Science Capability and Observing Plans

Vanessa Bailey, Bijan Nemati, Brian Kern

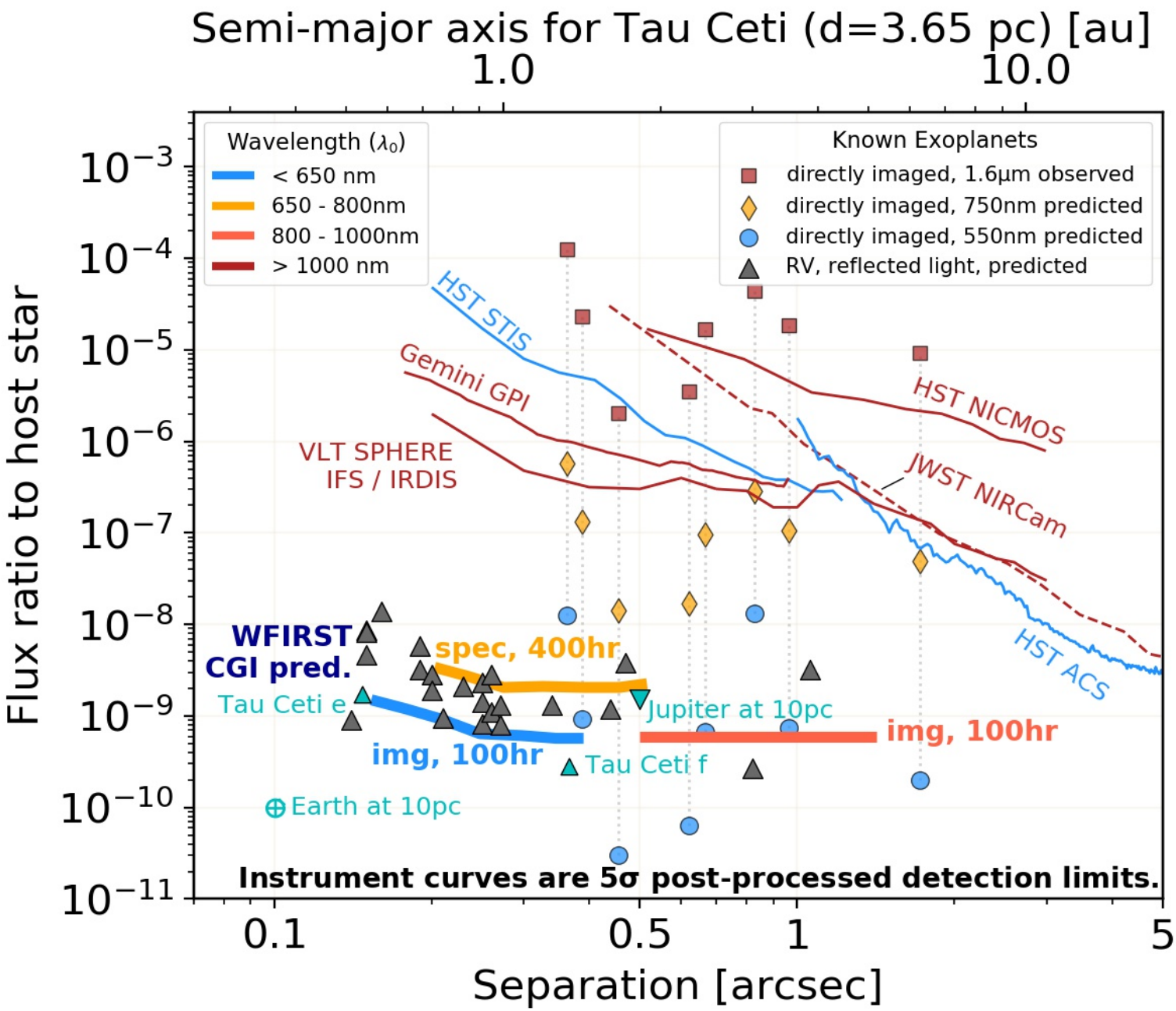
Jet Propulsion Laboratory

California Institute of Technology

March 19, 2018

© 2018 California Institute of Technology. Government sponsorship acknowledged. The research was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration. The decision to implement the WFIRST mission will not be finalized until NASA's completion of the National Environmental Policy Act (NEPA) process. This document is being made available for information purposes only.

Jet Propulsion Laboratory
California Institute of Technology


Semi-major axis for Tau Ceti (d=3.65 pc) [au]
1.0
10.0
Wavelength (λ_0)
< 650 nm
650 - 800nm
800 - 1000nm
> 1000 nm
Known Exoplanets
directly imaged, 1.6μm observed
directly imaged, 750nm predicted
directly imaged, 550nm predicted
RV, reflected light, predicted
HST STIS
Gemini GPI
VLT SPHERE
IFS / IRDIS
HST NICMOS
JWST NIRCam
HST ACS
WFIRST
CGI pred.
spec, 400hr
Tau Ceti e
Jupiter at 10pc
img, 100hr
img, 100hr
Tau Ceti f
Earth at 10pc
Instrument curves are 5σ post-processed detection limits.
Flux ratio to host star
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
0.1
0.5
1
5
Separation [arcsec]

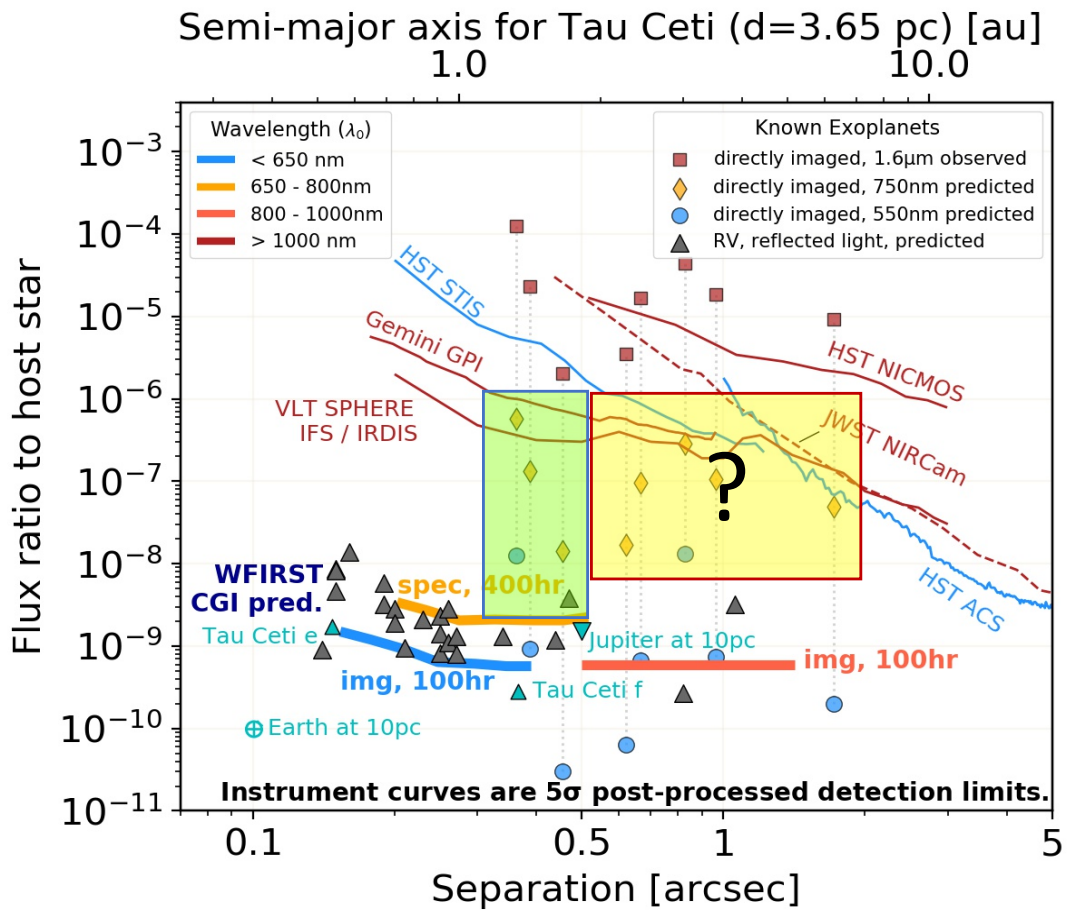
Kasdin+ NAS whitepaper

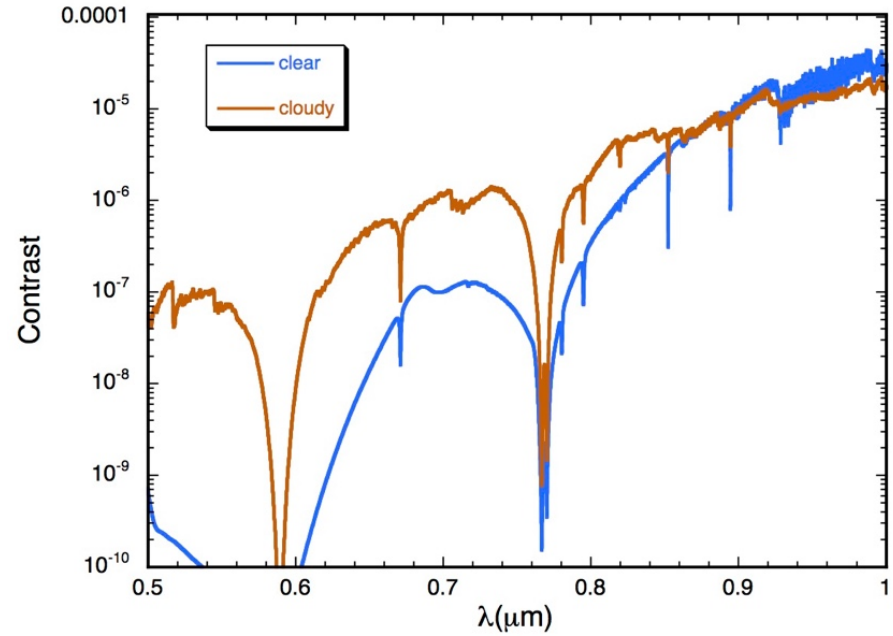
- Spectroscopy of young self-luminous giant planets
- Imaging & Spectroscopy of reflected light giant planets
- Blind search for gas giants (reflected & emitted light)

- Imaging and spectroscopy of disks
  - Debris
  - Protoplanetary
  - Exozodi

- Download at http://sites.nationalacademies.org/SSB/CurrentProjects/SSB_180659 "View submitted whitepapers"

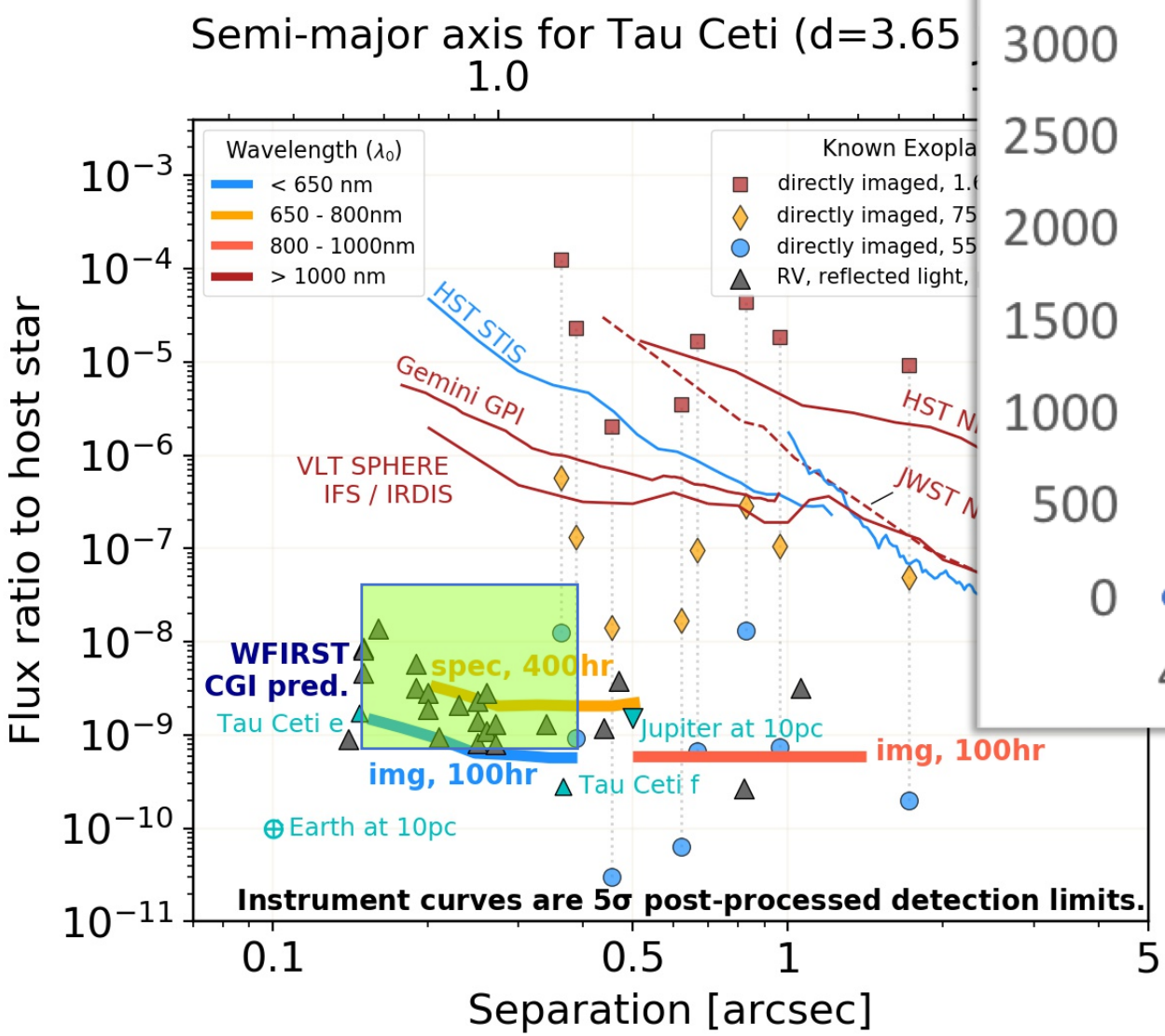
Spectra of self-luminous planets
Beta Pic b, HR 8799 e, 51 Eri b

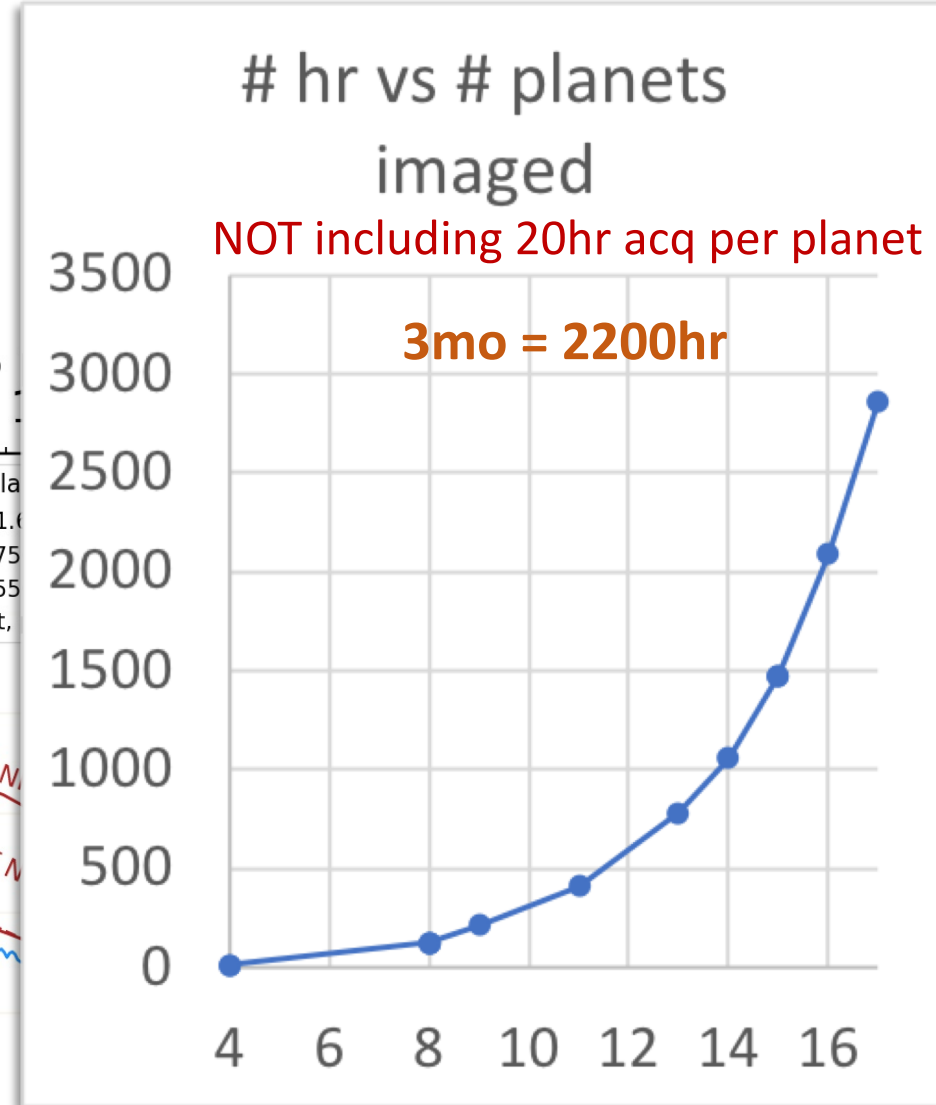




- New models needed!
- Others possible with IFS + SPC donut?
- Halpha accretion?

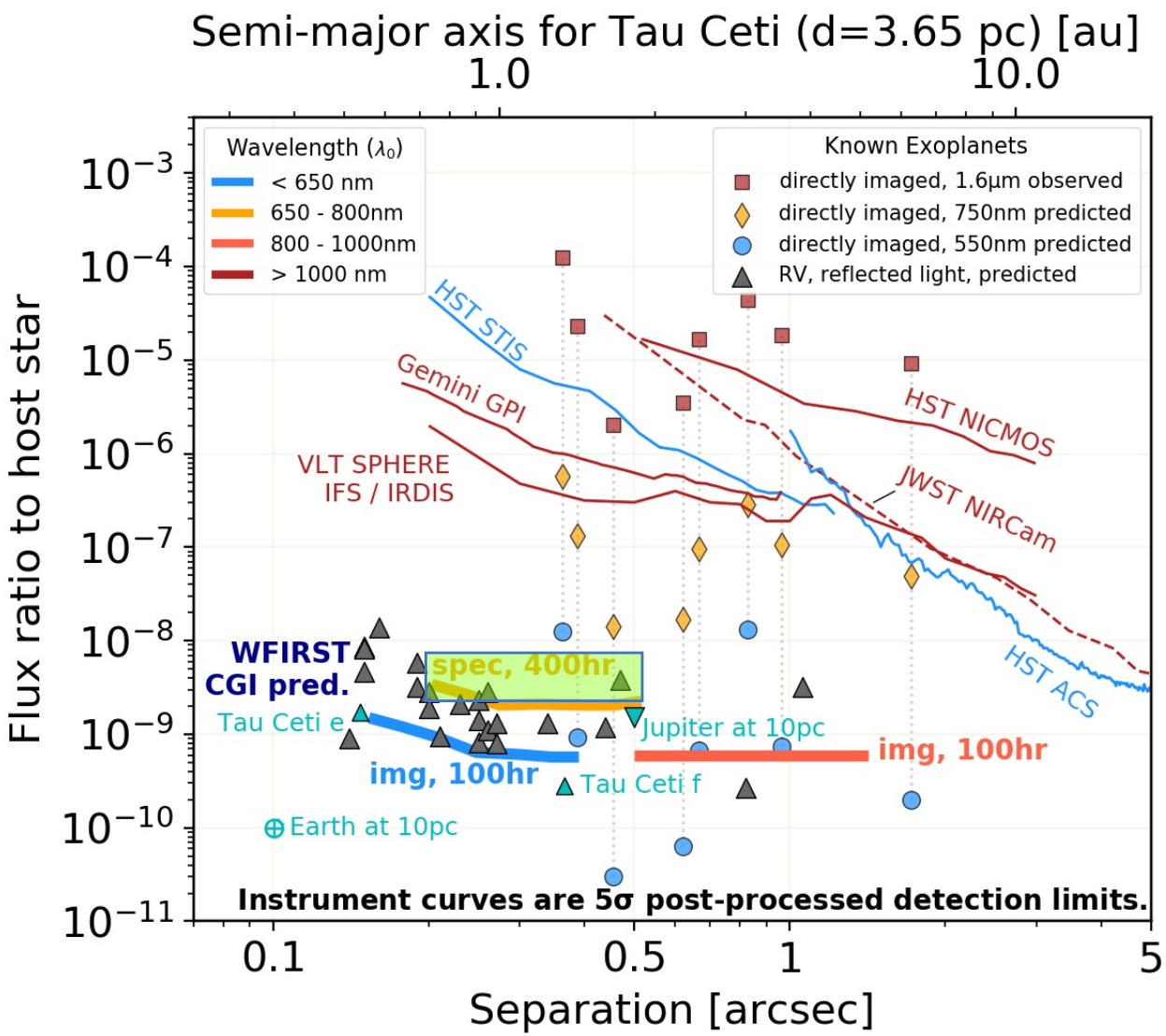
Reflected light imaging of RV





Nemati spreadsheet

Reflected light spectroscopy of RV planets



WITH
20hr initial acq
10% slew efficiency
+20% on reference

- Eps Eri ~ 15hr
- 47 Uma ~ 510hr
- HD 114614 ~ 1600hr

Blind search: 3 months ~ 10 new planets

Savransky 2016

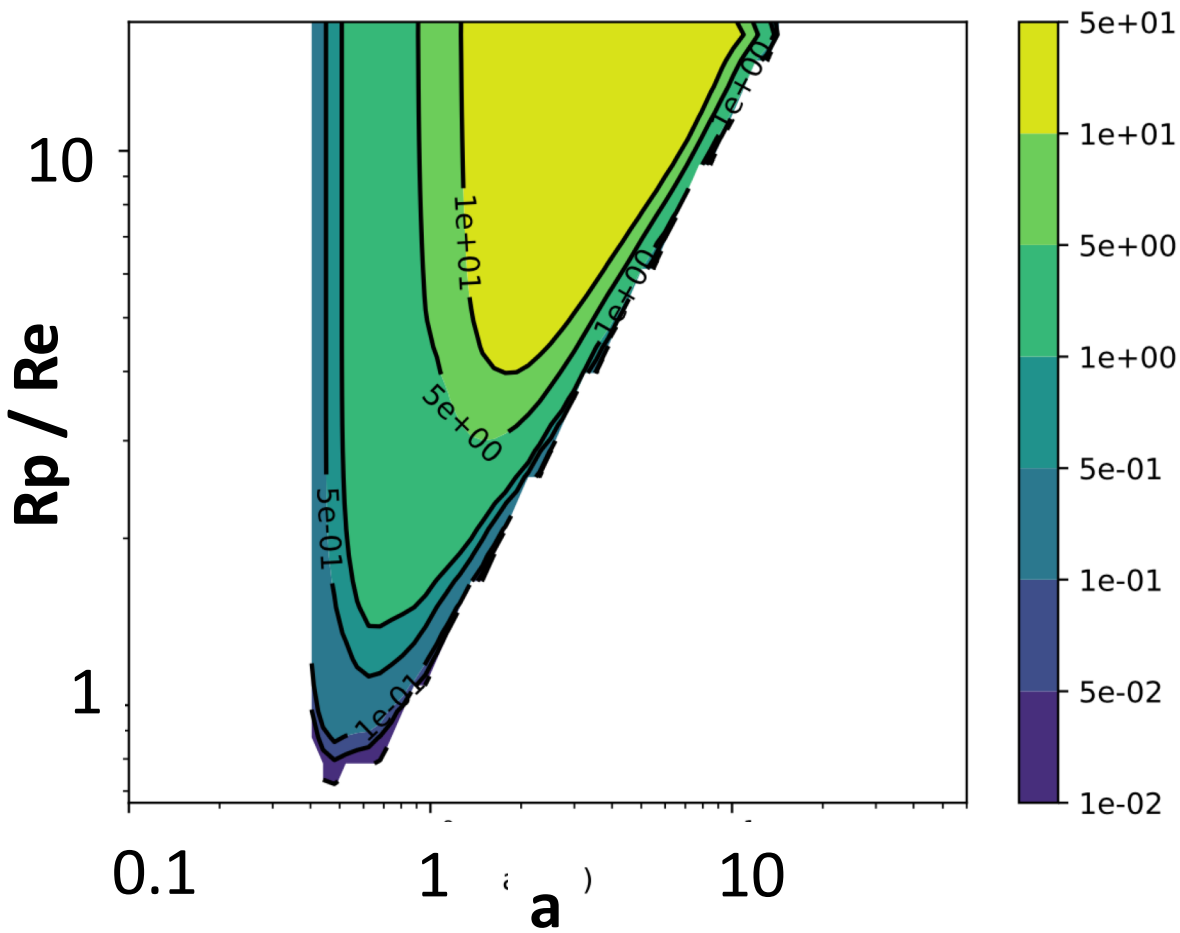
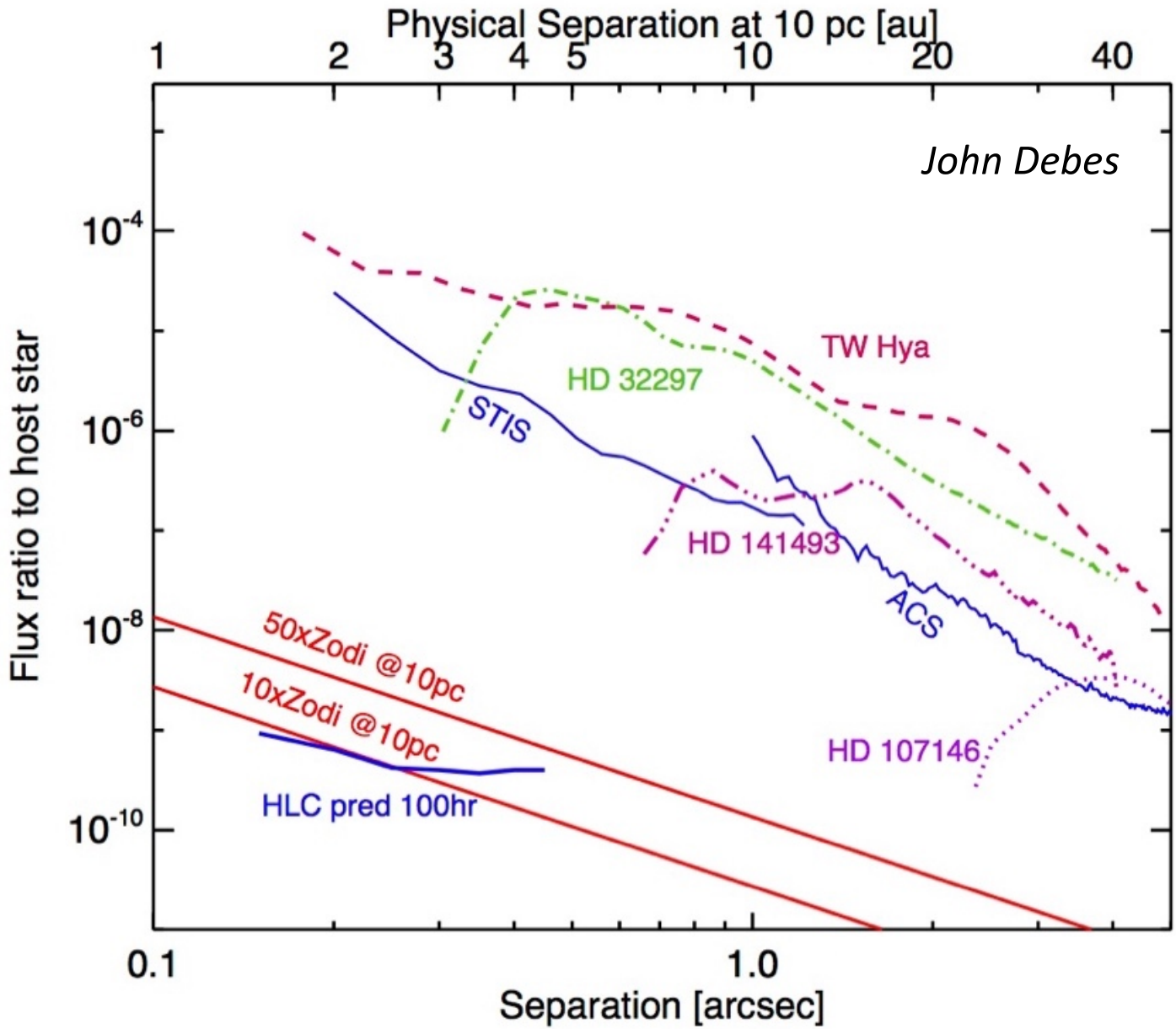


Figure 4: Depth of search (summed completeness assuming one planet per star at each location in the semi-major axis-Radius phase space) for the WFIRST CGI assuming optimal utilization of 3 months of integration time (96 total targets). Giant planets (>5 Earth radii) are found most frequently (>50%) while the CGI is barely sensitive to 2 Earth-radii planets (0.5%). Albedos were assumed to be uniformly 0.2 for planets below 1.4 Earth radii and 0.5 for larger planets.

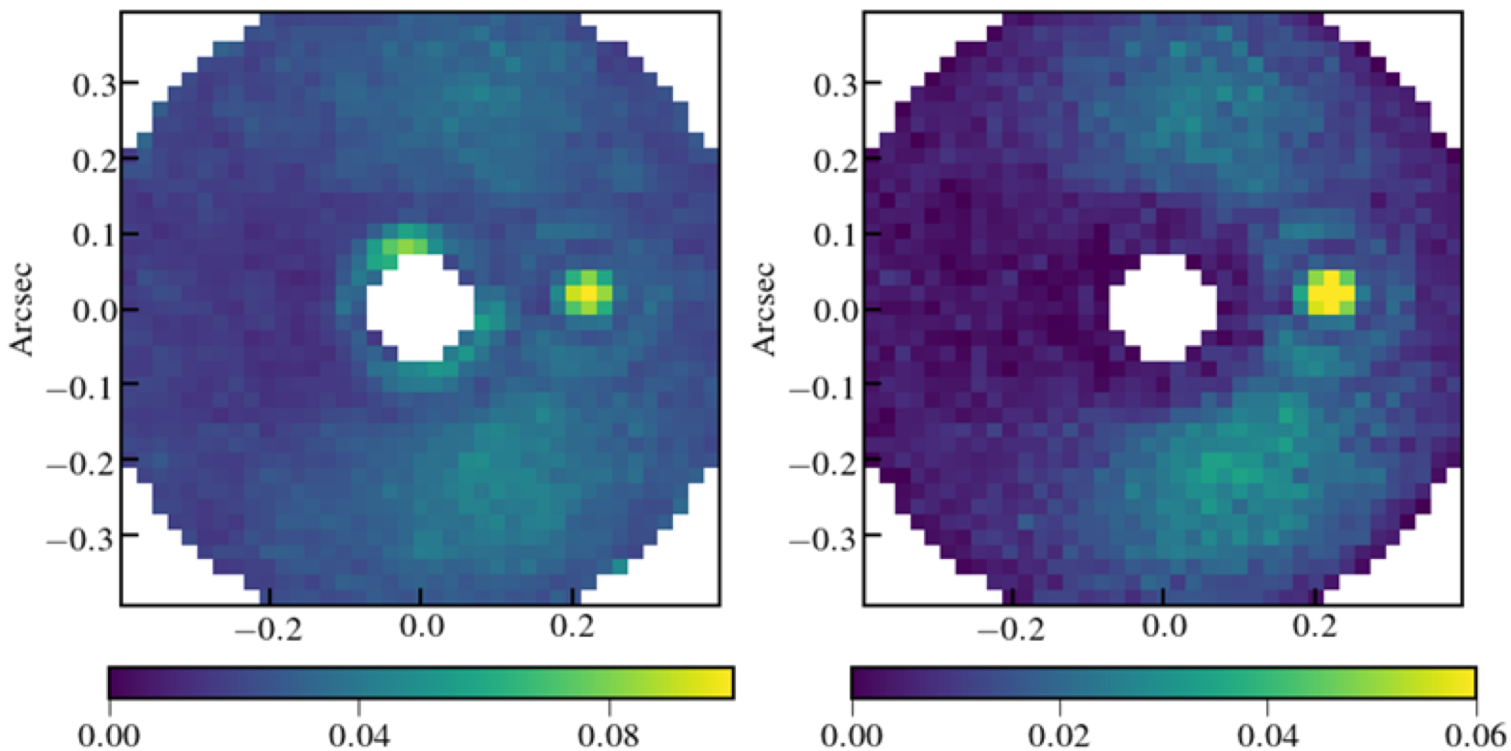
Disk Science

- Known disks guaranteed
- Intermediate disks likely

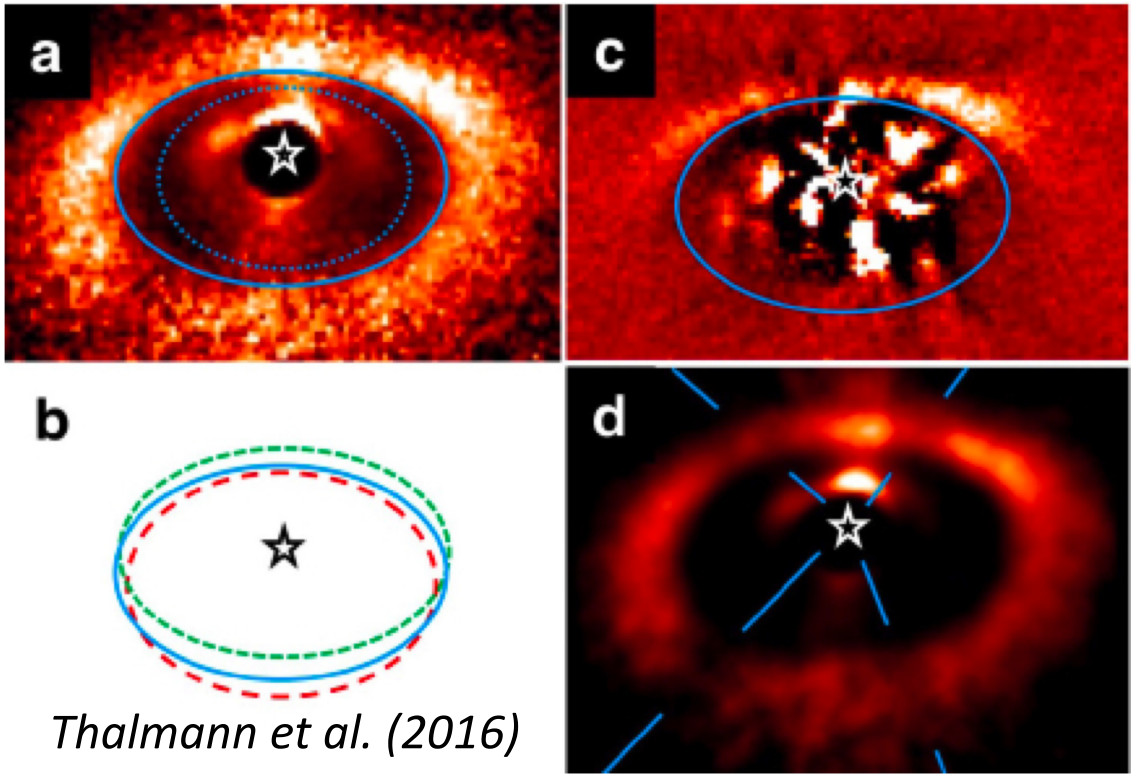


Exozodi “contaminants”

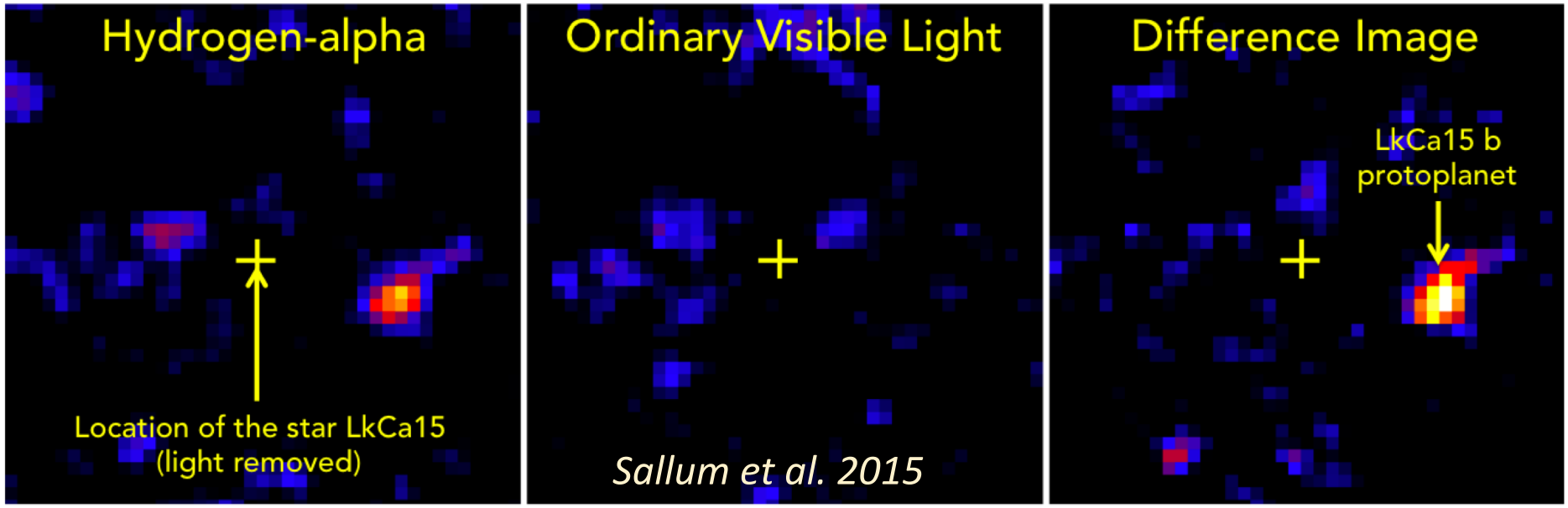
HLC 575 nm imaging. Nearby sunlike star. **10 zodi** disk & jovian planet located at 1.6 AU. Flux scale is square-root stretch in units of photoelectrons/s. Simulated exposure time is 2.8 h. (M. Rizzo, N. Zimmerman and the “Haystacks” team). Left/Right = image without/WITH PSF subtraction.



Protoplanetary disks & protoplanets



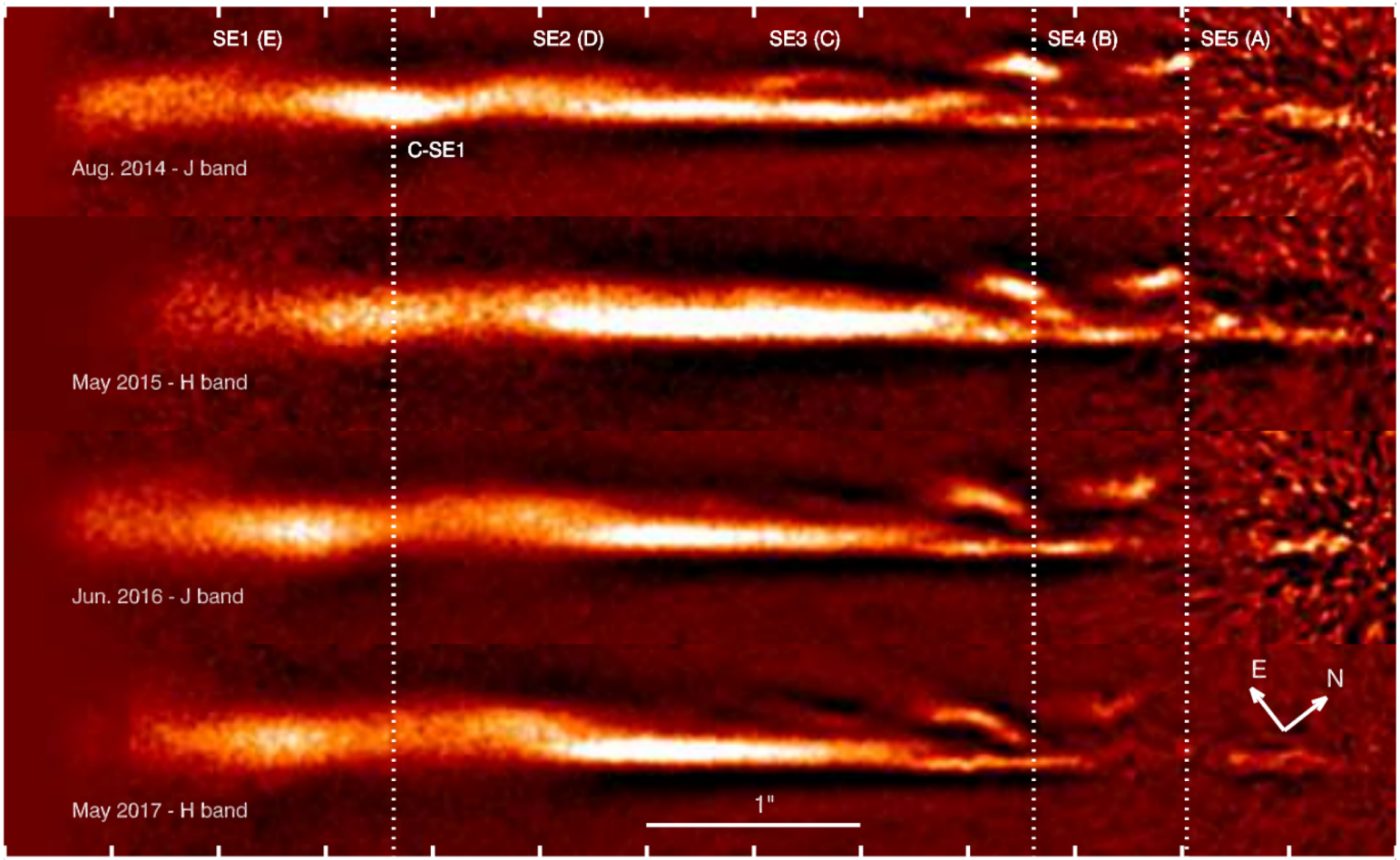
Thalmann et al. (2016)



Sallum et al. 2015

Time-variable structure (requires revisits)

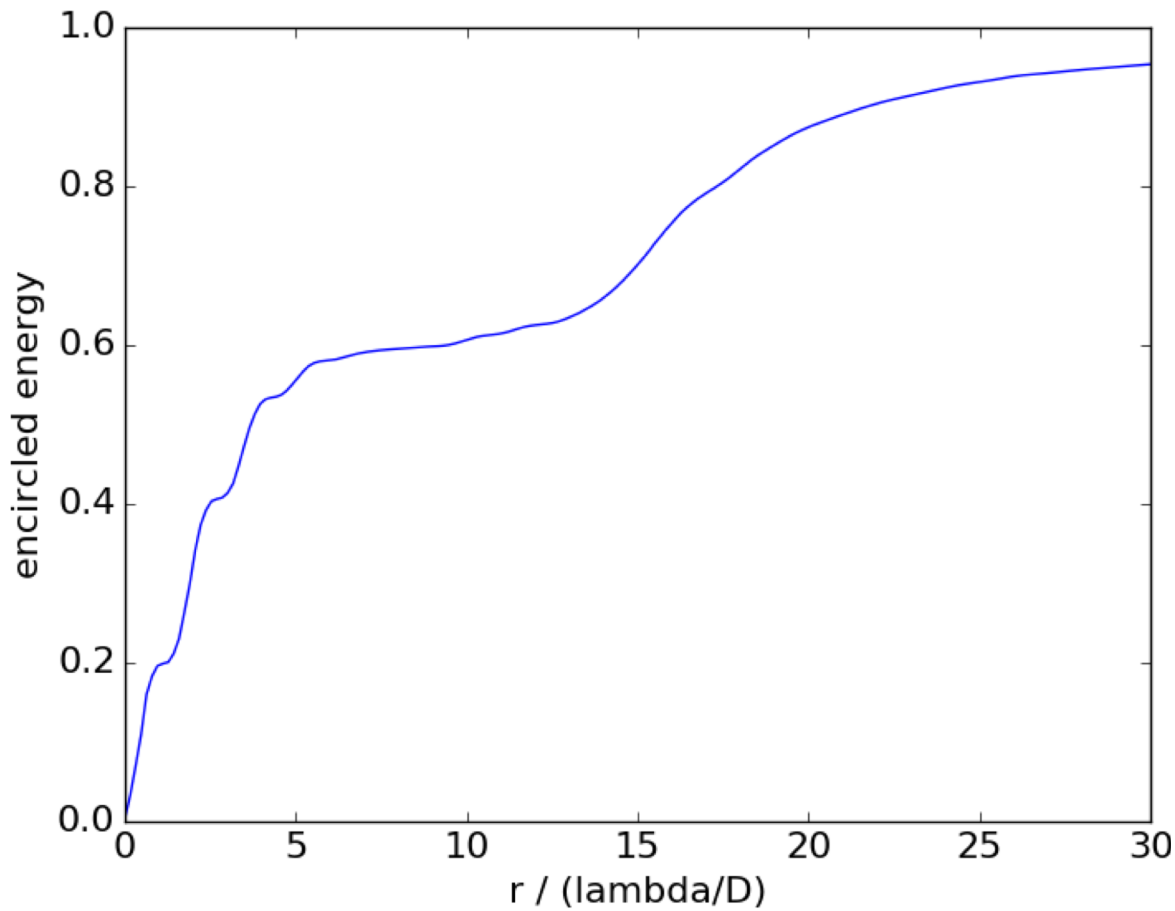
Au Mic : Bocaletti, et al. 2018



HLC PSF sends most of light out of the core

Brian Kern

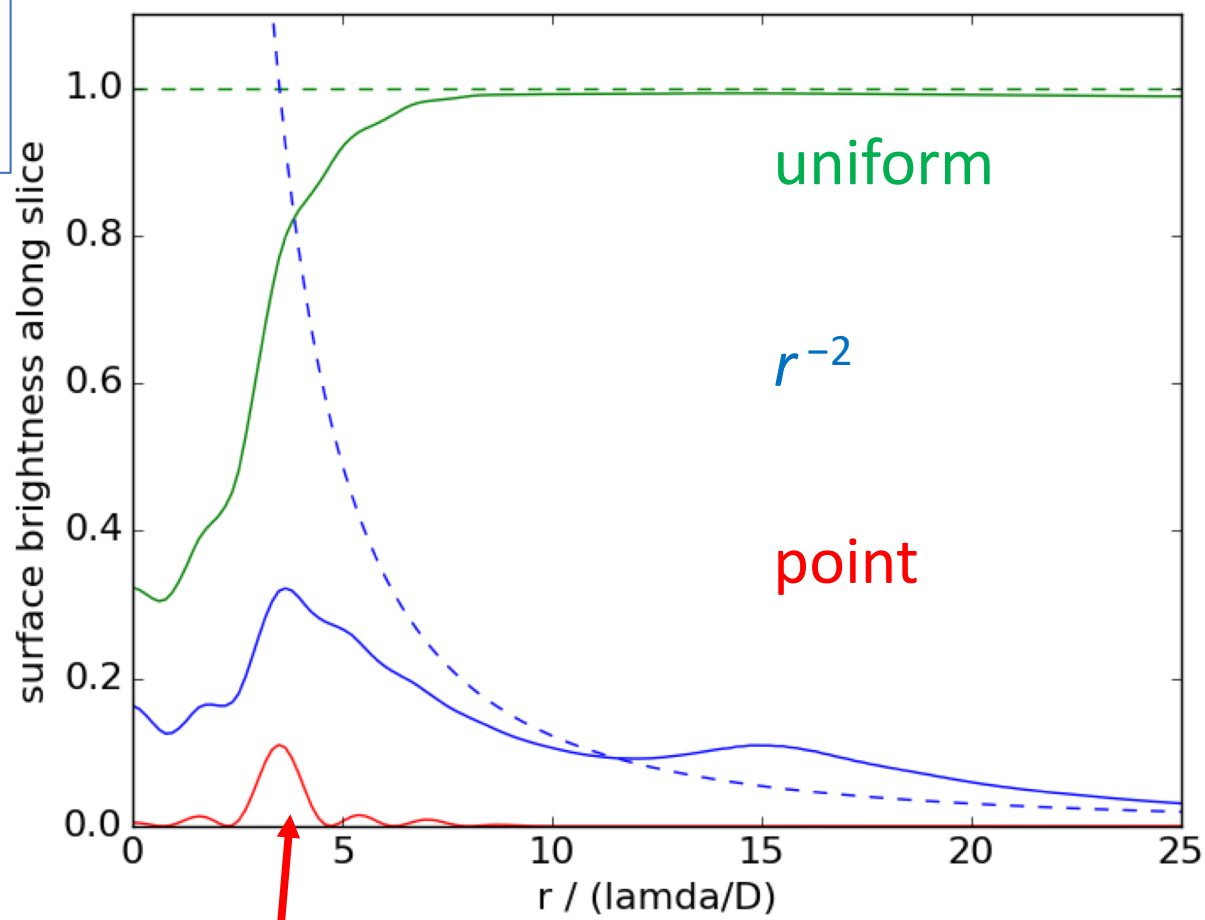
- ~ 10% of light inside half-max (r ~ 0.6 λ/D)
- ~ 40% of light outside of 15 λ/D
- extended objects accumulate light from distant regions



Brian Kern

HLC PSF convolution complicates disk morphology extraction

--- True profile
___ Image profile



slice through single point-source image

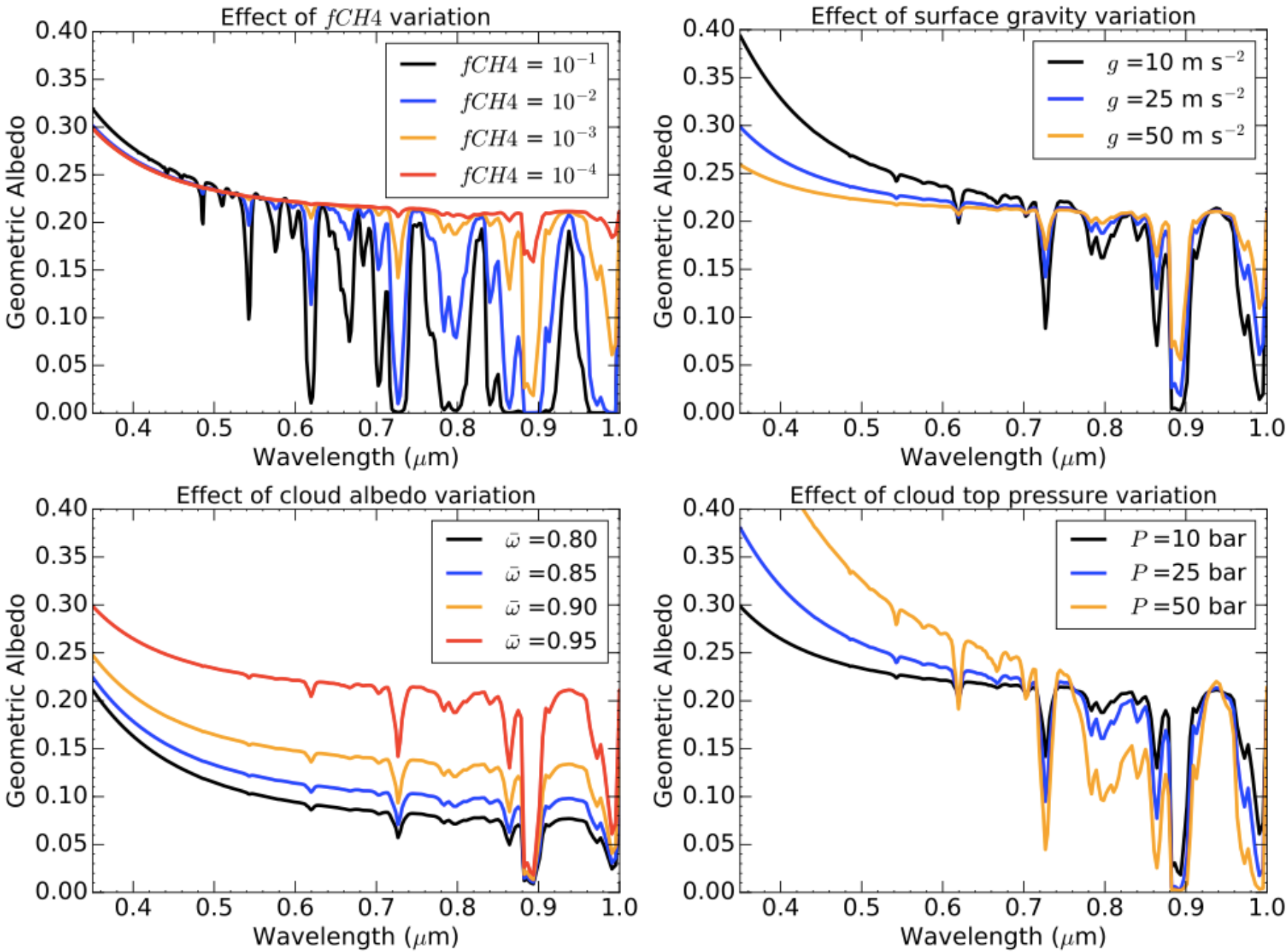
Disk sensitivity estimation is challenging

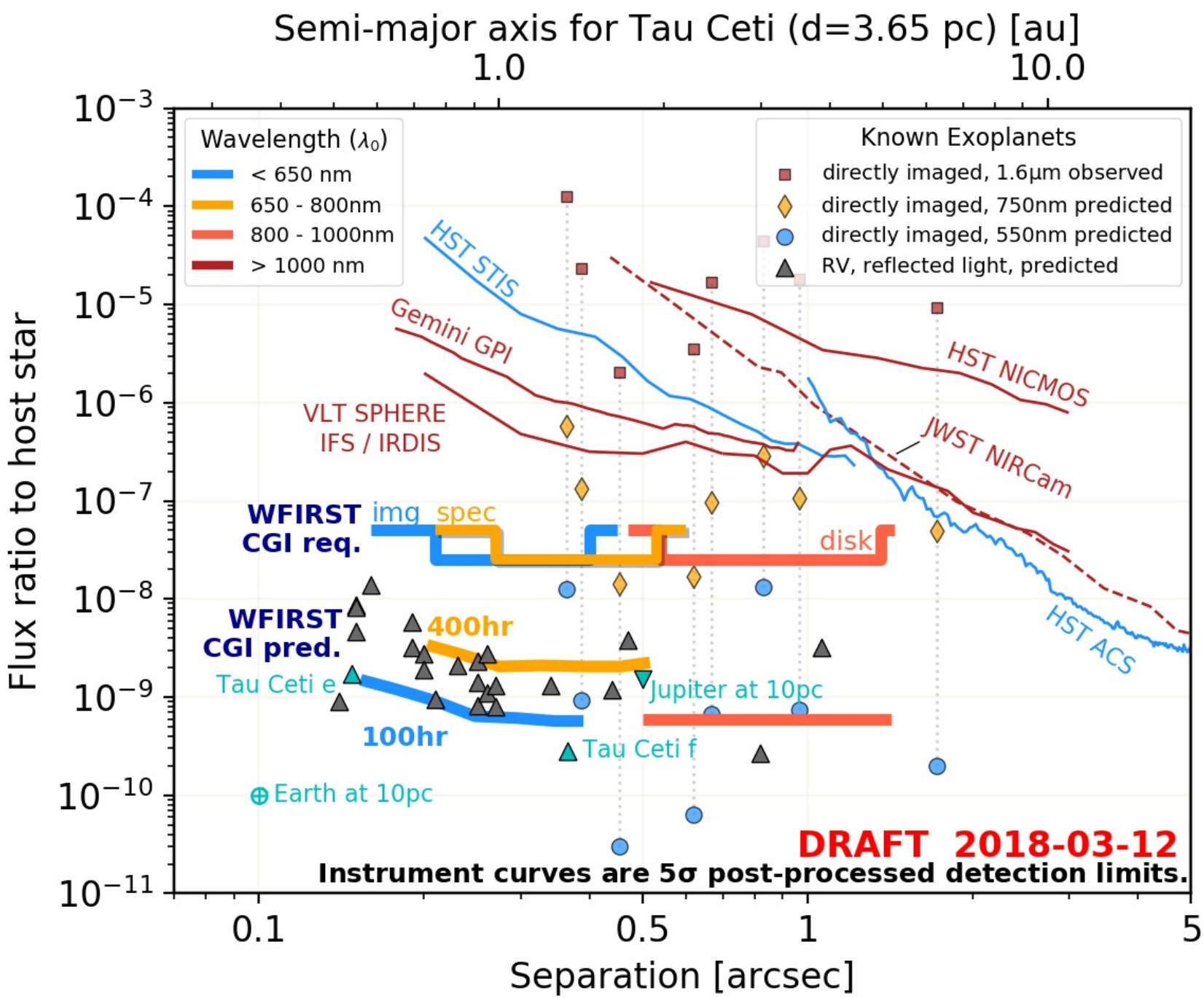
- Convolution with coronagraphic PSF is not trivial to correct

- Fidelity of different types of measurements:
  - 2D morphology (clumps, gaps, rings??)
  - radial profile
  - Inclination
  - Time-variable structure

To do

- Self-luminous planets: models in visible light
- Updated reflected light retrieval & blind search calculations for new instrument modes
- Disk retrieval studies (HLC especially)
  - Disk morphology
  - Embedded sources
- What to do about modeling “non-standard” coronagraph/filter combinations?


Effect of $fCH4$ variation
$fCH4 = 10^{-1}$
$fCH4 = 10^{-2}$
$fCH4 = 10^{-3}$
$fCH4 = 10^{-4}$
Geometric Albedo
Wavelength (μm)
Effect of surface gravity variation
g =10 m s^{-2}
g =25 m s^{-2}
g =50 m s^{-2}
Geometric Albedo
Wavelength (μm)
Effect of cloud albedo variation
$\bar{\omega}$ =0.80
$\bar{\omega}$ =0.85
$\bar{\omega}$ =0.90
$\bar{\omega}$ =0.95
Geometric Albedo
Wavelength (μm)
Effect of cloud top pressure variation
P =10 bar
P =25 bar
P =50 bar
Geometric Albedo
Wavelength (μm)


Semi-major axis for Tau Ceti (d=3.65 pc) [au]
1.0
10.0
Wavelength (λ_0)
< 650 nm
650 - 800nm
800 - 1000nm
> 1000 nm
Known Exoplanets
directly imaged, 1.6μm observed
directly imaged, 750nm predicted
directly imaged, 550nm predicted
RV, reflected light, predicted
HST STIS
Gemini GPI
VLT SPHERE
IFS / IRDIS
HST NICMOS
JWST NIRCam
HST ACS
WFIRST
CGI req.
img
spec
disk
WFIRST
CGI pred.
400hr
100hr
Tau Ceti e
Jupiter at 10pc
Tau Ceti f
Earth at 10pc
DRAFT 2018-03-12
Instrument curves are 5σ post-processed detection limits.
Flux ratio to host star
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
0.1
0.5
1
5
Separation [arcsec]