Worlds Next Door: A JWST/MIRI Imaging Search for Giant Planets Around α Centauri A

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MIRI Observations: Jonathan Aguilar, Dean Hines, Wilson Joy Skipper, George Chapman, JWST FGS and Short- and Long-Range Planning Teams, STScI Director's Office

MIRI Data Reduction: William Balmer, Laurent Pueyo, Jorge Llop-Sayson, Anthony Boccaletti, Jarron Leisenring, Eugene Serabyn, Marie Ygouf, Ruslan Belikov, Michael Ressler, Alexis Bidot

Astrometry: Pierre Kervella, Rachel Akeson, Edward Fomalont

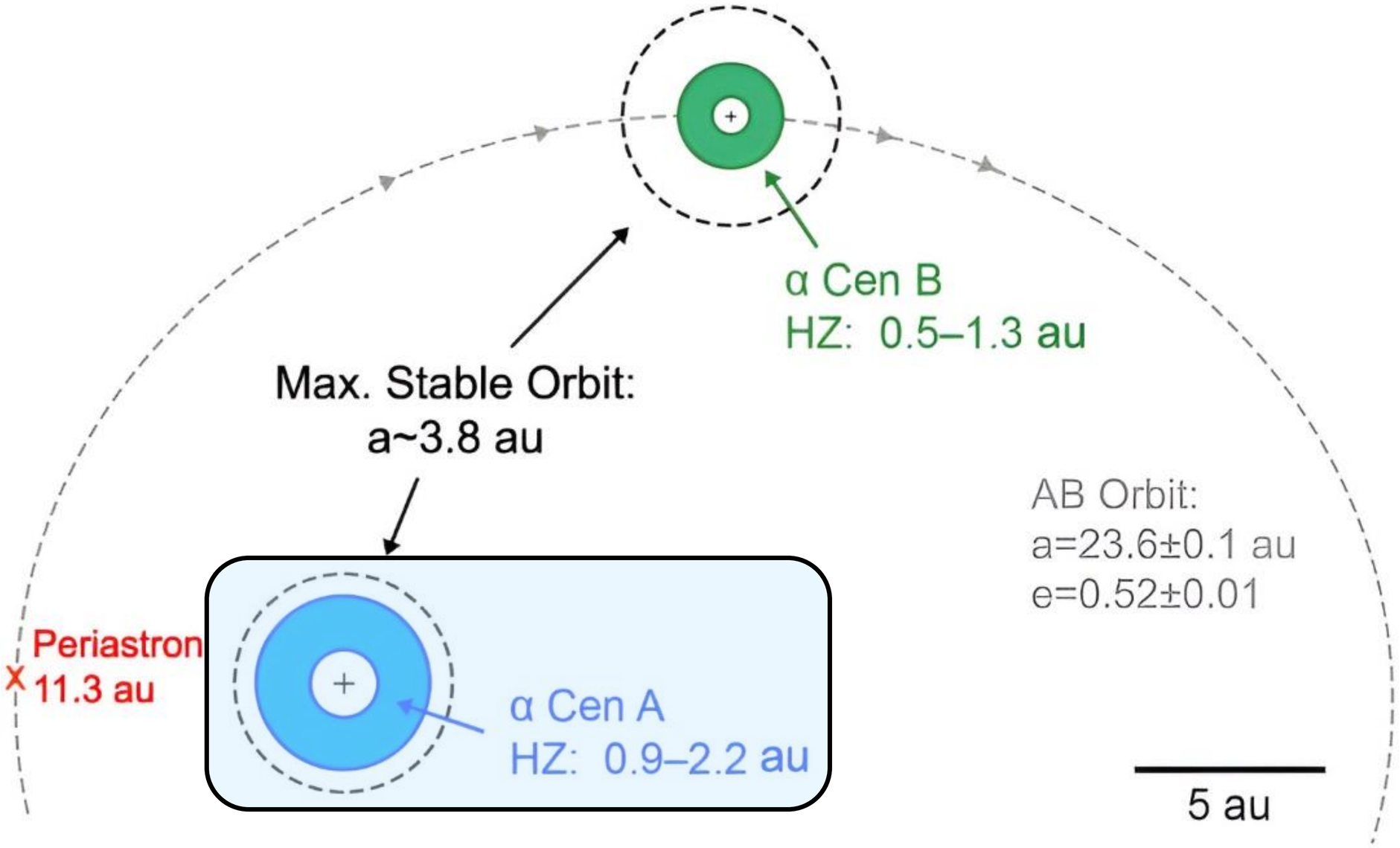
Orbits and Dynamics: Kevin Wagner, Billy Quarles, Jack Lissauer

Exozodi: Max Sommer, Mark Wyatt, Nicolas Godoy, Elodie Choquet, Pierre-Olivier Lagage

Planetary Atmospheres: Renyu Hu, James Mang, Mantas Zilinskas, Pascal Tremblin, Thomas Henning

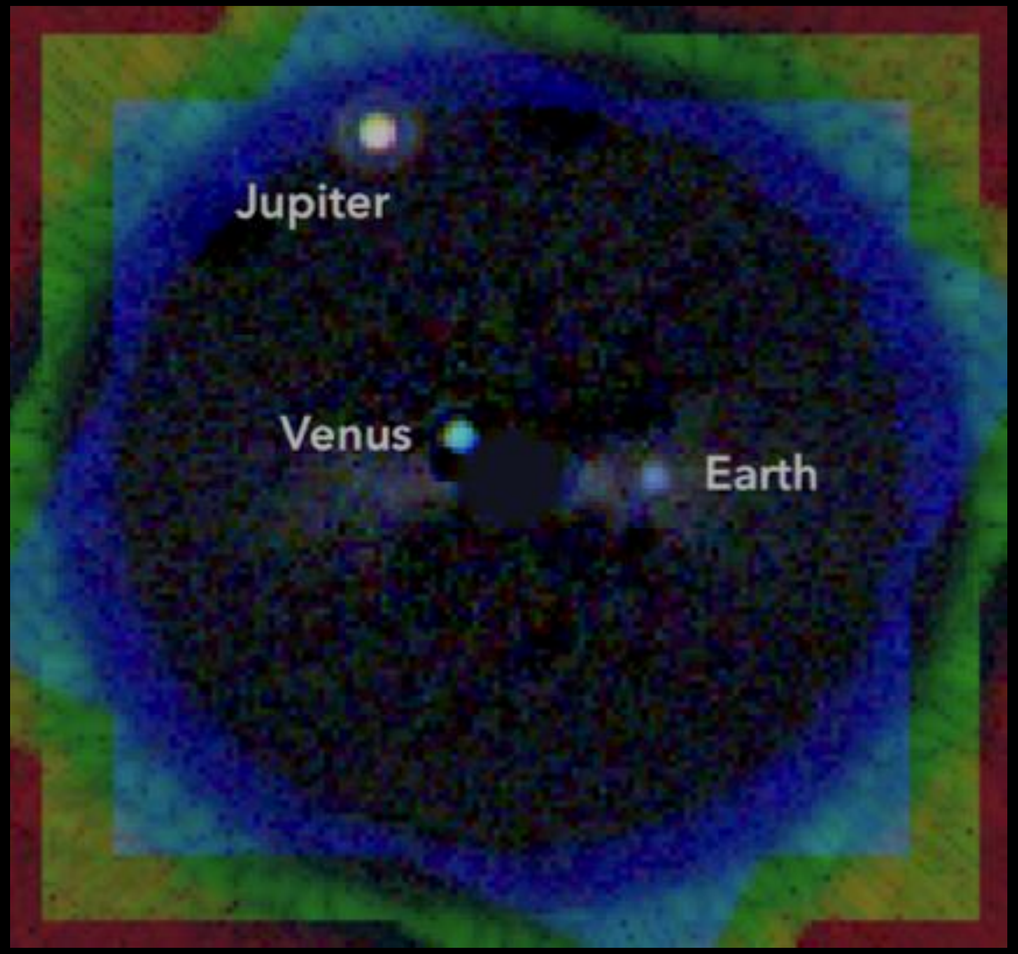
Image Credit: Robert Hurt (IPAC)

The α Centauri AB System



Wagner et al. (2021)

The Ultimate Goal: Search for Life



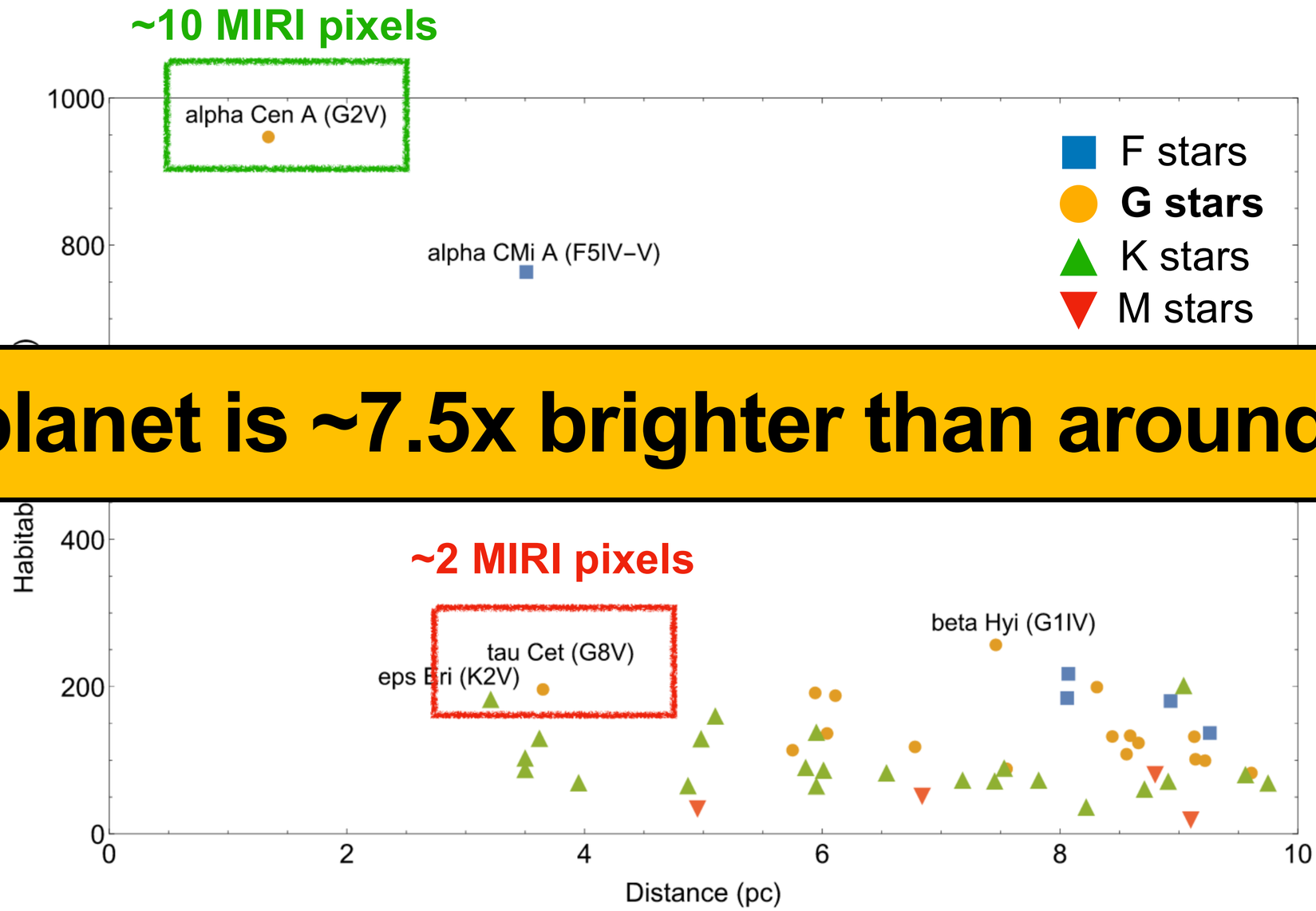
LUVOIR Report (2019)

The Habitable Worlds Observatory*

NASA GSFC/Conceptual Image Labs

*Engineering Architecture Concepts

Why α Centauri A?



Any planet is ~7.5x brighter than around τ Ceti

Beichman et al. (2020)

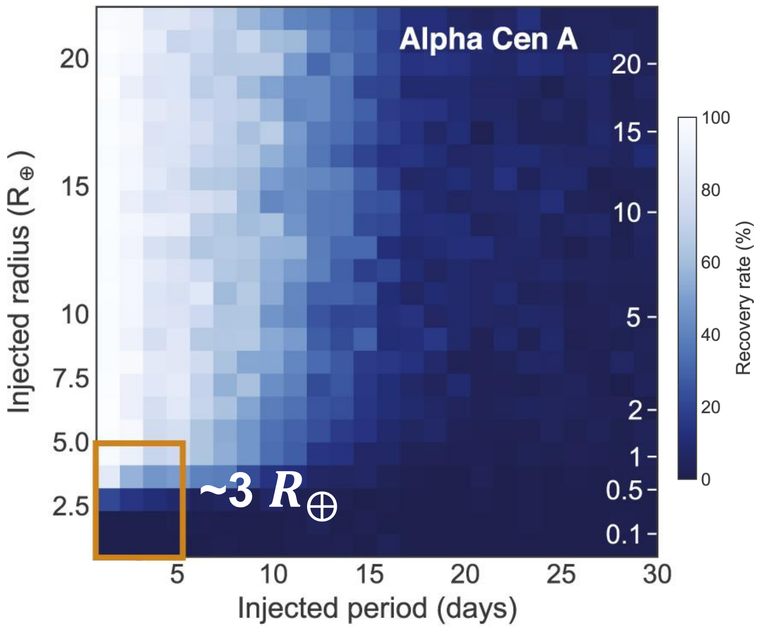
Prior Knowledge about Planets around α Cen A

No confirmed planets

Transit Observations

No detections

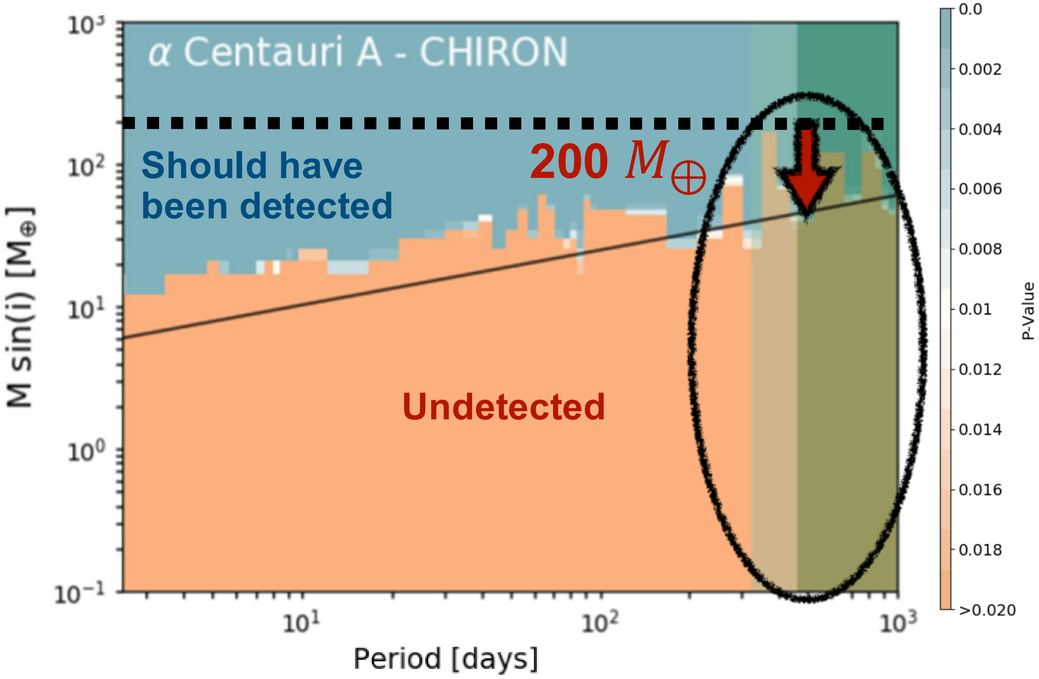
Krishnamurthy et al. 2021



Radial Velocity Observations

No detections

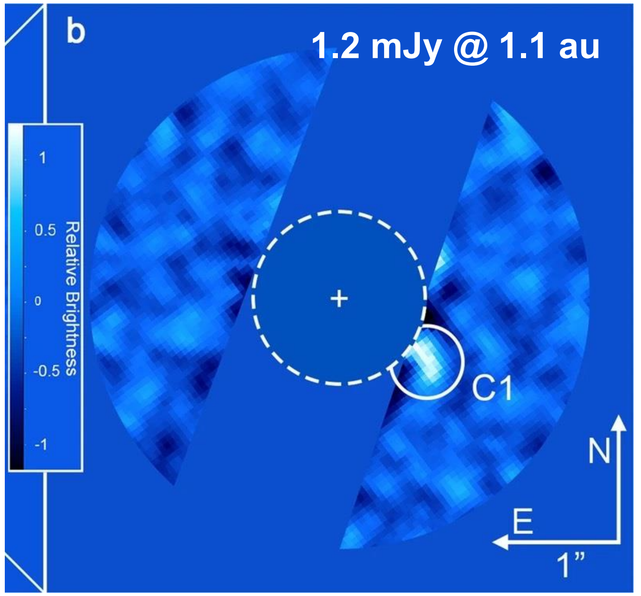
Zhao et al. 2018



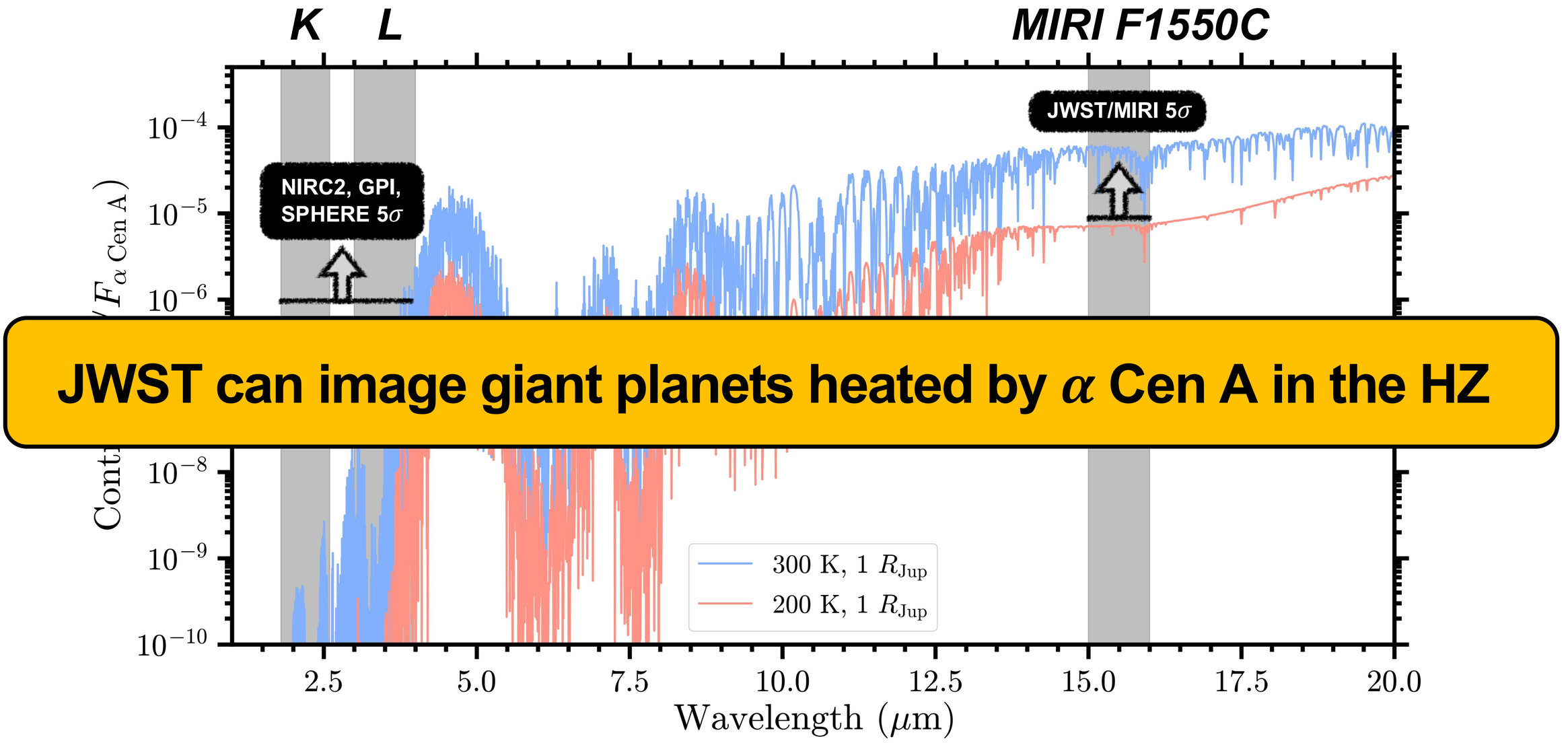
VLT/NEAR 10-11.25 μm Imaging

Candidate C1

Wagner et al. 2021



Why JWST/MIRI?



JWST can image giant planets heated by α Cen A in the HZ

How do you observe the third brightest star?

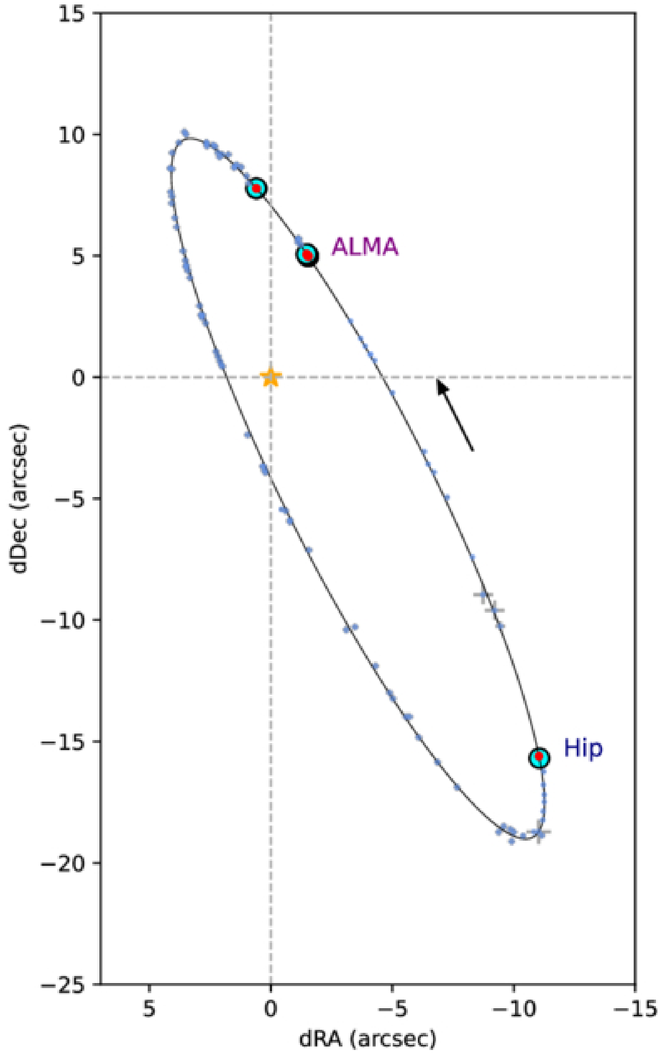
The MIRI coronagraph needs to be centered on the star with an **error <10 mas**.

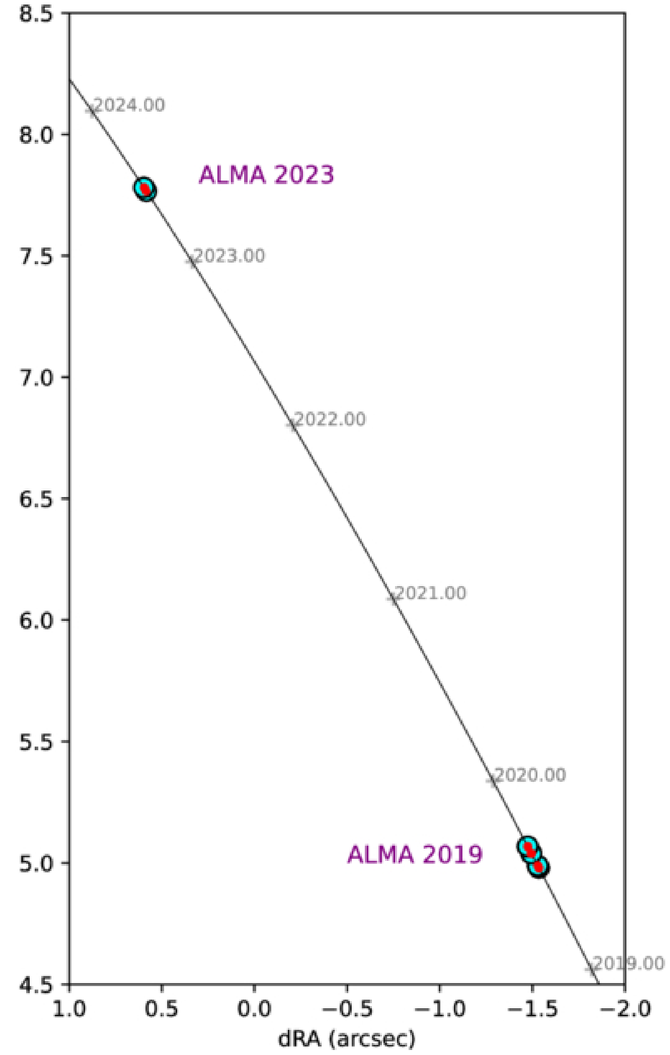
Problem 1: α Cen A is moving at **~10 mas/day (!)**

Problem 2: α Cen A **(K = –2 mag)** saturates MIRI TA

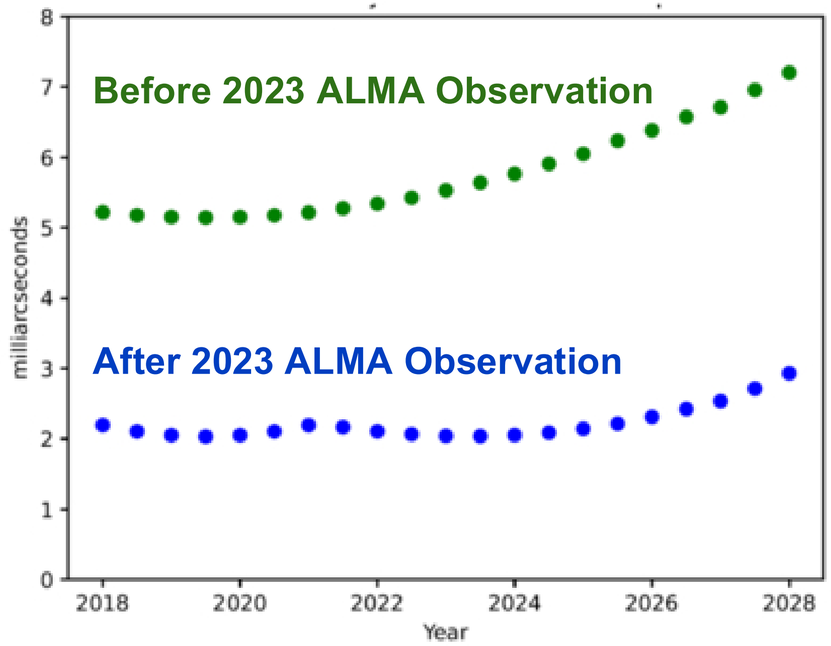
Overcoming the Challenge of Target Acquisition

(1) Determine the position of α Cen AB to ~2 mas precision





Positional Uncertainty

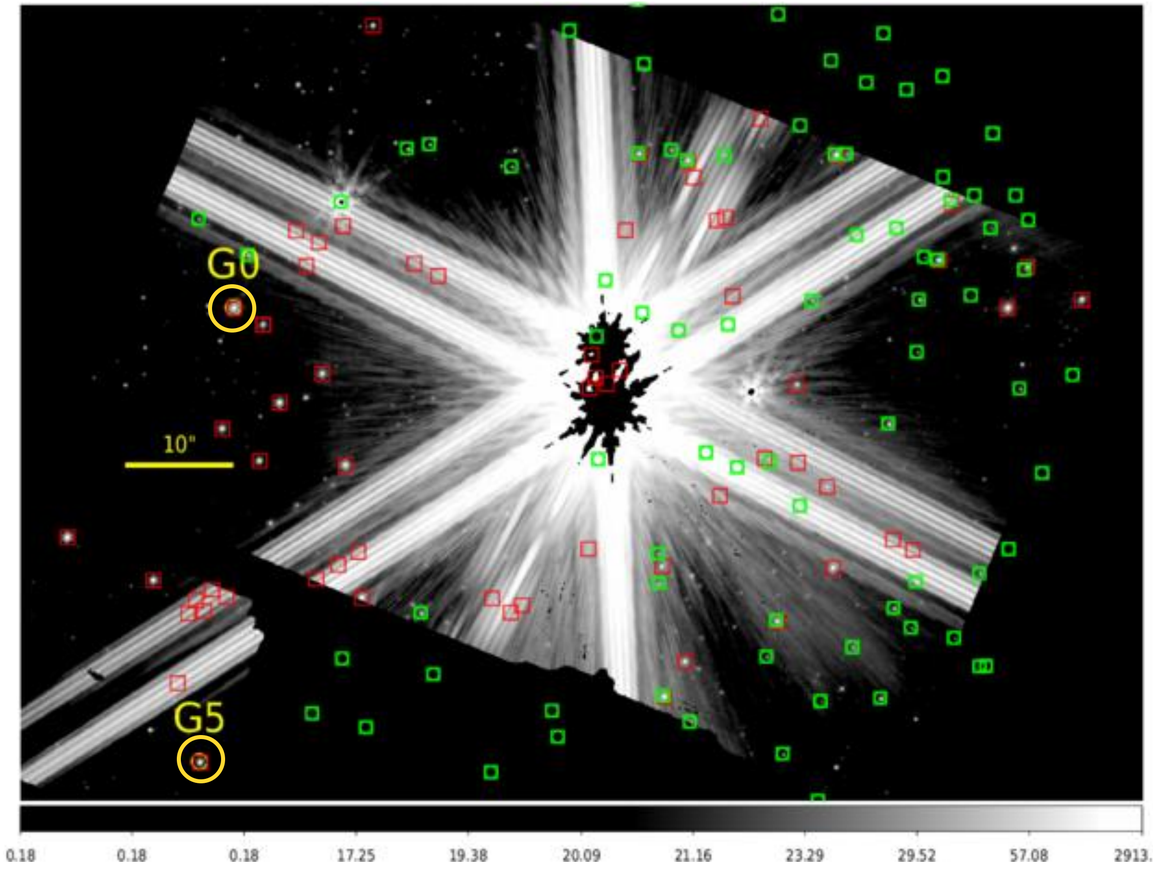


Akeson et al. (2021), Beichman & Sanghi et al. (202

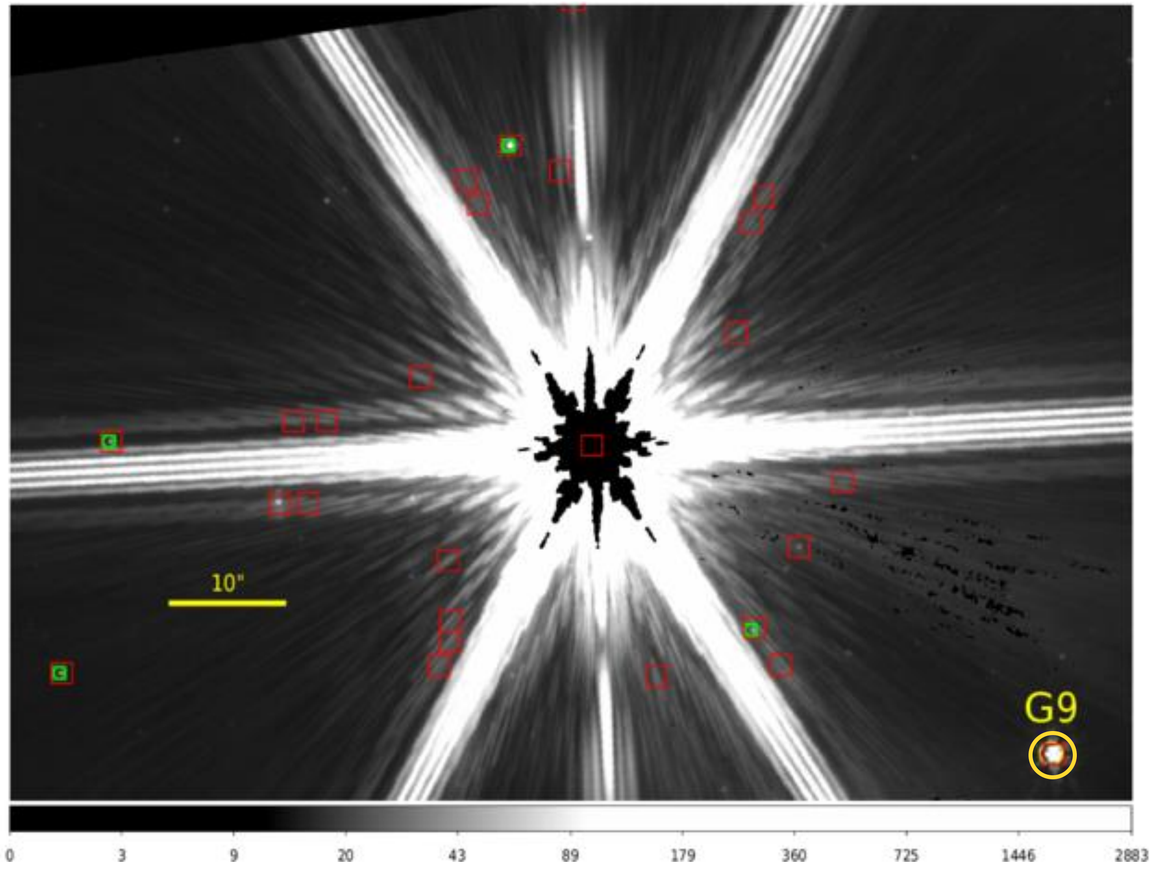
Overcoming the Challenge of Target Acquisition

(2) Identify Gaia stars suitably bright in F1000W in the field (June 2023)

Alpha Cen AB

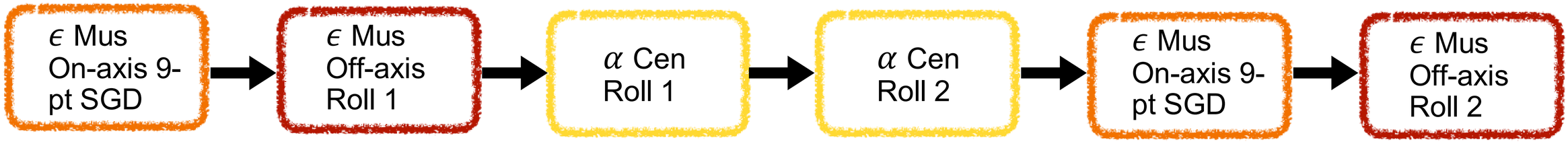


Epsilon Muscae (Reference Star)



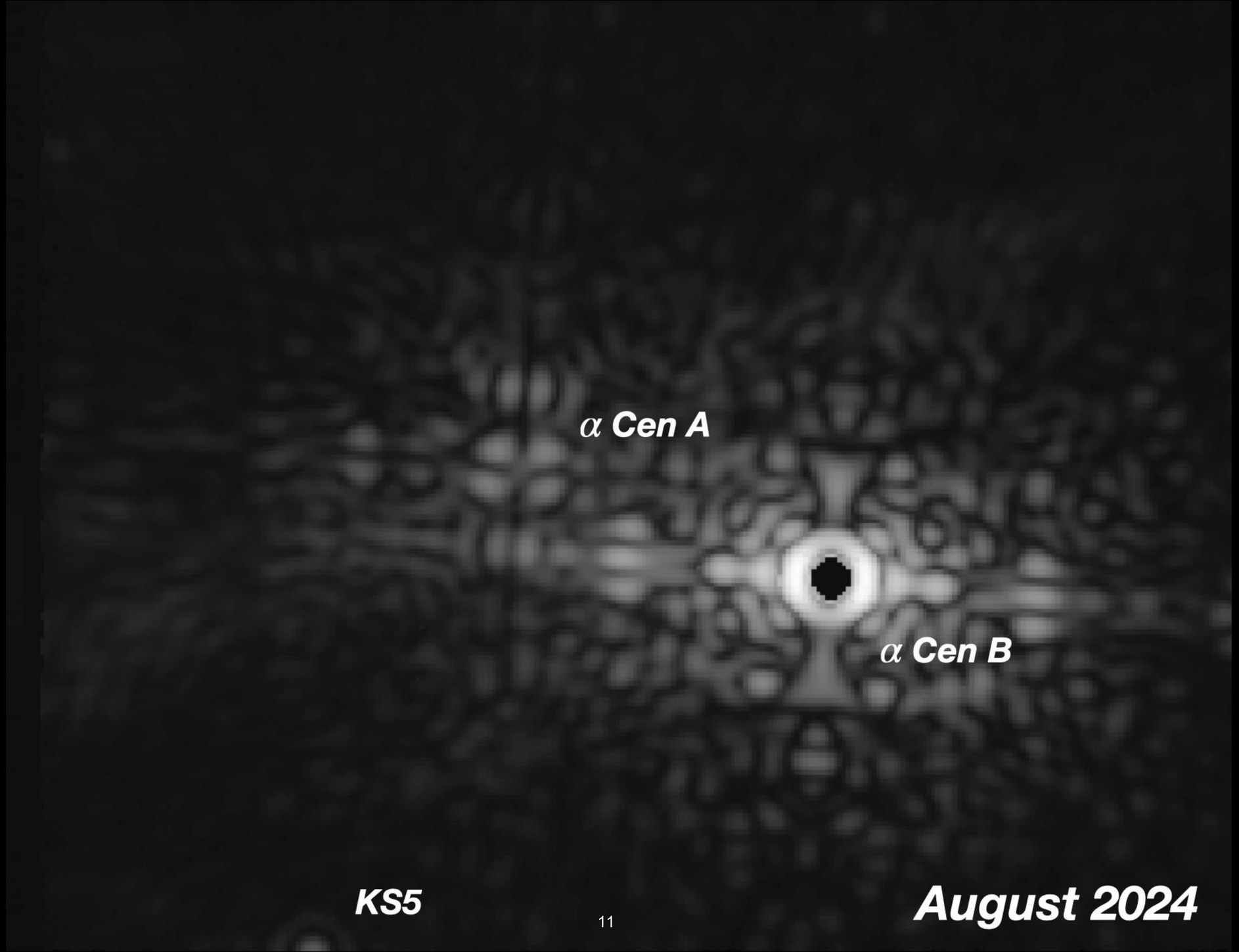
Sequence of Observations: Three Epochs of JWST Imaging

Aug 2024: JWST C1 GO Program #1618 (PI: Beichman, Co-PI: Mawet)
Feb 2025: JWST C3 DDT Program #6797 (PI: Beichman, Co-PI: **Sanghi**)
Apr 2025: JWST C3 DDT Program #9252 (PI: Beichman, Co-PI: **Sanghi**)

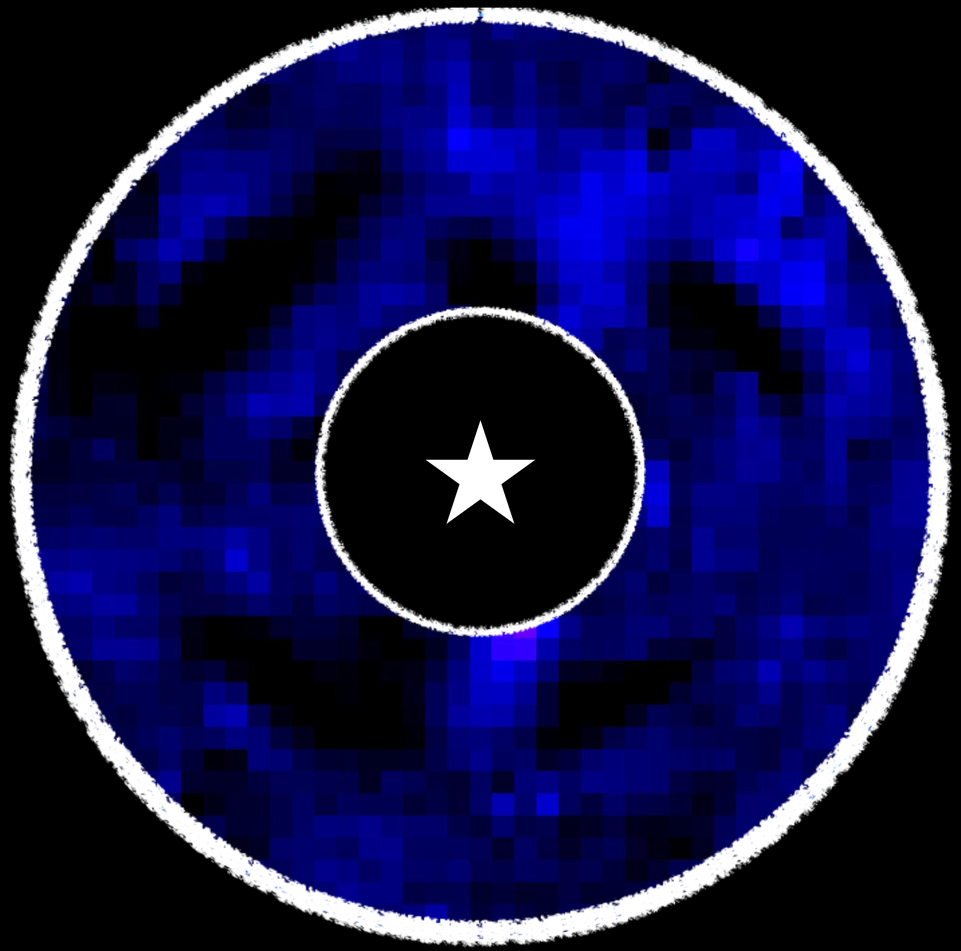


aCen AB **+** ***planet***

Repeat


α Cen A
α Cen B
KS5
August 2024

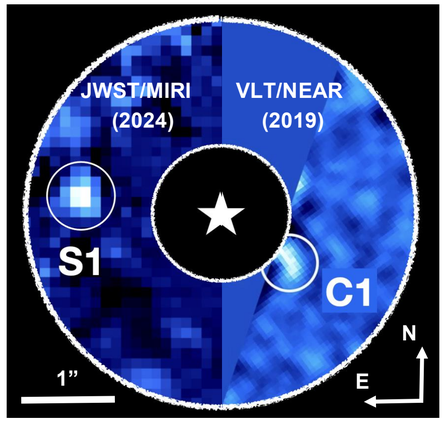
James Webb Space Telescope (April 2025)



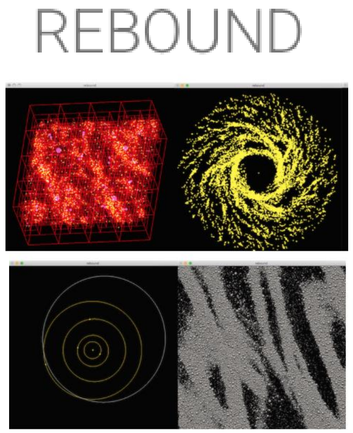
See Sanghi & Beichman et al. (2025) for data reduction, artifact testing, and background + foreground source rejection

Orbital and Physical **Properties**

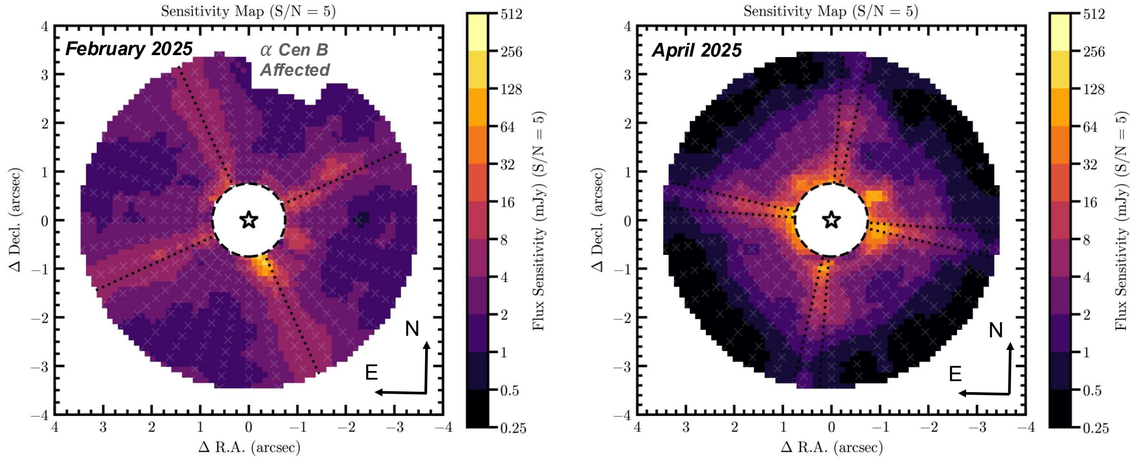
(1) Fit Orbits to S1+C1



(2) Select Stable Orbits



(3) Find Orbits Consistent with Non-Detections



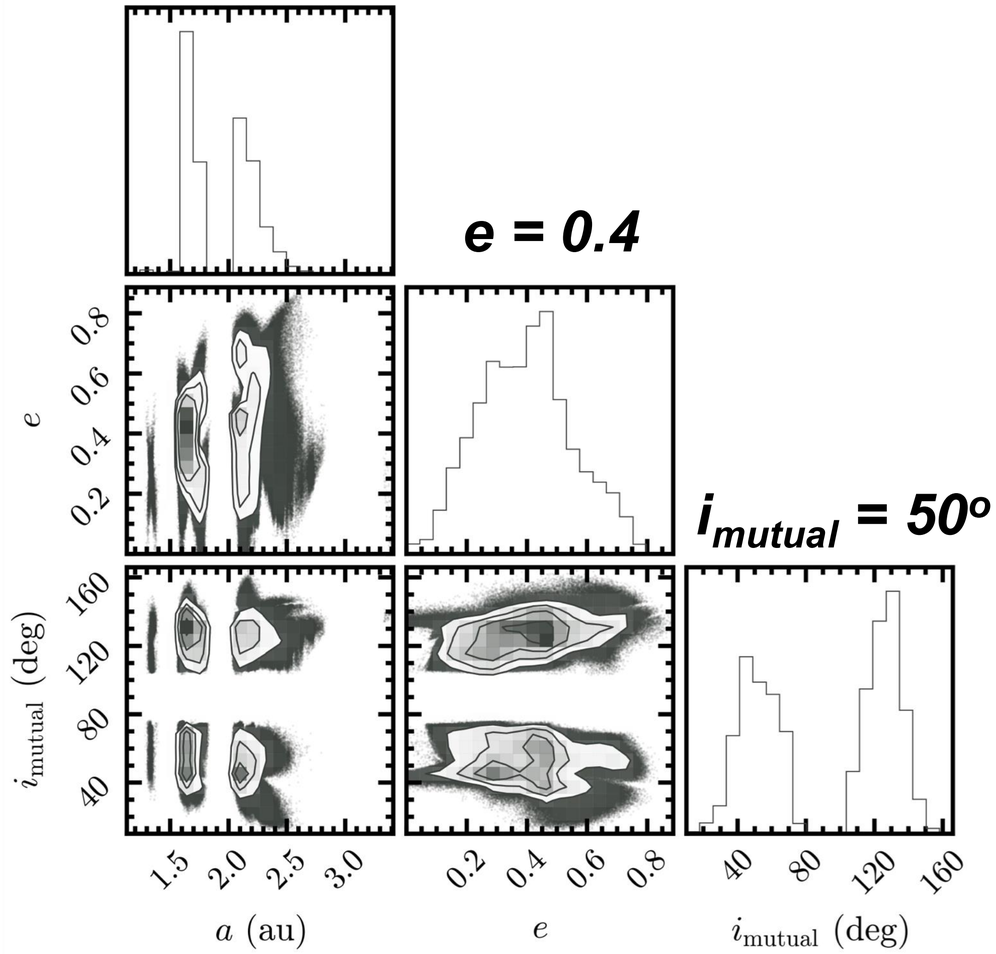
<u>52%</u> of Stable S1+C1 Orbits are Consistent with February and April 2025 Non-Detections!

Orbital and Physical **Properties**

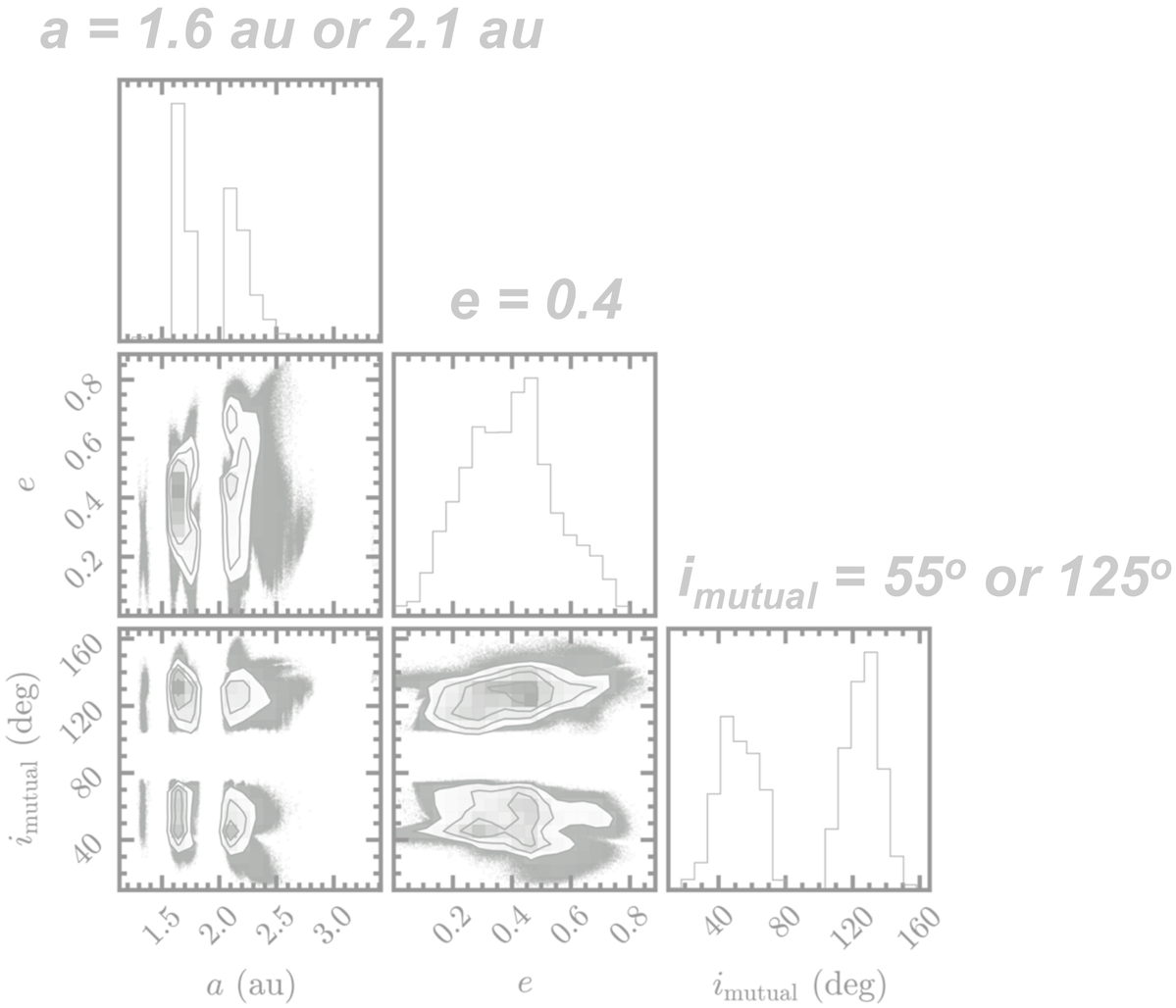
a = 1.6 au or 2.1 au

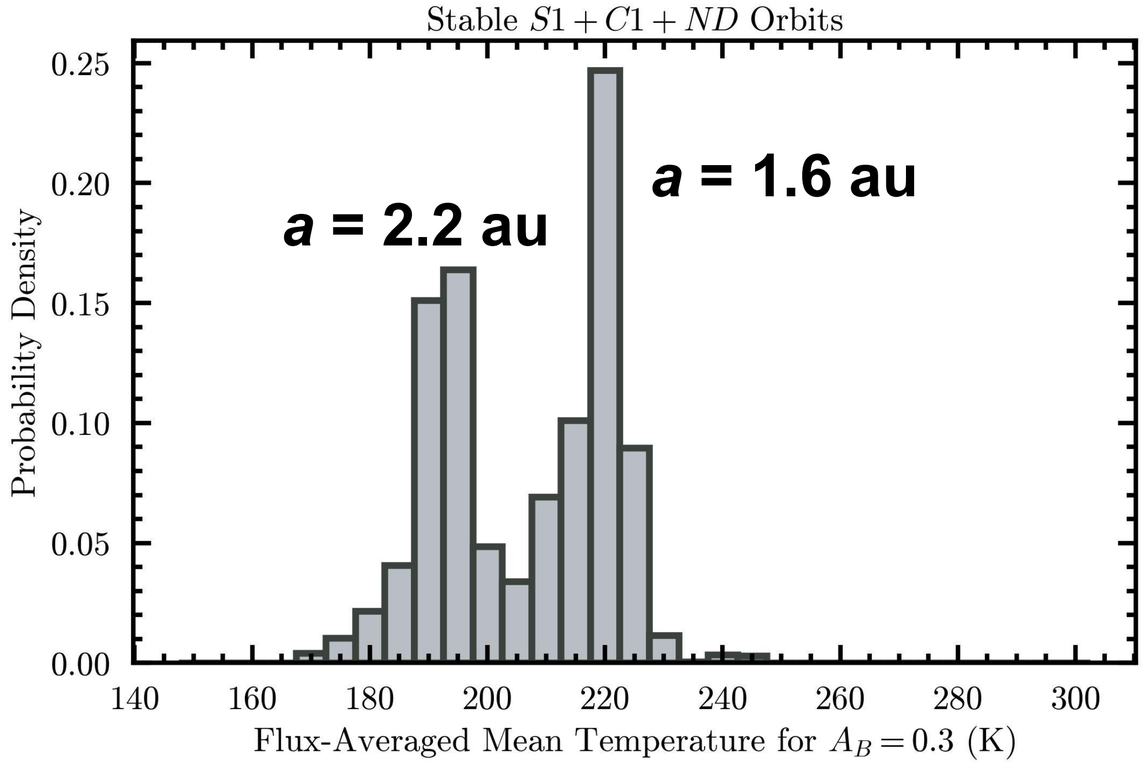
e = 0.4

i_{mutual} = 50^o or 130^o



Orbital and **Physical Properties**

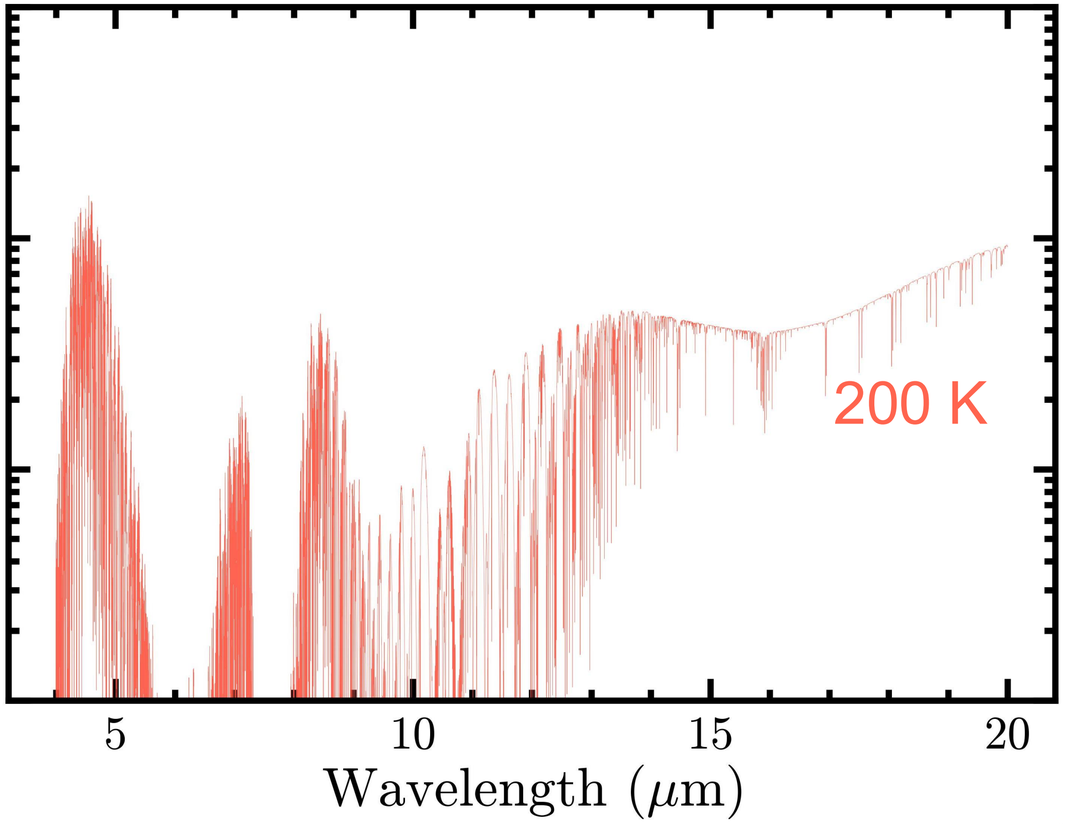




Orbit ➡ ***Temperature*** ➡ ***Flux***

Photometry can constrain the orbit!

Orbital and **Physical Properties**

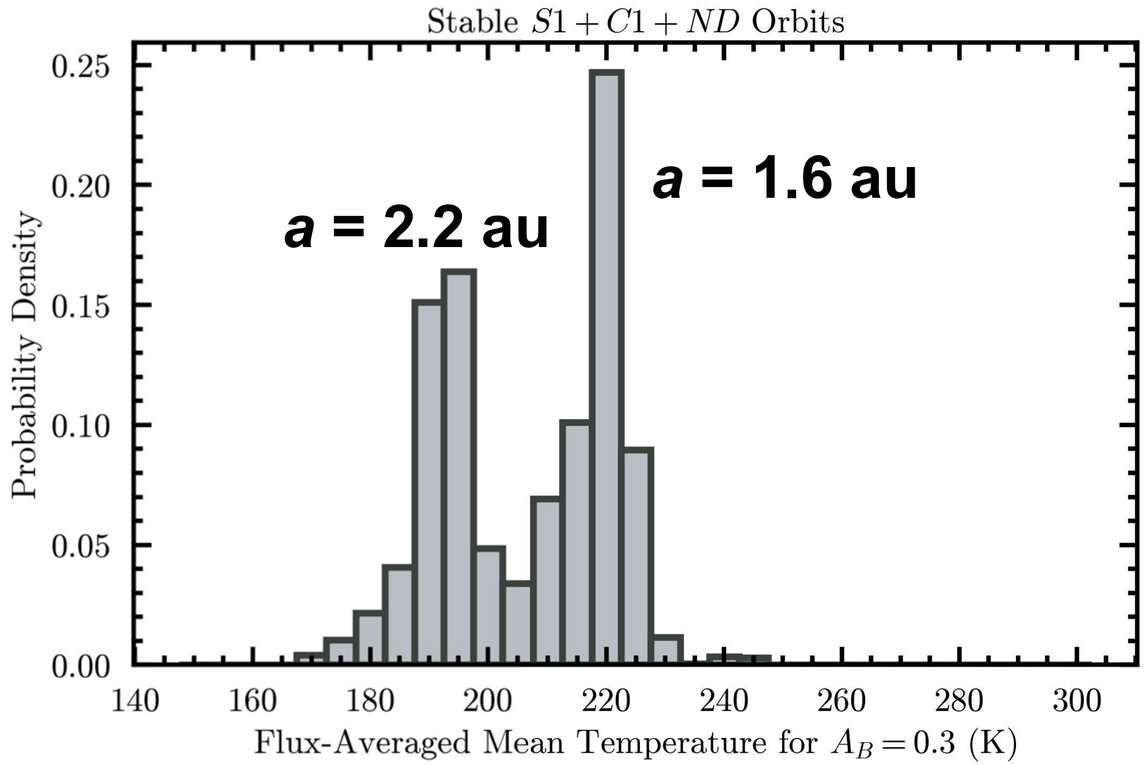


>1.7 $R_{\rm Jup}$ (!)

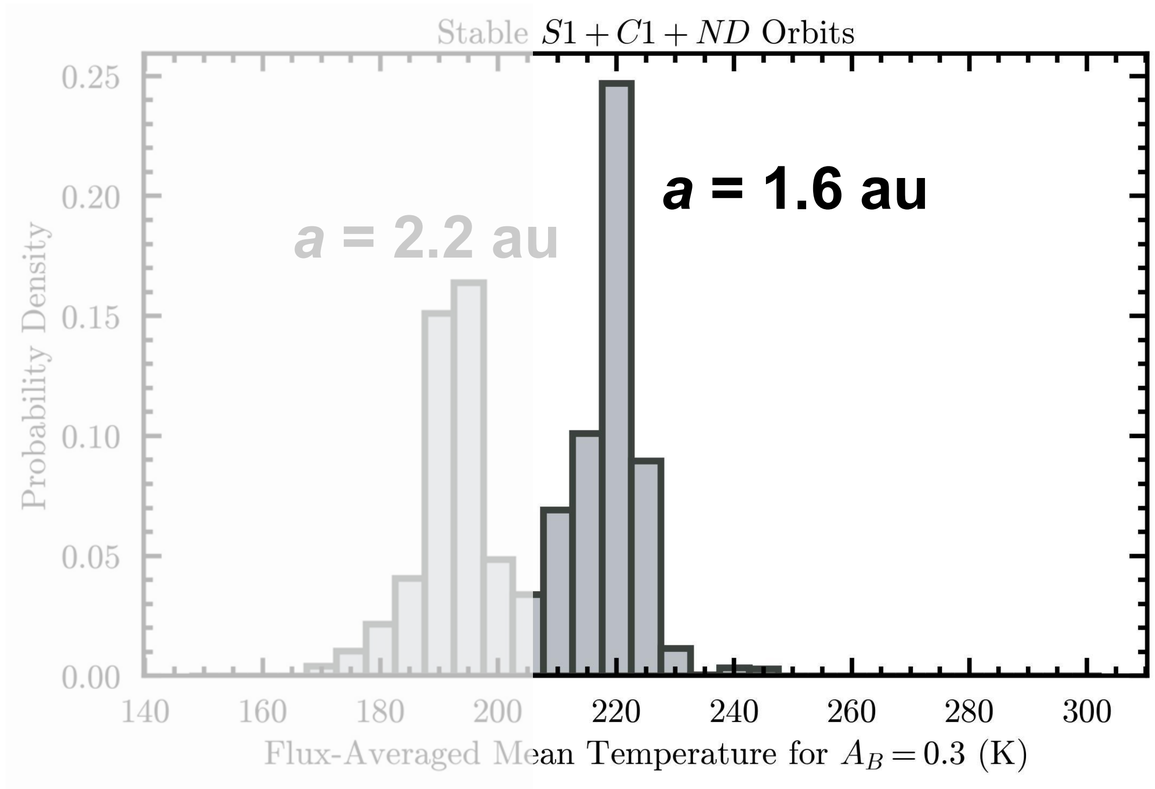
$$\times \left(\frac{R_p}{D}\right)^2 = 3.5\ \text{mJy}\ (15.5\ \mu\text{m})$$

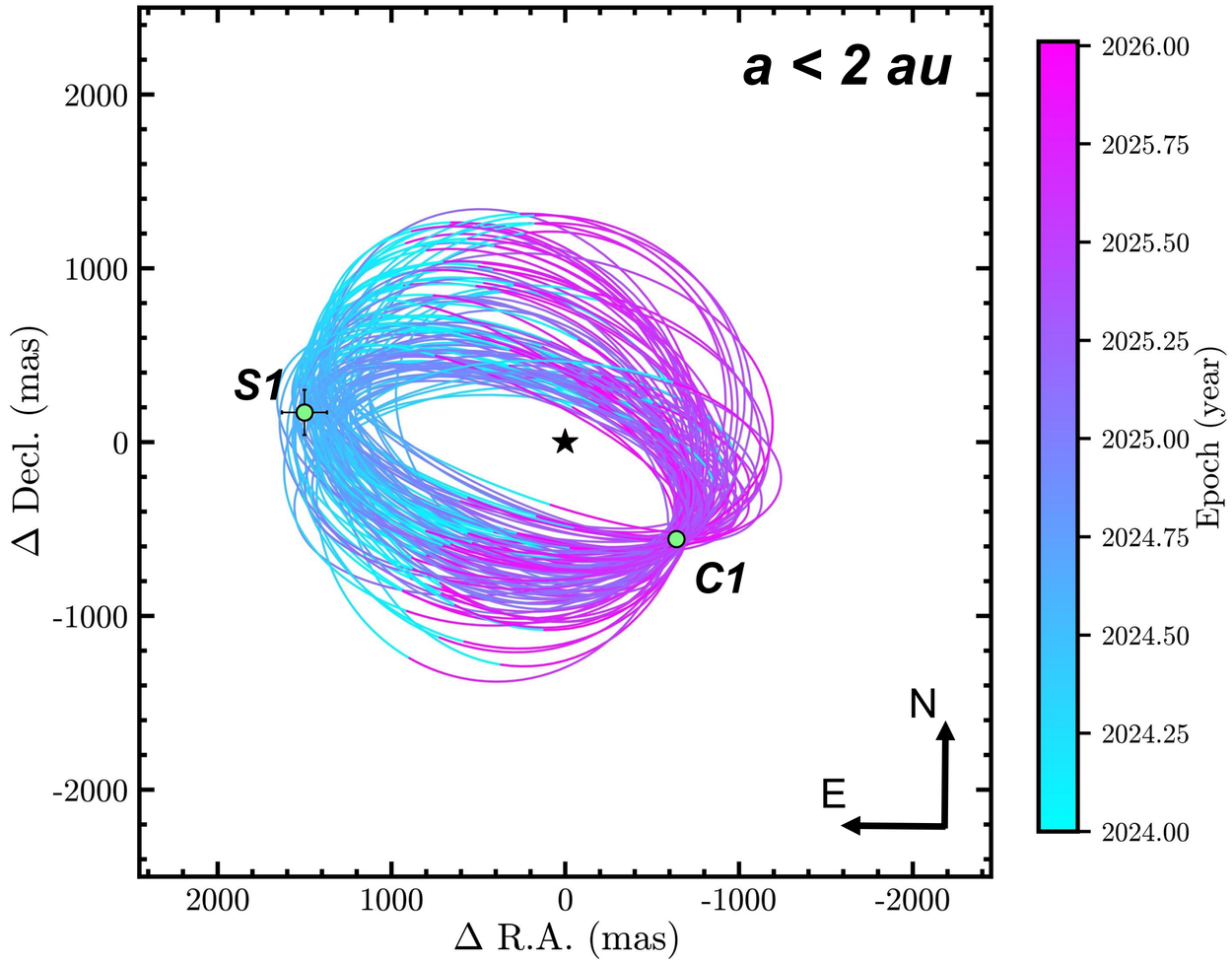
1.34 pc

Orbital and Physical Properties

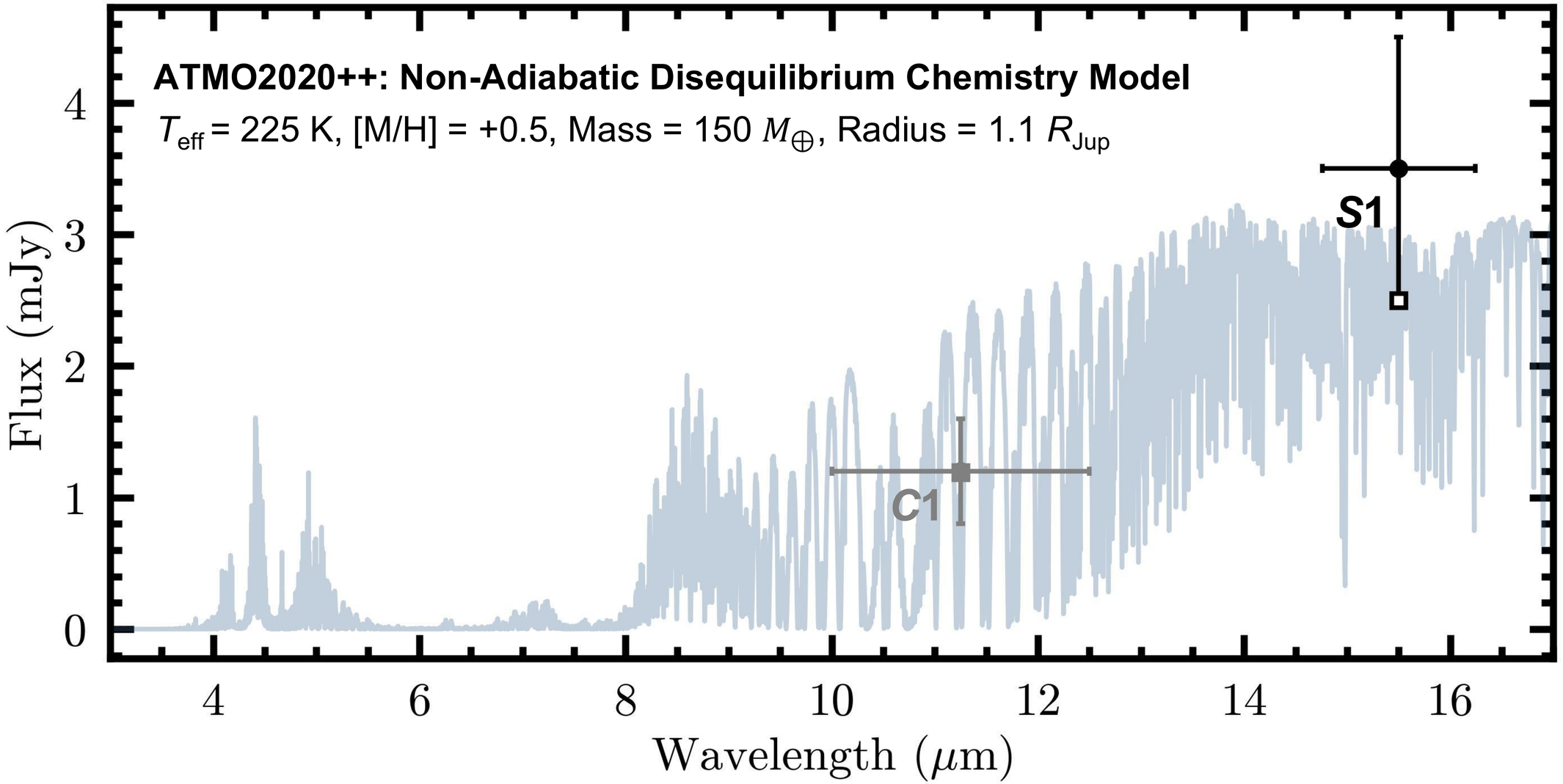


Orbital and Physical Properties



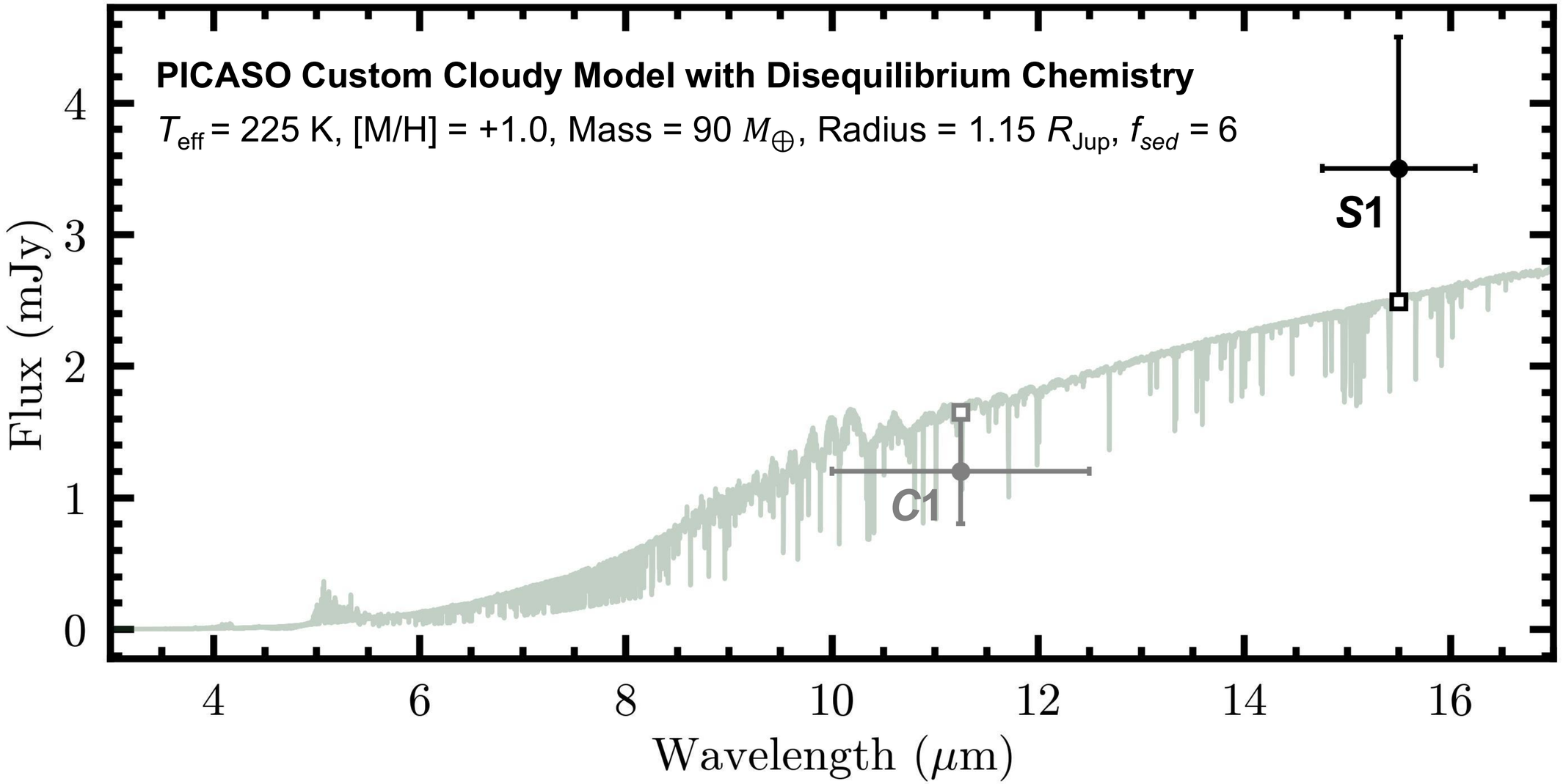


Orbital and Physical Properties



Model from Leggett & Tremblin (2023, 2024)

Orbital and Physical Properties

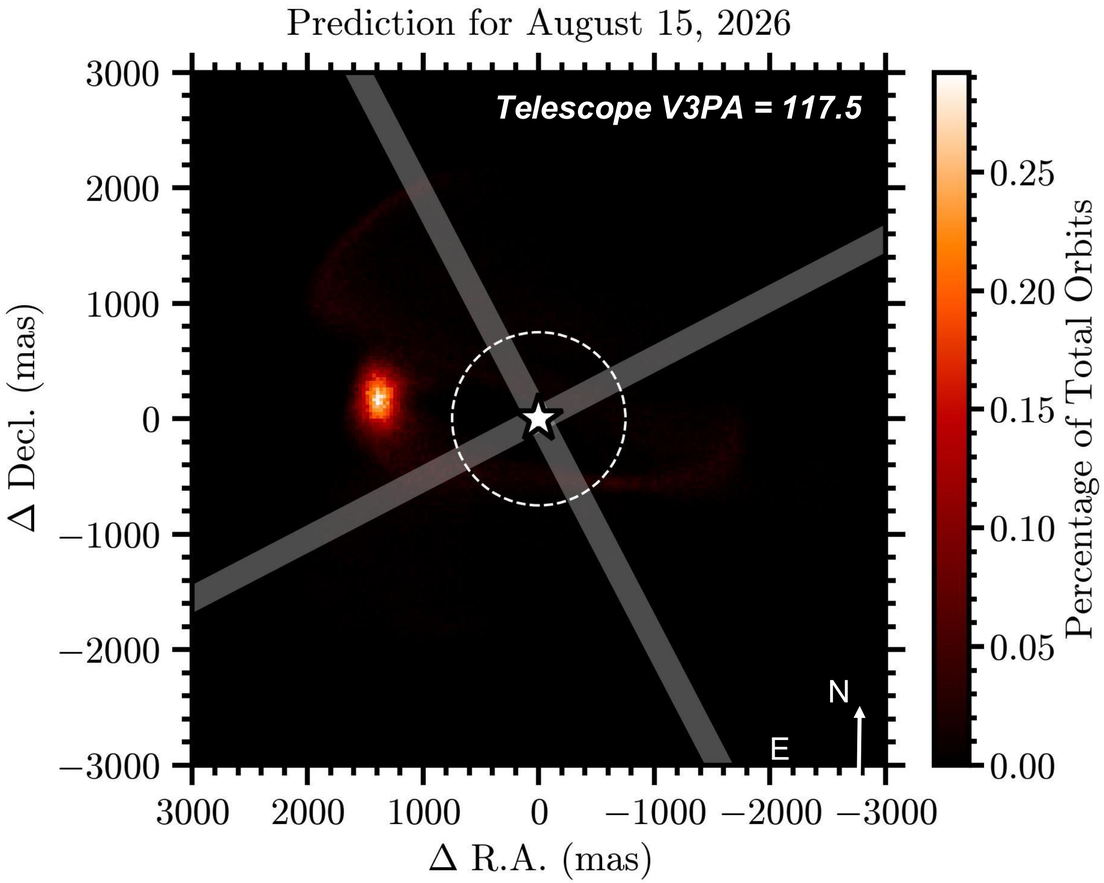


Model from Mang et al. (in preparation)

What's next?

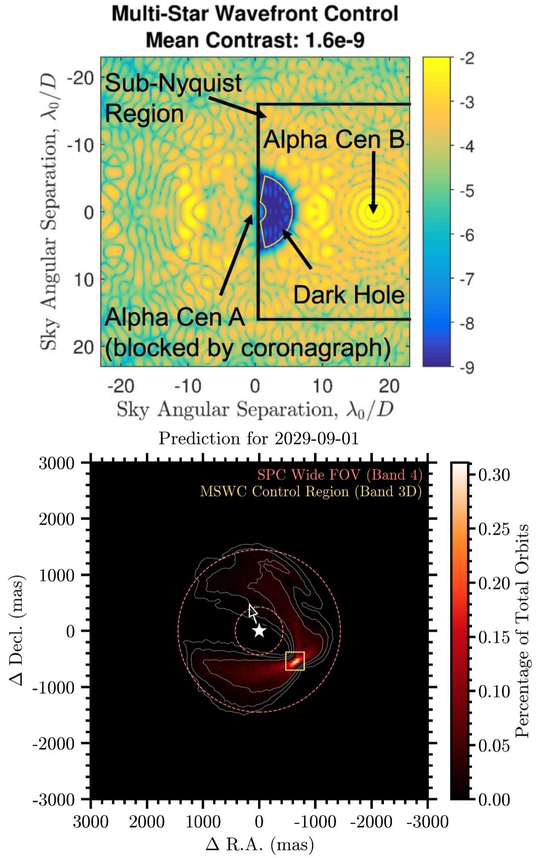
Recovery and Confirmation

JWST Cycle 5



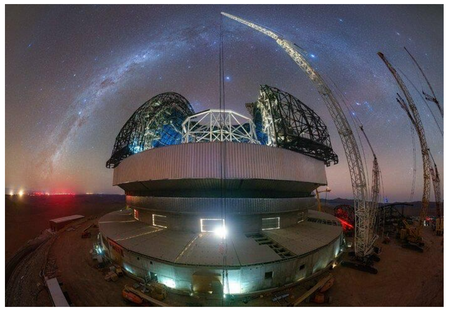
Future Characterization

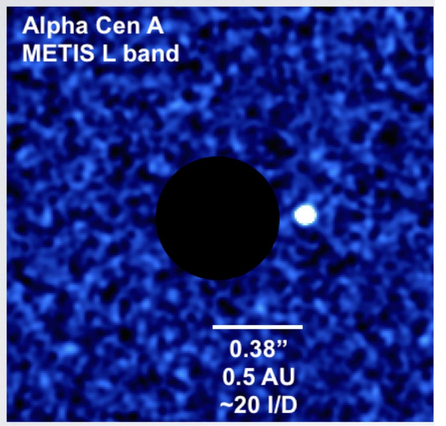
MSWC - Roman/CGI
Albedo



Sirbu et al. 2017
Bendek et al. (incl. **Sanghi**) CPP White Paper

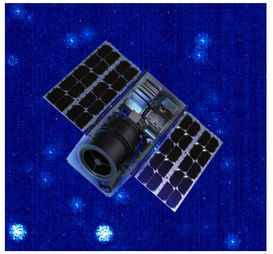
EELT/METIS
IR Spectrum

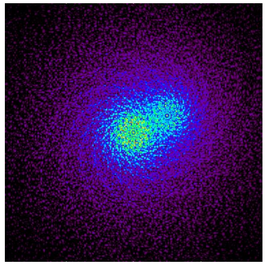




Quanz EPSC (2015)

TOLIMAN
Dynamical Mass



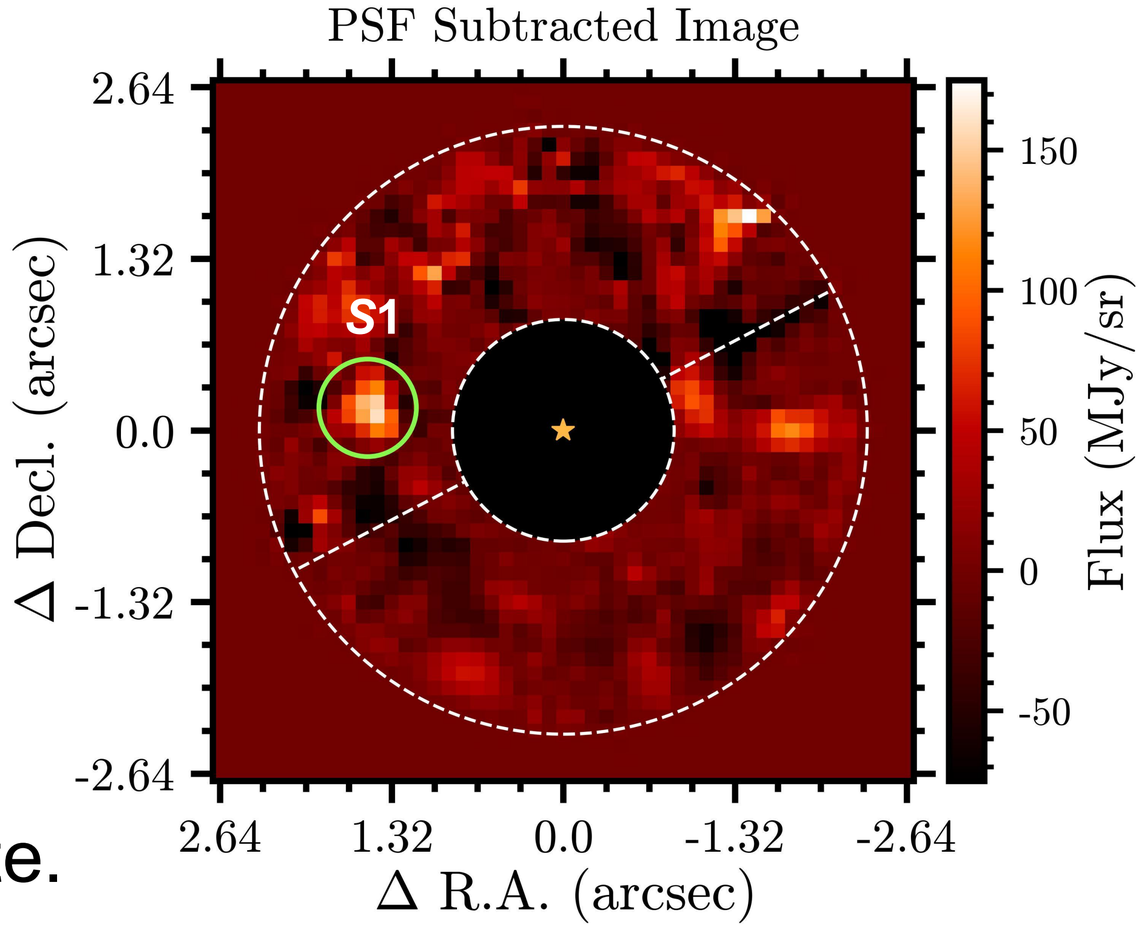


Tuthill et al. (2024)

Pushing the boundaries - - ->

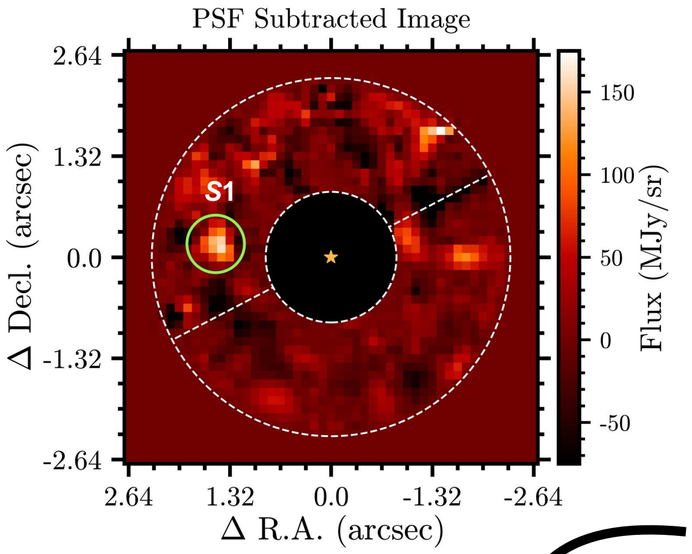
Confirmation of ***S1*** as "α **Cen Ab**" would make it the

- ★ nearest (1.33 pc),
- ★ coldest (~225 K),
- ★ oldest (~5 Gyr),
- ★ shortest period (~2 yr),
- ★ lowest mass (<200 $M_{\oplus}$) planet imaged orbiting a Sun-like star to date.



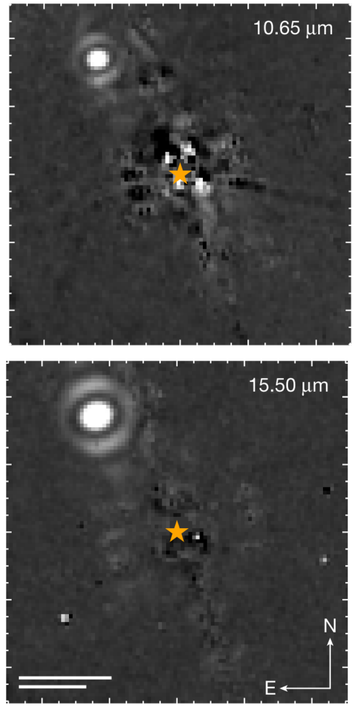
A New Population of Imaged Cold Planets

S1 Candidate ~225 K



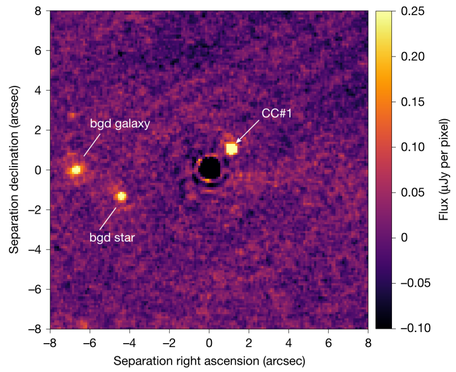
NIRSpec and MIRI MRS Spectroscopy, NIRCam and MIRI Imaging
Cycle 4 JWST Program
PI: Jerry Xuan
Co-PIs: **Aniket Sanghi**, Yapeng Zhang, Jean-Baptiste Ruffio

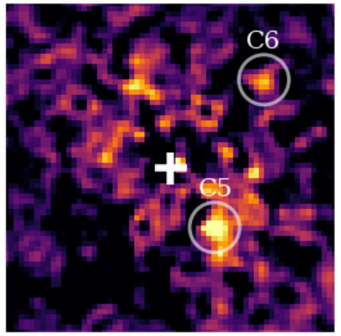
Eps Ind Ab ~275 K



Matthews et al. 2024

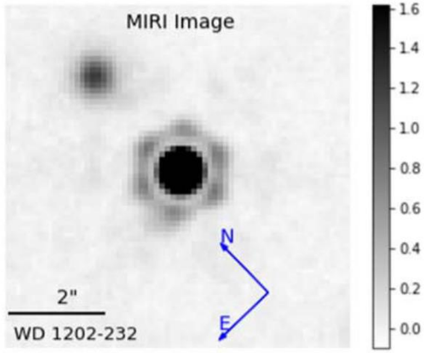
TWA 7b ~300-325 K

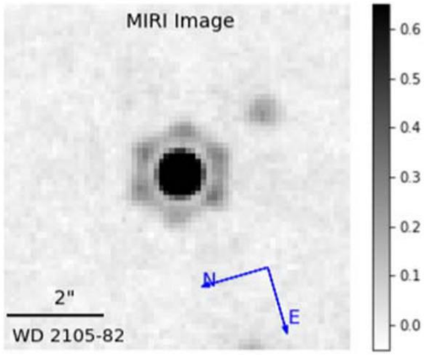




Lagrange et al. 2025
Crotts et al. 2025

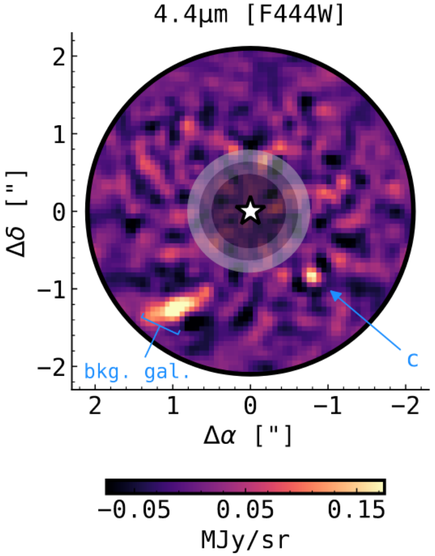
WD Planet Candidates < 300 K





Mullally et al. 2024
Also see MEOW Survey

14 Her c ~275-300 K



Bardalez Gagliuffi & Balmer et al. 20

Avatar: Pandora's View of Gas Giant Polyphemus in the HZ of aCen A

A conversation with James Cameron!

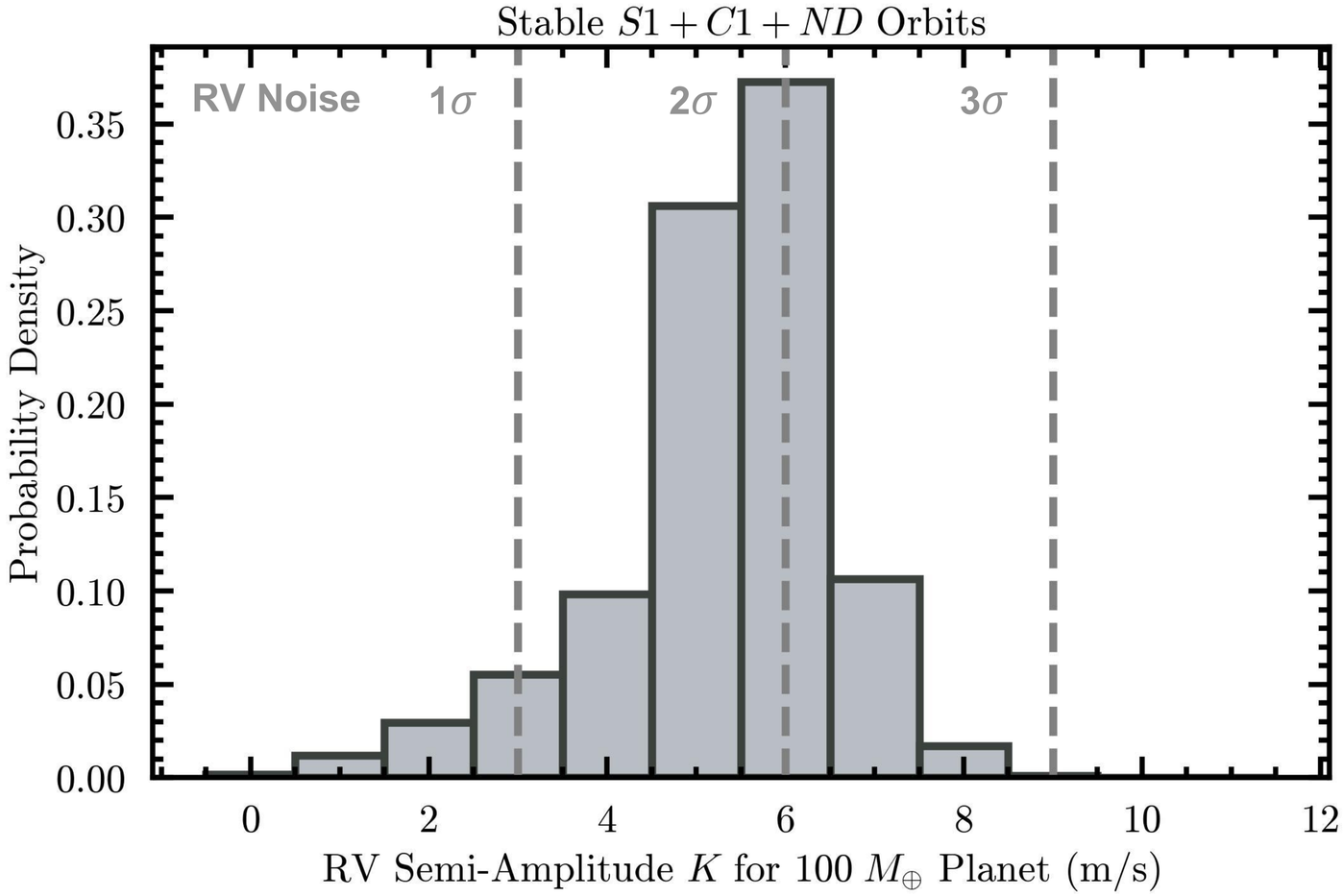
JWST's Candidate Gas Giant

Paper I: Beichman & **Sanghi** et al. 2025 (ApJL)
Paper II: **Sanghi** & Beichman et al. 2025 (ApJL)

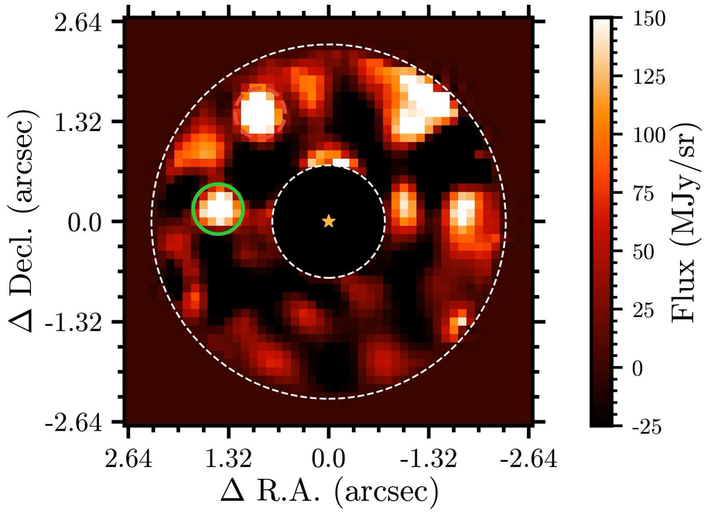
Bonus Content

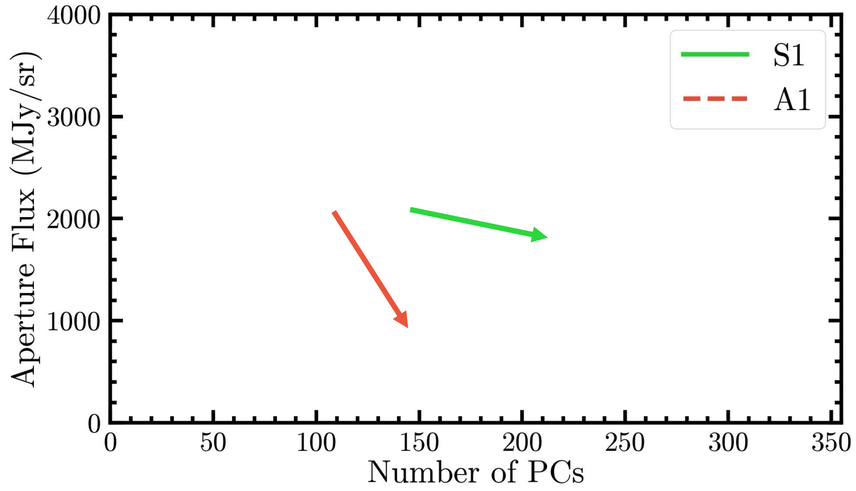
Orbital and Physical Properties

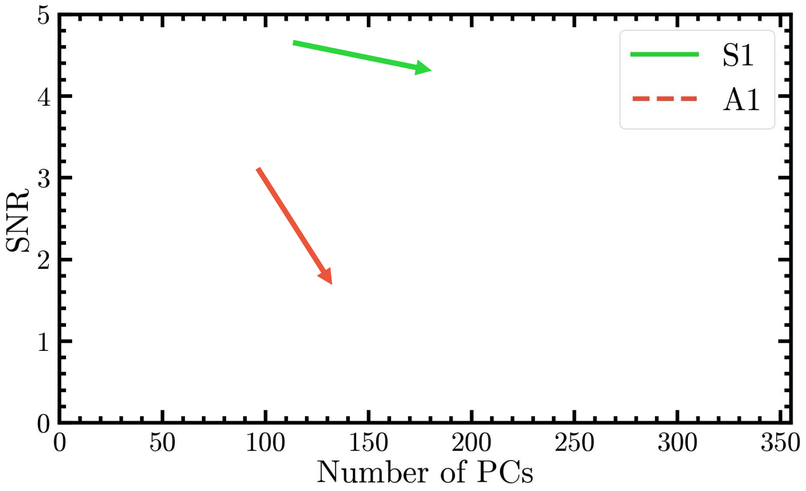
Are the orbits consistent with RV limits (1σ = 3 m/s)?



PSF Subtraction Artifact



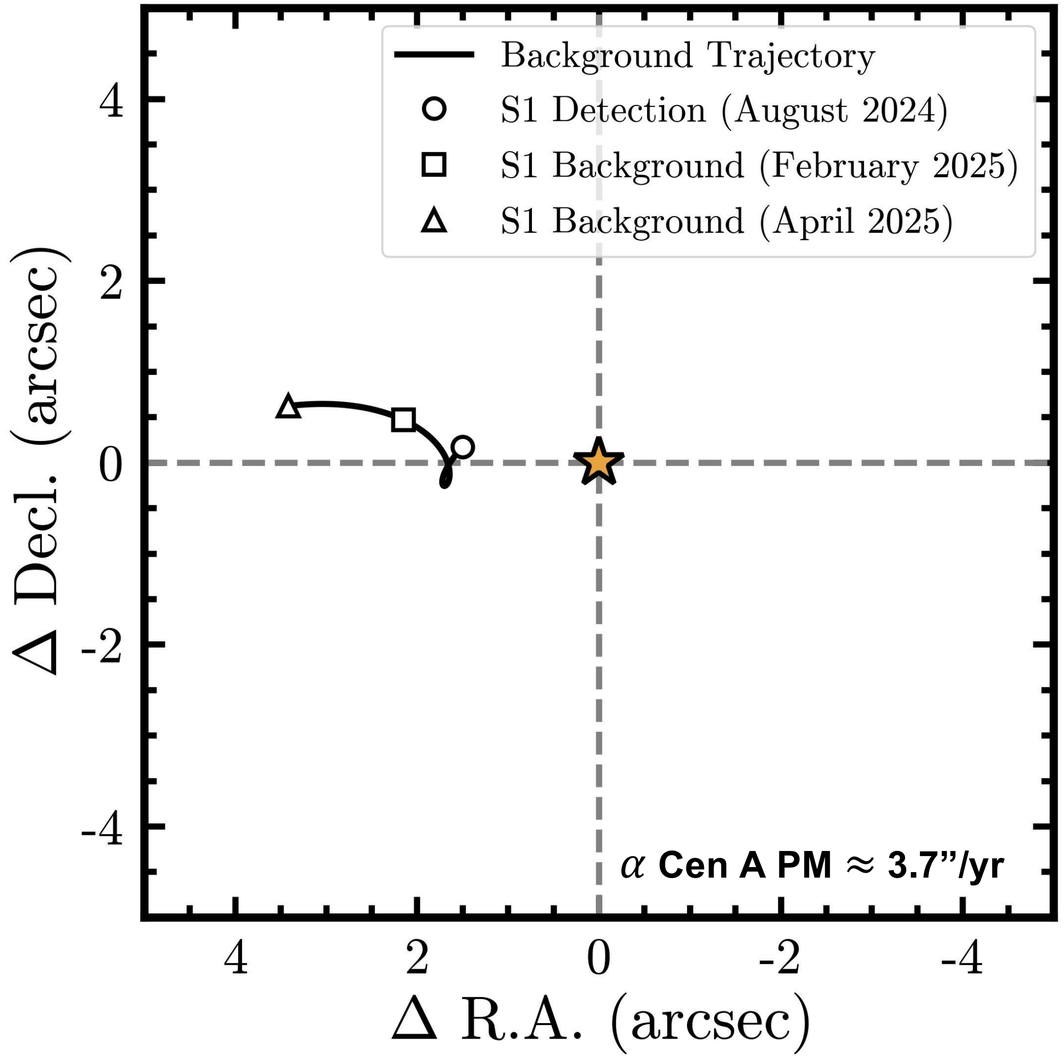


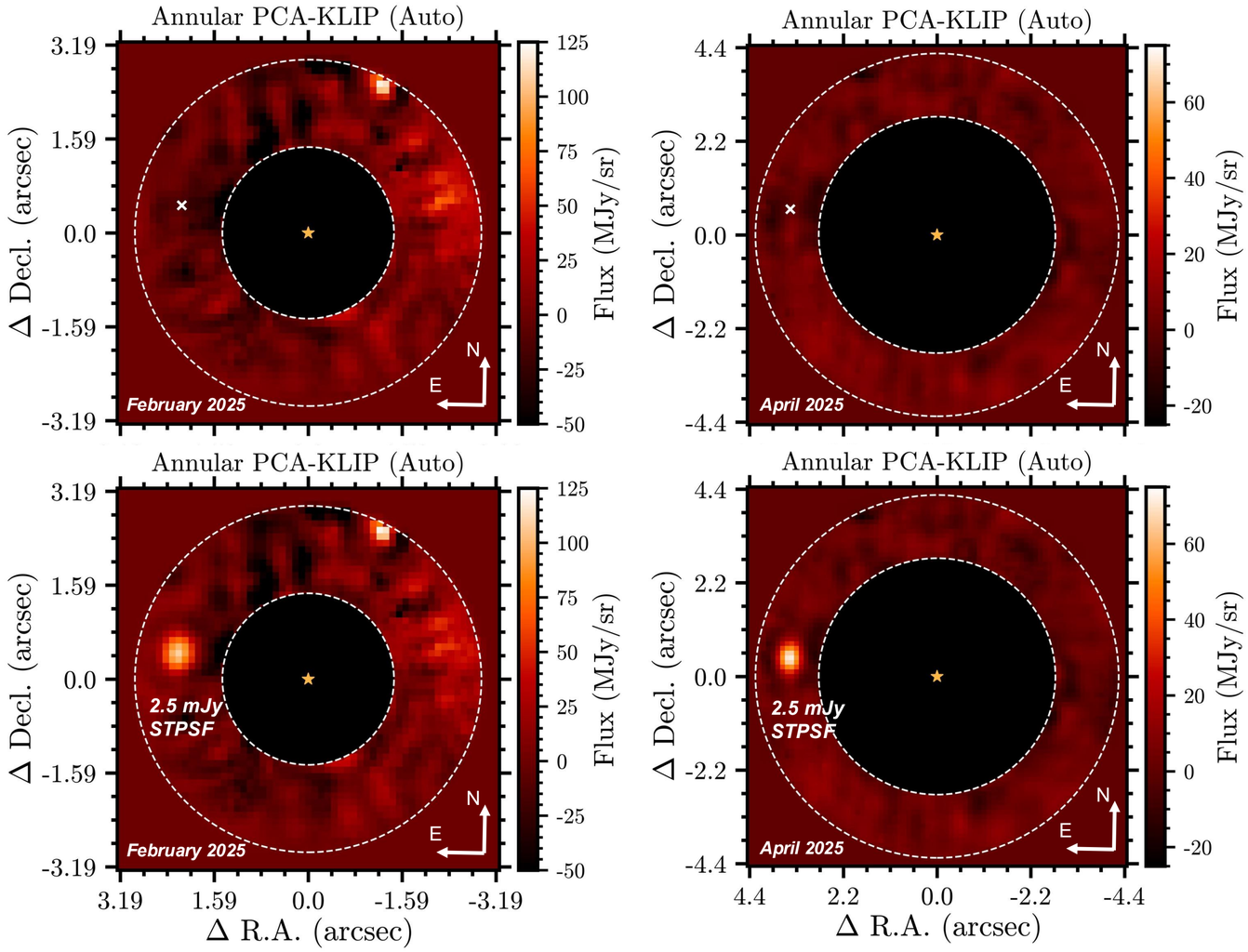


S1 is robust to variations in number of principal components *unlike* A1

Stationary Background Object

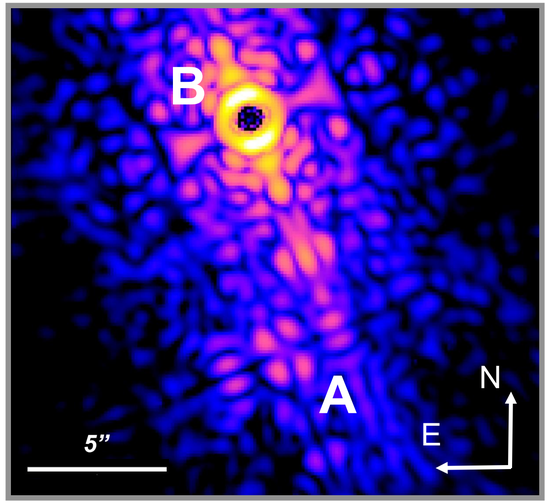
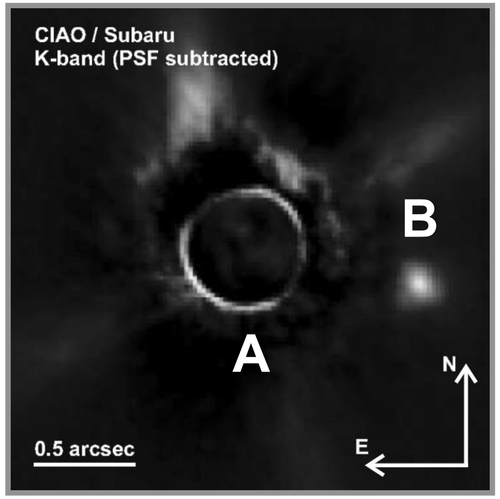
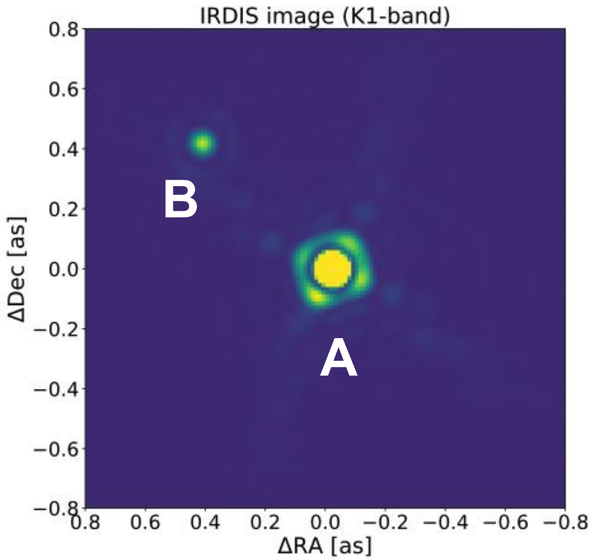
Is *S*1 a background object?





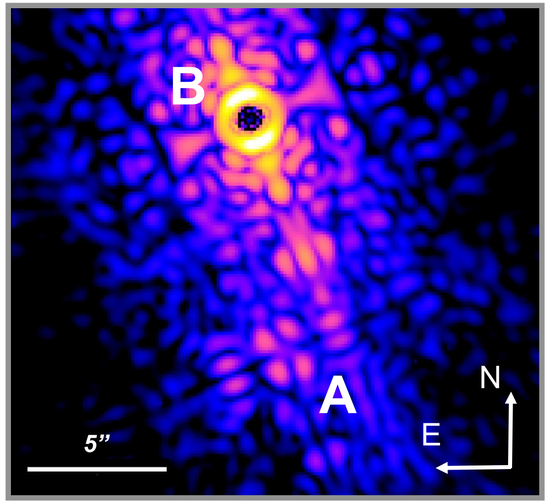
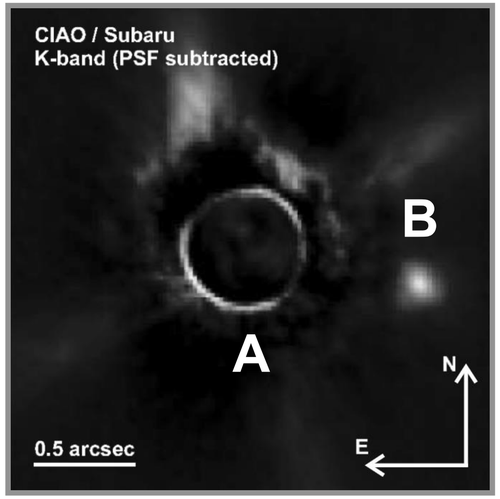
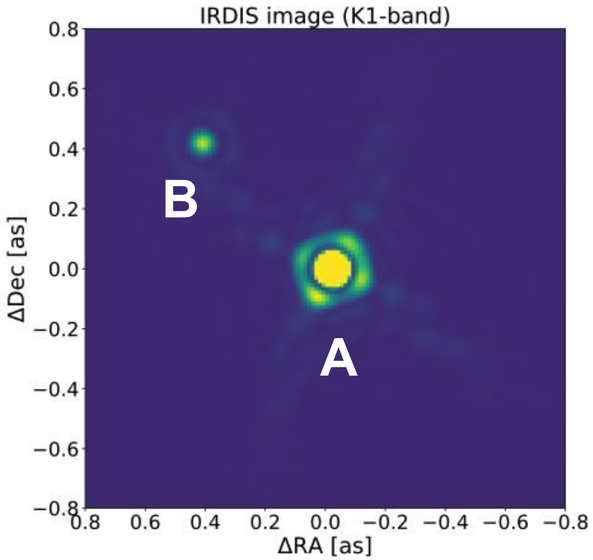
What is *S*1?

Orbital Properties: Extreme S-type Planetary Architectures

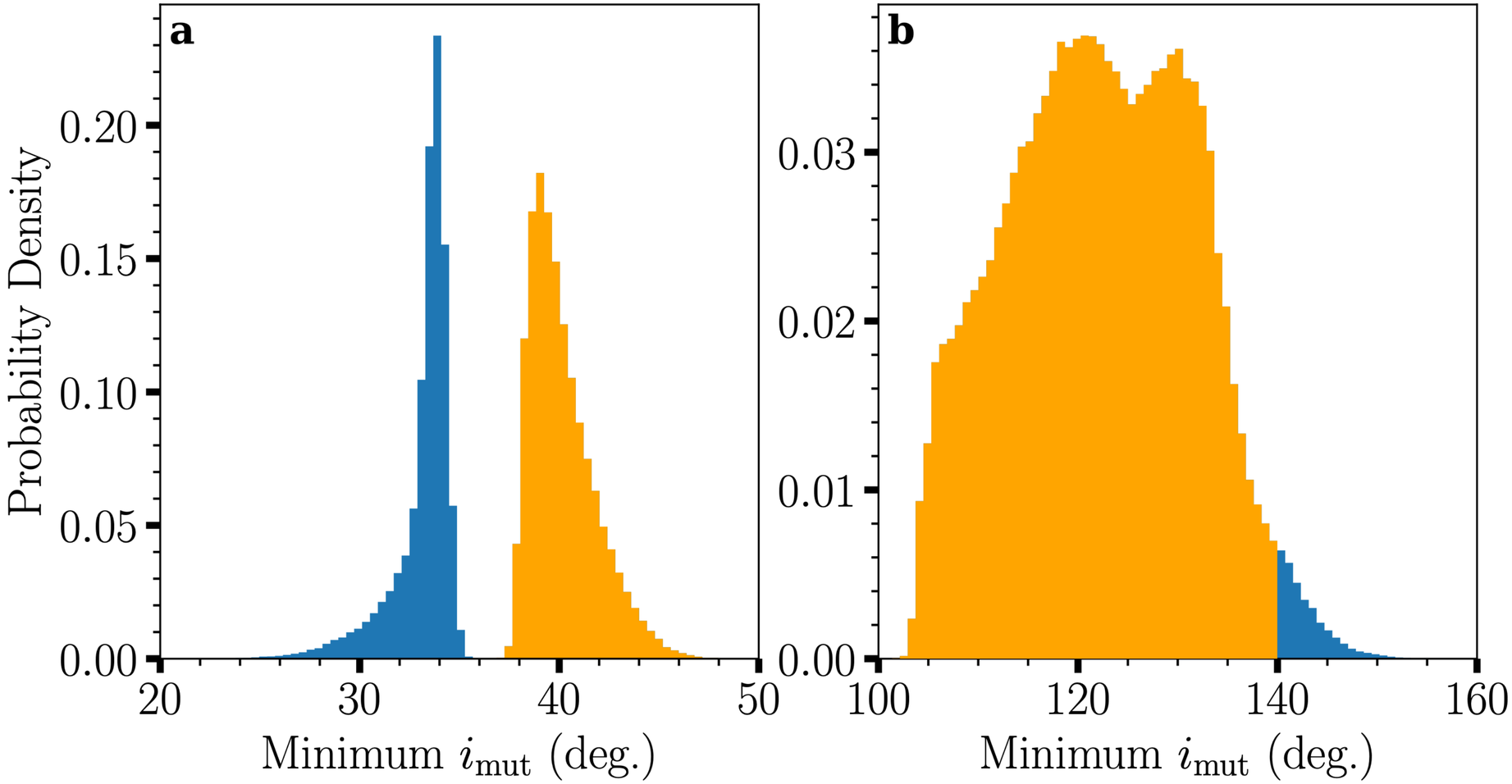
Planet	α Cen AB-(*S*1+C1)	γ Cep AB-Ab	HD 196885 AB-Ab
			
a_{A-Ab}	1.6 au or 2.1 au	2.1 au	2.6 au
e_{A-Ab}	0.4	0.1	0.5
i_{mutual}	50 or 130 deg	114 deg	25 deg

What is *S*1?

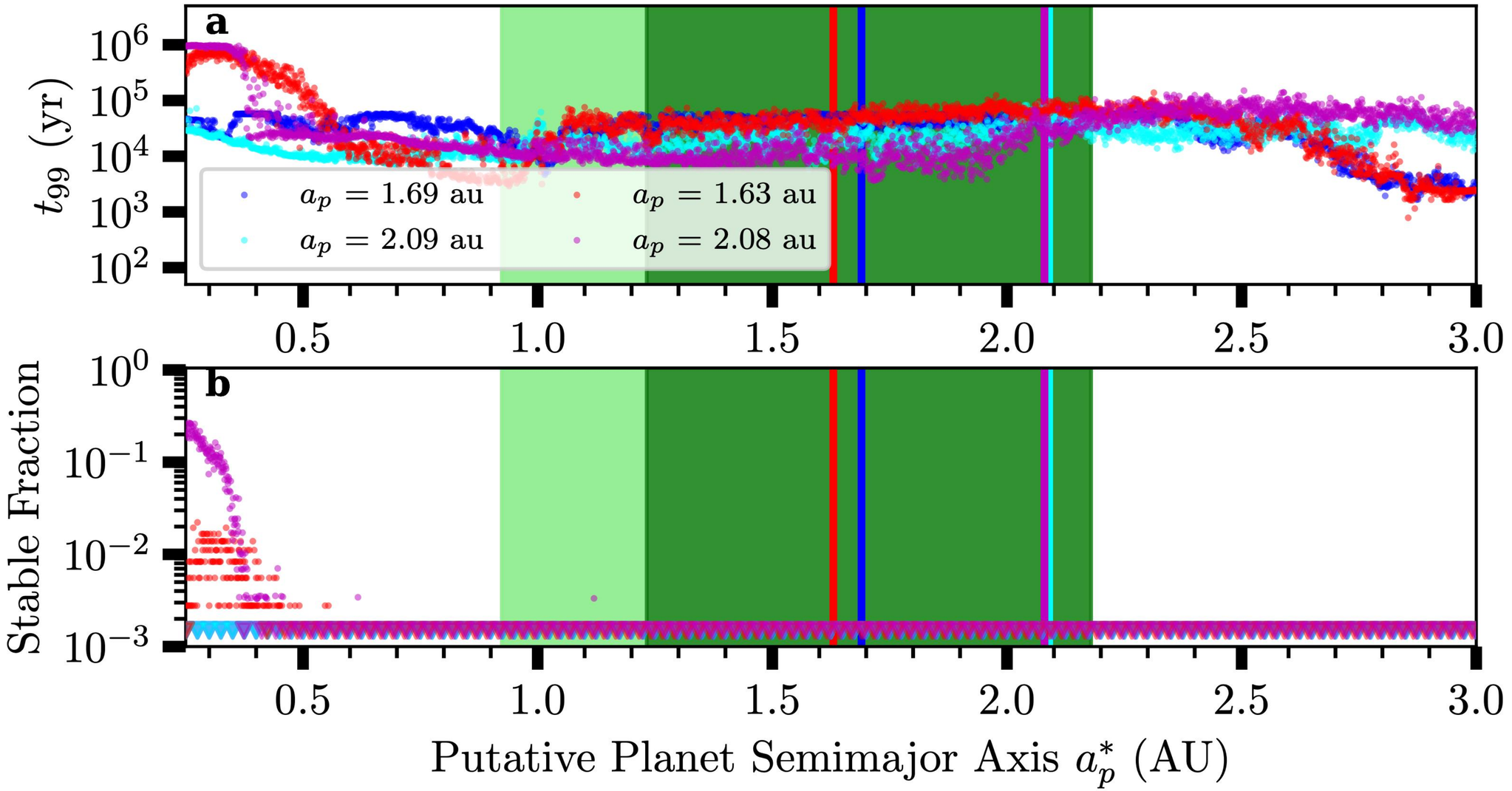
Orbital Properties: Extreme S-type Planetary Architectures

	α Cen AB-(*S*1+C1)	γ Cep AB-Ab	HD 196885 AB-Ab
Stellar Binary			
a_{A-B}	23 au	19 au	21 au
e_{A-B}	0.5	0.4	0.4

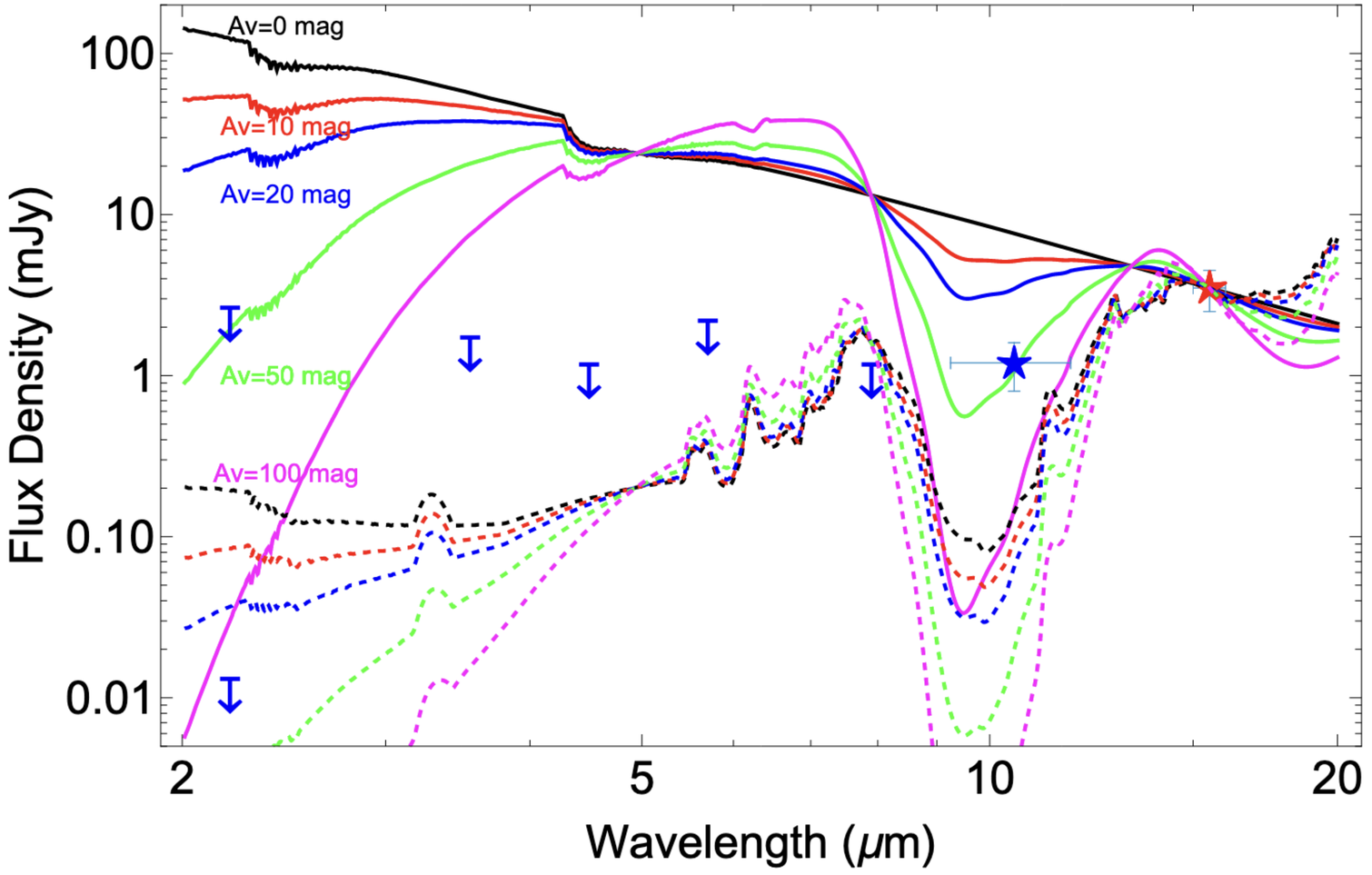
vZKL Oscillations



Survival of Other Planets or Dust



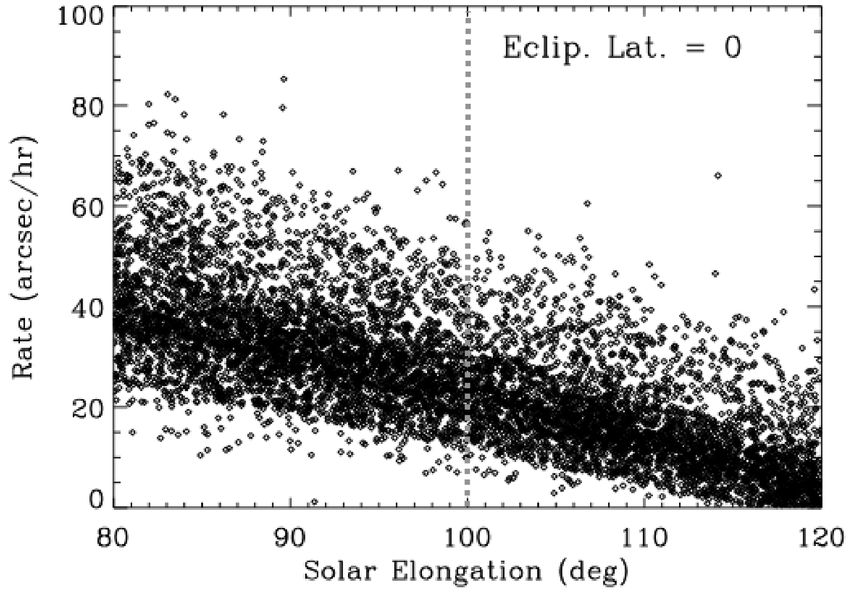
Archival Imaging



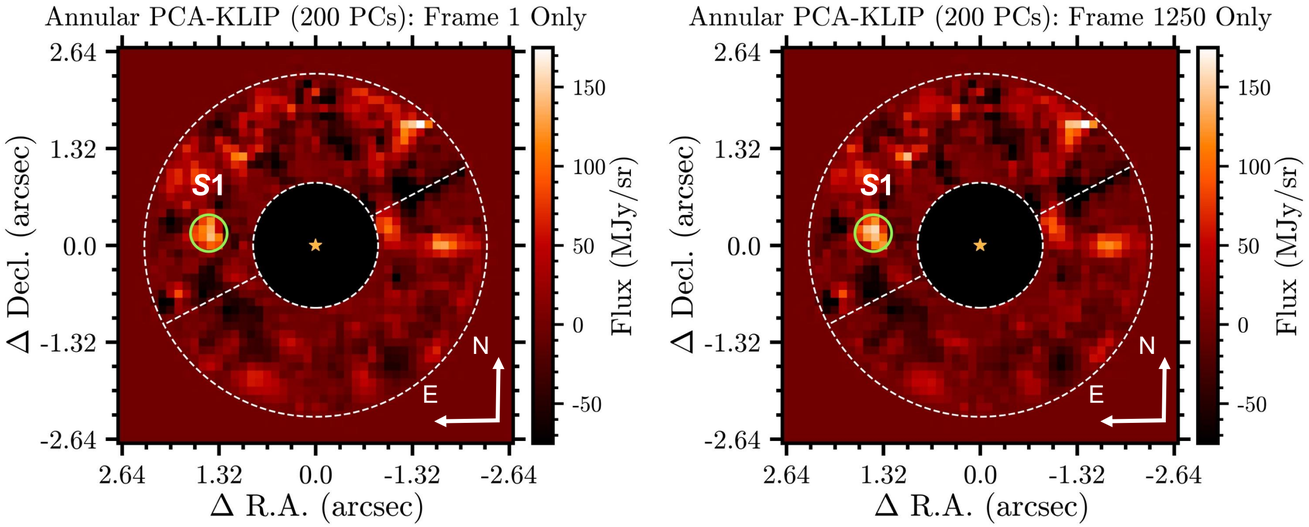
What is *S*1?

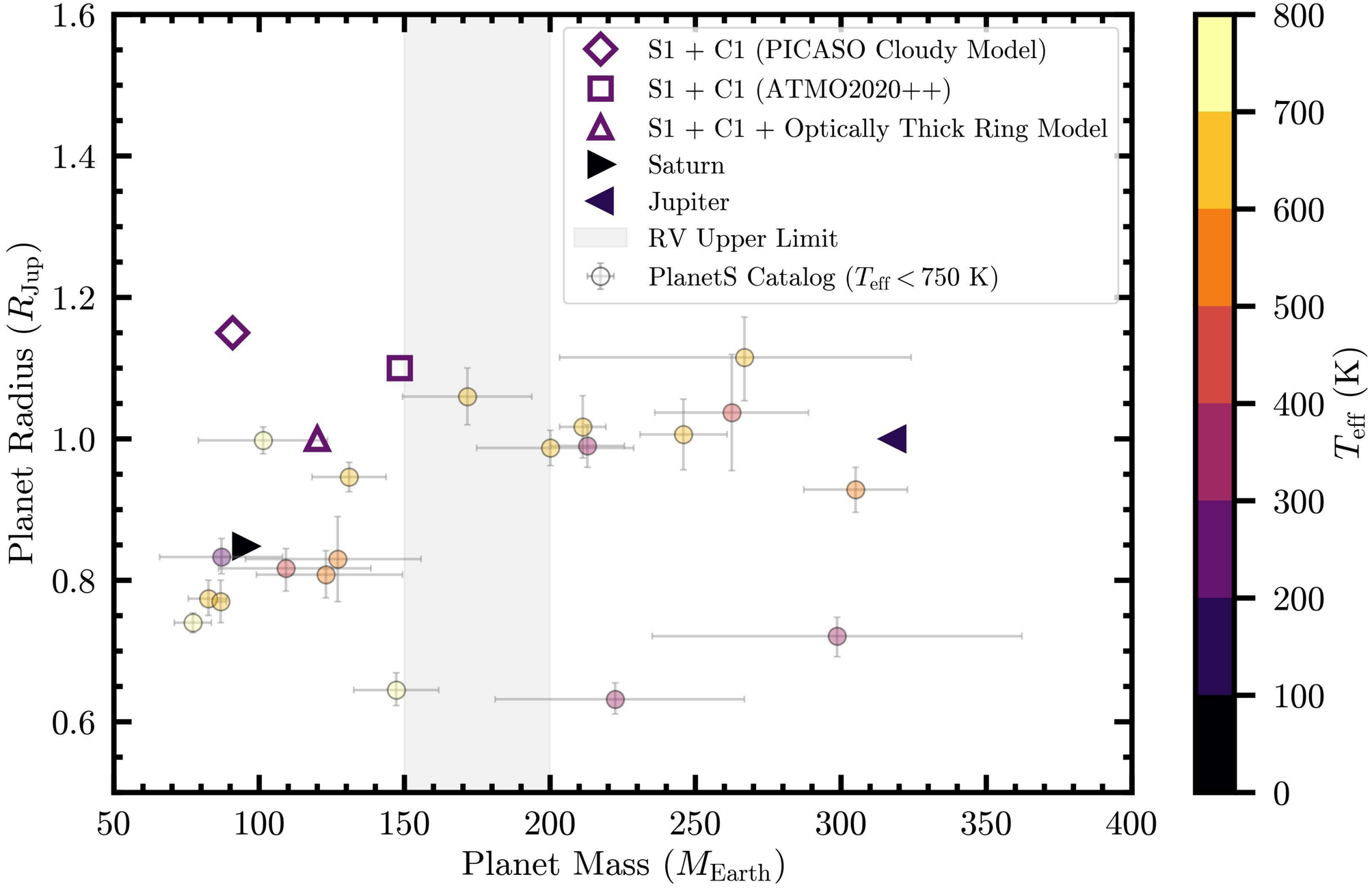
Is *S*1 a foreground object?

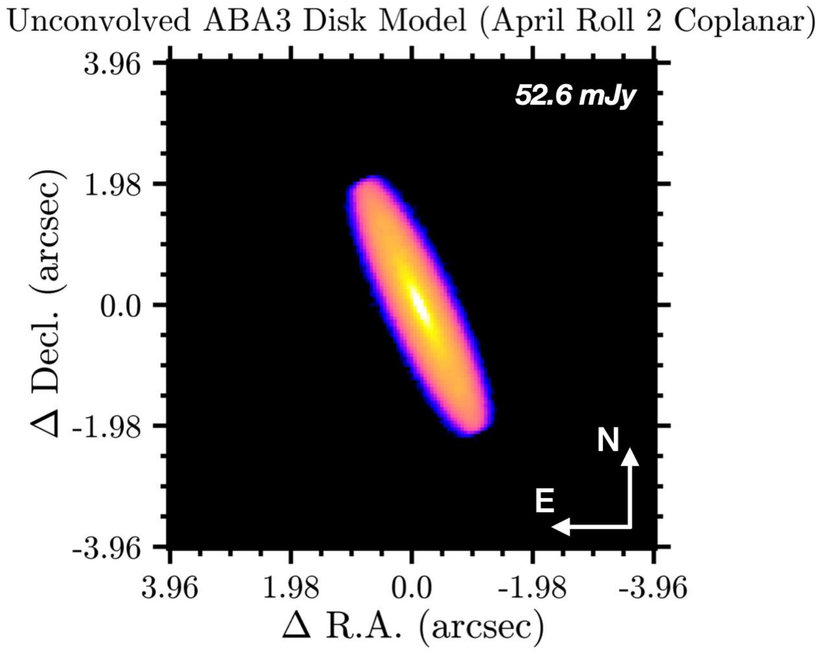
- No sources in the Minor Planet Catalog at position of α Cen A in August 2024.
- Inner Main Belt Asteroid (MBA) must be > 2 km in diameter to emit 3 mJy in F1550C. Probability$< 10^{-4}$ in 5 sq. arcsec region at α Cen A's ecliptic latitude (Brooke 2003).
- Detection in individual integrations (2.5 hour sequence) = Not a high proper motion MBA.

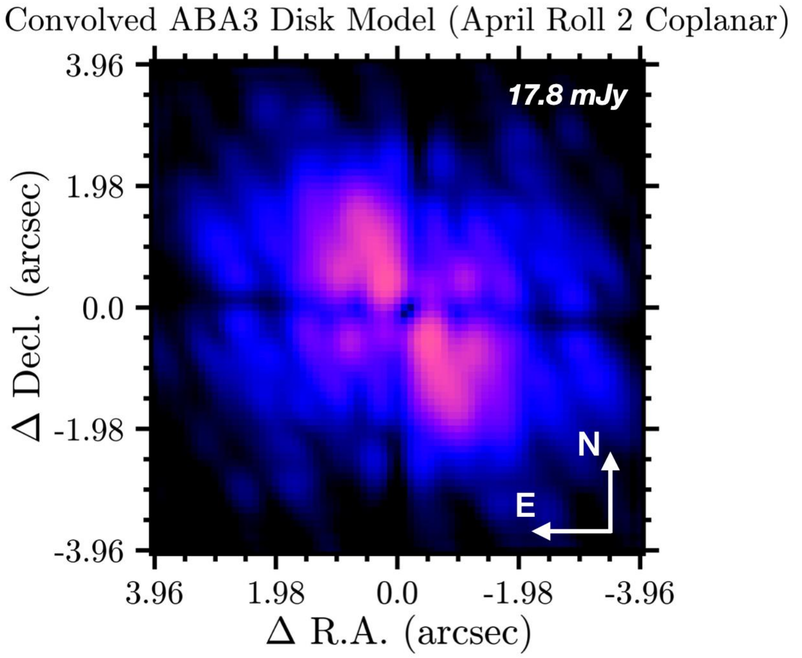


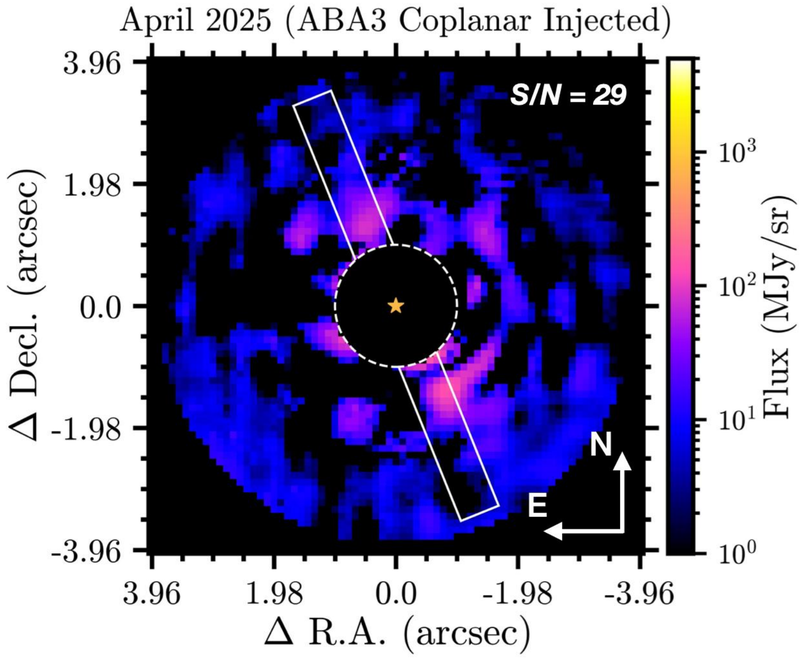
Brooke (2003)




S1 + C1 (PICASO Cloudy Model)
S1 + C1 (ATMO2020++)
S1 + C1 + Optically Thick Ring Model
Saturn
Jupiter
RV Upper Limit
PlanetS Catalog ($T_{\rm eff} < 750$ K)
Planet Radius ($R_{\rm Jup}$)
Planet Mass ($M_{\rm Earth}$)
$T_{\rm eff}$ (K)
1.6
1.4
1.2
1.0
0.8
0.6
50
100
150
200
250
300
350
400
800
700
600
500
400
300
200
100
0


Unconvolved ABA3 Disk Model (April Roll 2 Coplanar)
52.6 mJy
N
E
3.96
1.98
0.0
-1.98
-3.96
Δ Decl. (arcsec)
Δ R.A. (arcsec)

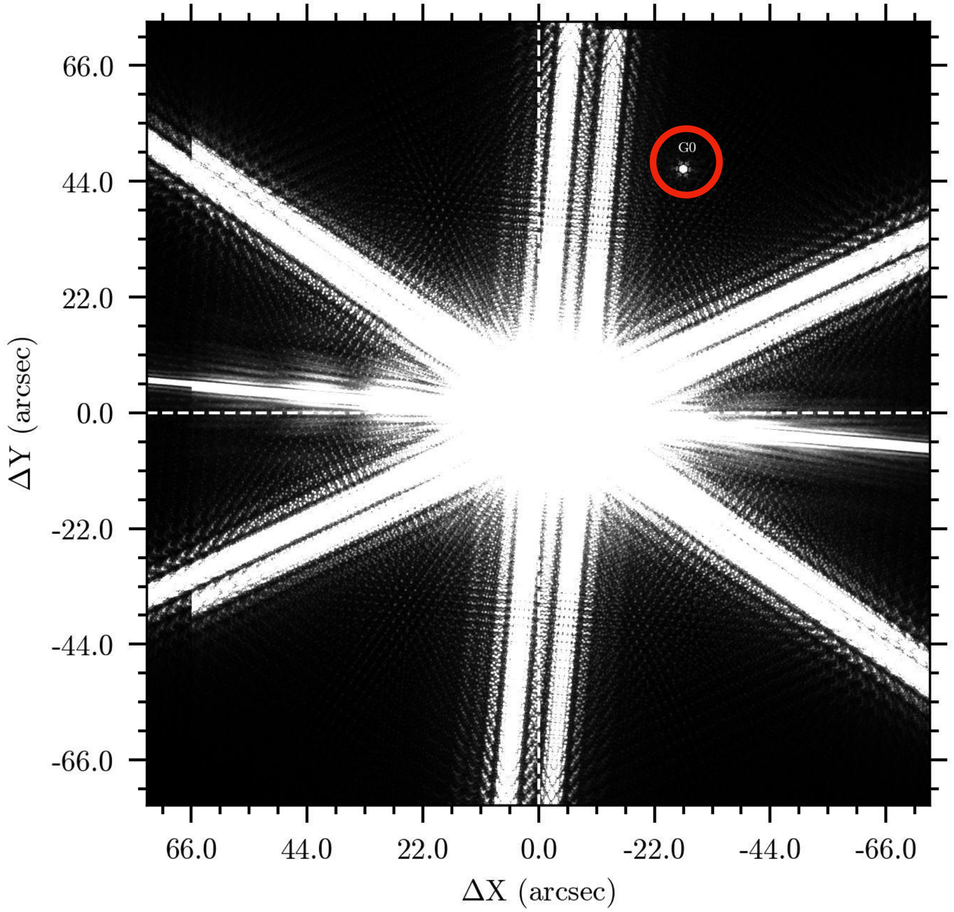

Convolved ABA3 Disk Model (April Roll 2 Coplanar)
17.8 mJy
N
E
3.96
1.98
0.0
-1.98
-3.96
Δ Decl. (arcsec)
Δ R.A. (arcsec)


April 2025 (ABA3 Coplanar Injected)
S/N = 29
N
E
3.96
1.98
0.0
-1.98
-3.96
Δ Decl. (arcsec)
Δ R.A. (arcsec)
10^3
10^2
10^1
10^0
Flux (MJy/sr)

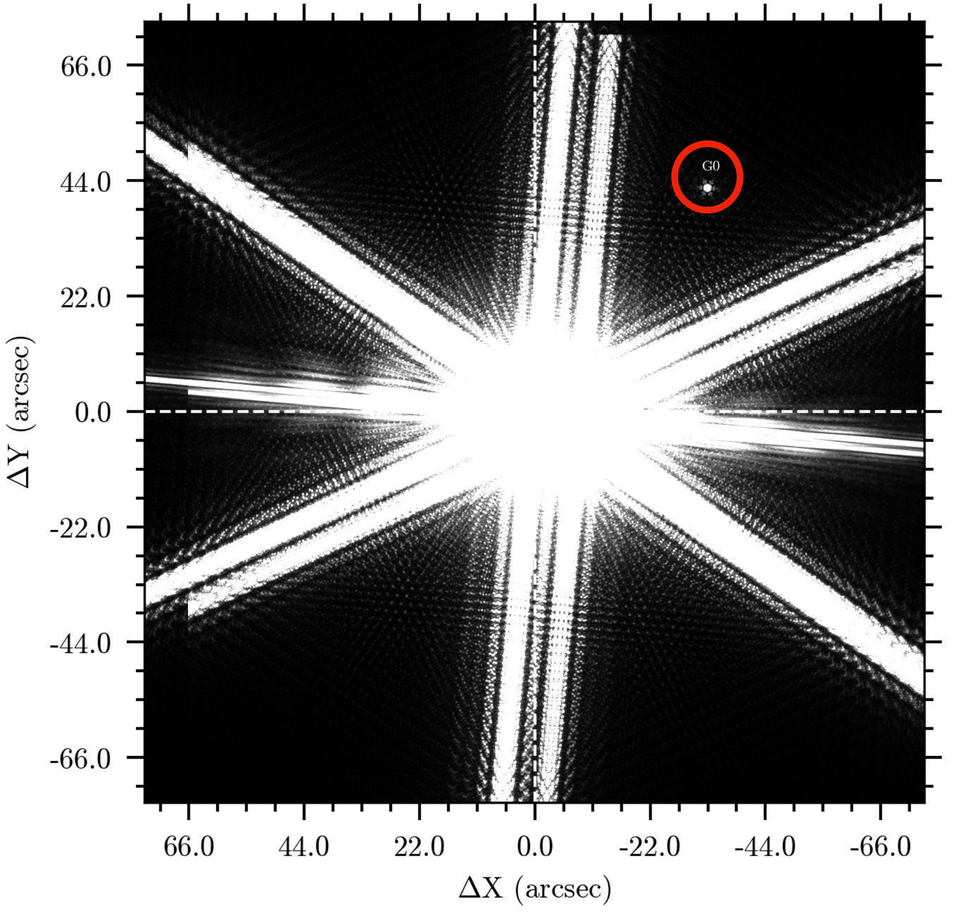
Overcoming the Challenge of Target Acquisition

(3) Select the final offset star based on simulations at the V3 angle of observations

V3PA = 103 degrees (G0)



V3PA = 110 degrees (G0)



Fluxes are to scale in F1000W.