

Astrometric Accelerations as Dynamical Beacons

*Searching for Planets Around
Young Accelerating Stars*



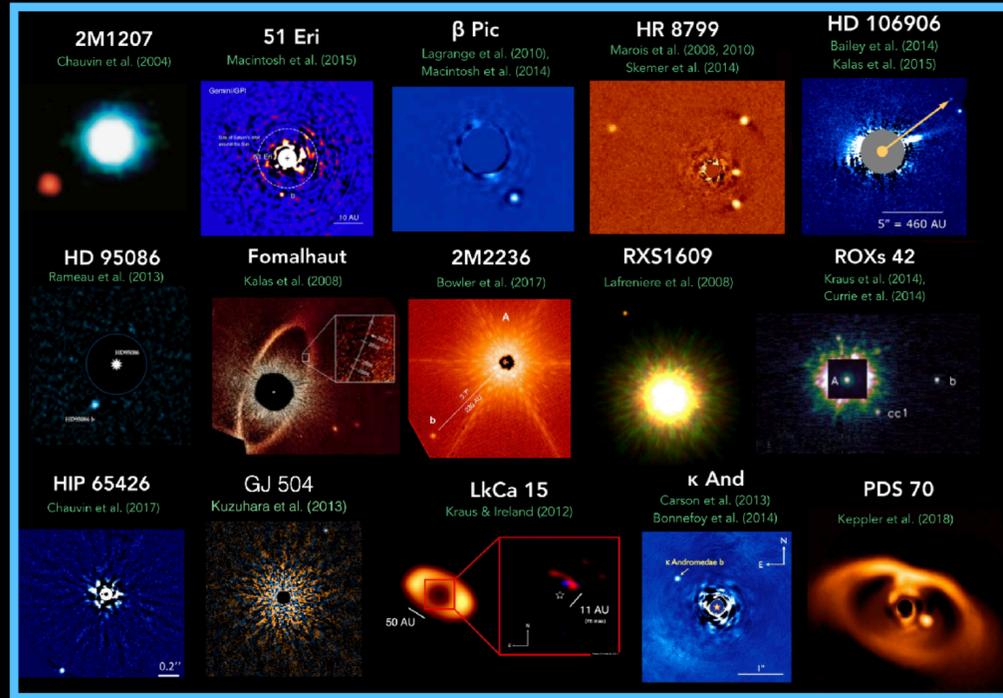
Kyle Franson

The University of Texas at Austin

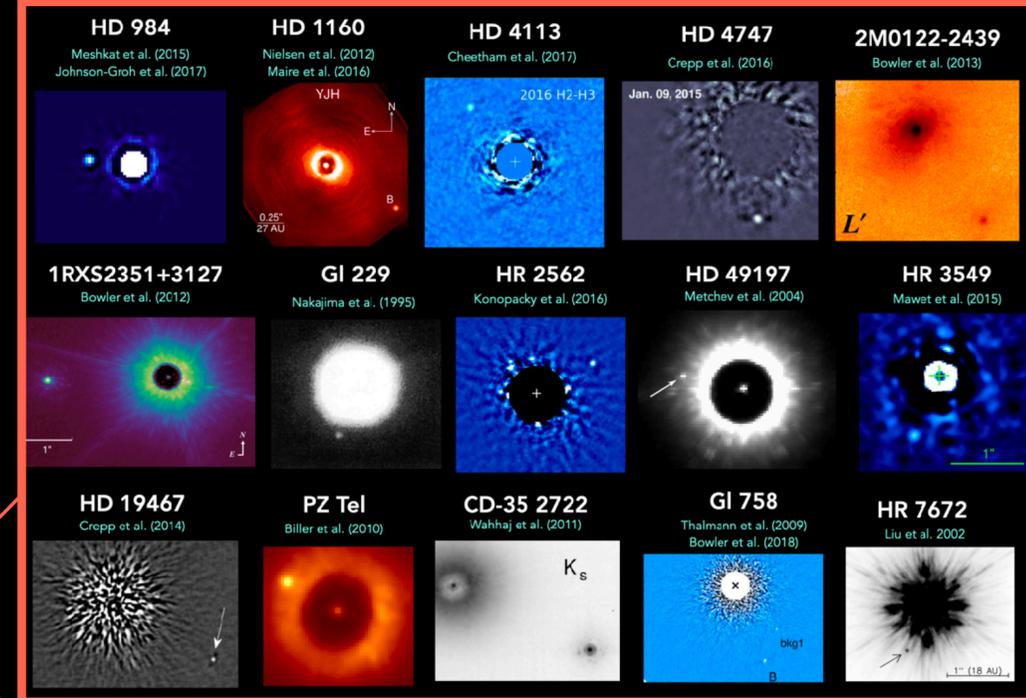
*Collaborators: Brendan Bowler, Tim Brandt, Trent Dupuy, Jackie Faherty, Daniella Bardalez-Gagliuffi,
Justin Crepp, Rebecca Jensen-Clem, William Balmer, Laurent Pueyo, among many others!*

Formation of Wide-Separation Substellar Companions

Giant Planets

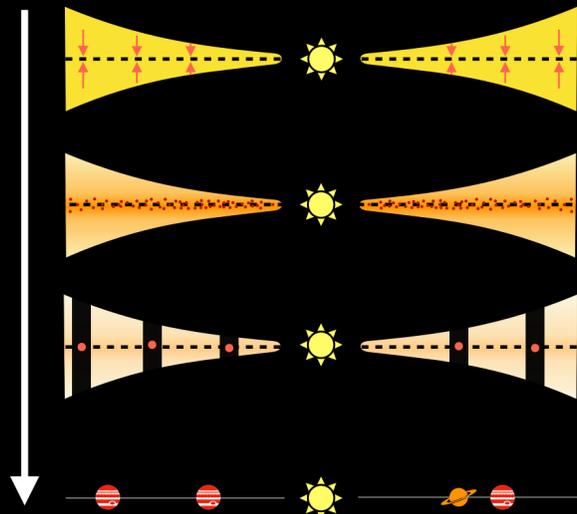


Brown Dwarfs



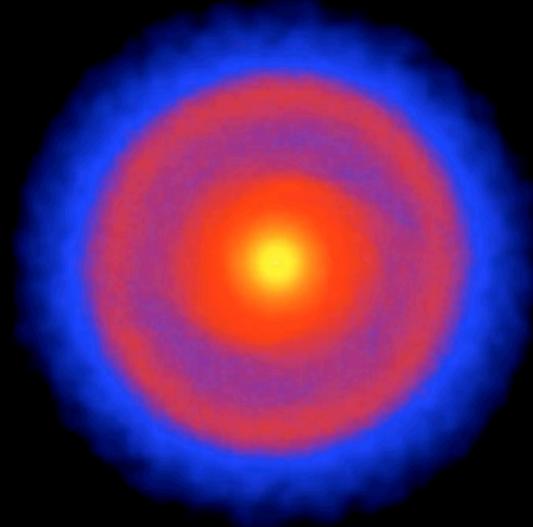
Core/Pebble Accretion

Pollack et al. (1996)
Lambrechts & Johansen (2012)



Gravitational Instability

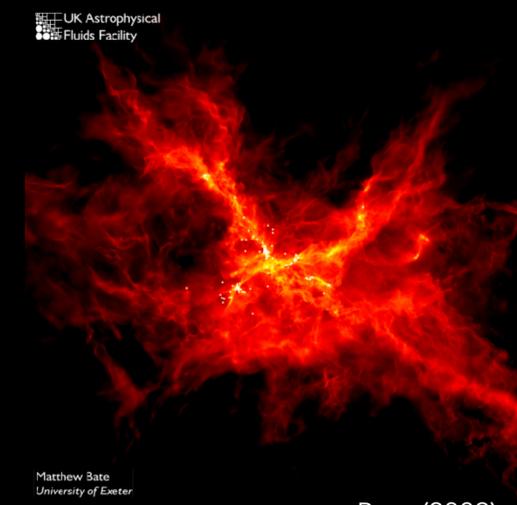
Boss (1997)



Credit: Ken Rice

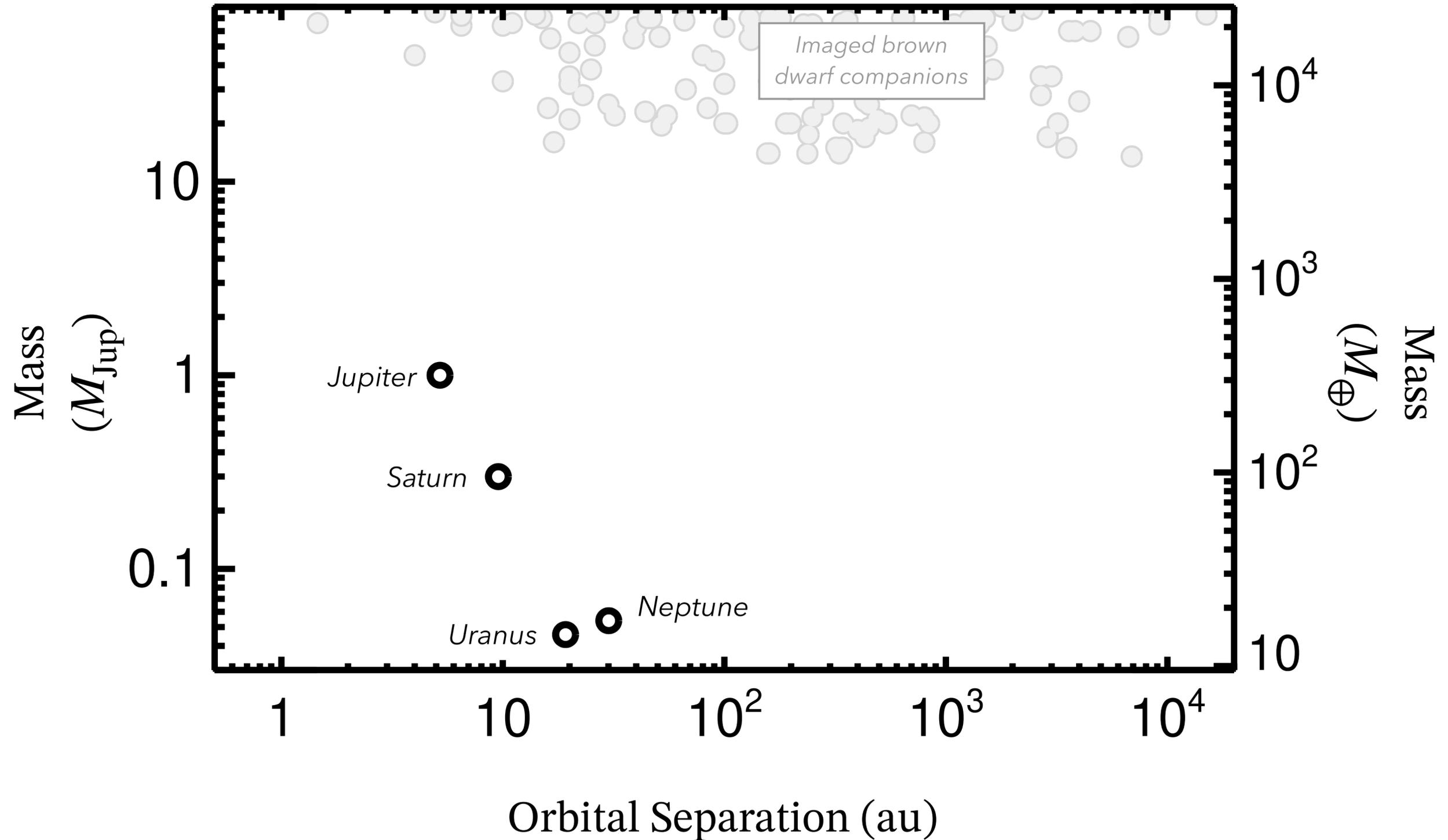
Cloud-Fragmentation

Boss (2001)
Bate et al. (2002)

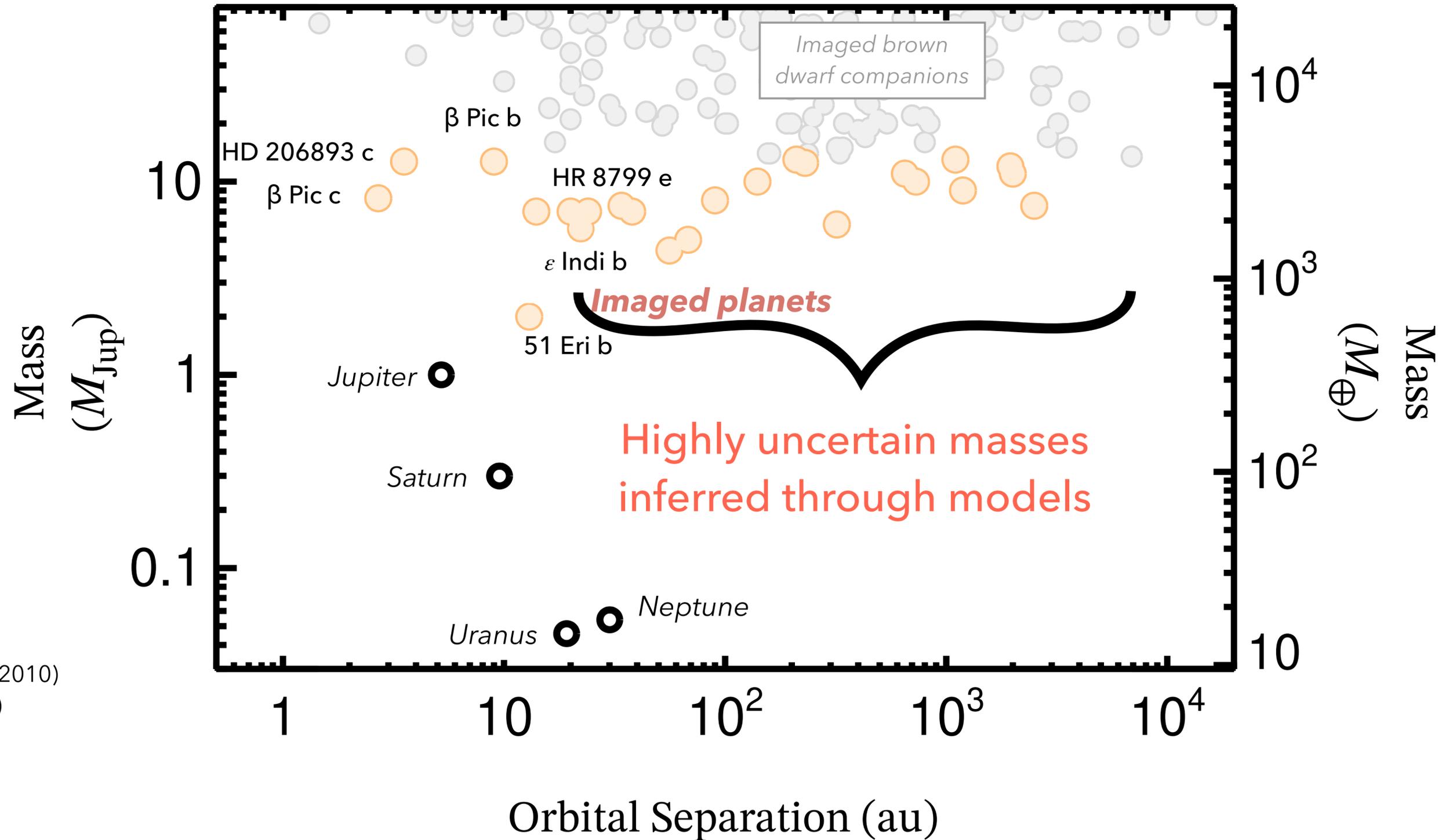


Bate (2009)

Few Imaged Exoplanets with Direct Mass Measurements

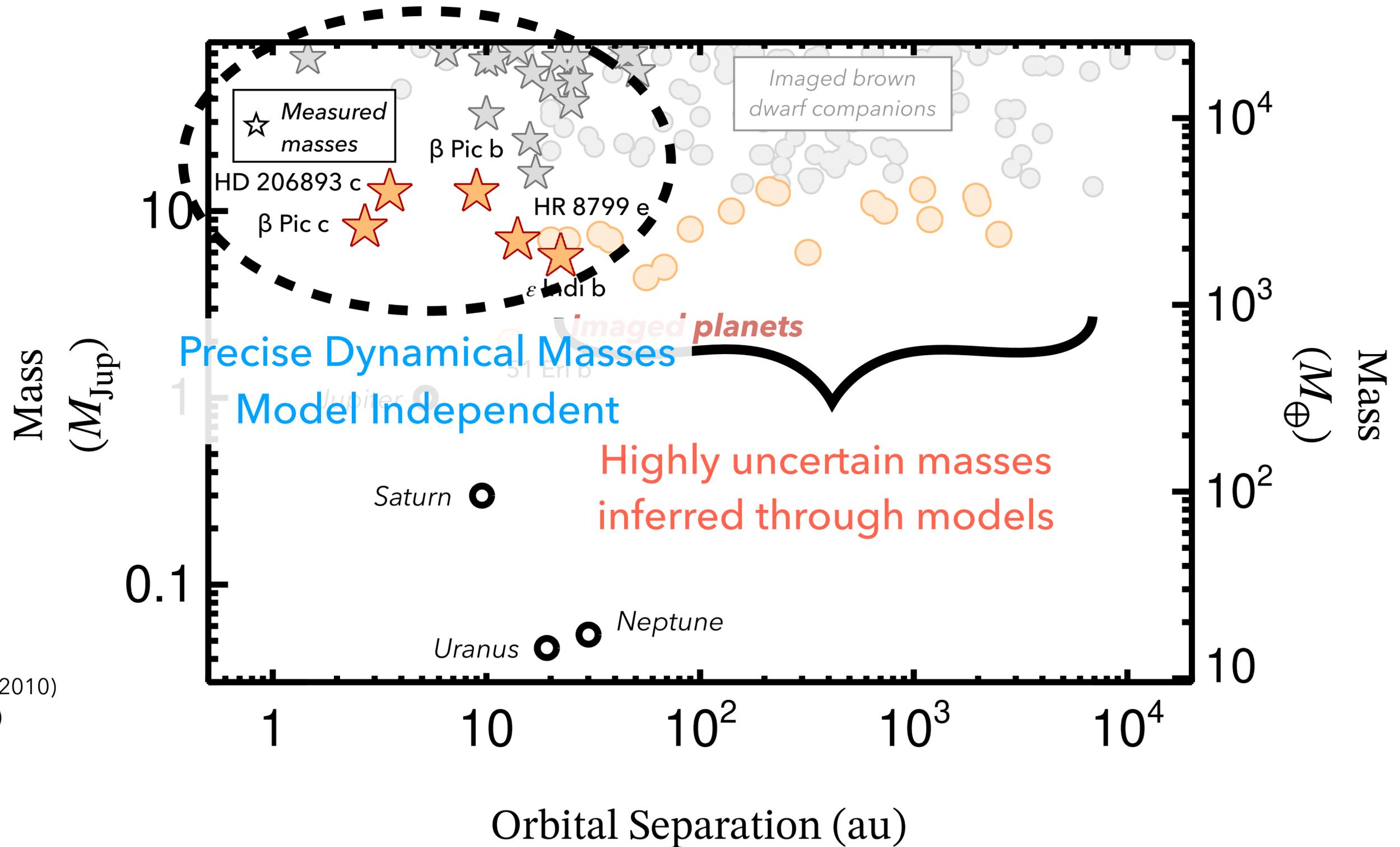


Few Imaged Exoplanets with Direct Mass Measurements



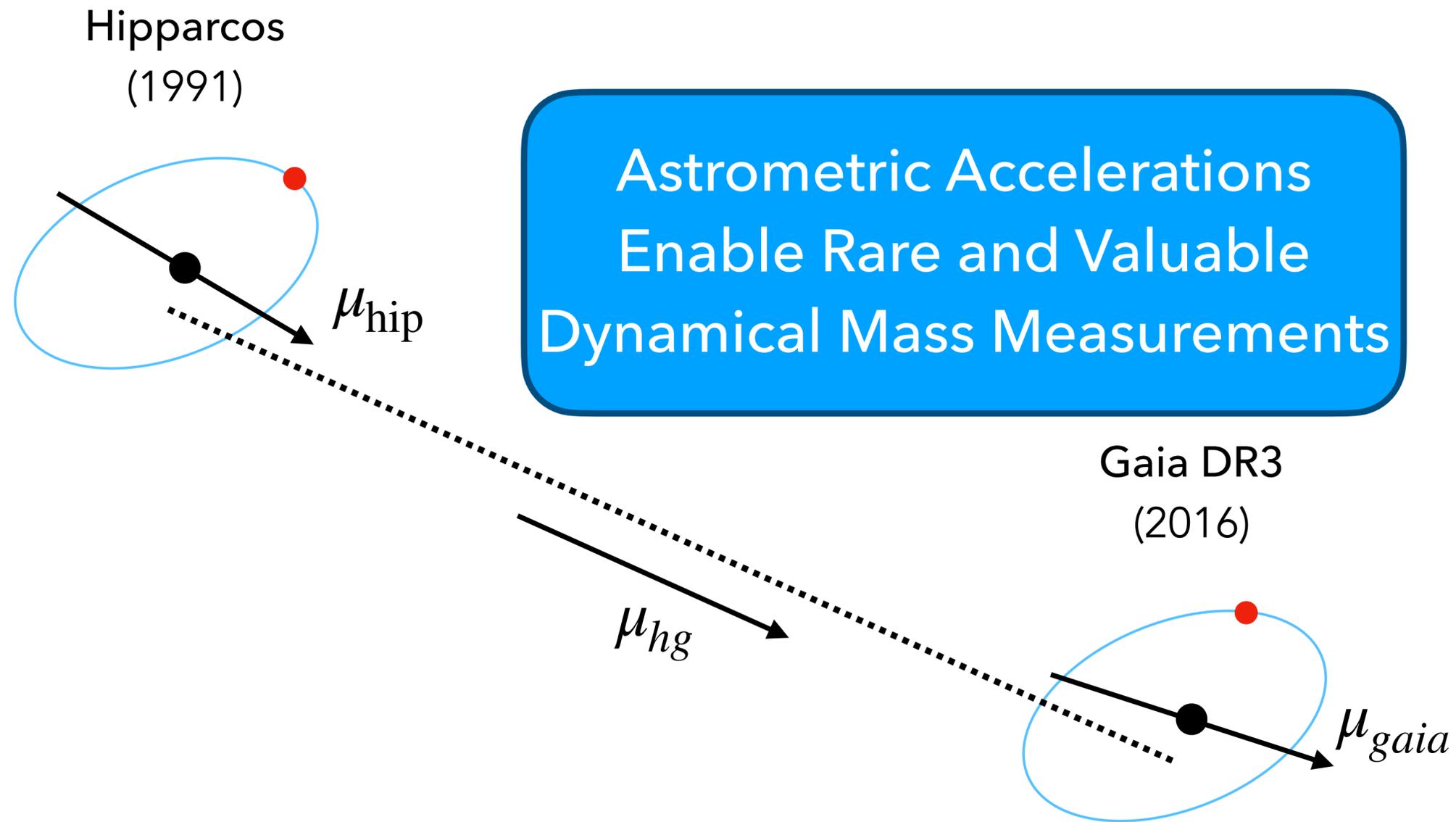
Marois et al. (2010)
 Lagrange et al. (2009, 2010)
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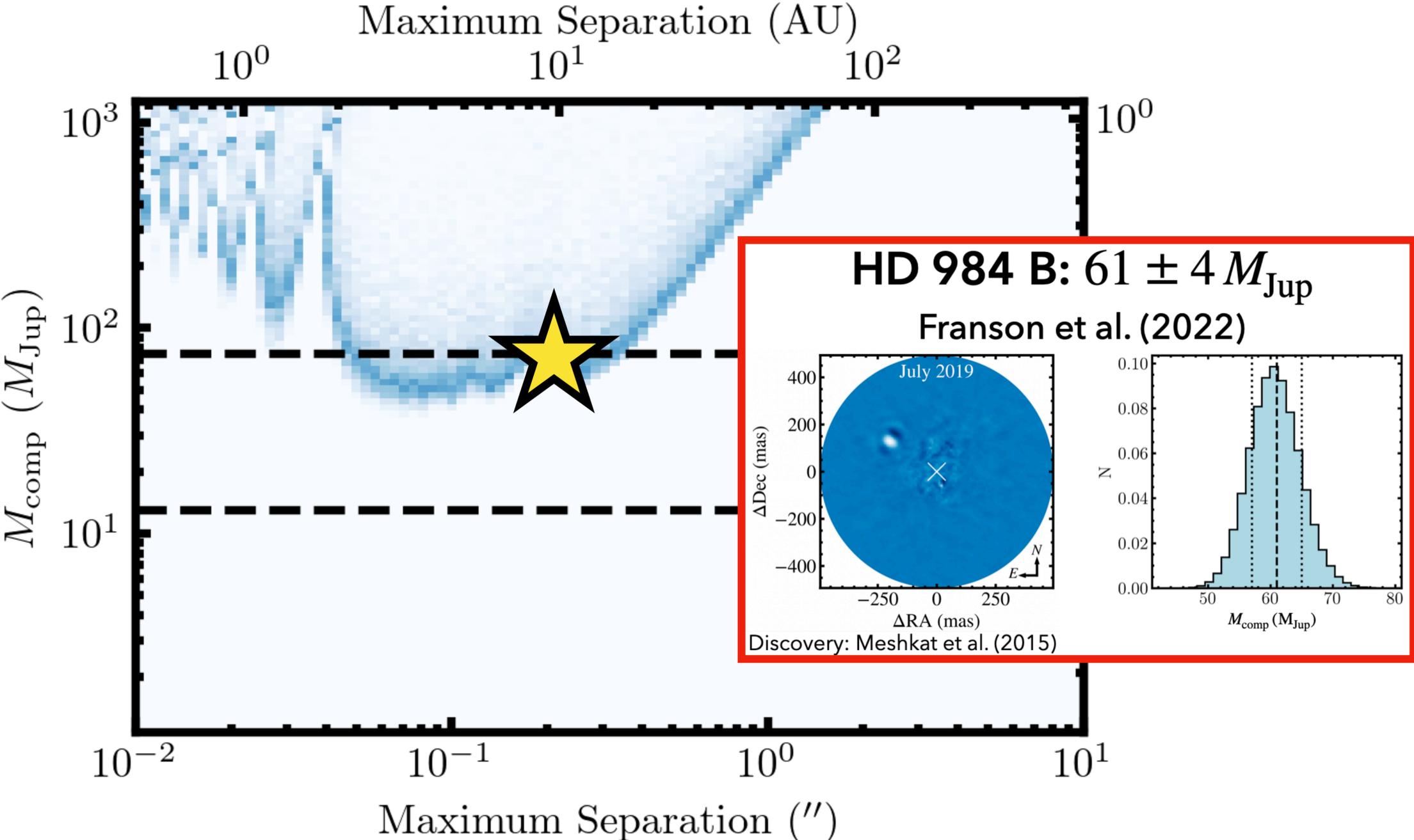
Finding Wide-Separation Planets through Astrometric Accelerations



Planets and Brown Dwarfs Induce Small Proper Motion Differences over 25 years between Hipparcos and Gaia EDR3

(See Brandt 2018, 2021; Kervella et al. 2019, 2021)

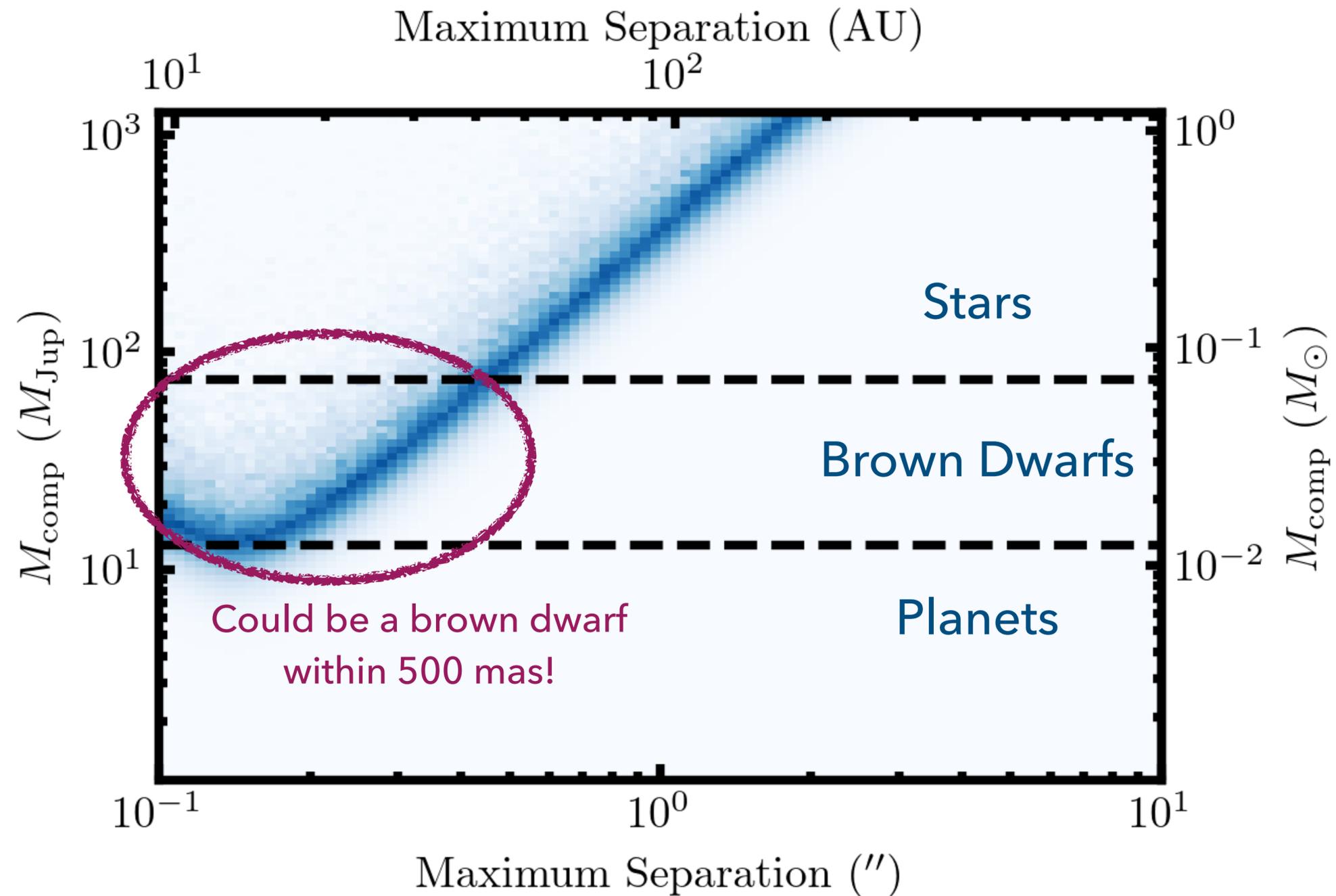
Predicted Mass From Astrometric Acceleration



See Franson et al. (2023a,b); Franson & Bowler (2023)

See also e.g., Brandt et al. (2019, 2021); De Rosa et al. (2019a,b); Fontanive et al. (2019); Mesa et al. (2022), Currie et al. (2020)

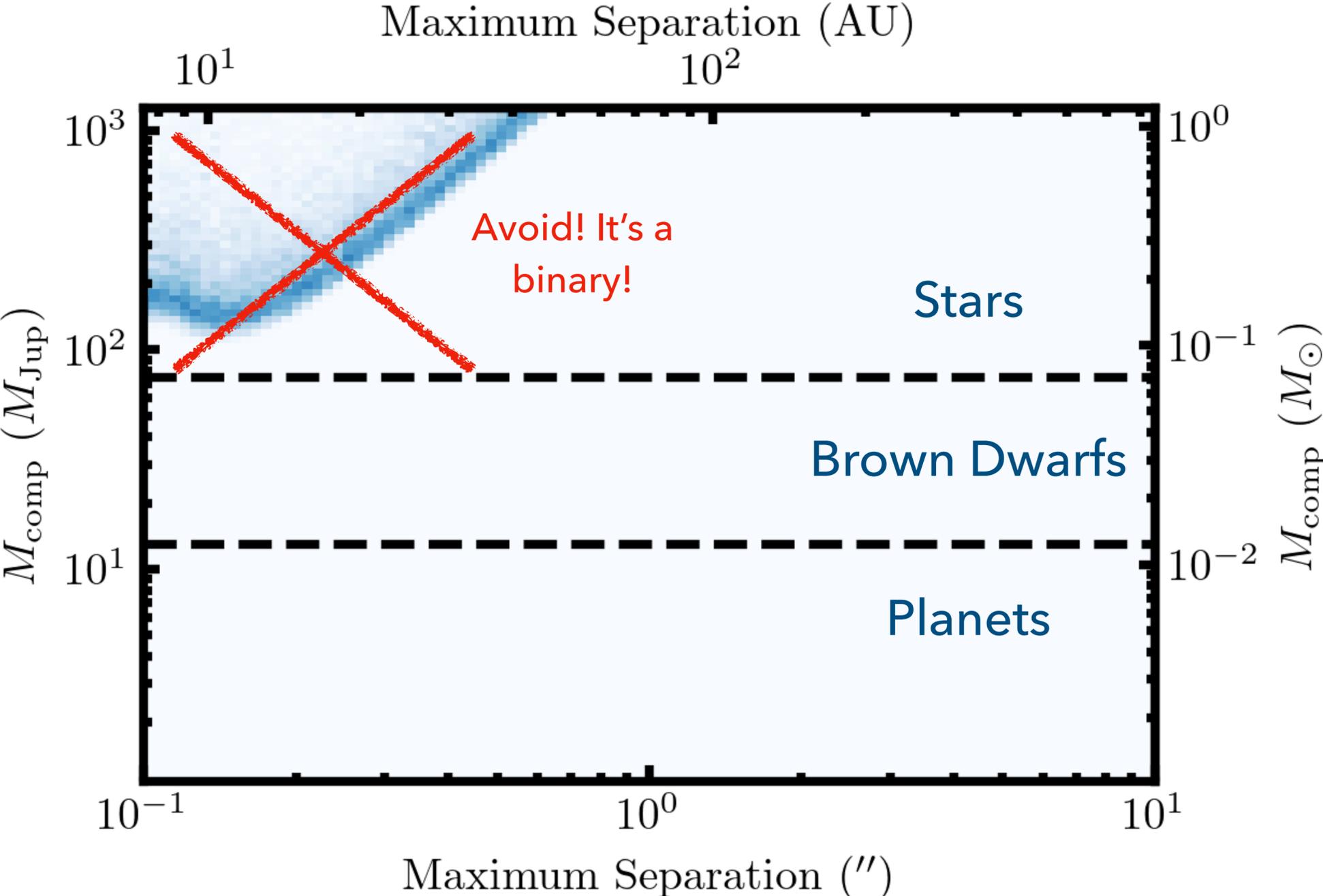
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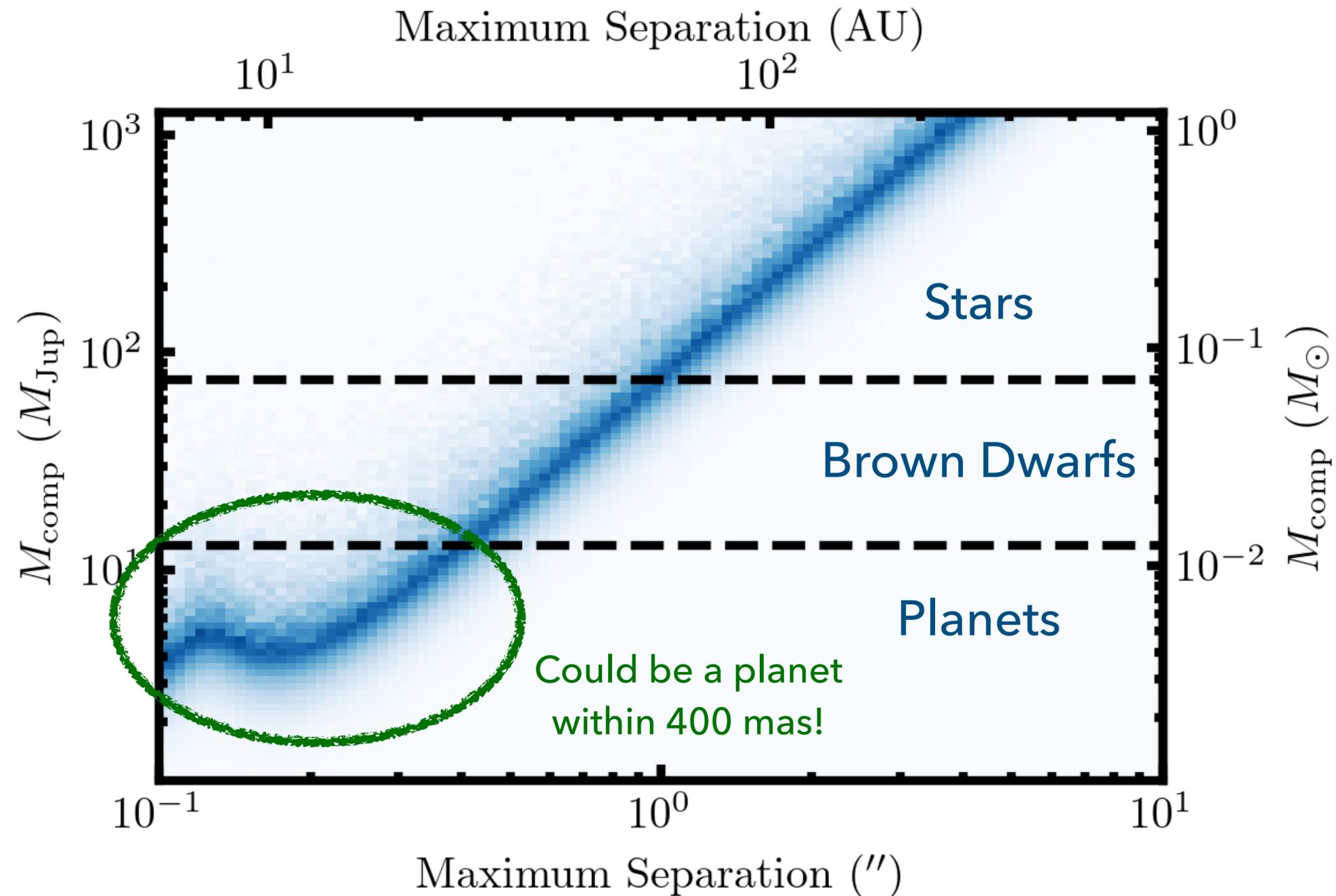
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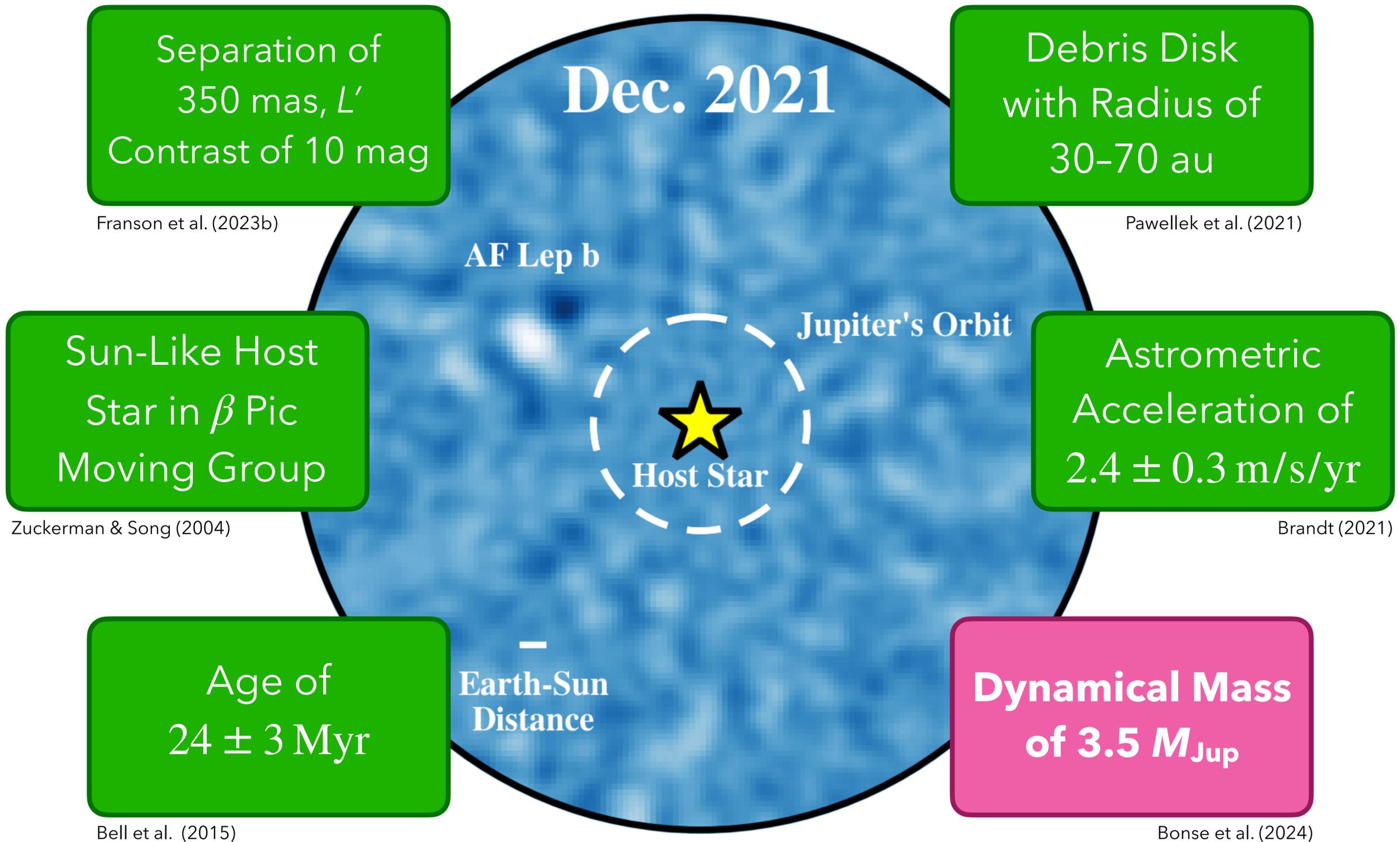
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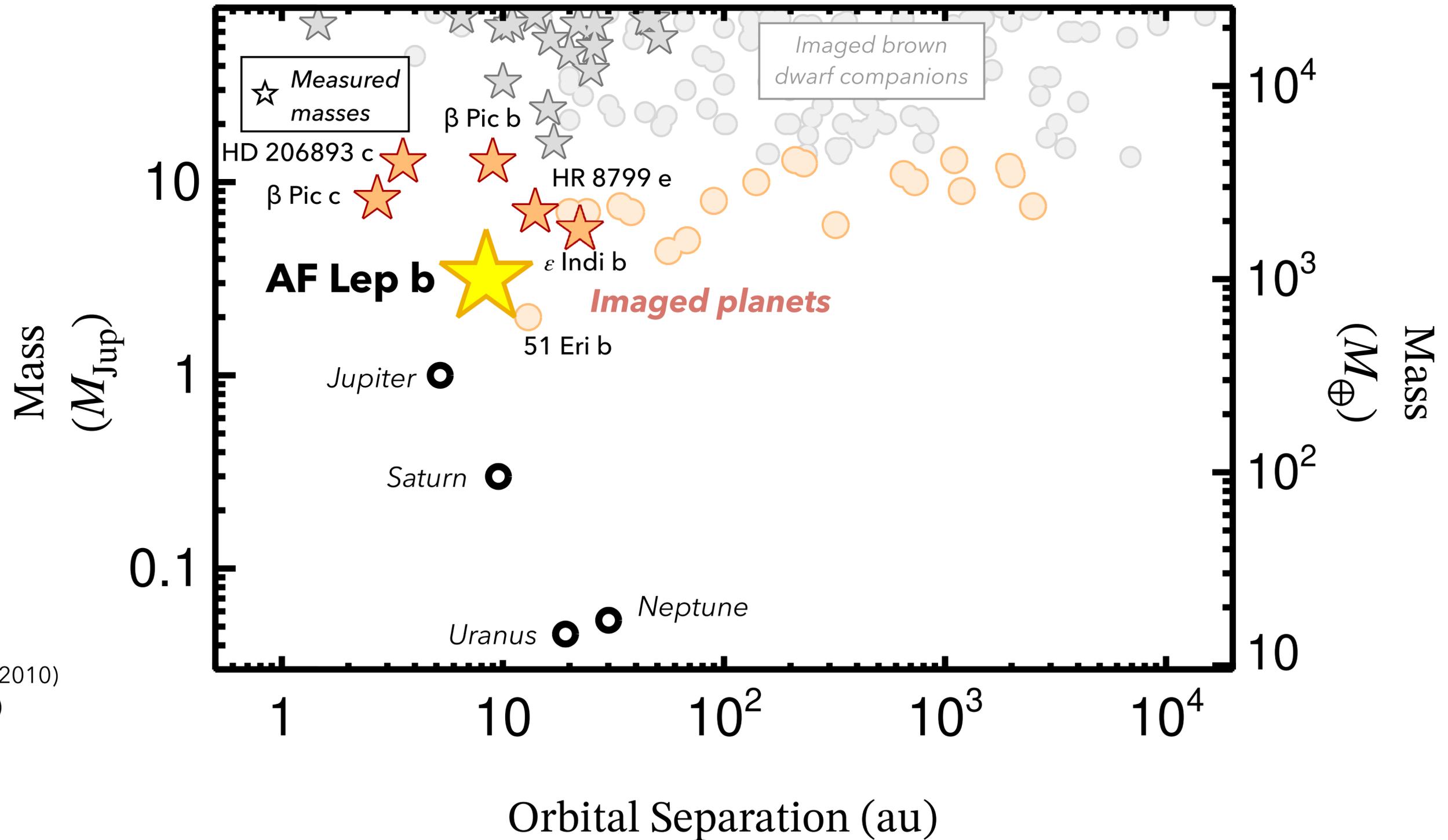
AF Lep b: Lowest Mass Imaged Planet with a Dynamical Mass



Franson et al. (2023b)

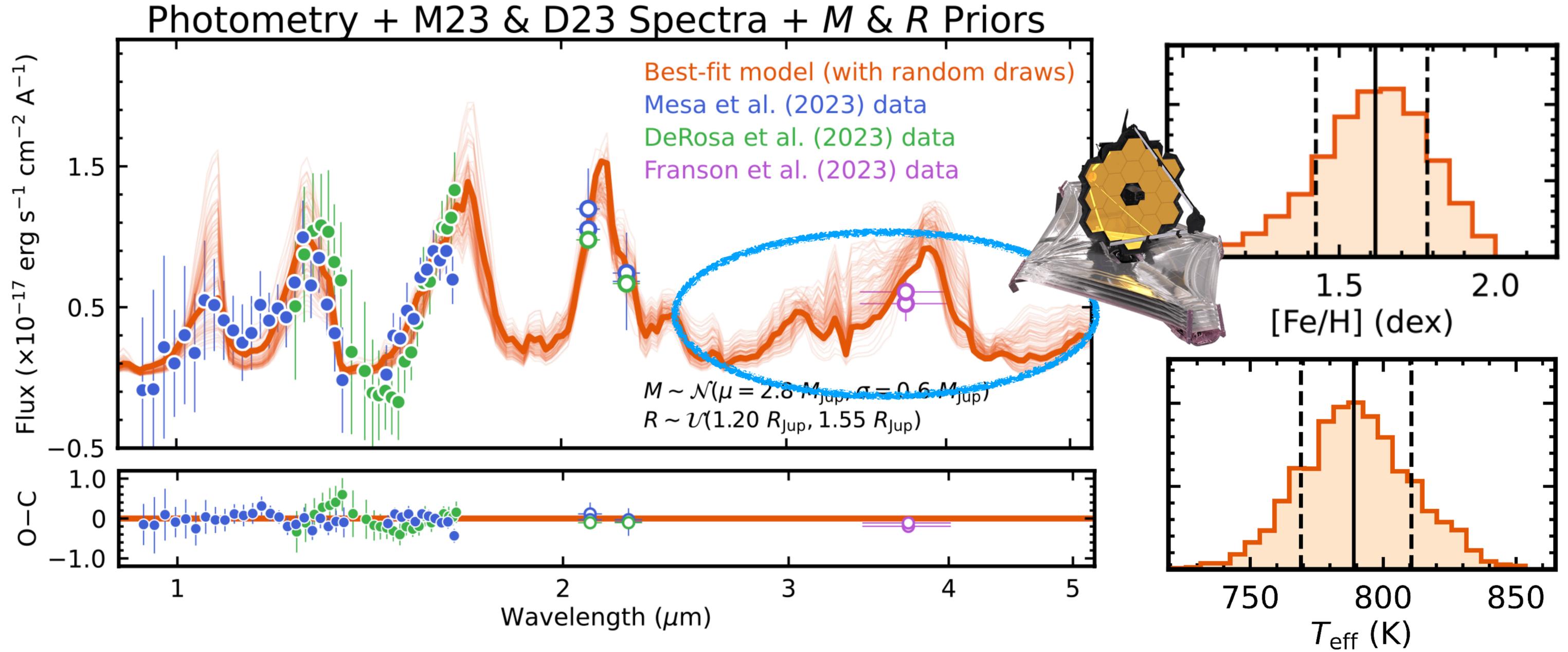
See also De Rosa et al. (2023) and Mesa et al. (2023)

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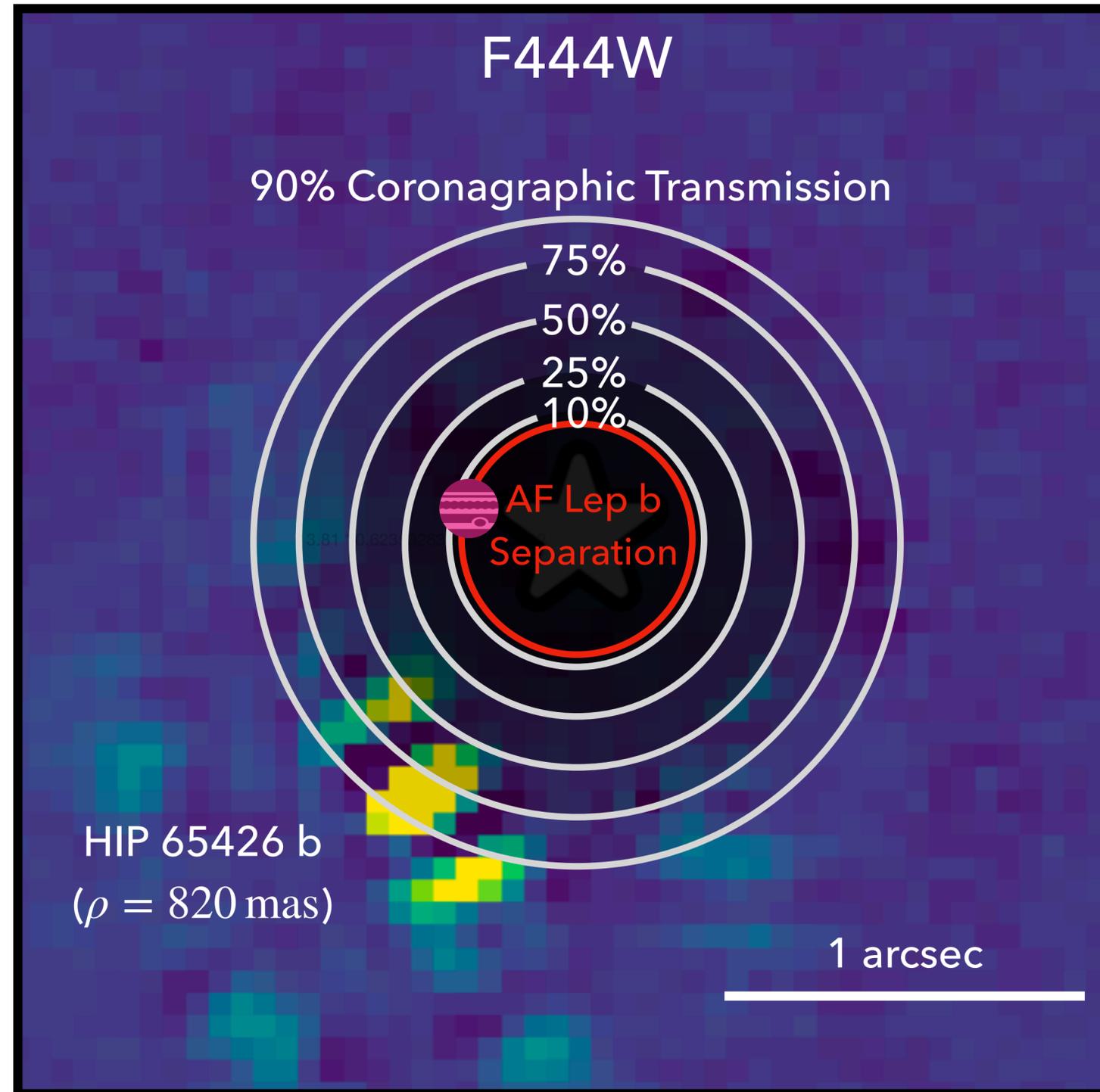
Potential Enhanced Metallicity of AF Lep b



Zhang et al. (2023)

See also Palma-Bifani et al. (2024)

Accessing Small Separations is Challenging with JWST

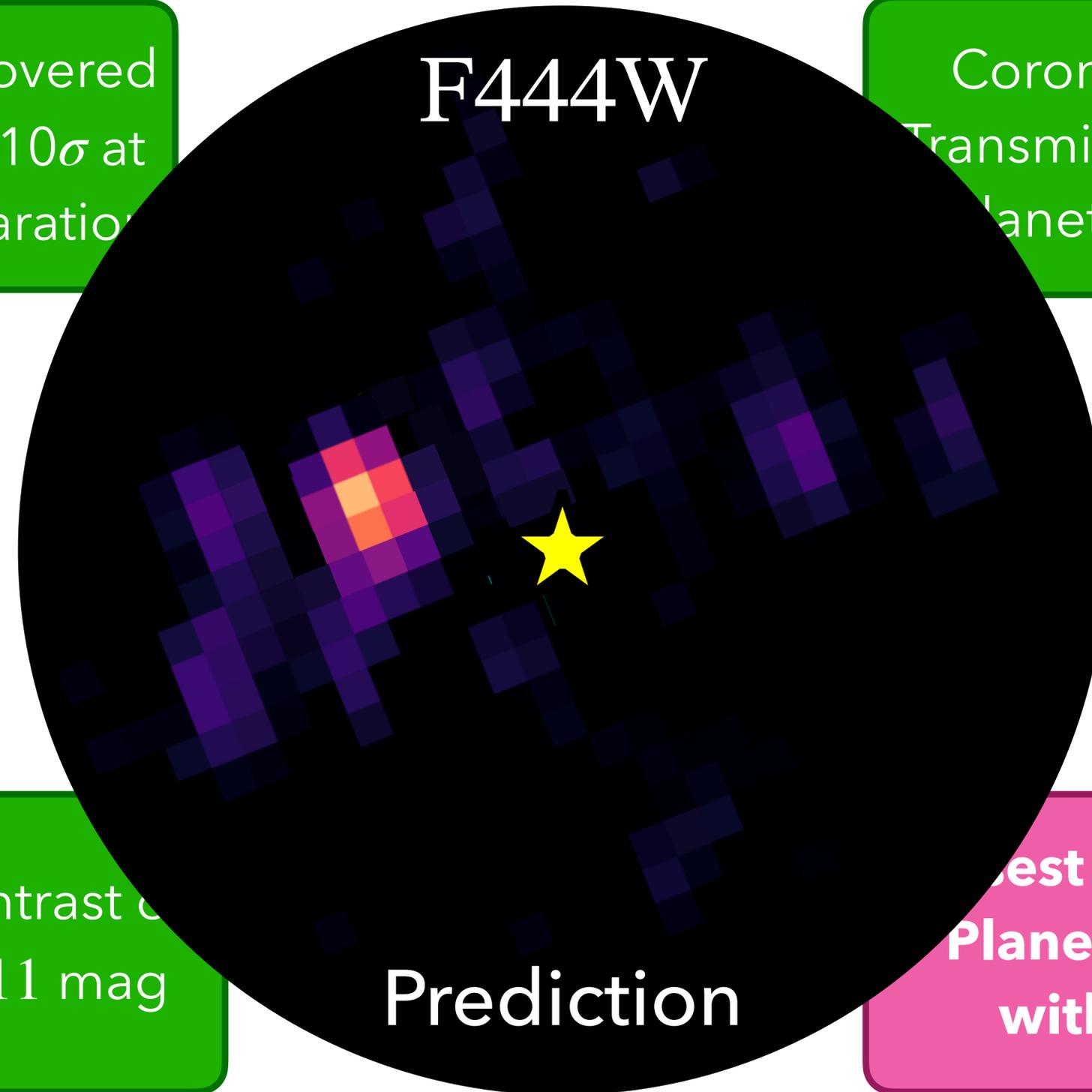


Carter et al. (2023)

JWST Imaging of AF Lep b at 4.4 μm

AF Lep b Recovered
with S/N of $\sim 10\sigma$ at
320 mas Separation

Coronagraphic
Transmission of 7%
Planet Separation

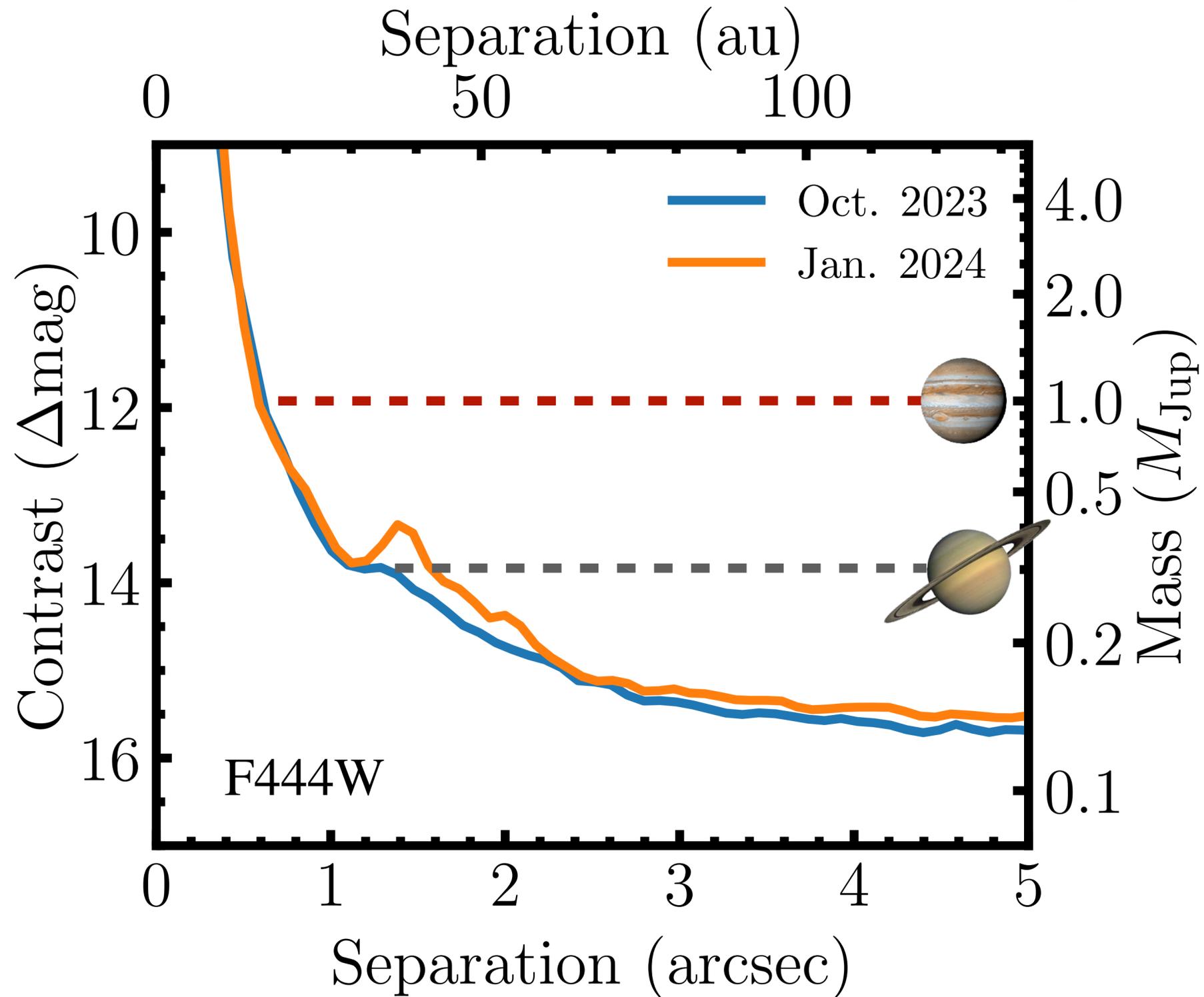


F444W Contrast of
 10.01 ± 0.11 mag

Closest Separation
Planet Imaged
with JWST

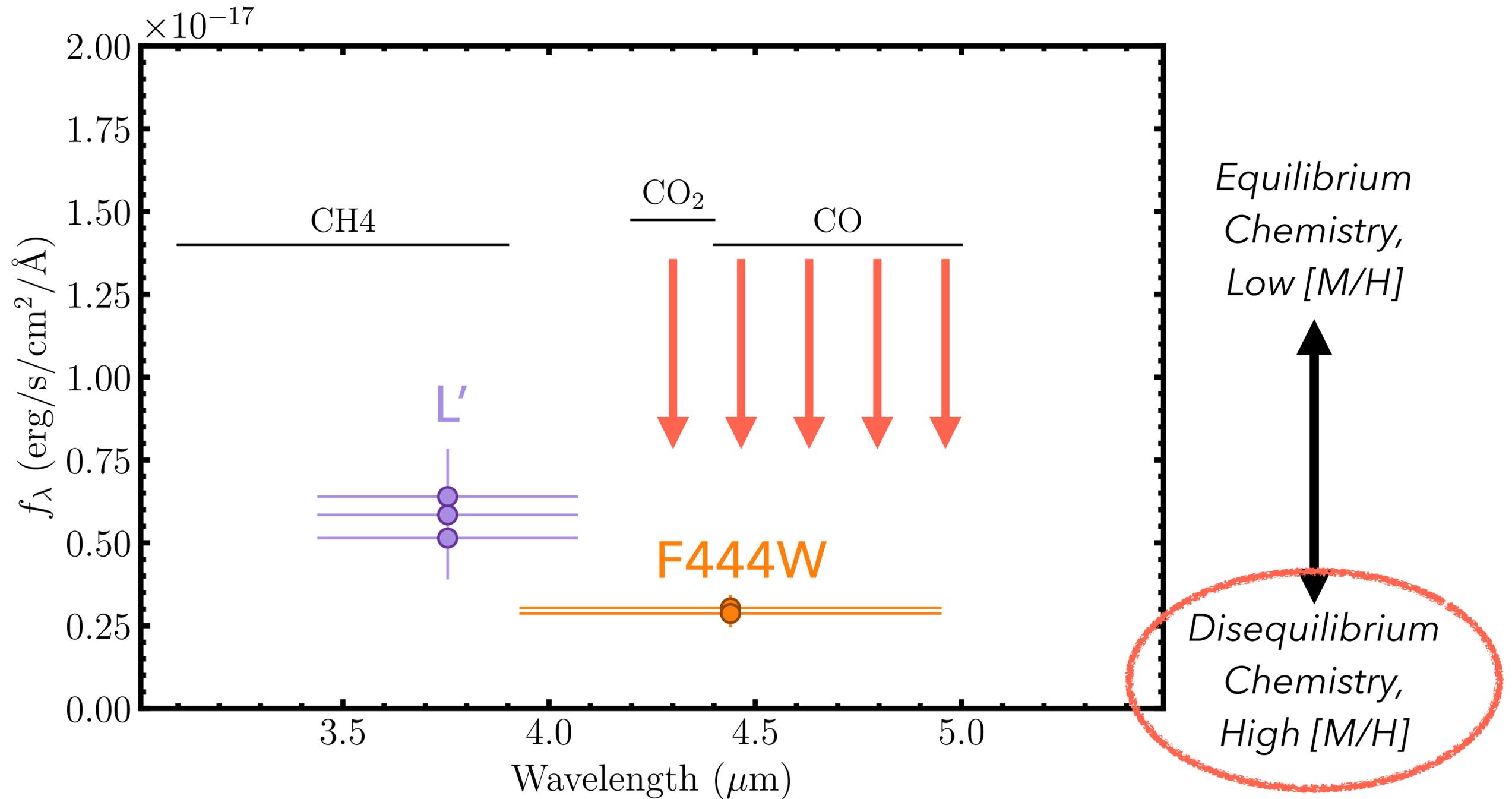
Franson et al. (2024)

No Additional Giant Planets at Wider Separations



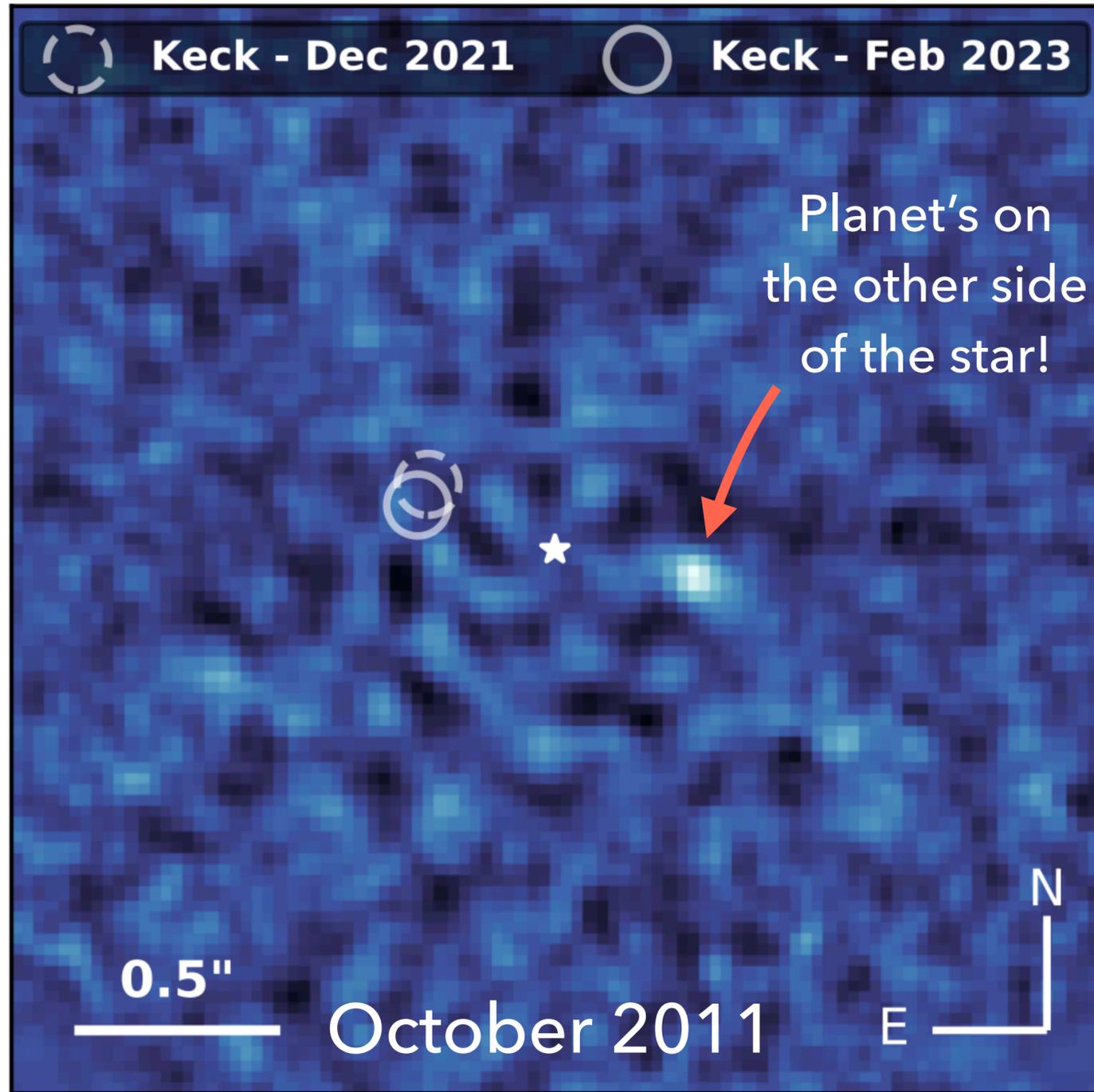
Franson et al. (2024)

3-5 μm Spectrum of AF Lep b



Franson et al. (2024)

Orbit Fit Including 2011 NACO Data and new GRAVITY Astrometry



Orbit Fit & GRAVITY Astrometry: Balmer et al. (2024)
Bonse et al. (2024)

- ◆ Semi-Major Axis: 9.0 ± 0.2 au
- ◆ Eccentricity: 0.01 ± 0.02 (Circular)
- ◆ Orbital inclination: $57.5 \pm 0.7^\circ$
 - Inclination of host-star: $54_{-9}^{+11}^\circ$
- ◆ Dynamical mass: $3.7 \pm 0.5 M_{\text{Jup}}$
 - Consistent with hot-start, warm-start if delayed formation
- ◆ Reinforces emerging trends in eccentricity and spin-orbit alignment (Bowler et al. 2020, 2023; Do Ó et al. 2023; Nagpal et al. 2023; Sepulveda et al. 2024)

Clues About the Formation of AF Lep b

Consistent with Spin-Orbit Alignment

Circular Orbit

Semi-Major Axis at Peak of Gas Giant Production
(Fulton et al. 2021)

Core Accretion

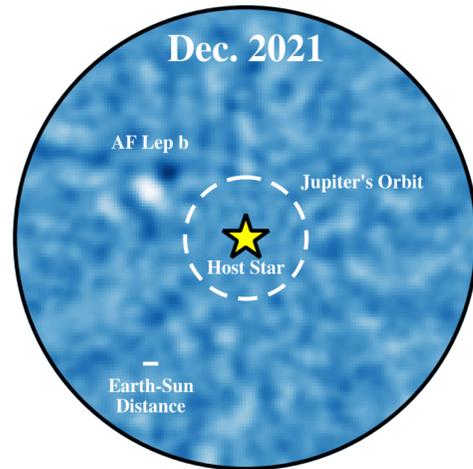
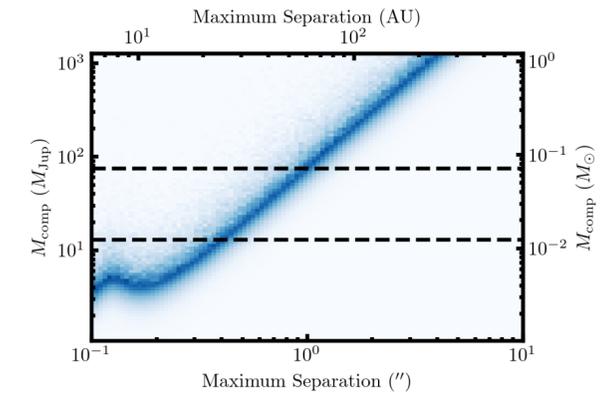


Dynamical Mass of
 $\sim 3-4 M_{Jup}$

Enhanced Atmospheric Metallicity

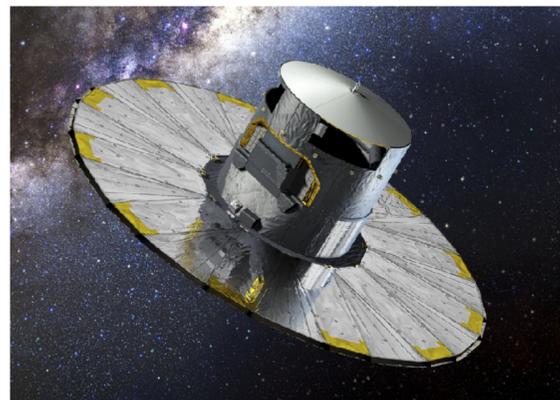
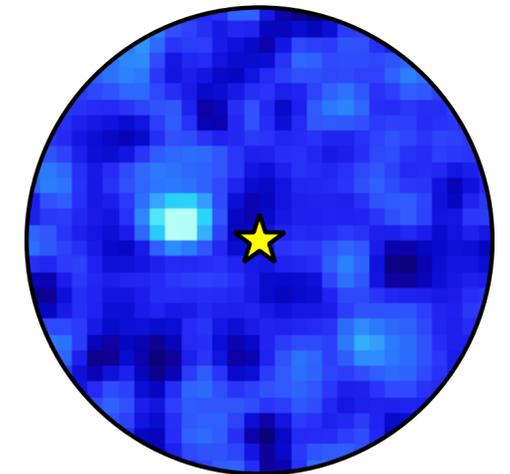
Summary

We are conducting an **exoplanet imaging survey** targeting stars with promising **astrometric accelerations**



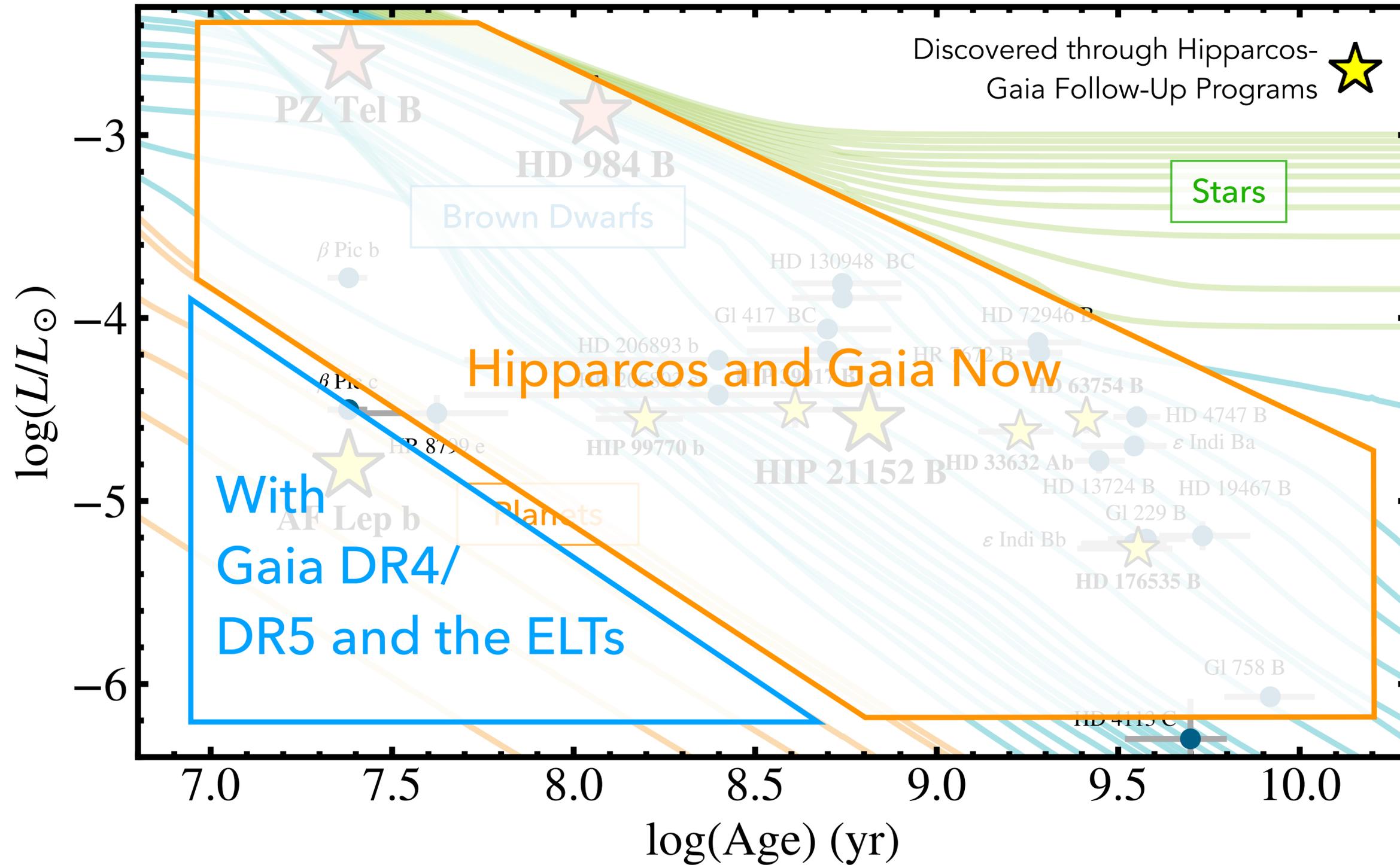
AF Lep b: The Lowest-Mass Imaged Planet with a Dynamical Mass

Successful recovery of AF Lep b with **JWST** at a separation of **320 mas**

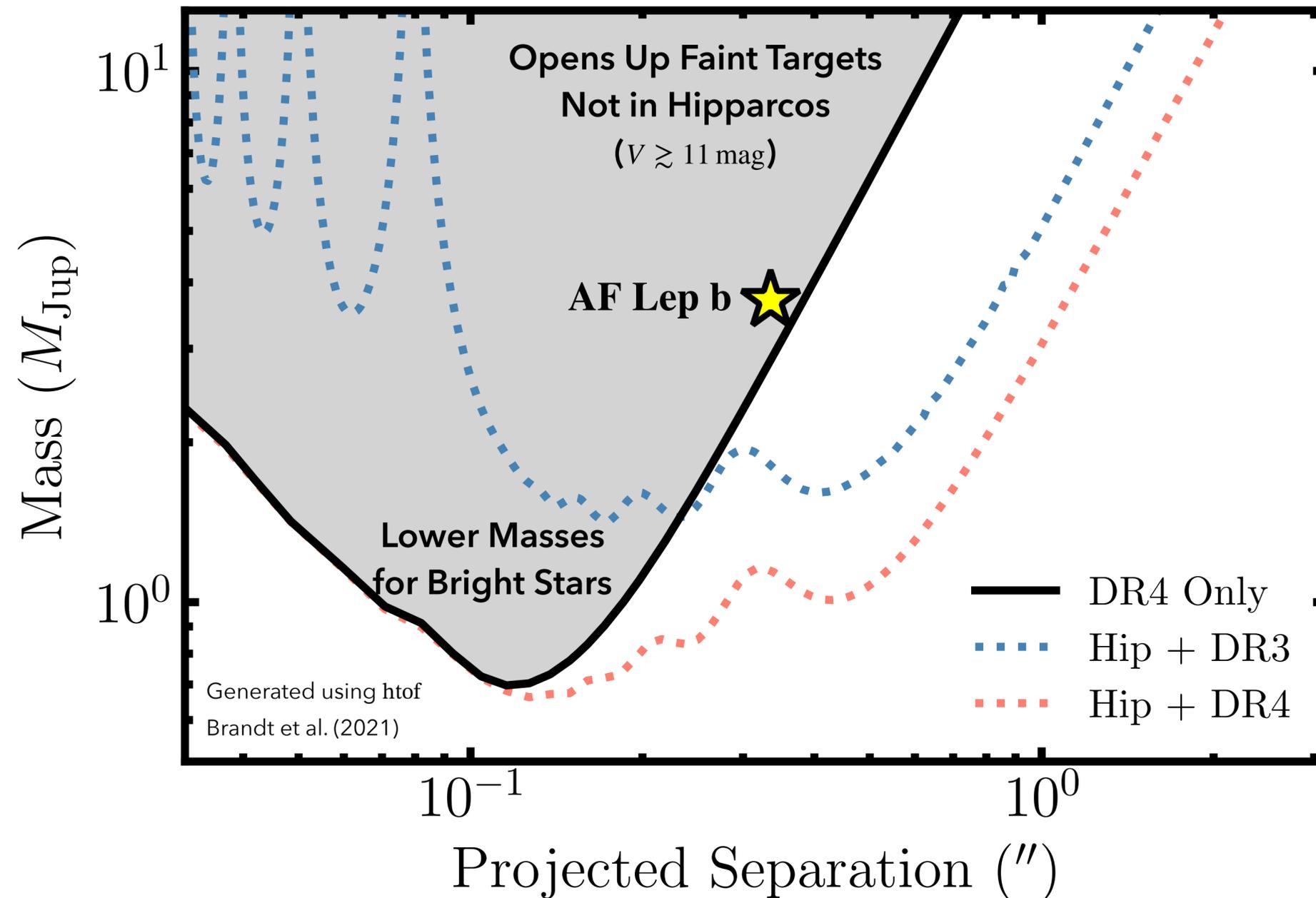


The Future of Astrometric Accelerations: **Gaia DR4/DR5** and the **ELTs**

Dynamical Masses Now and in the Future



Gaia DR4-Informed Imaging Campaigns



*A Treasure Trove of Informed Targets for Next-Generation High-Contrast
Imagers and the ELTs*