



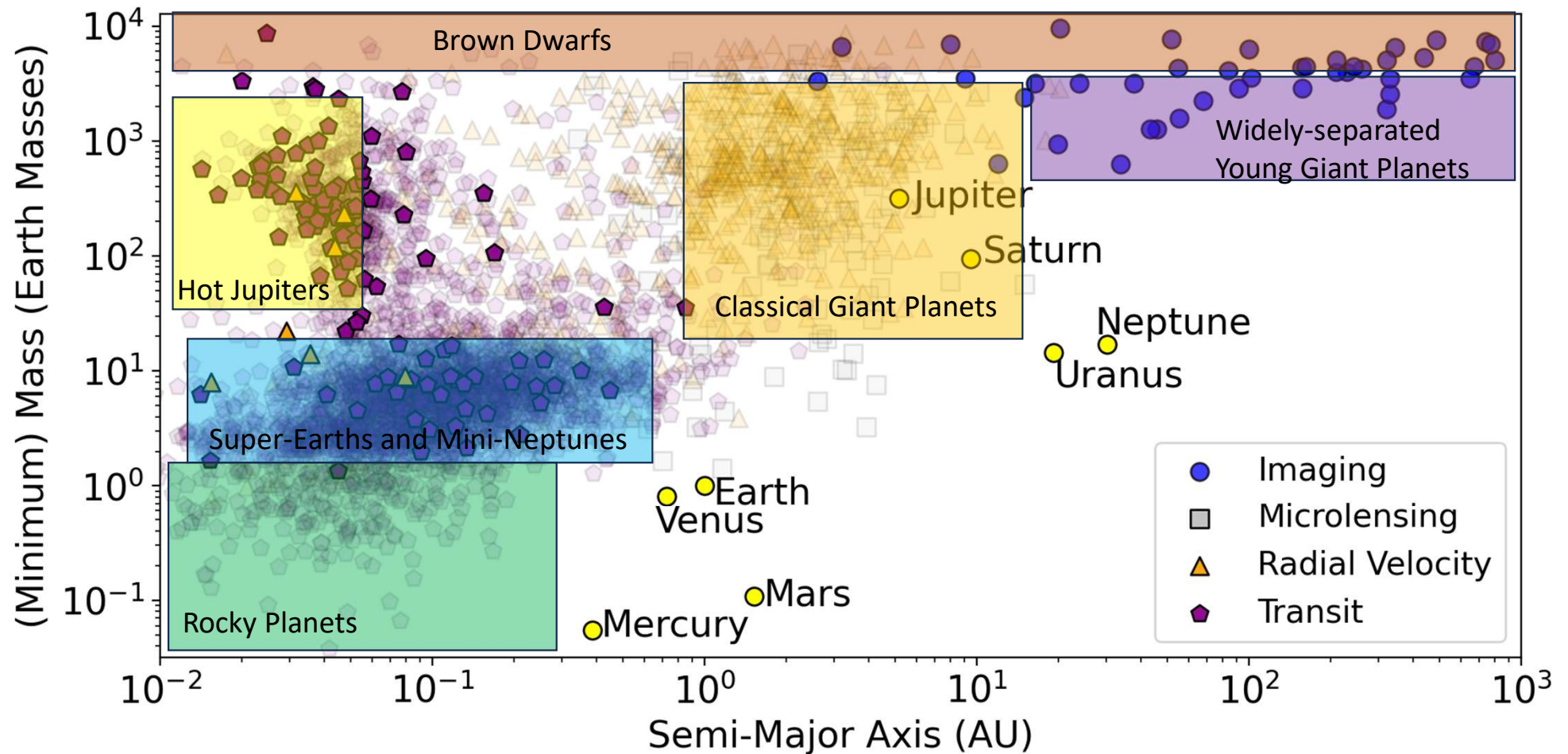
# JWST direct imaging searches for sub-Jupiter exoplanets as a pathfinder towards ELT exoplanet imaging

Beth Biller, University of Edinburgh  
on behalf of the SURVEY 6005 (PI Biller),  
GO 5835 (PI Carter), and GO 4050  
(PI Carter) Survey Teams



# The Exoplanet Zoo

Figure from Currie et al. 2022, courtesy of Dmitry Savransky, using data from the NASA Exoplanet Archive.



From the  
ground, we  
can image  
"baby  
Jupiters":

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Masses  $>3$  Jupiter masses

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Effective temperatures  $\sim 600\text{-}1400$  K

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Ages  $< 100$  Myr – close to epoch of formation

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Separations from 10s to hundreds of AU

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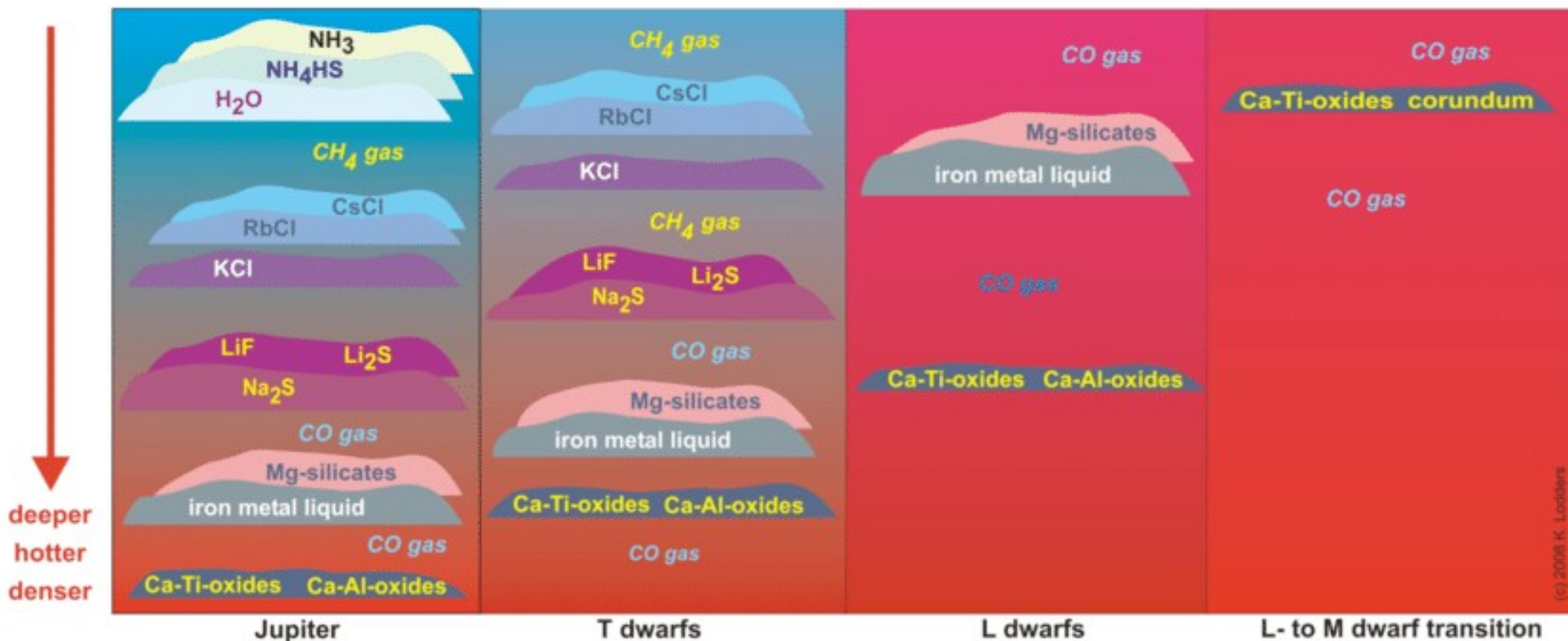
Factor of  $10^4$  to  $10^6$  contrast with star

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Mostly detected in near-IR using 8-m ground-based telescopes + adaptive optics + coronagraphy

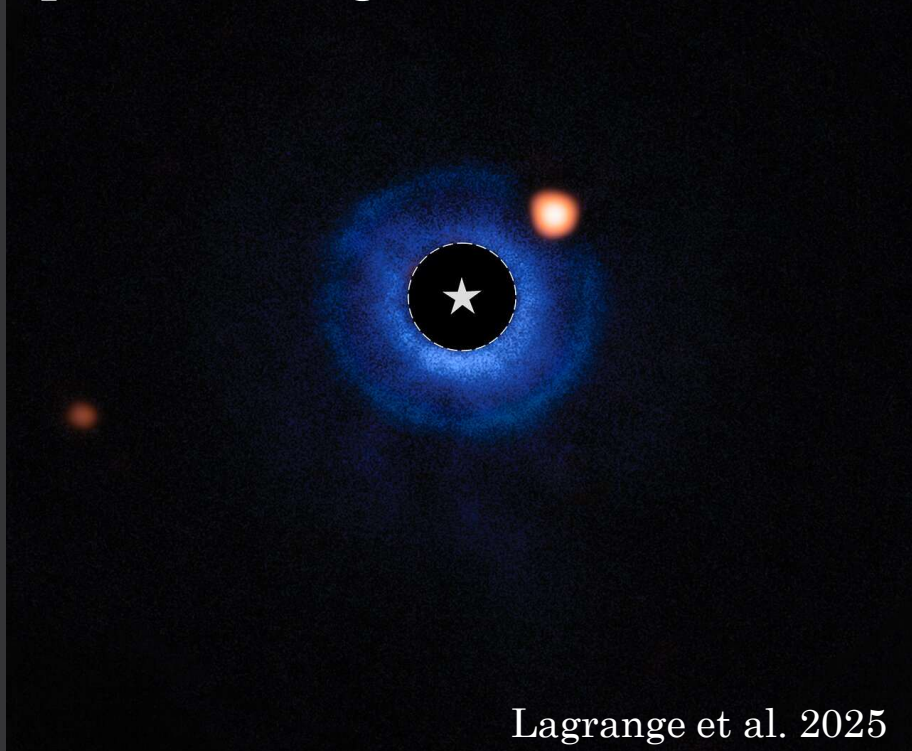
# Temperate exoplanets unlock new cloud species and atmospheric physics

Lodders & Fegley 2006



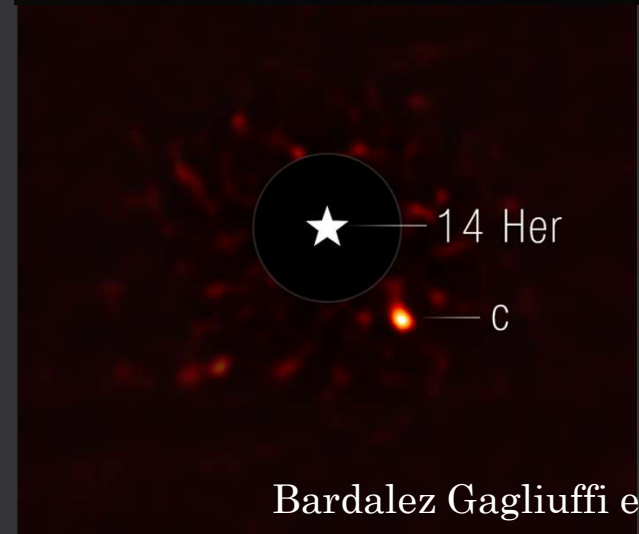
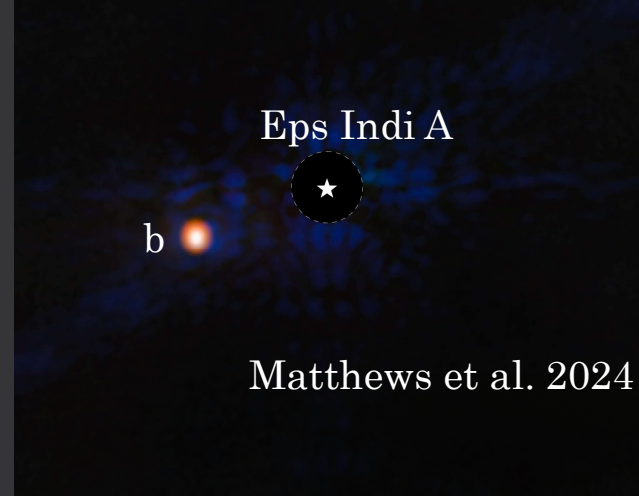


TWA 7b – the first Saturn mass planet imaged!



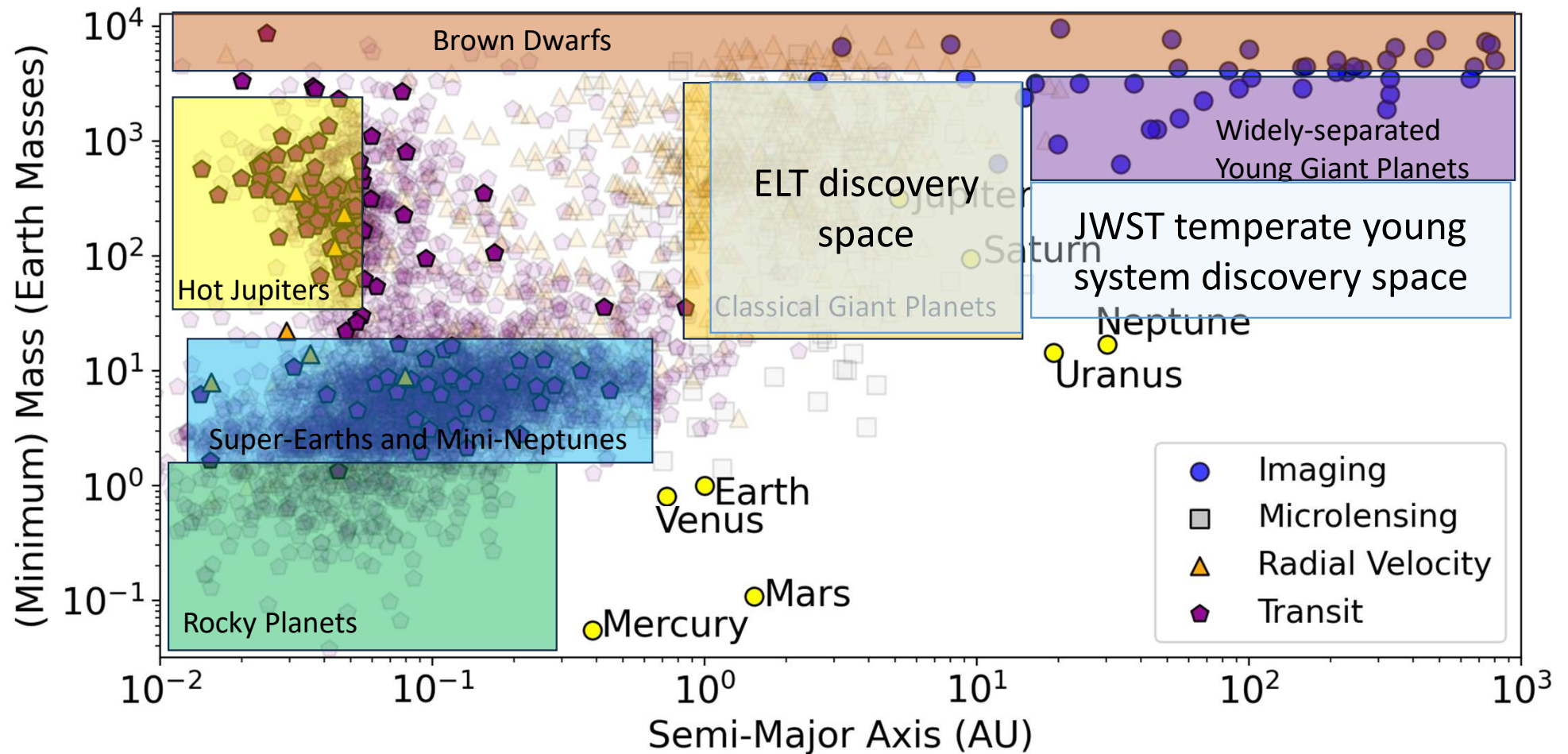
In the last 2 years, three temperate ( $<400$  K) exoplanets have been imaged with JWST!

Eps Indi Ab and 14 Her c – the coldest planets imaged!



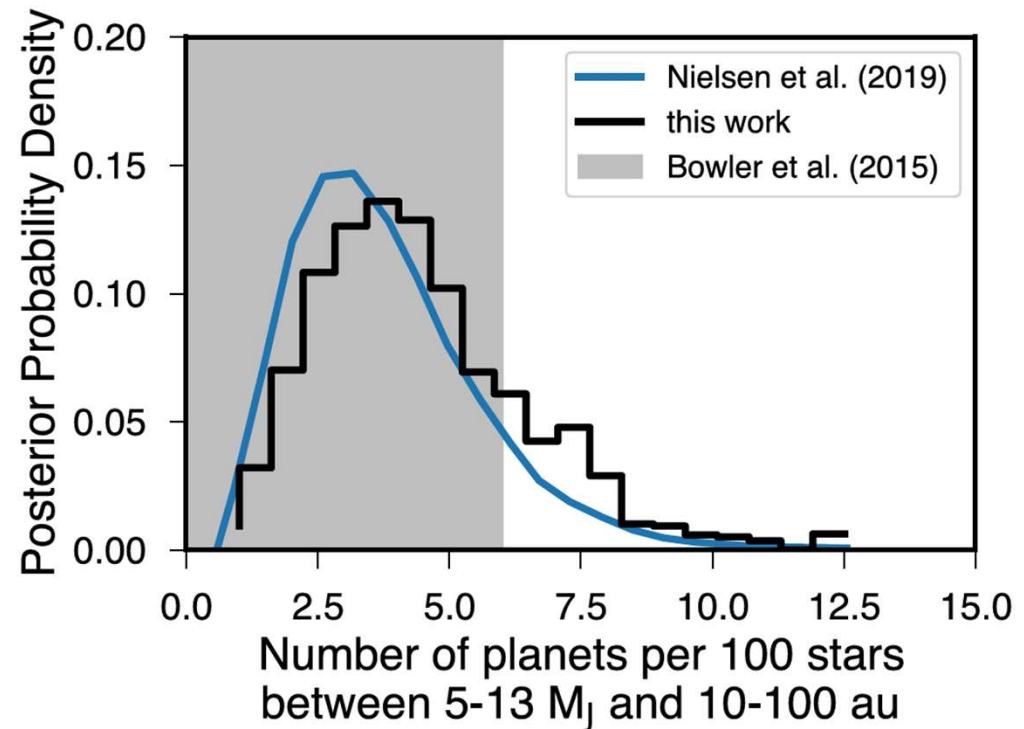
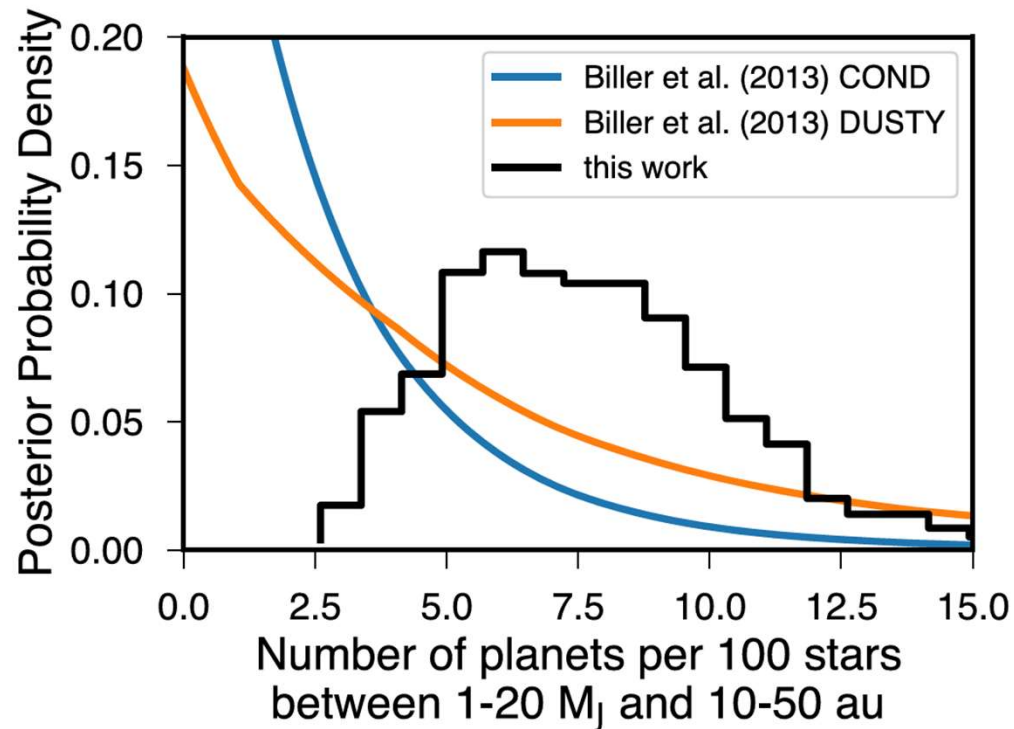
# The Exoplanet Zoo

Figure from Currie et al. 2022, courtesy of Dmitry Savransky, using data from the NASA Exoplanet Archive.



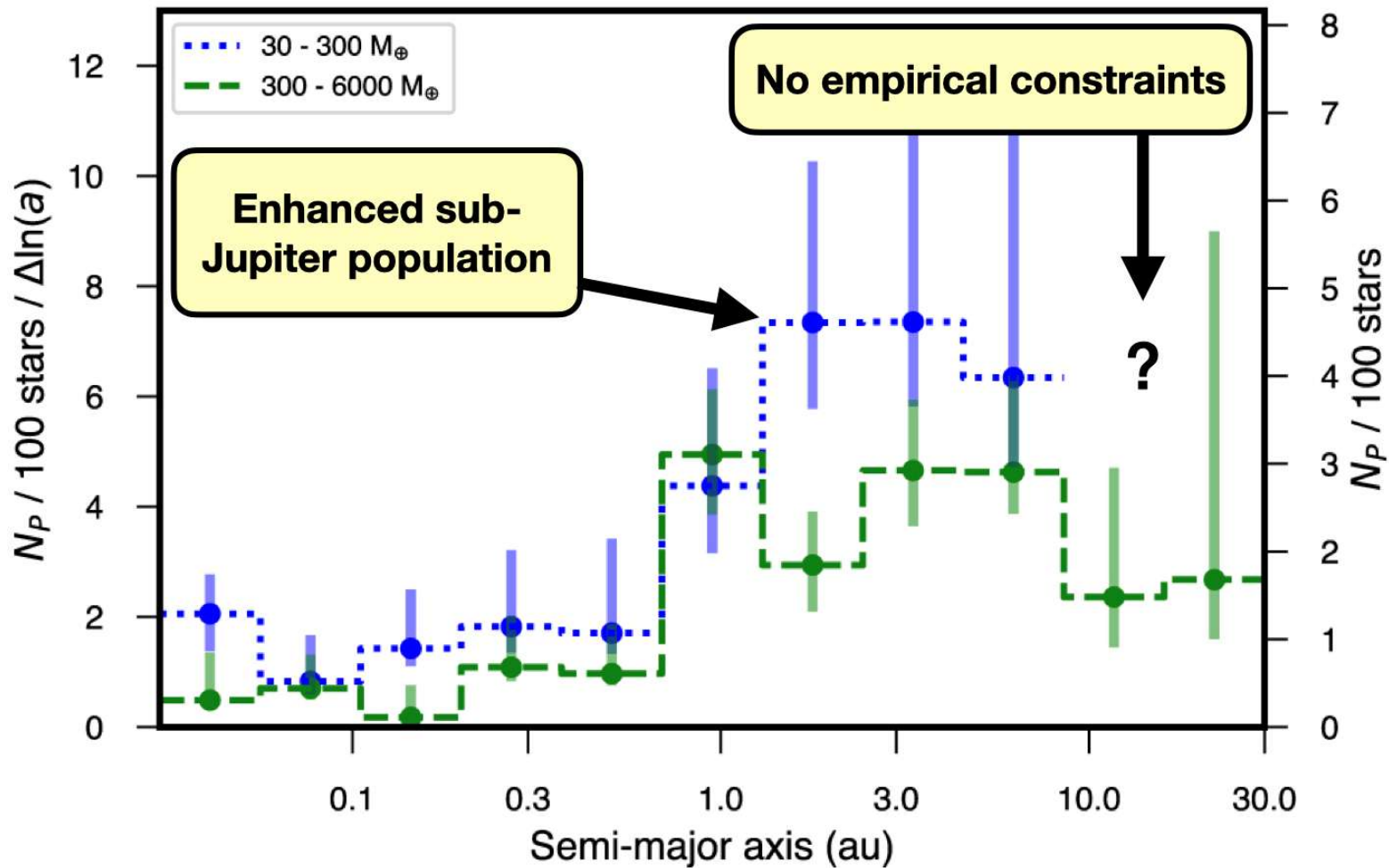
Imaging and RV agree that widely separated,  
> 1  $M_{\text{Jup}}$  companions are rare

Fulton et al. 2021



~500 stars have been surveyed as part of the SPHERE SHINE (Vigan et al. 2021) and the Gemini GPIES survey (Nielsen et al. 2019), with only a handful of exoplanets detected. Do we expect JWST to do any better?

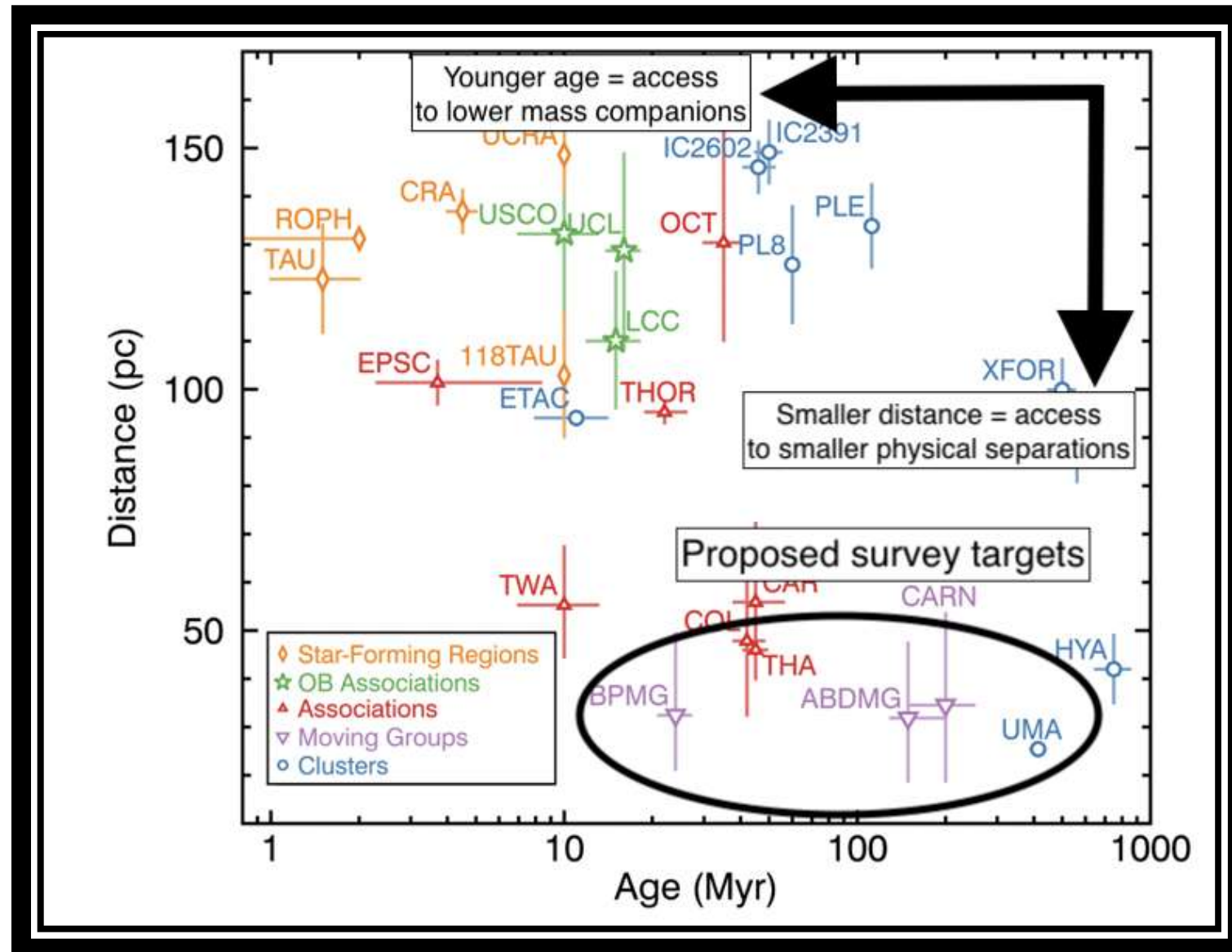
RV studies suggest an enhanced population of sub-Jupiter exoplanets



Fulton et al. 2021



# The moving group opportunity





GO 4050 (PI Carter) — Cycle 2, 23 TW Hya association stars, mostly M dwarf targets



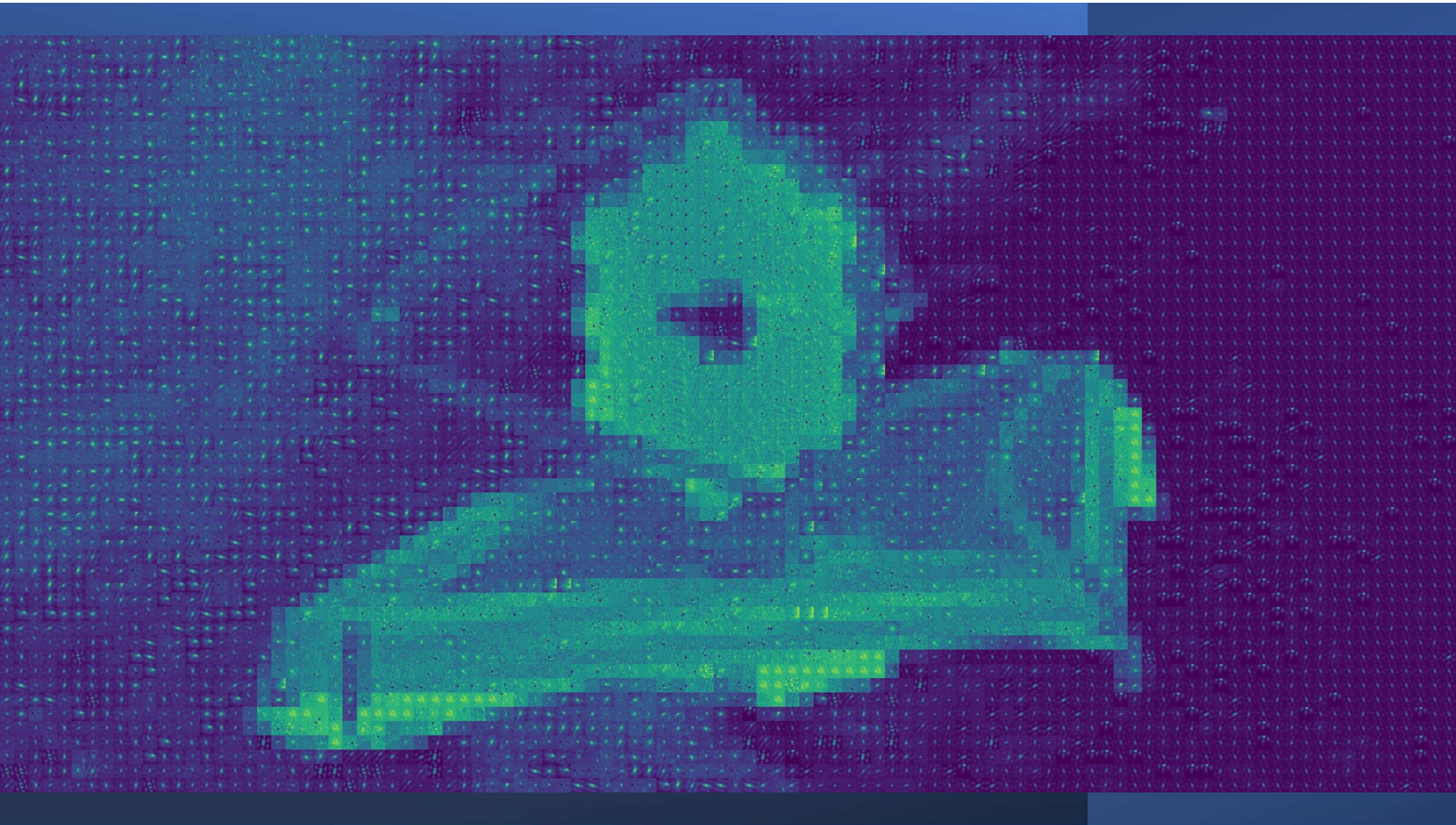
GO 5835 (PI Carter) — Cycle 3, 56 Beta Pic MG stars



SURVEY 6005 (PI Biller) — Cycle 3, 90 stars, various nearby moving groups with members within 60 pc, FGK star targets

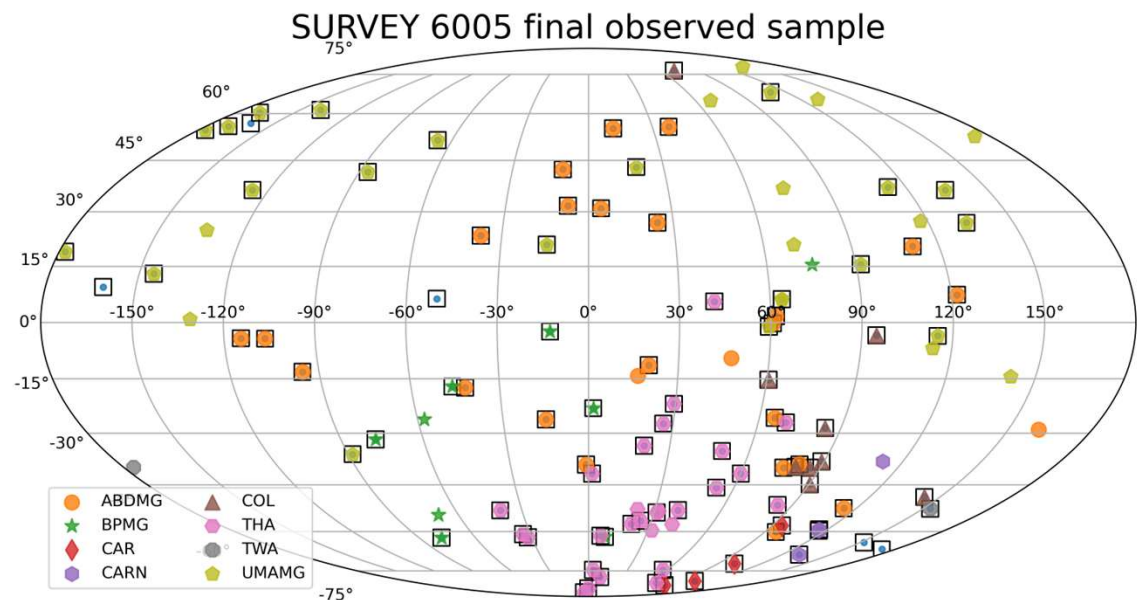
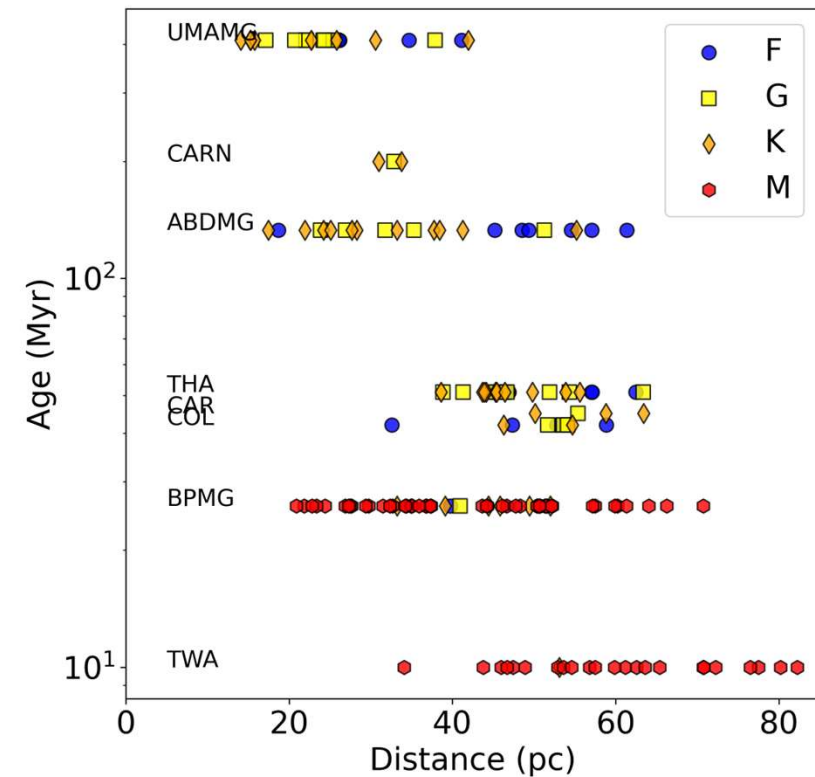
170 Moving Group stars surveyed  
in JWST Cycle 2 and Cycle 3





# A statistically significant sample observed with JWST NIRCam F200W+F444W dual-band coronagraphy

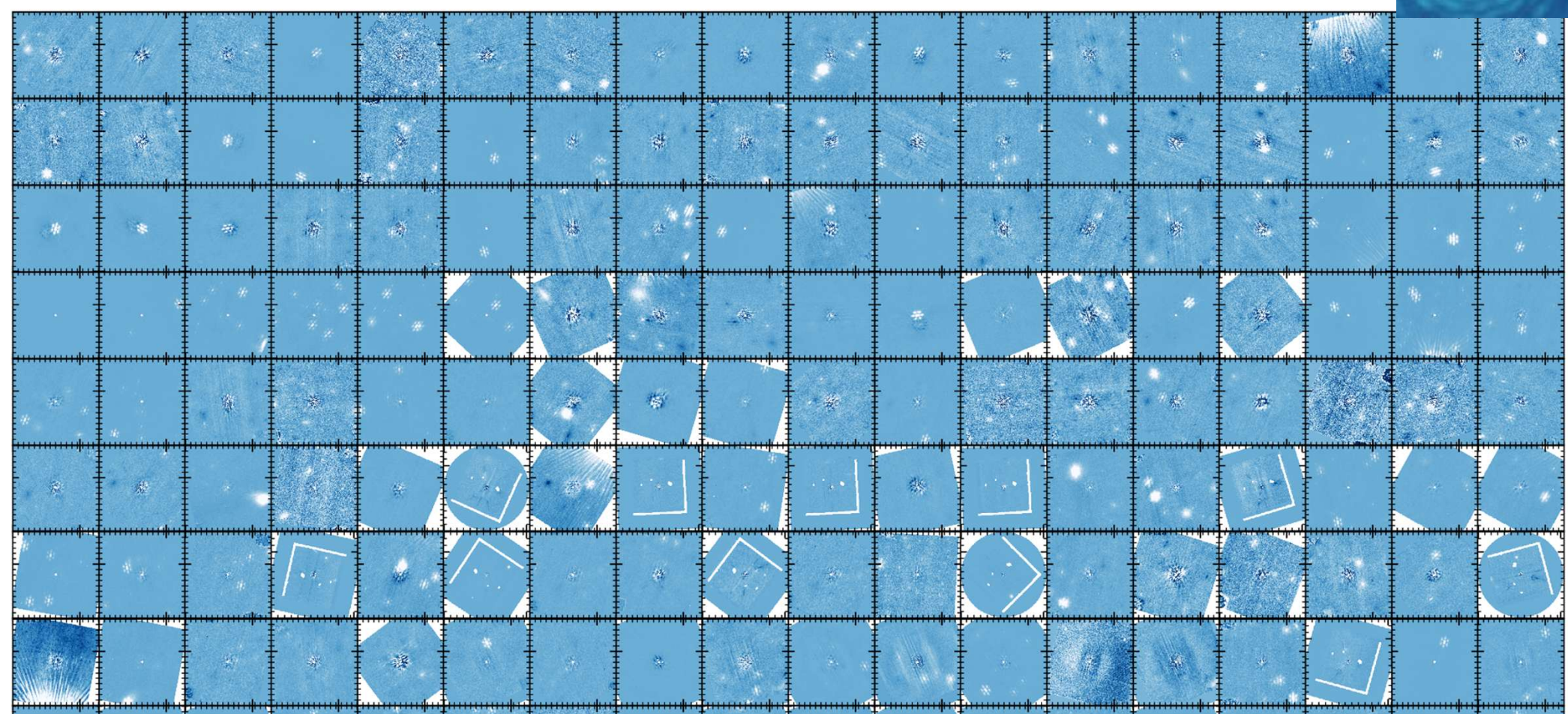
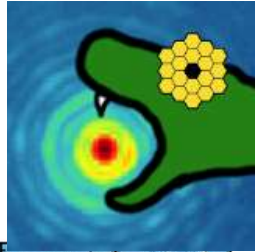
Combined GO 4050, GO 5835, and SURVEY 6005 samples





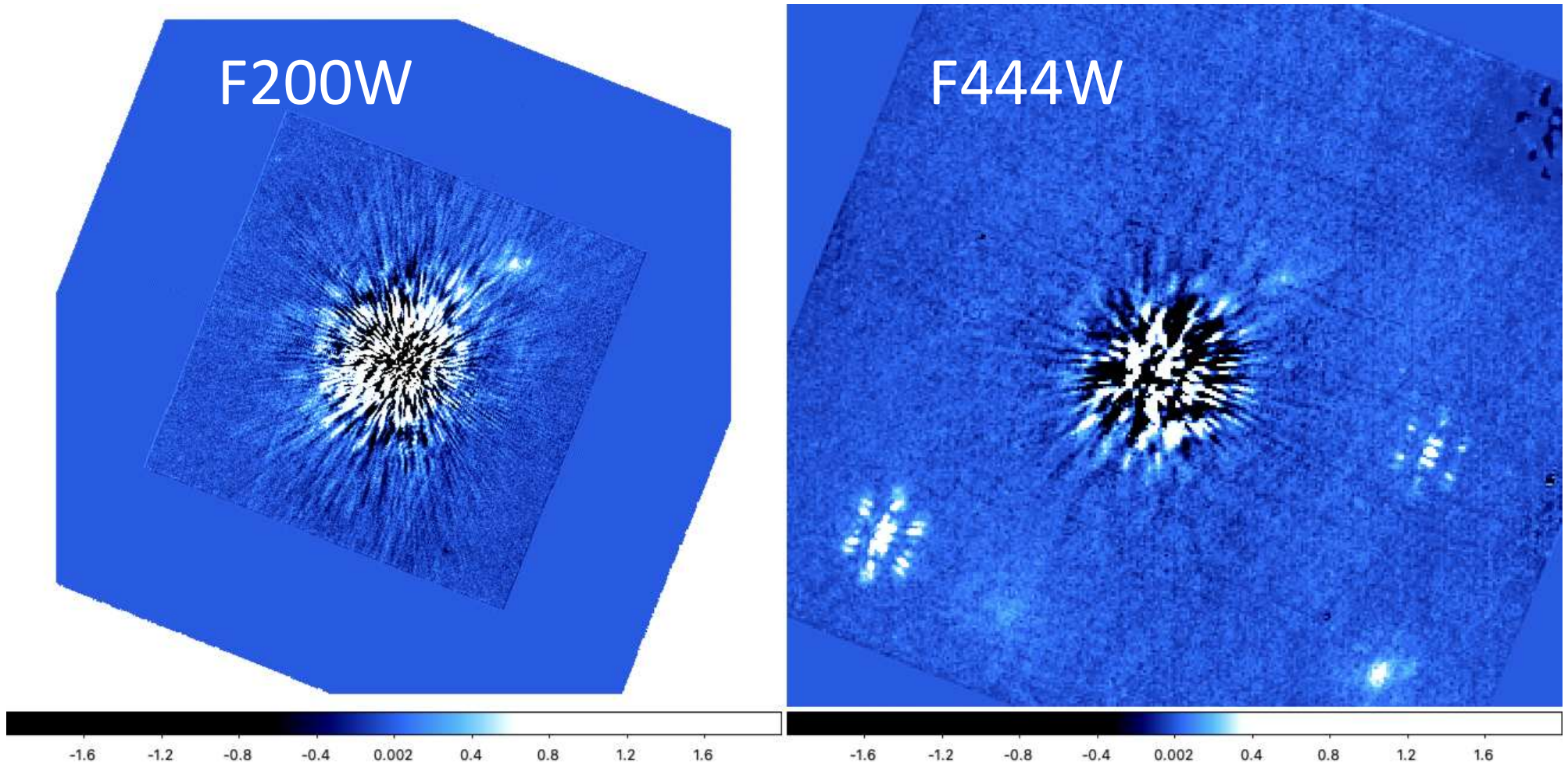
# All F444W images – after processing with spaceKLIP

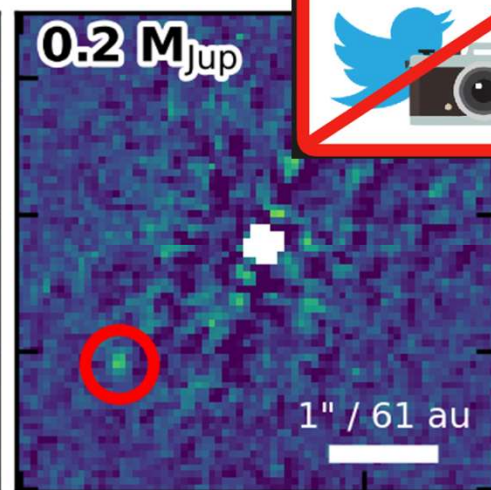
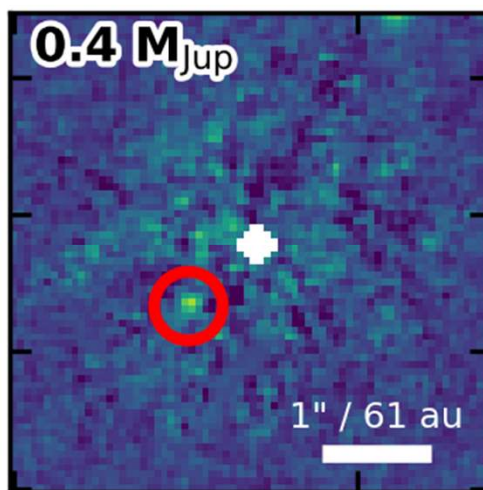
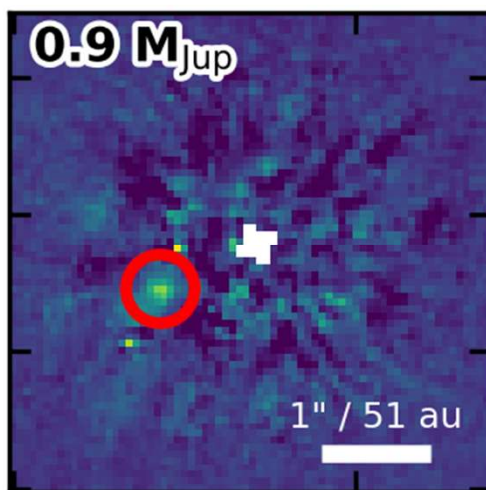
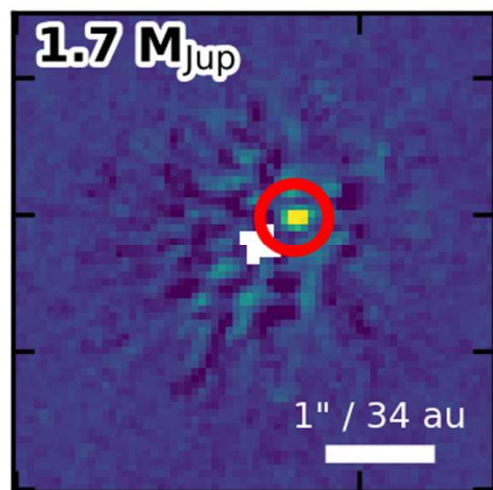
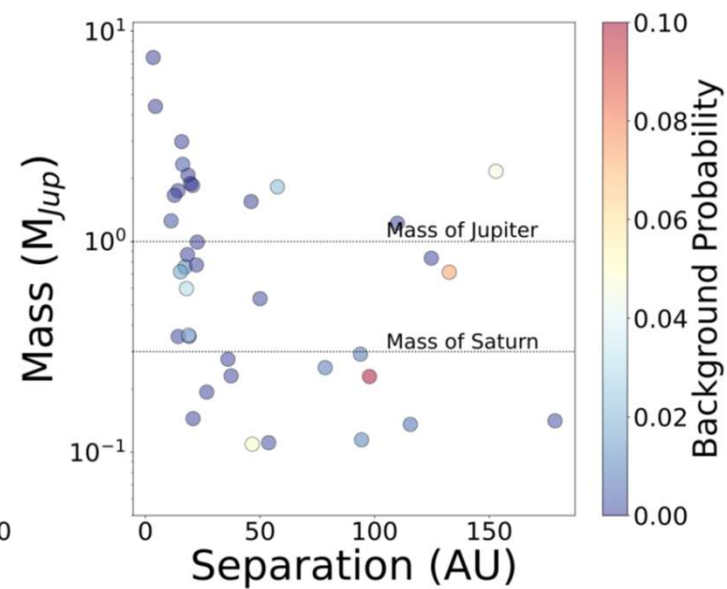
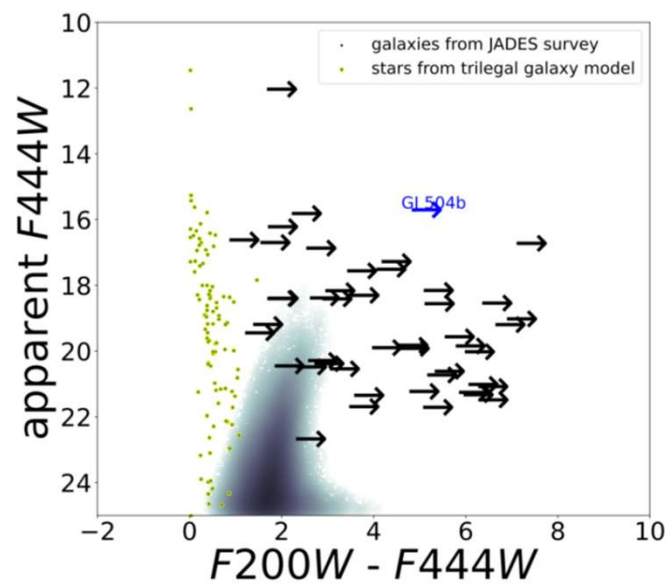
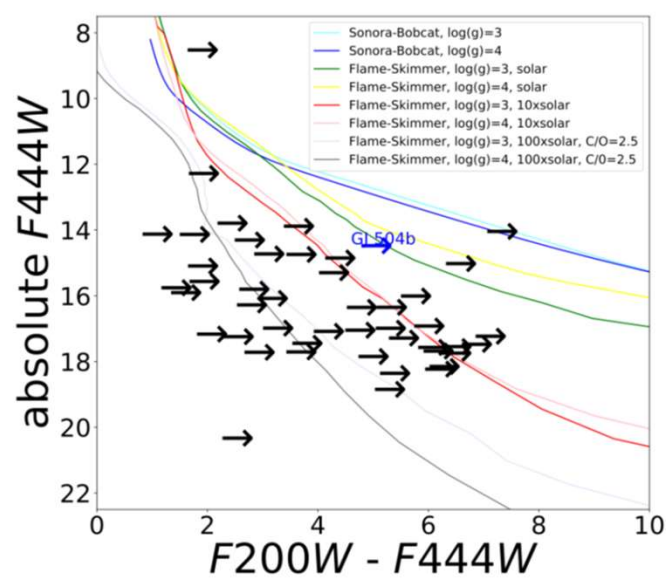
<https://spaceklip.readthedocs.io/>, Kammerer et al. 2022, Carter et al. 2023





A whole new world... of background contaminants







[M1.5]

+

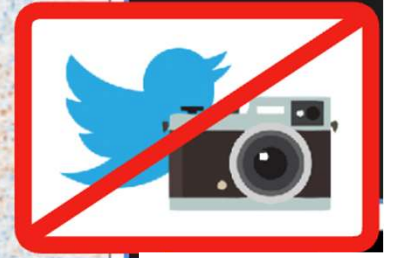
Discovery

[K7]

First time resolved

[G0]

First  
scattered light



[K6]

Discovery

[M2]

Discovery

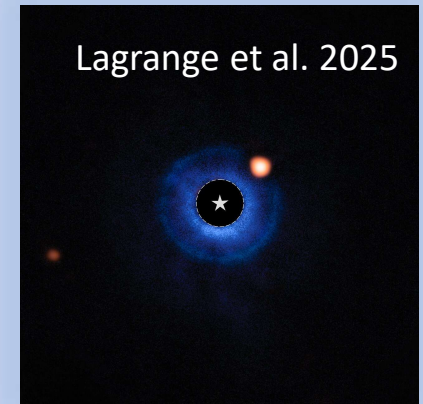
[M4]

Discovery



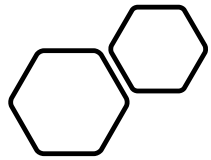
# Takeaways:

Hopefully more of these soon! →



- Temperate ( $<400$  K) giant exoplanets are the next frontier for exoplanet atmospheric studies
- JWST has yielded the first images of such exoplanets in the last 2 years
- This class of planets will be imaged and characterized in detail with the ELT
- A systematic survey of young, nearby stars with JWST can detect cool, young planets down to Saturn masses
- With  $\sim 170$  stars observed, we have identified  $\sim 40$  candidate companions and have proposed for common-proper motion follow-up

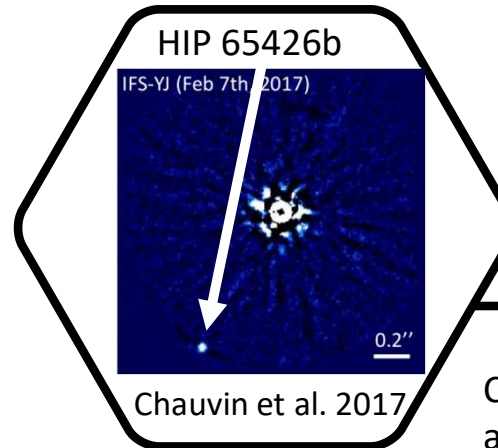
Backup Slides



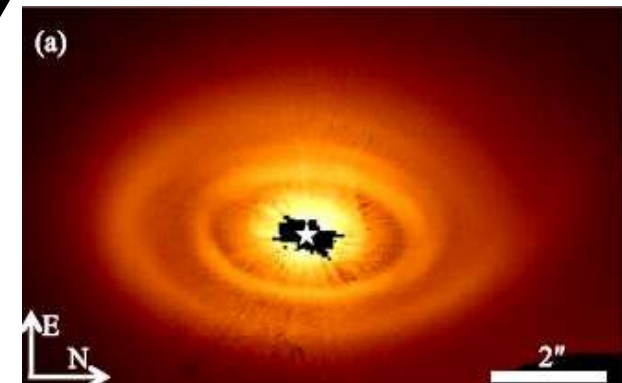
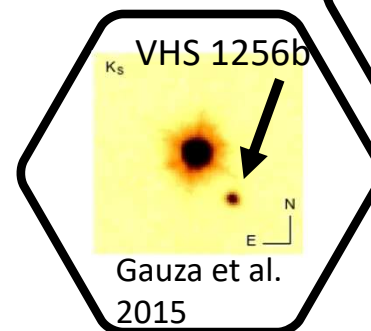
## JWST ERS 1386: High-Contrast Imaging of Exoplanets and Exoplanetary Systems with JWST (PI: Hinkley, Co-PIs: Biller, Skemer)

68-hour programme observing 3 targets with all 4 instruments:

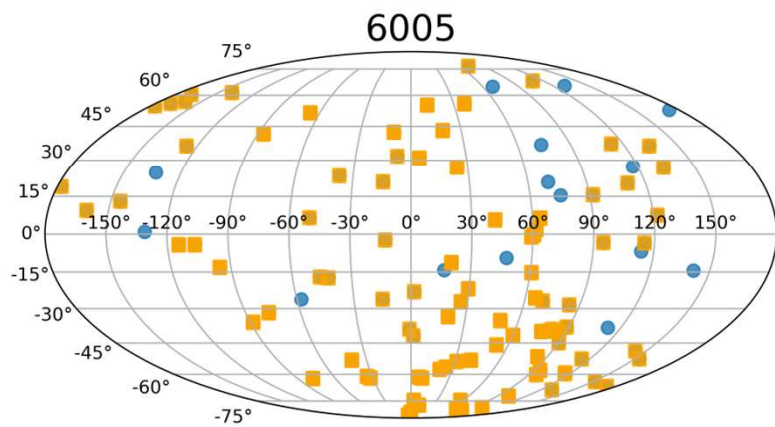
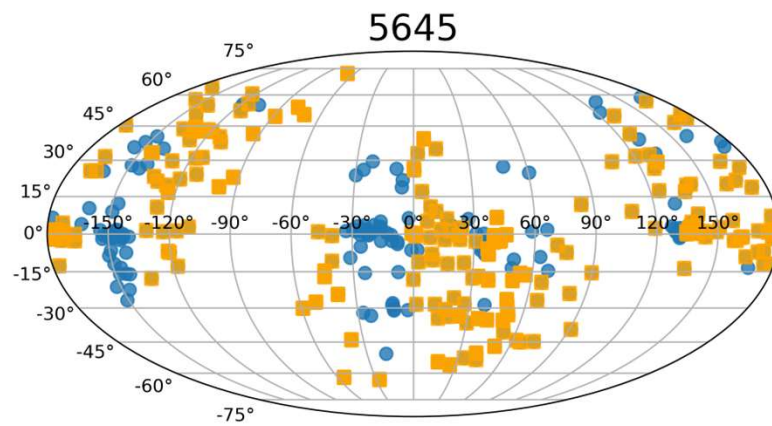
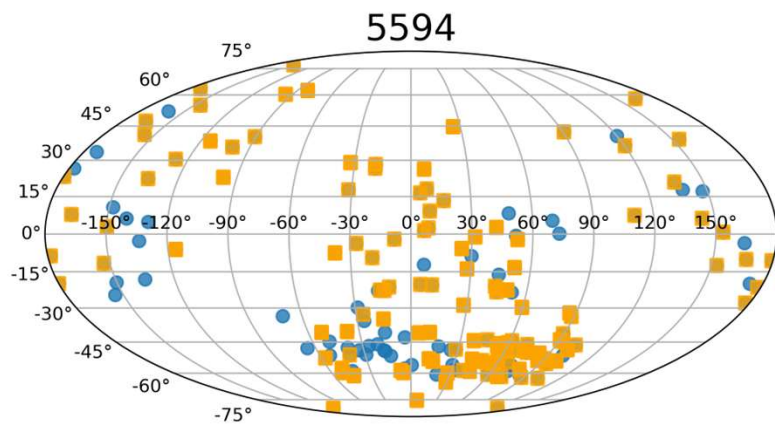
- Dusty young giant planet HIP 65426b (Carter et al. 2023)
- Protoplanetary disk around HD 141569 (Millar-Blanchaer et al. accepted, Choquet et al. in prep)
- Wide (8" separation) <20 Jupiter mass companion to late-M binary VHS 1256 (Miles et al. 2023)



Circumstellar Disk around HD 141569



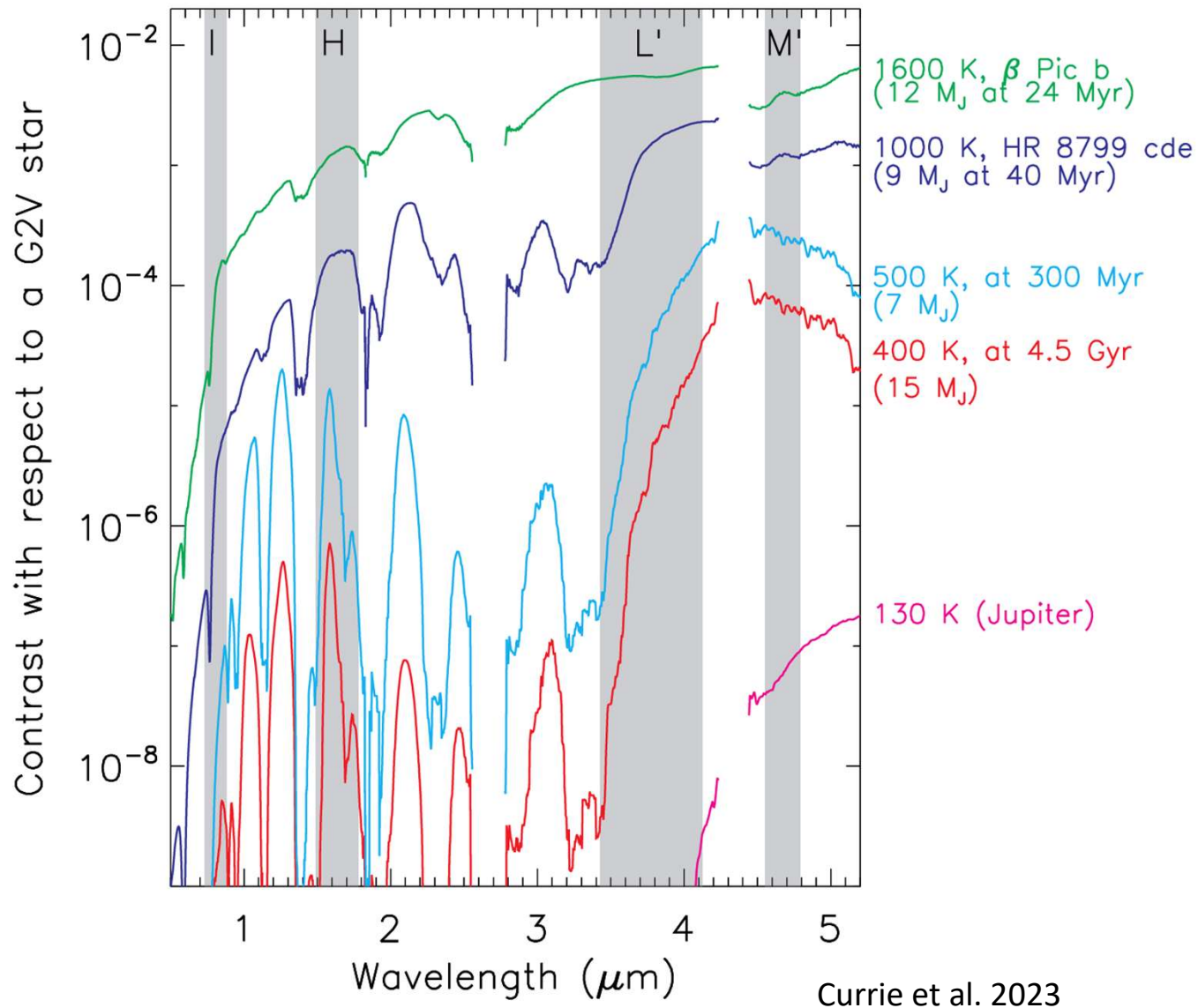
Konishi et al. 2016



● Survey Target  
■ Observed



New Frontiers –  
Colder and  
Lower Mass  
Exoplanets, first  
with JWST and  
then ELT



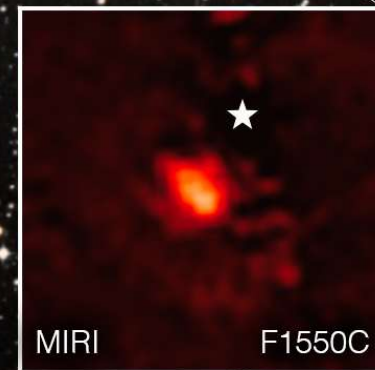
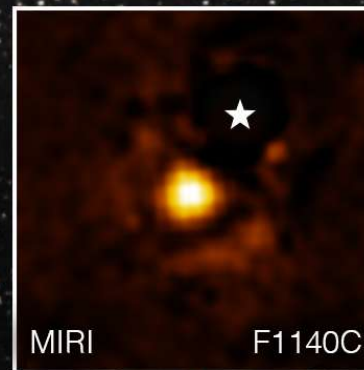
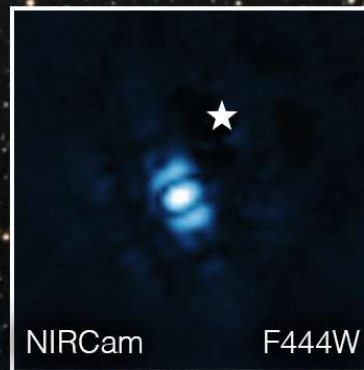
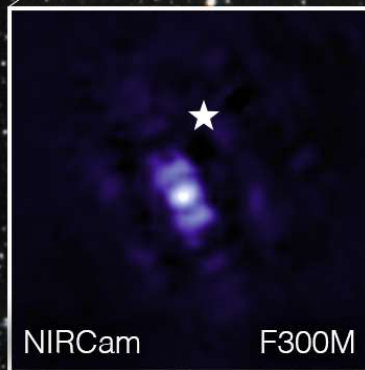
Digitized Sky Survey

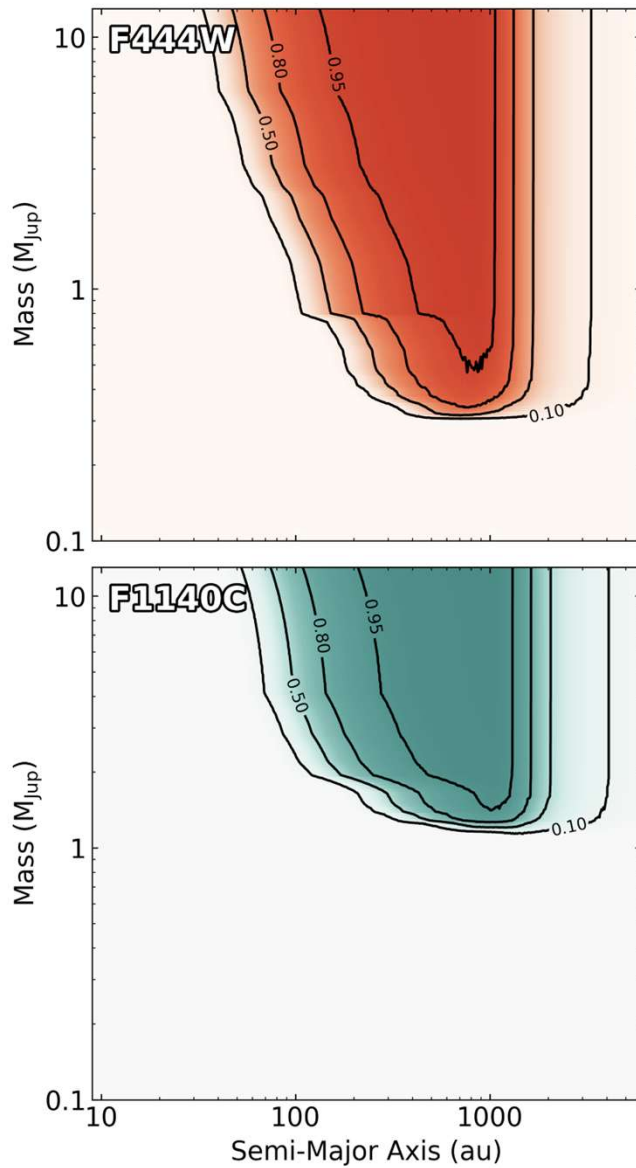
HIP 65426

# The First Image of an Exoplanet with JWST

Carter et al. 2023

HIP 65426b





JWST is sensitive to widely-separated young analogues of Saturn

Carter et al. 2023, using Mariangela Bonavita's EXO-DMC code