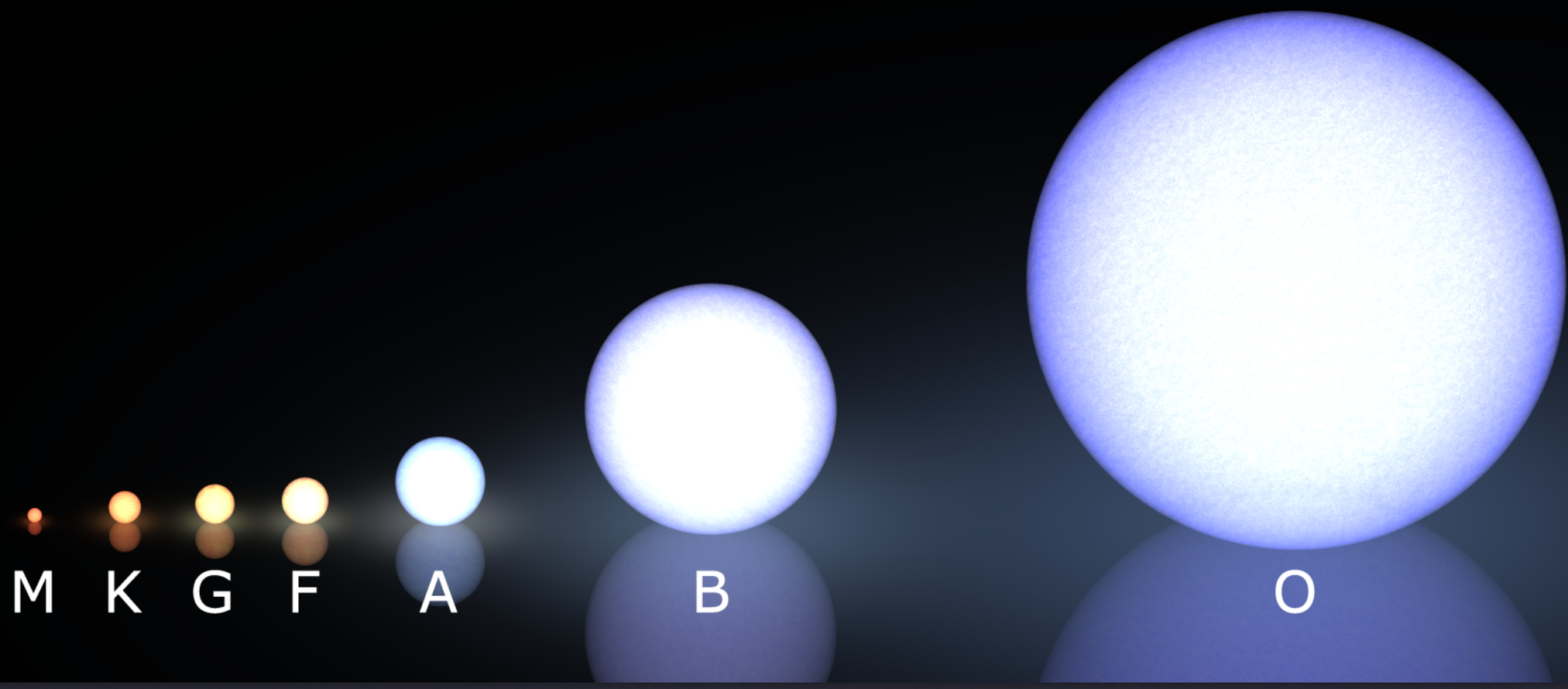
Young M Dwarfs and their Planets: Discoveries from *K2* and Prospects for the *JWST*

Joshua Schlieder
NASA Ames - *soon to be* NExScI/Caltech

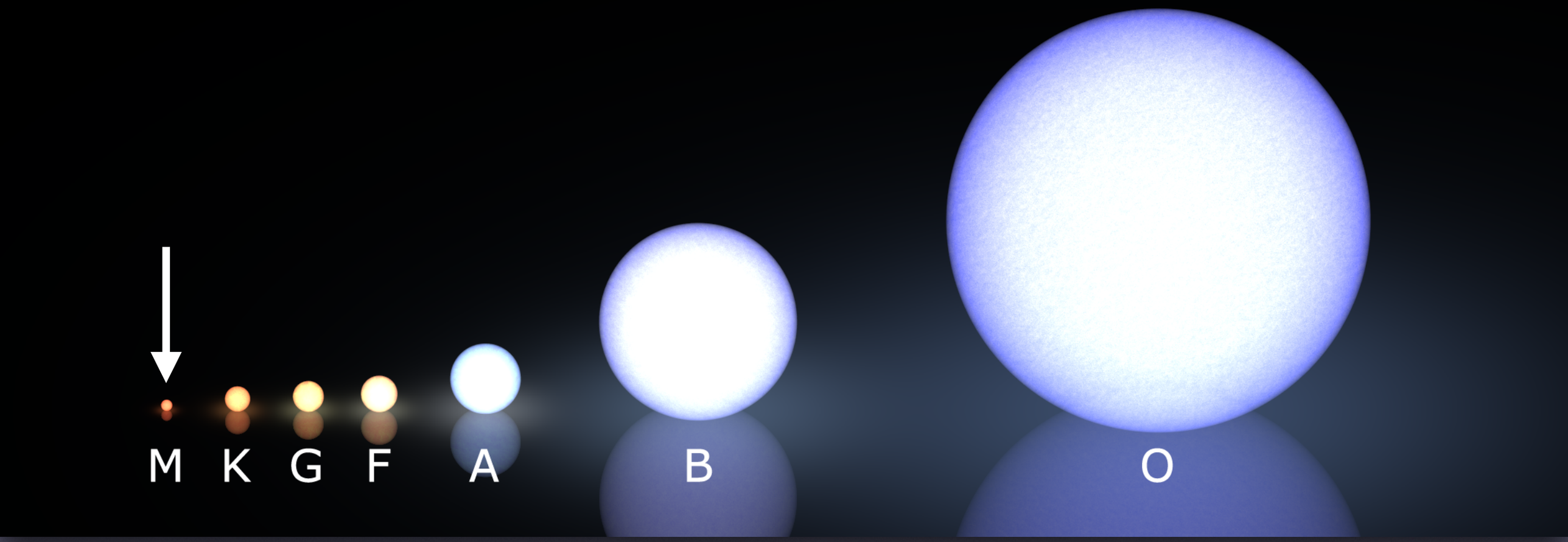
JPL NExScI Science Briefing
2016-05-23

M Dwarfs: Runts of the Litter



M Dwarfs: Runts of the Litter

M Dwarfs: Runts of the Litter



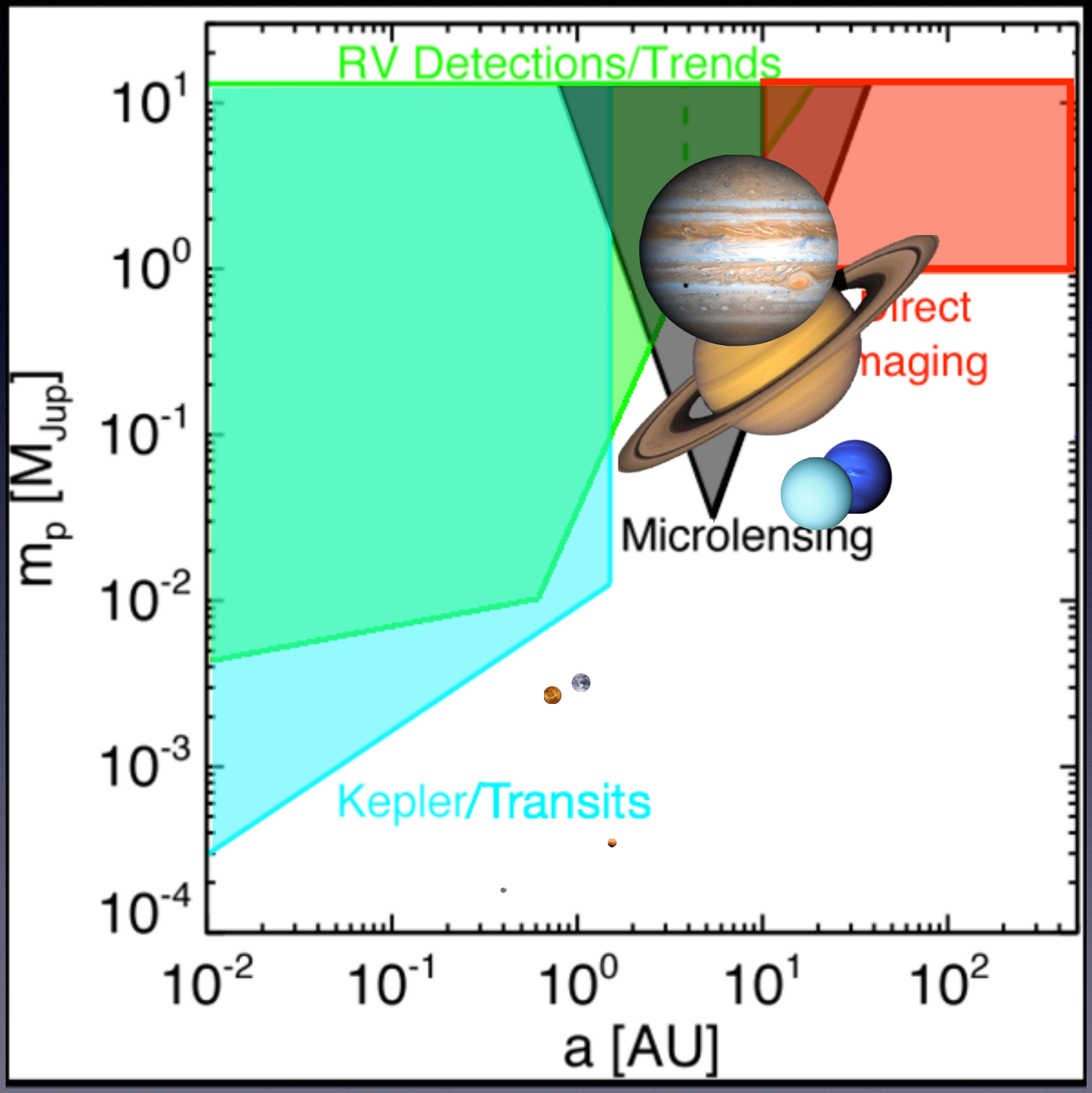
M Dwarf Stats: Small — $R_{\star}$, $M_{\star} \approx 0.6$ - $0.08\ R_{\odot}, M_{\odot}$

Faint — $L_{\star} \approx 0.03$ - $0.0003\ L_{\odot}$

Cool — $T_{eff} \approx 3900$ - 2500 K

Many - ~75% of all stars

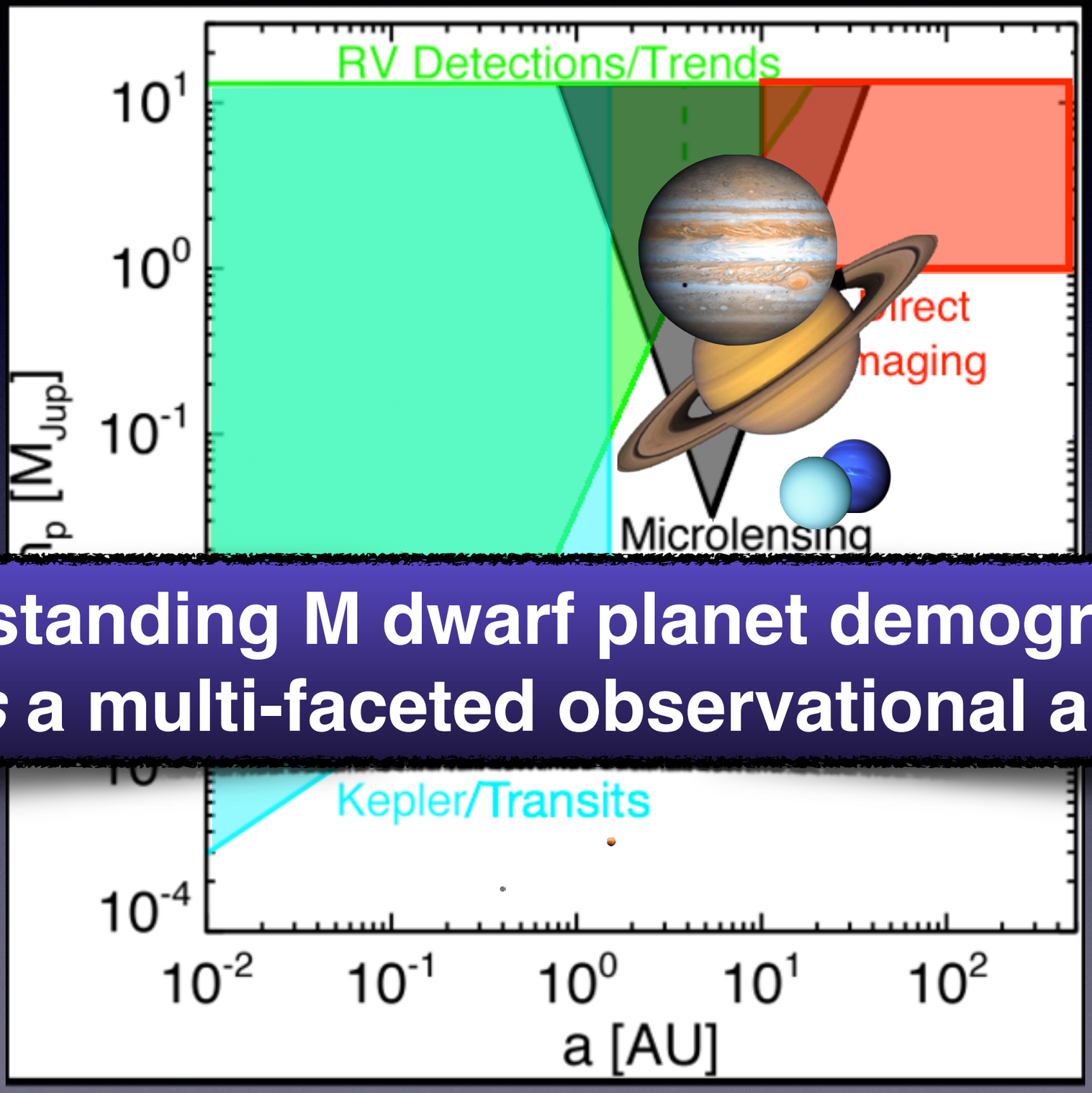
M Dwarf Planets



adapted from Clanton et al. 2014b

data: NASA Exoplanet Archive

M Dwarf Planets

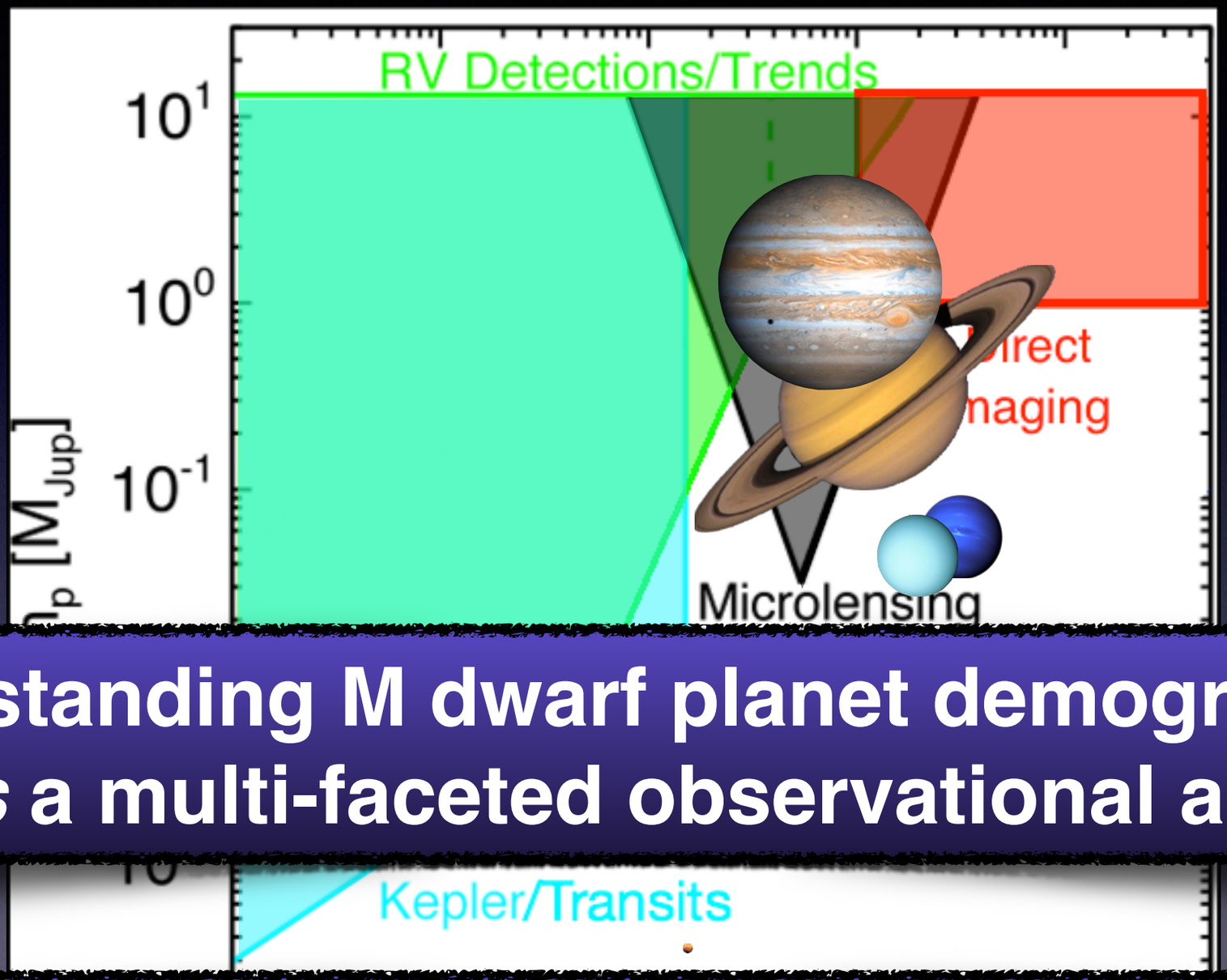


Understanding M dwarf planet demographics *requires* a multi-faceted observational approach

adapted from Clanton et al. 2014b

data: NASA Exoplanet Archive

M Dwarf Planets



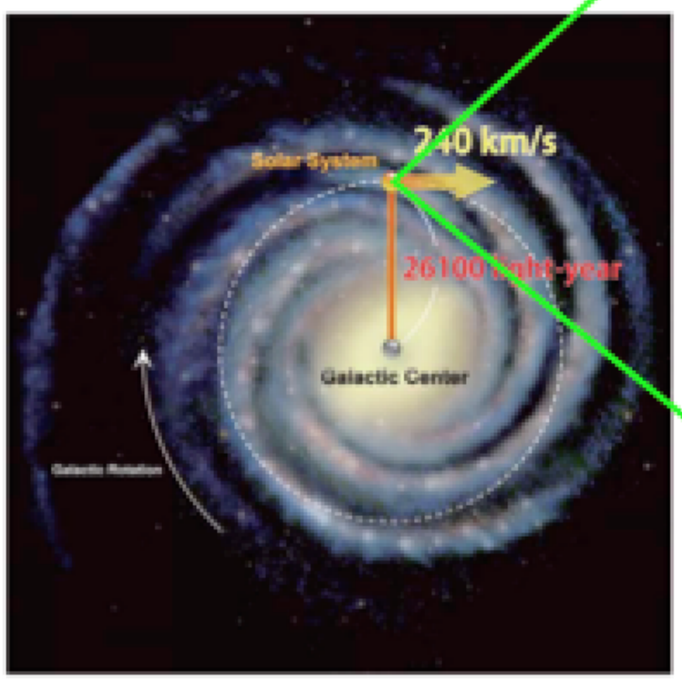
Understanding M dwarf planet demographics *requires* a multi-faceted observational approach

Studying young M dwarfs provides access to young planets at key times in their evolution

adapted from Clanton et al. 2014b

data: NASA Exoplanet Archive

Young M Dwarfs Near the Sun



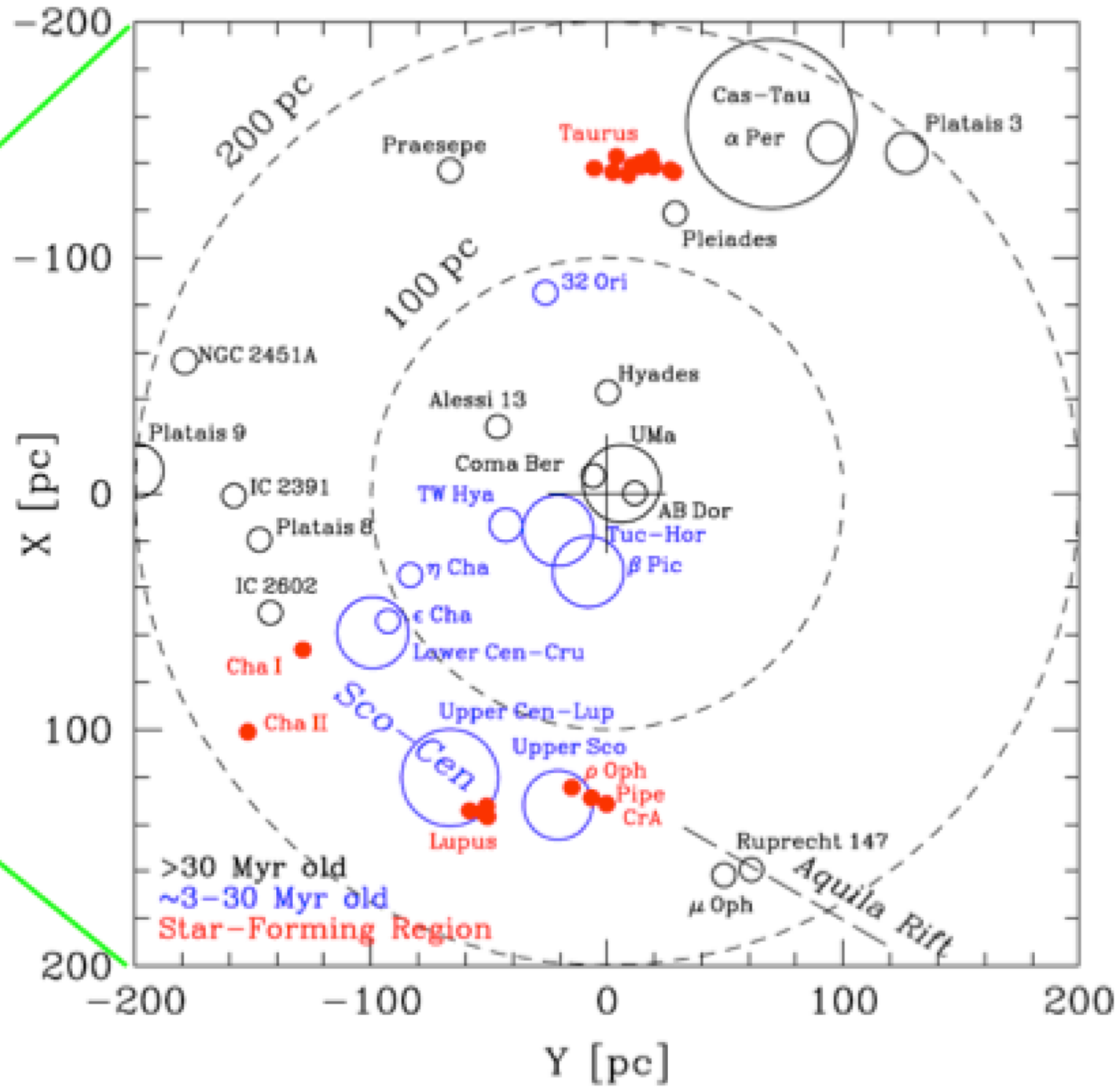
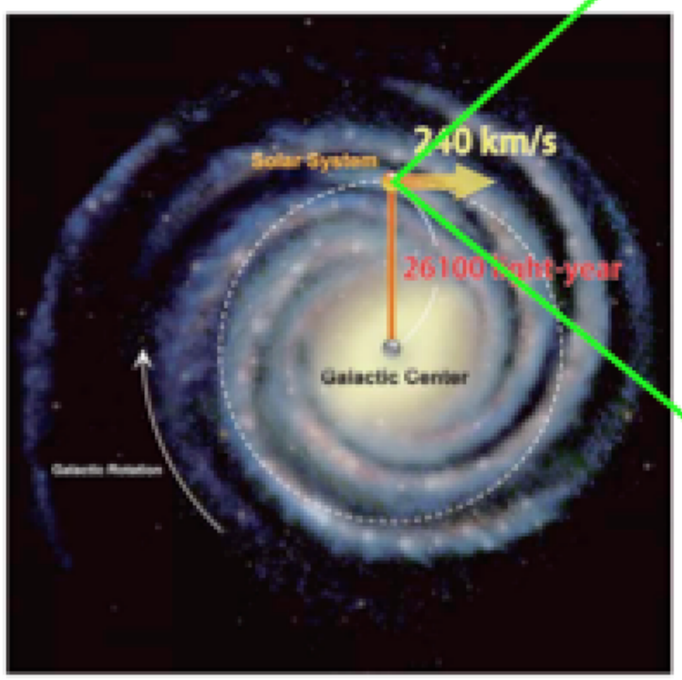


Fig. - E. Mamajek

Young M Dwarfs Near the Sun



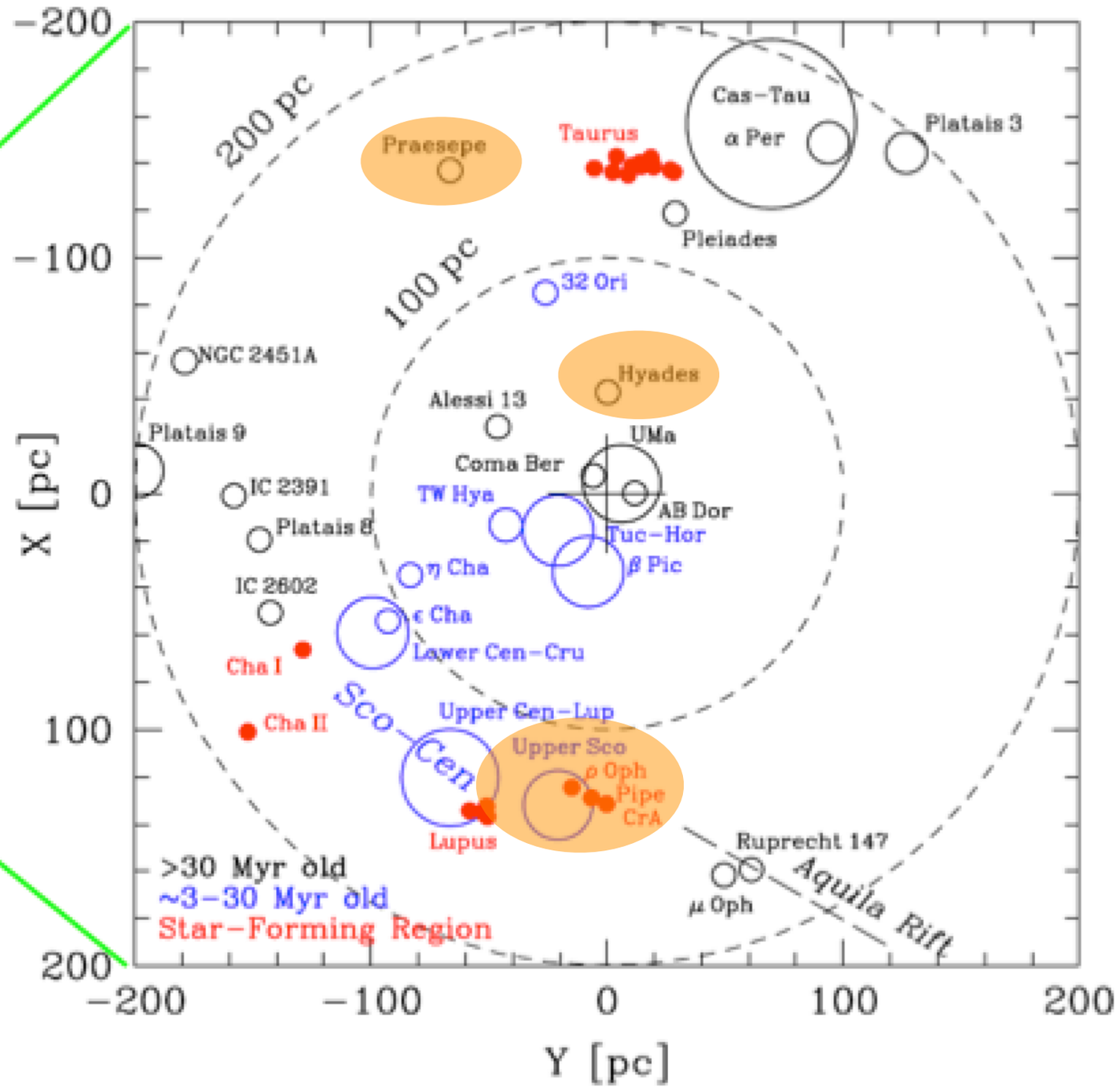
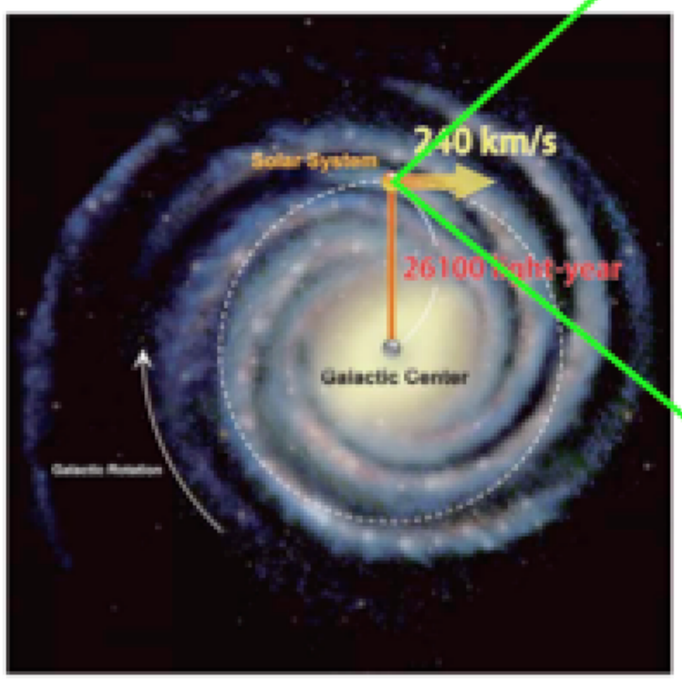


Fig. - E. Mamajek

Young M Dwarfs Near the Sun



Open Clusters
-ages 5 - 800 Myr

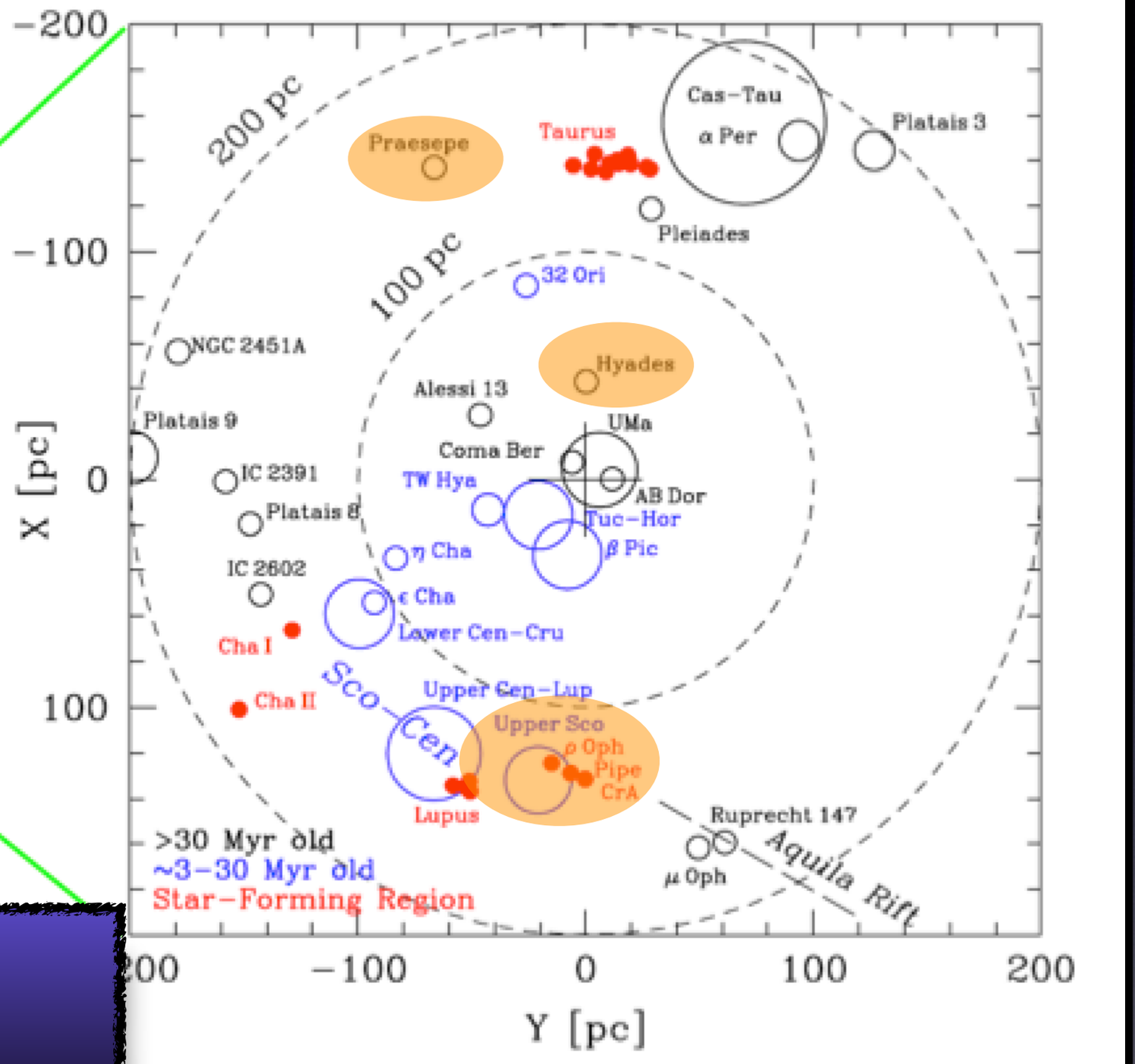
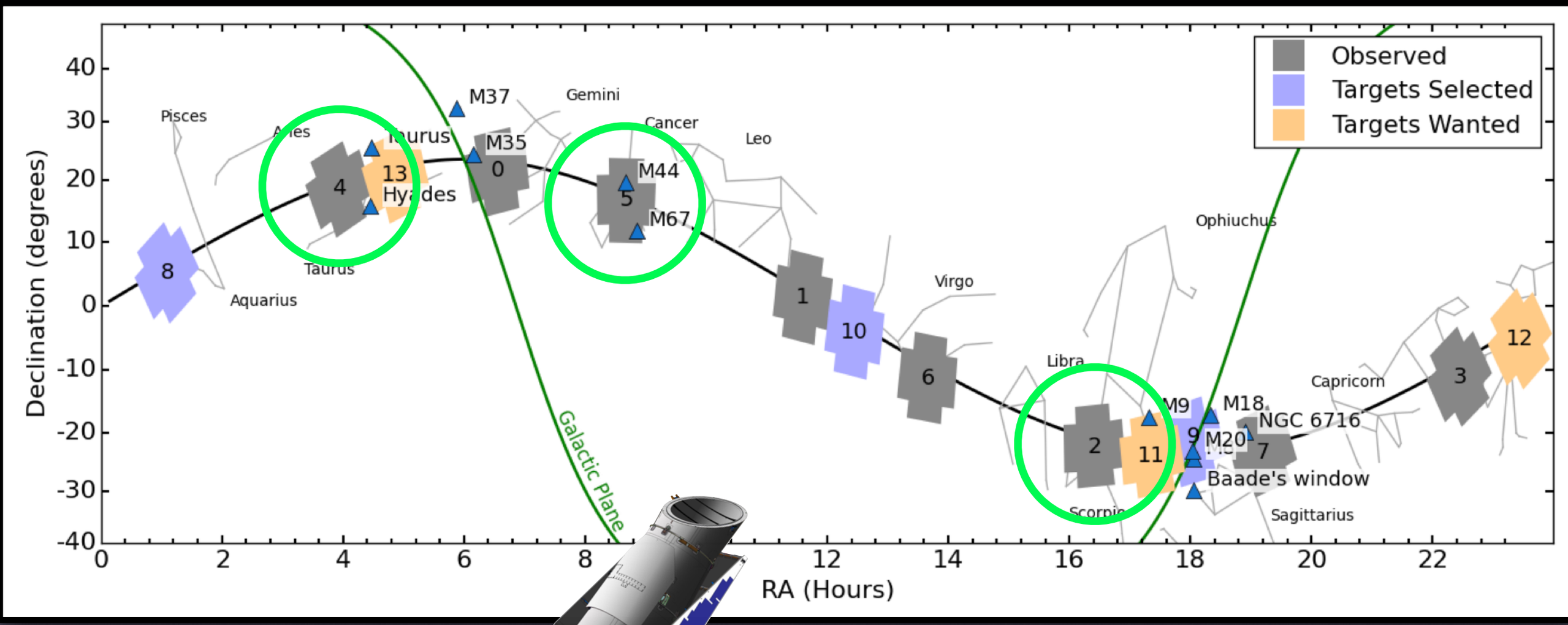


Fig. - E. Mamajek

Open Clusters with *K2*



K2 has observed several open clusters with wide spanning ages - search for planets transiting M dwarfs

http://keplerscience.arc.nasa.gov/k2-fields.html

The Beehive Cluster, M44, Praesepe

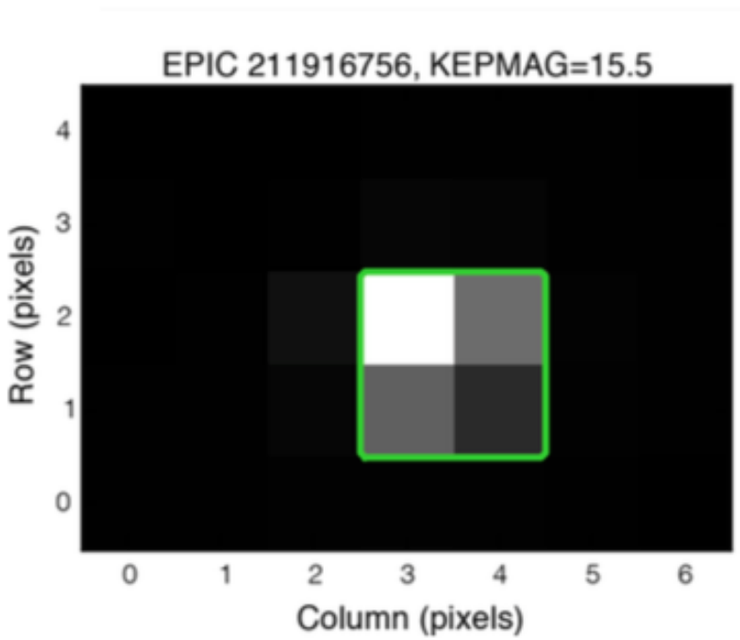
1000 stars, 500 - 600 $M_\odot$,

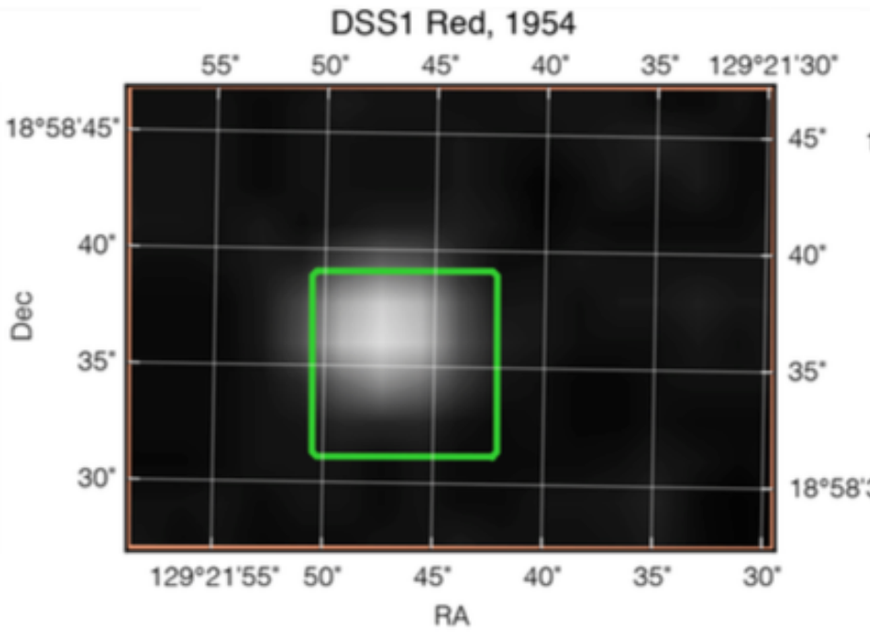
600 - 800 Myr, 180 pc

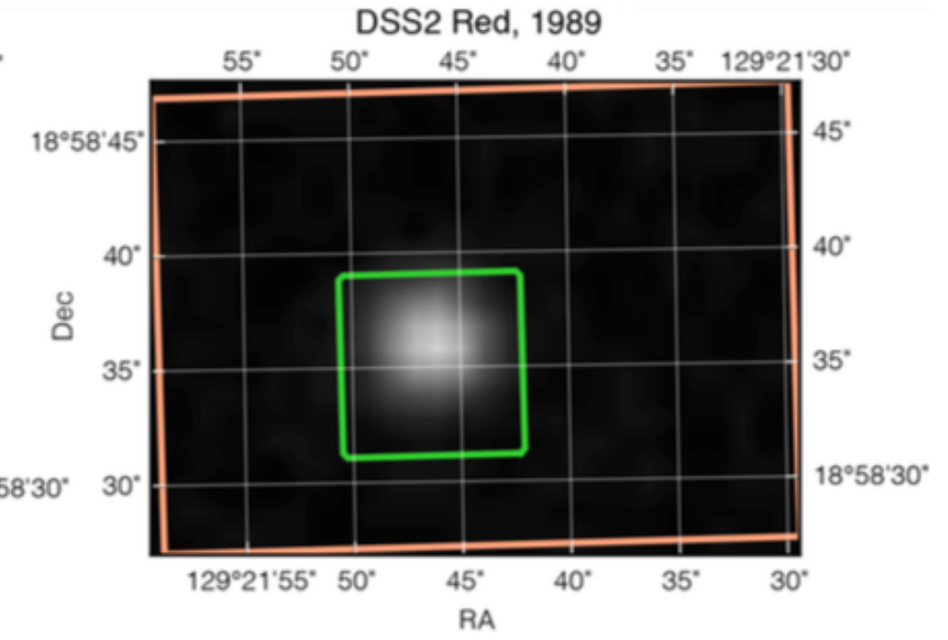
Observed by *K2* in Campaign 5

EPIC 211916756

K2 Campaign 5





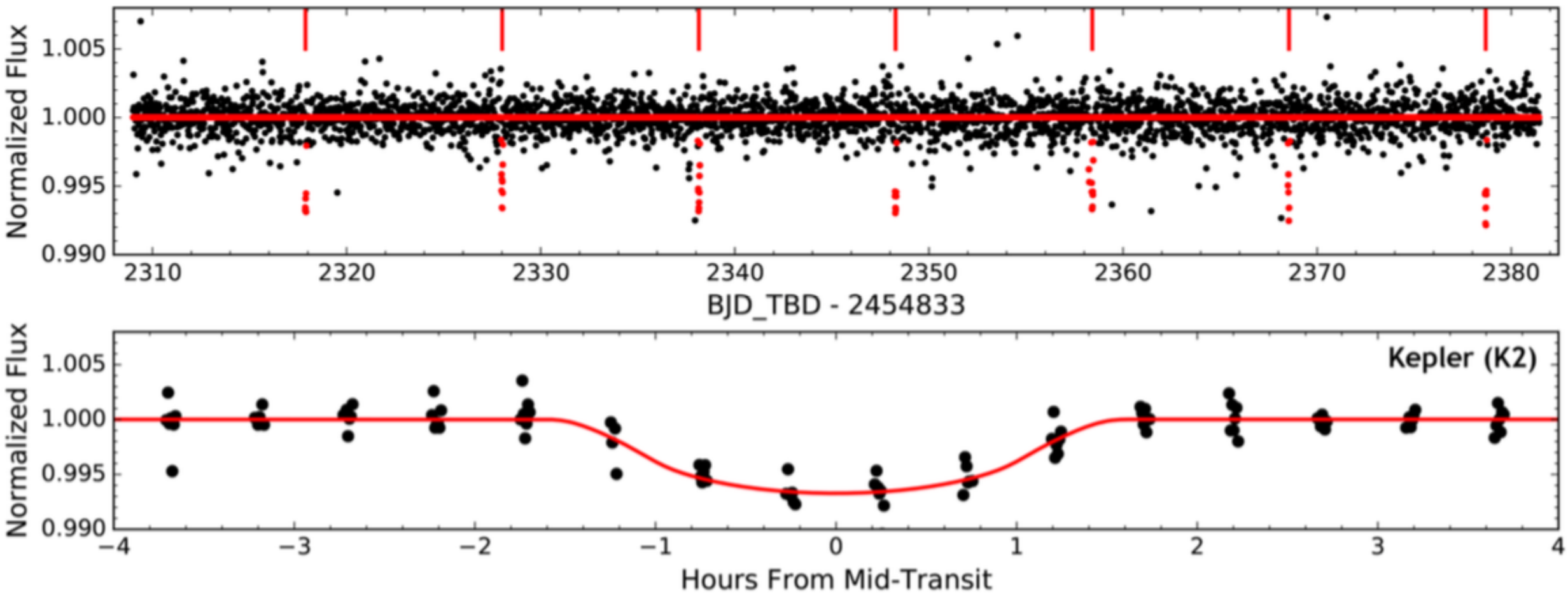


Praesepe member with >99% prob.
(Kraus & Hillenbrand 2007)

Obermeier et al., 2016, submitted

EPIC 211916756

Light curve



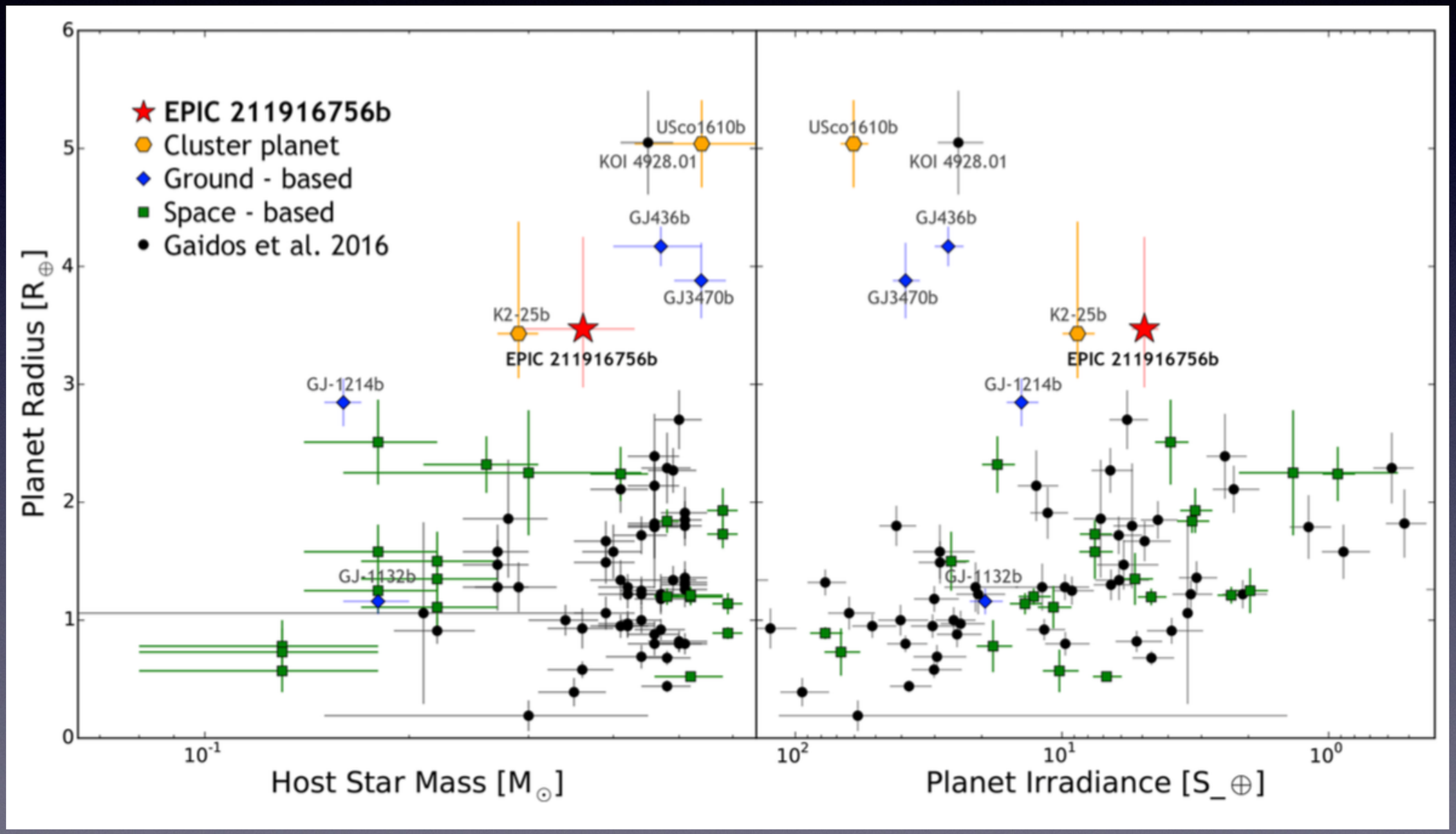
From spectroscopy - host star is M3 dwarf, R_{star} = 0.4 R_{Sun}

Planet validated using RV and photometric follow-up

R_{planet} = 3.47 R_{Earth}

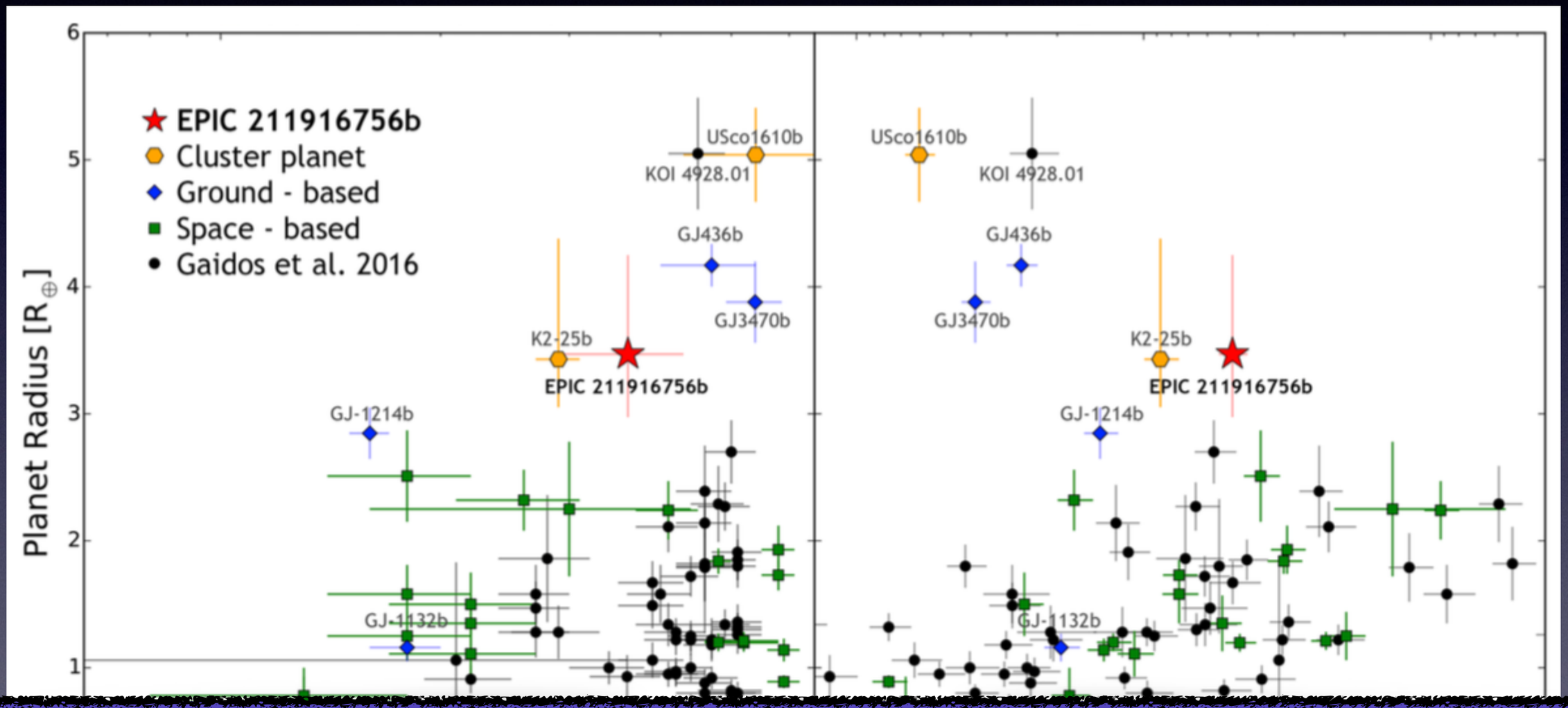
Obermeier et al., 2016, submitted

A Trend in Radii?



Obermeier et al., 2016, submitted

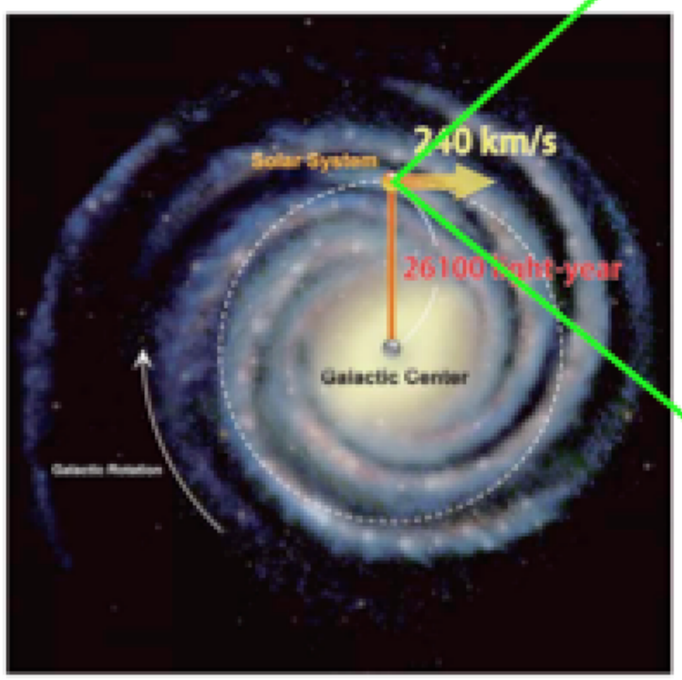
A Trend in Radii?



Young planets transiting M dwarfs have large radii: still contracting?, internal heat?, active host stars?

Obermeier et al., 2016, submitted

Young M Dwarfs Near the Sun



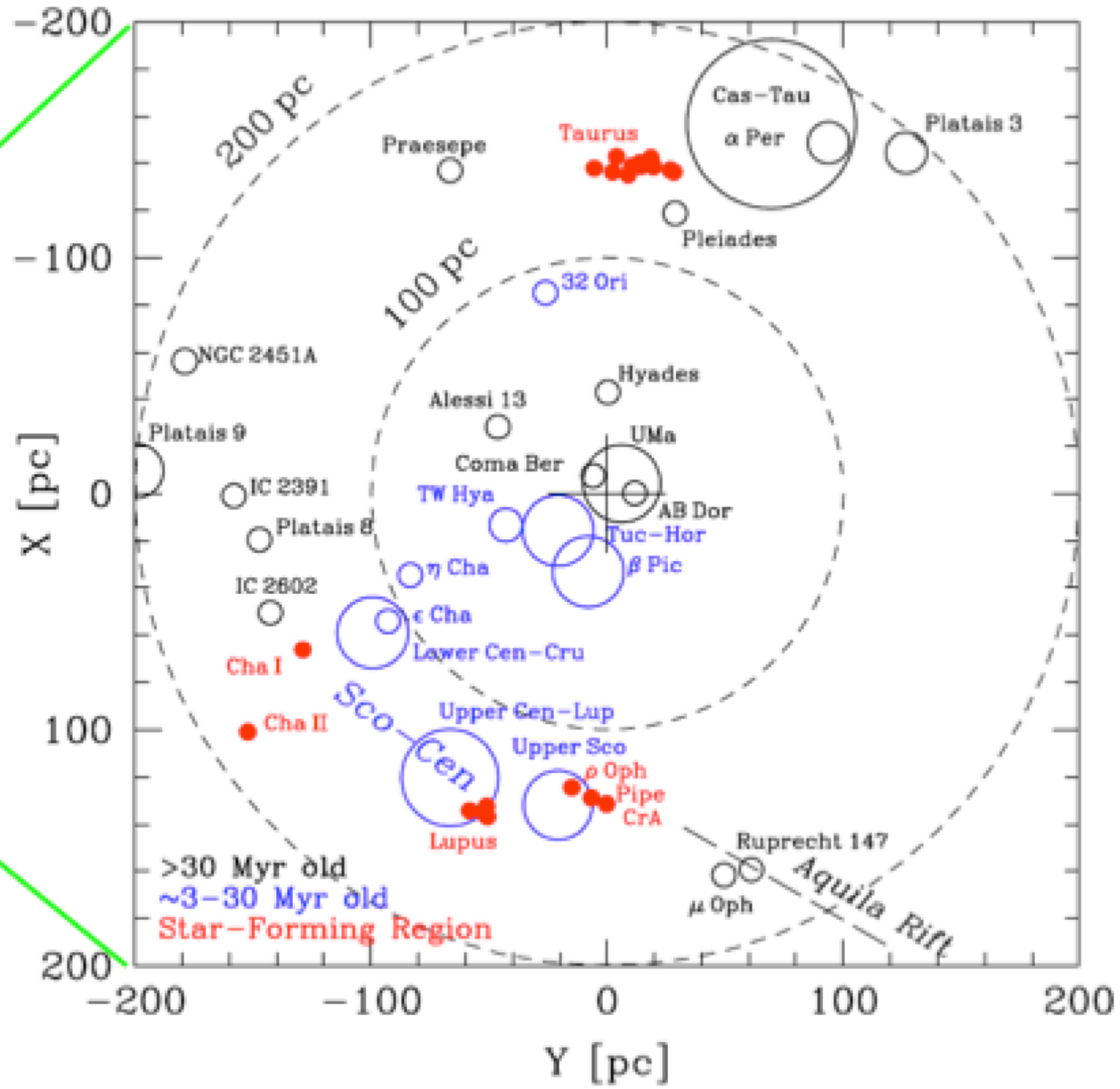
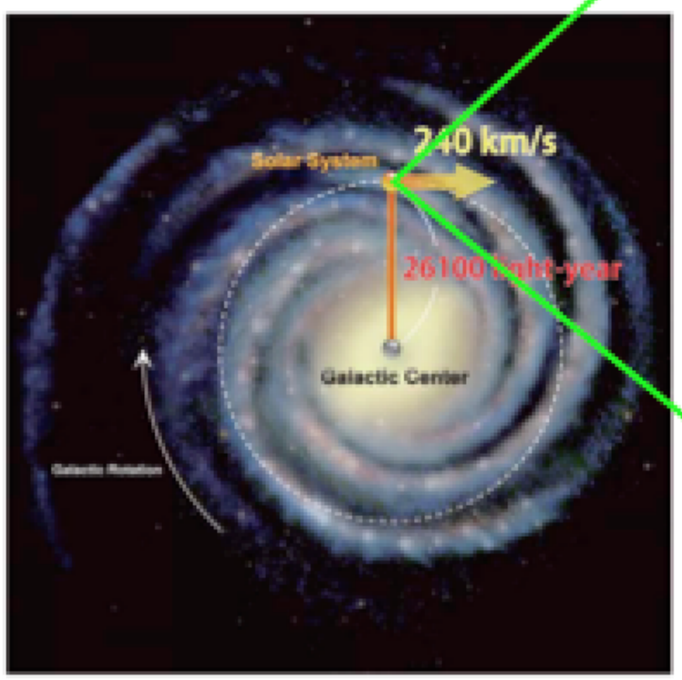


Fig. - E. Mamajek

Young M Dwarfs Near the Sun



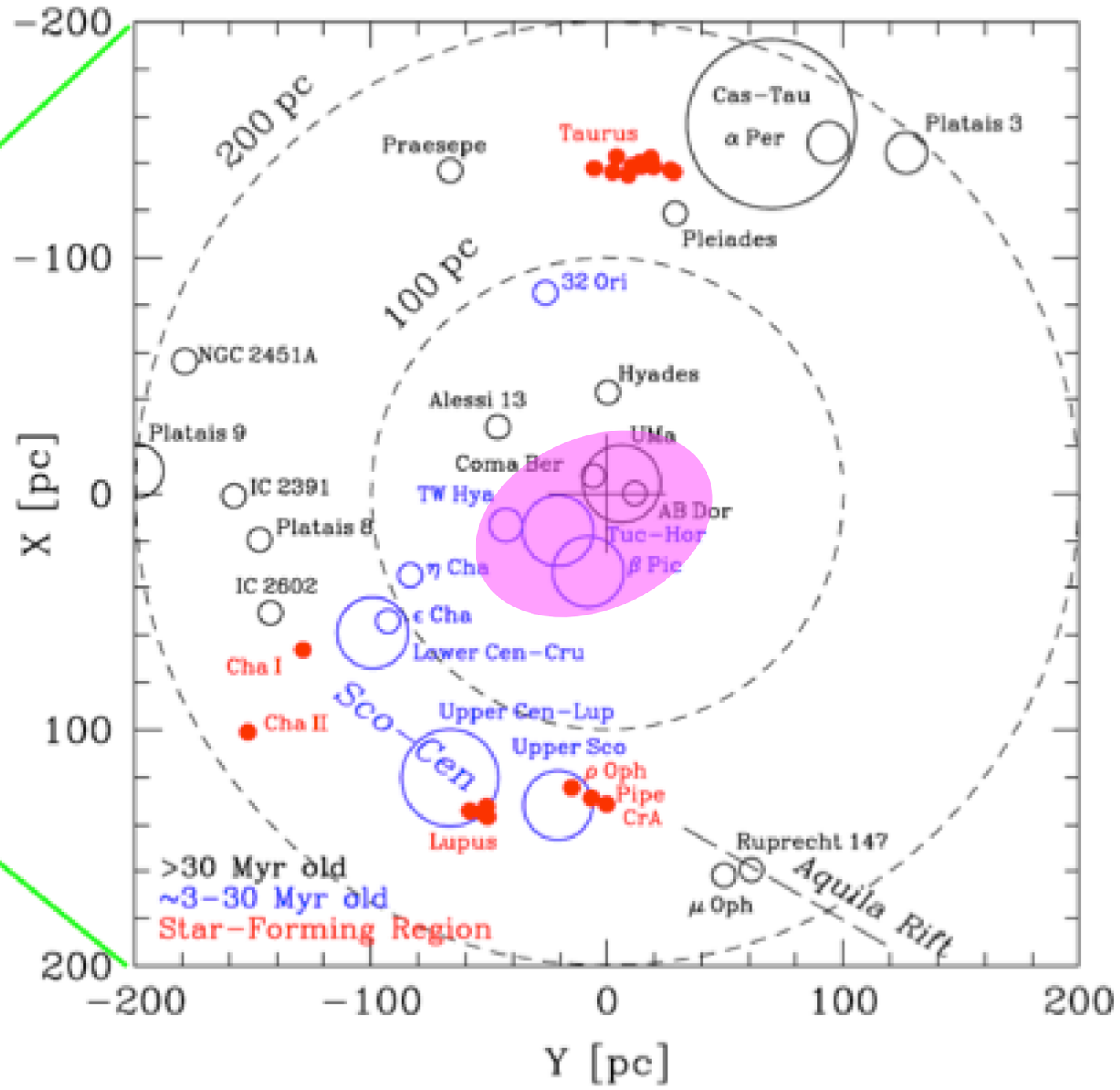
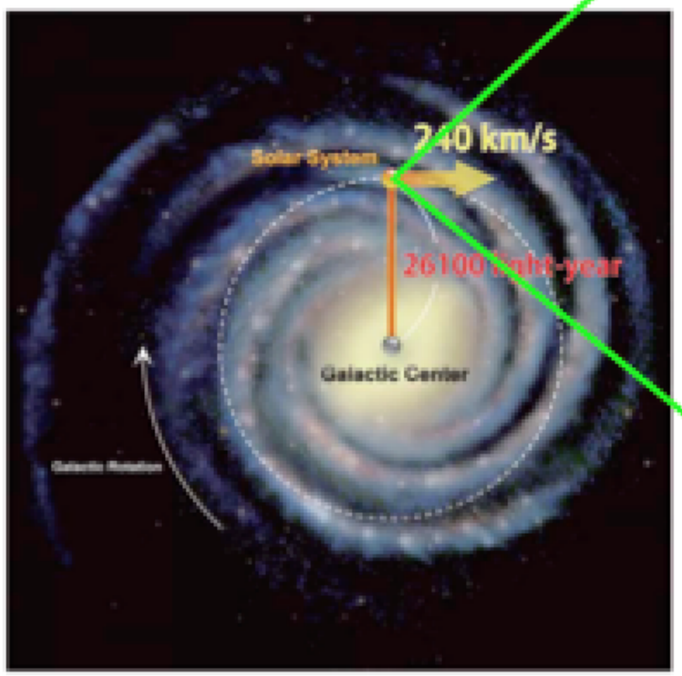


Fig. - E. Mamajek

Young M Dwarfs Near the Sun

Young Moving Groups
-ages 10 - 500 Myr



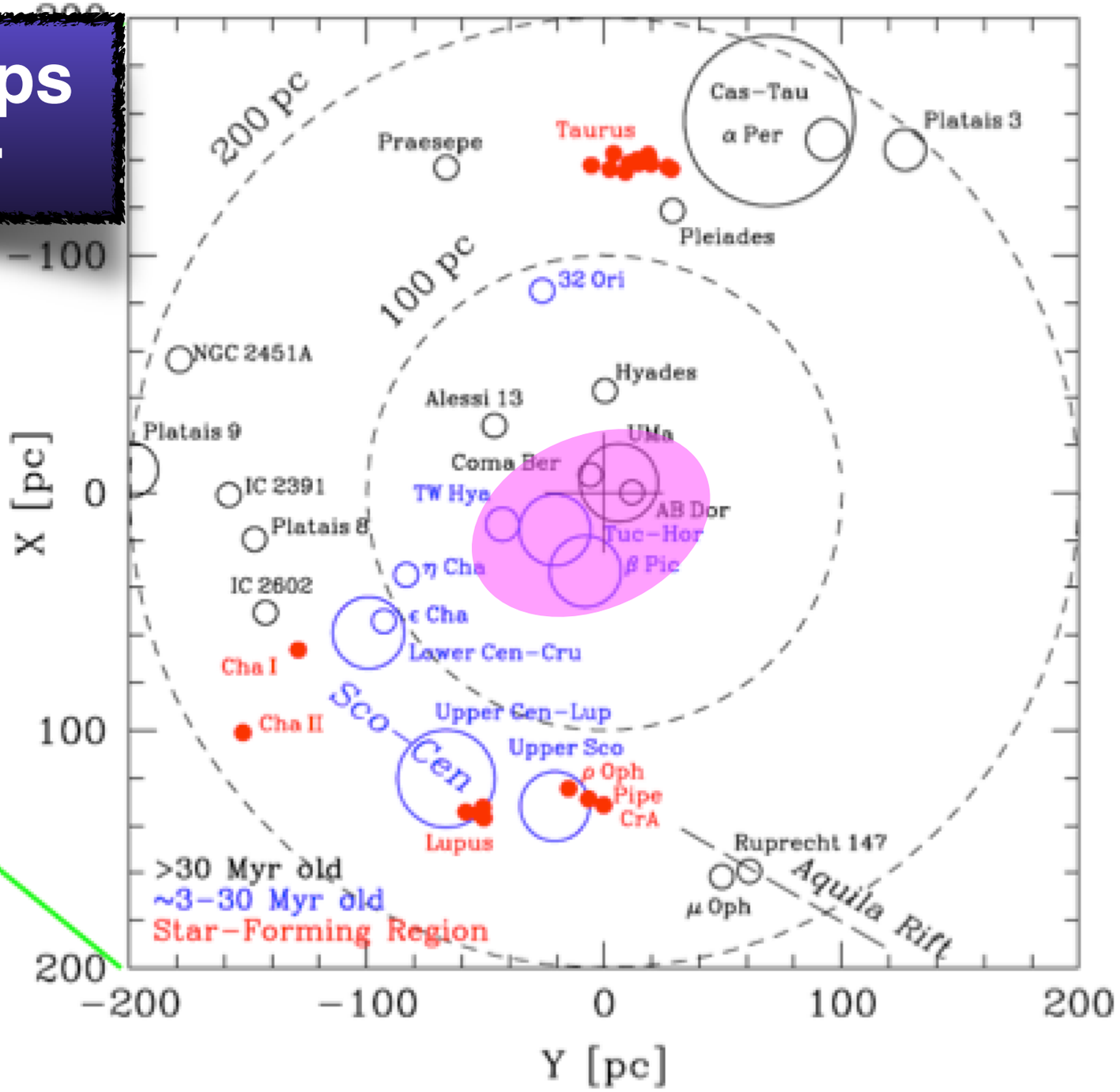
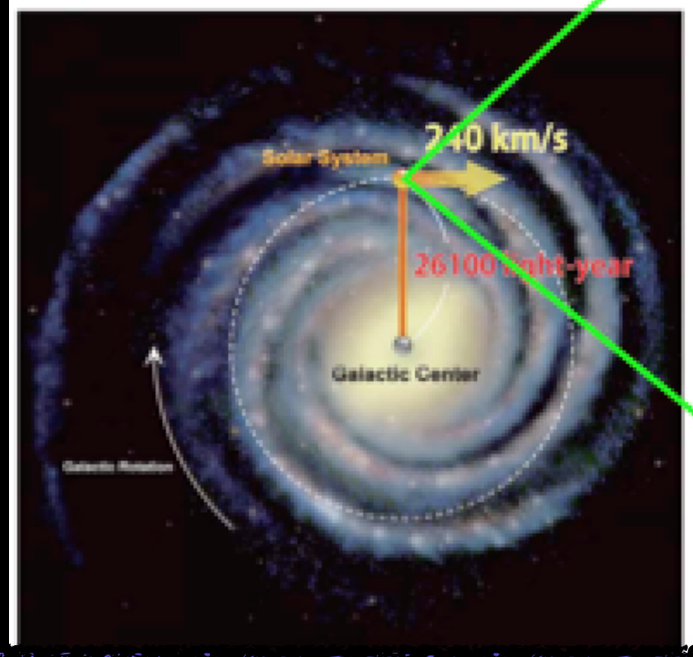


Fig. - E. Mamajek

Young M Dwarfs Near the Sun

Young Moving Groups
-ages 10 - 500 Myr



Very nearby young stars are best targets for direct imaging

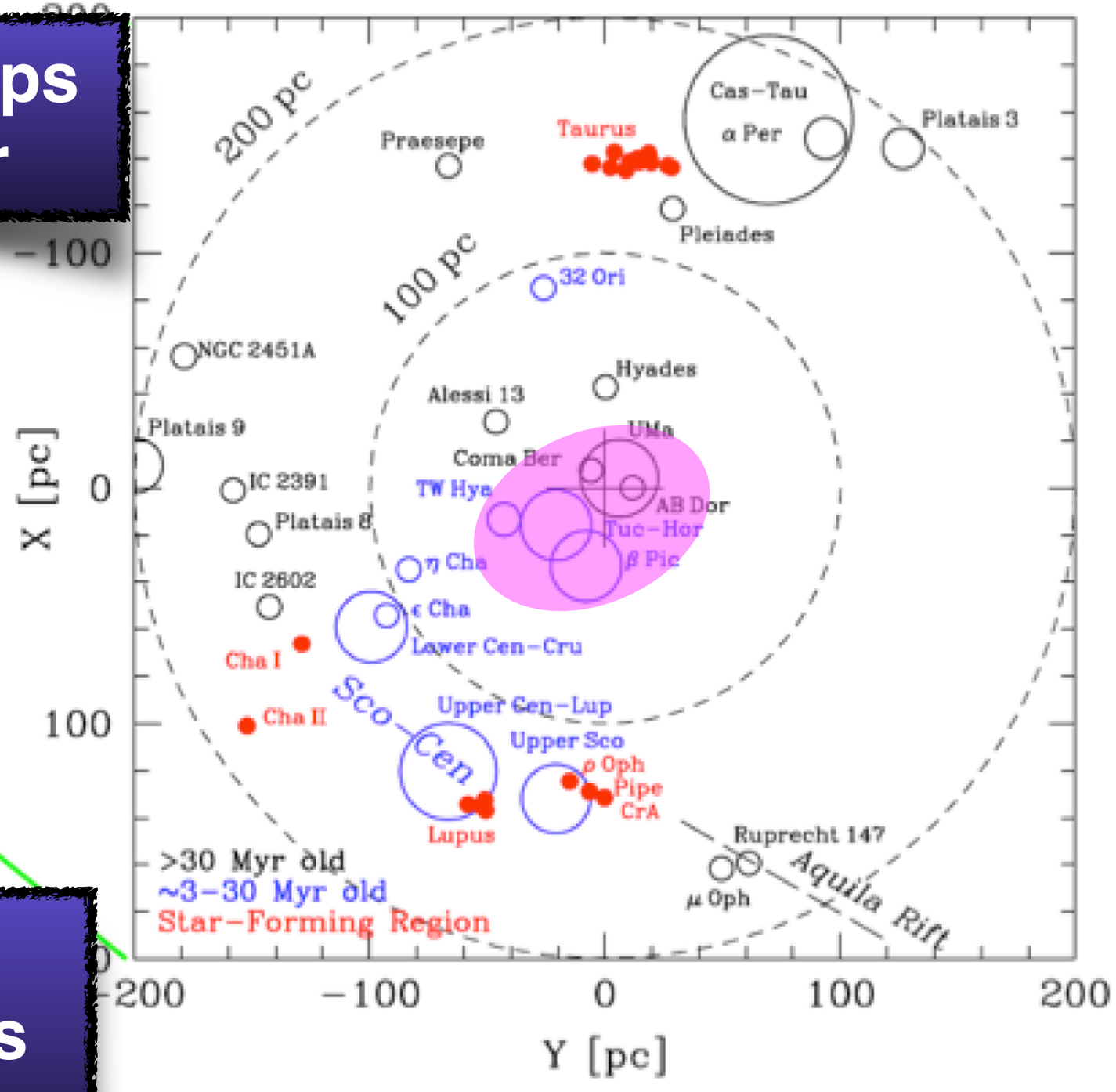
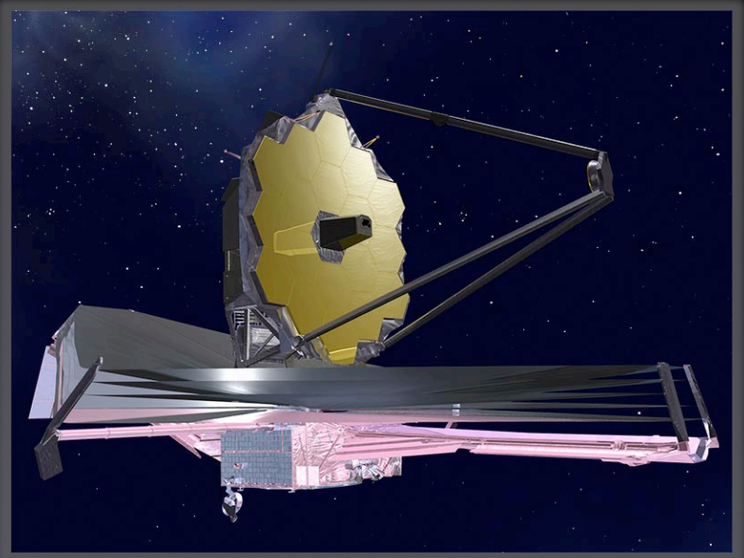
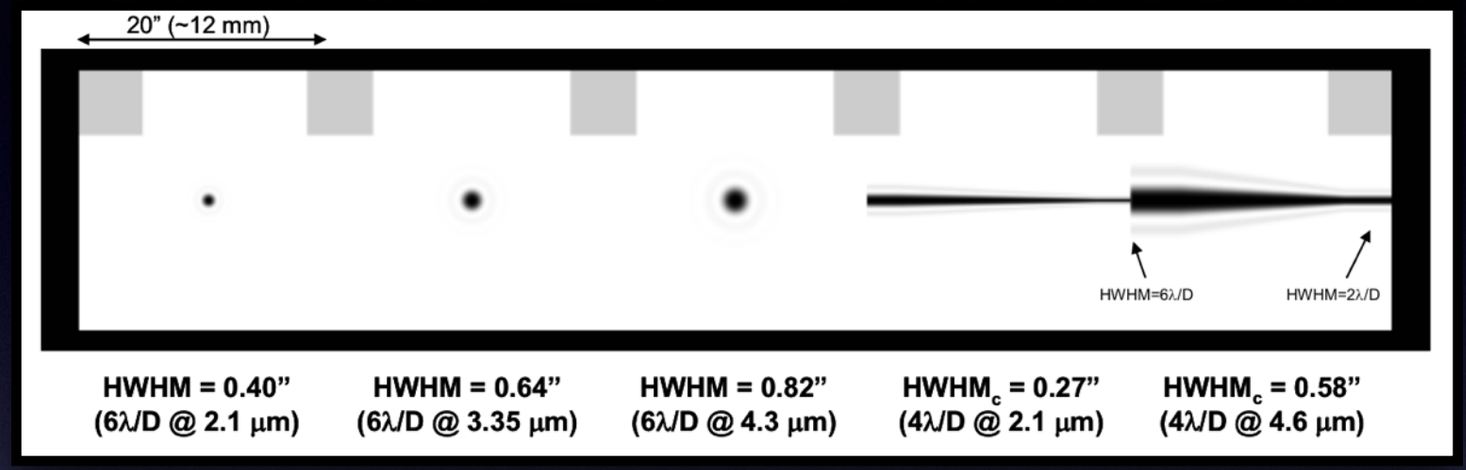


Fig. - E. Mamajek

Planet Imaging with the *JWST*

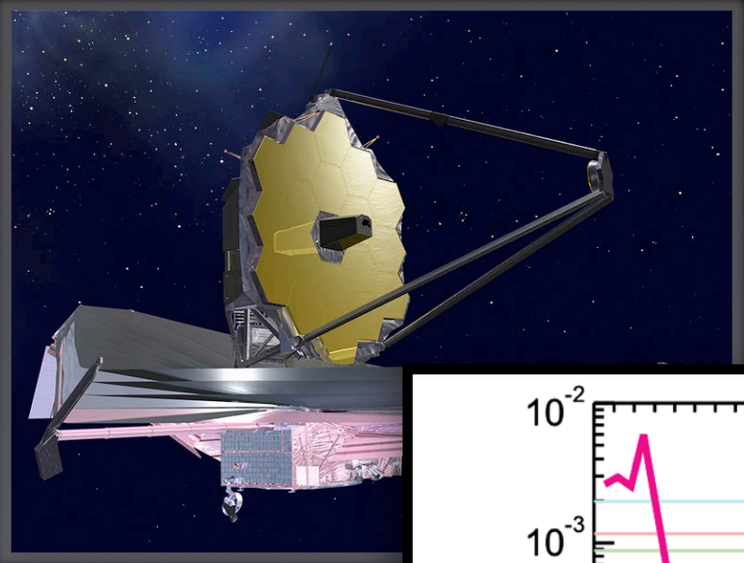


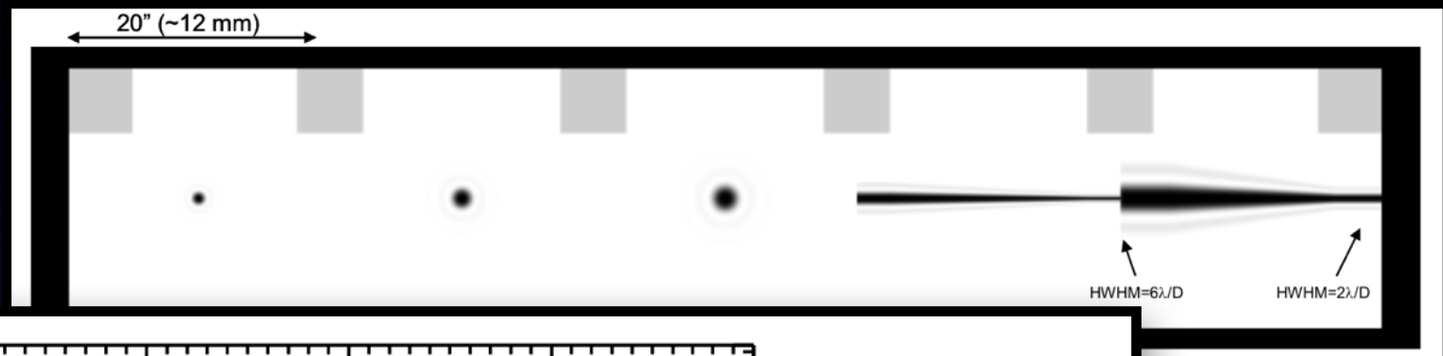


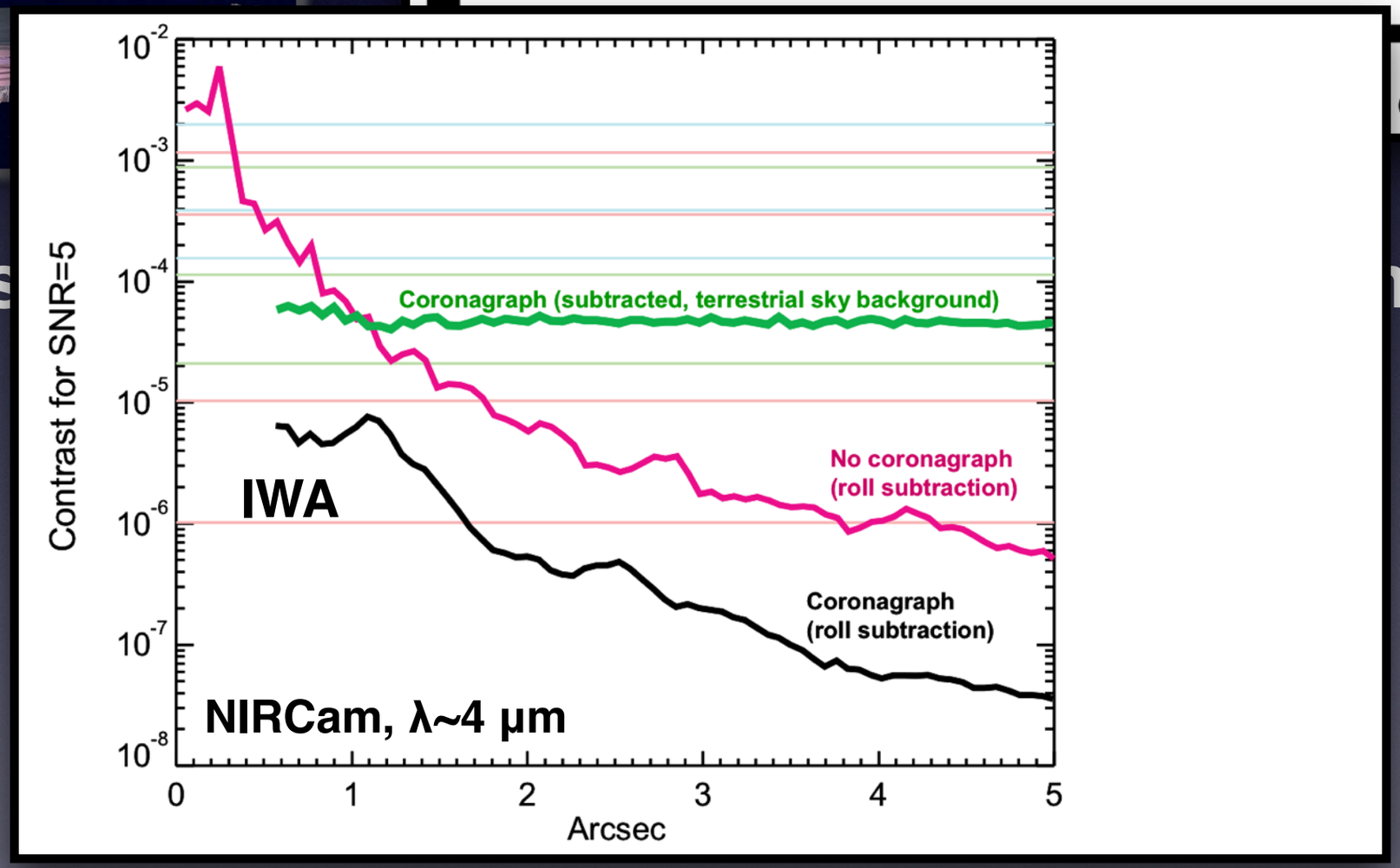
6.5m space telescope with coronagraphic imaging
NIRCam - 2-5 μm, MIRI - 11-23 μm

Krist et al. 2007
Beichman et al. 2010

Planet Imaging with the *JWST*





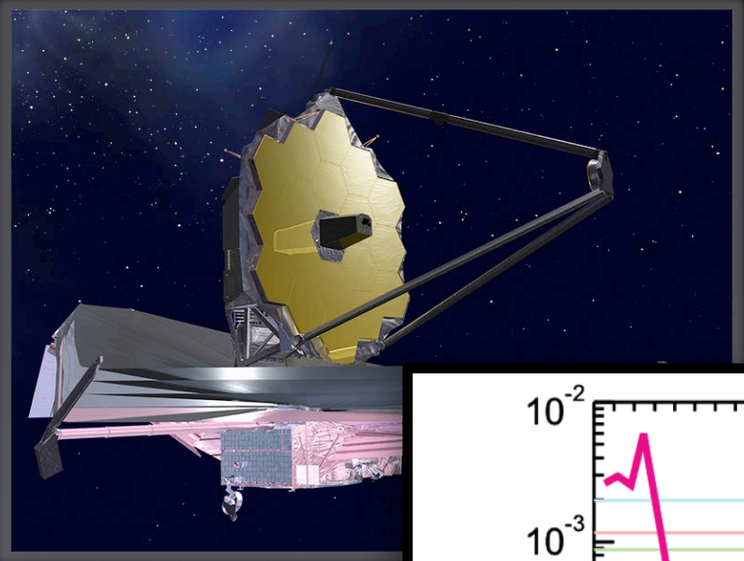


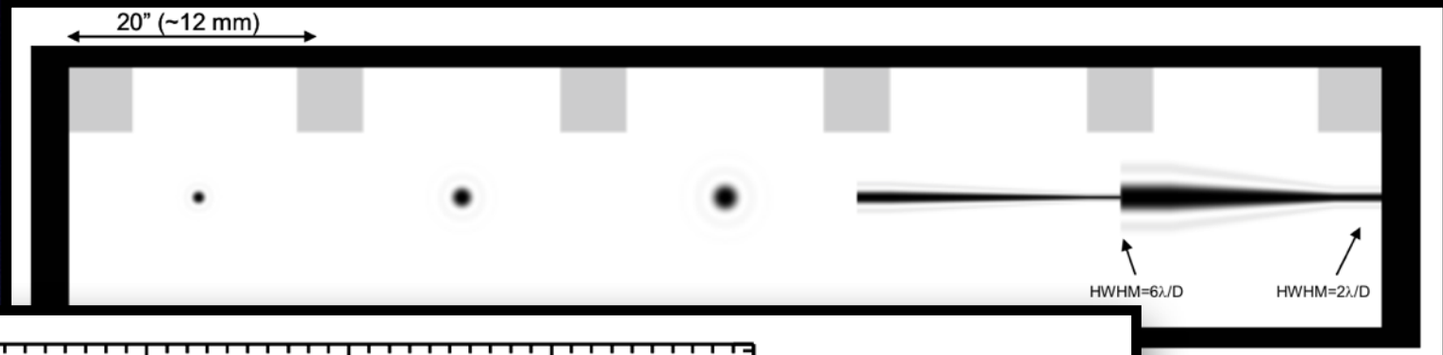
HWHM$_c$ = 0.58"
(4λ/D @ 4.6 μm)

6.5m s … **naging**

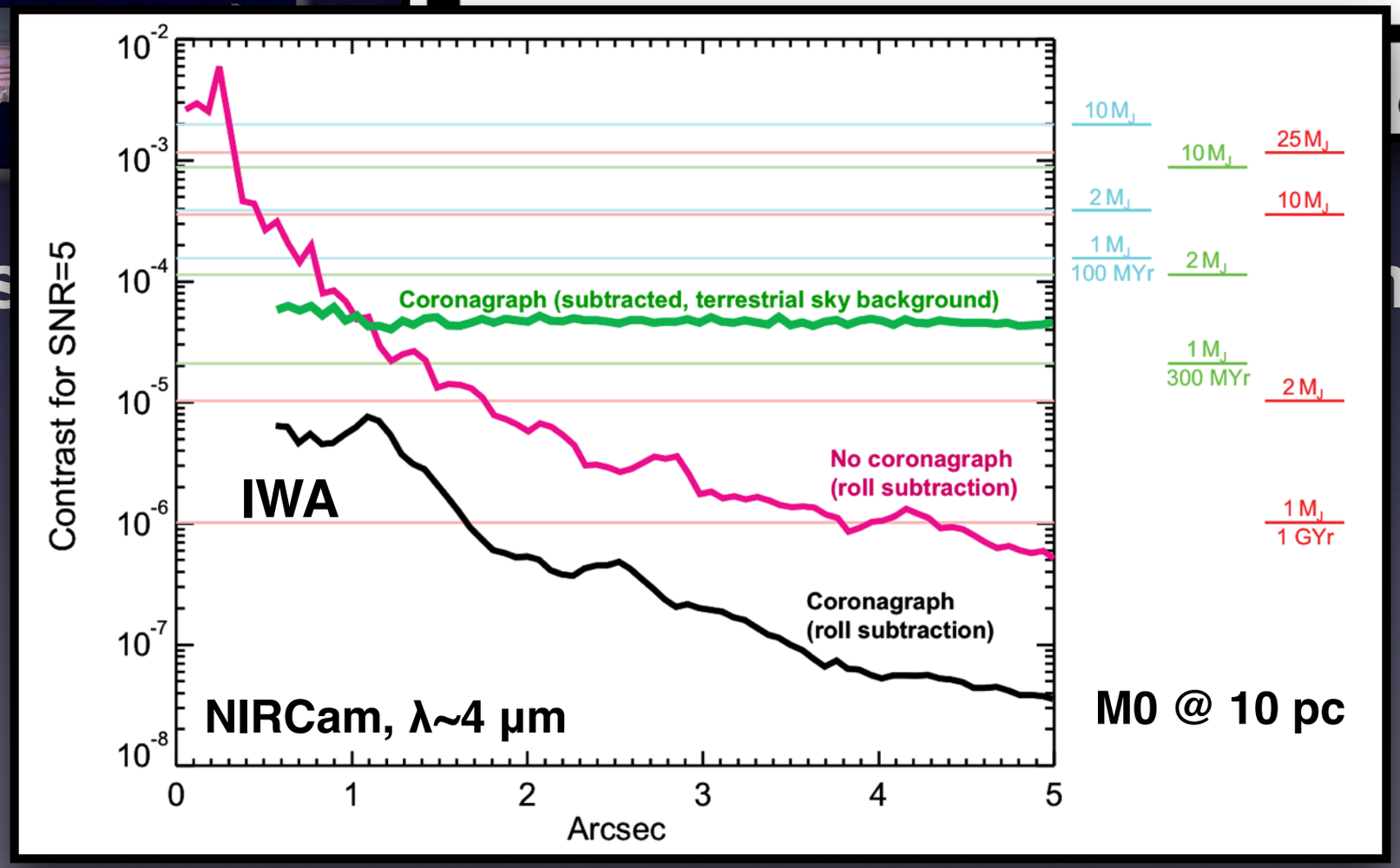
Krist et al. 2007
Beichman et al. 2010

Planet Imaging with the *JWST*



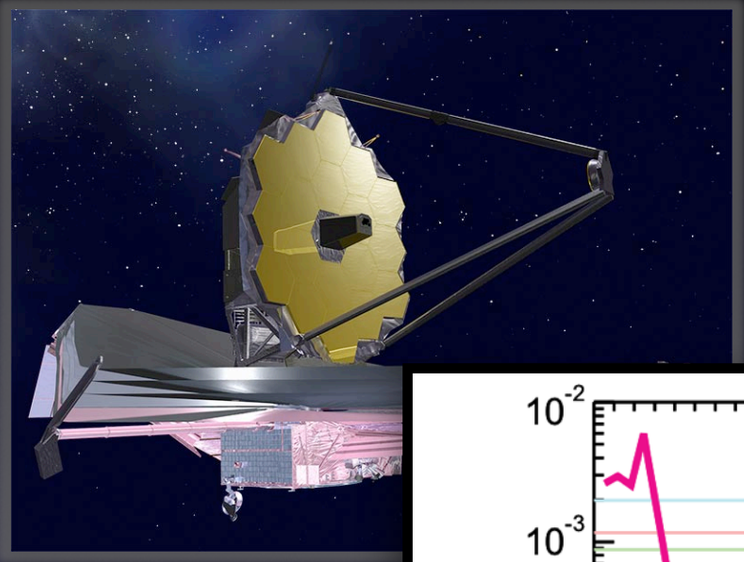


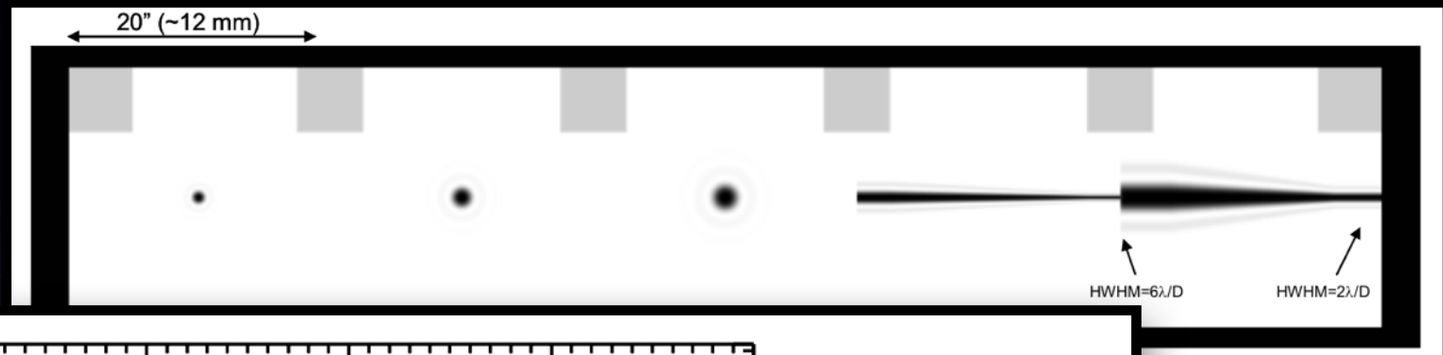
6.5m s **naging**



Krist et al. 2007
Beichman et al. 2010

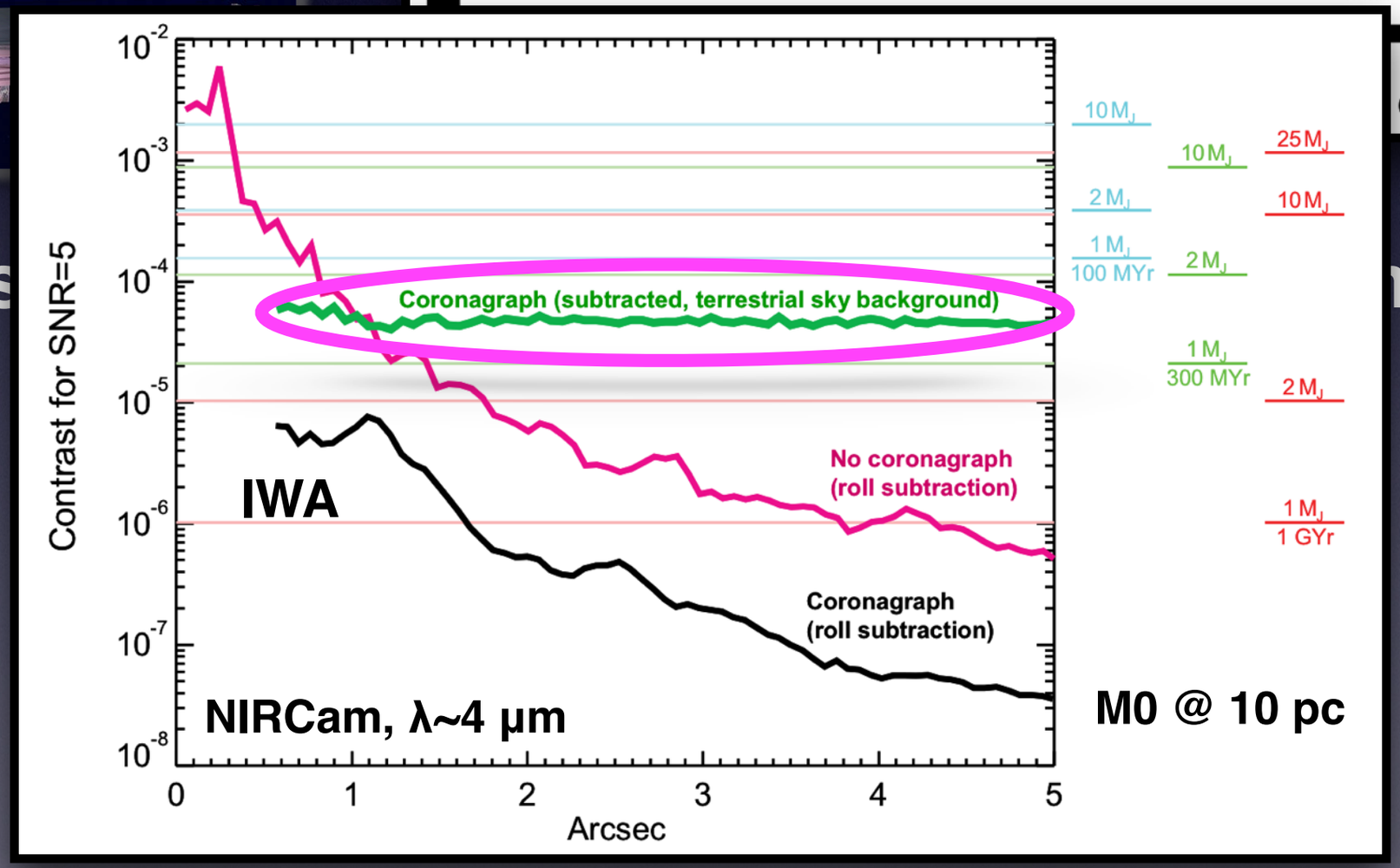
Planet Imaging with the *JWST*





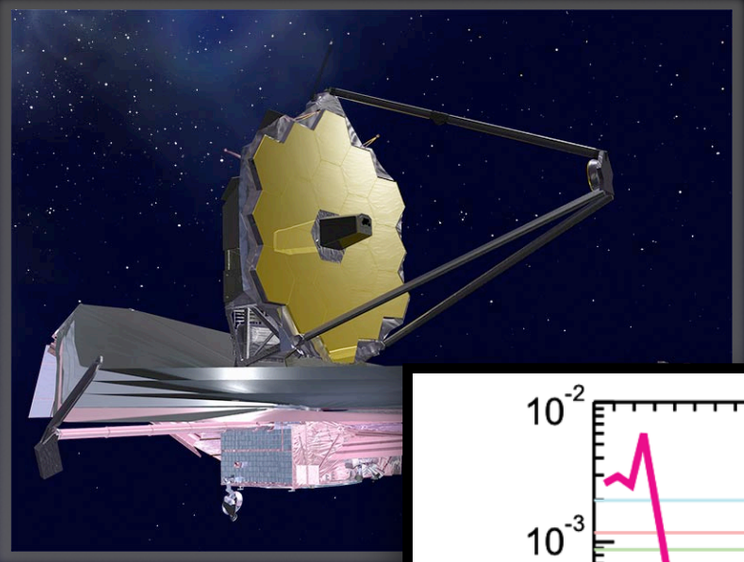
HWHM$_c$ = 0.58"
(4λ/D @ 4.6 μm)

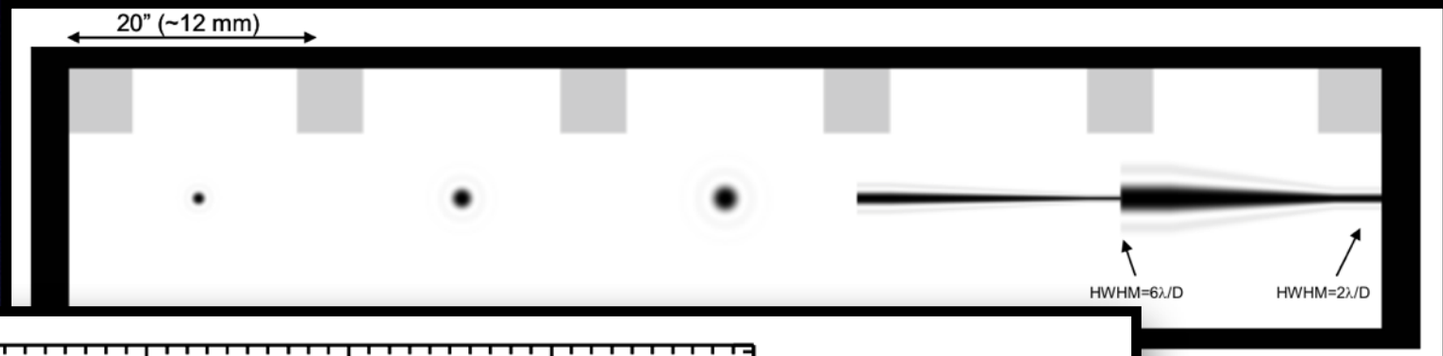
6.5m s **naging**



Krist et al. 2007
Beichman et al. 2010

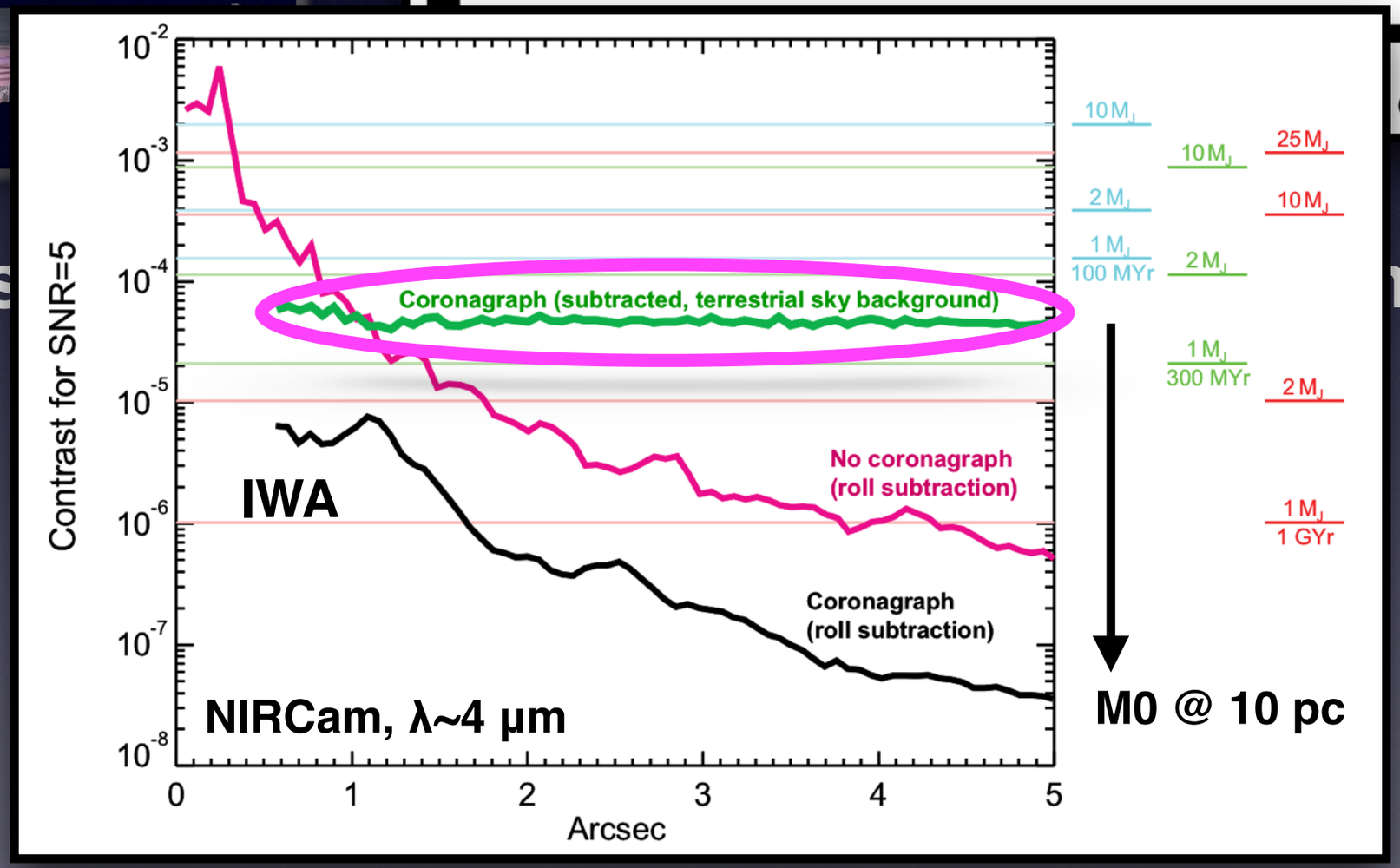
Planet Imaging with the *JWST*





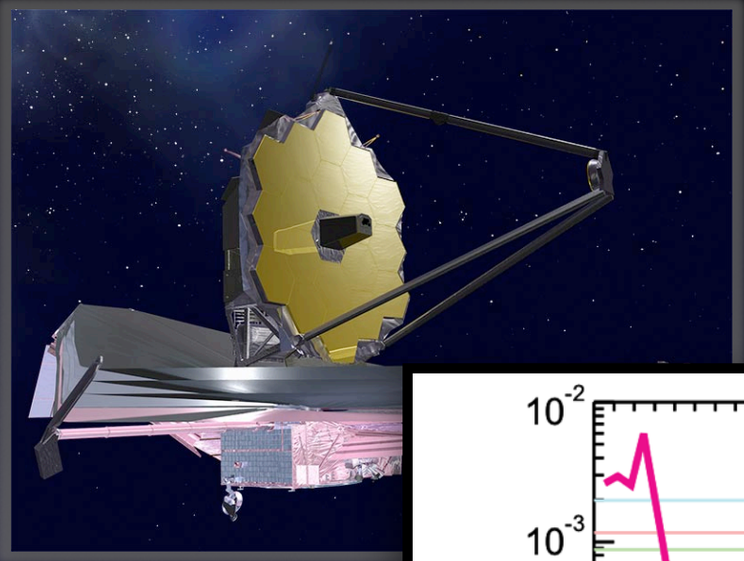
HWHM$_c$ = 0.58"
(4λ/D @ 4.6 μm)

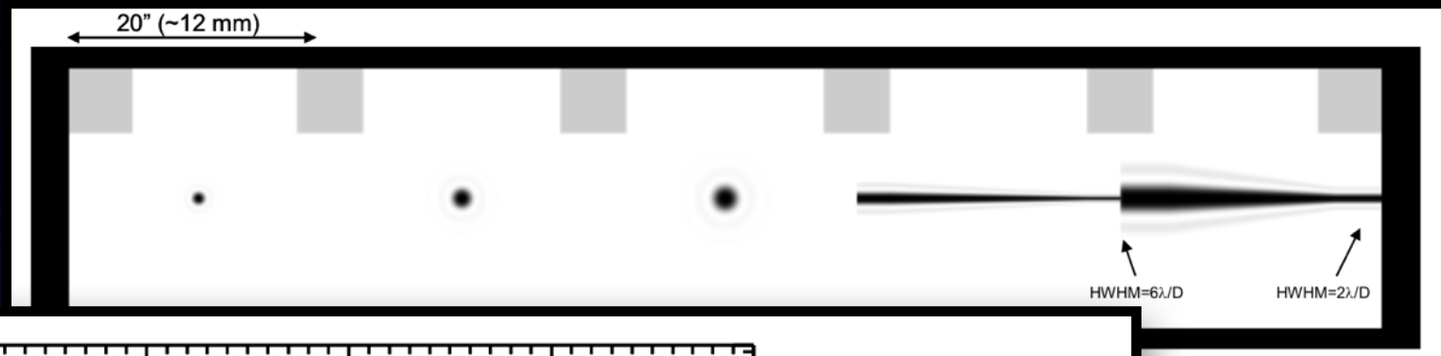
6.5m s **naging**

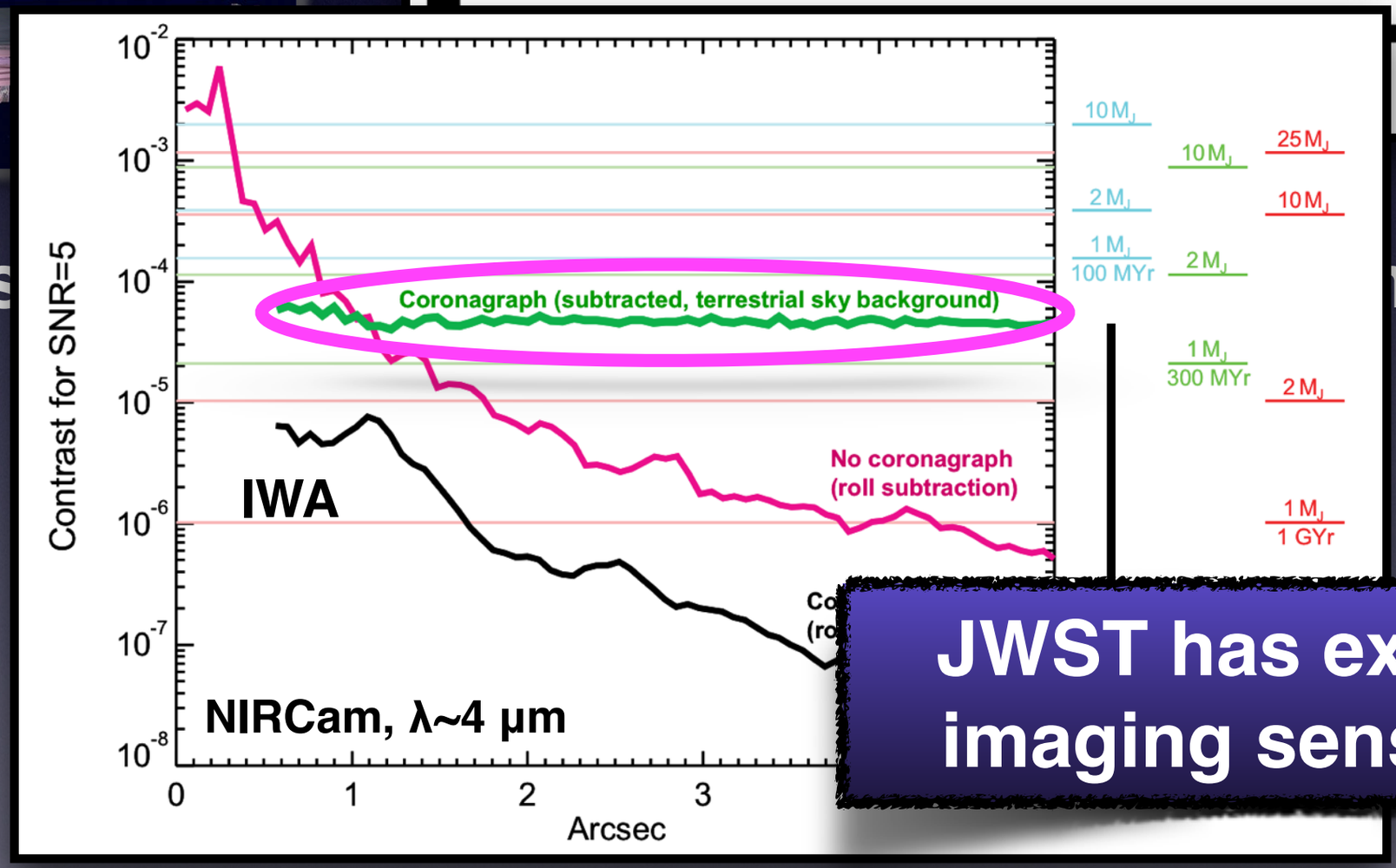


Krist et al. 2007
Beichman et al. 2010

Planet Imaging with the *JWST*







HWHM$_c$ = 0.58"
(4λ/D @ 4.6 μm)

6.5m s **naging**

JWST has excellent imaging sensitivity.

Krist et al. 2007
Beichman et al. 2010

Planet Survey Simulations

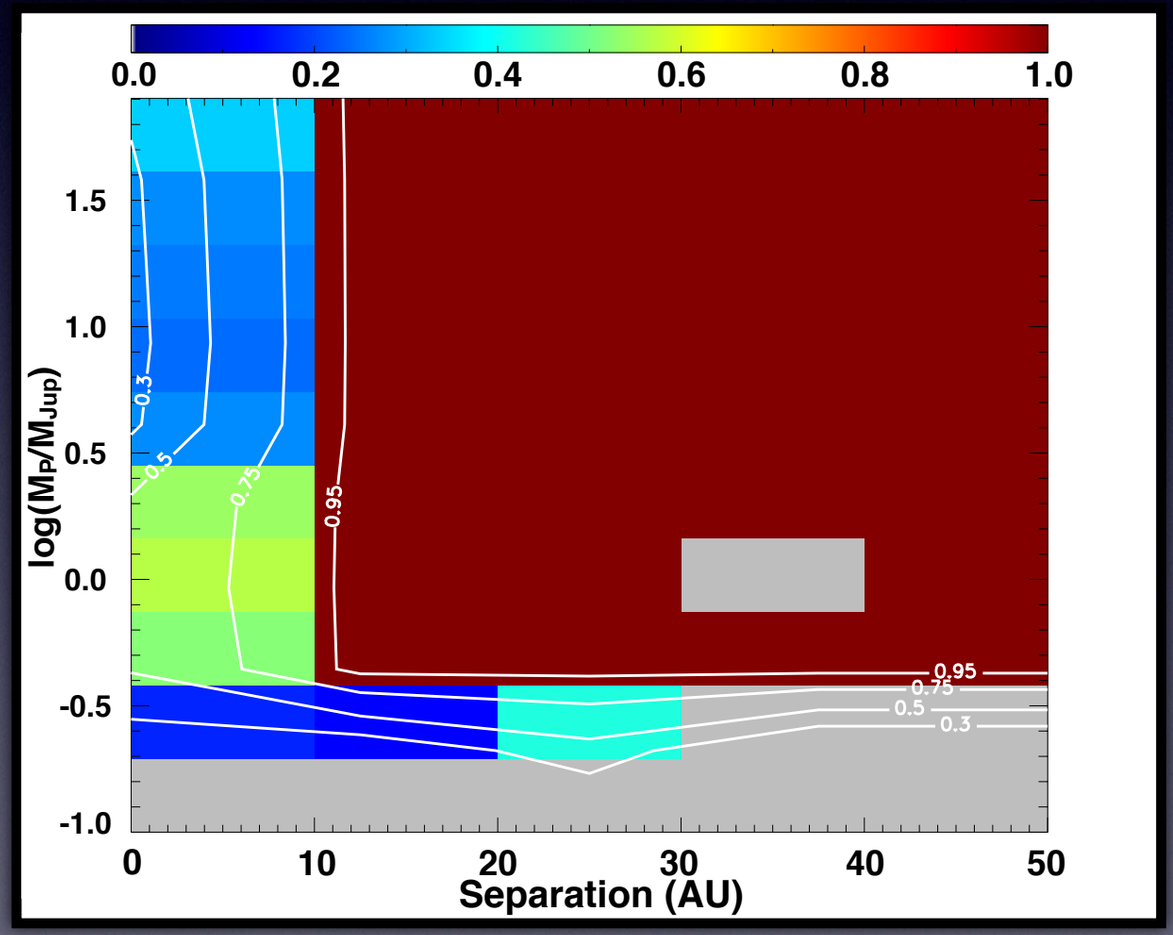
Compared VLT/NaCo and *JWST*/NIRCam @~3.5 μm

50 closest M's from young moving groups
-Distances <26 pc

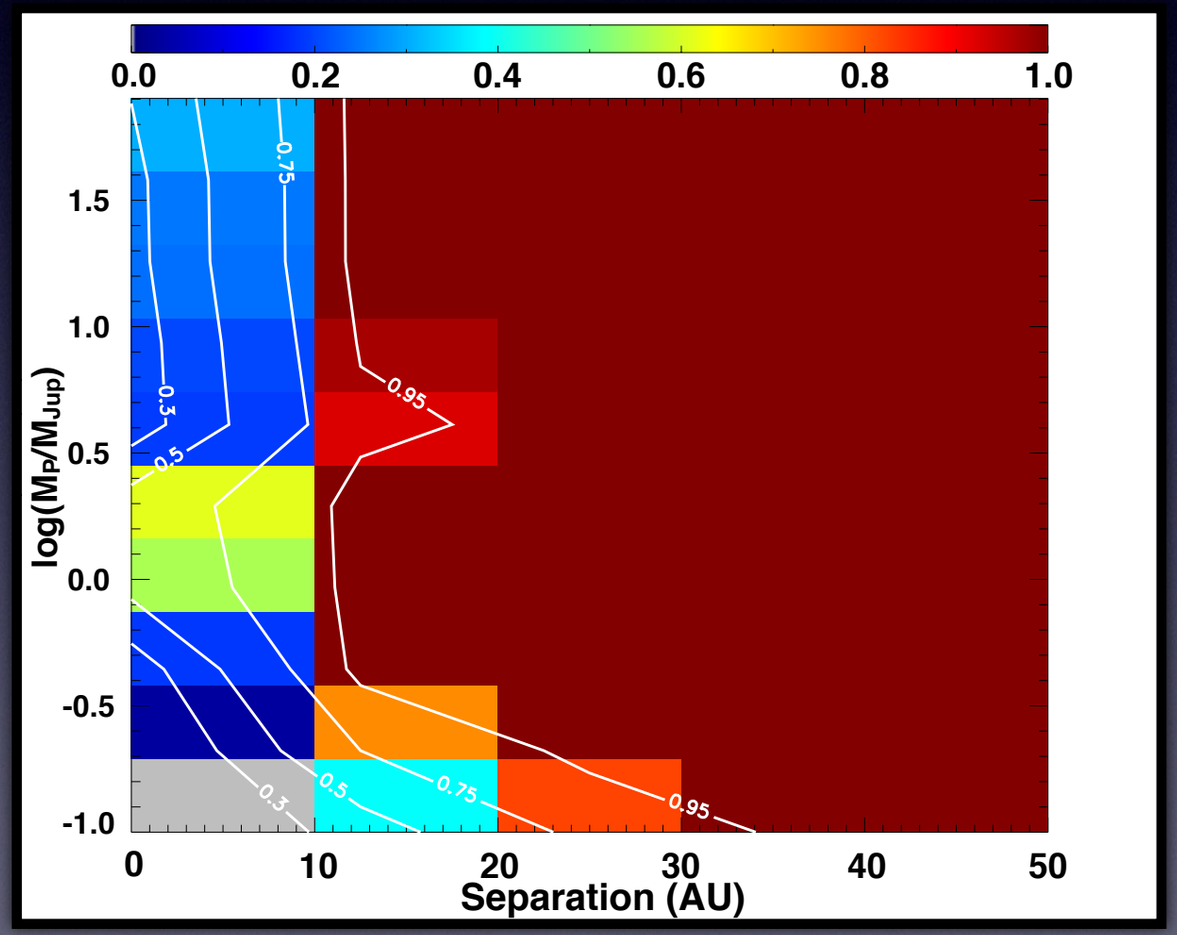
- Simulations follow Reggiani et al. 2015
- Planet population from Meyer et al. 2016
- Planet luminosities from Baraffe et al. 2003, 2008

Simulation Results: Ideal Single Star
-150 Myr M5 @ 14 pc-

VLT/NaCo

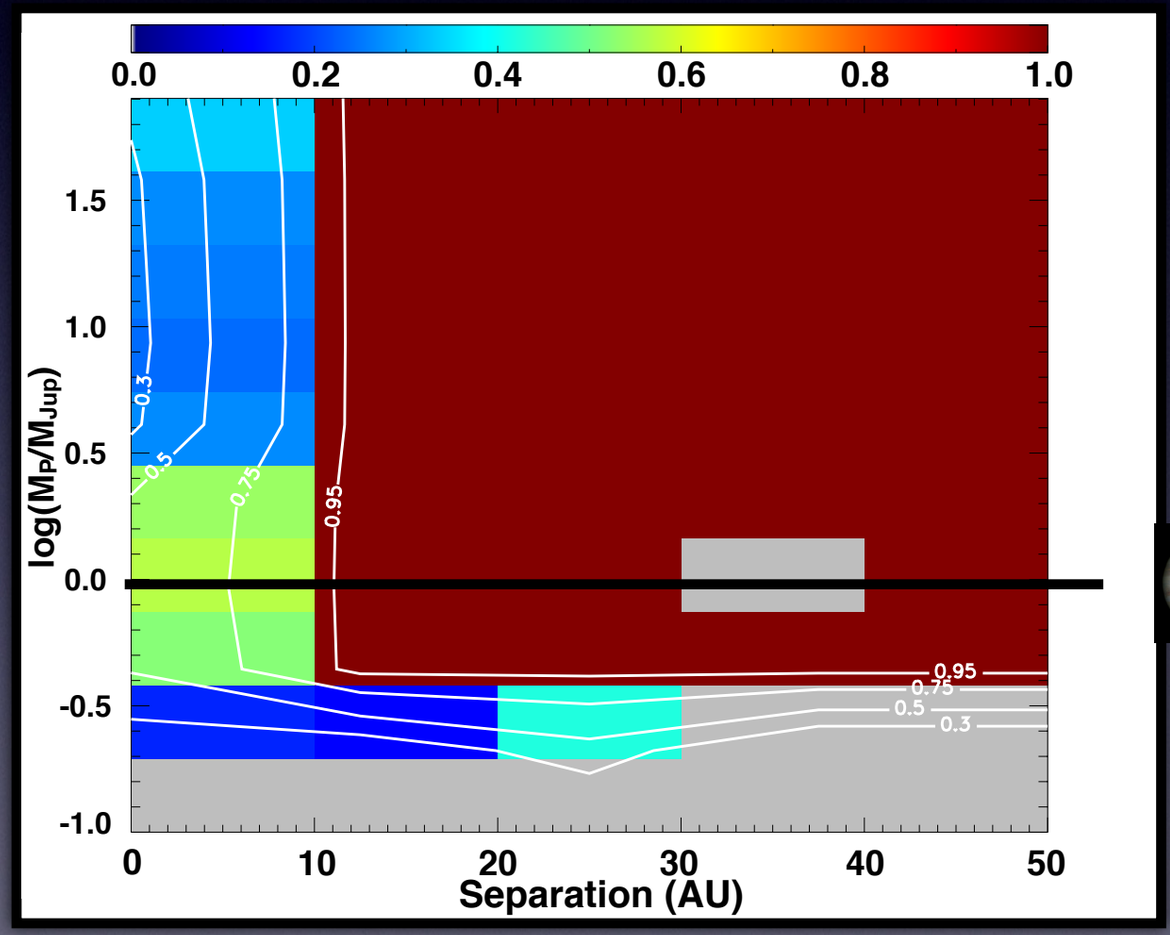


JWST/NIRCam

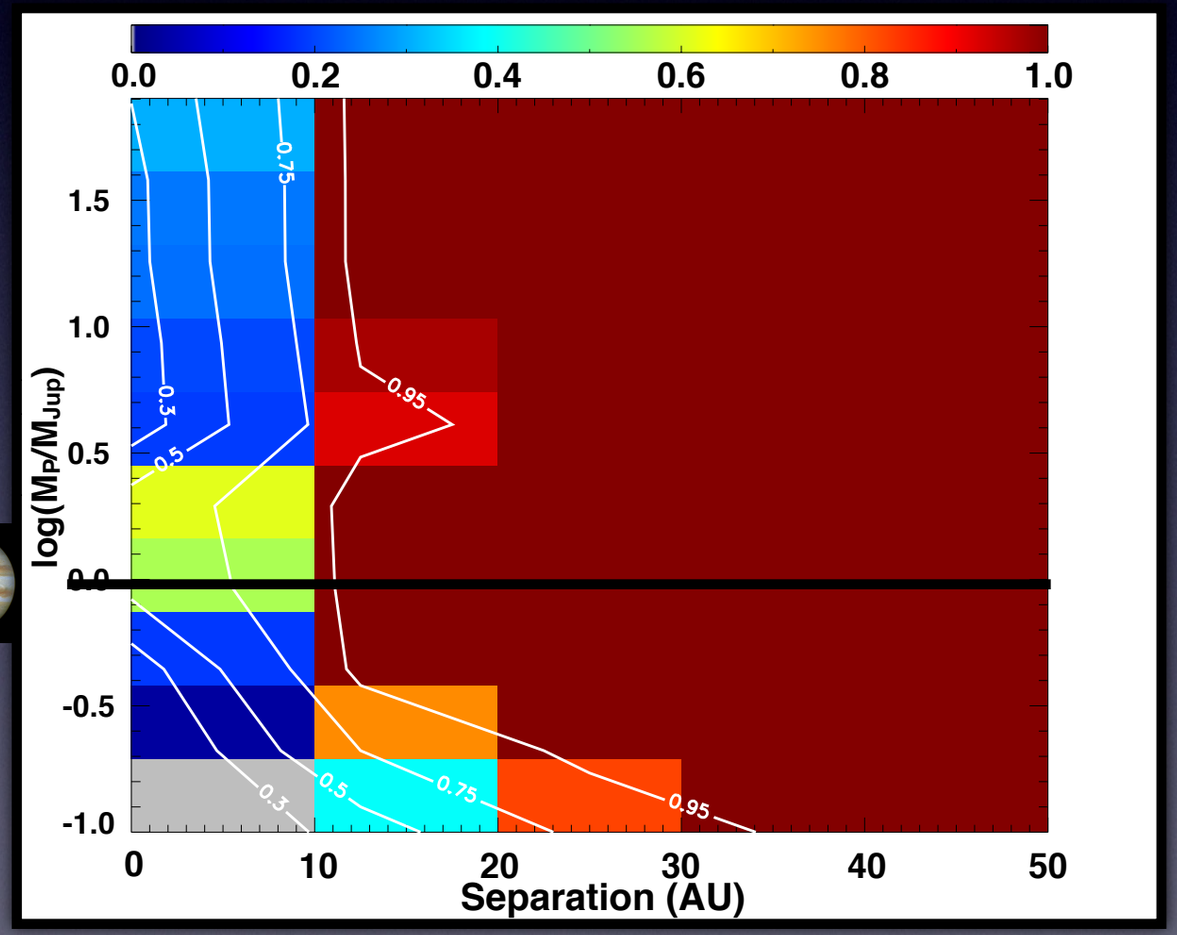


Simulation Results: Ideal Single Star
-150 Myr M5 @ 14 pc-

VLT/NaCo

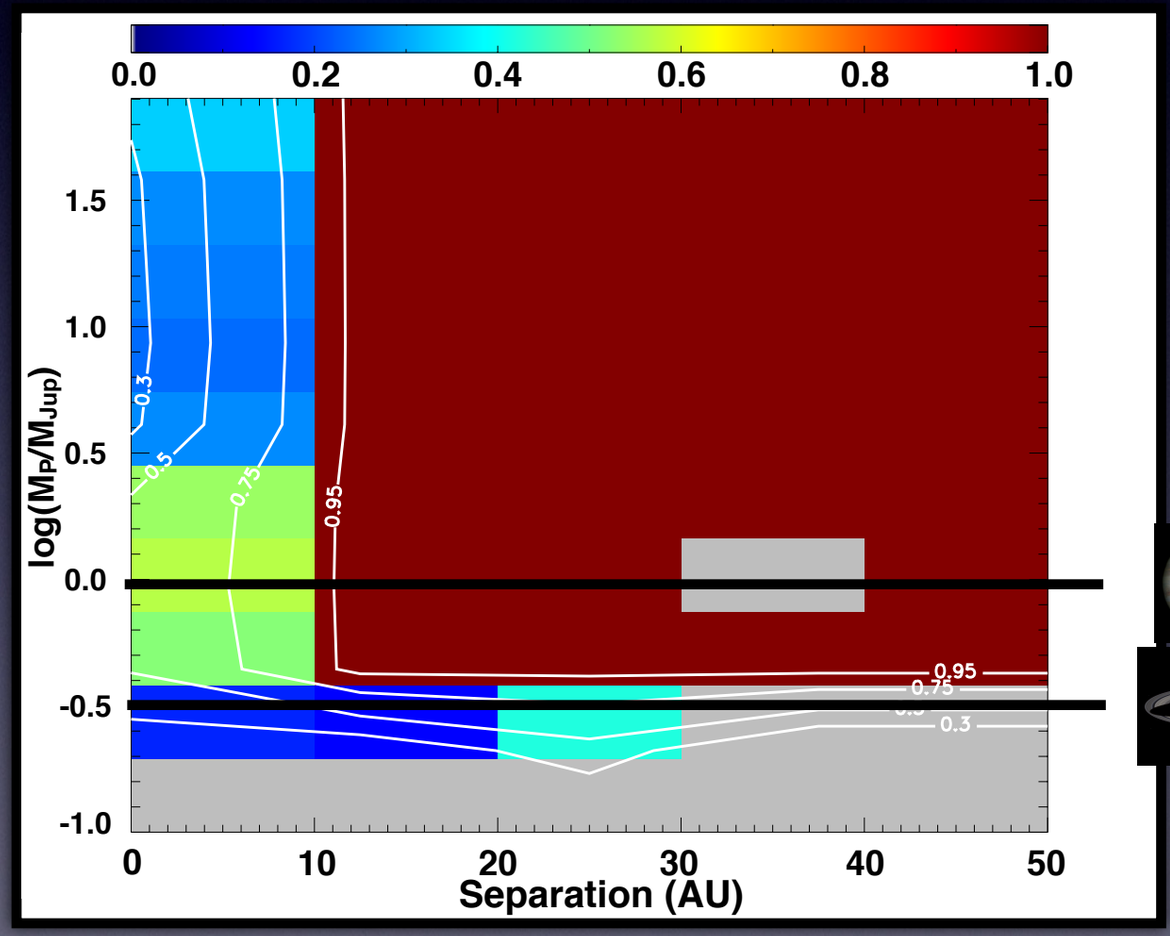


JWST/NIRCam

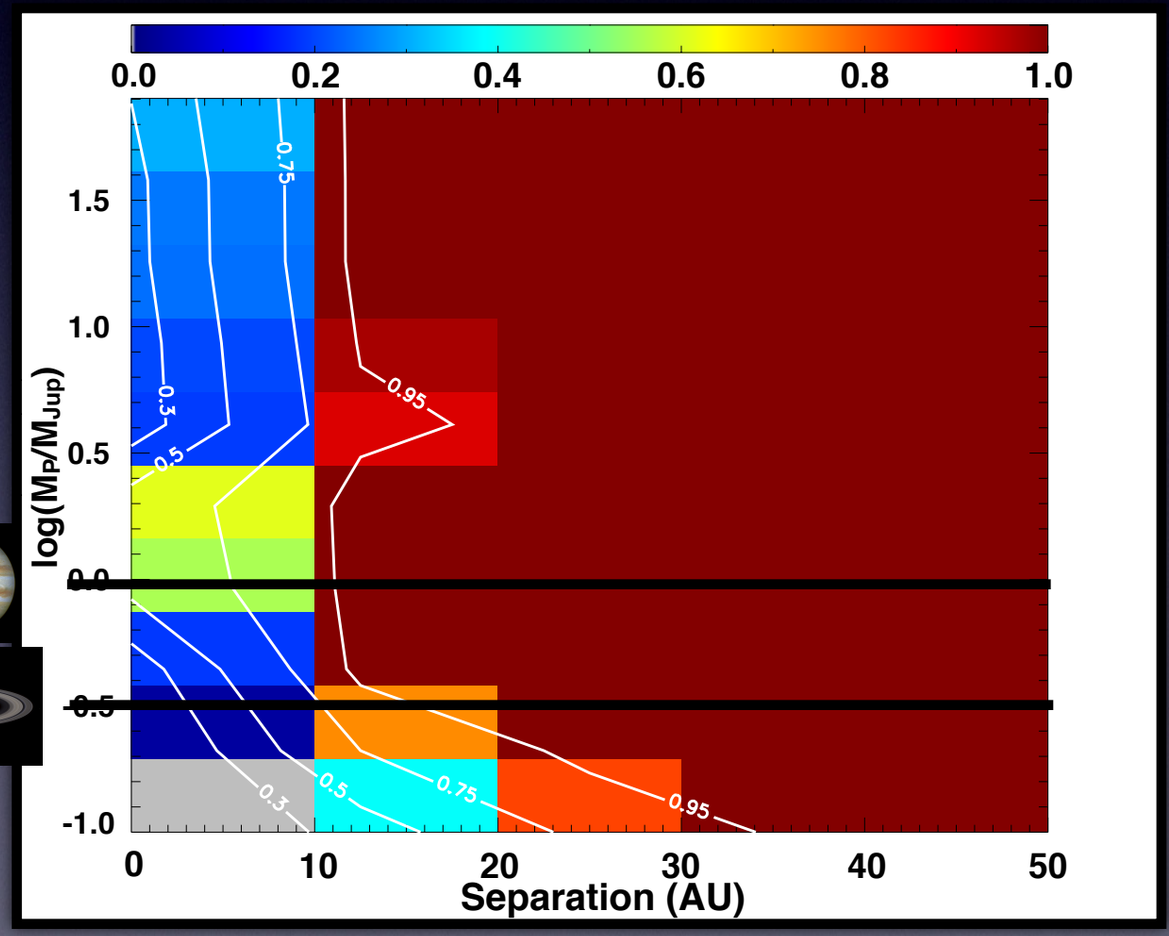


Simulation Results: Ideal Single Star
-150 Myr M5 @ 14 pc-

VLT/NaCo

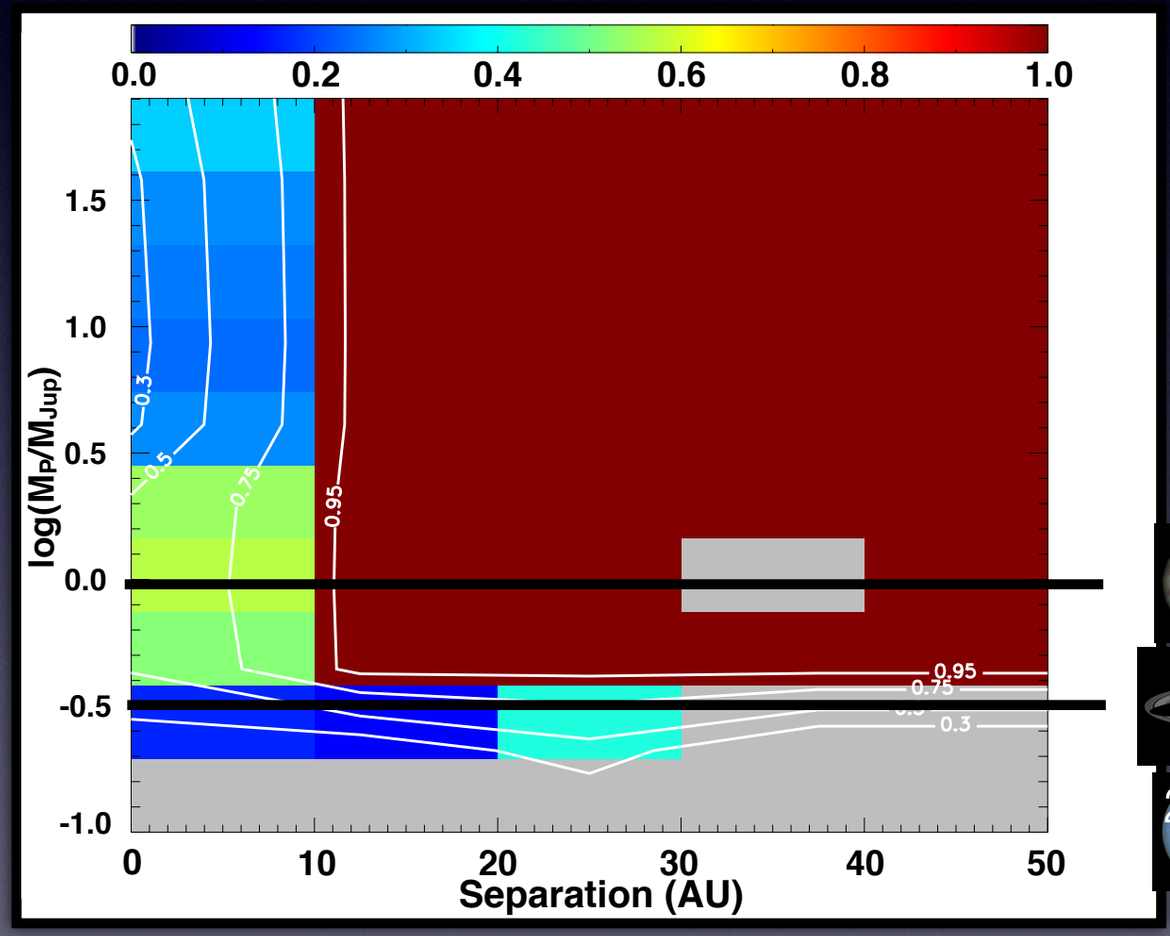


JWST/NIRCam

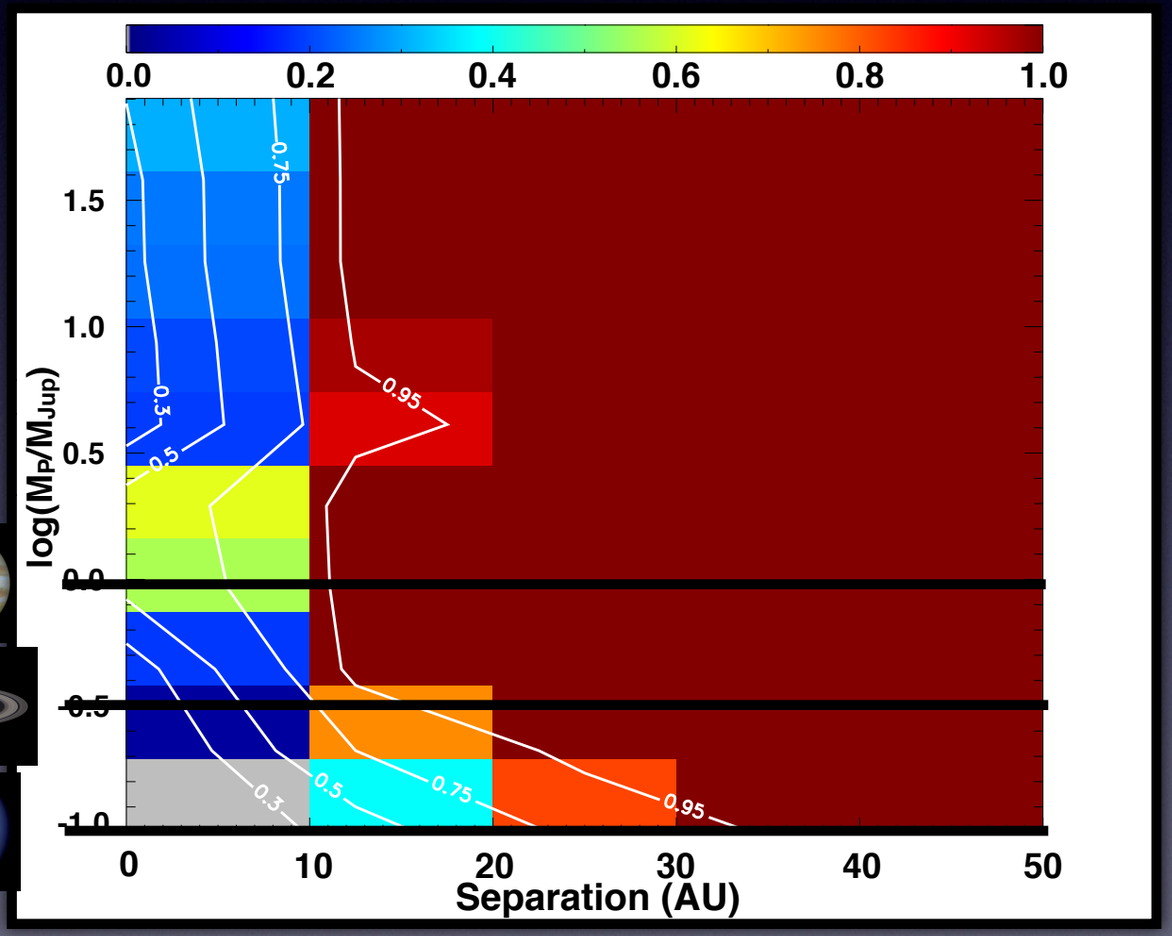


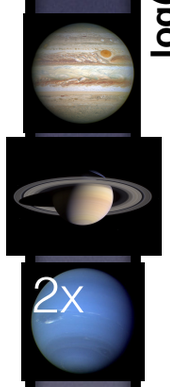
Simulation Results: Ideal Single Star
-150 Myr M5 @ 14 pc-

VLT/NaCo

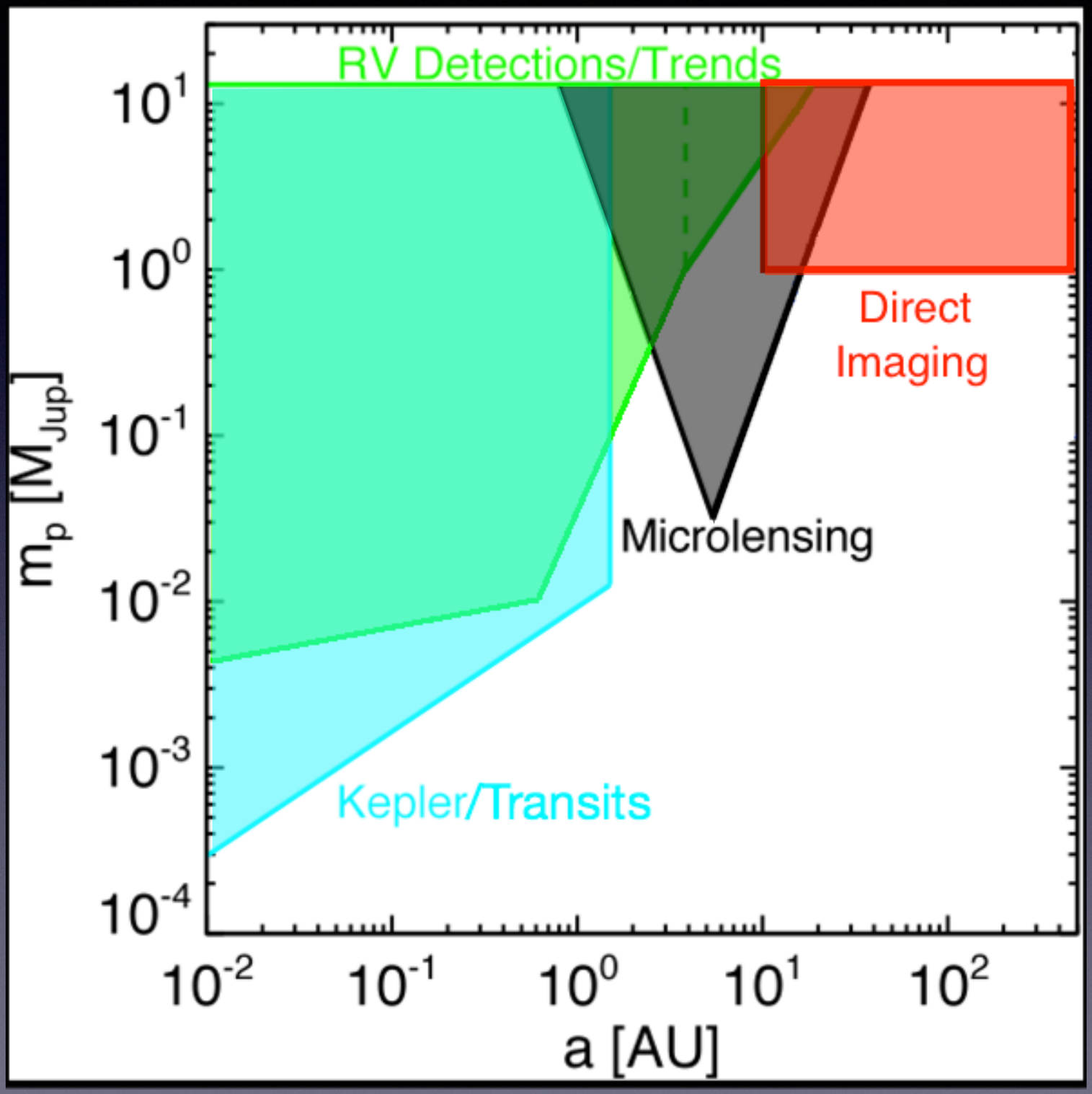


JWST/NIRCam





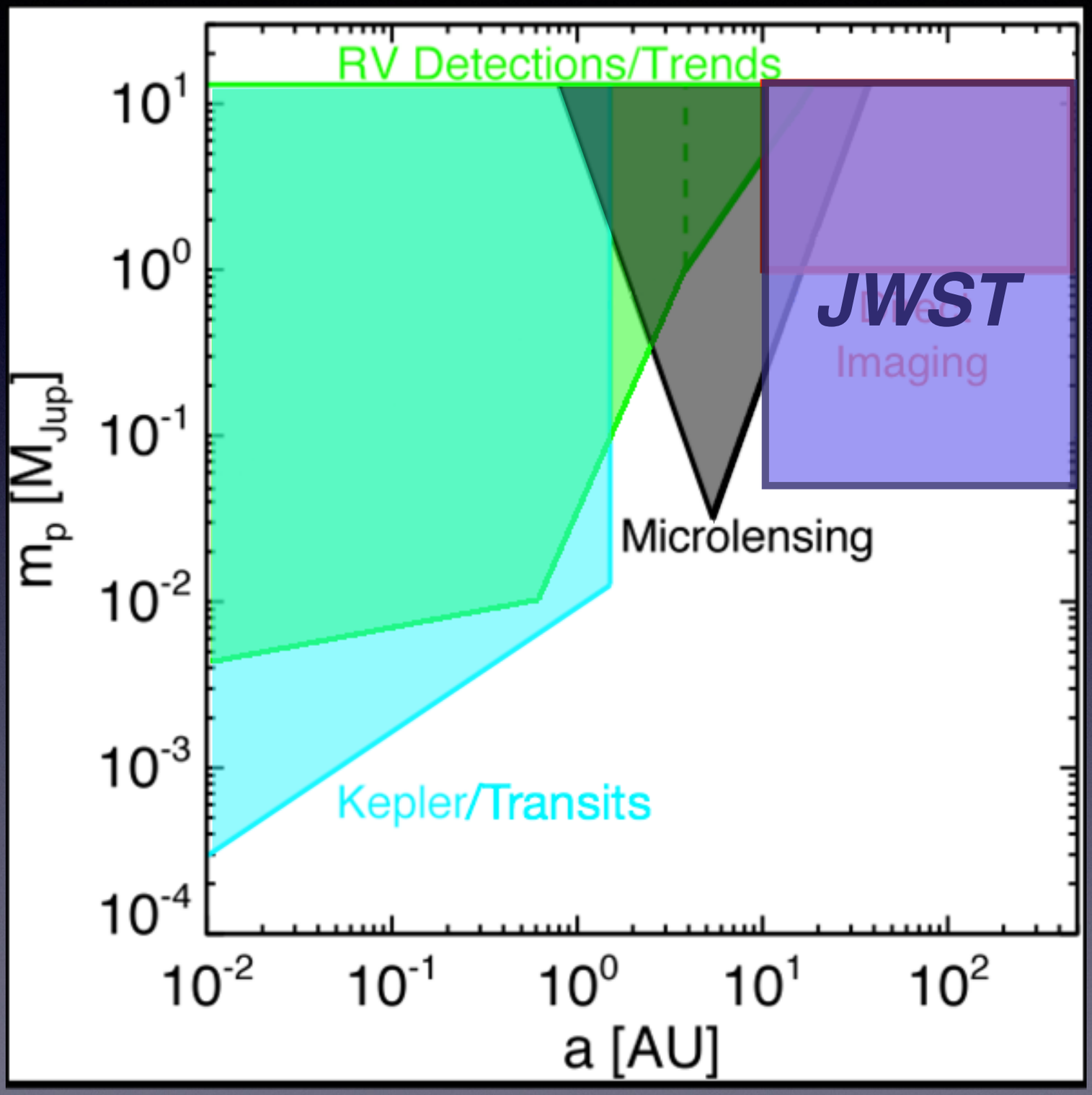
New Parameter Space with the JWST



adapted from Clanton et al. 2014b

data: NASA Exoplanet Archive

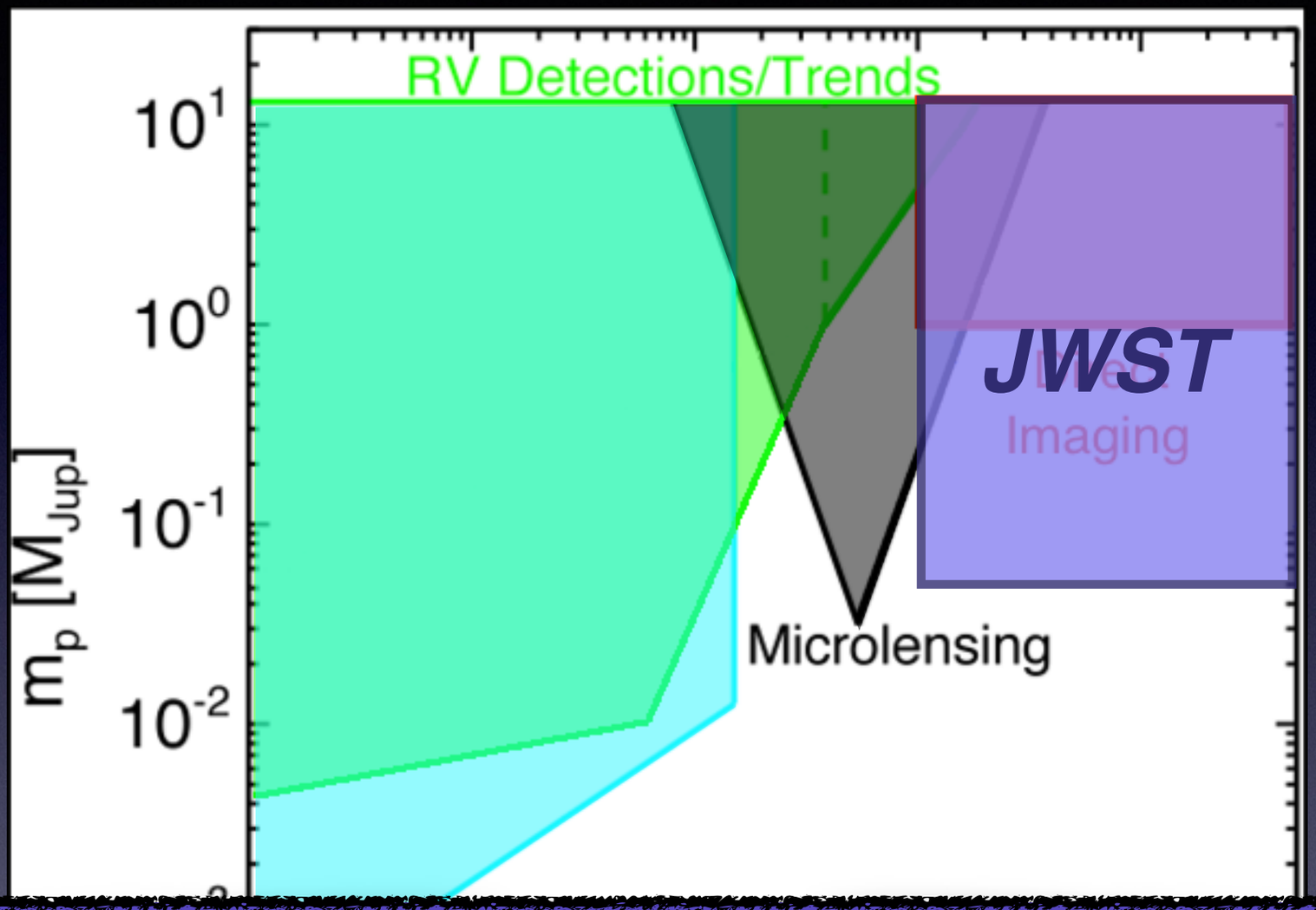
New Parameter Space with the JWST



adapted from Clanton et al. 2014b

data: NASA Exoplanet Archive

New Parameter Space with the JWST



***JWST* NIRCam can test microlensing mass function at wider separation; sensitivity to detect first young Saturn and Neptune analogs**

adapted from Clanton et al. 2014b

data: NASA Exoplanet Archive

Summary

- M dwarfs offer unique population for young exoplanet studies

- *K2* discoveries of transiting planets in open clusters hint at trend in young planet radii
    - *K2* searches ongoing
    - *Spitzer* follow-up

- The closest youngest M dwarfs are excellent targets for *JWST* coronagraphic imaging
    - Unprecedented sensitivity allows access to sub-Jupiters and ice-giants.
    - Need to find more young M dwarfs within 25 pc —> *Gaia*

Thanks to Collaborators

K2 - Ian Crossfield, Erik Petigura, Andrew Howard, Evan Sinukoff, Kimberly Aller, Courtney Dressing, Howard Isaacson, B.J. Fulton, David Ciardi, Tim Morton, Chas Beichman, Christian Obermeier, Sebastien Lepine, Thomas Henning, Tom Greene

Spitzer - Mike Werner, John Livingston, Varoujan Gorjian, Jessica Krick, Jessie Christiansen, Bjoern Benneke

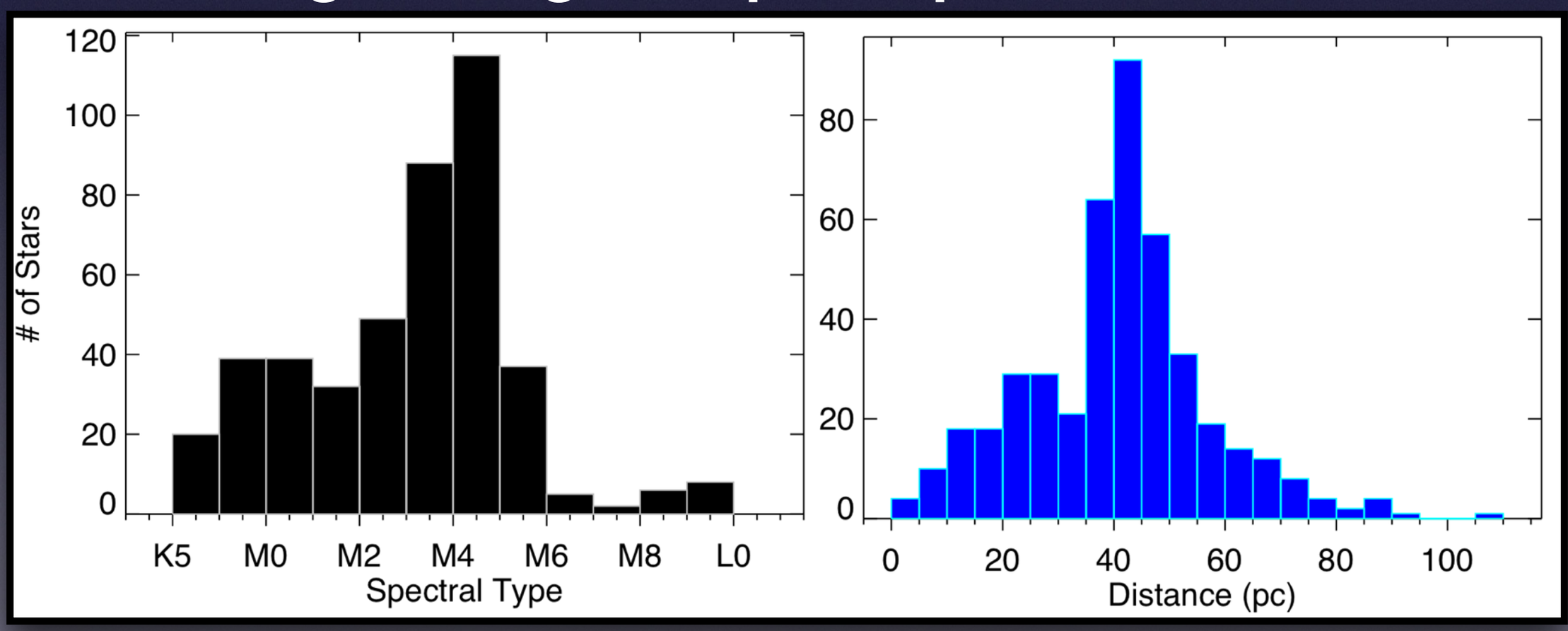
M Dwarf Imaging - Brendan Bowler, Philippe Delorme, Justine Lannier

JWST/NIRCam - Michael Meyer, Maddalena Reggiani, Chas Beichman, George Rieke, Adam Burrows, Sascha Quanz, Tom Greene

JWST Targets: Young M Dwarfs

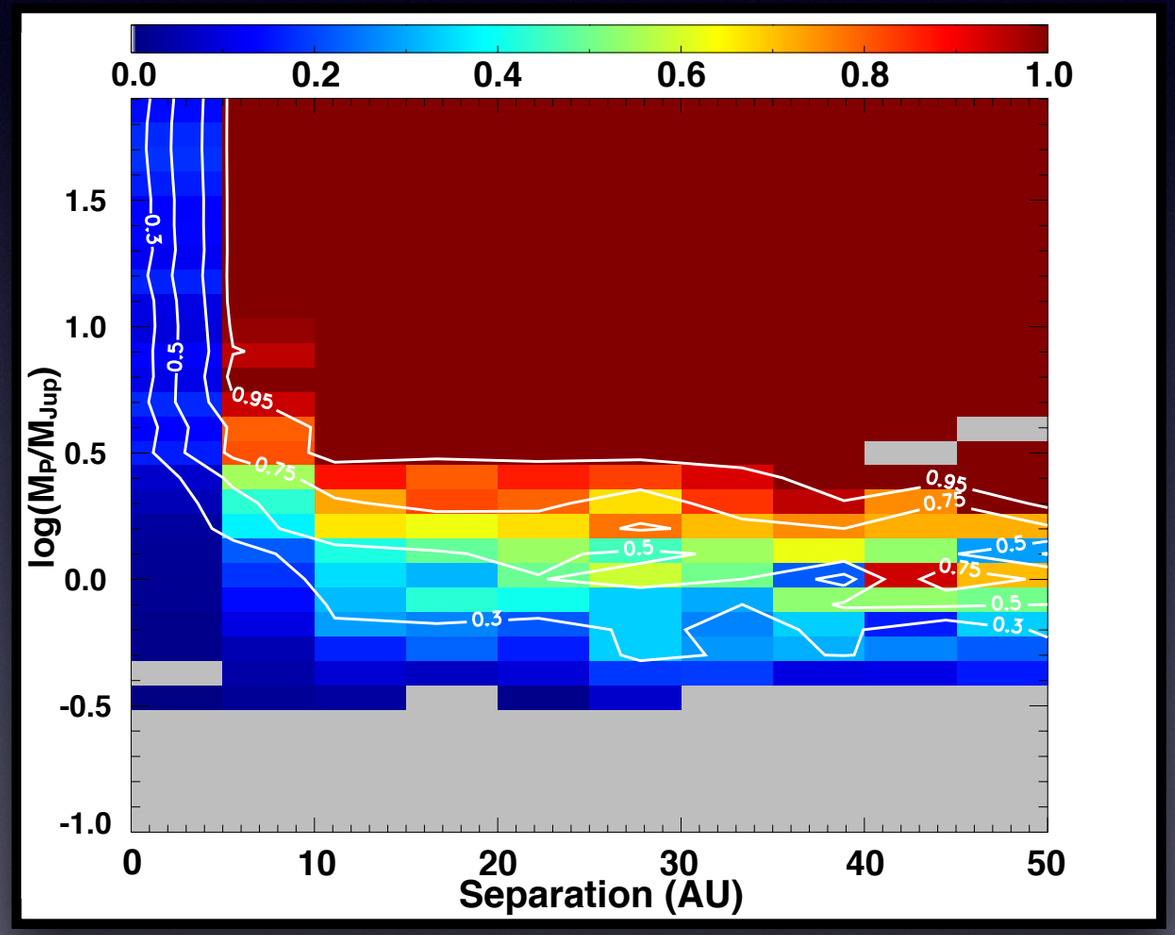
- Compiled all K5 - M9 members of the youngest moving groups @<100 pc
  - 338 systems vetted for known binaries
  - Includes *CASTOFFS* survey stars (Schlieder et al. 2016, in prep)

Young Moving Group Sample Distributions

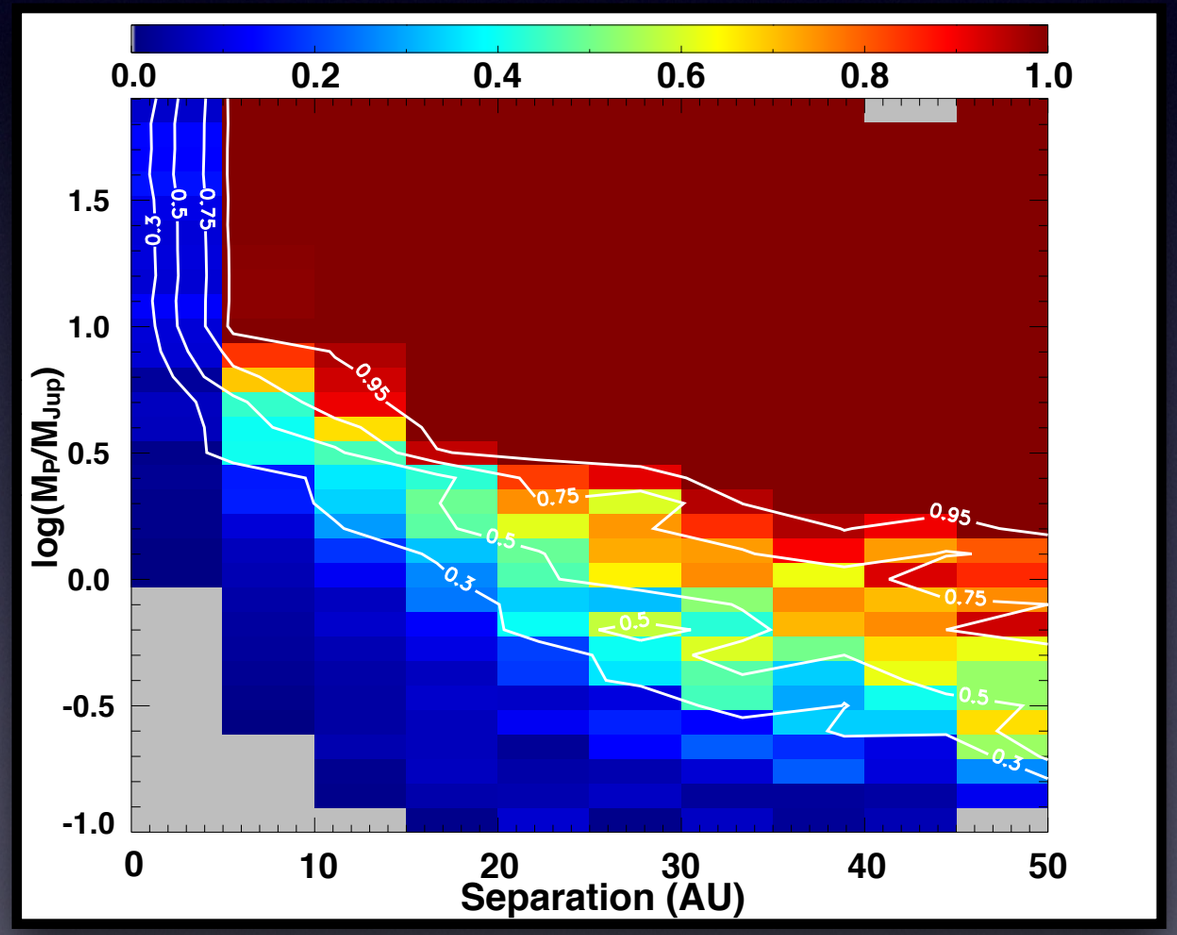


Simulations: 10-150 Myr MG sample -50 M dwarfs @<26 pc-

VLT/NaCo

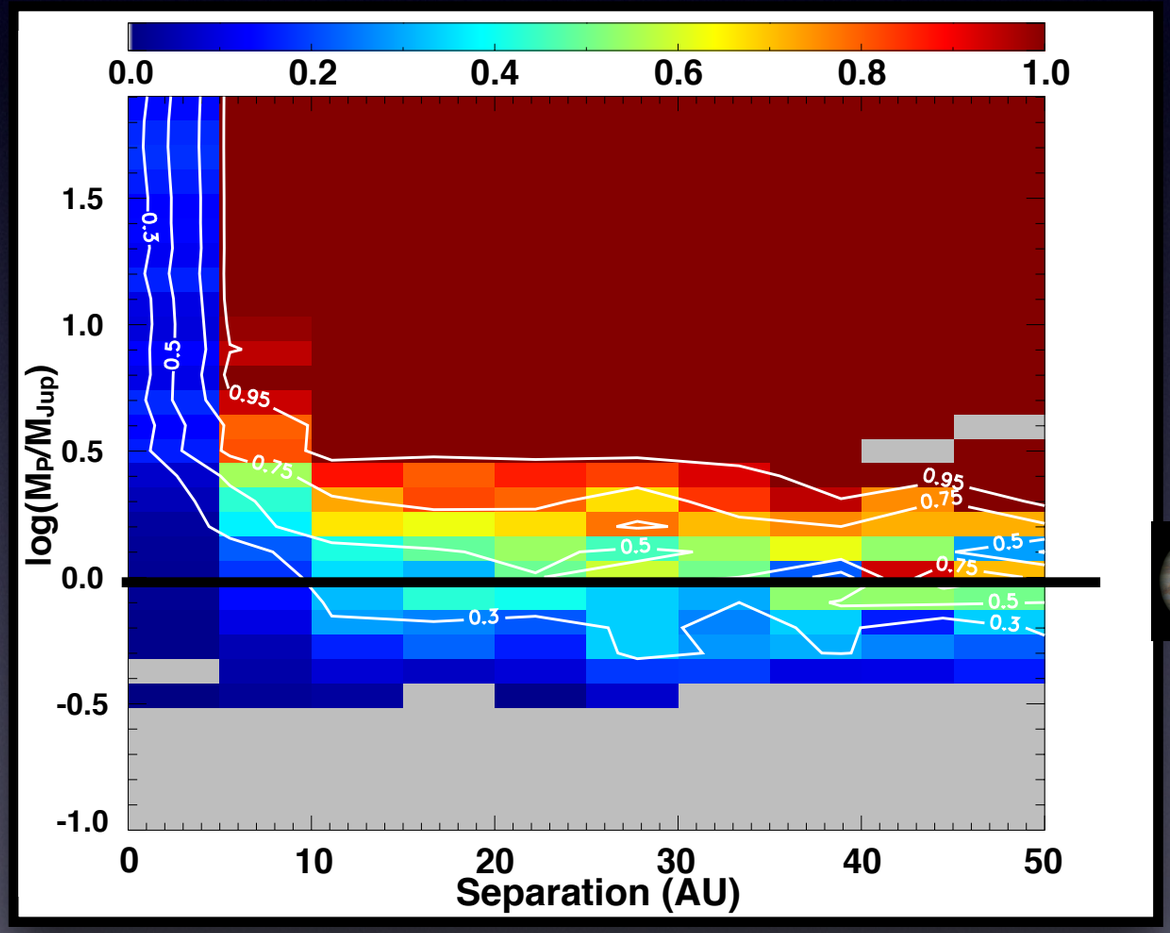


JWST/NIRCam

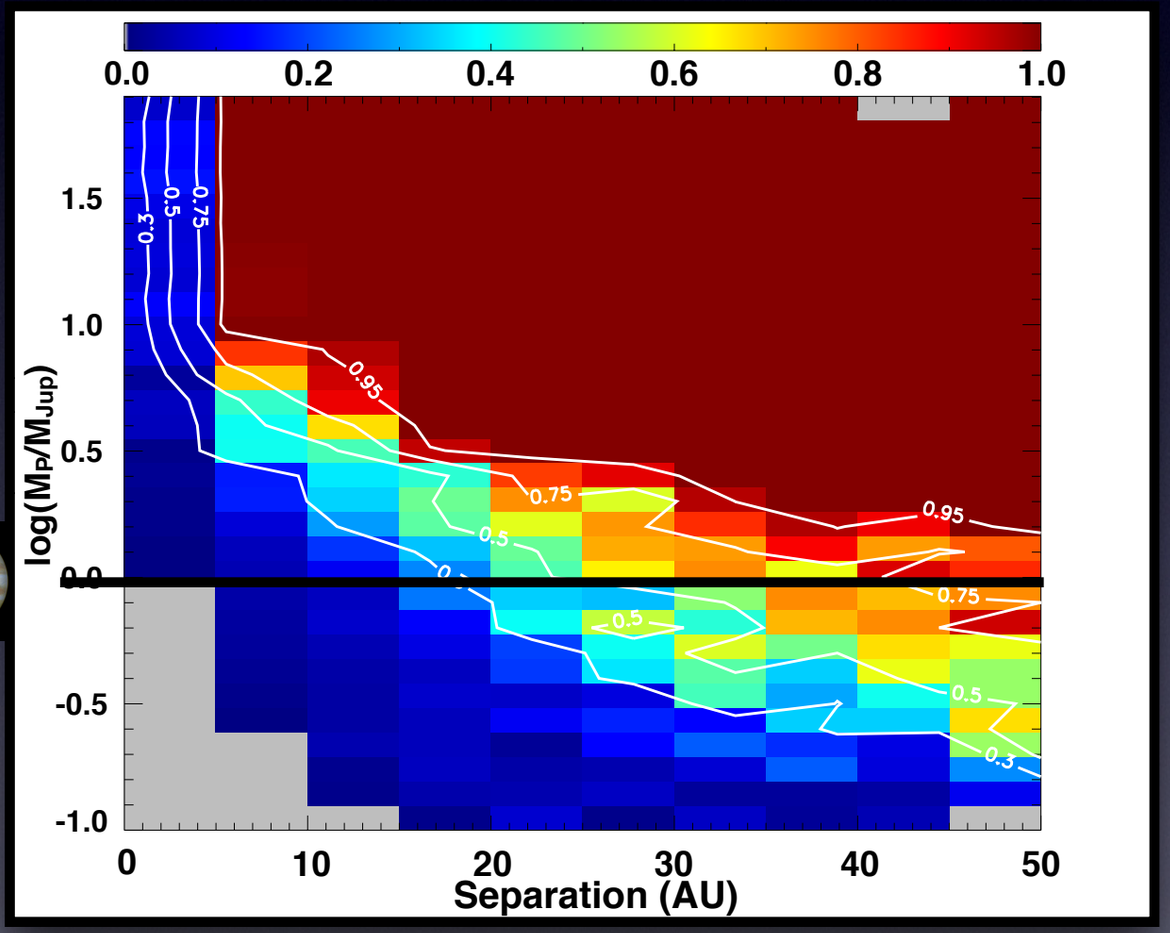


Simulations: 10-150 Myr MG sample
-50 M dwarfs @<26 pc-

VLT/NaCo

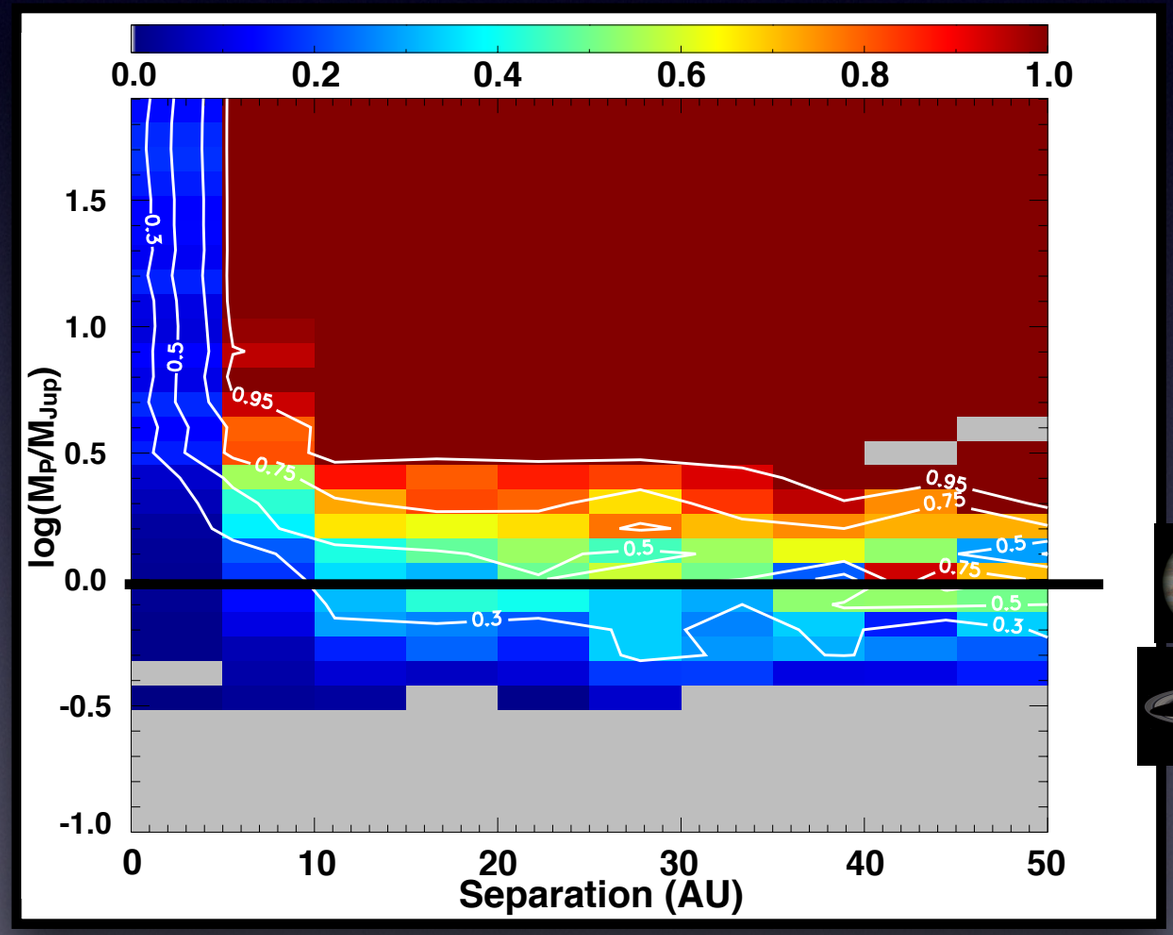


JWST/NIRCam

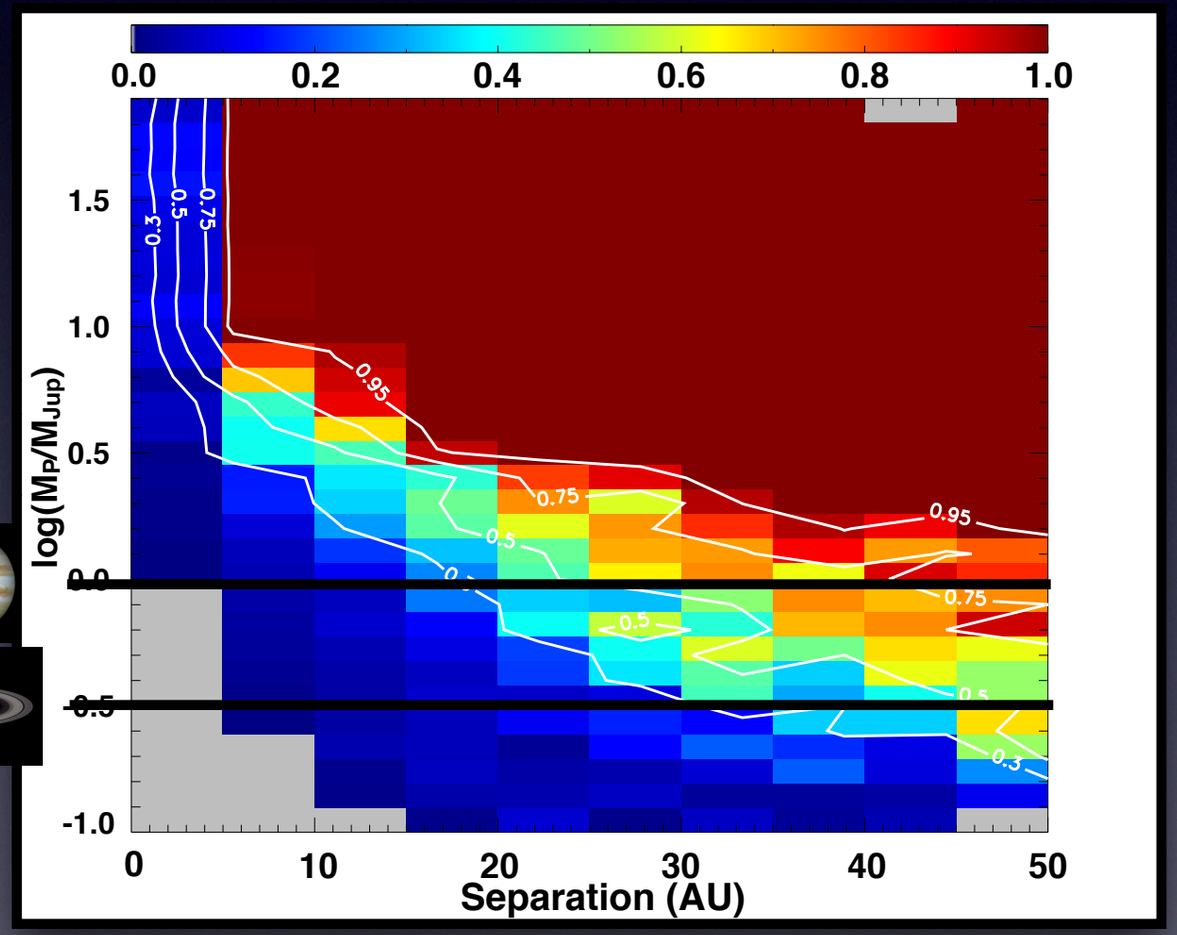


Simulations: 10-150 Myr MG sample
-50 M dwarfs @<26 pc-

VLT/NaCo

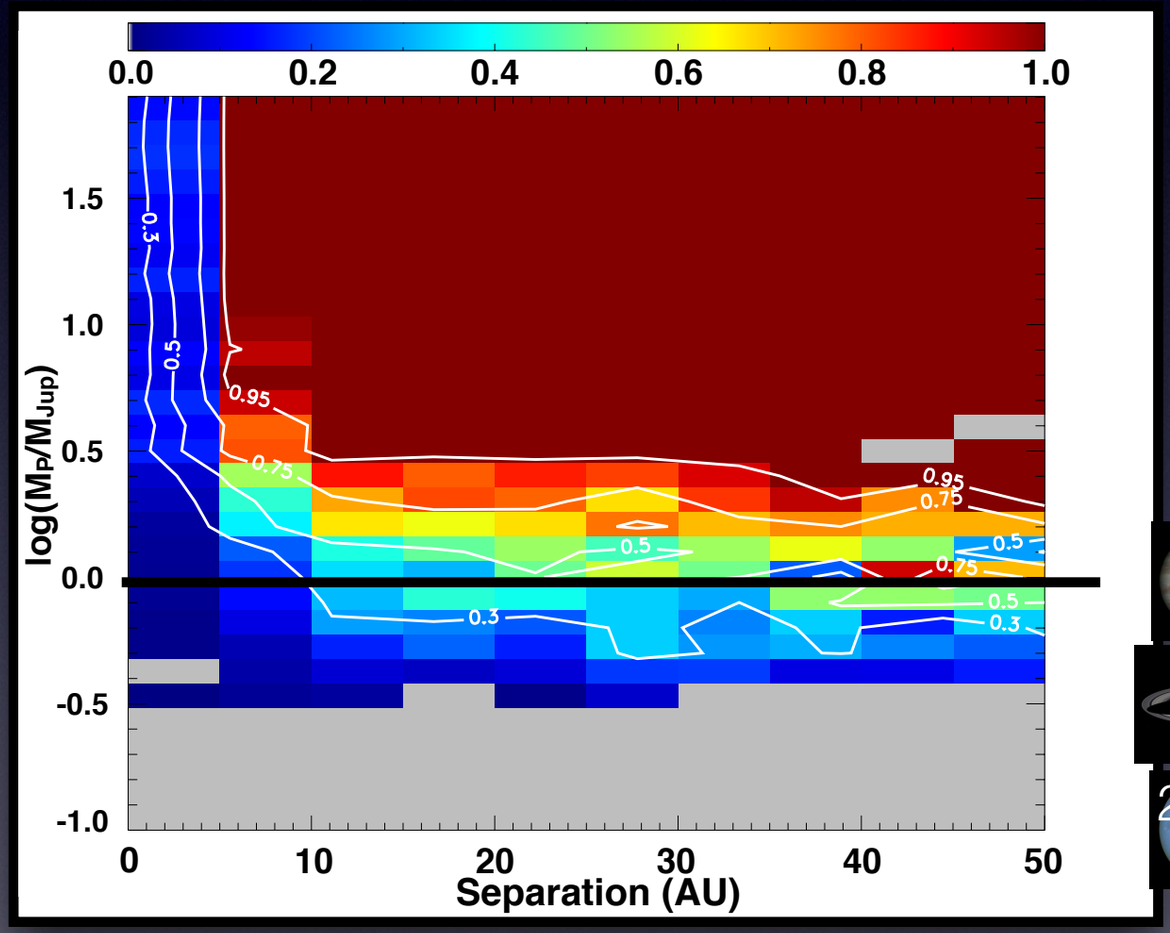


JWST/NIRCam



Simulations: 10-150 Myr MG sample
-50 M dwarfs @<26 pc-

VLT/NaCo



JWST/NIRCam