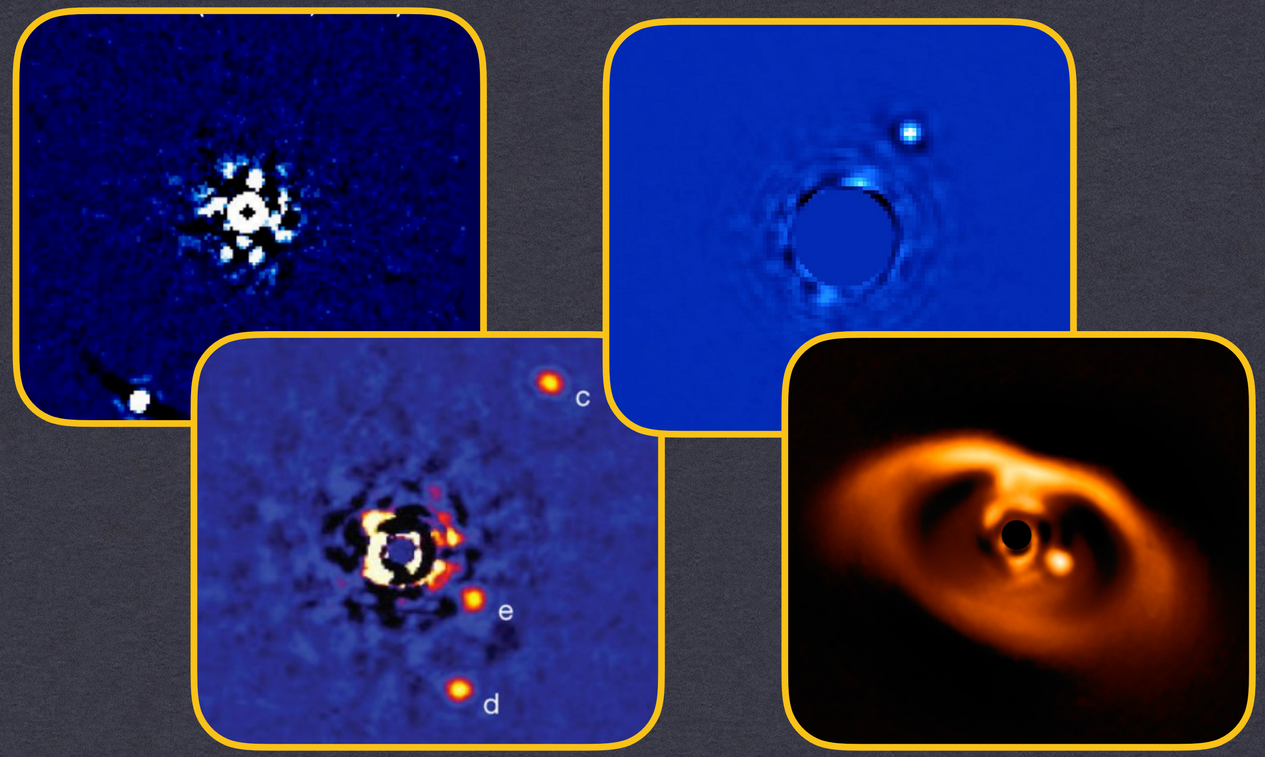
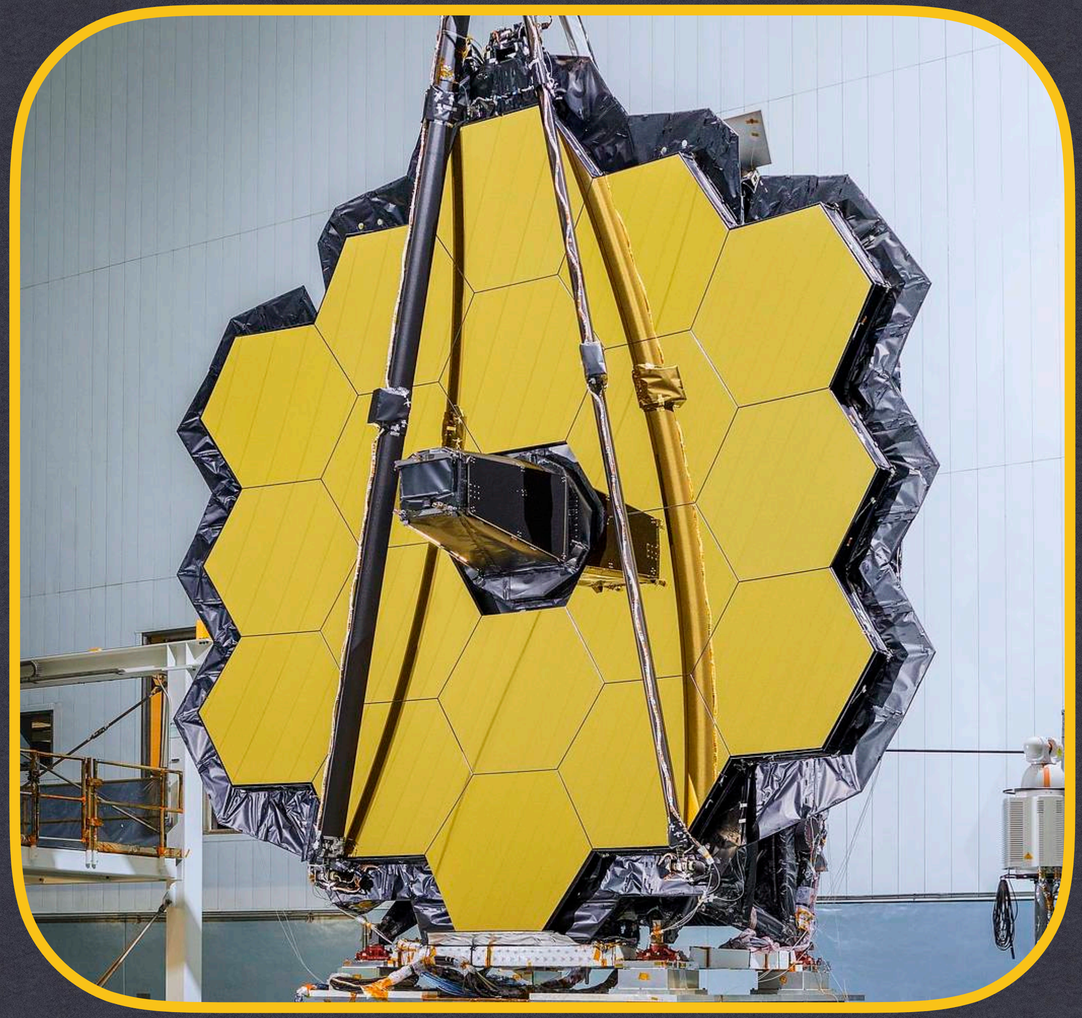
Directly Imaging Exoplanets with JWST

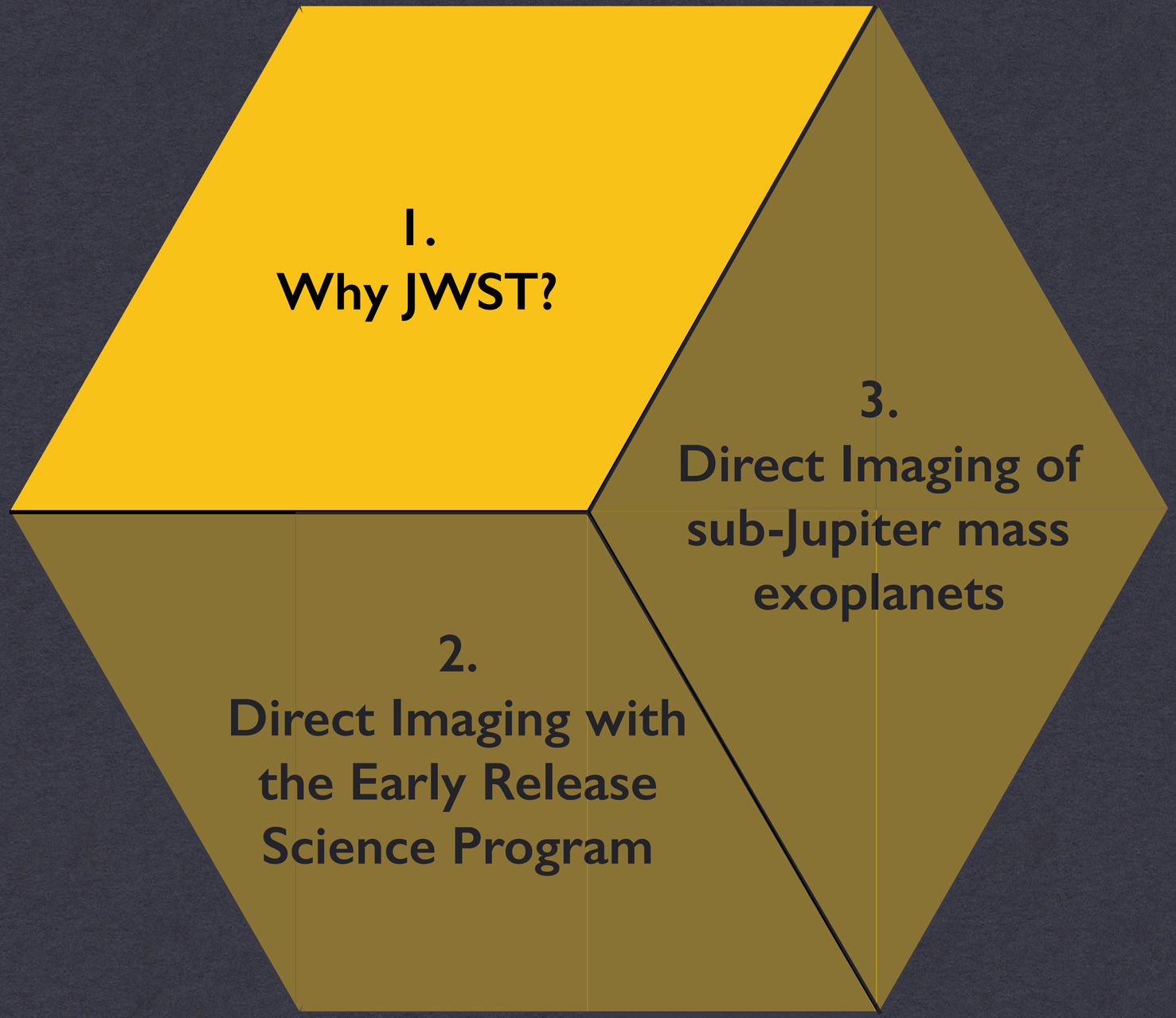




Aarynn Carter

UNIVERSITY OF EXETER

UNIVERSITY OF CALIFORNIA SANTA CRUZ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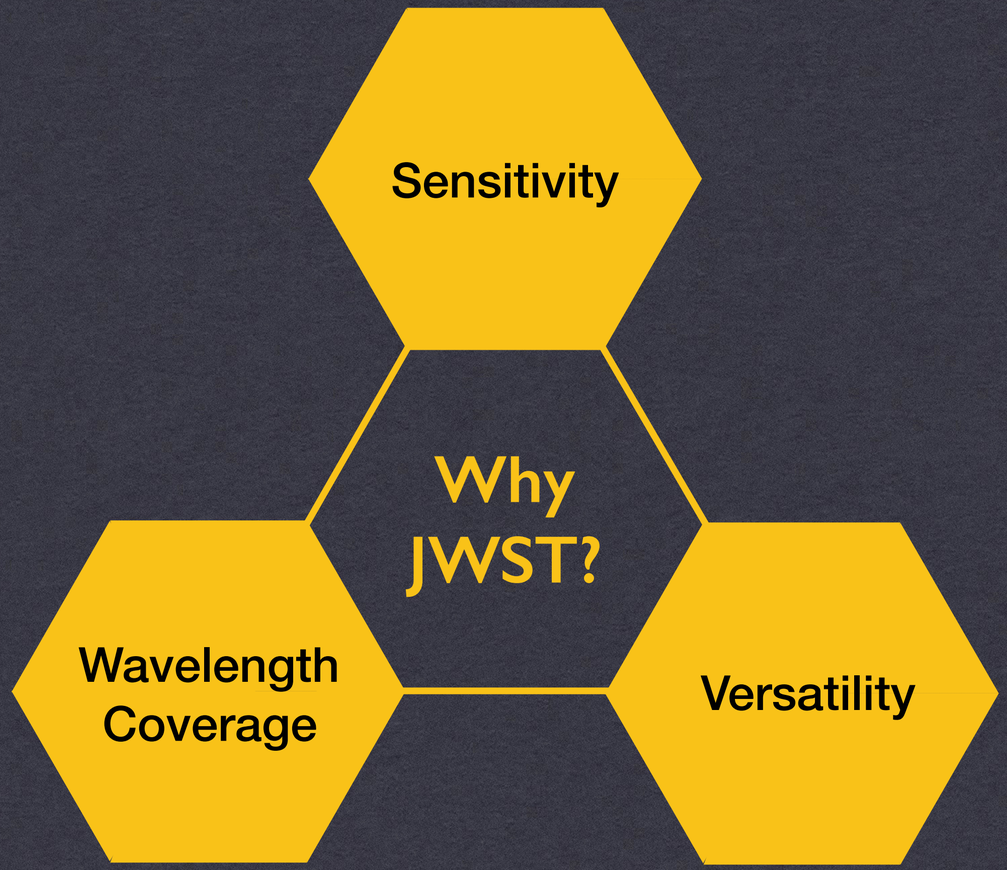
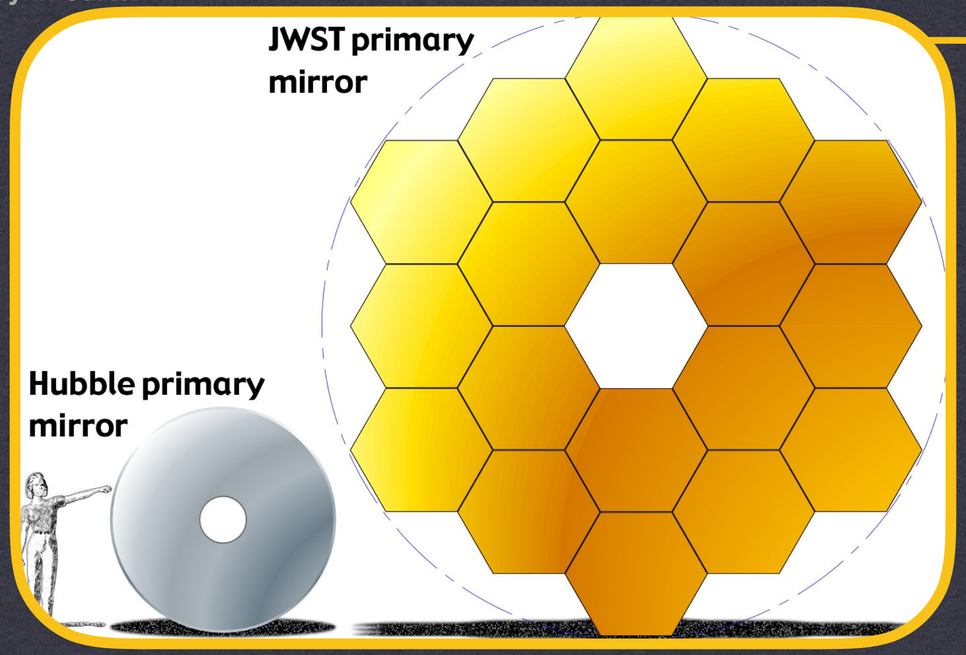
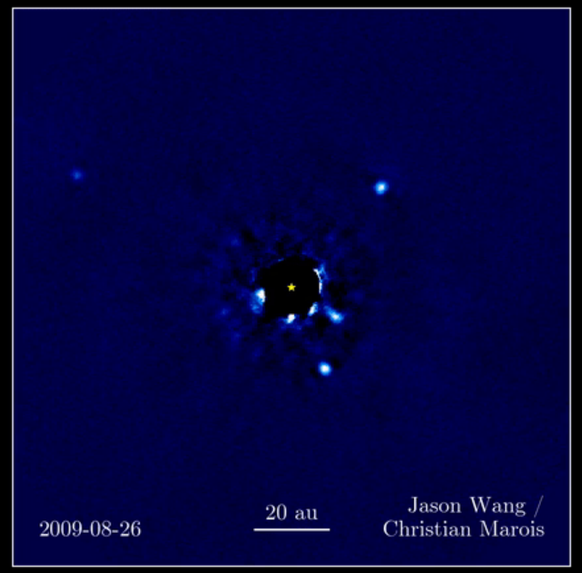
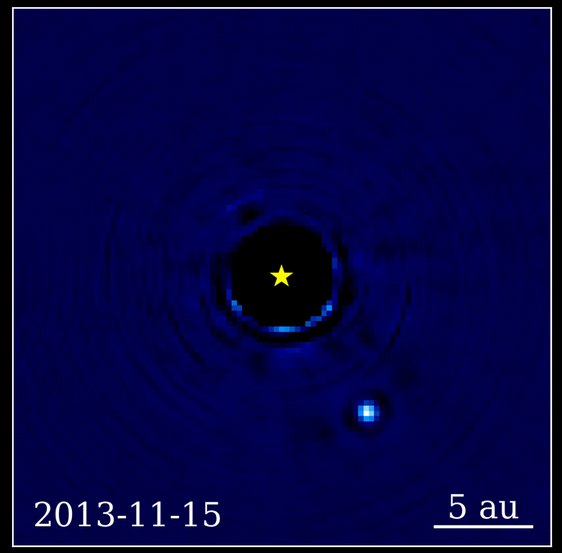

Sensitivity
Why JWST?
Wavelength Coverage
Versatility



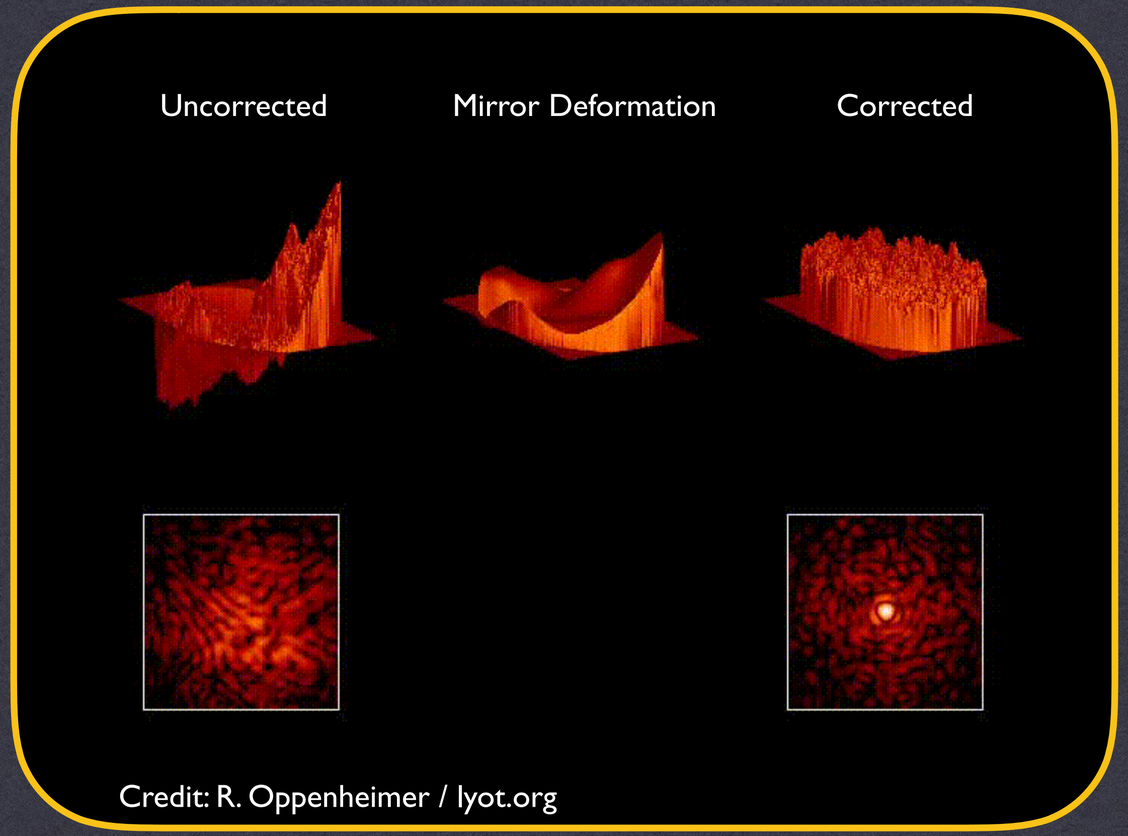
Why JWST?

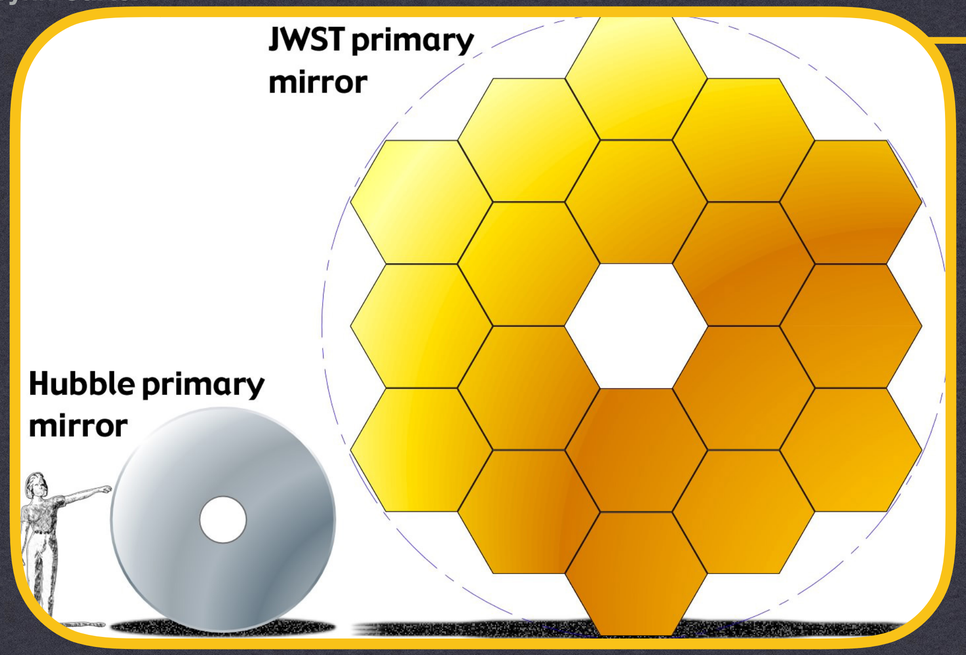
- Sensitivity
- Wavelength Coverage
- Versatility





Sensitivity



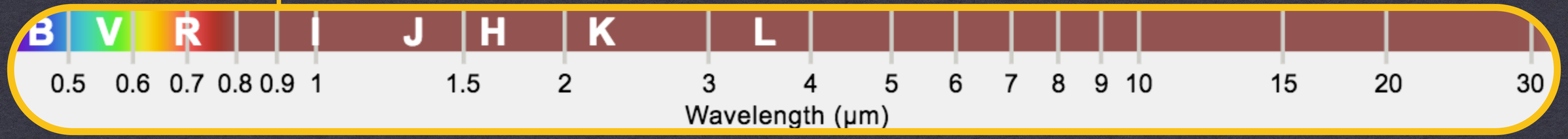


Sensitivity

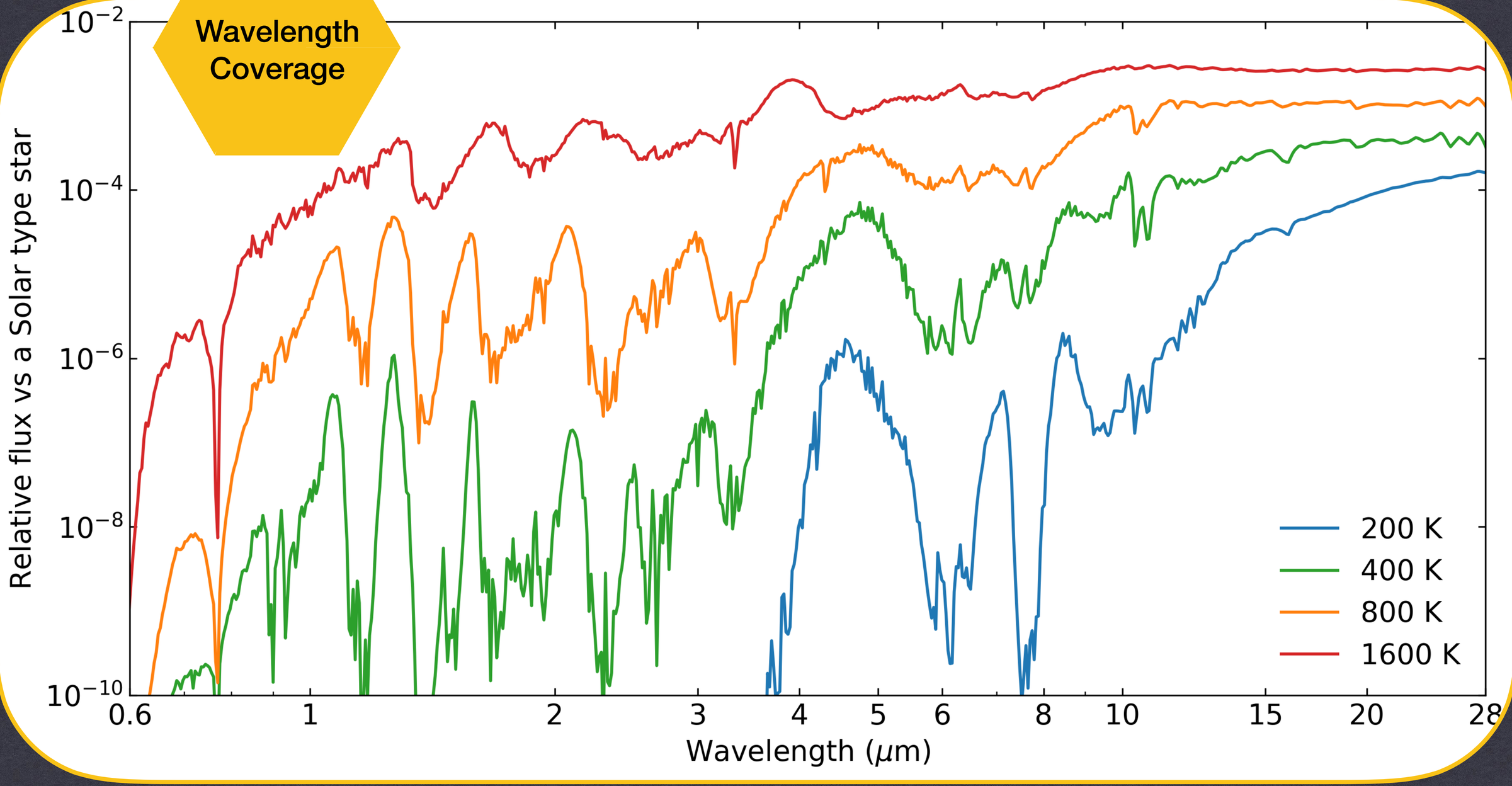
Why JWST?

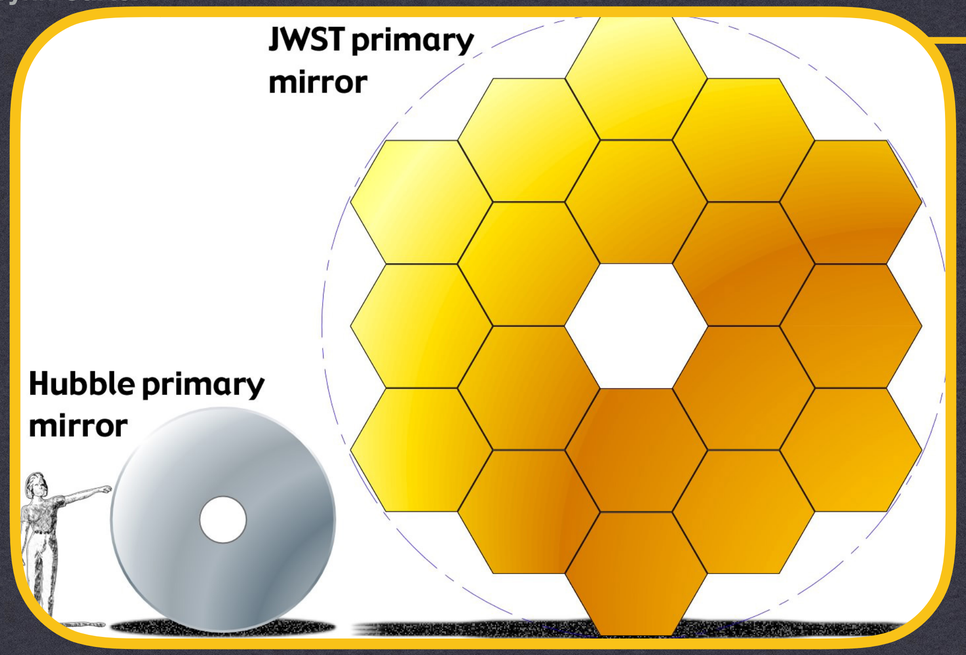
Wavelength Coverage

Versatility



Wavelength Coverage





Why JWST?

Sensitivity

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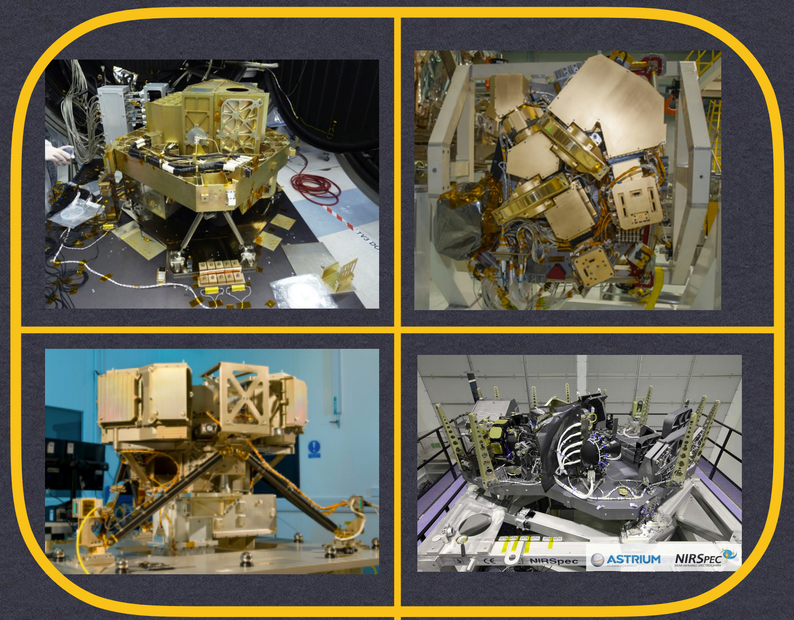
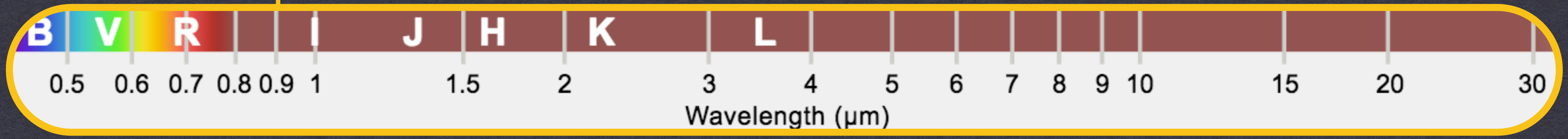
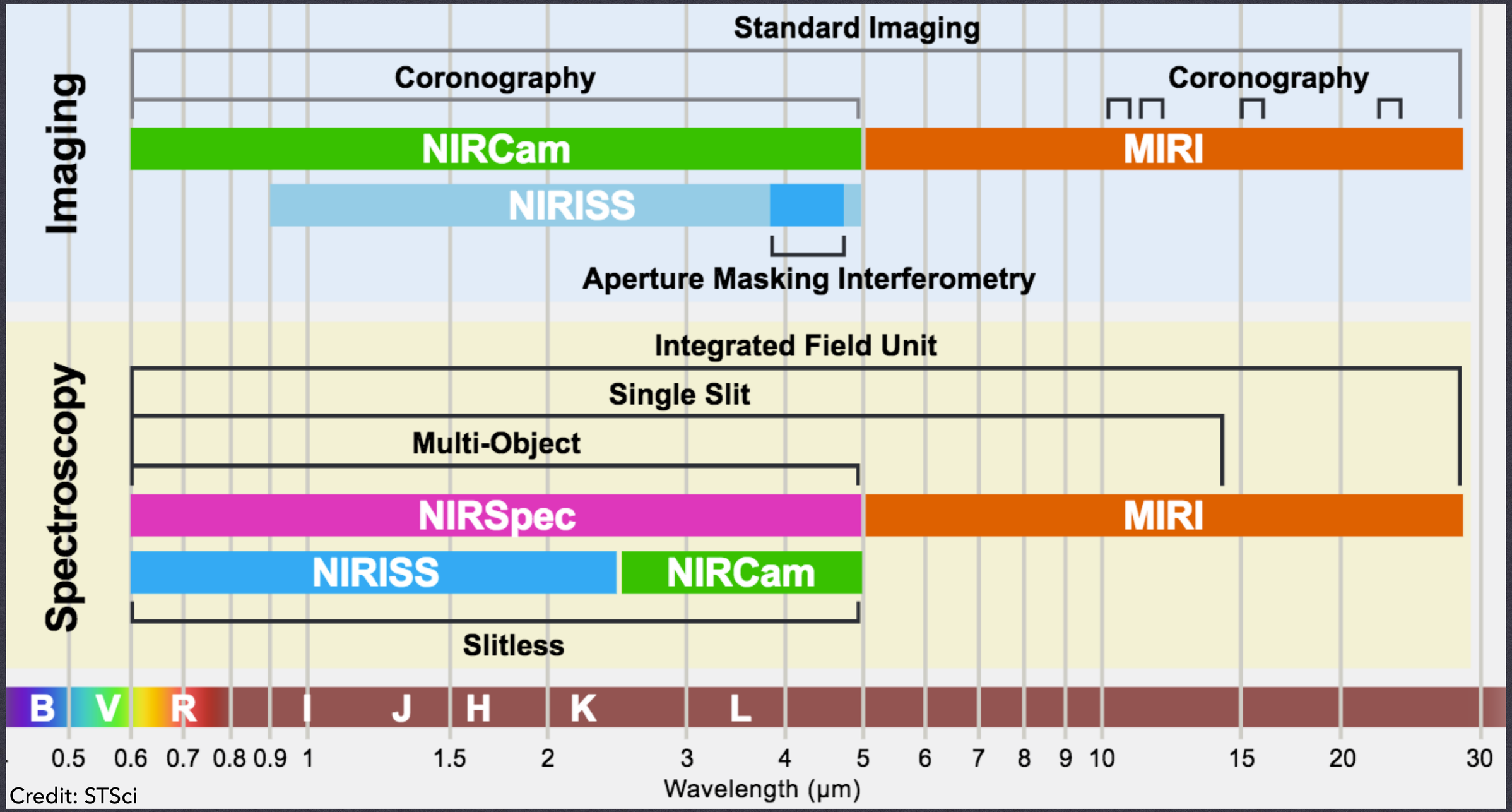
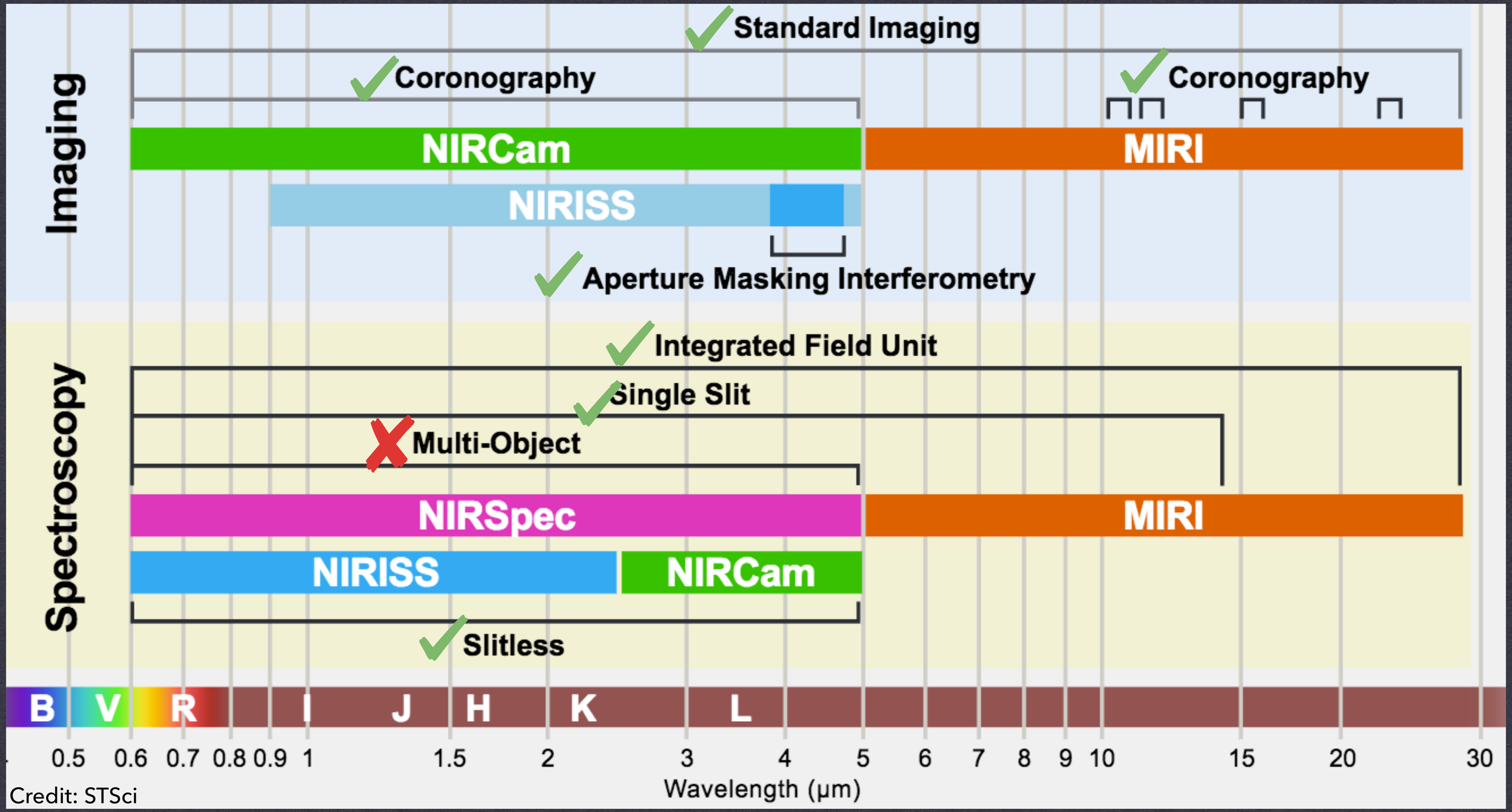






Credit: STSci



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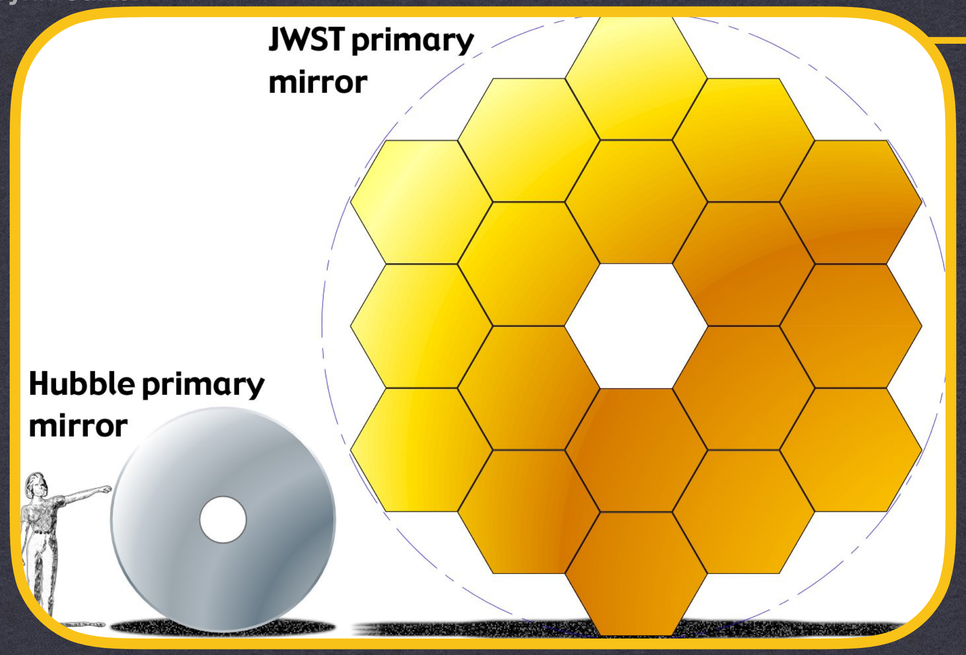

Why JWST?

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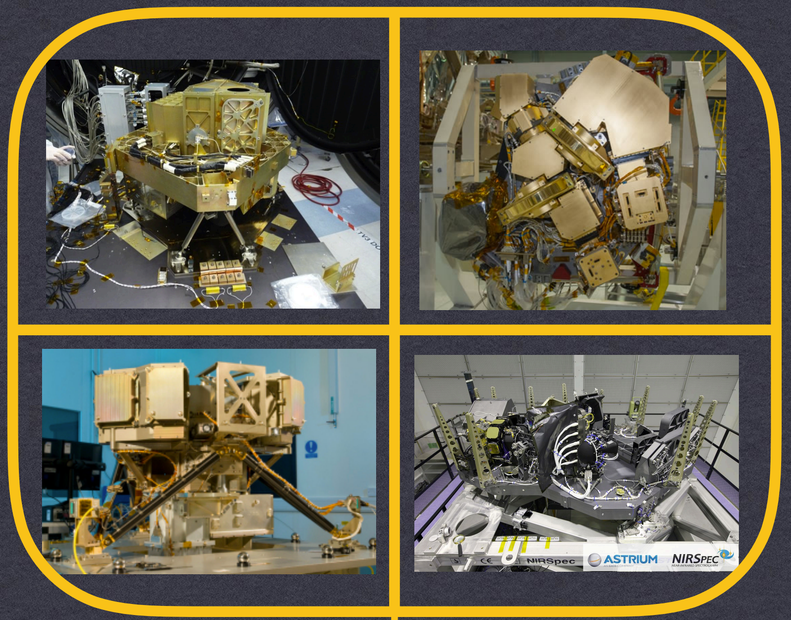

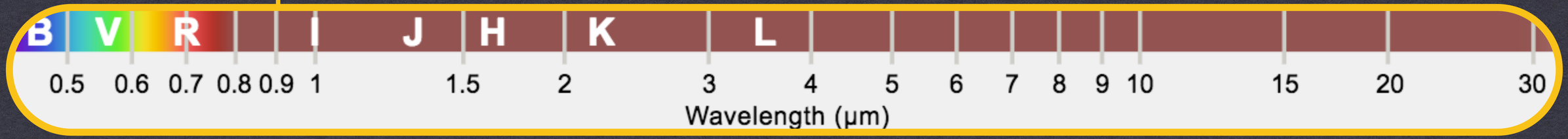

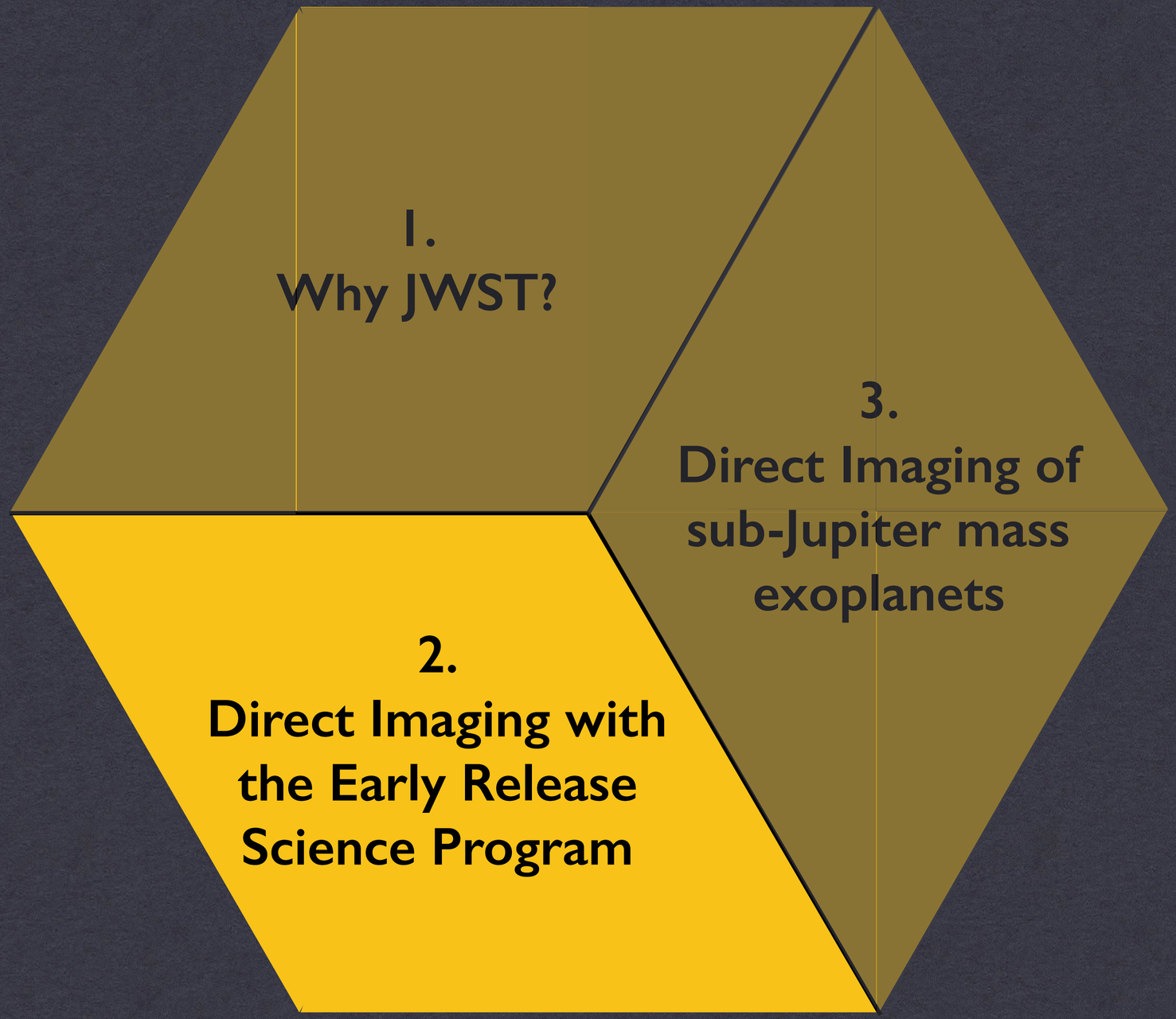
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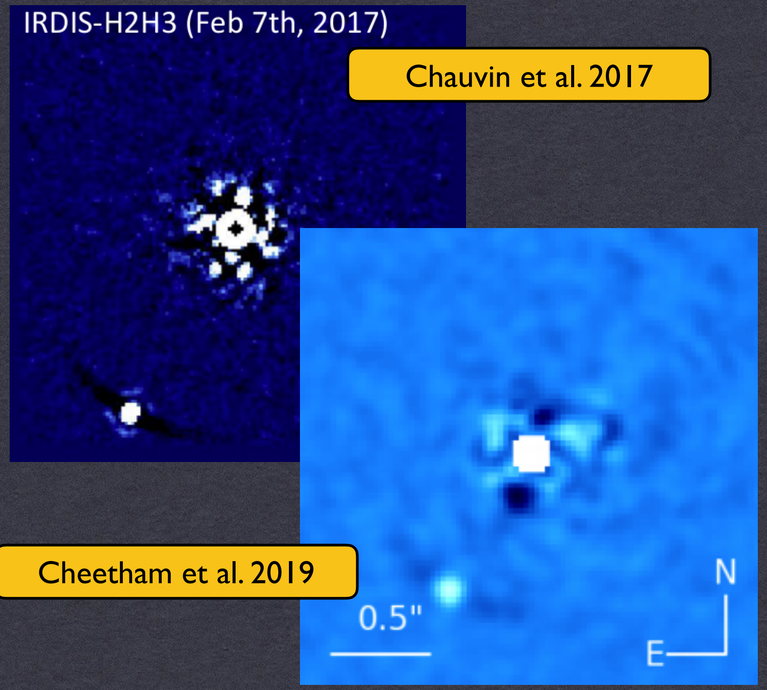
HIP 65426 b

~7-9 M_{Jup}, 1300-1600 K



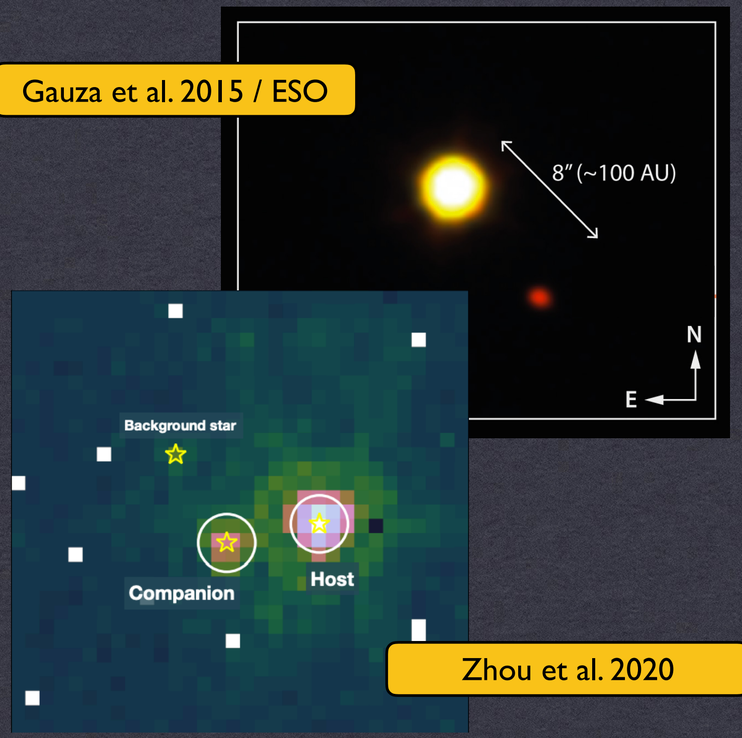
Chauvin et al. 2017

Cheetham et al. 2019

Coronagraphic photometry from 3-15 microns

VHS 1256 B

~14-24 M_{Jup}, 1000-1200 K



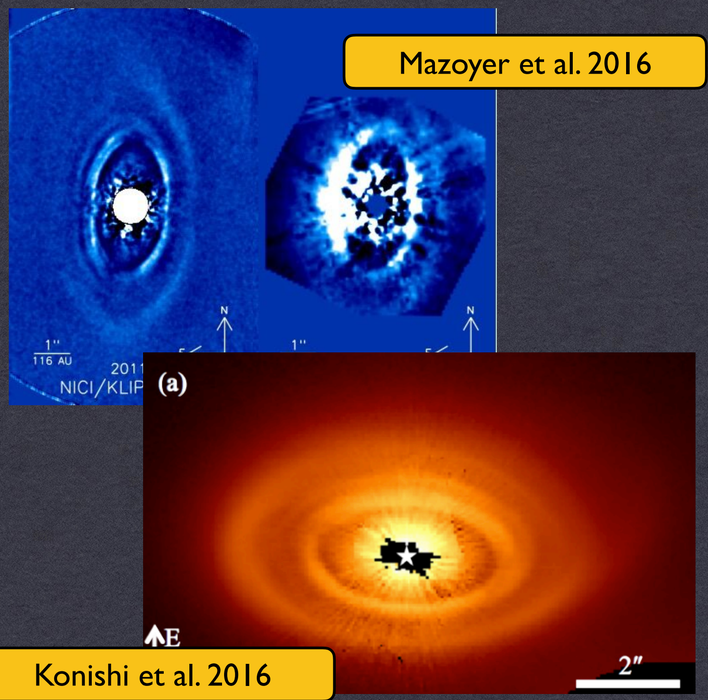
Gauza et al. 2015 / ESO

Zhou et al. 2020

Spectroscopy from 0.6-28 microns at R>1000

HD 141569 A

Triple ring disk system

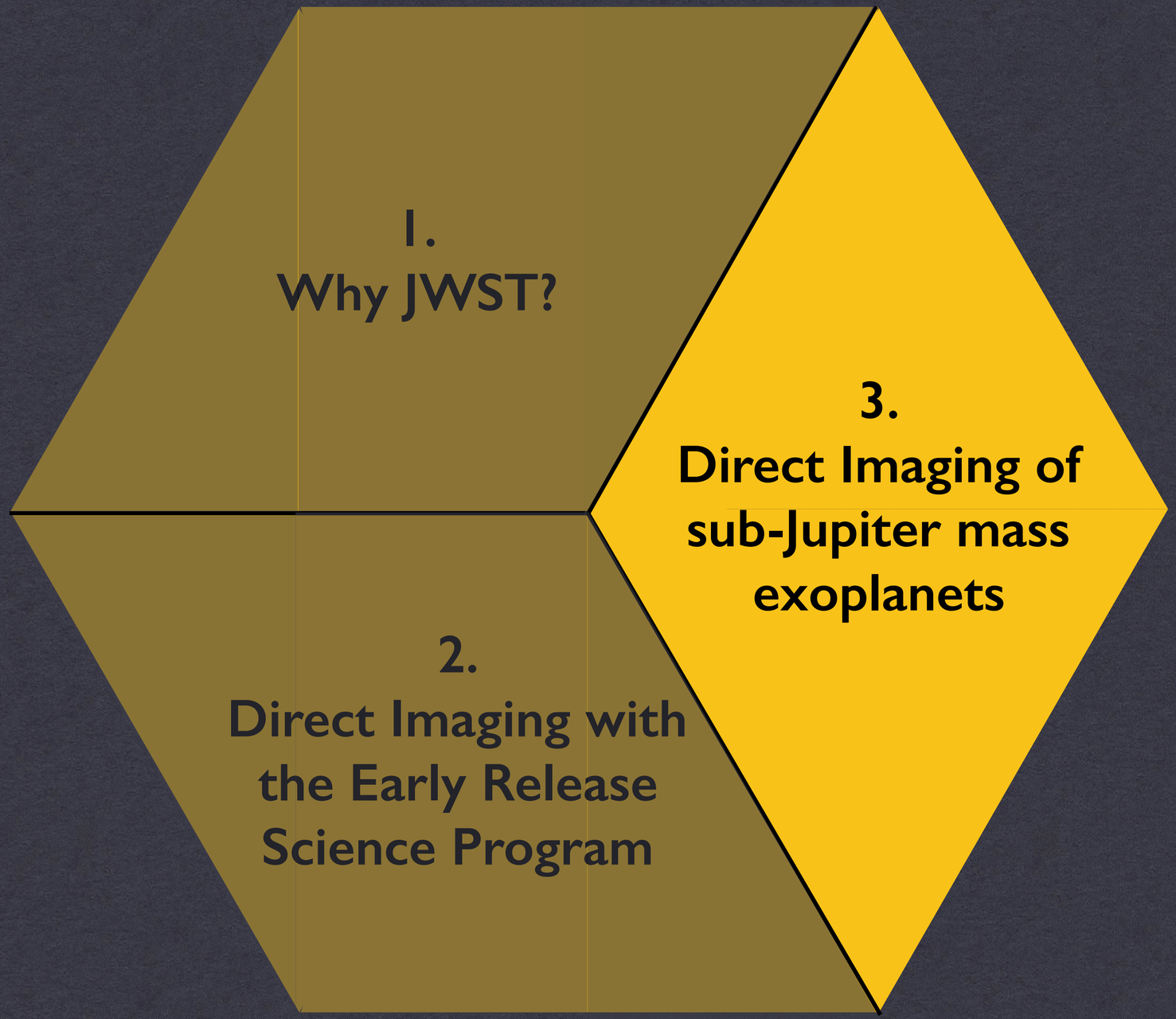


Mazoyer et al. 2016

Konishi et al. 2016

Coronagraphic photometry from 3-15 microns

https://ers-imaging.github.io/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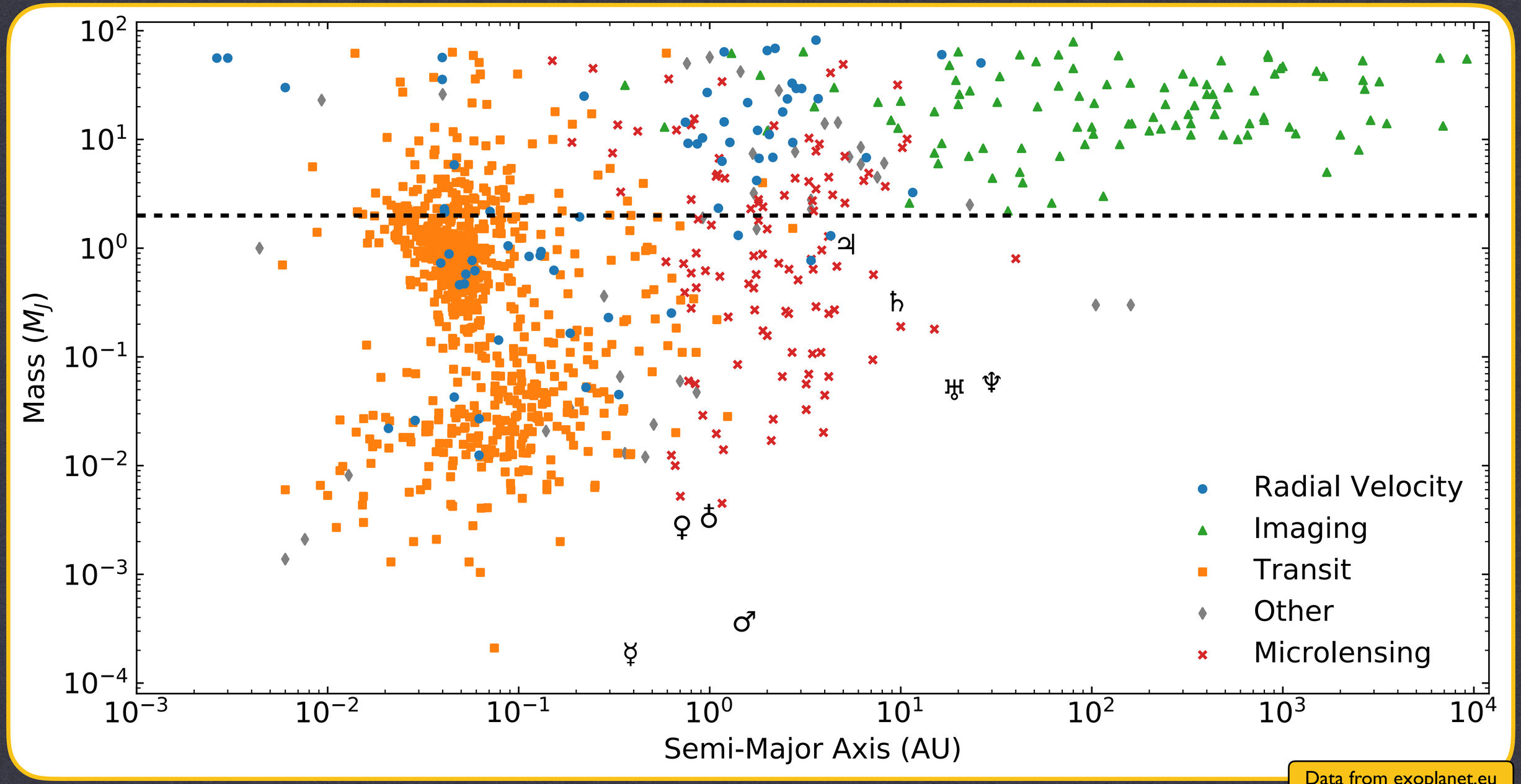
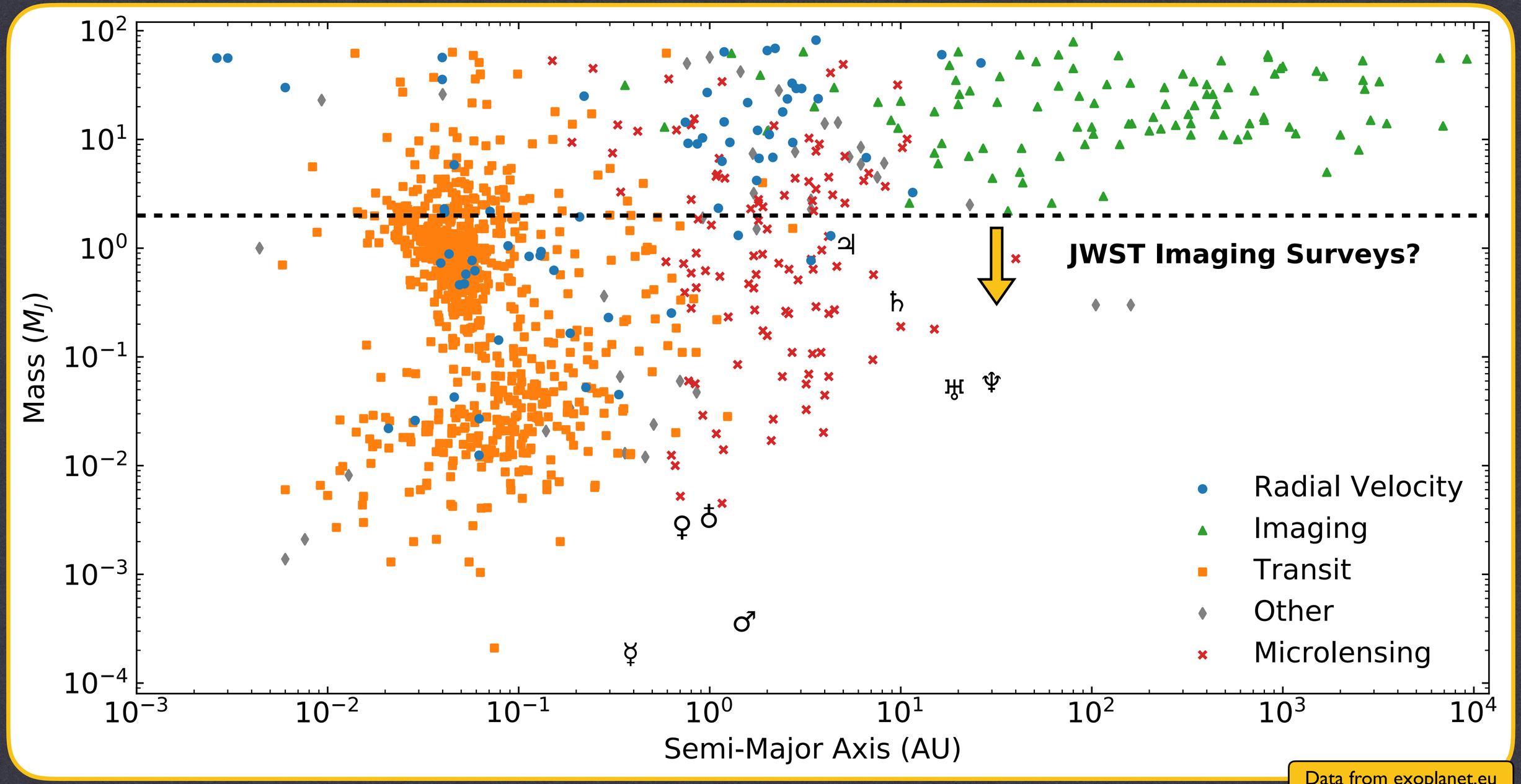
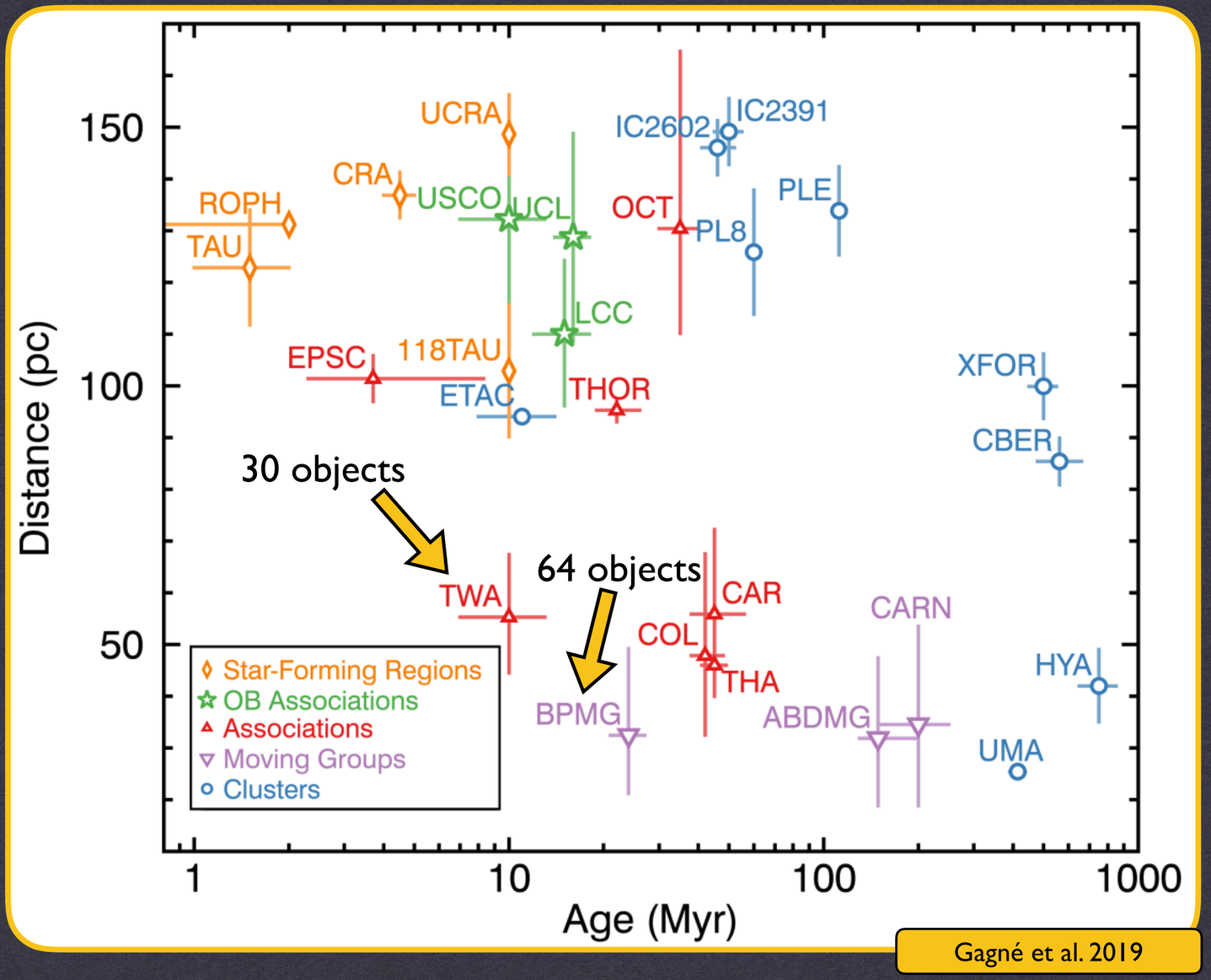

Mass (M_J)
Semi-Major Axis (AU)
Radial Velocity
Imaging
Transit
Other
Microlensing
Data from exoplanet.eu


JWST Imaging Surveys?
Mass (M_J)
Semi-Major Axis (AU)
Radial Velocity
Imaging
Transit
Other
Microlensing
Data from exoplanet.eu

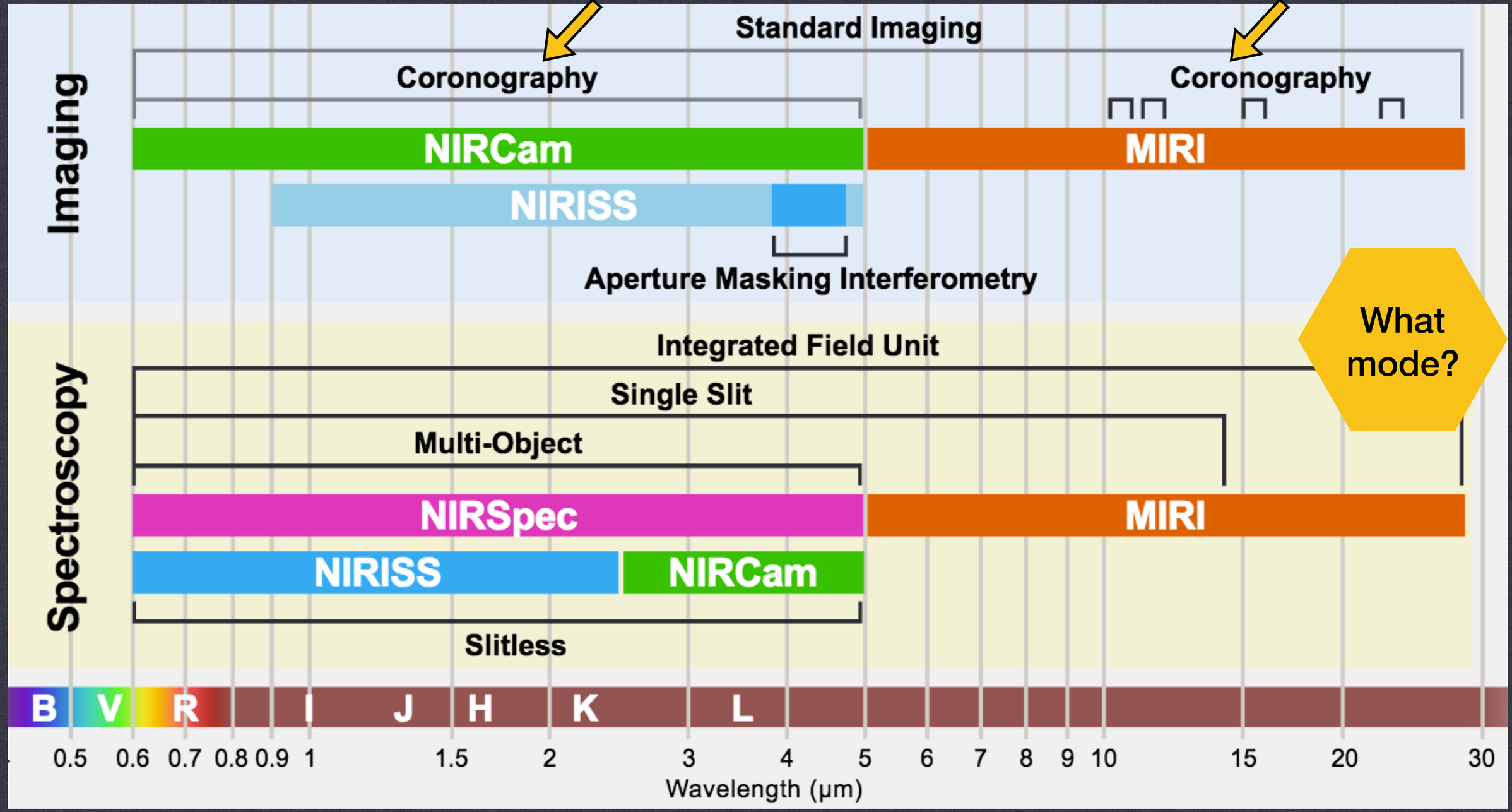
What targets?

- Young moving groups / stellar associations provide relatively strong age constraints.

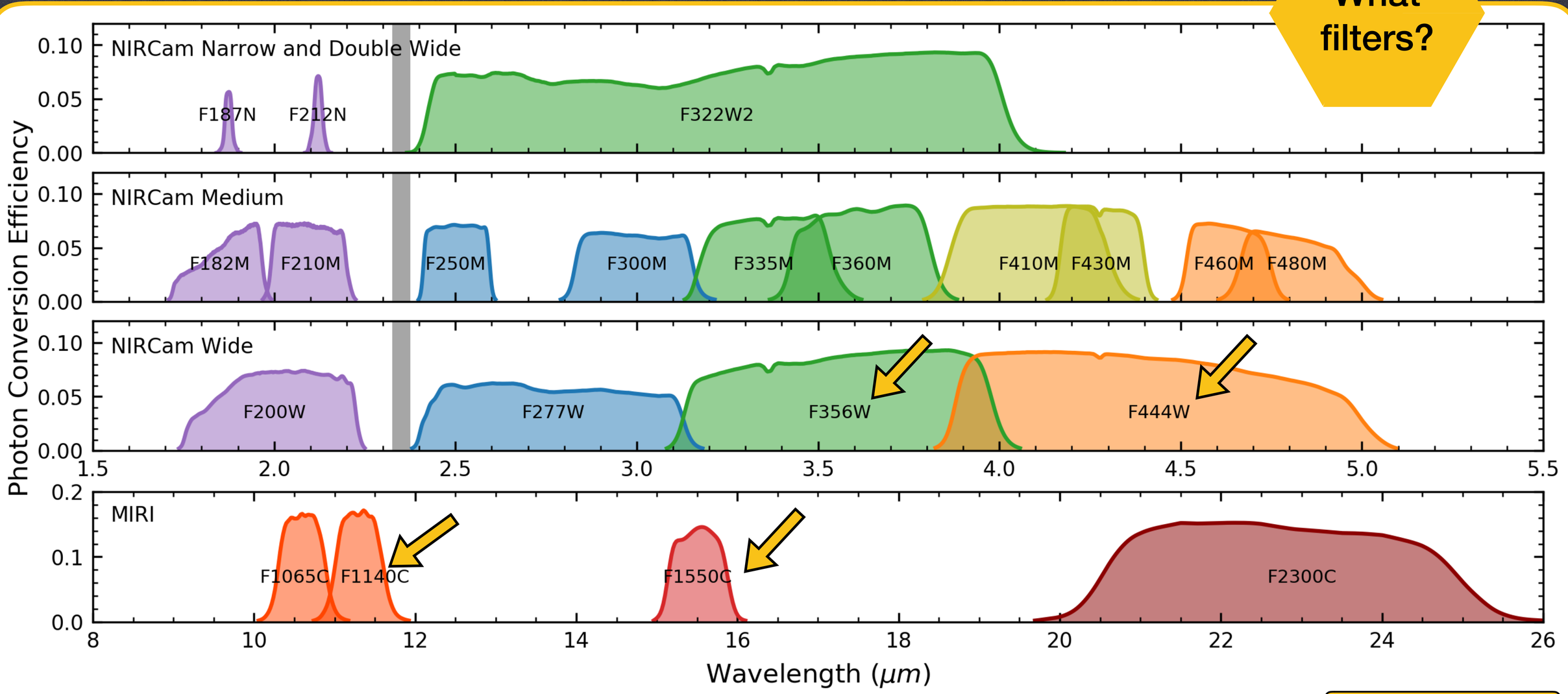
- βPMG and TWA are both nearby and have suitably young ages.



Gagné et al. 2019


Imaging
Standard Imaging
Coronography
Coronography
NIRCam
MIRI
NIRISS
Aperture Masking Interferometry
What mode?
Spectroscopy
Integrated Field Unit
Single Slit
Multi-Object
NIRSpec
MIRI
NIRISS
NIRCam
Slitless
B
V
R
I
J
H
K
L
0.5
0.6
0.7
0.8
0.9
1
1.5
2
3
4
5
6
7
8
9
10
15
20
30
Wavelength (μm)

What filters?



Carter et al. in prep

Estimating JWST Coronagraphic Sensitivity

Estimating JWST Coronagraphic Sensitivity

1) Simulate Observation Images

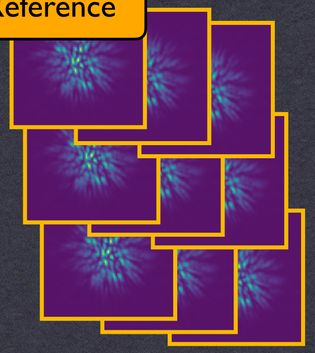
Target

PanCAKE

https://github.com/spacetelescope/pandeia-coronagraphy

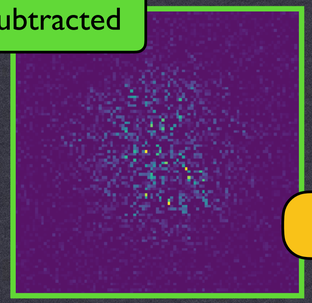
\-

Reference



=

Subtracted



Assumptions

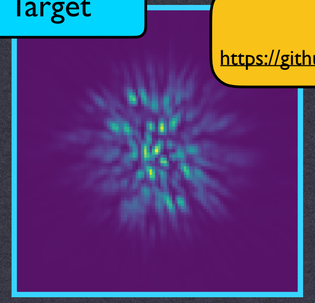
- Target Acquisition
- Wavefront Error
- Dithering Strategy
- Observation Duration
- Reference Properties
- Background
- Subtraction Strategy
- Reference Slew Angles
- Slew Duration
- Thermal Drift
- .
- .
- .
- .

Intensity scale 100x smaller!

Estimating JWST Coronagraphic Sensitivity

1) Simulate Observation Images

Target



PanCAKE

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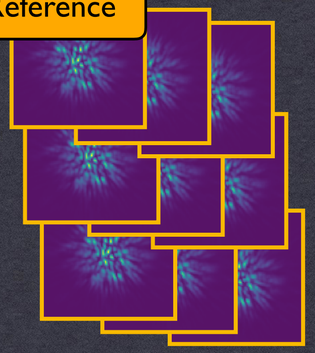

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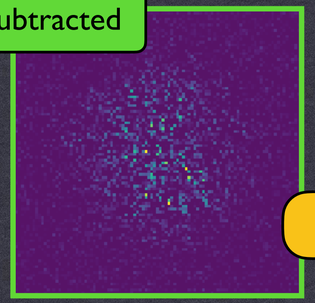
Subtracted



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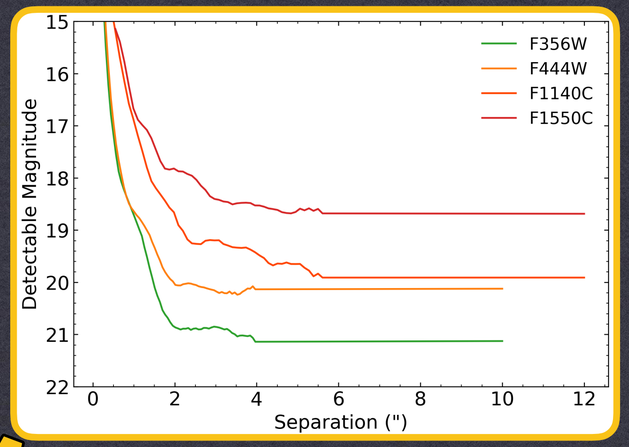
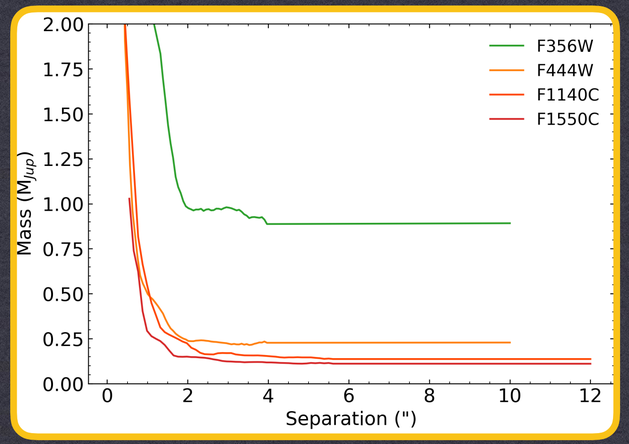
2) Compute Detection Sensitivity



Evolutionary Models

Linder et al. 2019 (5 M_{Earth} - 2 M_{Jup})

Phillips et al. 2020 (0.5 - 75 M_{Jup})



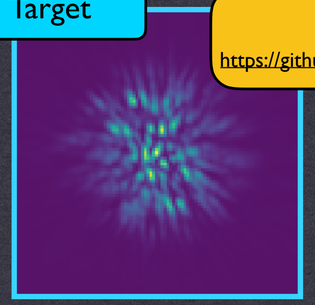
Aarynn Carter

Exo-Webbinar - July 2020

Estimating JWST Coronagraphic Sensitivity

1) Simulate Observation Images

Target



PanCAKE

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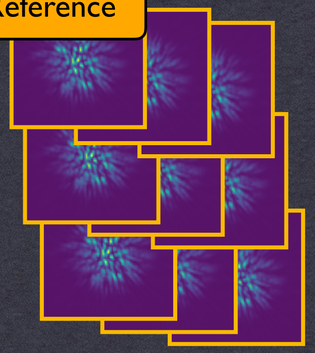
Reference



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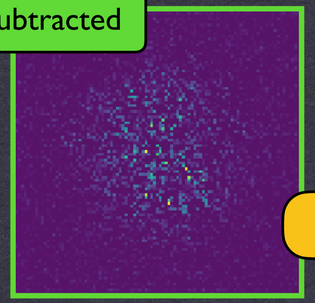
Subtracted



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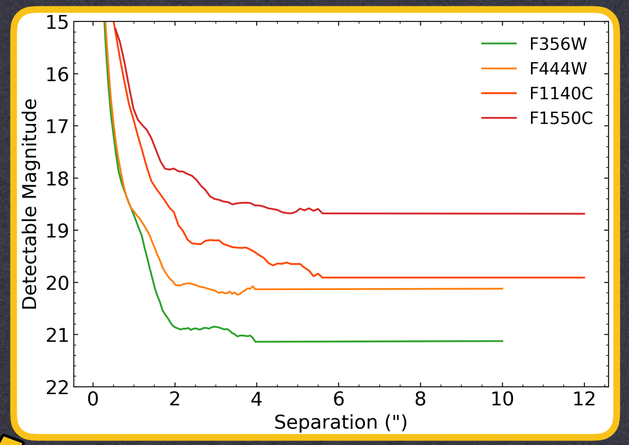
Intensity scale 100x smaller!

2) Compute Detection Sensitivity



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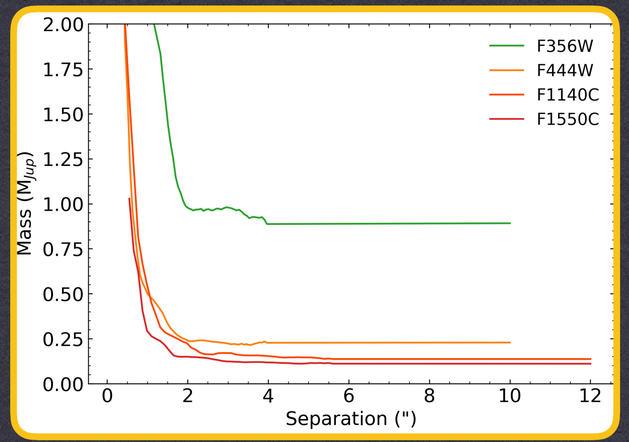
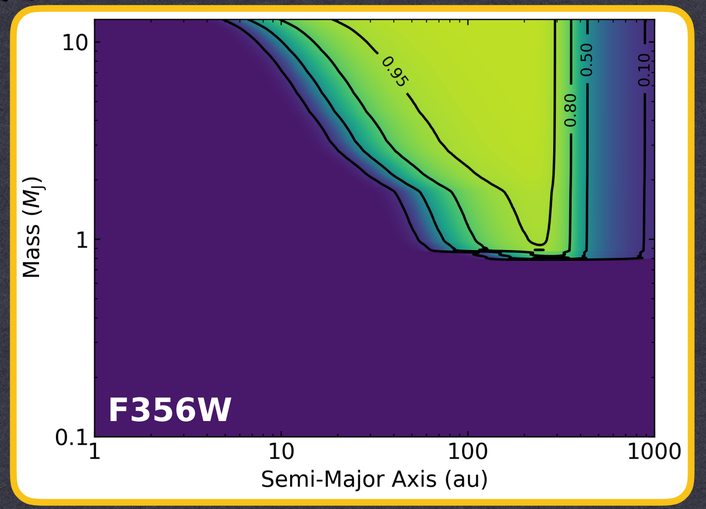
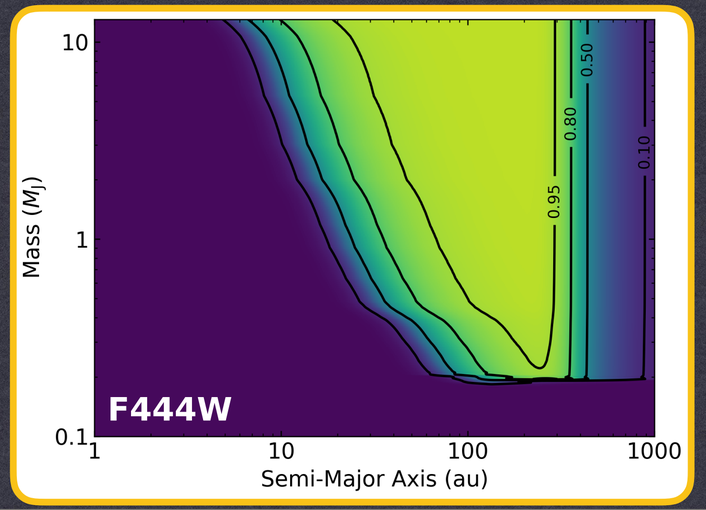


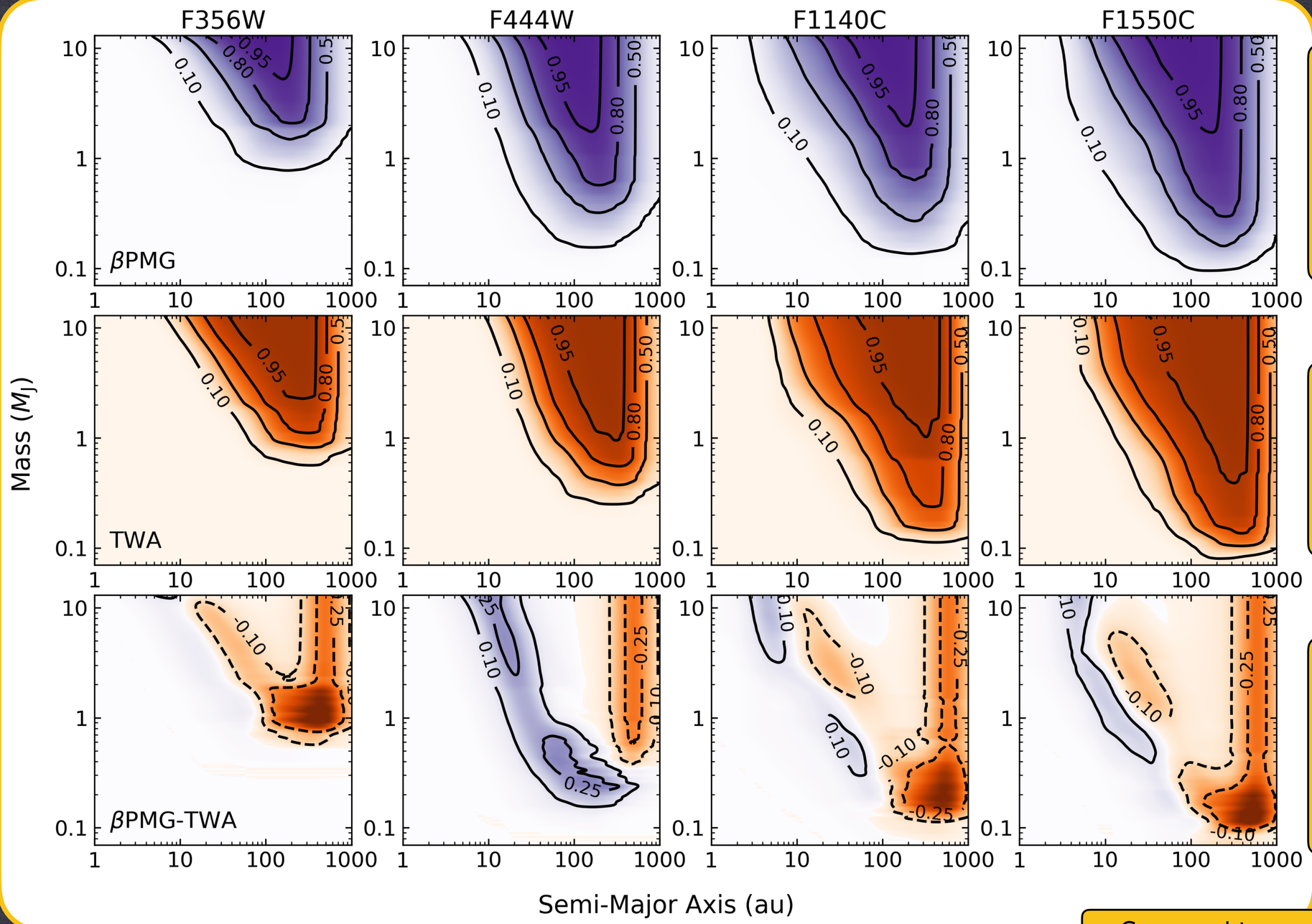
3) Produce Detection Probability Maps

Quick-MESS

Bonavita et al. 2012, 2013, in prep







MIRI presents the best opportunity to directly image sub-Jupiter mass companions.

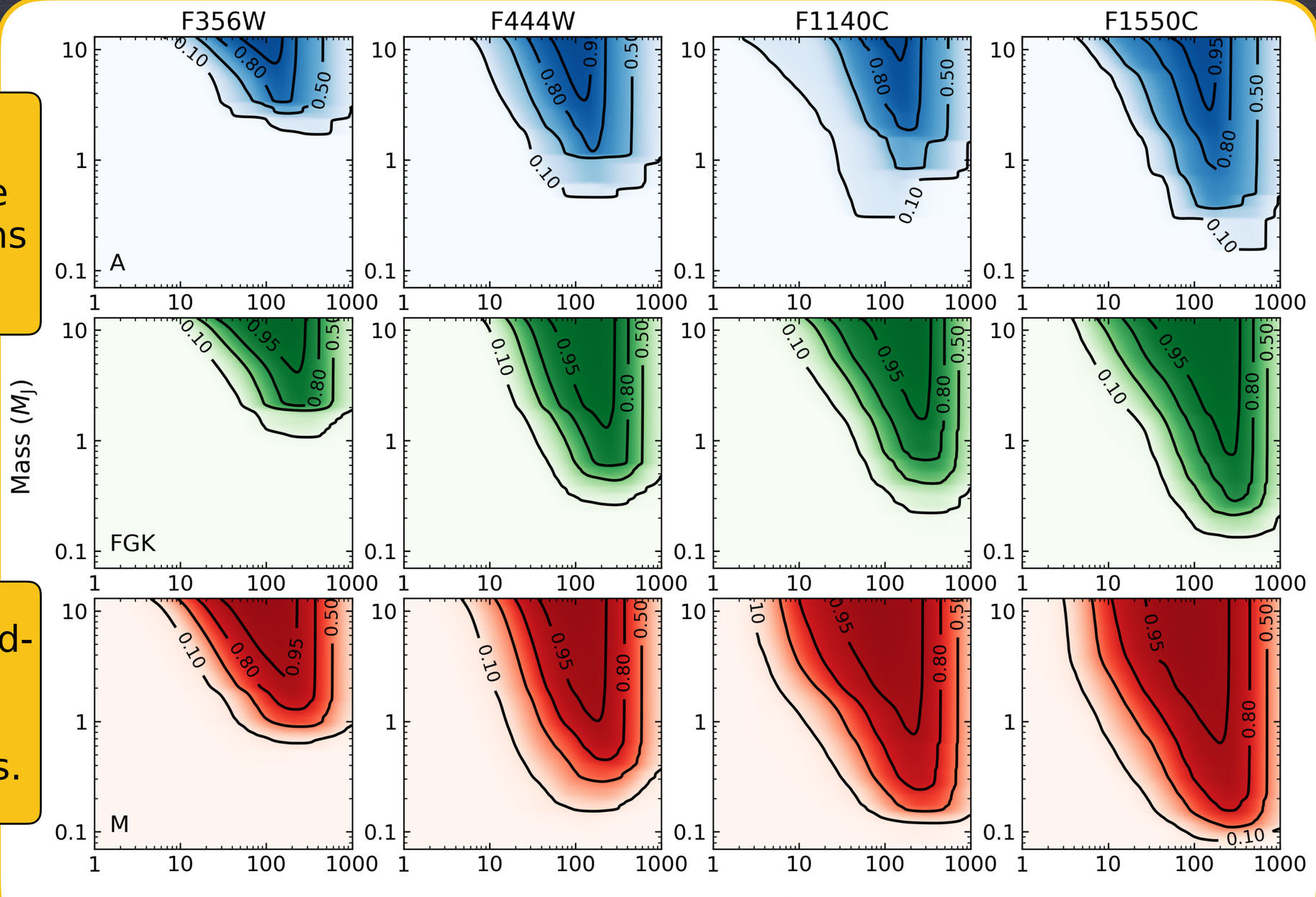
βPMG members generally superior at smaller separations.

TWA members generally sensitive to the smallest mass objects.

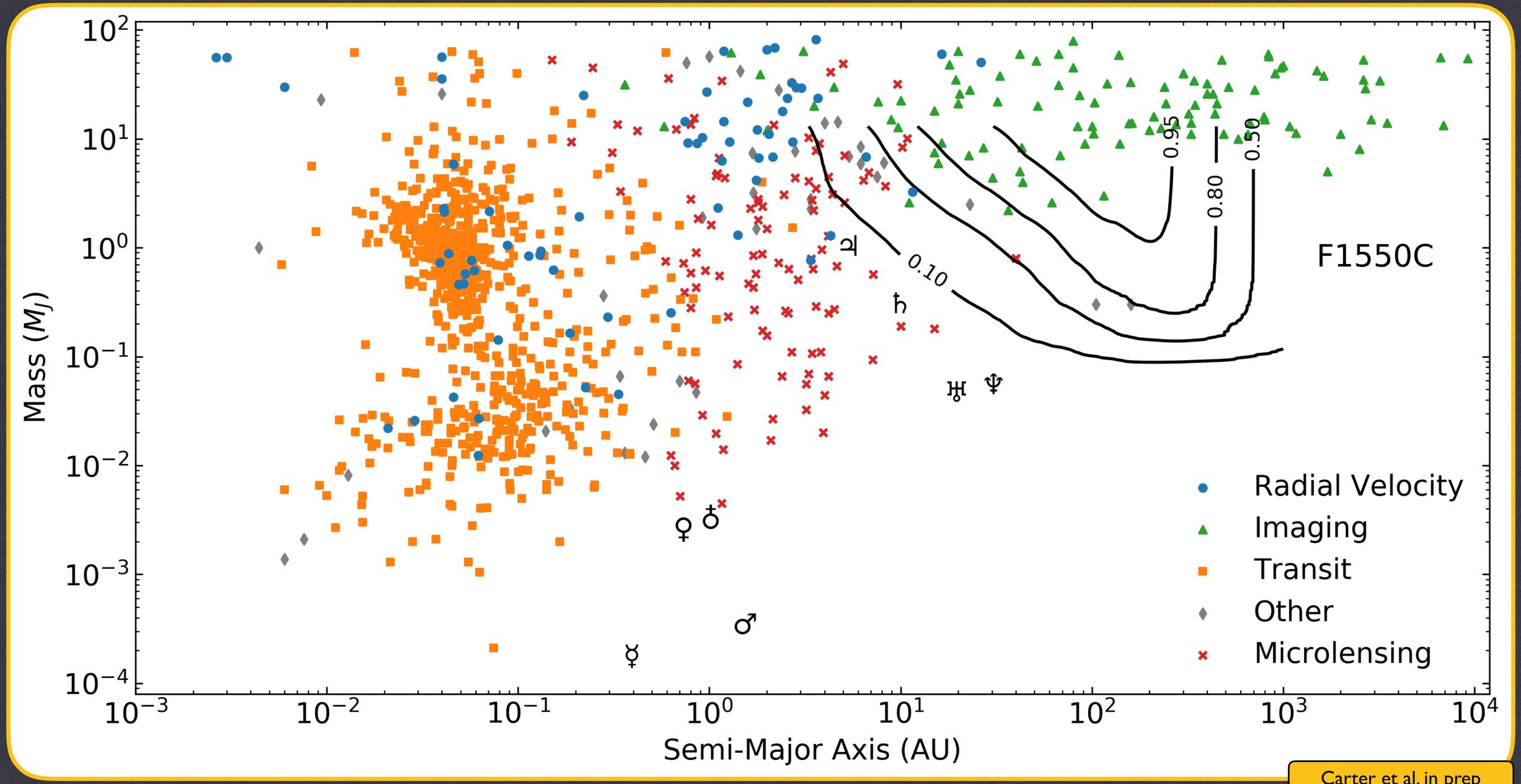
Carter et al. in prep

M stars are the best targets for imaging the lowest mass companions with JWST.

Contrast to many ground-based observations, where M stars are typically inferior targets.



Carter et al. in prep



Carter et al. in prep

Conclusions

- JWST will not only dramatically advance our understanding of exoplanetary atmospheres through transit observations, but also **offers unique capabilities with regards to directly imaging and characterising wide separation exoplanets.**

- Though focused on informing the community on the capabilities of JWST, **the direct imaging ERS program will make the first steps in this era of discovery** with its own clearly defined scientific goals.

- Beyond the ERS program, more targeted **JWST surveys have the potential to directly image wide separation exoplanets with masses as low as 0.1 - 1 M_{Jup}** across a broad sample of stars for the first time.