

The Bleeding Wedge: *JWST* Coronagraphy at the Limits of Believability

William O. Balmer (JHU)

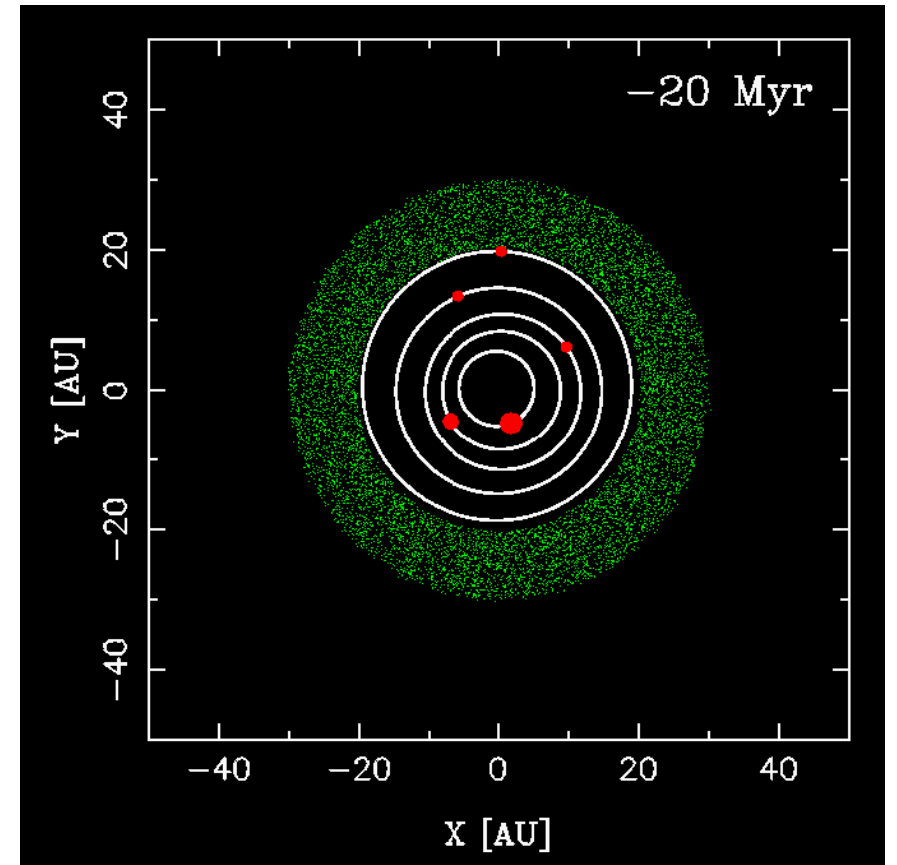
On behalf of the JWST-TST High Contrast GT0 team

Adv. Laurent Pueyo (STScI)

ExoPAG, Jan. 11th, 2025

How did we get here?

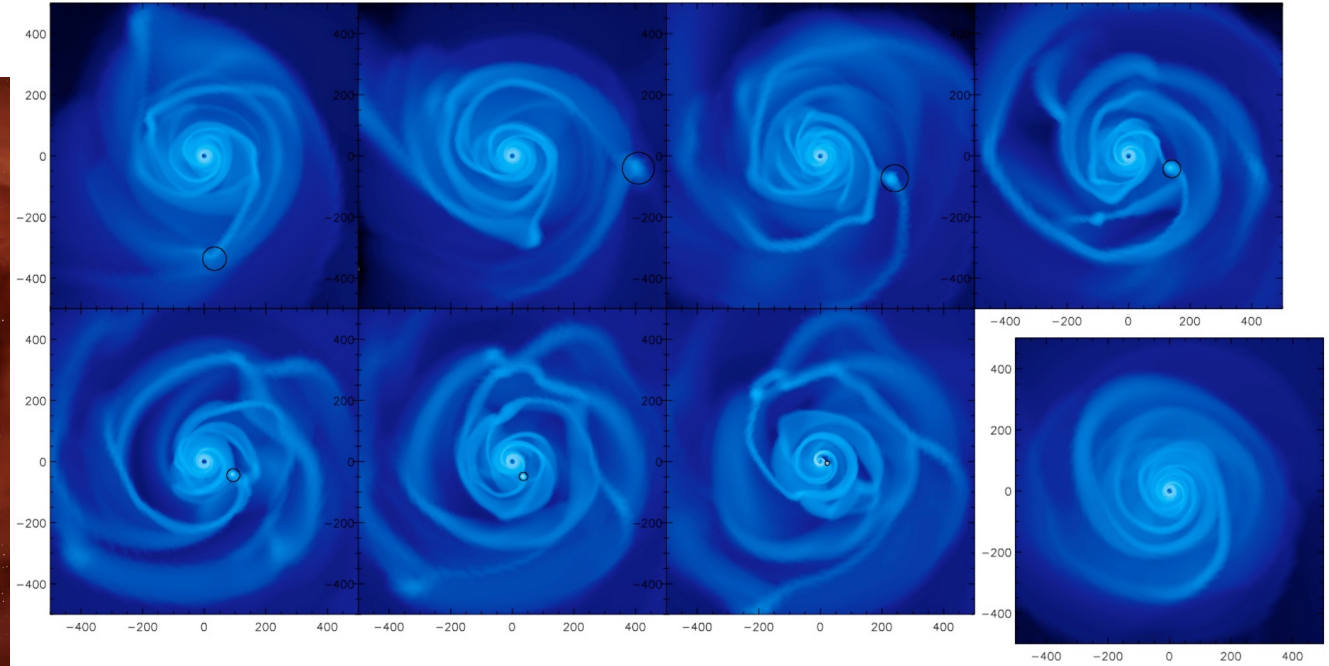
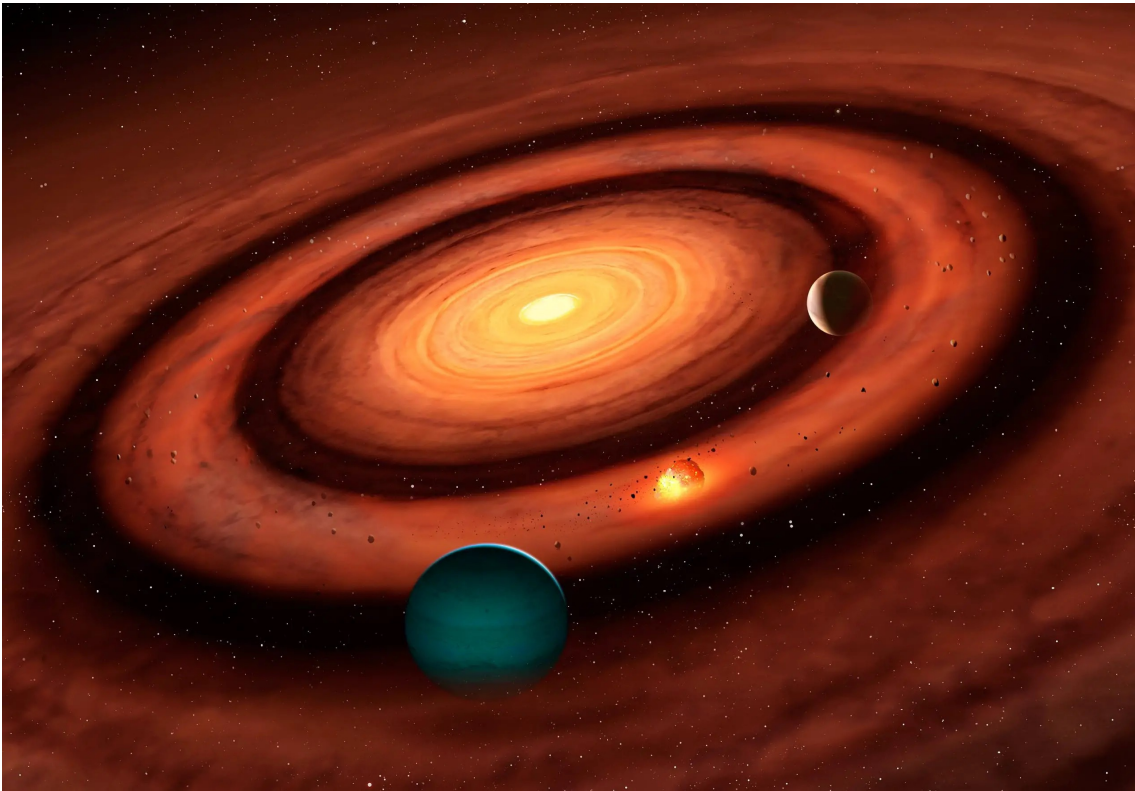
- Understanding our own Solar System (and therefore life) in context means understanding:
 - How do giant planets form and dynamically evolve?
 - How do giant planet frequencies change as functions of _____ (stellar metallicity, stellar mass, galactic location, galactic time)?
 - How unusual is the Solar System's architecture?



Scattering of a 5th solar system giant
David Nesvorny / SWRI

How can GPs form?

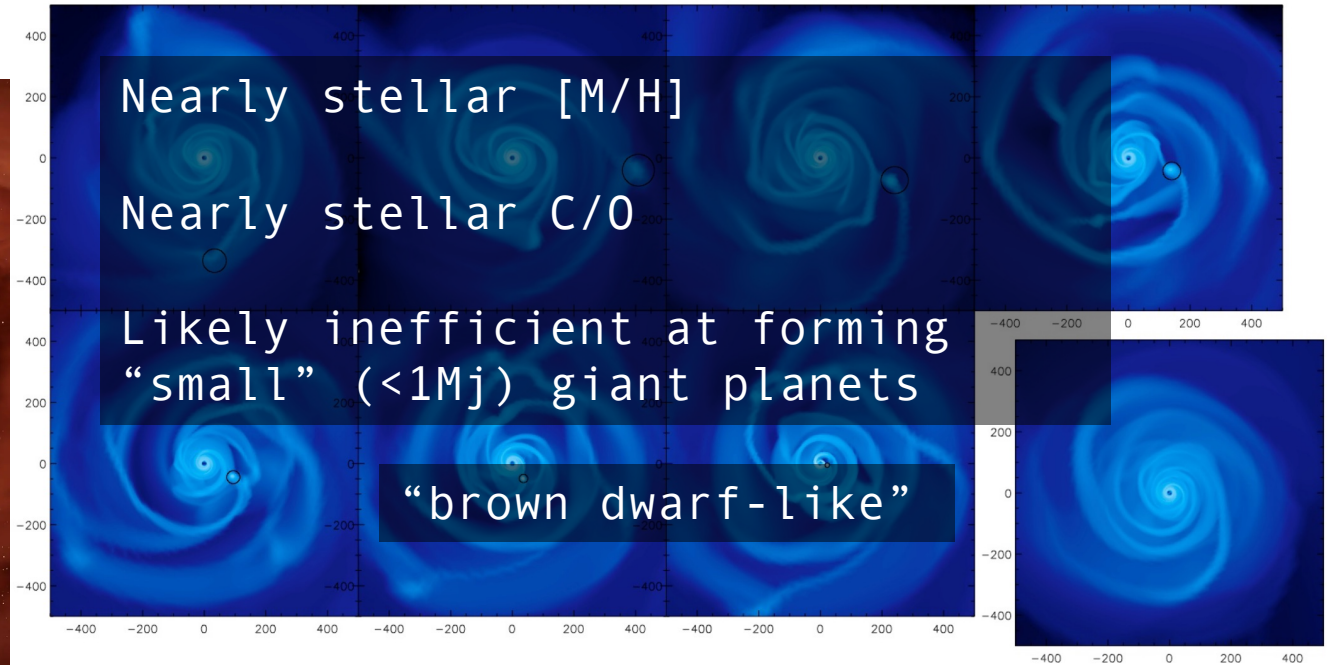
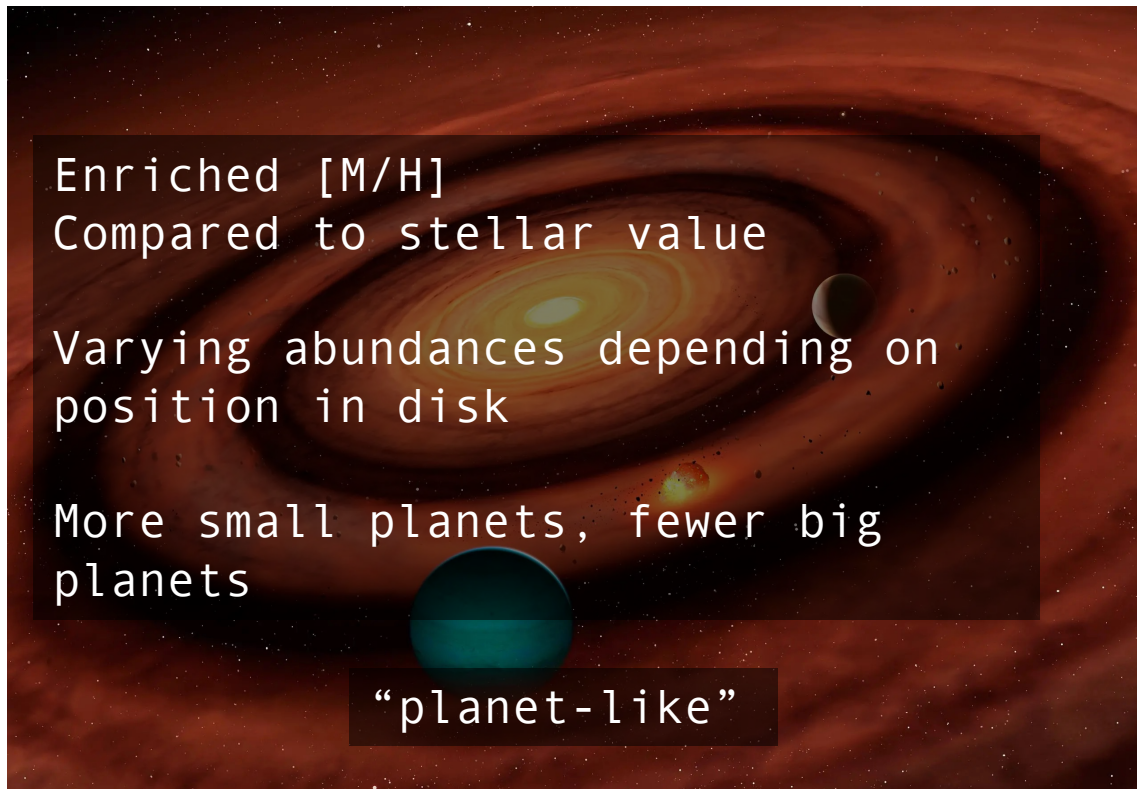
Core accretion rendition,
Garlick/University of Warwick



Disk instability SPH sim., Zhu+2011

How can GPs form?

Core accretion rendition,
Garlick/University of Warwick



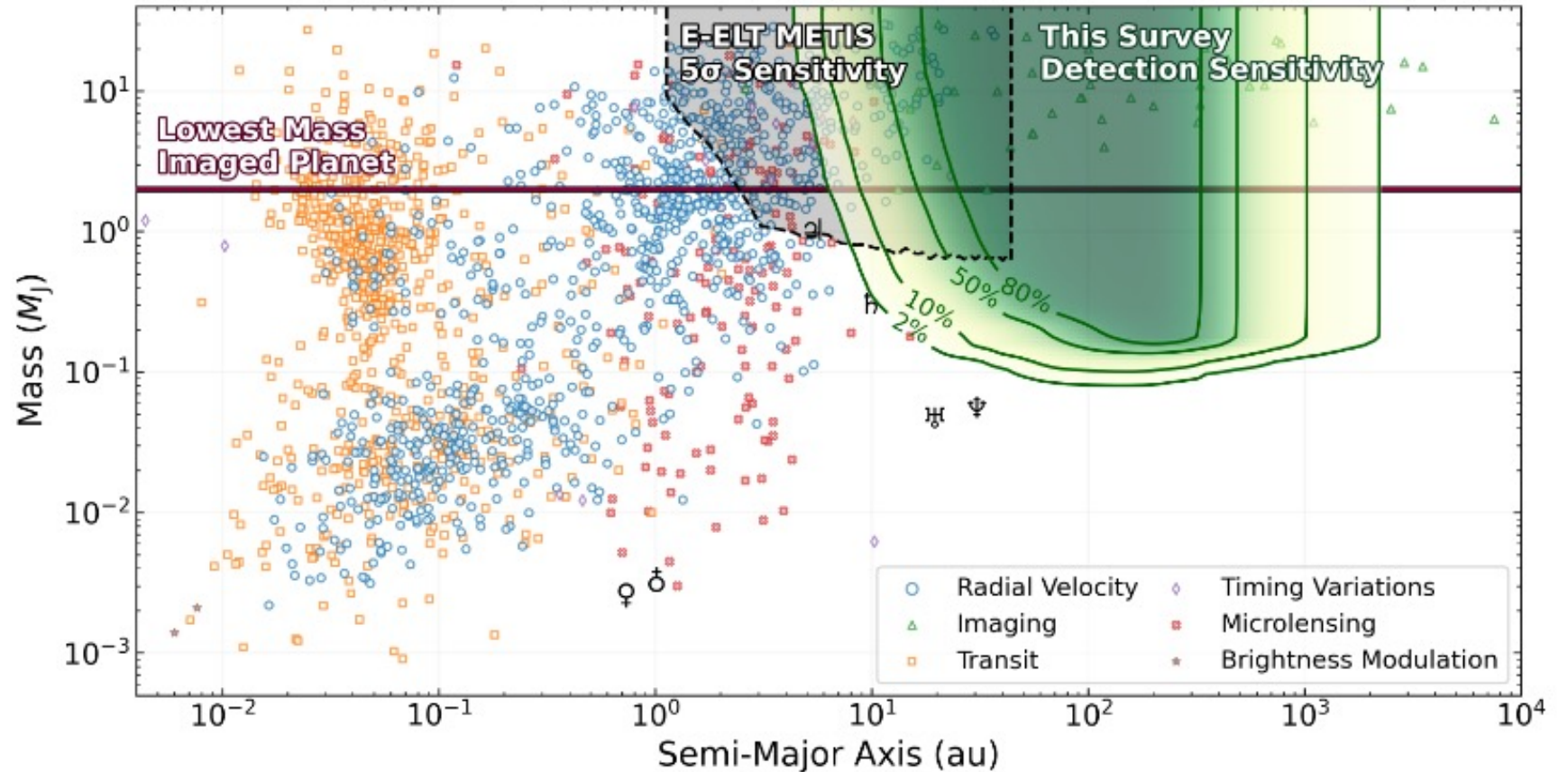
Disk instability SPH sim., Zhu+2011

Why go to space?

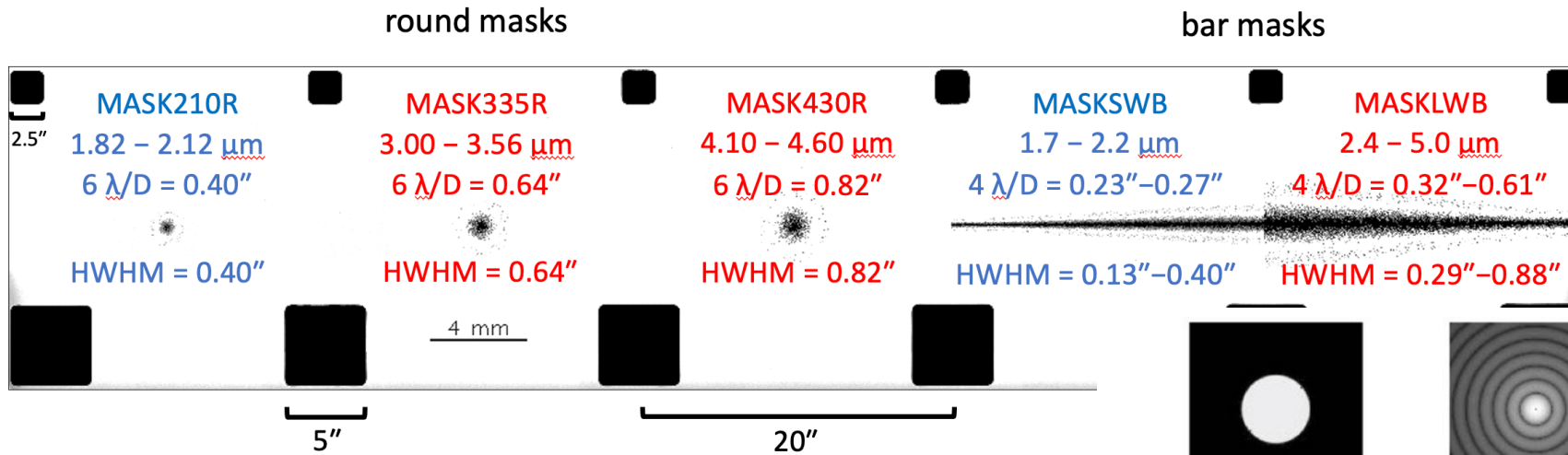
Figure courtesy A. Carter

Mid-IR wavelengths are sensitive to 1) colder temperature planets, meaning either lower masses or older ages and 2) new molecules than can be studied from the ground in the near-IR.

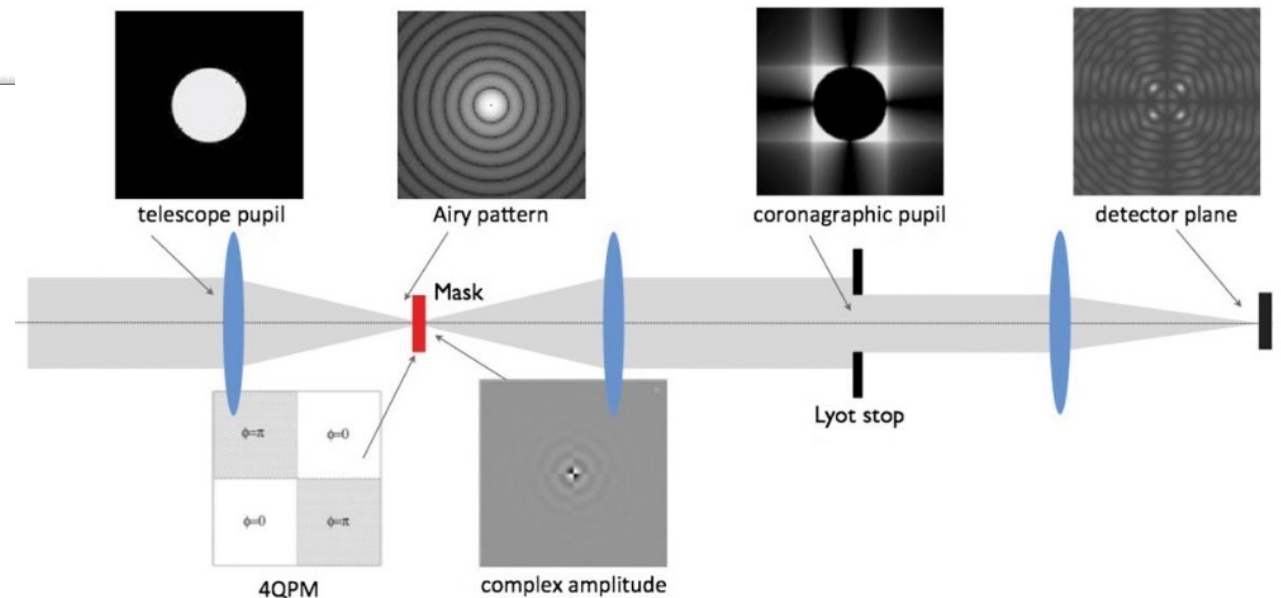
Relative to 8-10m class imaging:
Wavefront stability improves, telescope diameter decreases, λ increases



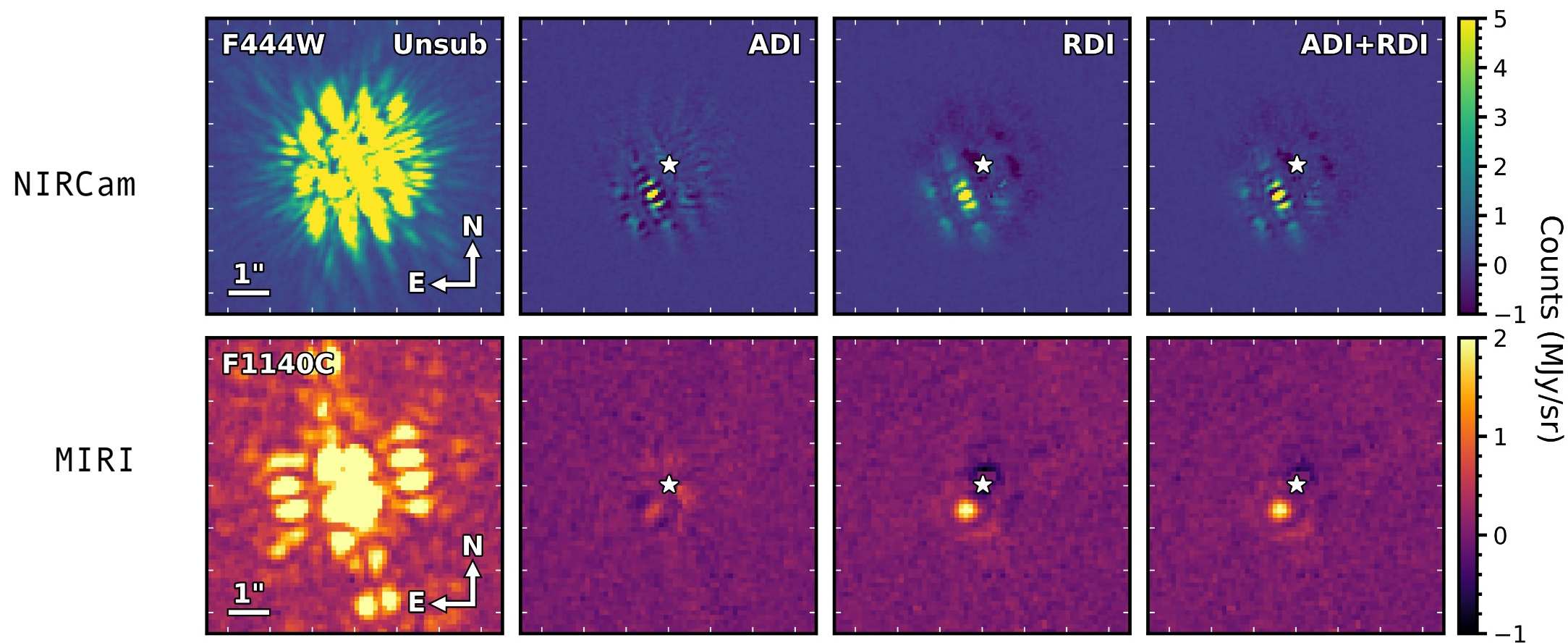
JWST Coronagraphs



NIRCam coronagraphs (above)
MIRI coronagraph (right)
jwst-docs

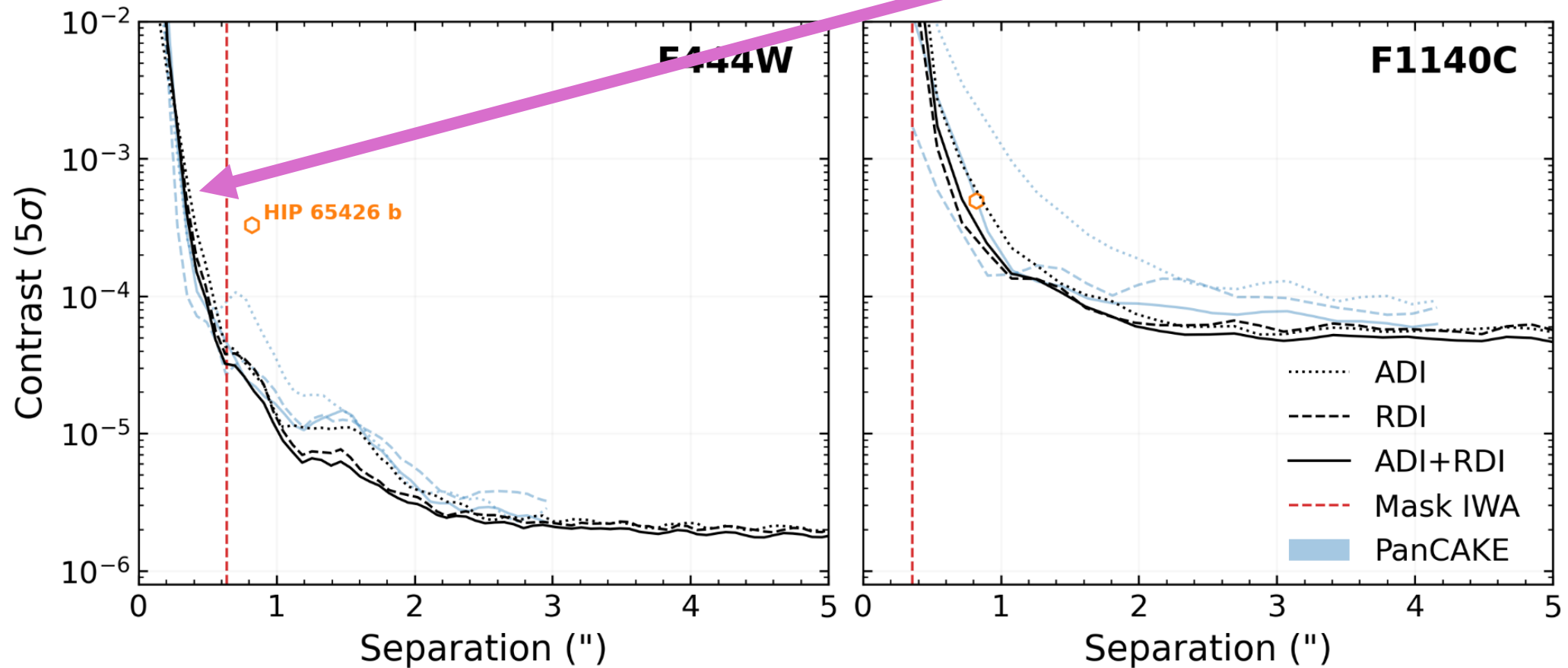


ERS result (Carter+ 2023)



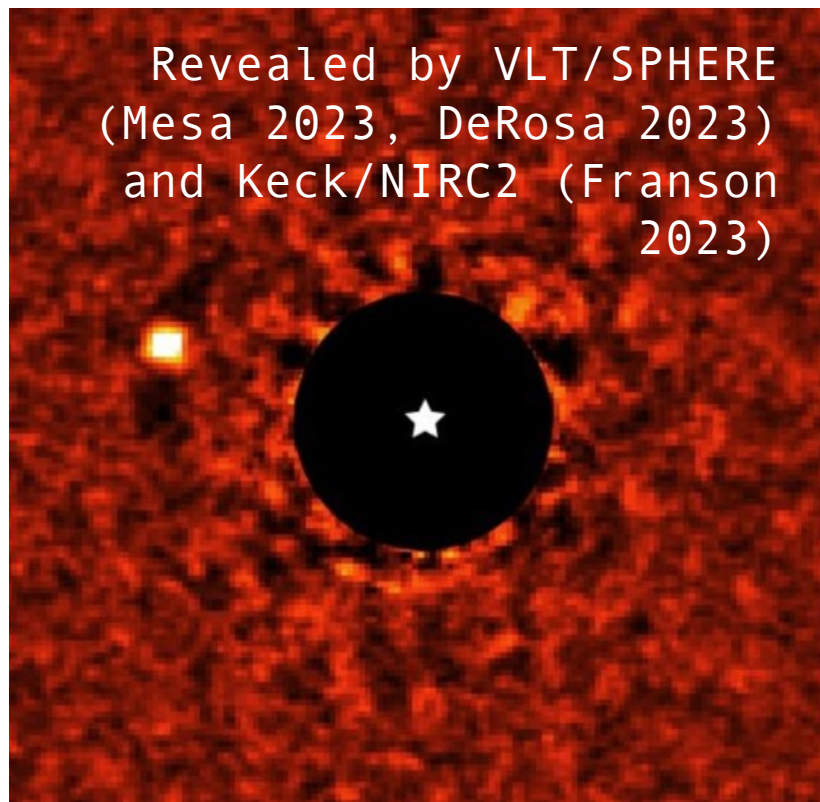
ERS contrast curve

These NIRCcam BLCs are
not hard edged!
Still throughput
at seps << IWA

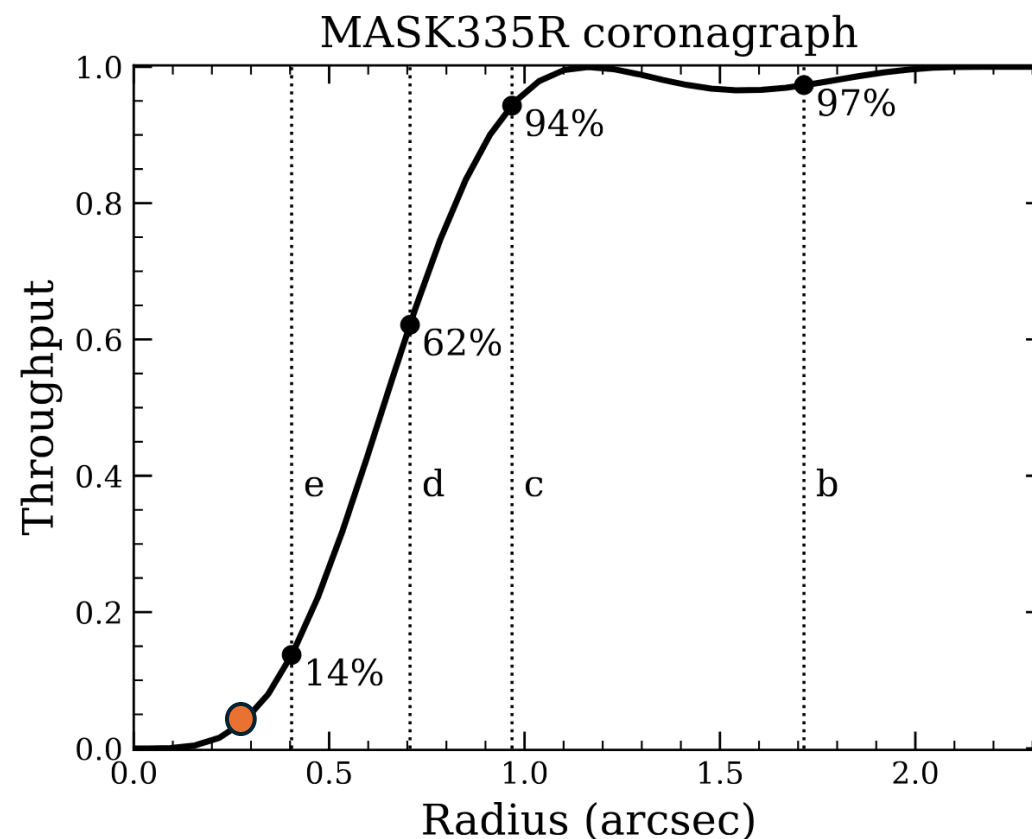


DD AF Lep b – NIRC2 round

Franson, Balmer+ (in press)

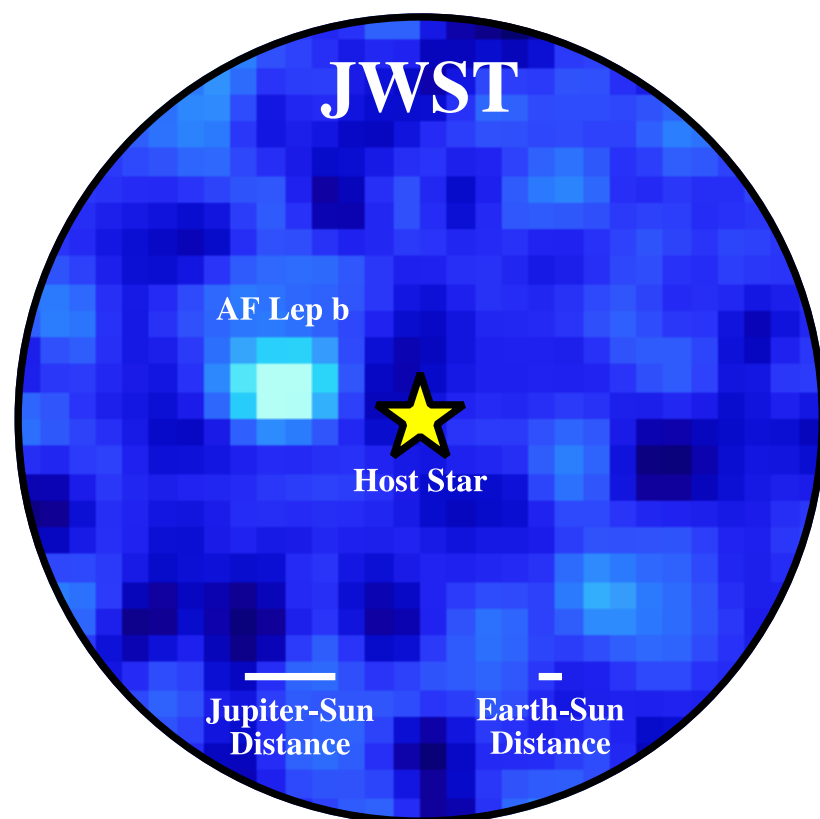


800K planet at $0.31''$ => 7% throughput

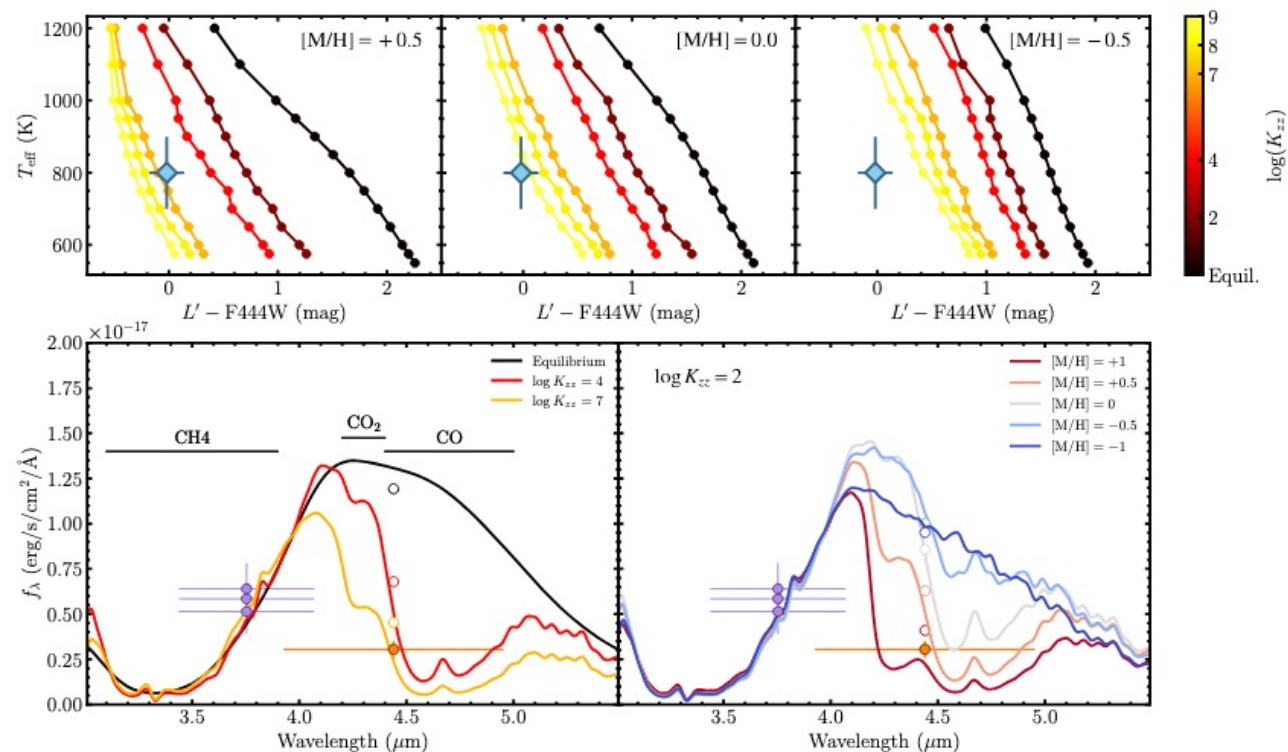


DD AF Lep b – NIRCam round

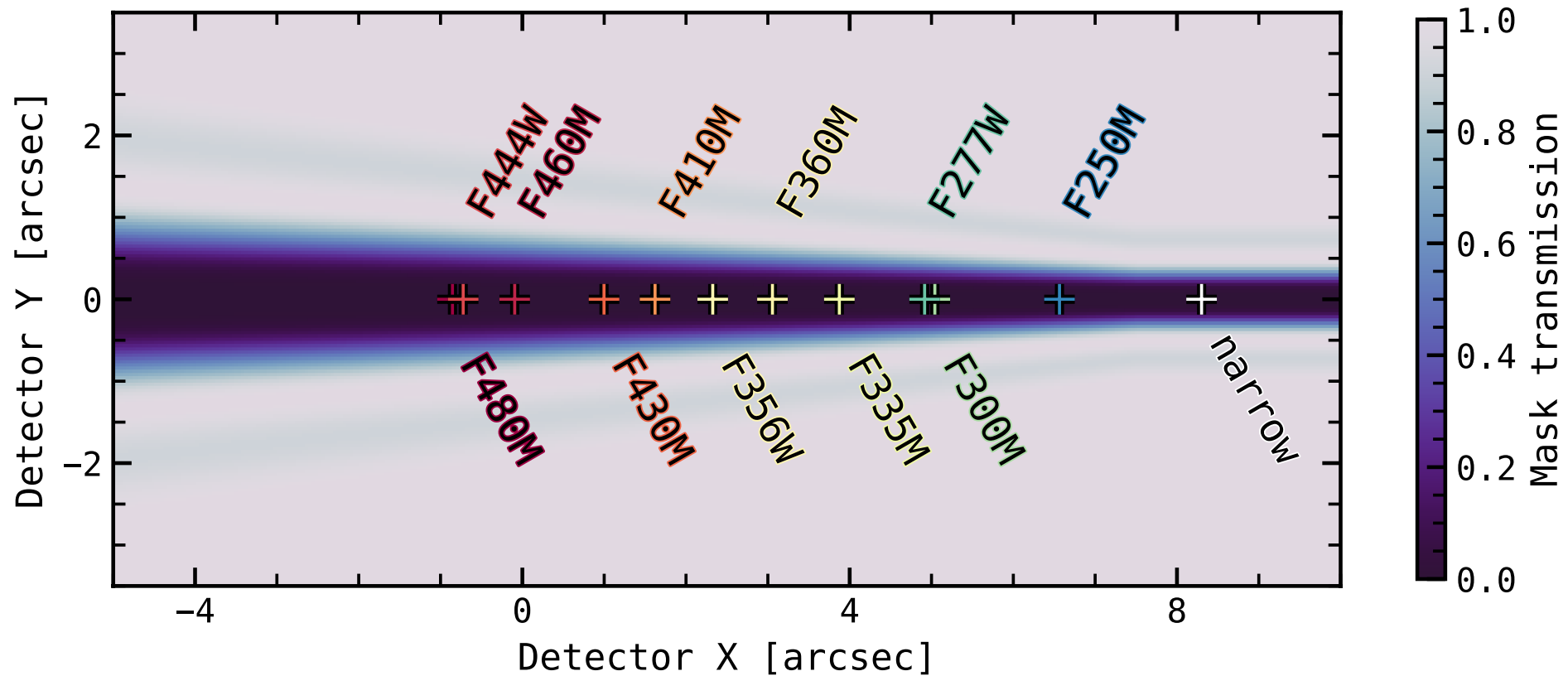
Franson, Balmer+ (in press)



800K planet at 0.31"
5 pixels from star!



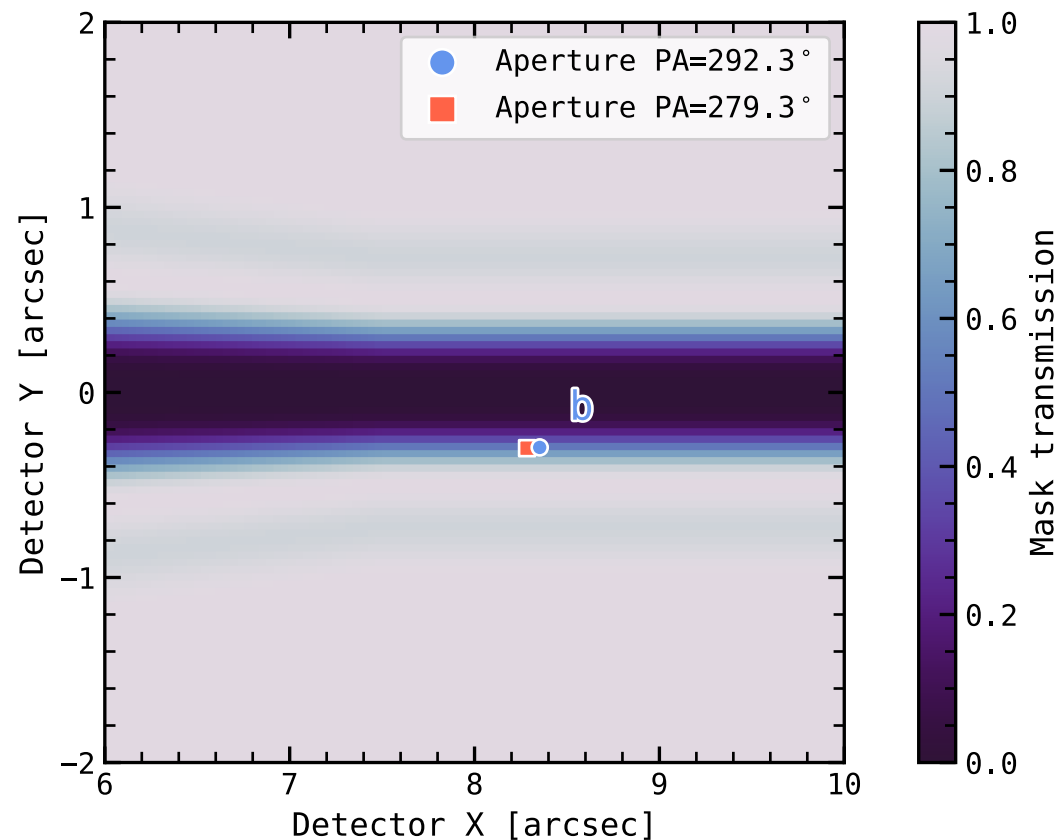
How to get better throughput this close in?



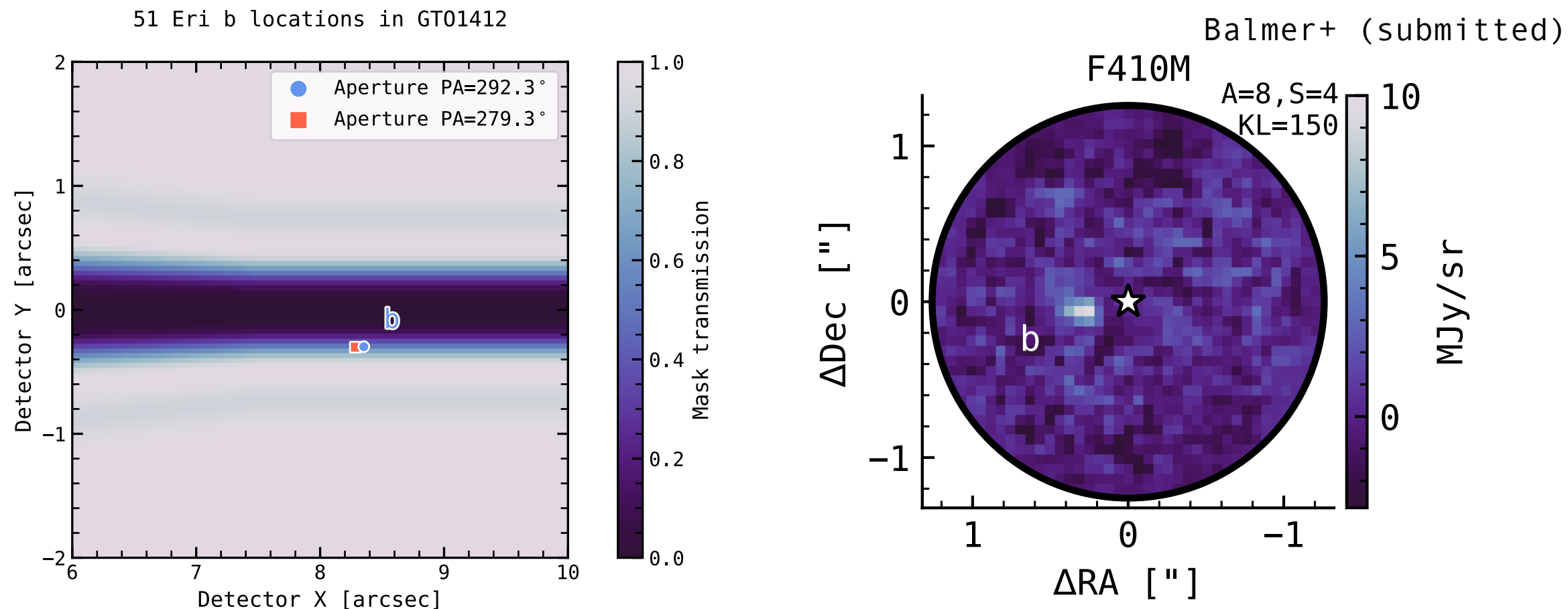
GT0 51 Eri - NIRCam bar mask

51 Eri b locations in GT01412

Balmer+ (submitted)



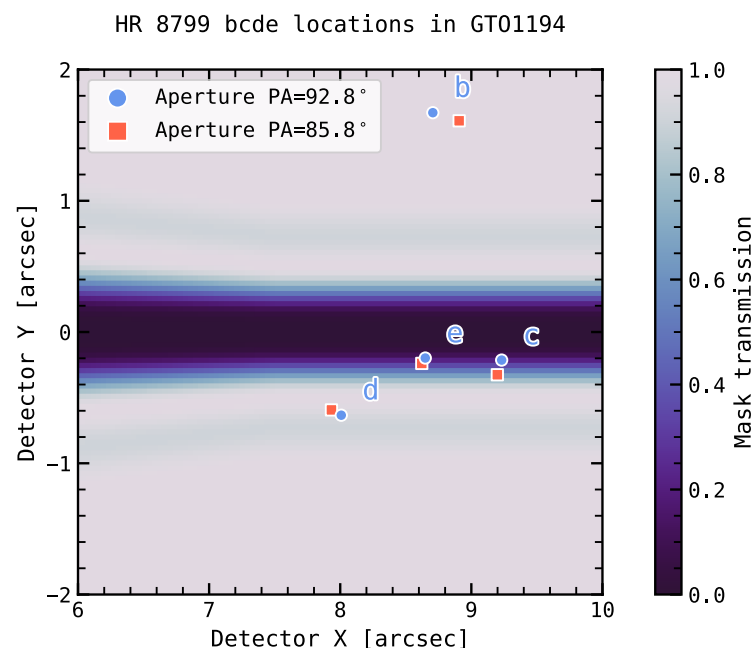
GT0 51 Eri - NIRCam bar mask



Detected a 700K planet at 0.28" => closest planet yet imaged with JWST

GT0 HR 8799 - NIRCcam bar mask

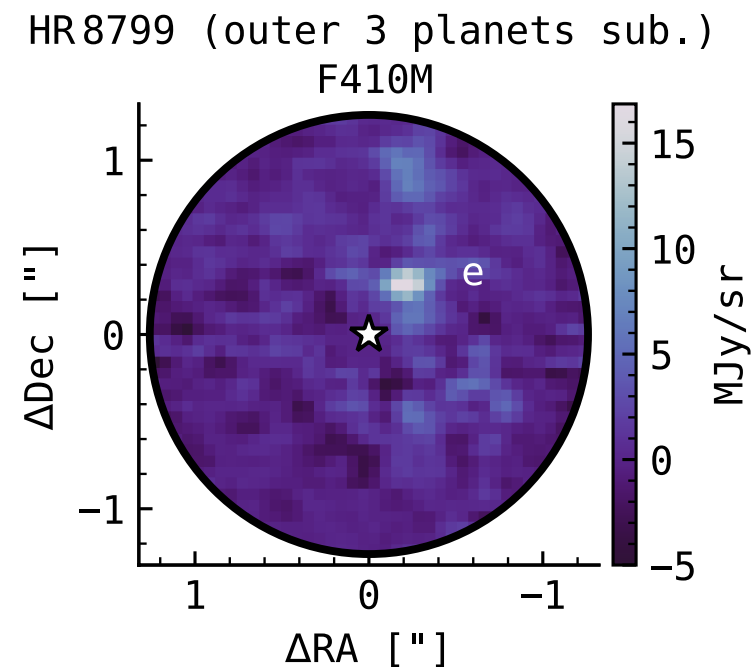
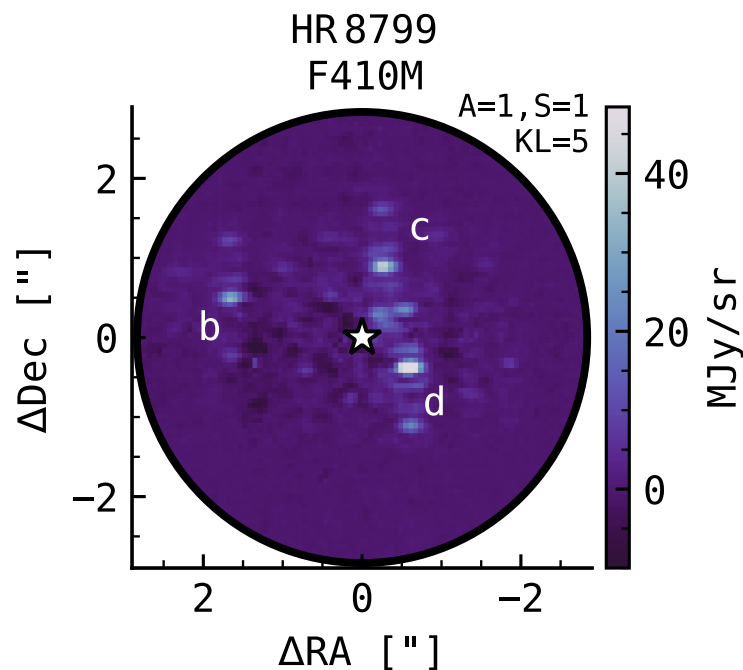
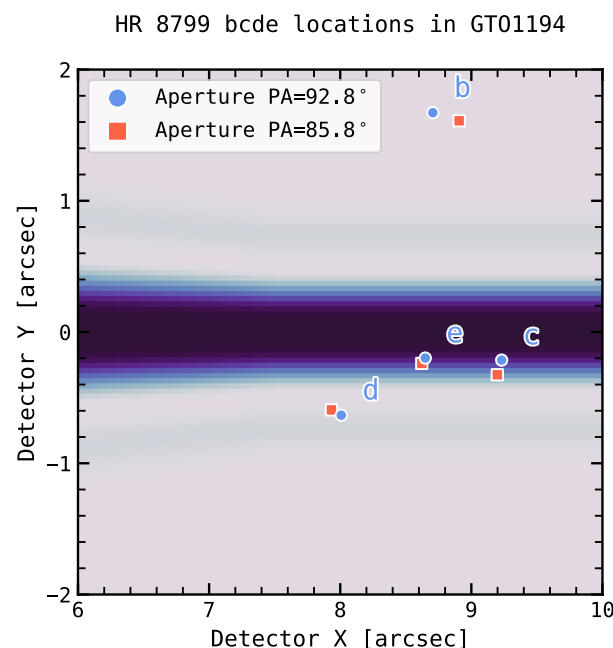
Balmer+ (submitted)



Better throughput than round mask!

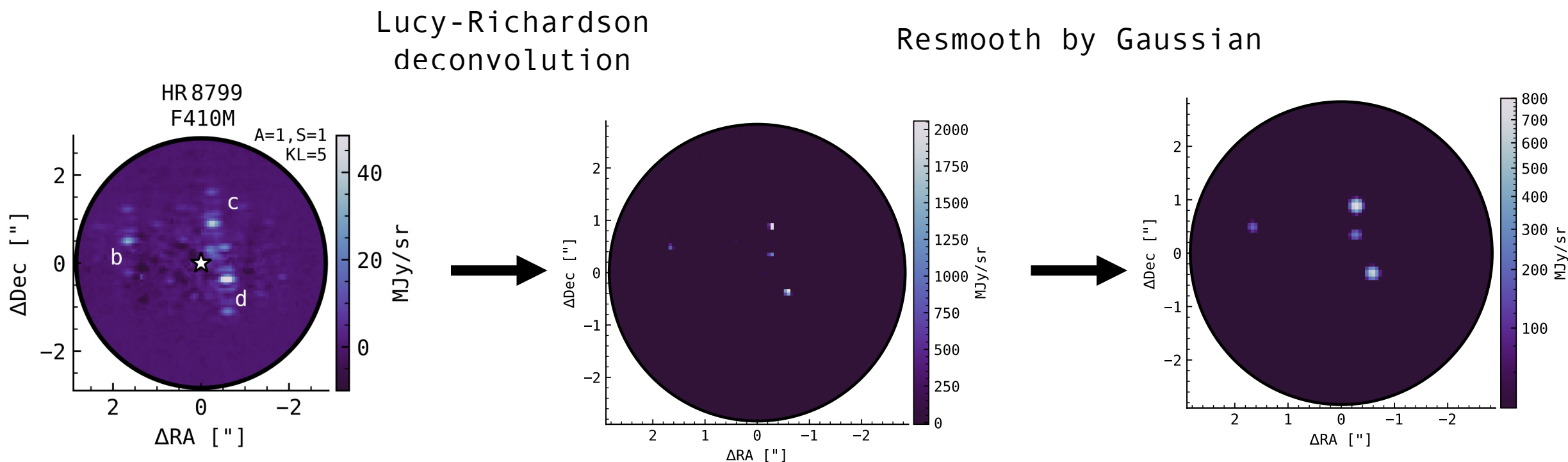
GT0 HR 8799 - NIRCam bar mask

Balmer+ (submitted)



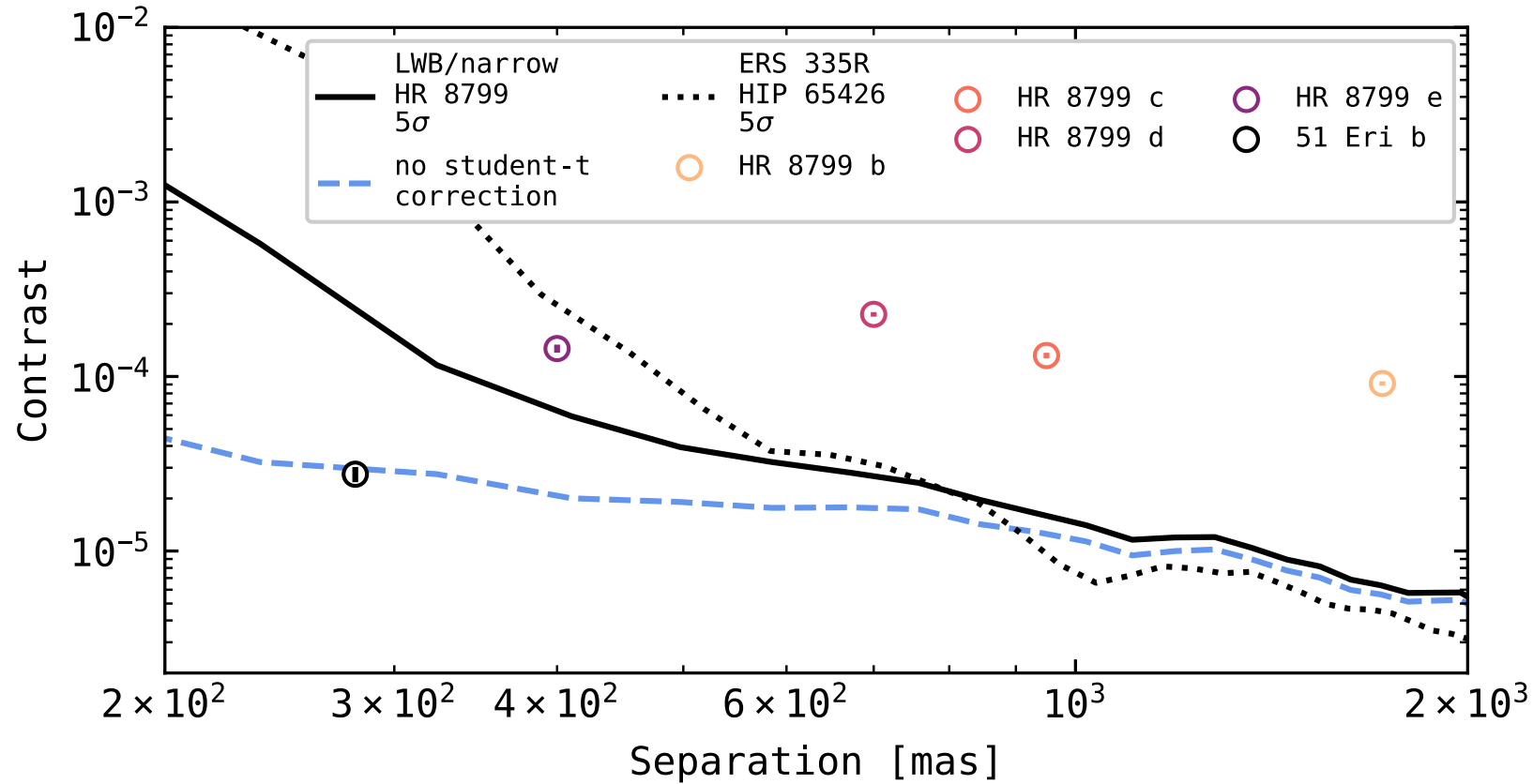
Better throughput than round mask!

GT0 HR 8799 - NIRCam bar mask



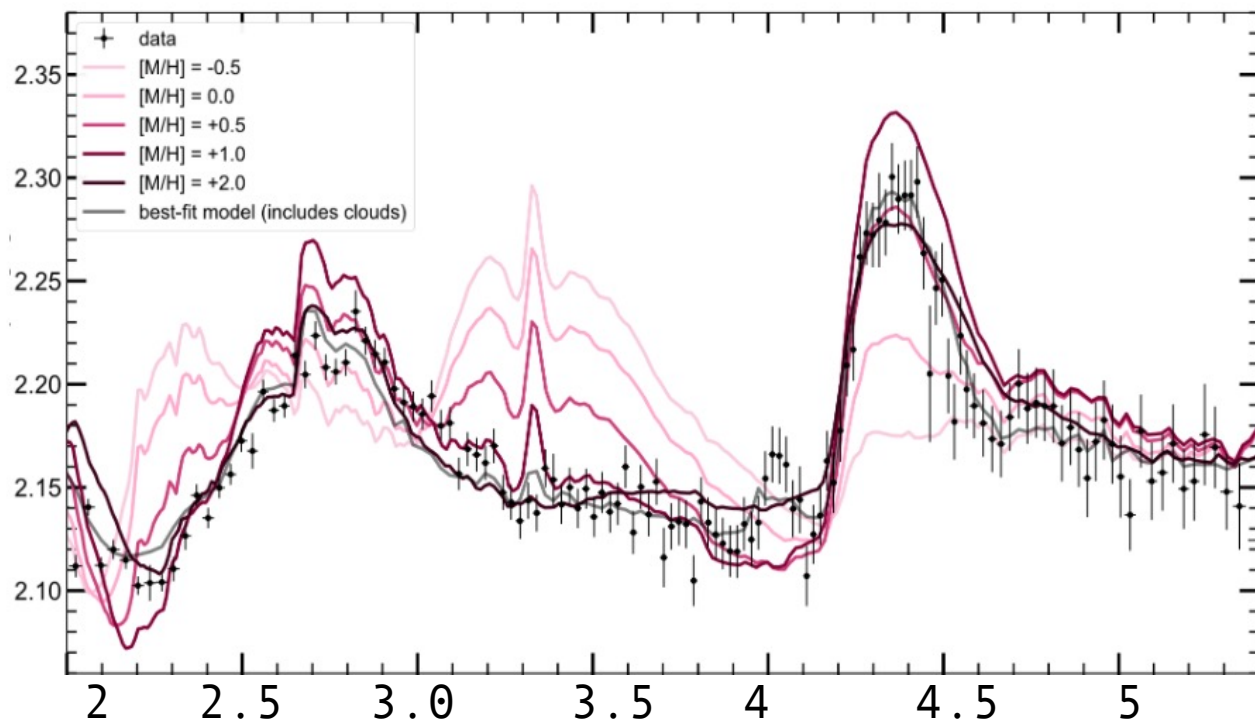
Balmer+ (submitted), deconv. work by Kellen Lawson @ Goddard

GTO - NIRCam bar mask contrasts

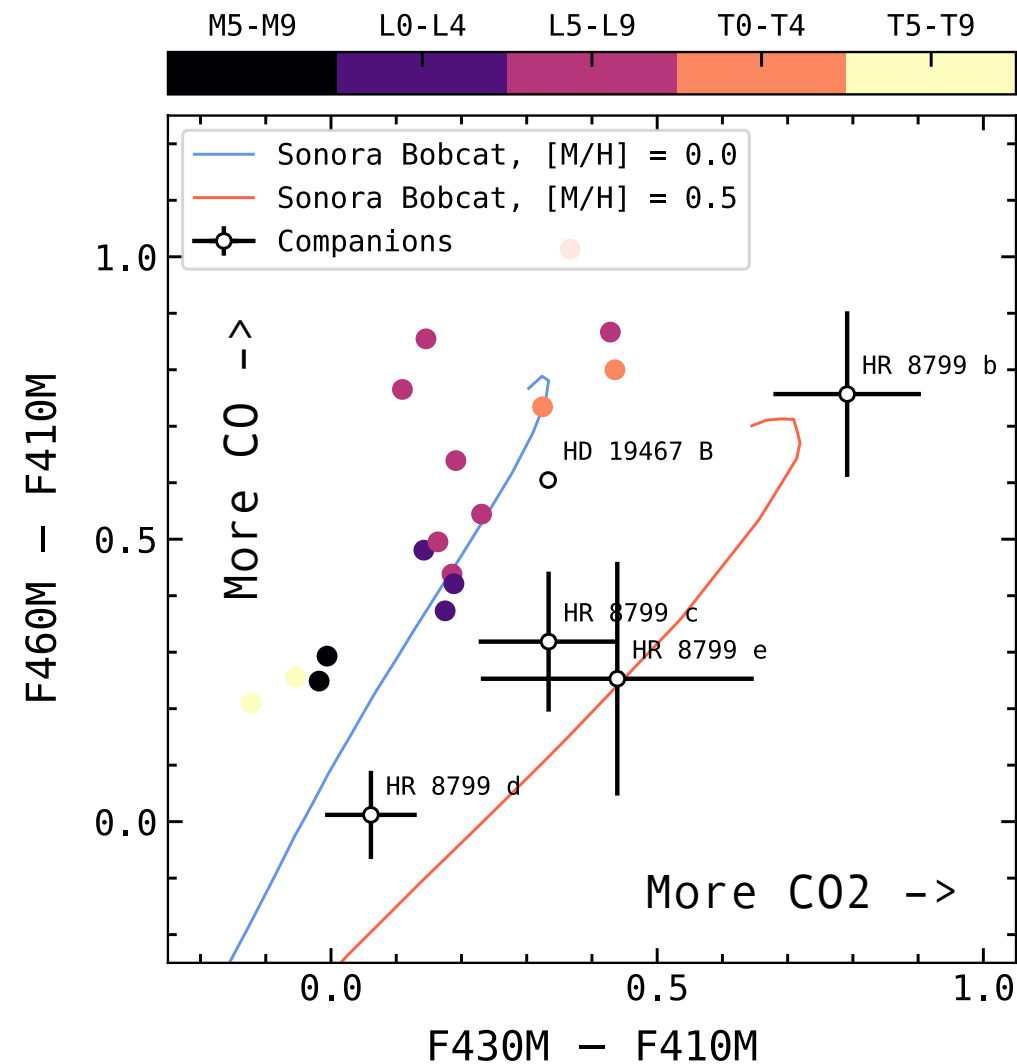


Balmer+ (submitted)

Constraining planetary metallicity “unambiguously”



Rustamkulov+ (2023)



Balmer+ (submitted)

Takeaways :

- In the era of JWST we have access to precise photometry that covers the metallicity dependent CO₂ feature at closer separations and deeper contrasts than previously expected
- This allows us to finally discern between “brown dwarf-like” companions and “planet-like” companions relatively unambiguously
- This could be applied to both the current sample of imaged companions (C4 proposal), and potentially a subsample of new, massive Gaia discovered exoplanets in young moving groups in the future
- Chat with me about this project, JWST coronagraphy of cold (<500K) exoplanets, or optical interferometry at the VLT during the rest of the meeting! Thank you :~)