

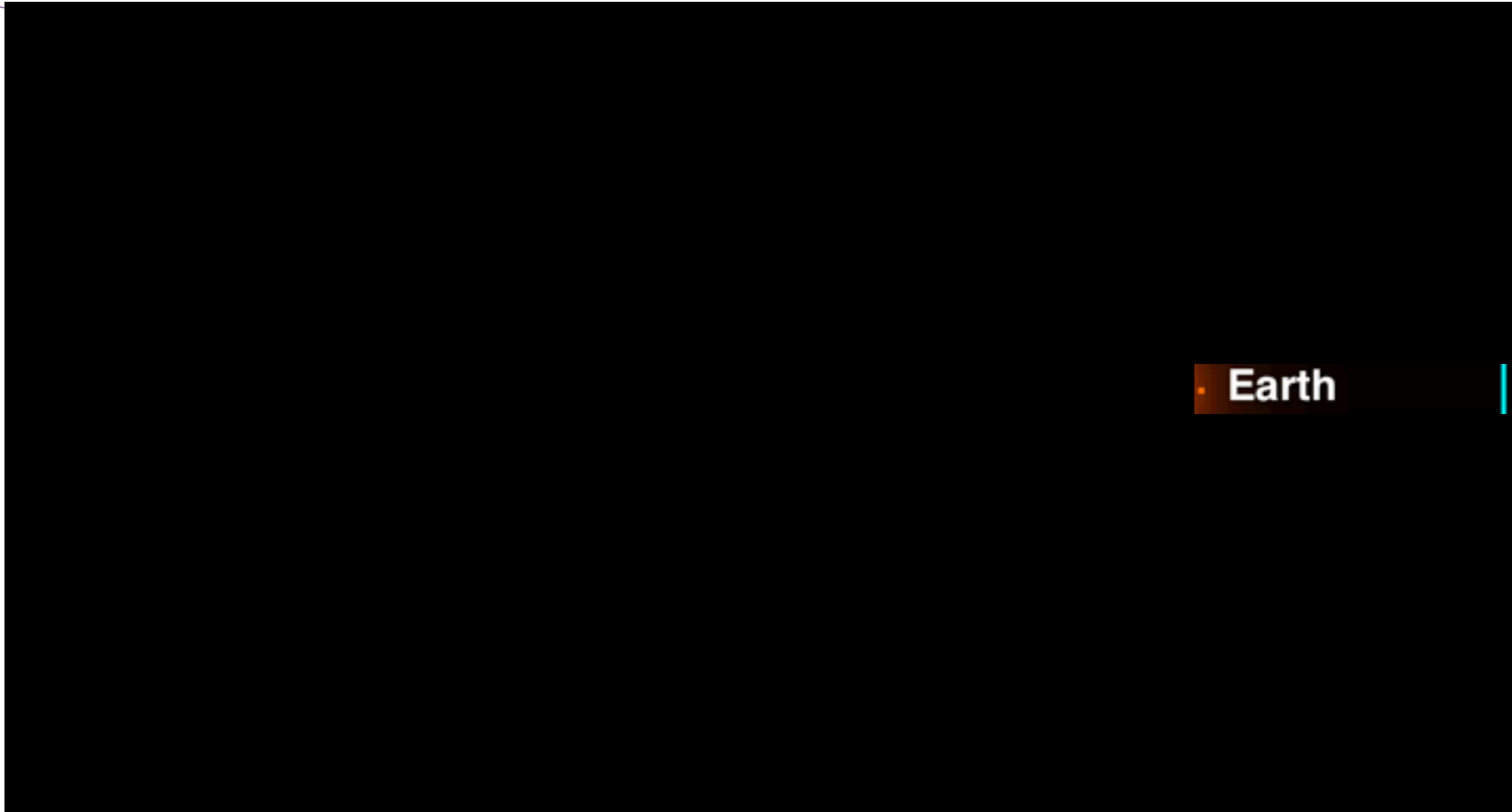
Observing Circumstellar Disks with WFIRST/CGI

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Mennesson, Bijan Nemati, Bin Ren, Hannah Jang-Condell,
Christine Chen, Charles Poteet, and the Macintosh CGI SIT
Team

 @JohnDebes
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Dust provides a wide-angle photo of planetary systems



• Earth

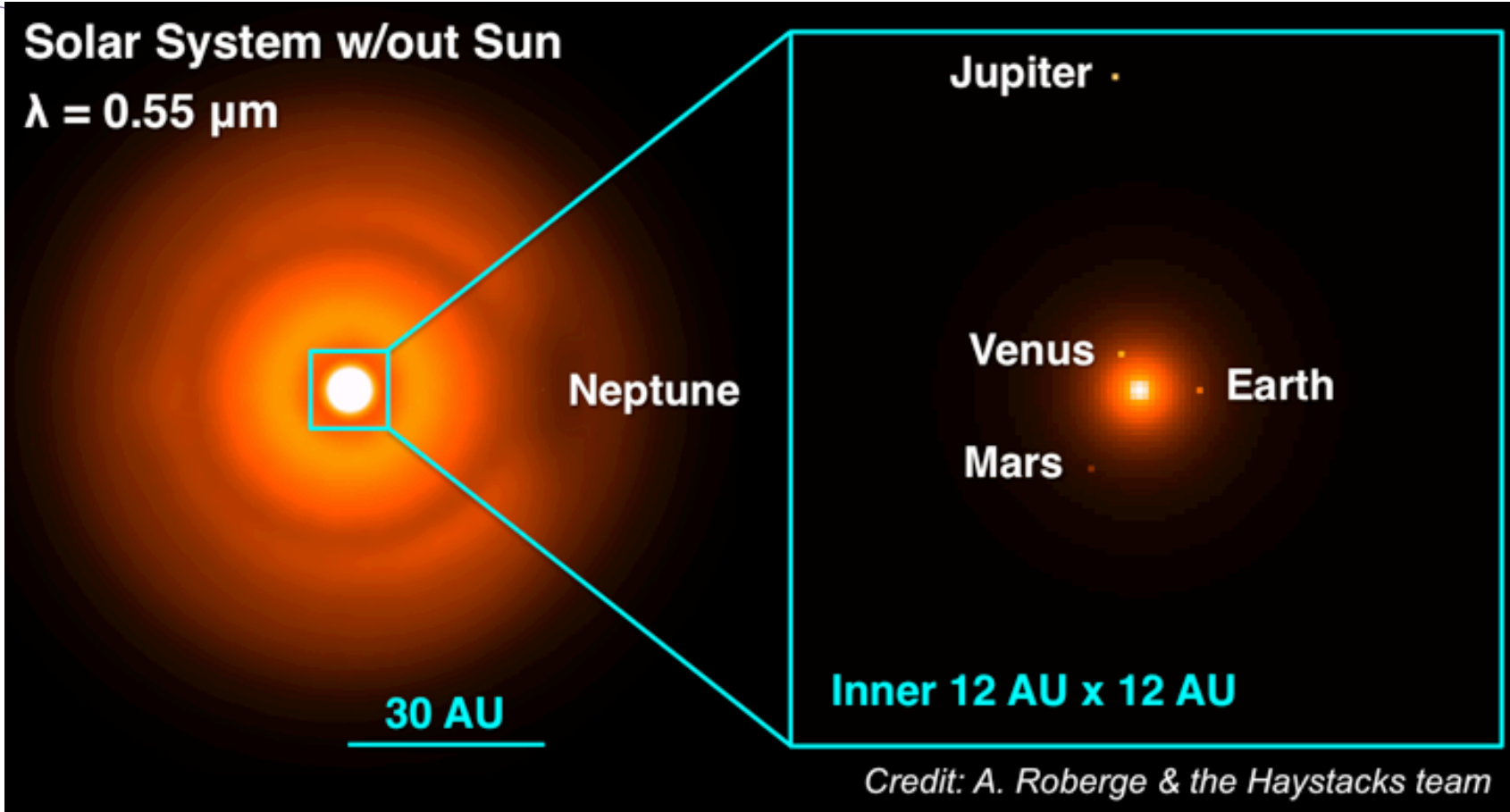


Dust provides a wide-angle photo of planetary systems





Dust provides a wide-angle photo of planetary systems





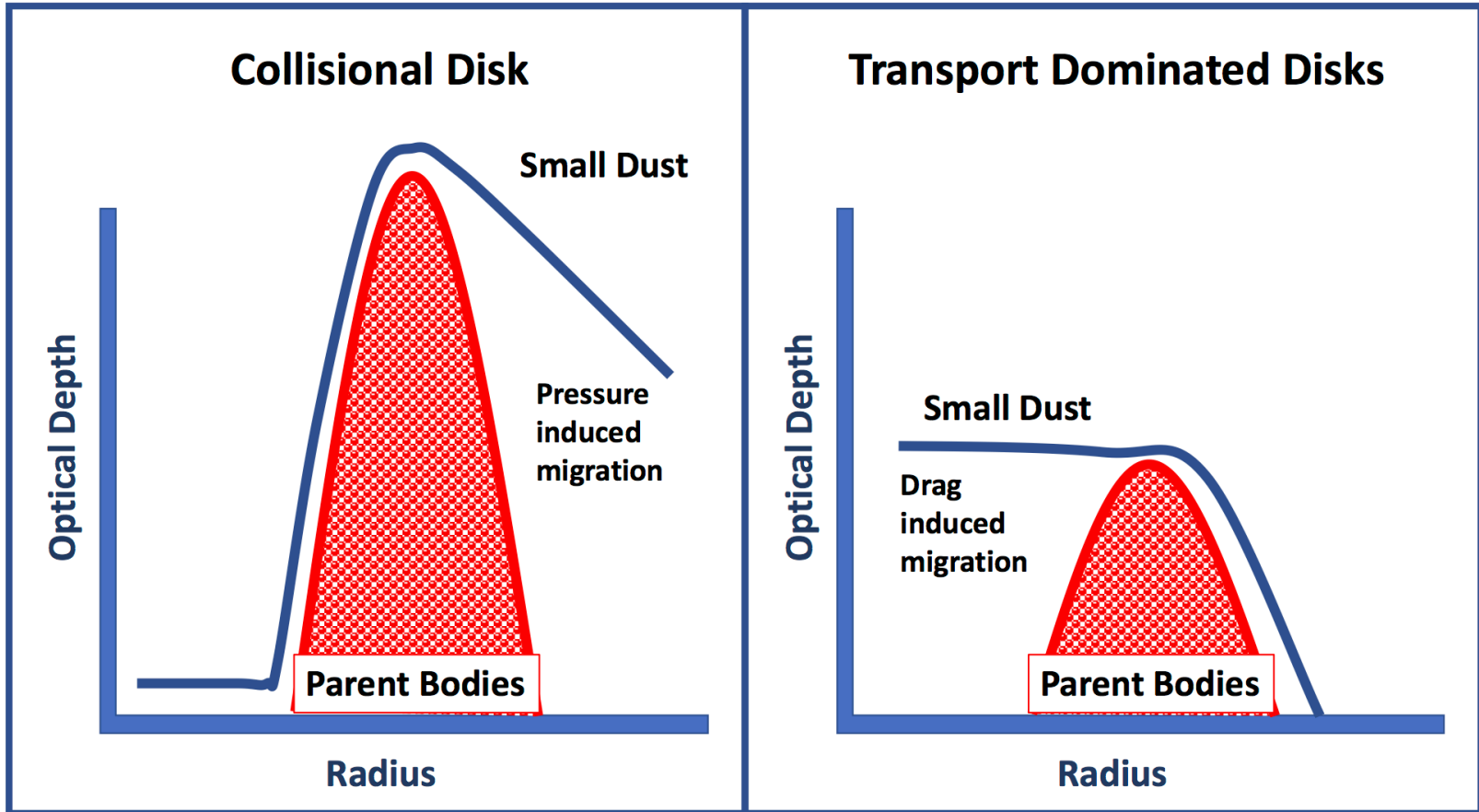
Dust samples the environment of stars

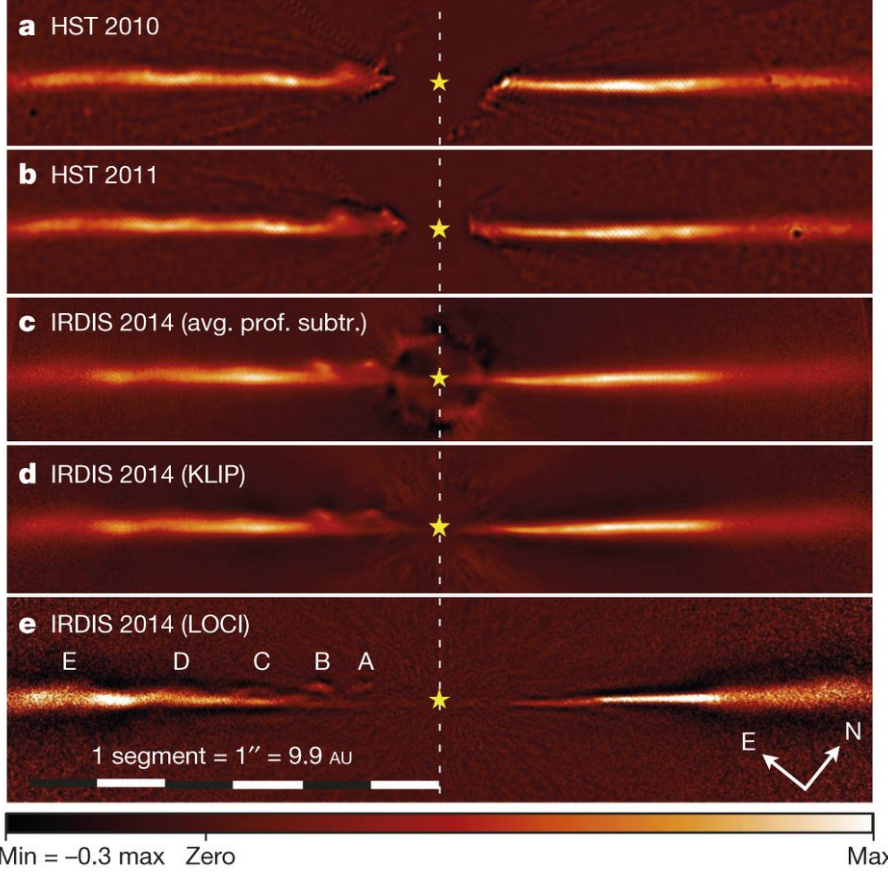


(c) Talbot Wilson

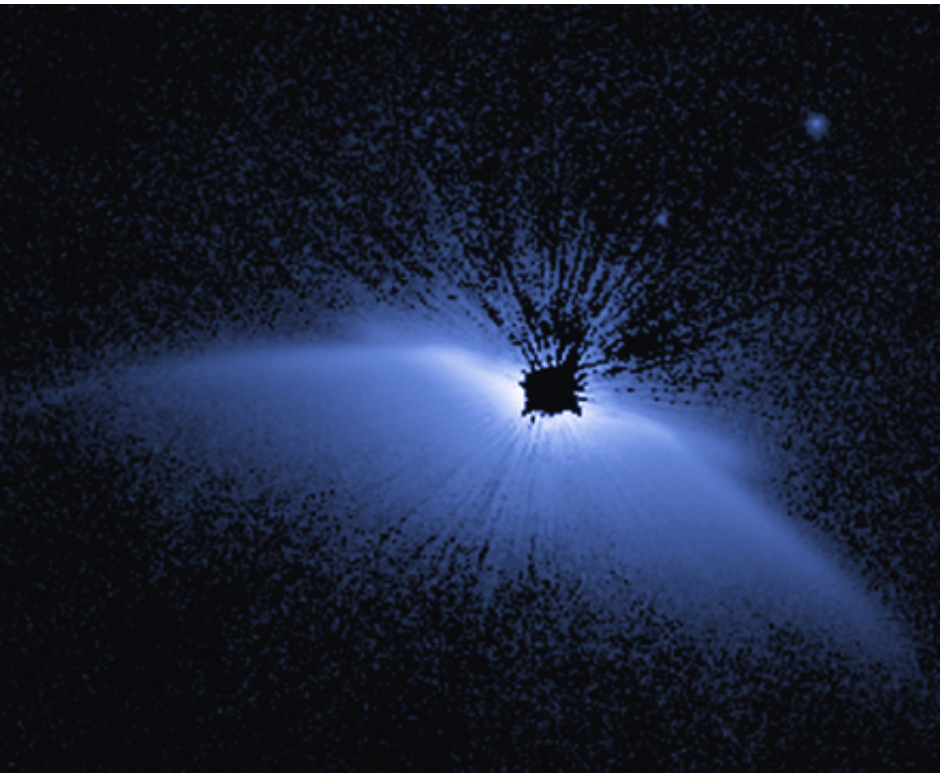


WFIRST will probe different types of disks





Boccaletti et al., 2015

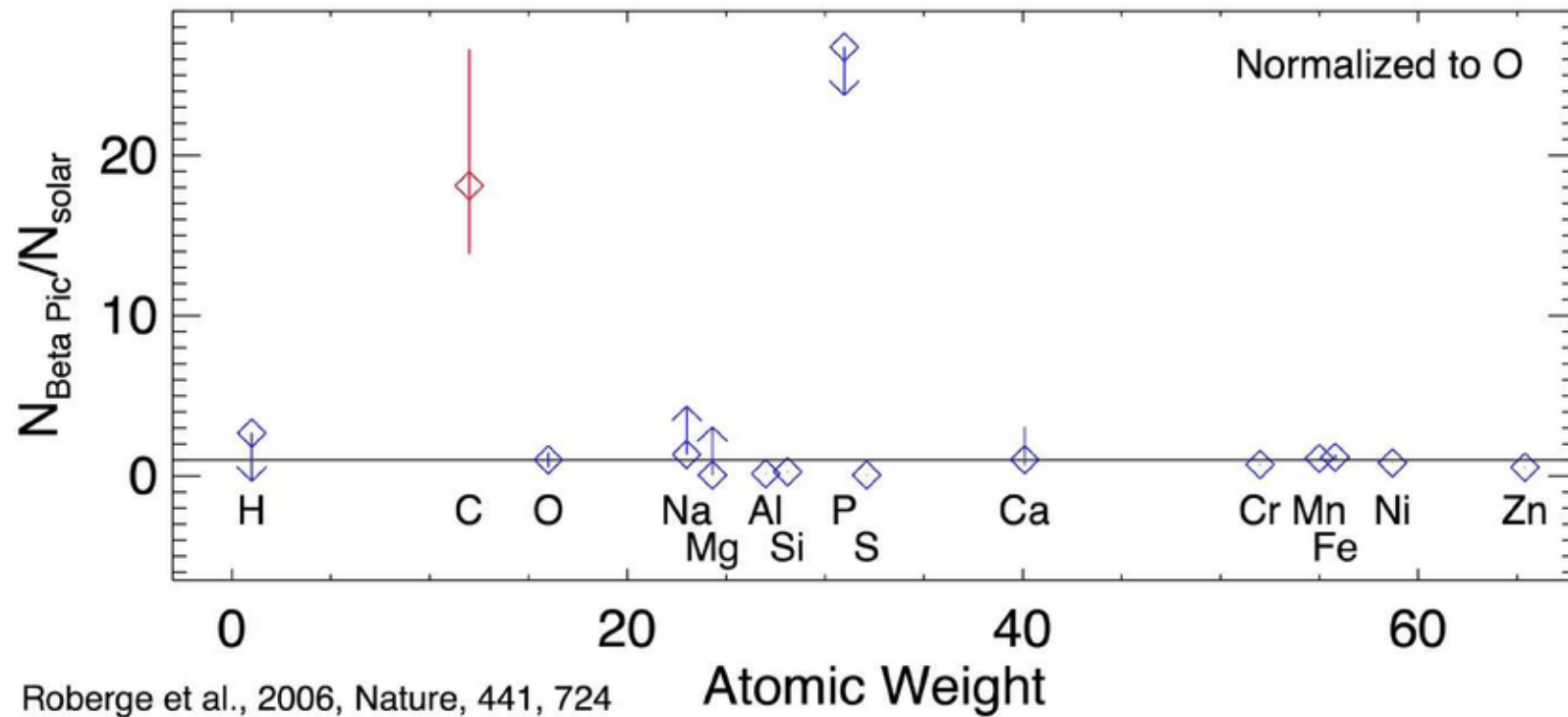


Schneider et al., 2014



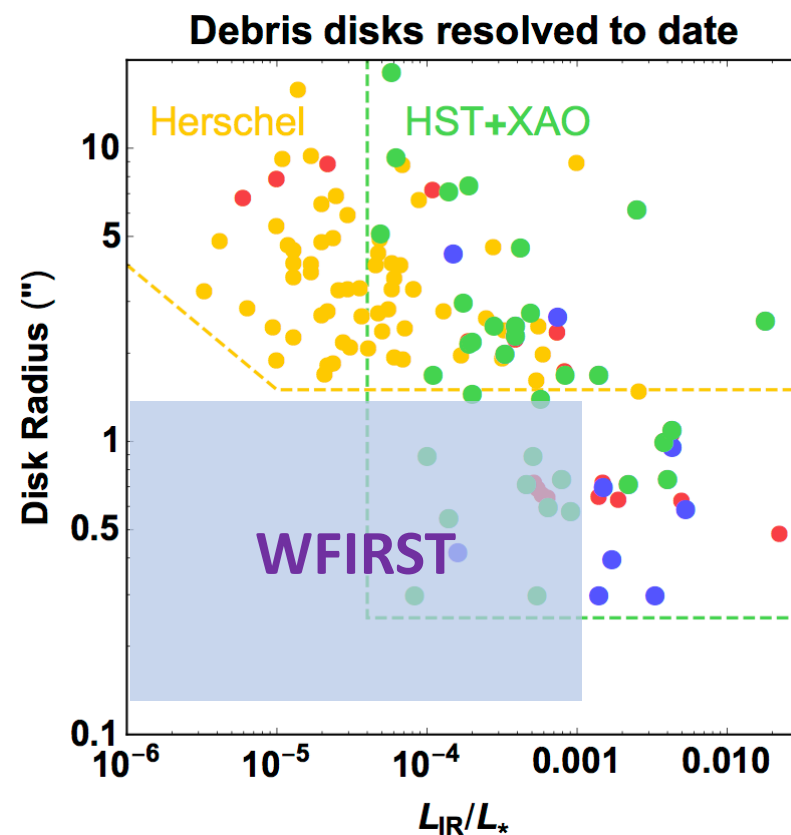
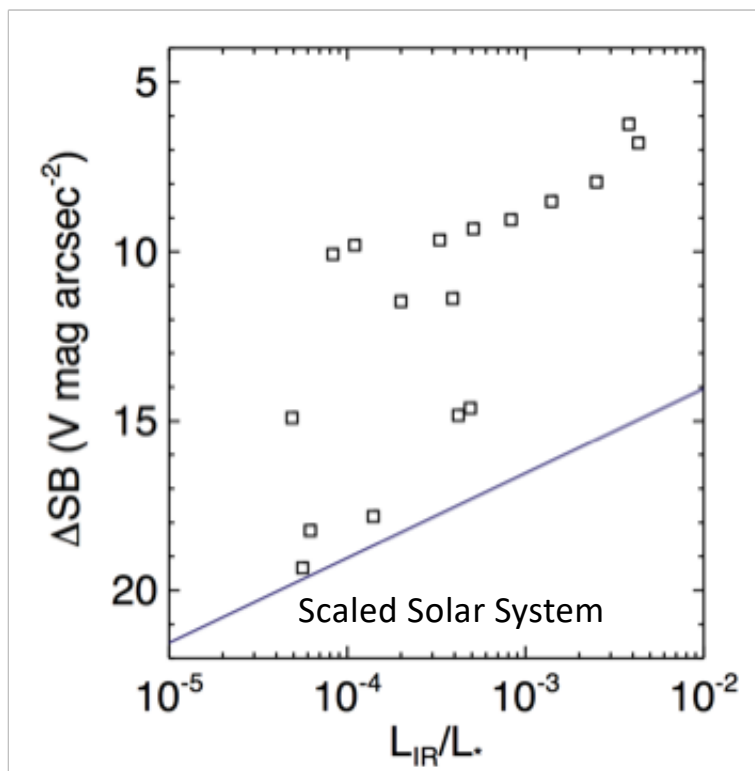
Dust and gas provide a chemical insight into planet formation

Beta Pic Gas Abundances Relative to Solar





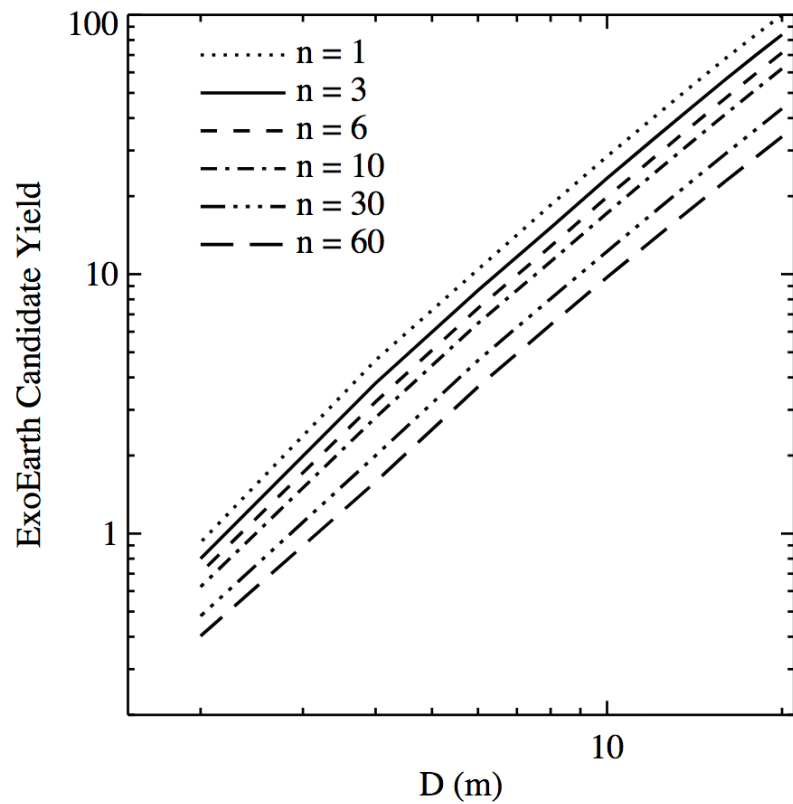
Known Cold Debris Disks



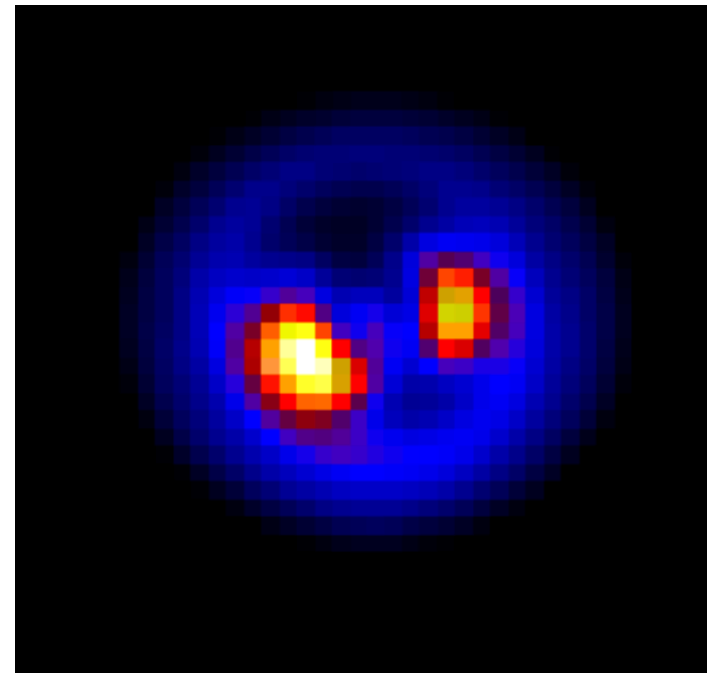
Debes et al. 2019, BAAS, 51, 566



Our ignorance about dust may prevent us from imaging Earths



Stark et al., 2014

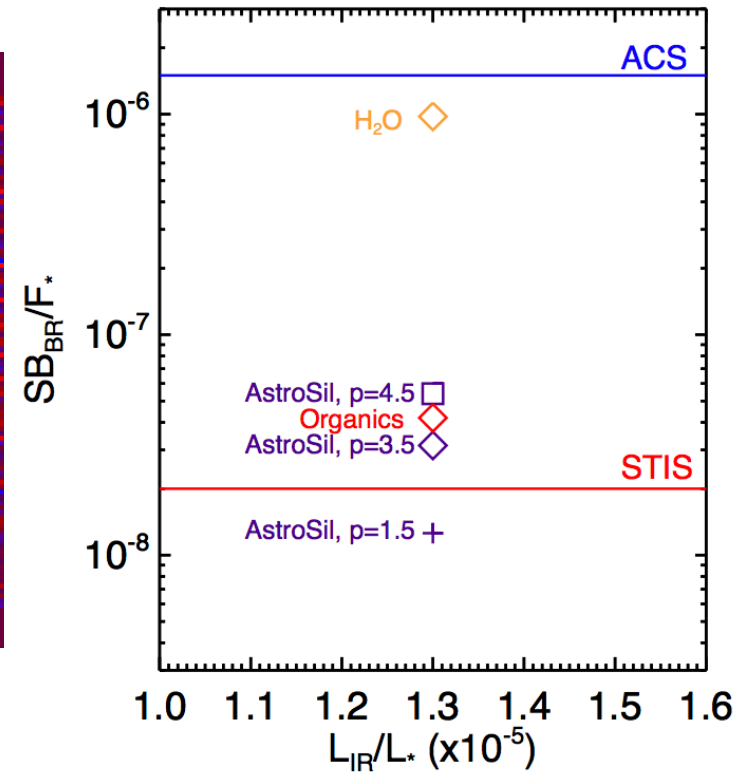
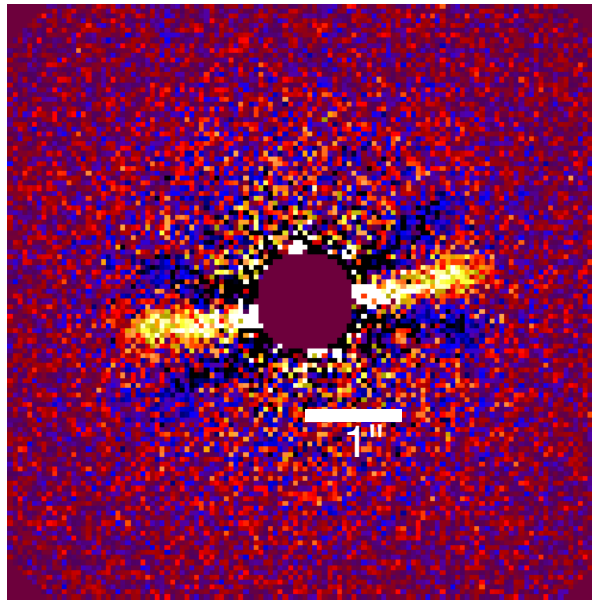
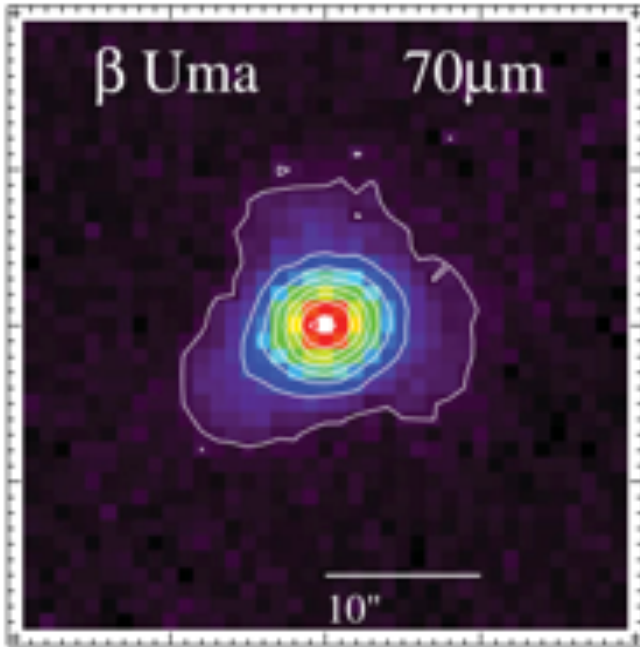


Clumps in Disks
(cf. Defrere et al., 2012)



Our ignorance about dust may prevent us from imaging Earths

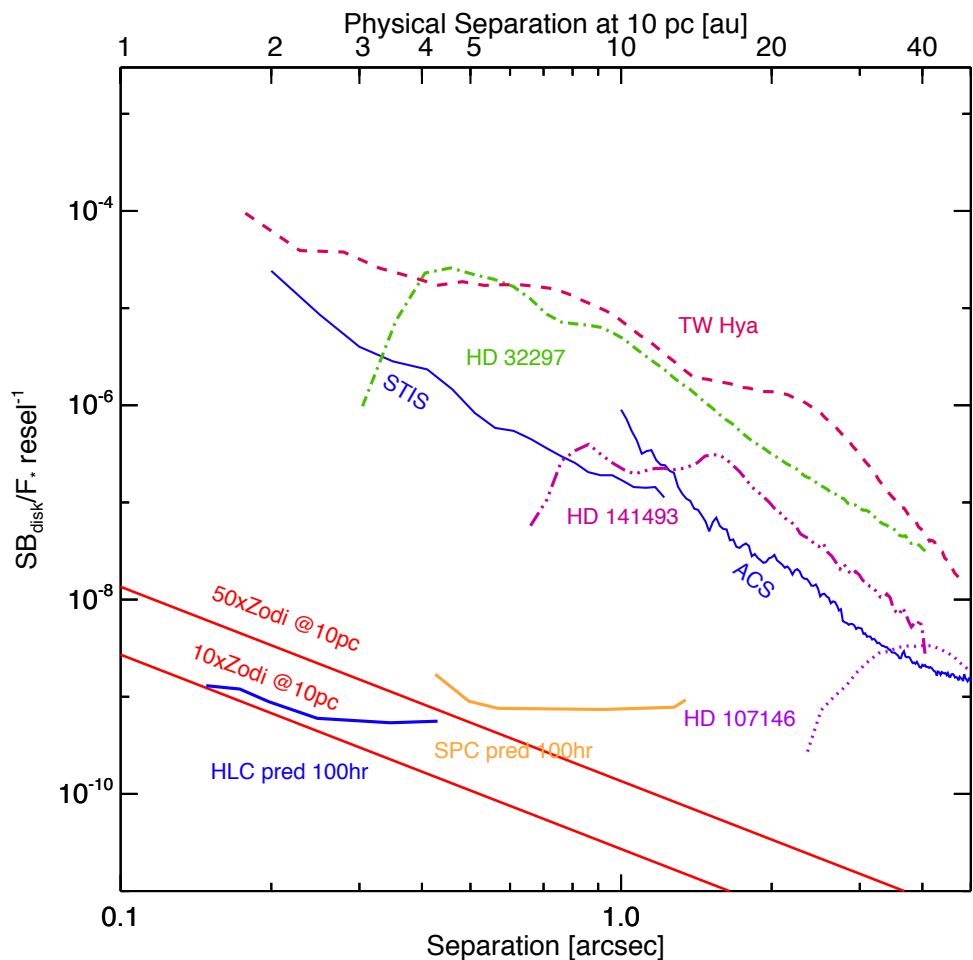
Composition/Size Distribution



Booth et al., 2012



CGI Predicted Performance



For $V=5$ stars
HLC/SPC will get to
(100hrs, SNR=5/resol):

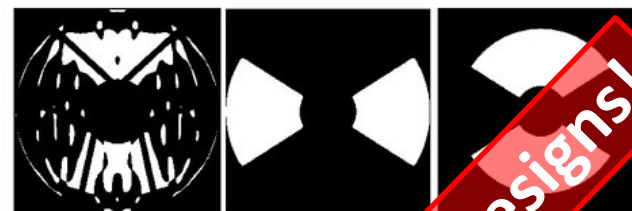
- ~21 mag/sq. “ (predicted)
- ~18 mag/sq. “ (required)



CGI Modes Relevant for Disks

Mode	Band	Killer App
HLC	1 (575 nm)	Smallest IWA
SPC	4 (825 nm)	Largest FOV
IFS	3 (730 nm)	Spectra!
Linear Polarizers	TBD	Polarimetry

Mask set for SPC spectroscopy mode

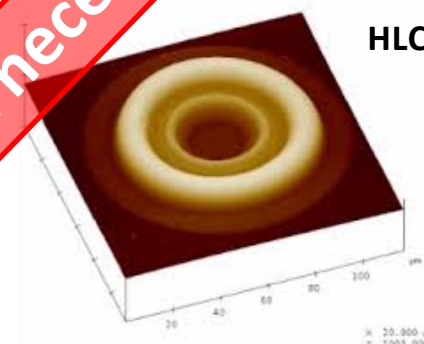


Mask set for SPC wide field-of-view mode



Pupil plane mask focal plane mask Lyot stop mask

HLC FPM



Not necessarily final designs!

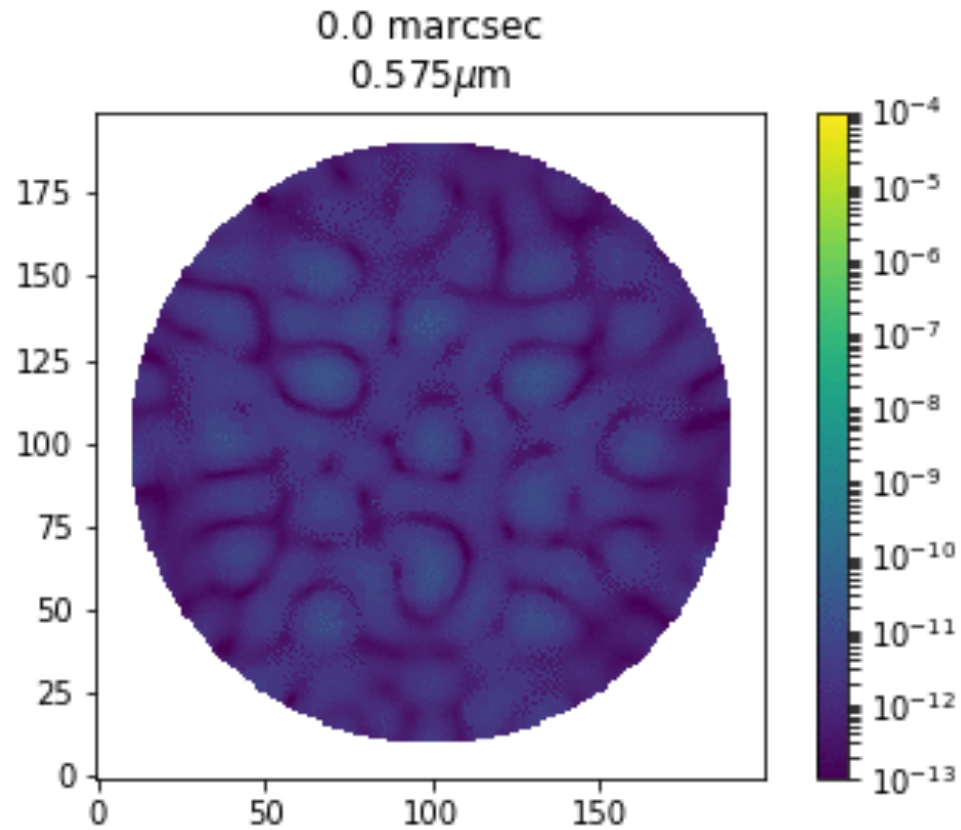


Preparing for CGI via disk modeling

- Assist in defining requirements for CGI
- Simple model disk grids convolved with field dependent mask PSFs
- Assess observing implications of field dependent PSF
 - Quantifying “effective throughput” for extended sources
 - Quantifying post processing gains for extended sources
 - Quantifying noise from dust “under the mask” or exterior to dark hole
- Predict performance for extended sources during Tech Demonstration
- Assess scientific returns for known debris disks with filters/polarization
- Assess performance without dark hole over full field of view
- Assess ultimate sensitivity of CGI to extended sources (i.e. exo-zodis)



Warning: Spatially Dependent PSFs



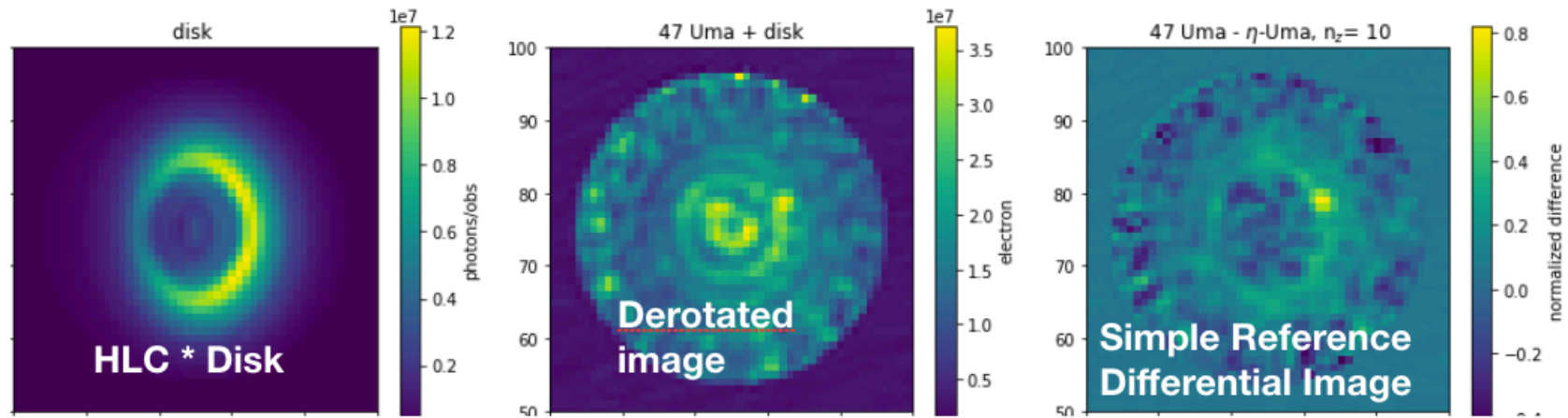
Download the PSFs here: https://wfirst.ipac.caltech.edu/sims/off_axis_PSF.html

Courtesy: E. Douglas

Now with noise

A 0.2" 45 degree inclined disk:

Using OS6



Douglas, E., Debes, J., et al, *in prep*

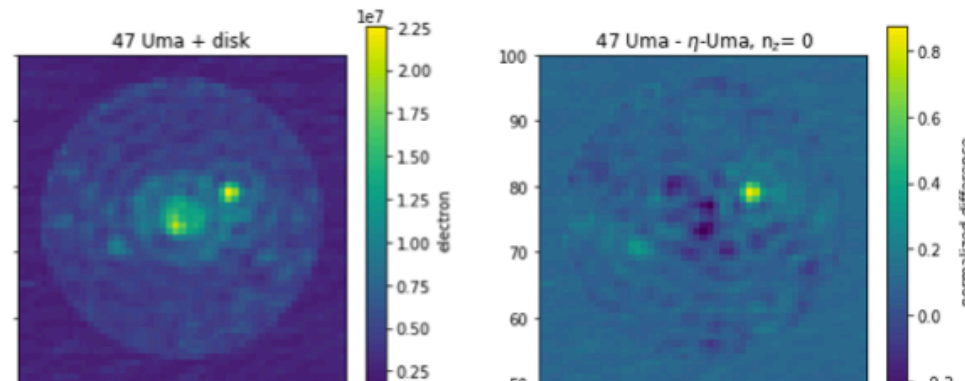
- Peak normalized to $\sim 10x$ Solar Zodi (1 zodi = 22 mags/as^2)
- Noise and performance margin = “Model Uncertainty Factor”
 - 121 hr total observing sequence*

*https://wfirst.ipac.caltech.edu/sims/Coronagraph_public_images.html

Bright dust inside the “IWA”

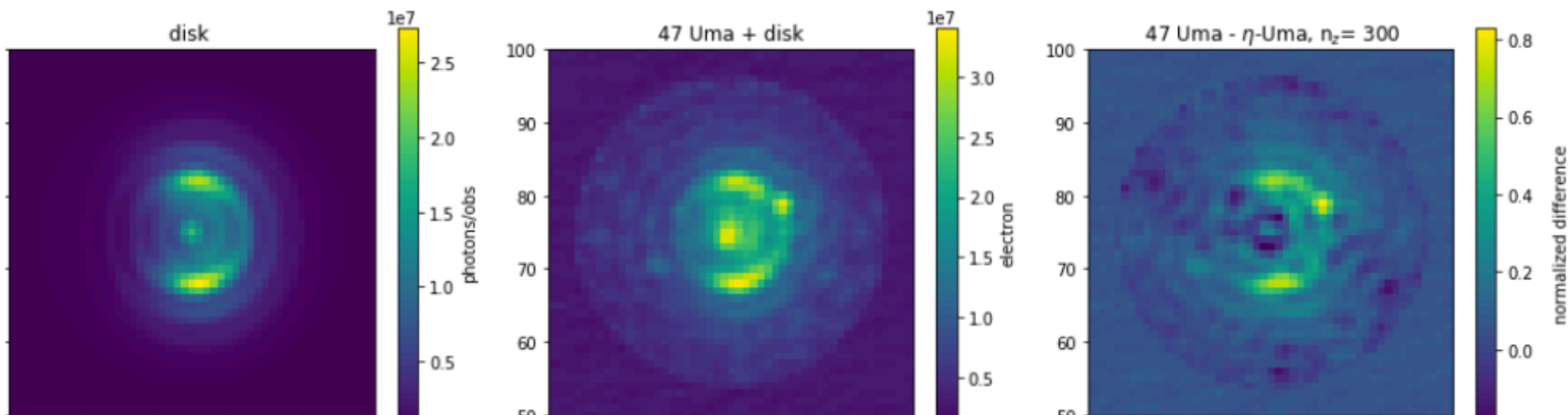
Using OS6

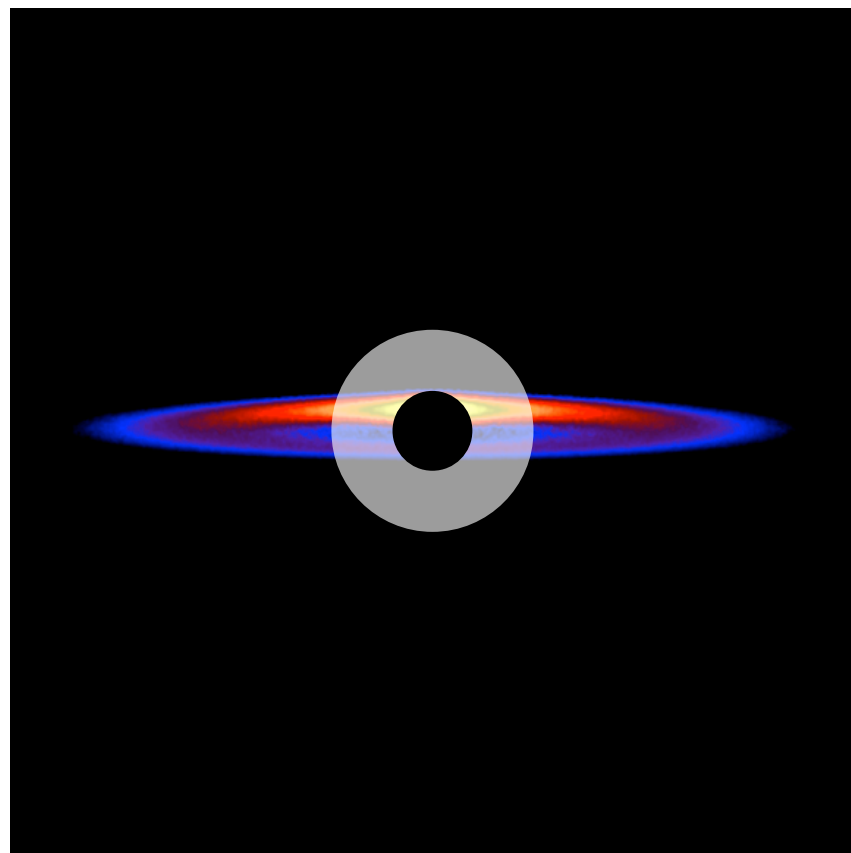
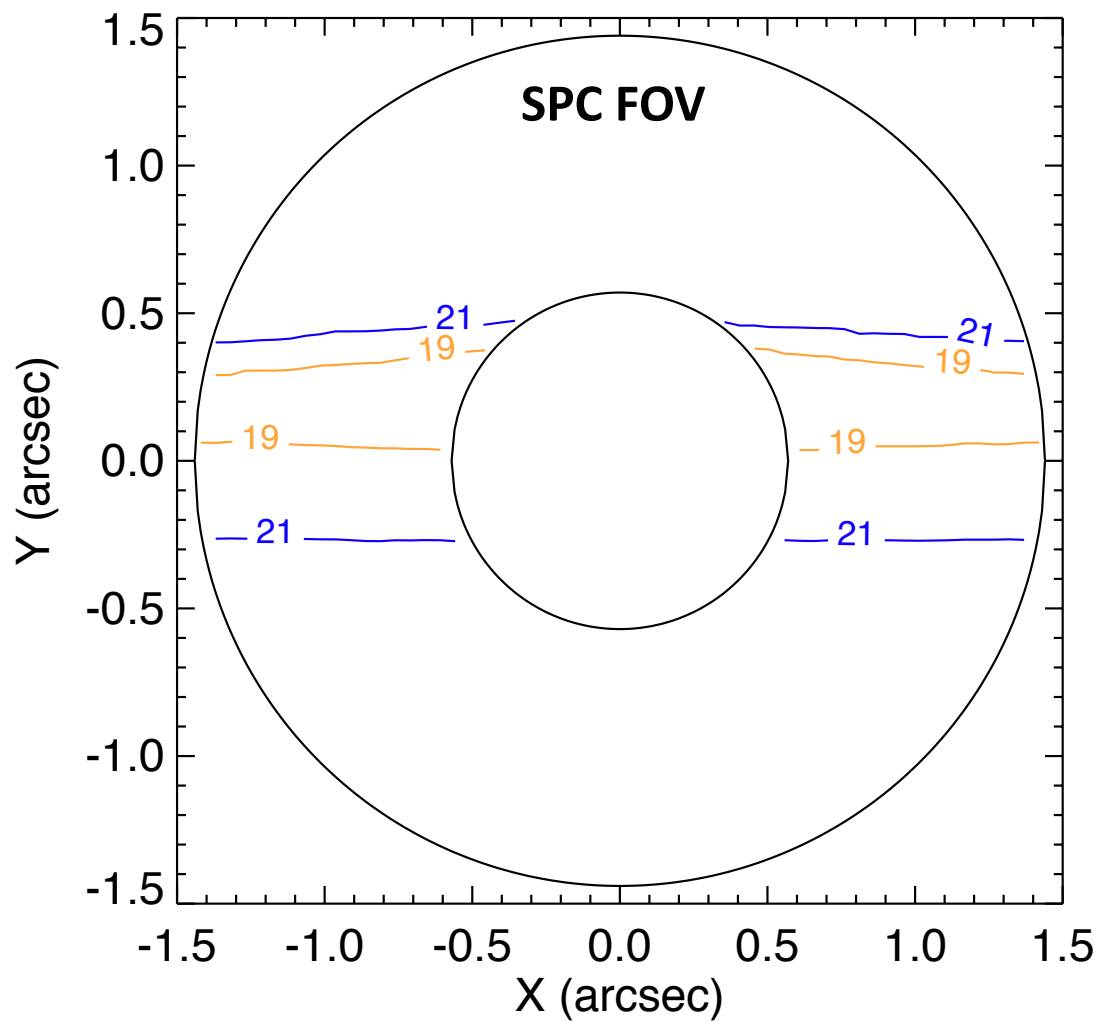
No margin
No dust

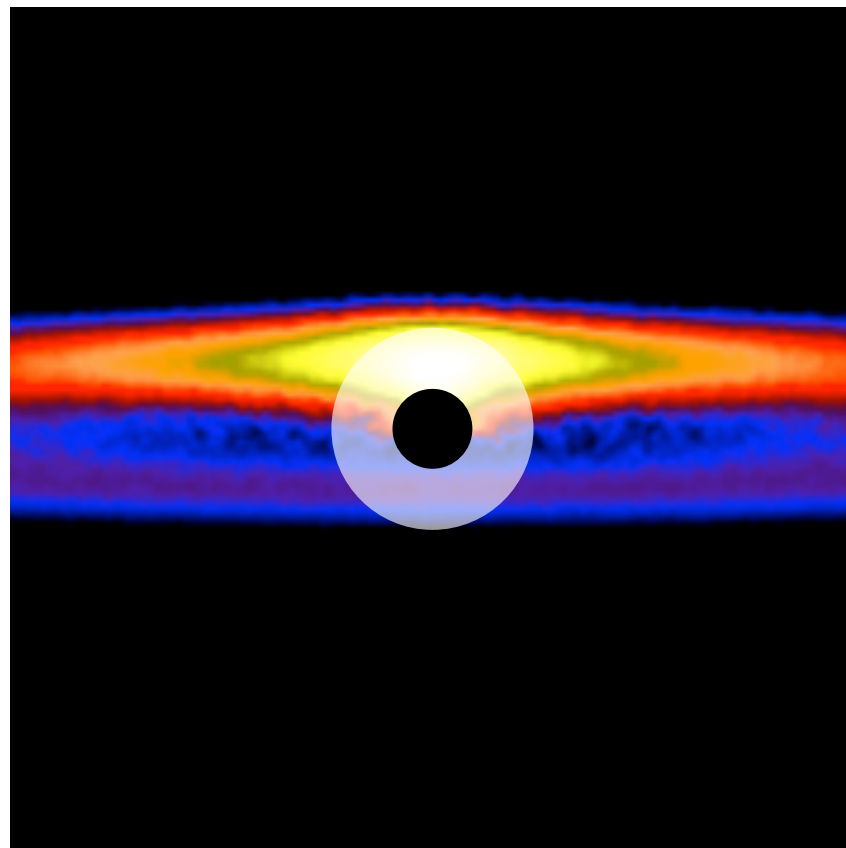
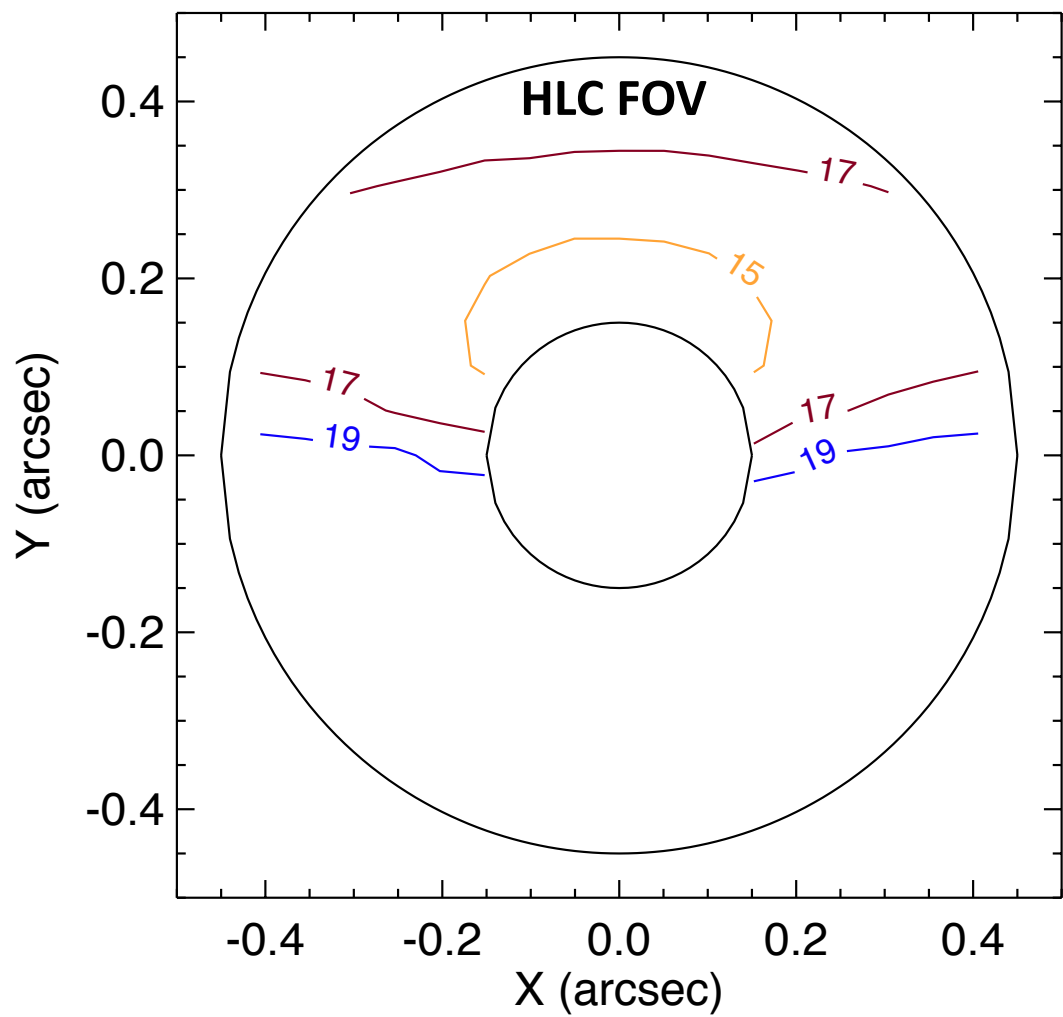


0.1" radius disk
300x zodi

Douglas, E., Debes, J. et al., *in prep.*





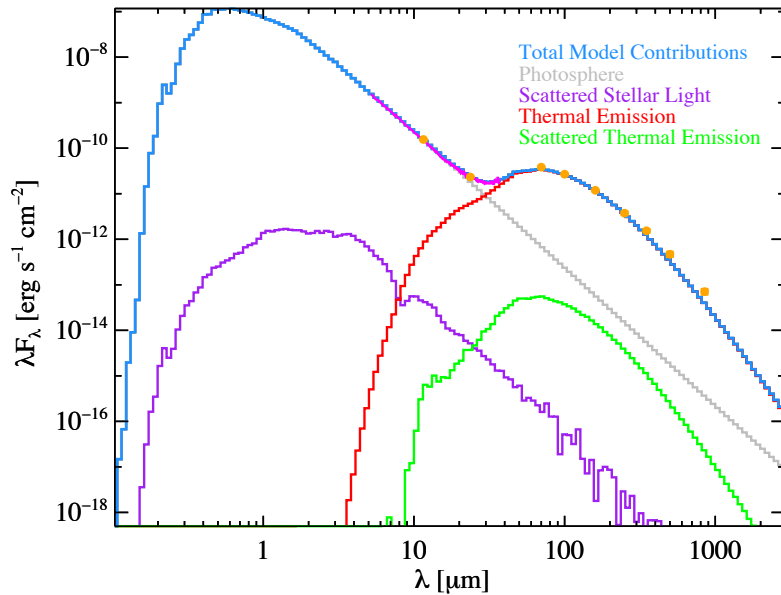




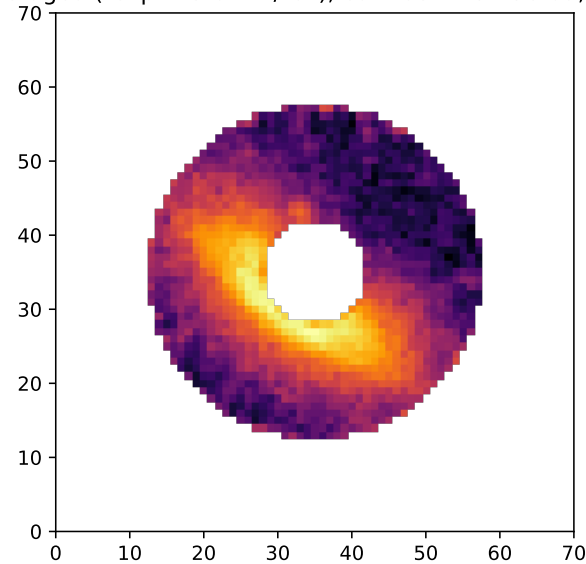
Modeling Known Planet+Disk Systems

7 Disk+Planet Systems

- Model Disks+planets constrained by observed IR SED (https://wfirst.ipac.caltech.edu/sims/Chen_WPS.html)
- Model HLC images simulated with planets+OS6 parameters
- Useful for DRM/Tech Demo studies (i.e., Tau Ceti)



Roll Averaged ($t_{\text{exp}} = 3.67$ hr/roll), contrast = 3.43×10^{-9} , $\theta = 51.8^\circ$



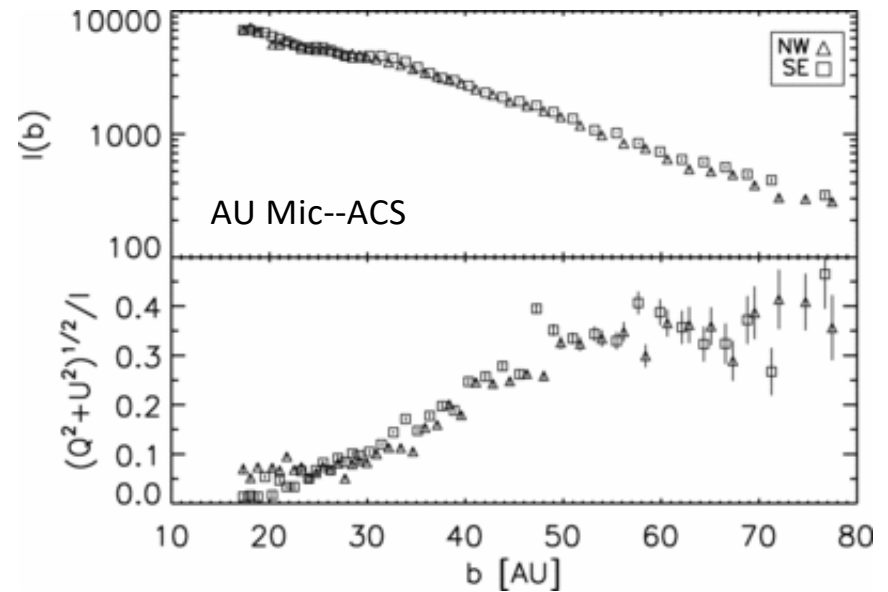
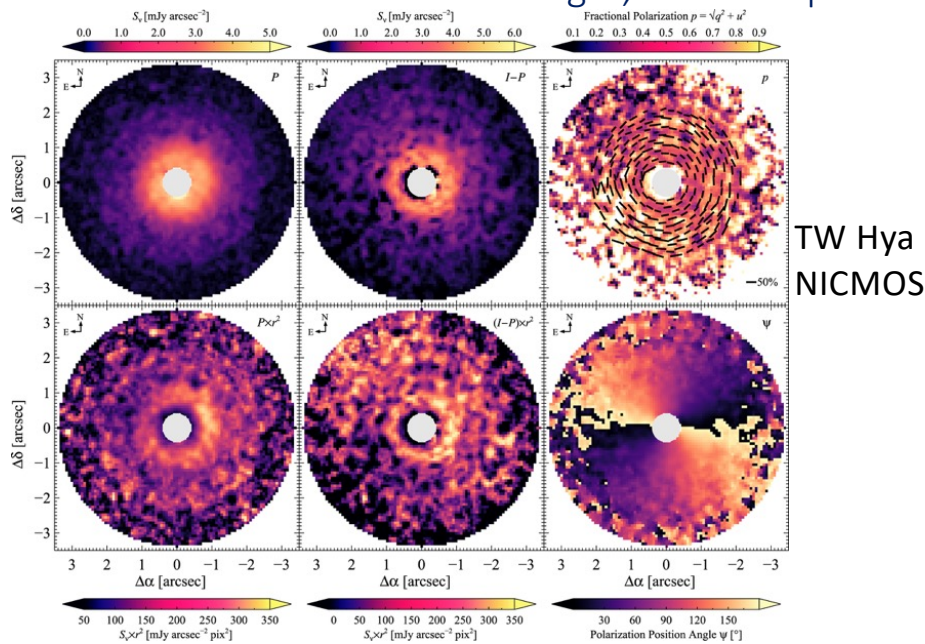
HD 10647



High Contrast Polarimetry in Space

HST possessed two sets of polarizers in combination with coronagraphic modes

- NICMOS-set of 3 polarized filters with coronagraphic camera-1.9-2.2 μ m
- ACS-set of 3 polarized filters that could be used in concert with coronagraphic spots; short blue visible wavelength, V-band equivalent (**only 2 disks observed**)

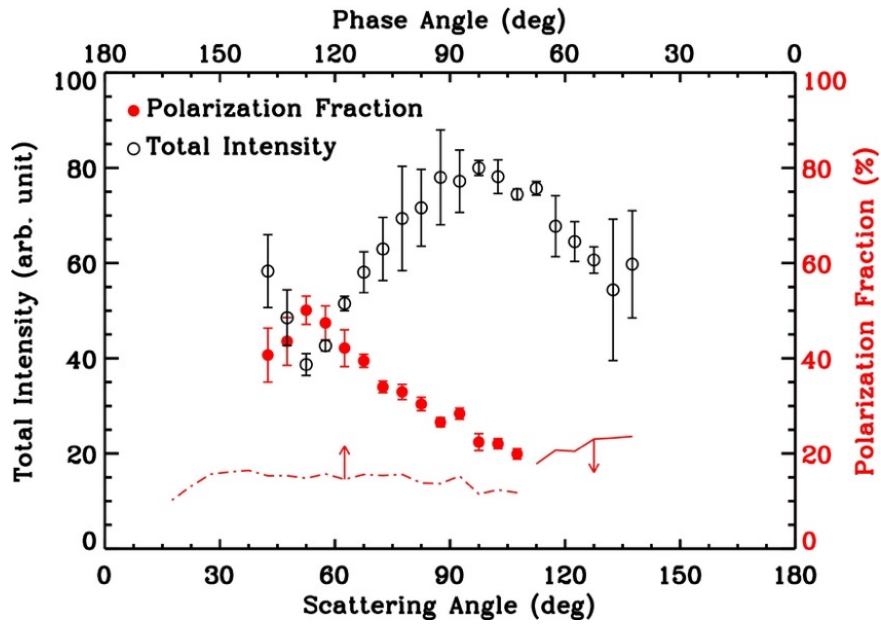


Poteet et al., 2018

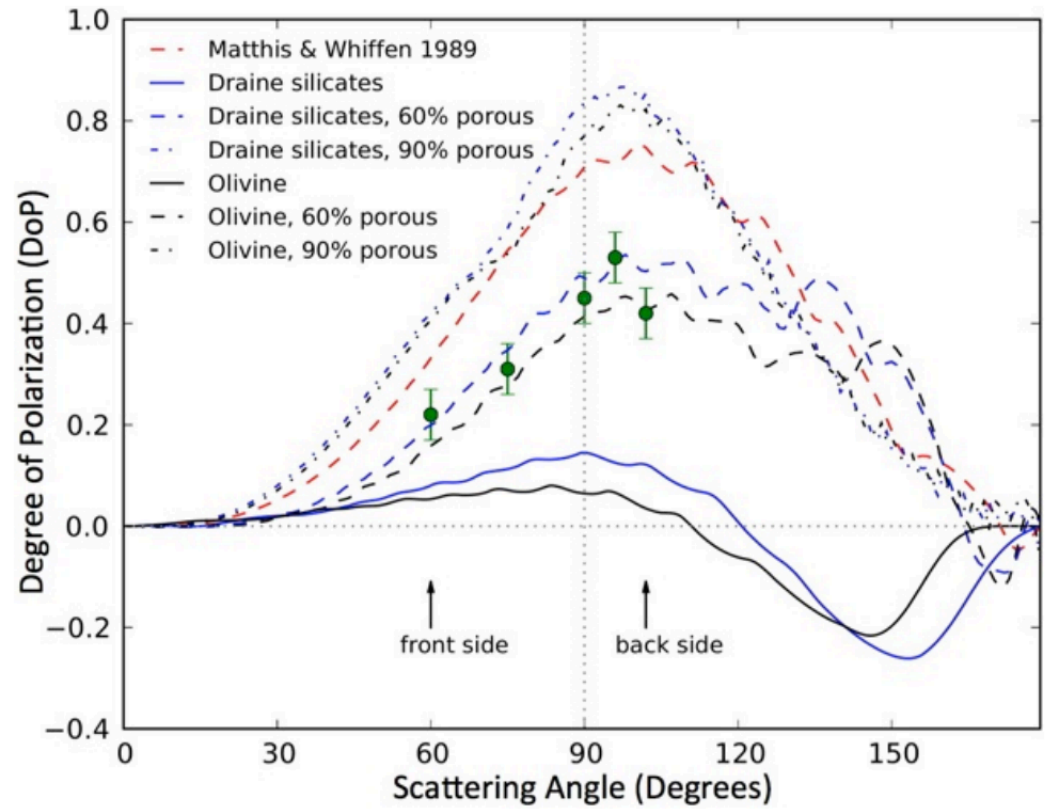
Graham et al., 2007



Grain Properties



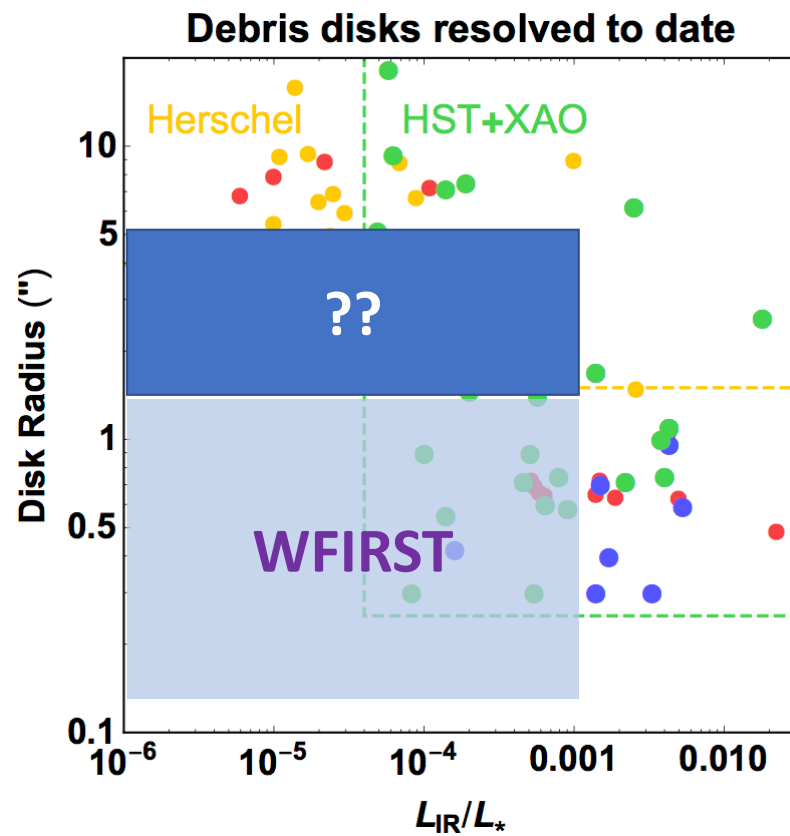
Perrin et al., 2015



Schneider et al., 2016
STScI SPACE TELESCOPE SCIENCE INSTITUTE

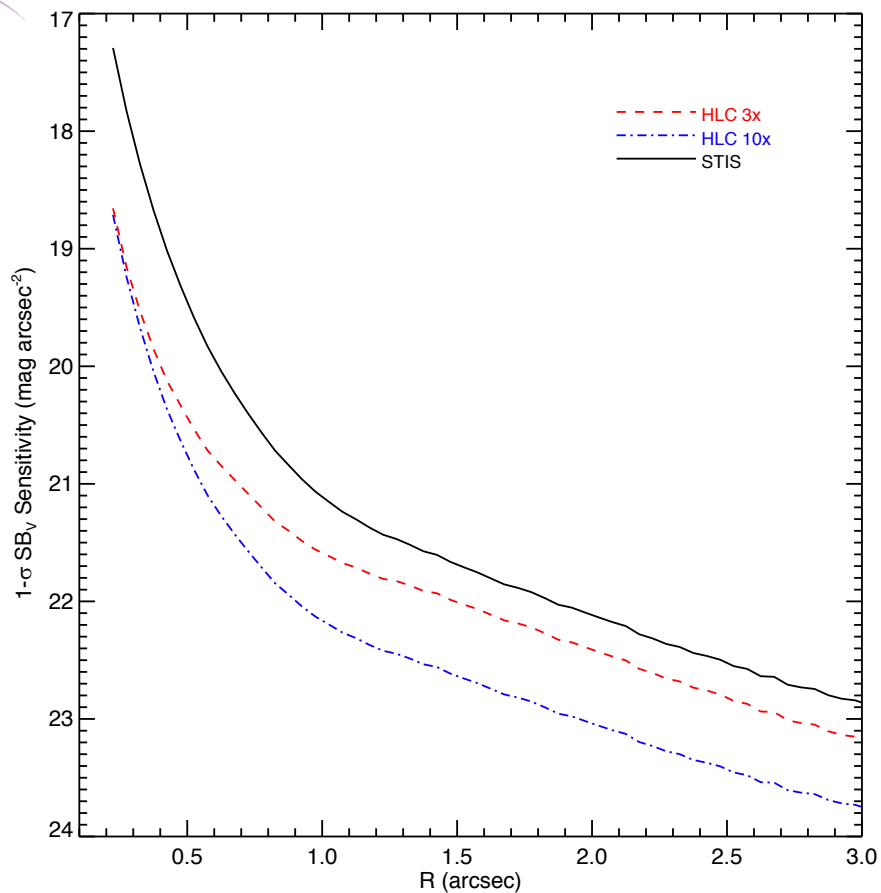


Can CGI also help characterize cold debris disks?





Utilizing the Full CGI FOV



Assume HLC PSF Wings suppressed by 3-10x relative to STIS

Without a dark hole

Assume 24 hr of exposure time for both STIS/WFIRST
For V=5 star

Assume latest CGI detector parameters

More details:

Debes, Ren, & Schnieder, 2019 JATIS, 5, 035003



While a tech demo, CGI will be a disk imaging wizard

- Orders of magnitude more contrast at small inner working angle in the visible
- Linear polarization (good for many science cases beyond disks)
- Comparable or superior far-field high contrast sensitivity to HST (to 3-5")
- First measures of exo-zodis in scattered light



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