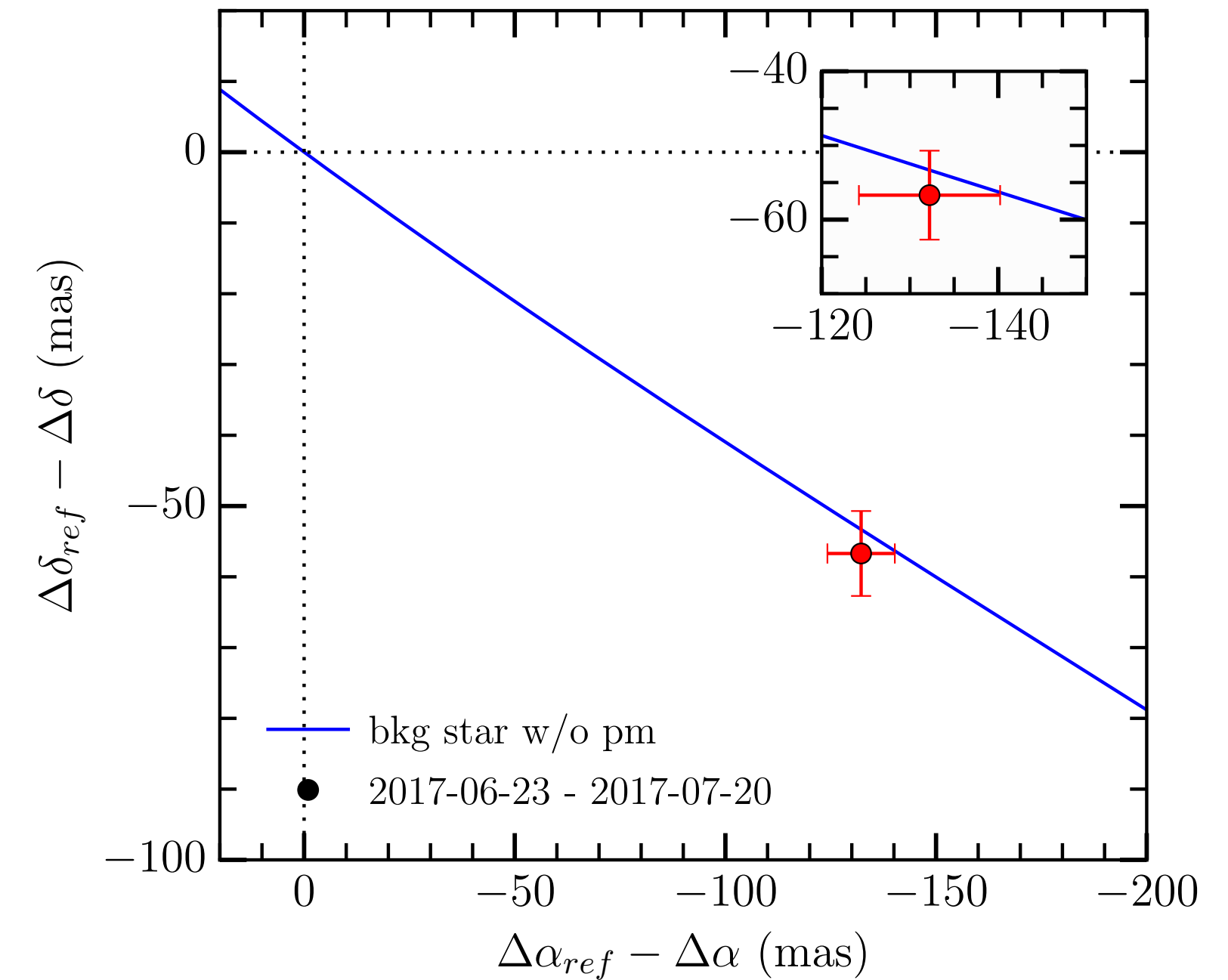
47 SPHERE observations

337 companion candidates

Color Magnitude Diagram



Common Proper Motion



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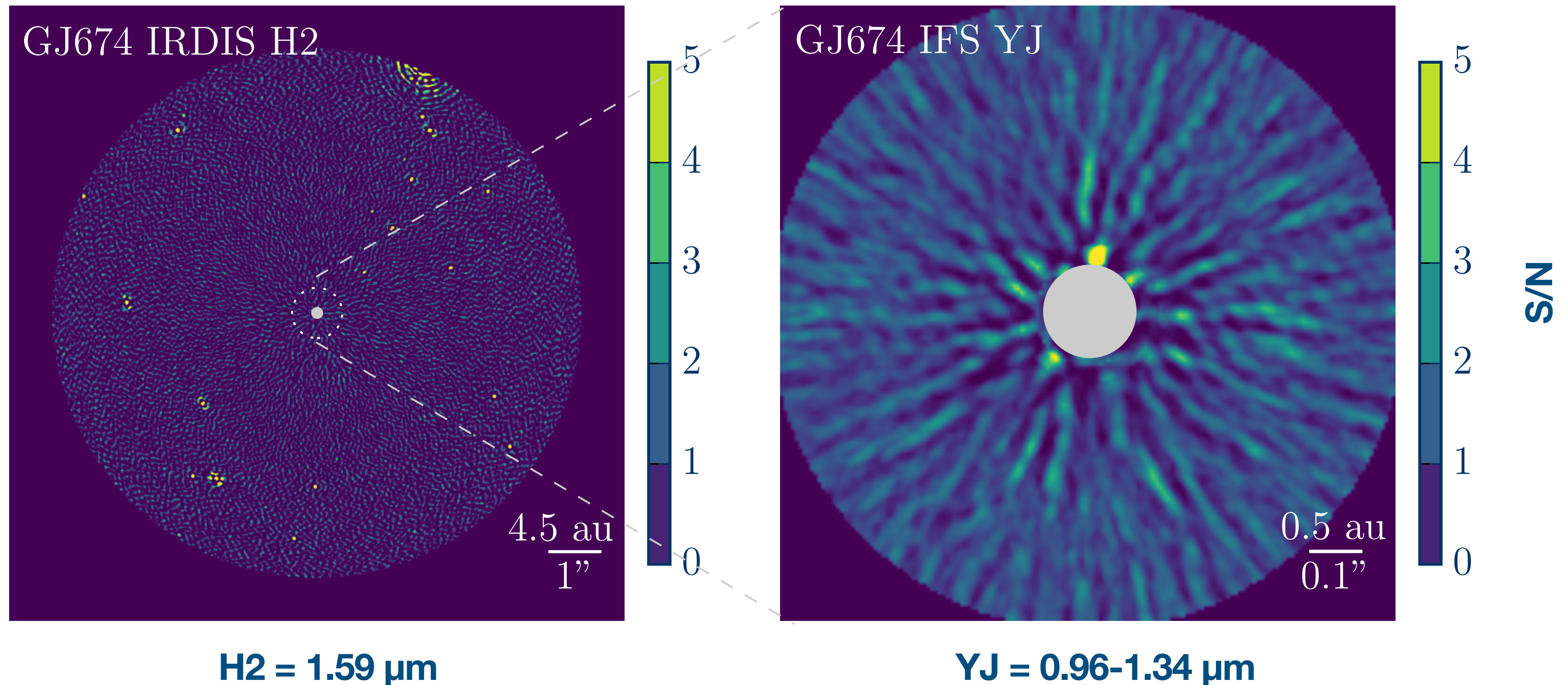
Or background stars, or instrumental artifacts?

two criteria

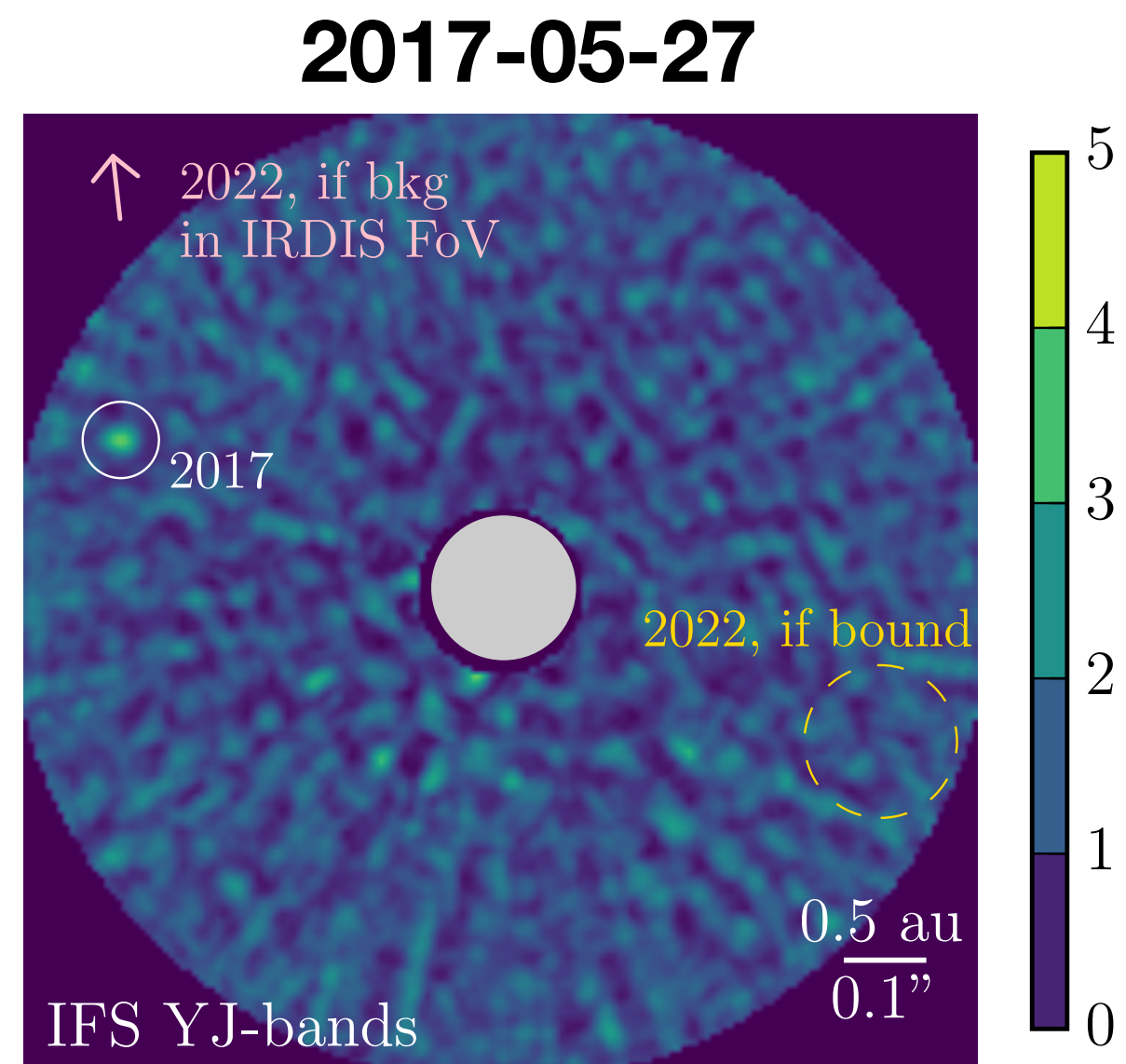
SPHERE-IRDIS and SPHERE-IFS observations

Example: 1 observation among 47 observations

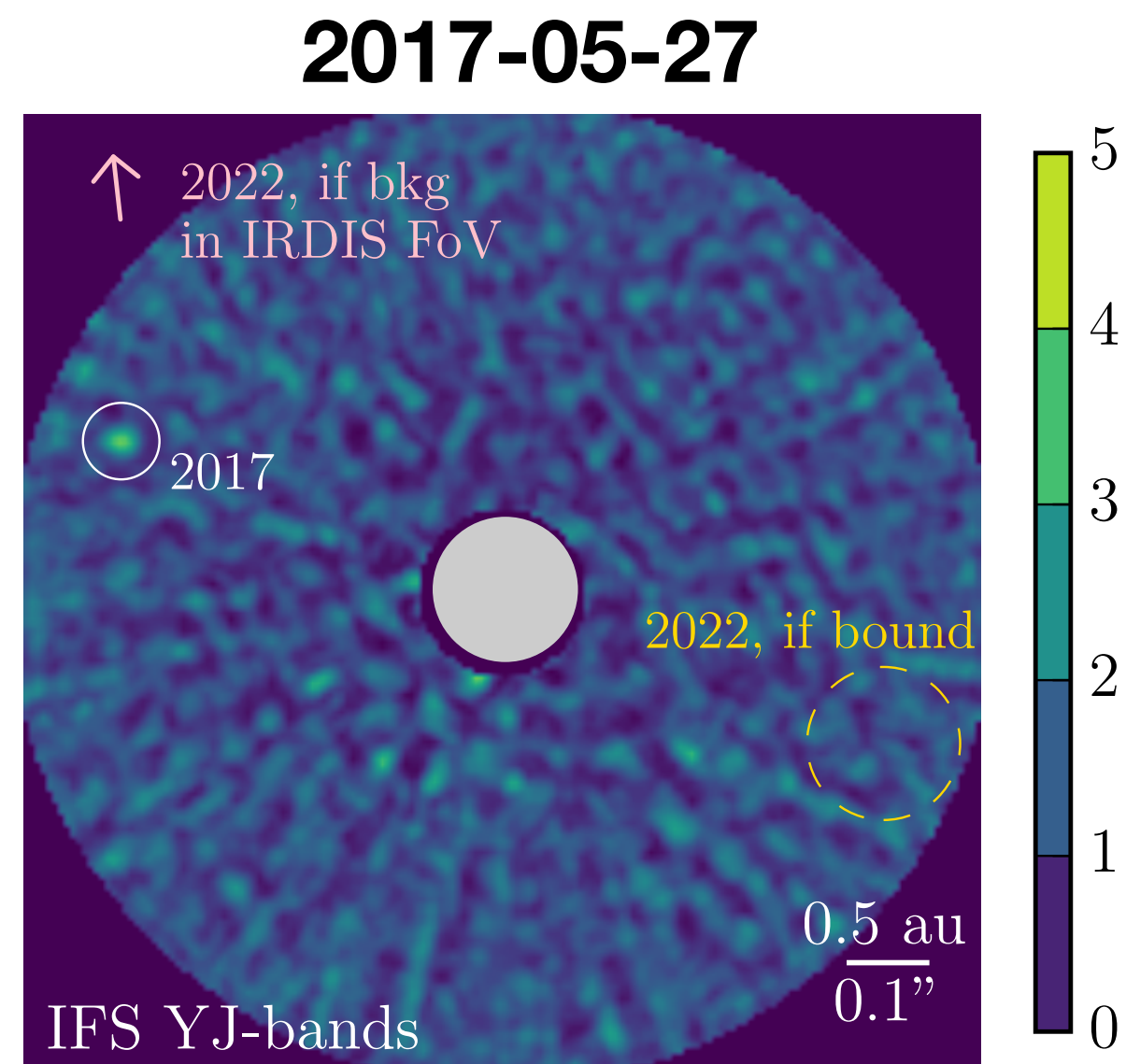
Pre-processing: High Contrast Data Center (Delorme+2017a); Post-processing: ANDROMEDA (Cantalloube+2015)



Interesting detection in GJ 832



Direct imaging of the exoplanet GJ 832 b?

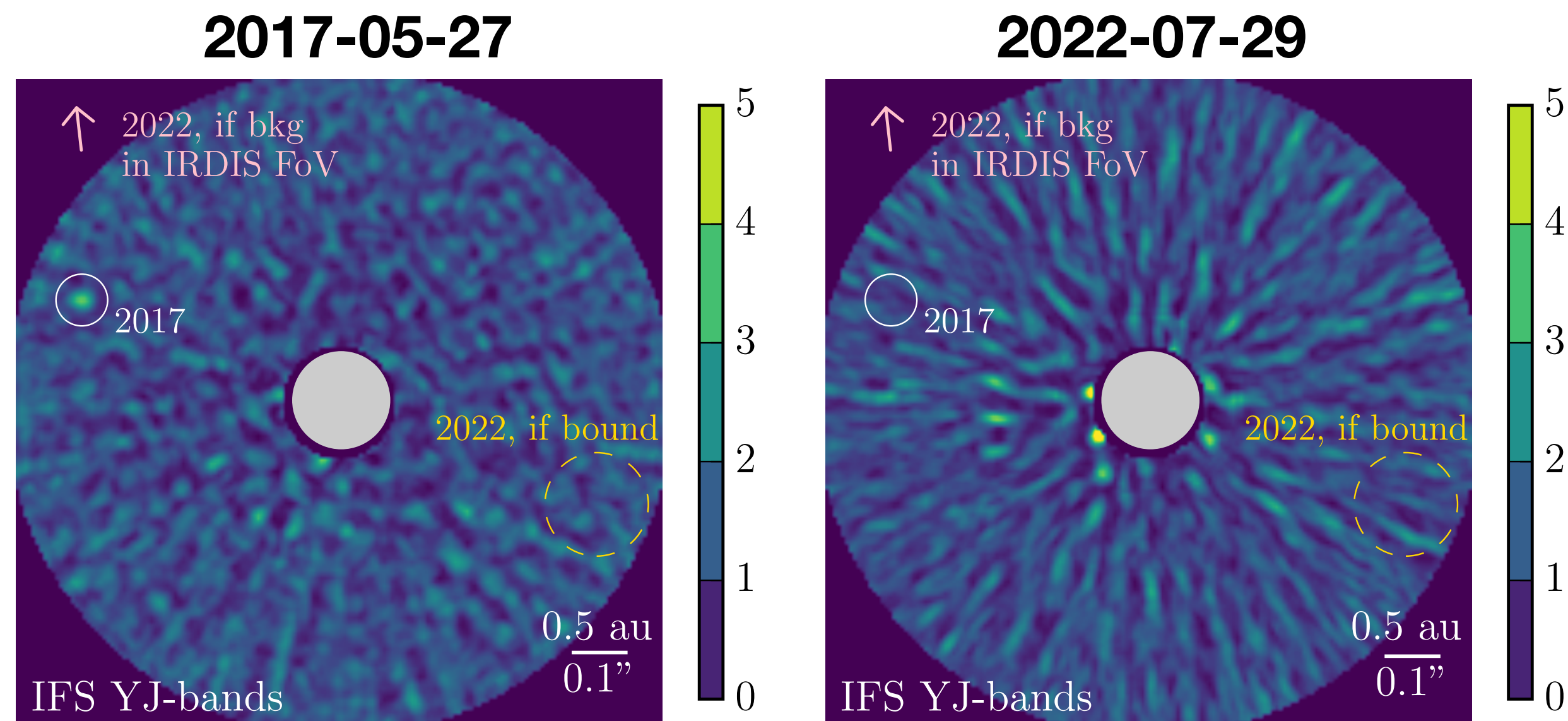


Planet GJ 832 b:

$a \sim 2.5$ au, $P \sim 10$ yr, $M \sin i = 0.74$ MJup
(Bailey et al. 2009, Gorrini et al. 2022)

The DI candidate might coincide with the RV GJ 832 b
(depending on its inclination and stellar age). Rare!

Direct imaging of the exoplanet GJ 832 b?

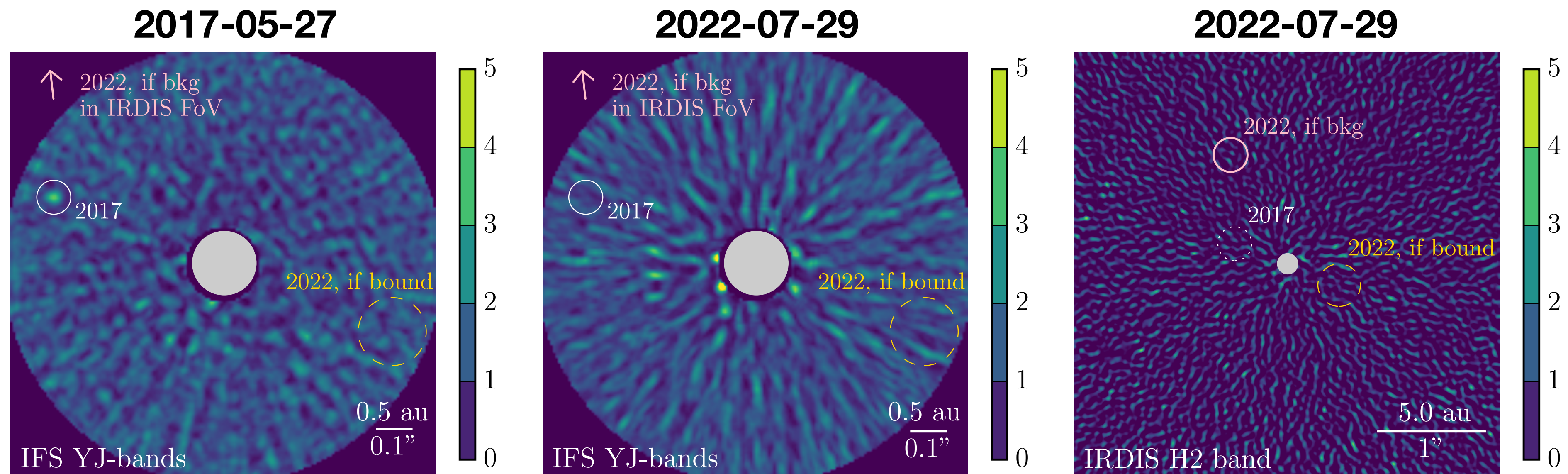


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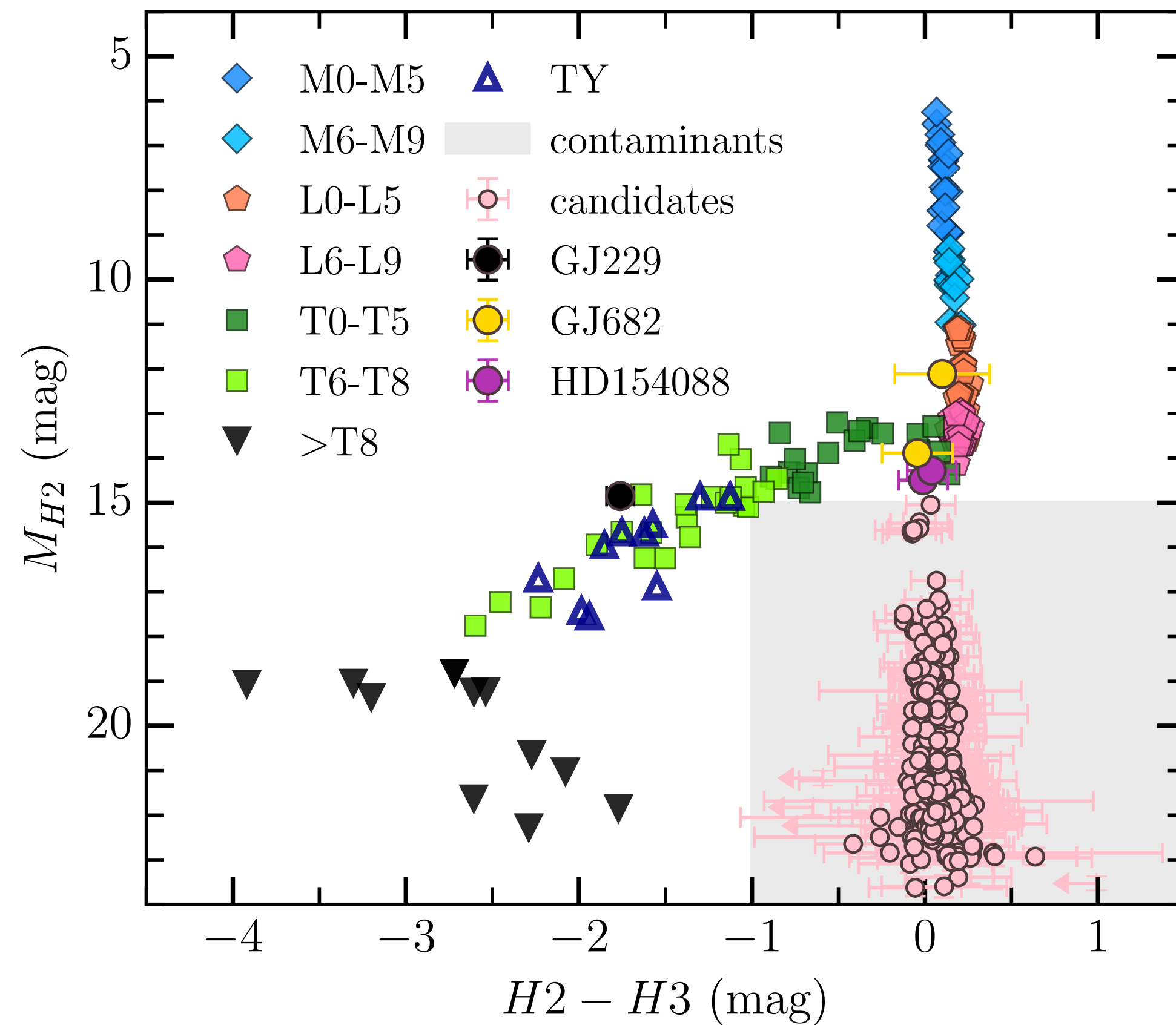
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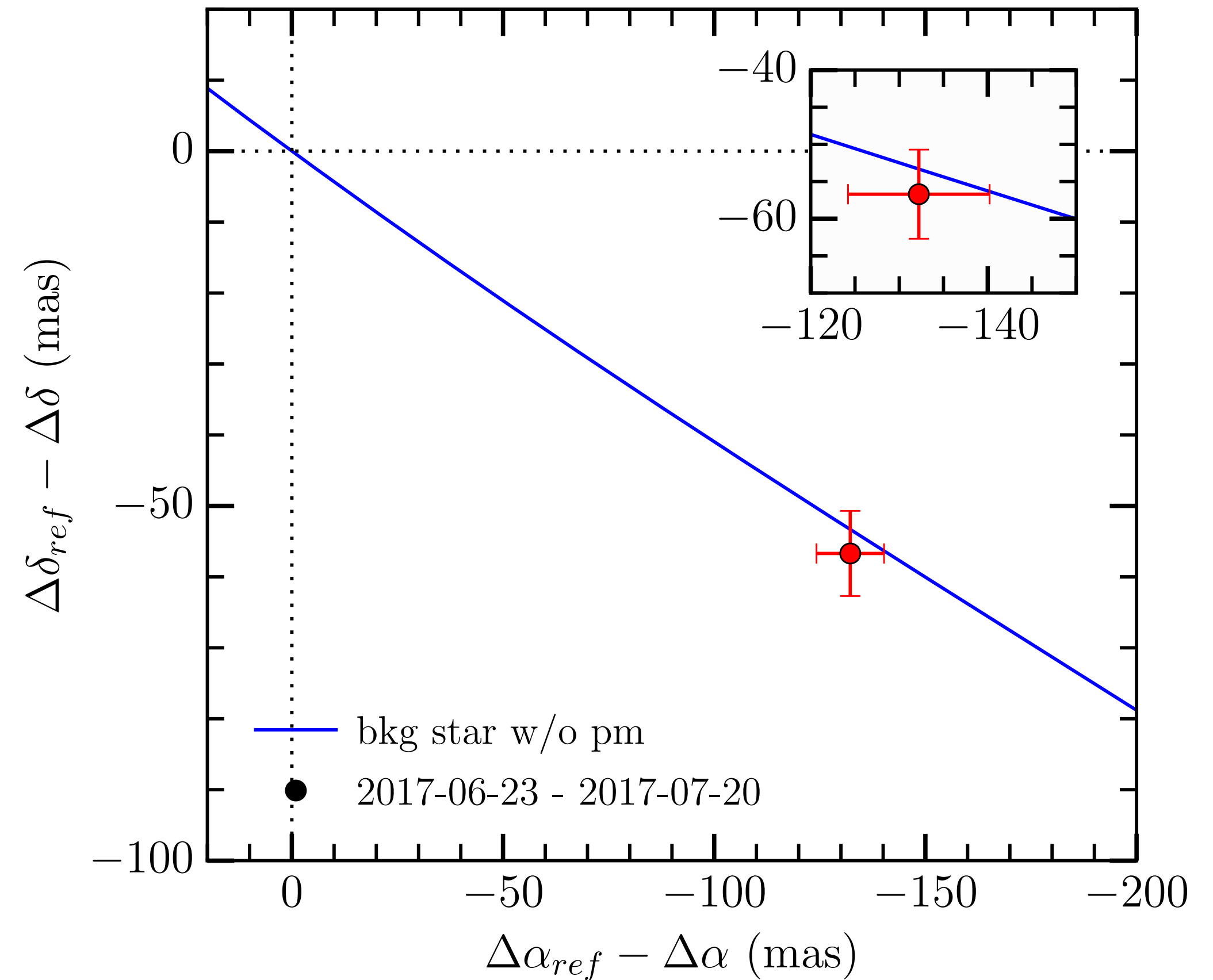
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Classification of the companion candidates

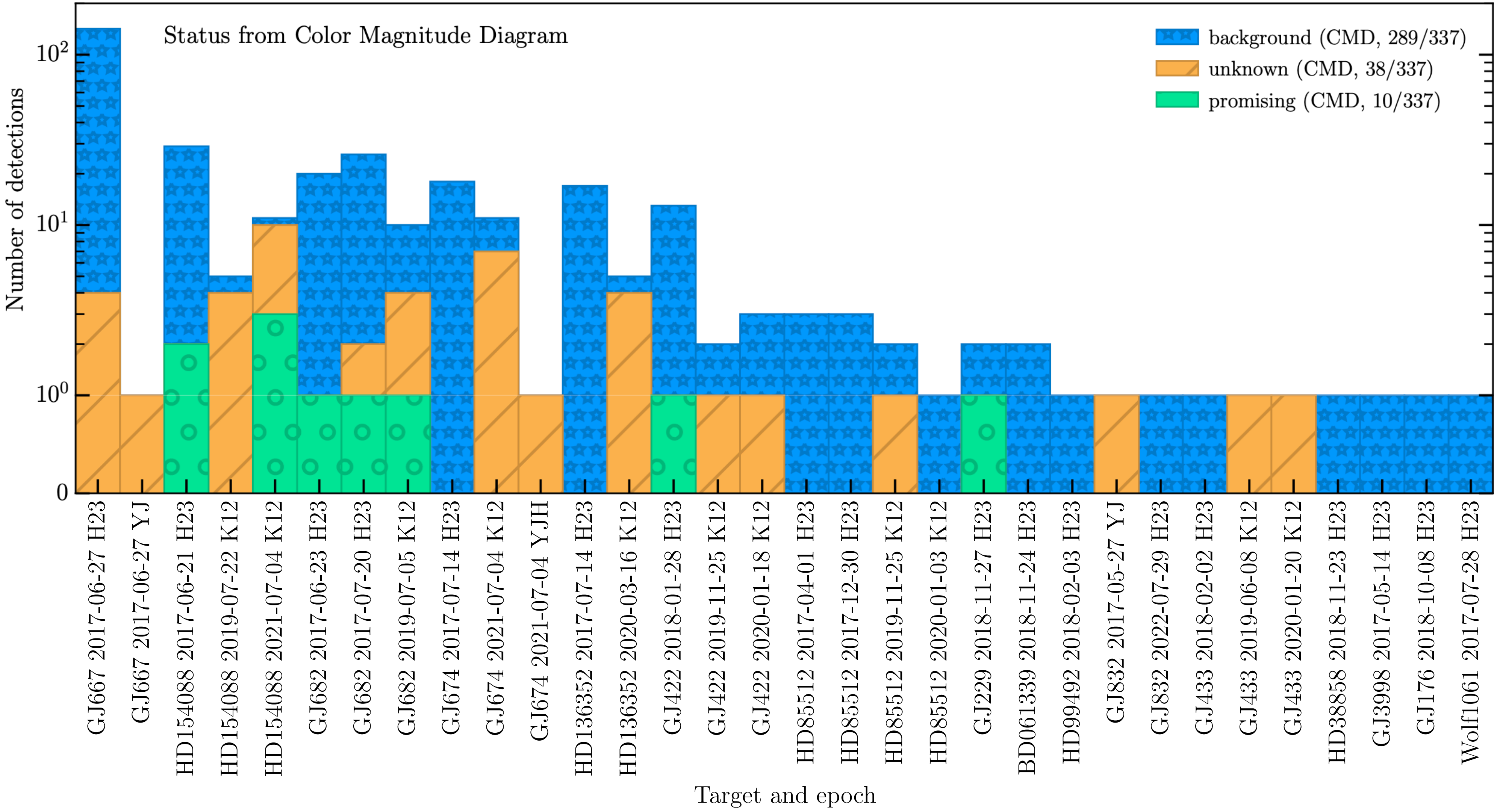
Color Magnitude Diagram



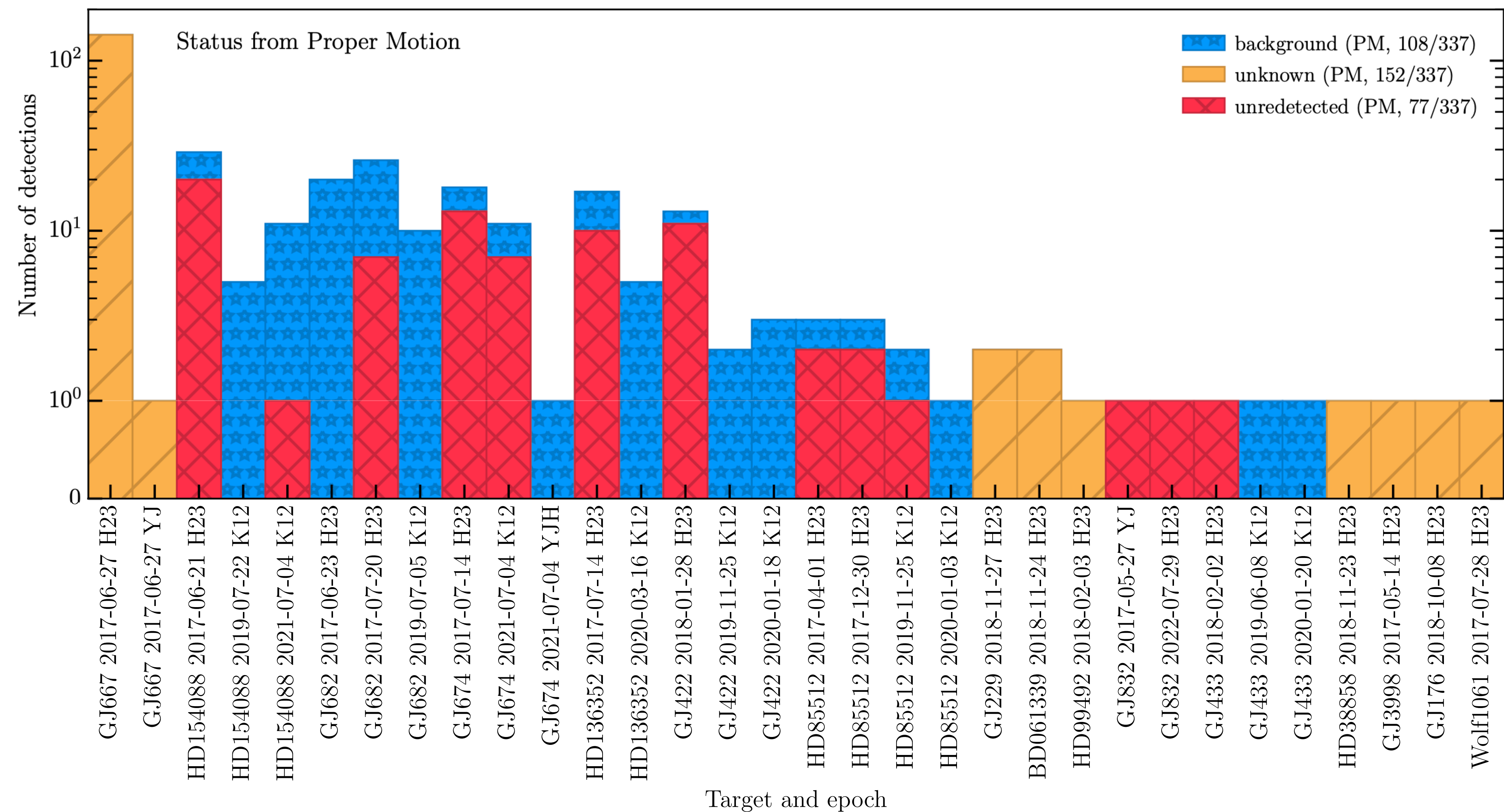
Common Proper Motion



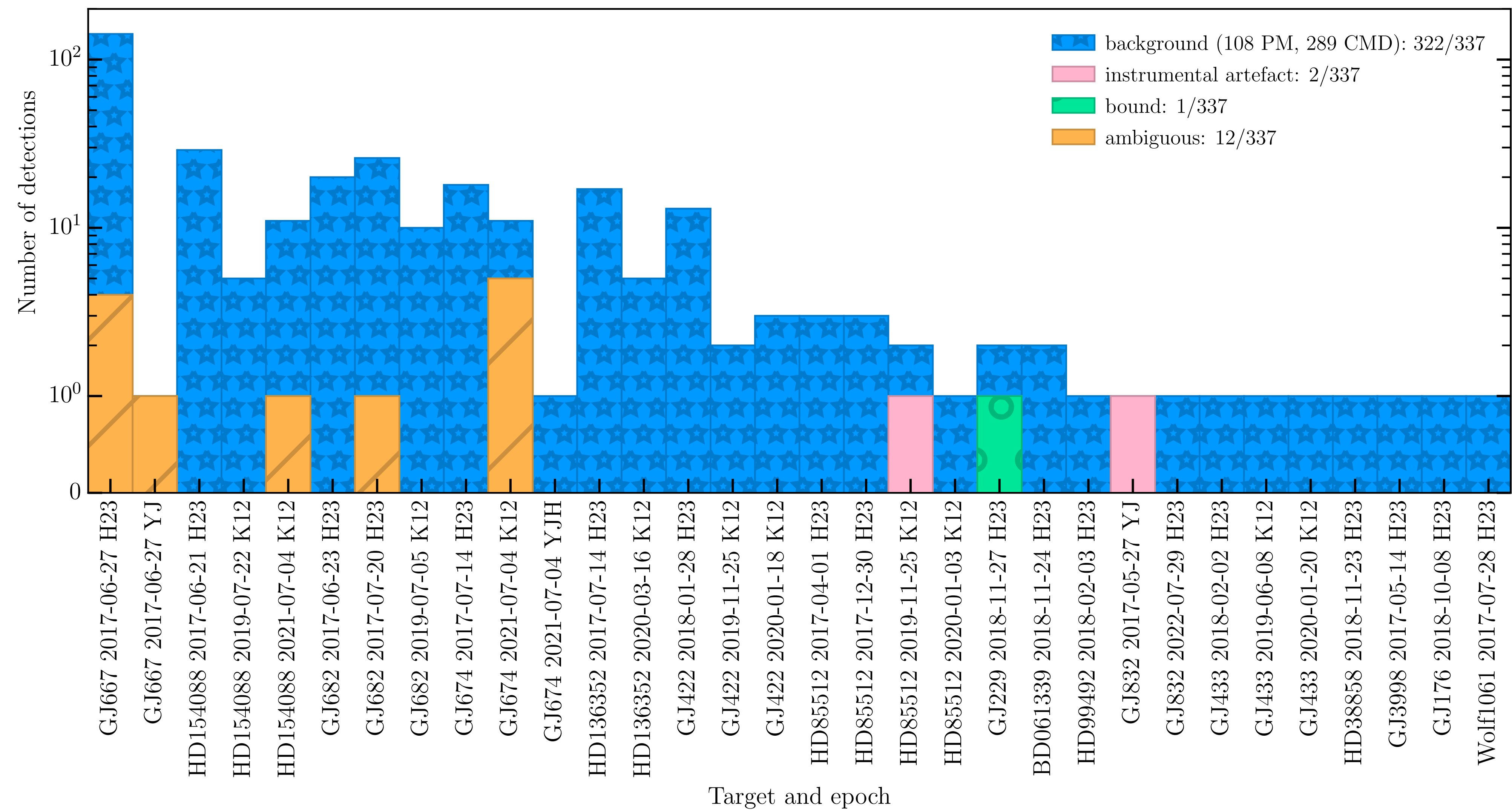
Classification of the companion candidates



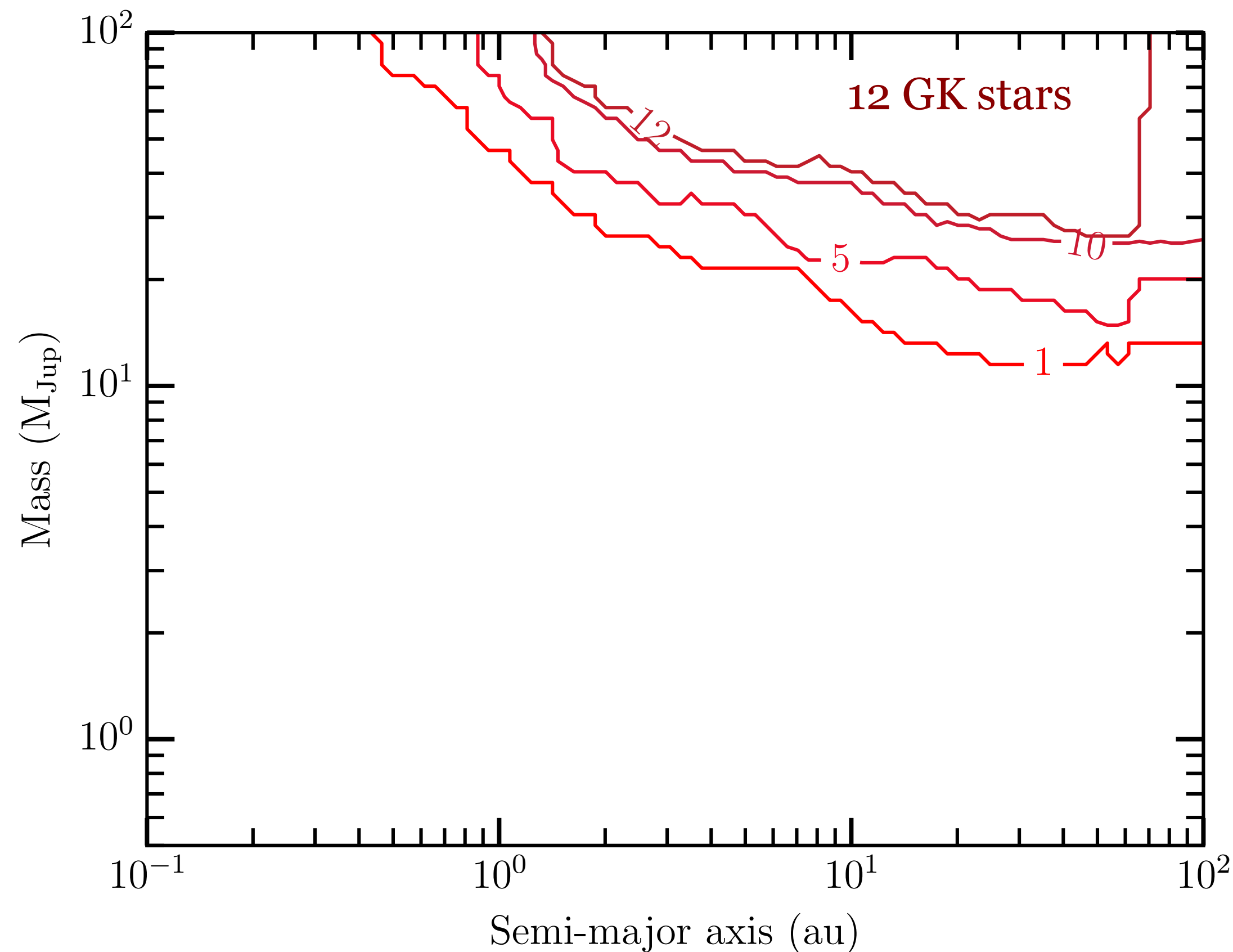
Classification of the companion candidates



Classification of the companion candidates



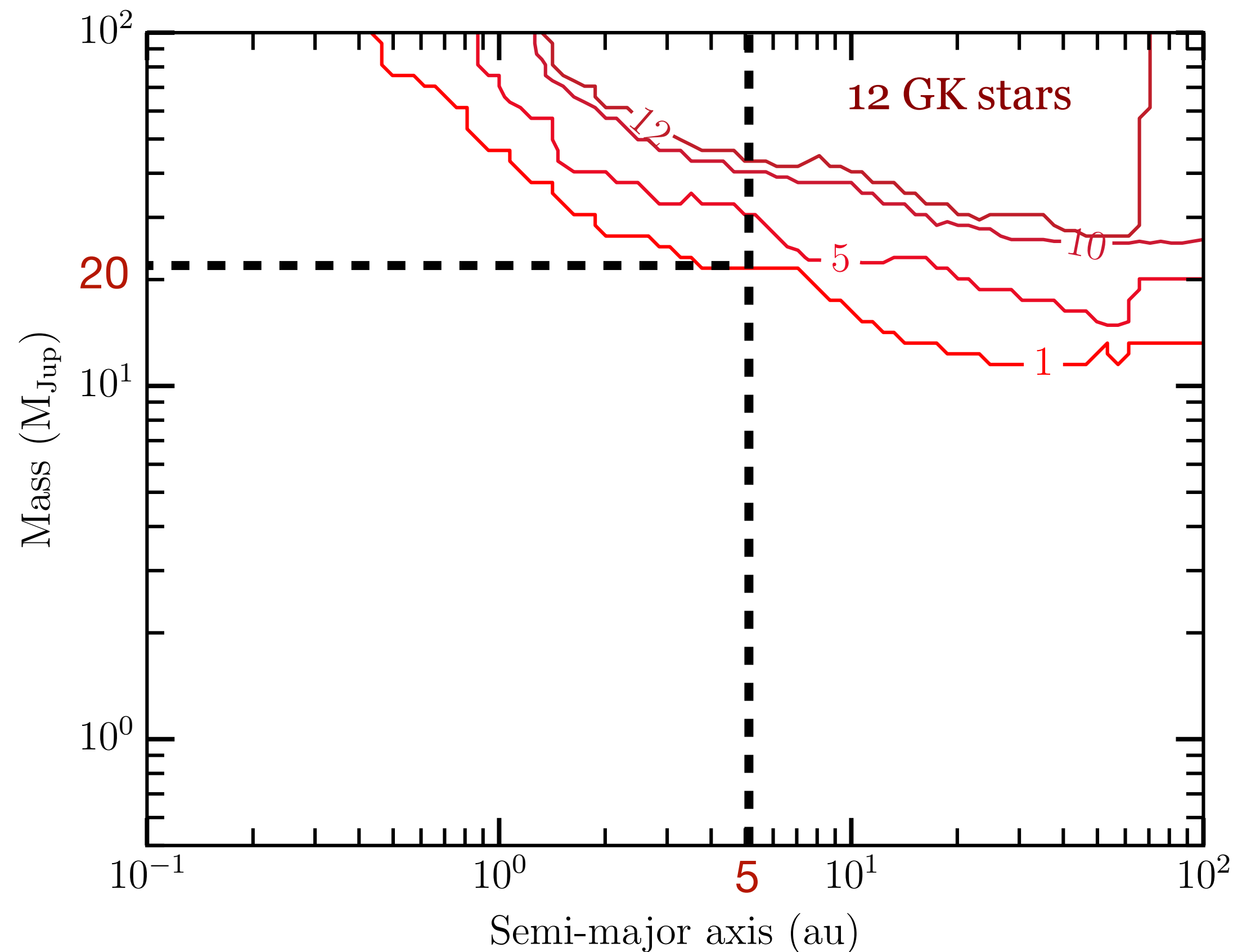
Survey sensitivity vs theoretical predictions



Detection limits: contrast $\rightarrow$ mass, using evolutionary models COND (*Baraffe et al. 2003*)

- Very nearby systems (< 20 pc): **sensitive from ~ 1 au.**
- But for old stars (1 Gyr – 10 Gyr): **sensitive mainly to brown dwarfs $\gtrsim 30 M_{\text{Jup}}$.**

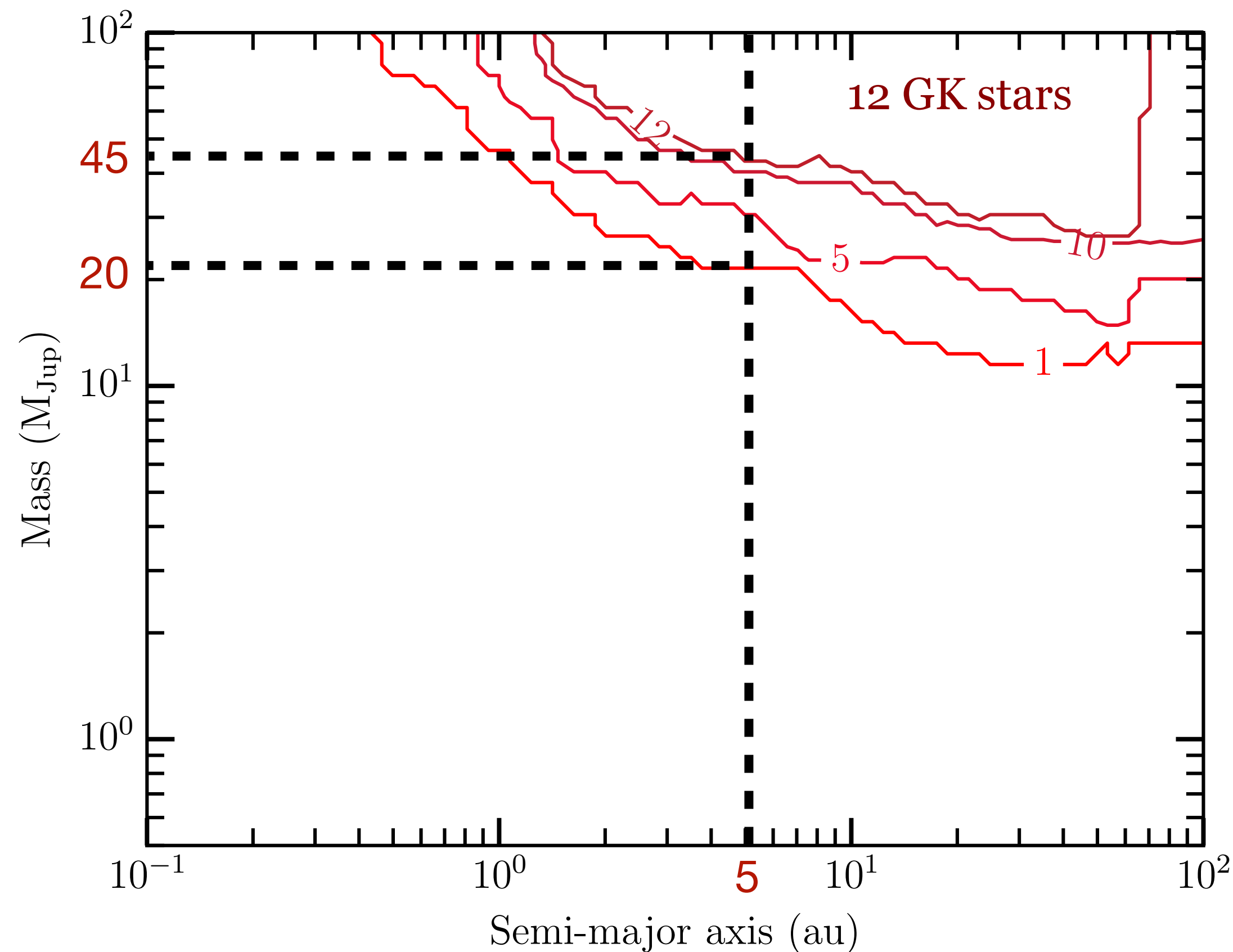
Survey sensitivity vs theoretical predictions



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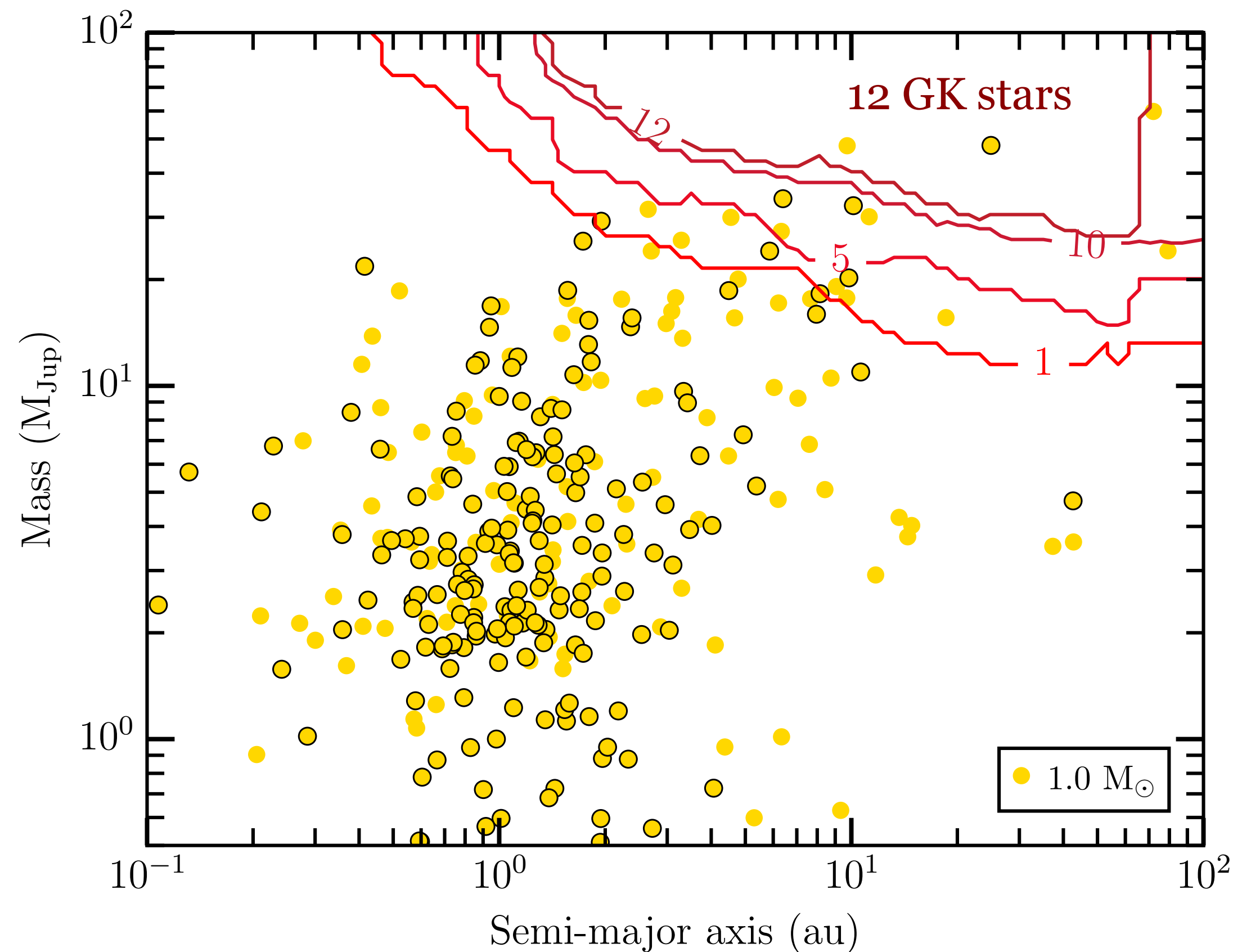
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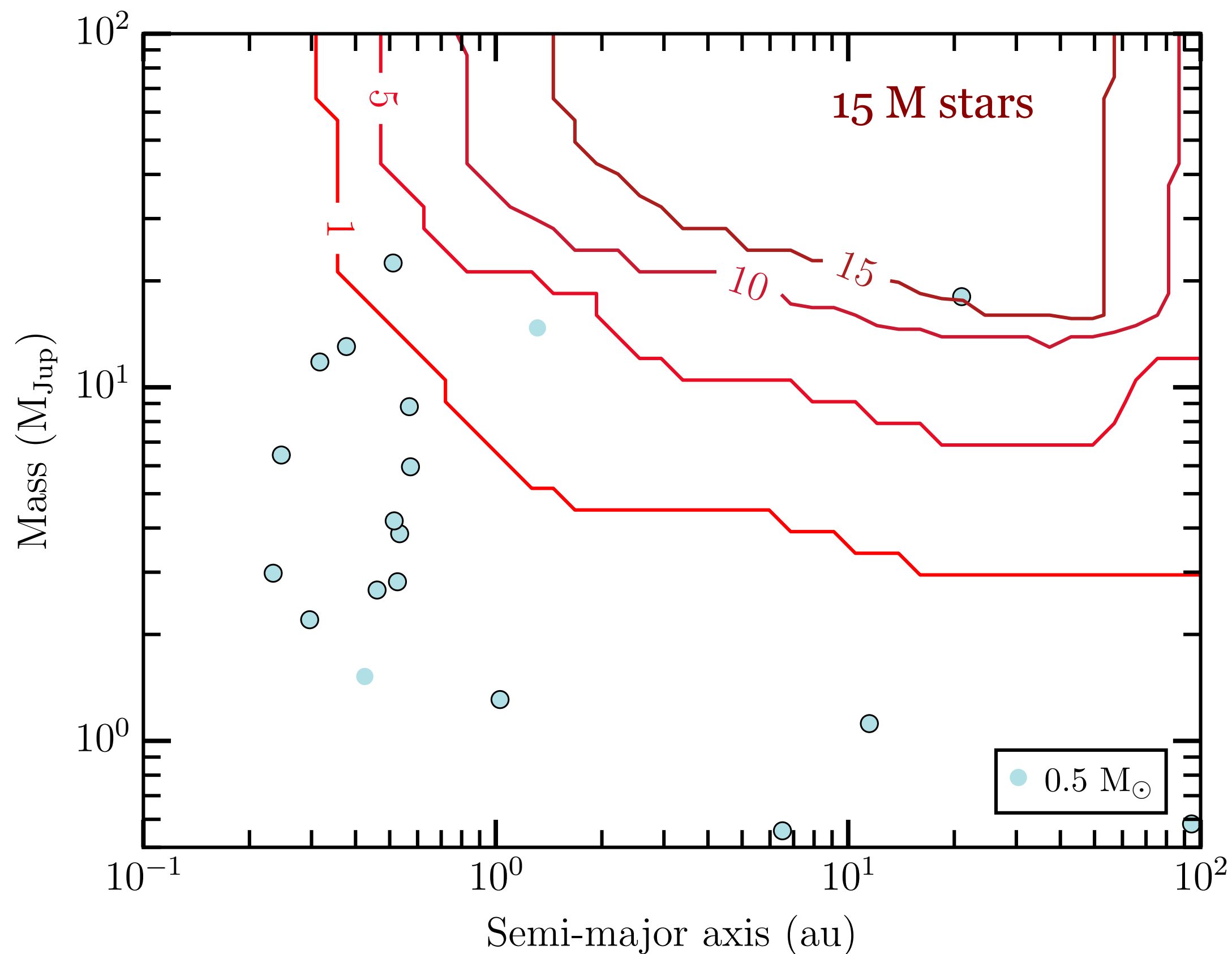
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Population models:

Predicted planets for **1000 simulated systems** at 5 Gyr, for the core-accretion Bern planetesimal models (*Emsenhuber et al. 2021a, Burn et al. 2021*).

Survey sensitivity vs theoretical predictions



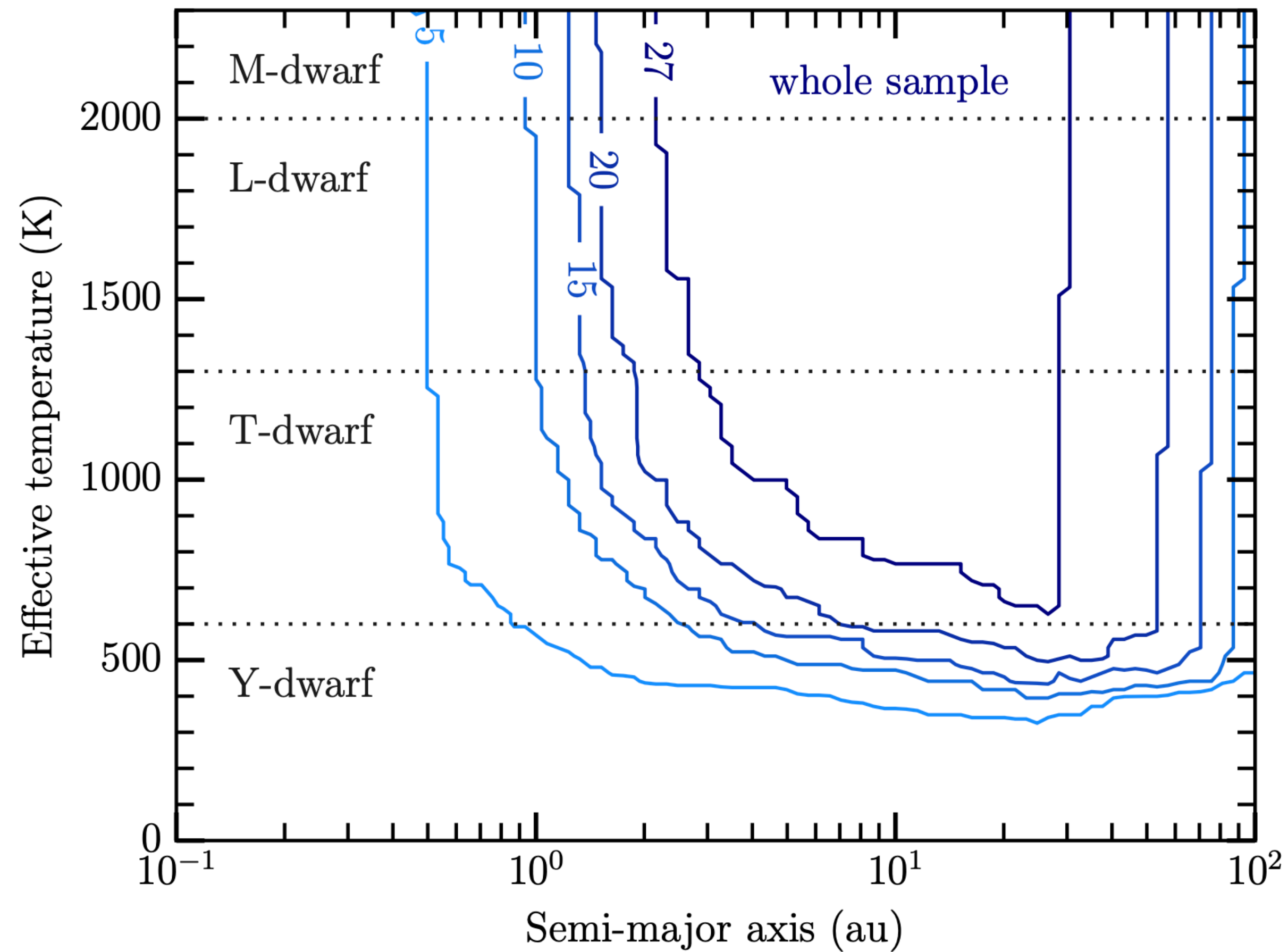
Detection limits: contrast $\rightarrow$ mass, using evolutionary models COND (*Baraffe et al. 2003*)

- Very nearby systems (< 20 pc): **sensitive from ~ 0.4 au.**
- But for old stars (500 Myr – 10 Gyr): **sensitive mainly to companions $\gtrsim 8 M_{\text{Jup}}$.**

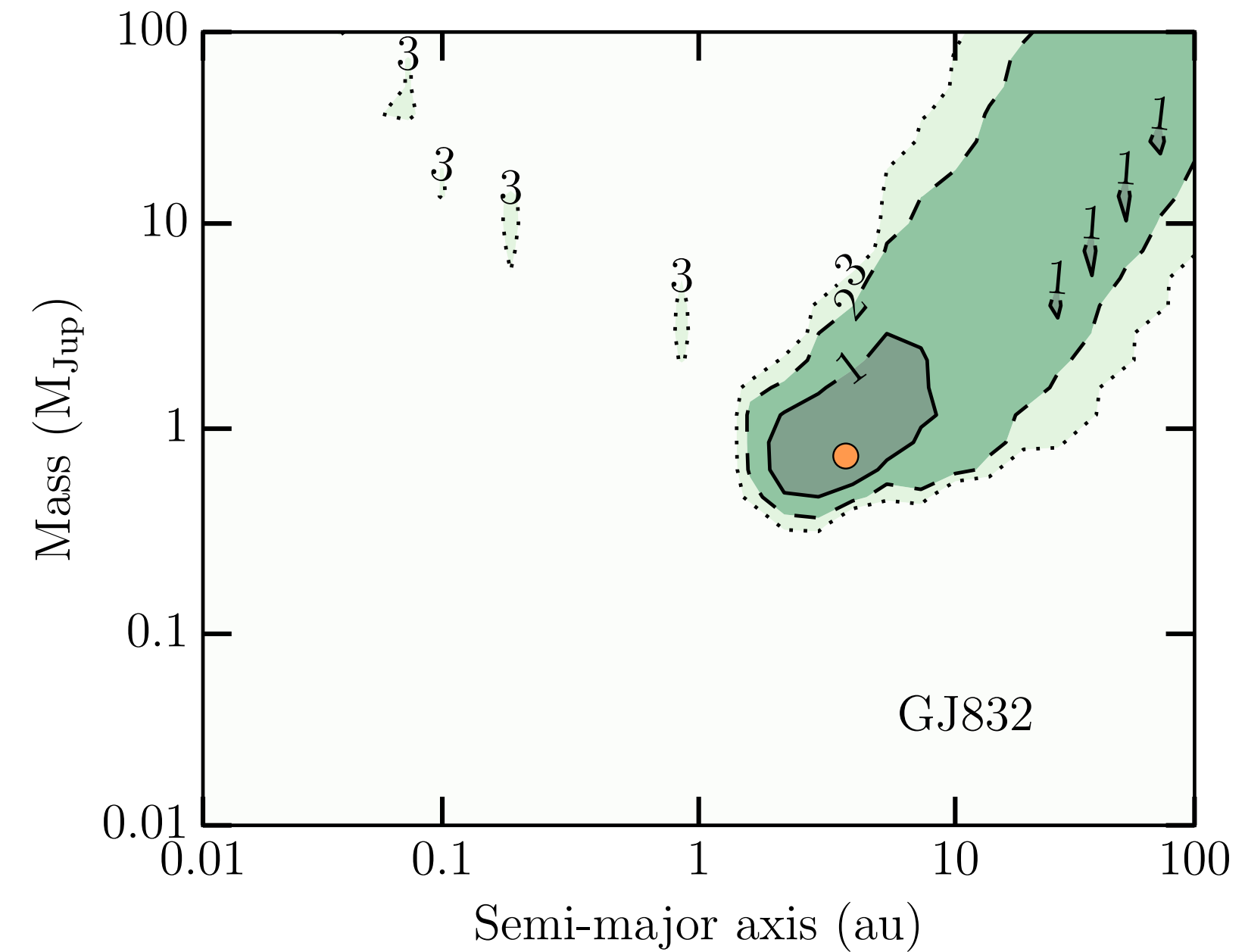
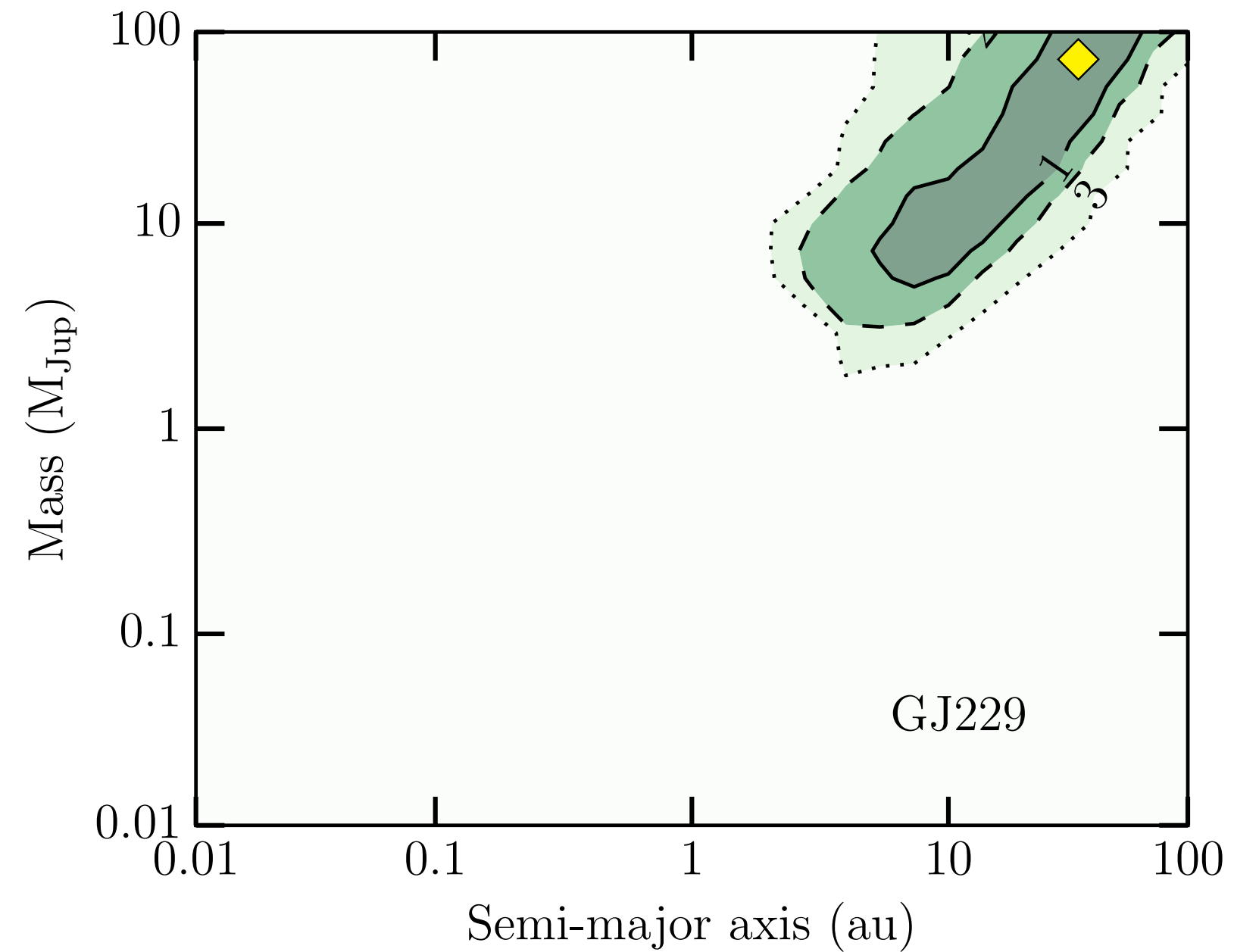
Population models:

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Survey sensitivity in terms of effective temperature



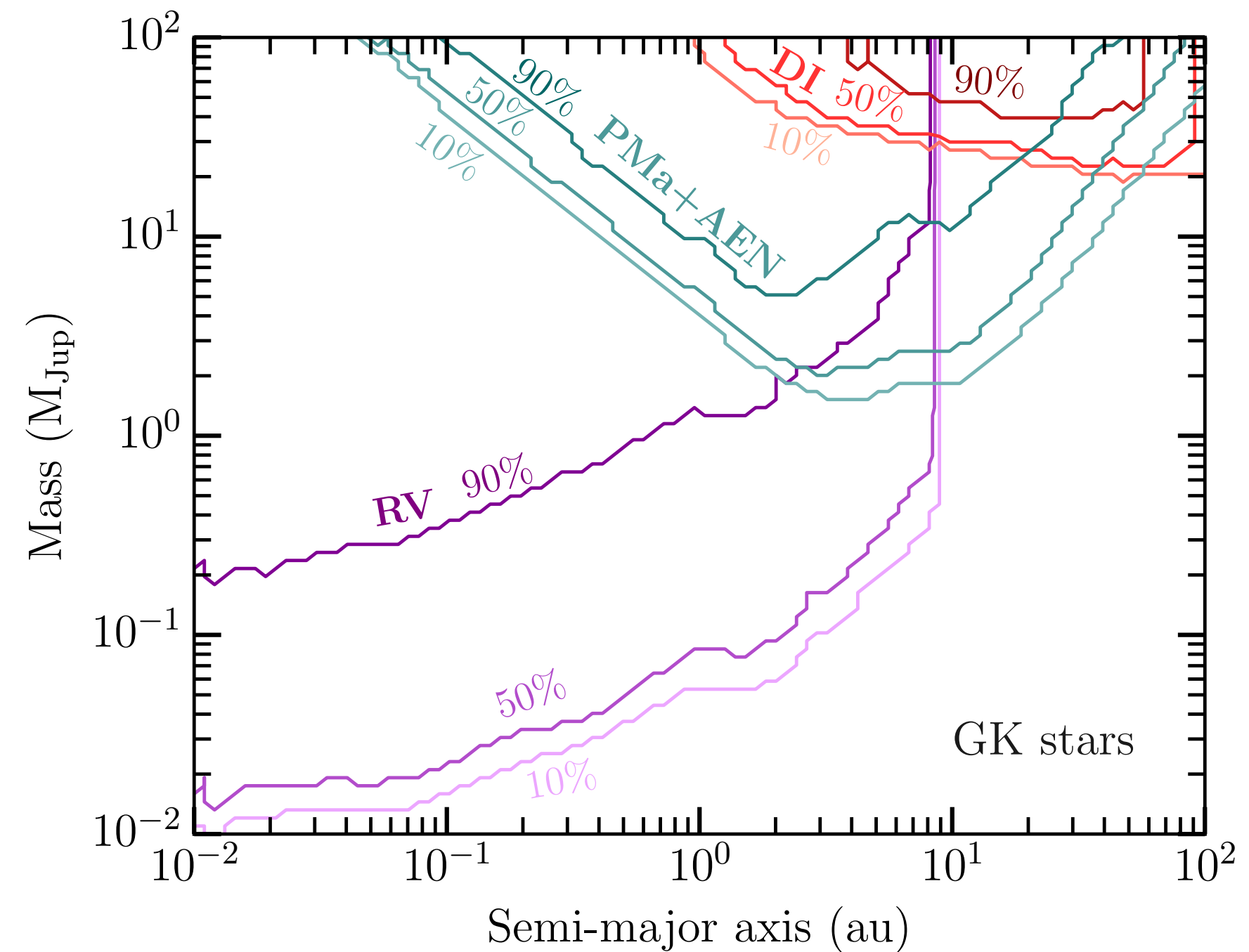
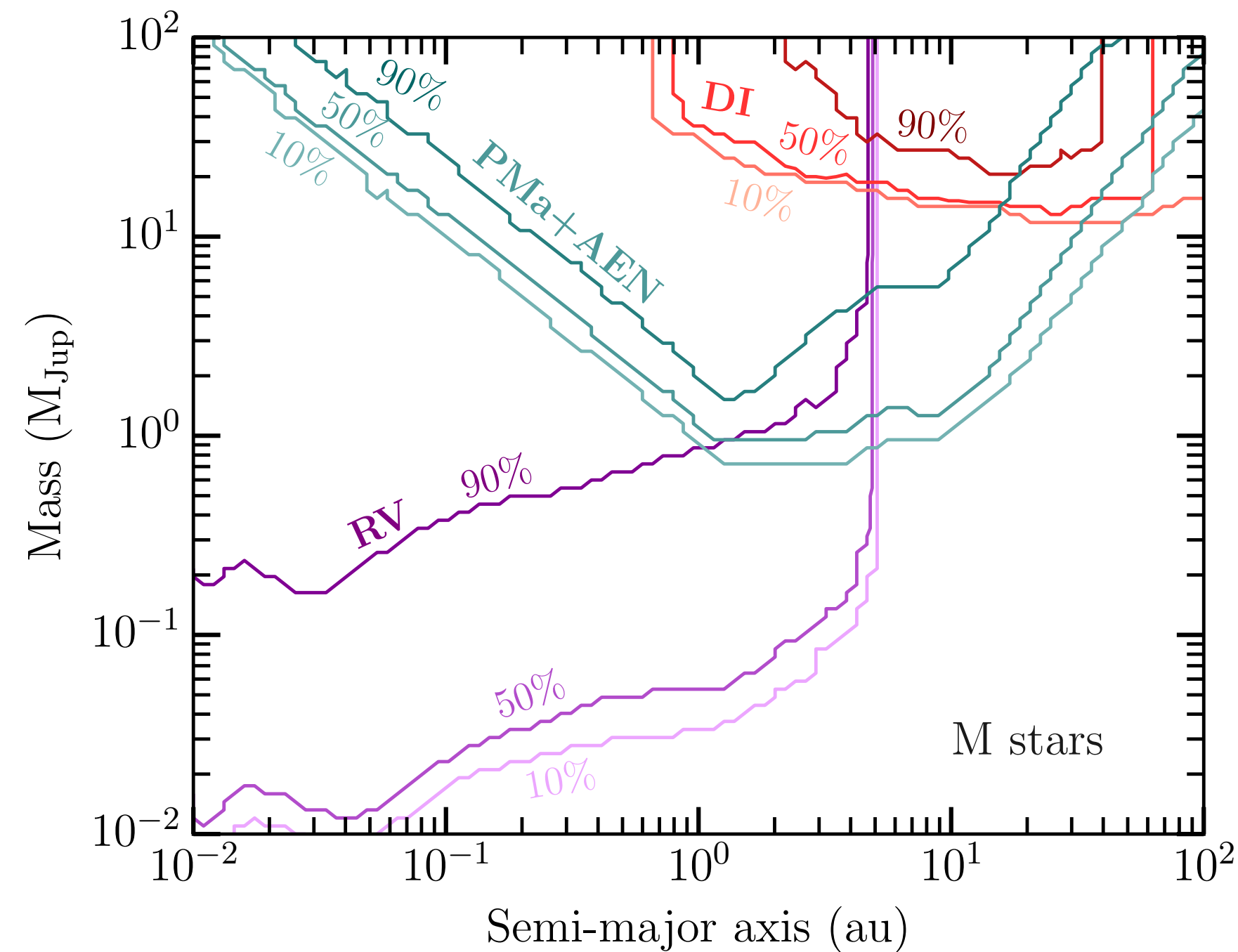
Using Gaia+Hipparcos information



Based on Proper Motion anomaly and *Gaia* excess noise

Tool: GaiaPMEX (Kiefer et al. 2025)

Survey sensitivity with respect to the detection method



Detection limits:

contrast -> mass evolutionary models COND (Baraffe et al. 2003)

detection probability derived with MESS3 (Lannier et al. 2017, Kiefer et al. 2025)

Summary and perspectives

Our pilot DI SPHERE survey demonstrates synergies with RV+Gaia/Hipparcos to offer a global view of planetary systems.

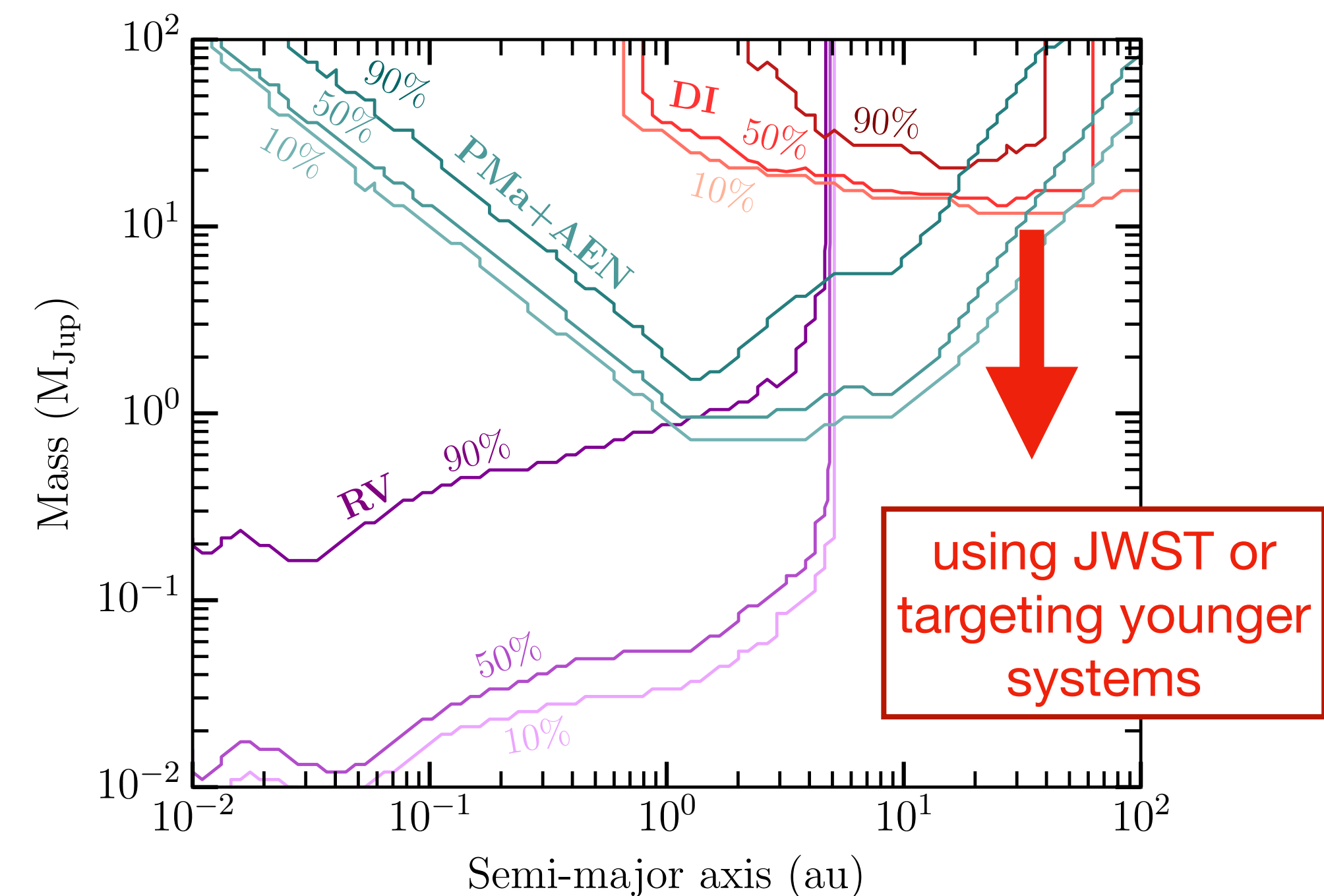
Results:

- ☾ Sensitive to 3-30 MJup companions beyond $\gtrsim 0.4$ au (even Y-spectral type!)
- ☾ 337 candidates identified, mostly background. Not surprising concerning theoretical predictions from planetesimal models.
- ☾ Survey completeness derived.

Limitations:

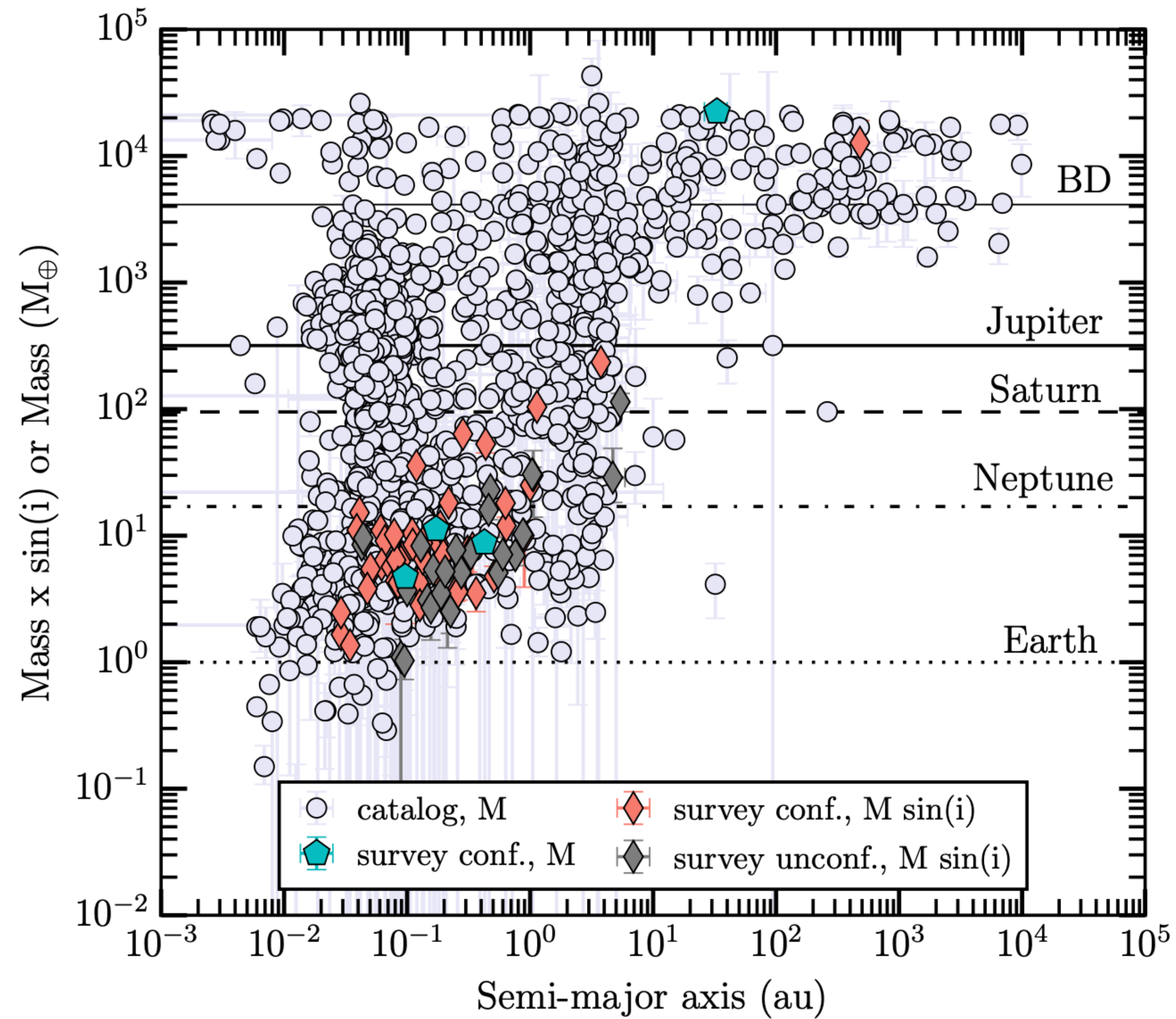
- ☾ Age of the systems (old = 500 Myr — 10 Gyr)
- ☾ Sample size and bias

What's next?

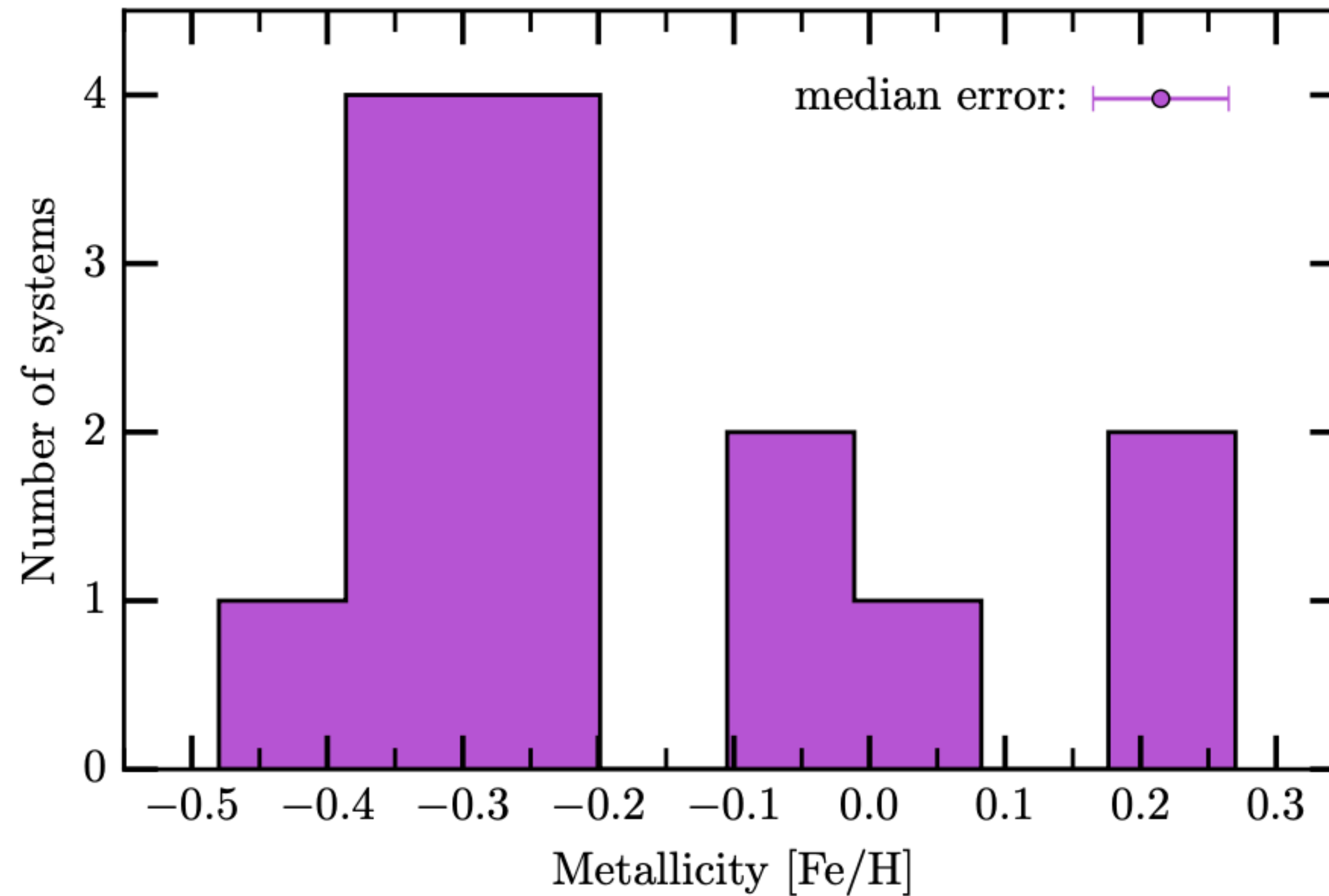


Backup slides

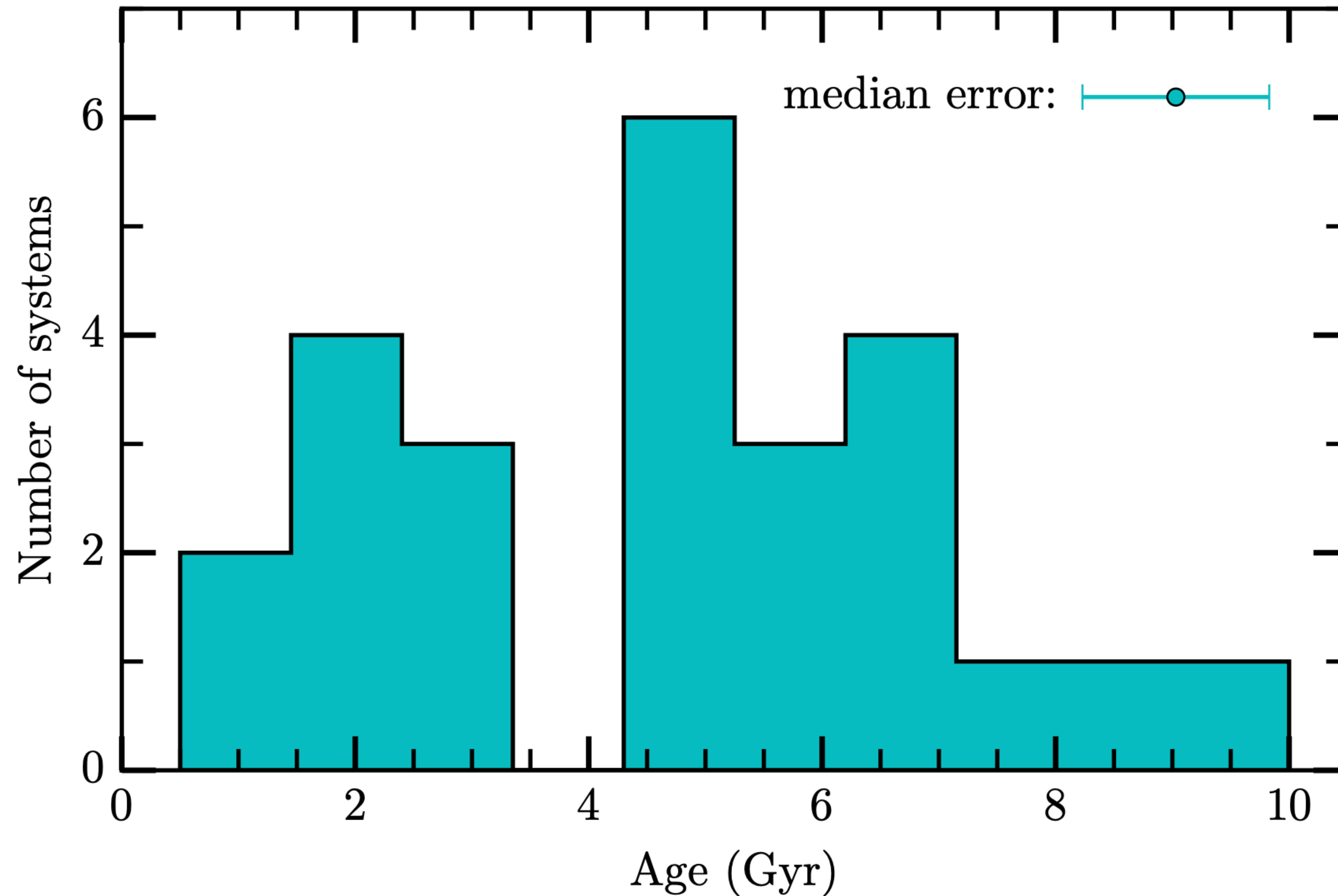
Close-in, low-mass planets already known



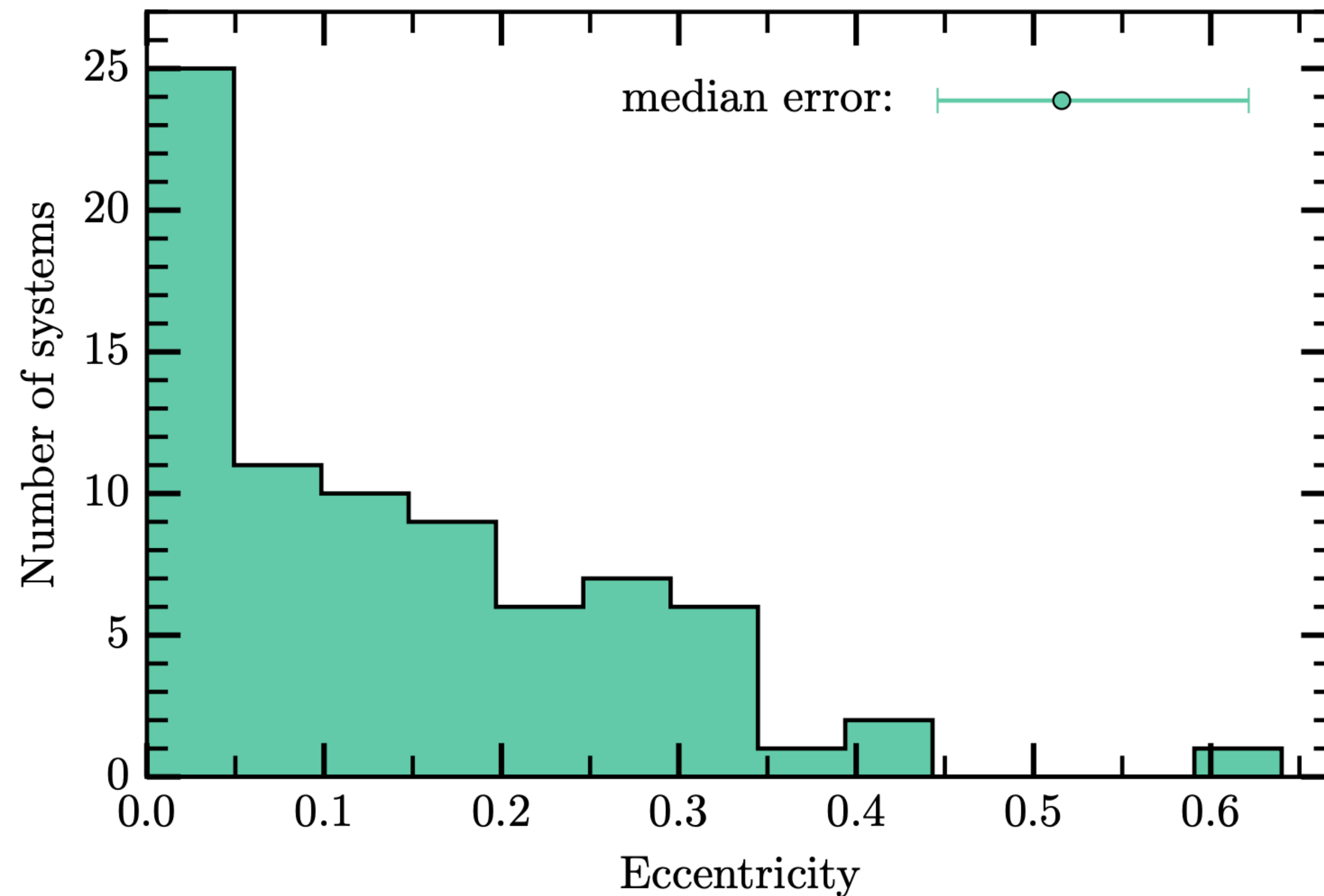
Distribution of the stellar metallicity for our sample



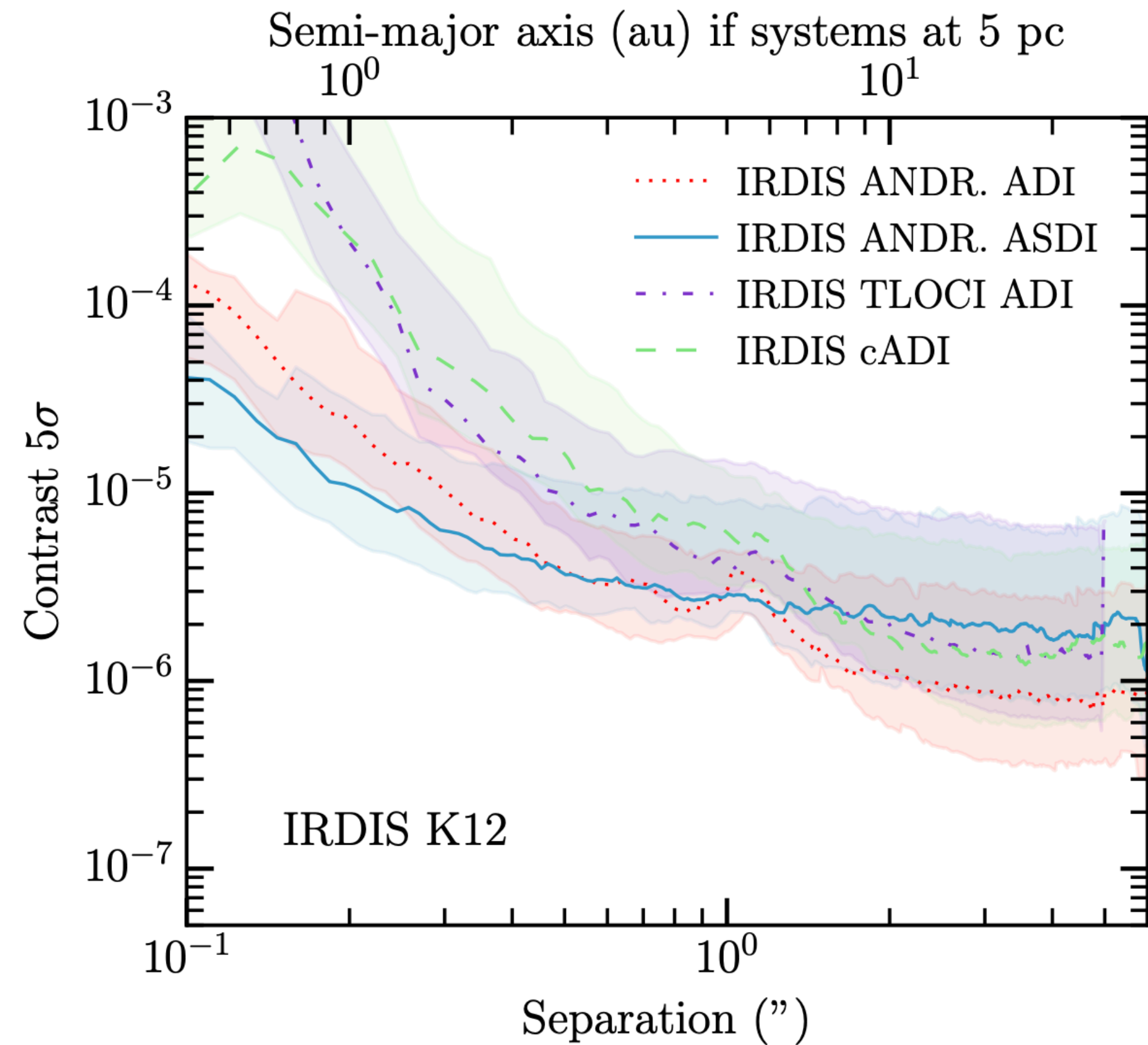
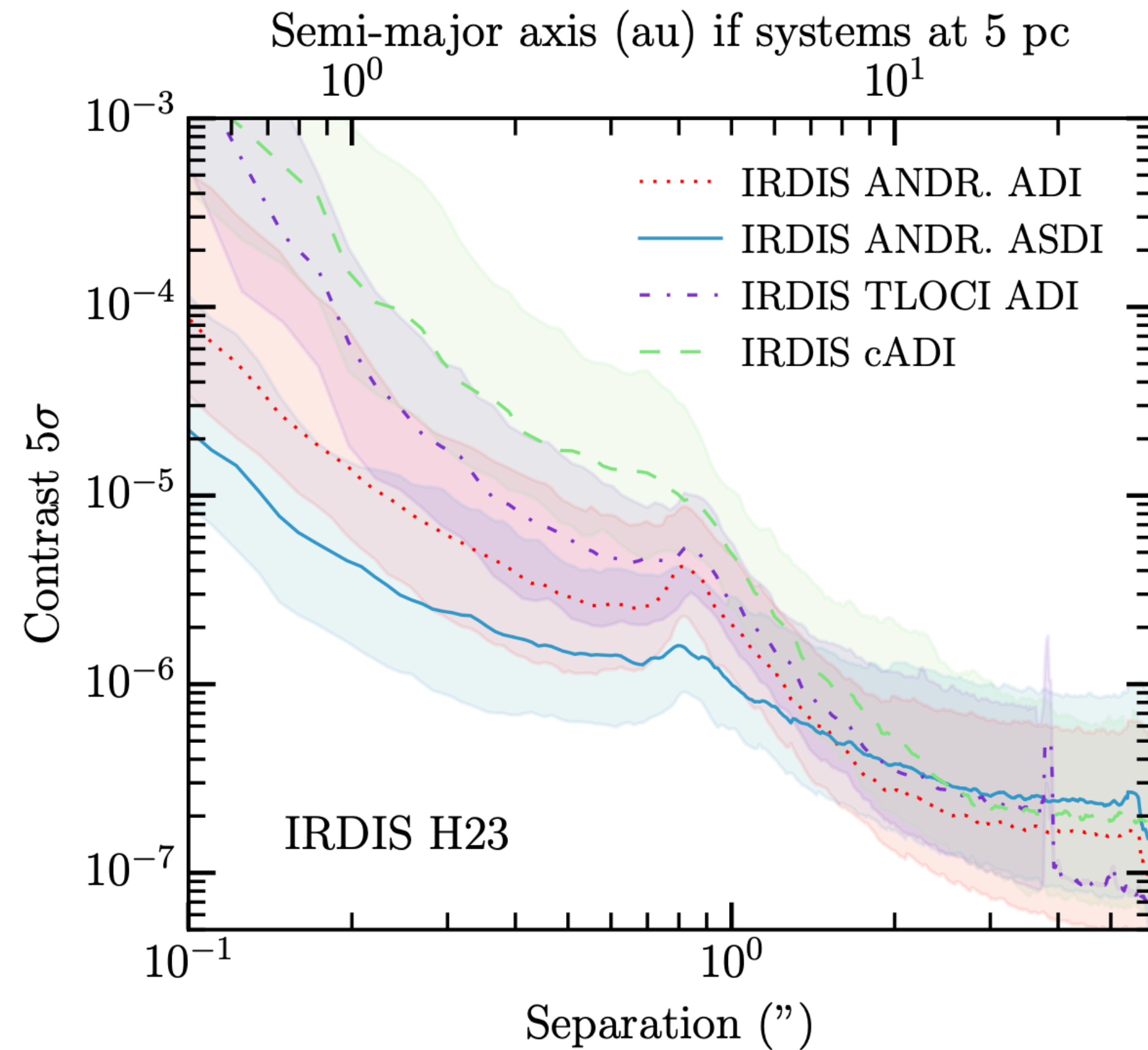
Distribution of the stellar ages from our sample



Distribution of the eccentricity of the already known close-in, low-mas planets



Detection limits in terms of contrast (IRDIS)



Detection limits in terms of contrast (IFS)

