Coronagraph update and steps forward

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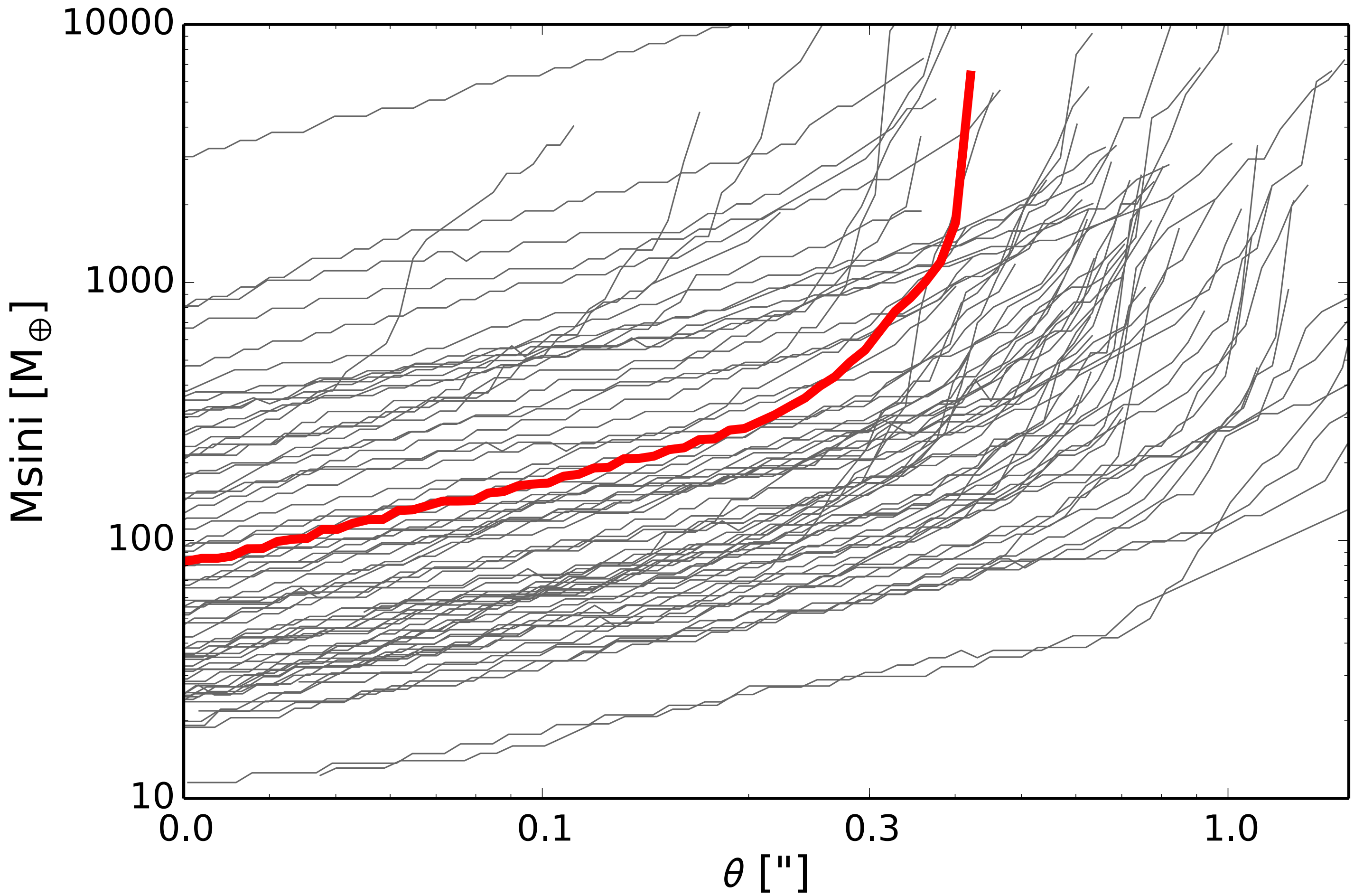
JPL instrument team

Update on coronagraph effort

- Coronagraph science/engineering meetings ~0.5/month
- Finalized filter selection, mask combinations for CATE cycle
- Integrated modeling progressing and showing promising results
- Quick-studies on exoplanet characterization completed
- Study on Doppler completeness delivered
- Discussion on polarimeter architectures

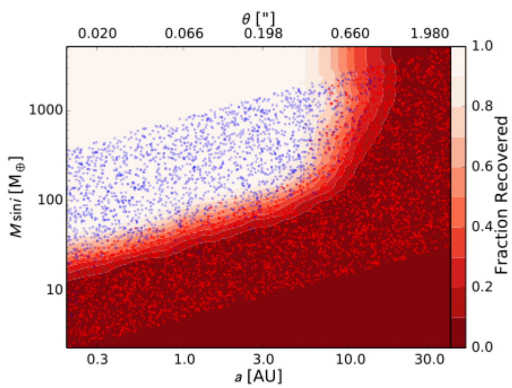
Doppler completeness for 76 coronagraph targets (Howard &Fulton)

Completeness vs. Projected Separation



Doppler survey starting now very valuable

HD 182572

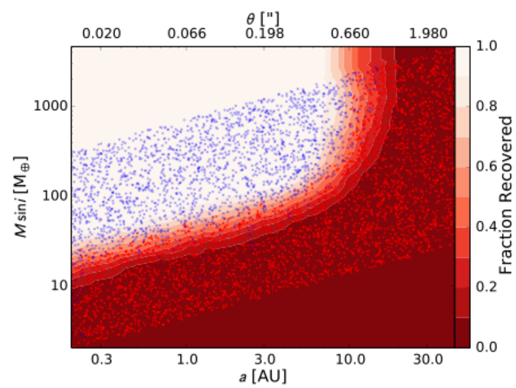


Current RVs:

N_{obs} = 82 RVs

T_{span} = 17.8 yr

σ_{RV} = 4.0 m/s

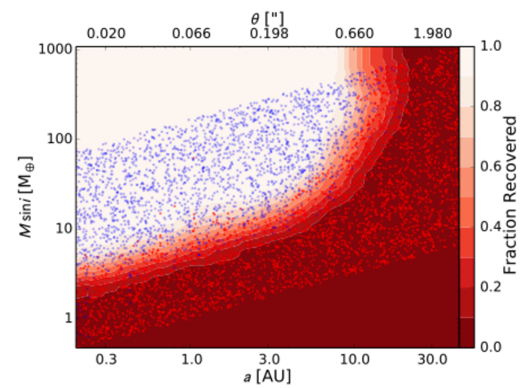


Continued RVs:

N_{obs} = 82 + 30 RVs

T_{span} = 17.8 yr + 10 yr

σ_{RV} = 3.6 m/s (new RVs)



Ideal Survey:

N_{obs} = 82 + 100 RVs

T_{span} = 17.8 yr + 10 yr

σ_{RV} = 0.5 m/s (new RVs)

Detailed full-physics simulations to validate coronagraph with AFTA

Parameters:

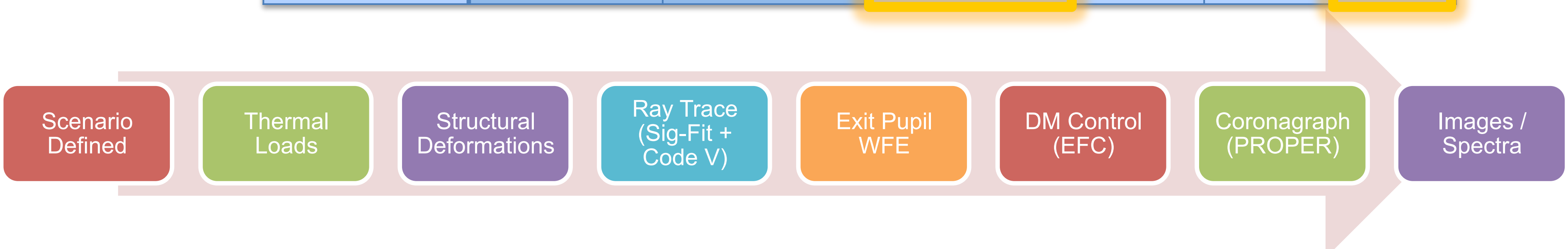
03 Jan 2023 00:00 ET; Altitude = 35786 km; Period = 86164 sec;

Inclination = 28.5 deg; RA of Ascending Node = 236 deg

Arg. Of Periapsis = 270 deg; Solar = 0.001354 W/mm^2 ;

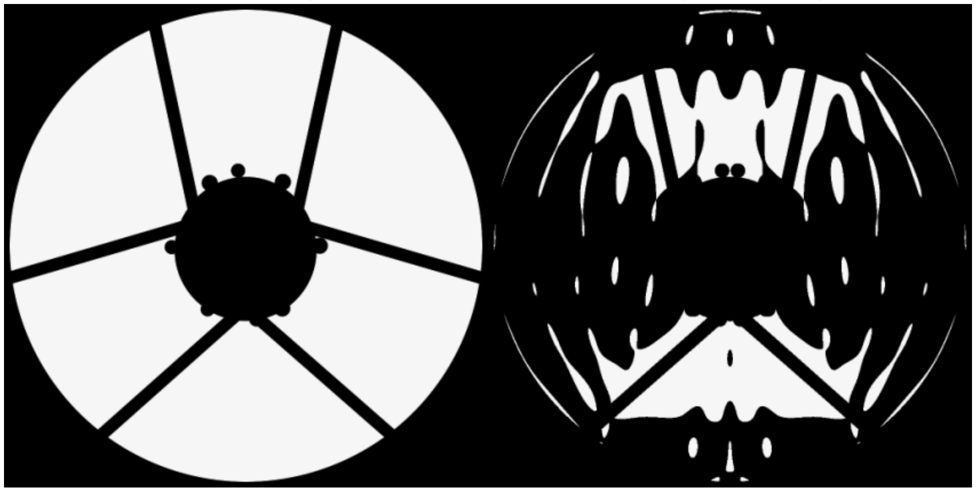
Beta Angle = 41.6 deg; IR = 0.0002215 W/mm^2; Albedo = 0.35

State	Operation	Duration (sec)	Start Time (sec)	RZ	RY	ΔFlux (% abs.)
Prior Star 61 Uma	Stare	infinity	-infinity	-53.7°	26.9°	--
DH Star: Beta Uma	Slew & Settle	700	0	-79.4°	34.1°	+6.4%
	Stare	22000				
Target Star: 47 Uma	Slew & Settle	700	22700	-60.0°	35.7°	+1.6%
	Stare	80300				
Cal Star: 61 Uma	Slew & Settle	700	103700	-53.7°	26.9°	-8.0%
	Stare	80300				



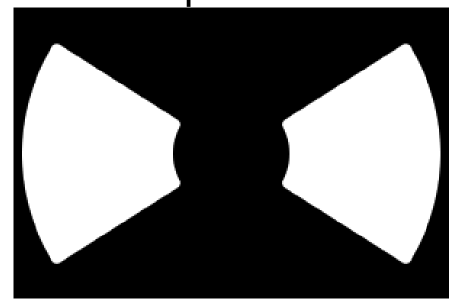
Coronagraph simulations use validated wave-optics code

AFTA Pupil Shaped Pupil

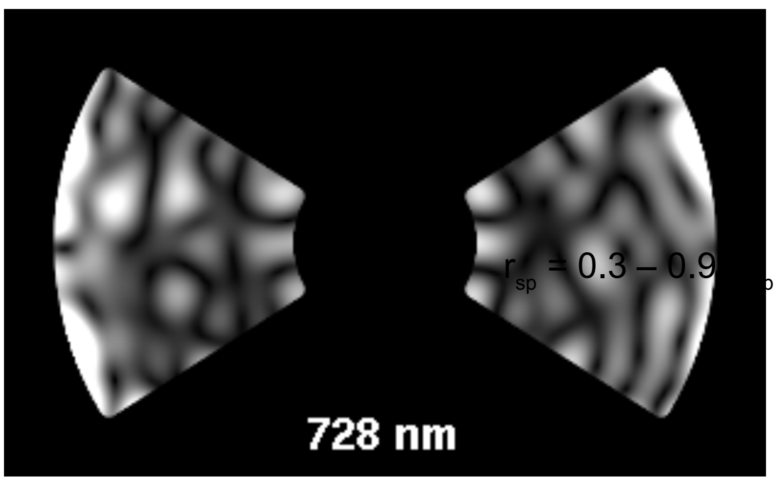


27% mask transmission

Focal plane mask

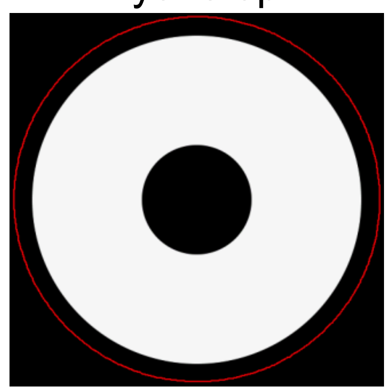


r = 2.5 – 9 λ_c/D
65° opening angle

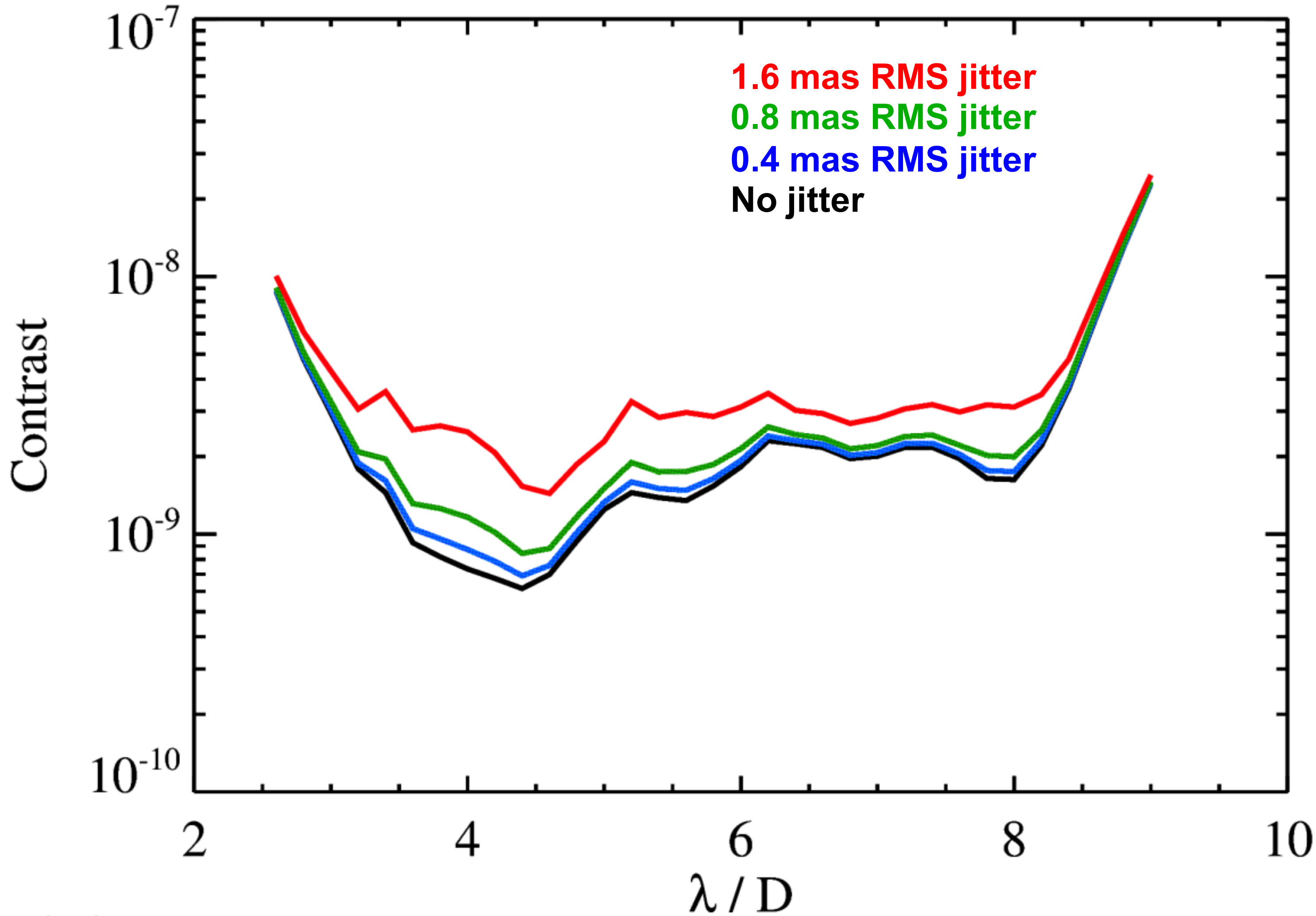


r_{sp} = 0.3 – 0.9

Lyot stop



Simulations show e.g. robust performance against jitter



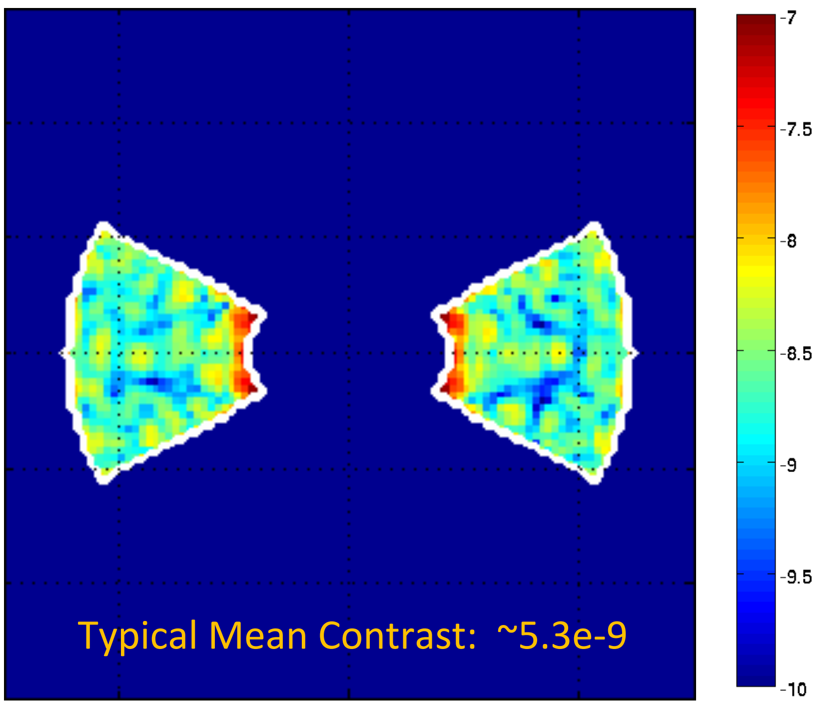
728 – 872 nm

Jitter levels shown here are after coronagraph fast tip/tilt

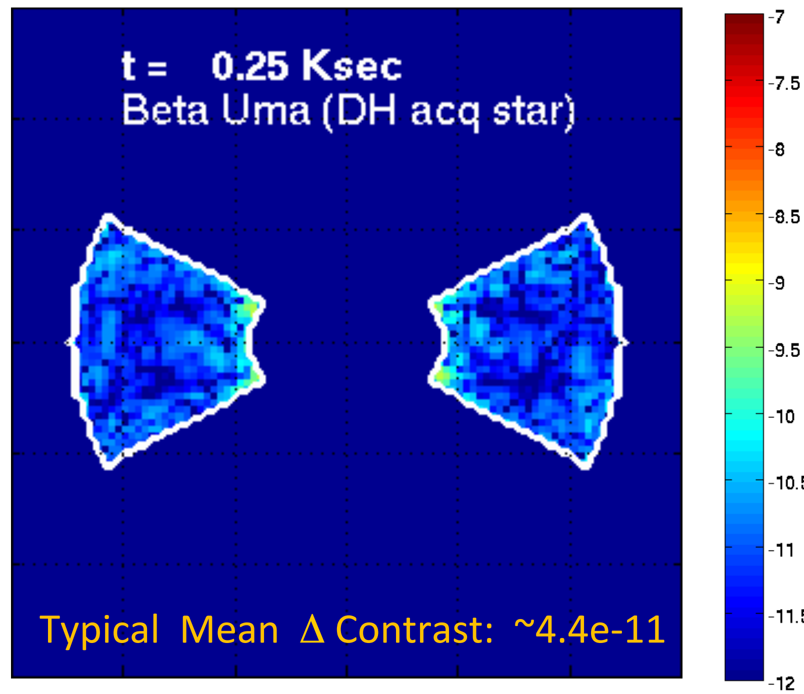
Simulations show stable high contrast with AFTA in thermal scenarios

- Proper EFC correction for telescope nominal wavefront (initial DM setting)
  - Gen 1 SPC design , 10% bandwidth, l = 550 nm, 3.9 ~12.3 l /D WA, 56 deg opening angle
  - Realistic AFTA surface aberration (amplitude +phase), and
  - Piston/tip/tilt/focus correction computed only once initially
  - The system configuration is held constant throughout the observations

Raw speckle, S(t)



ΔSpeckle (rel. to nominal): S(t) – S(0)



Exoplanet characterization section outline

2.4.3.1 Introduction to characterization of exoplanetary systems (Macintosh)

2.4.3.2 Coronagraph technology: concepts, motivation, processing (Kasdin, Breckenridge)

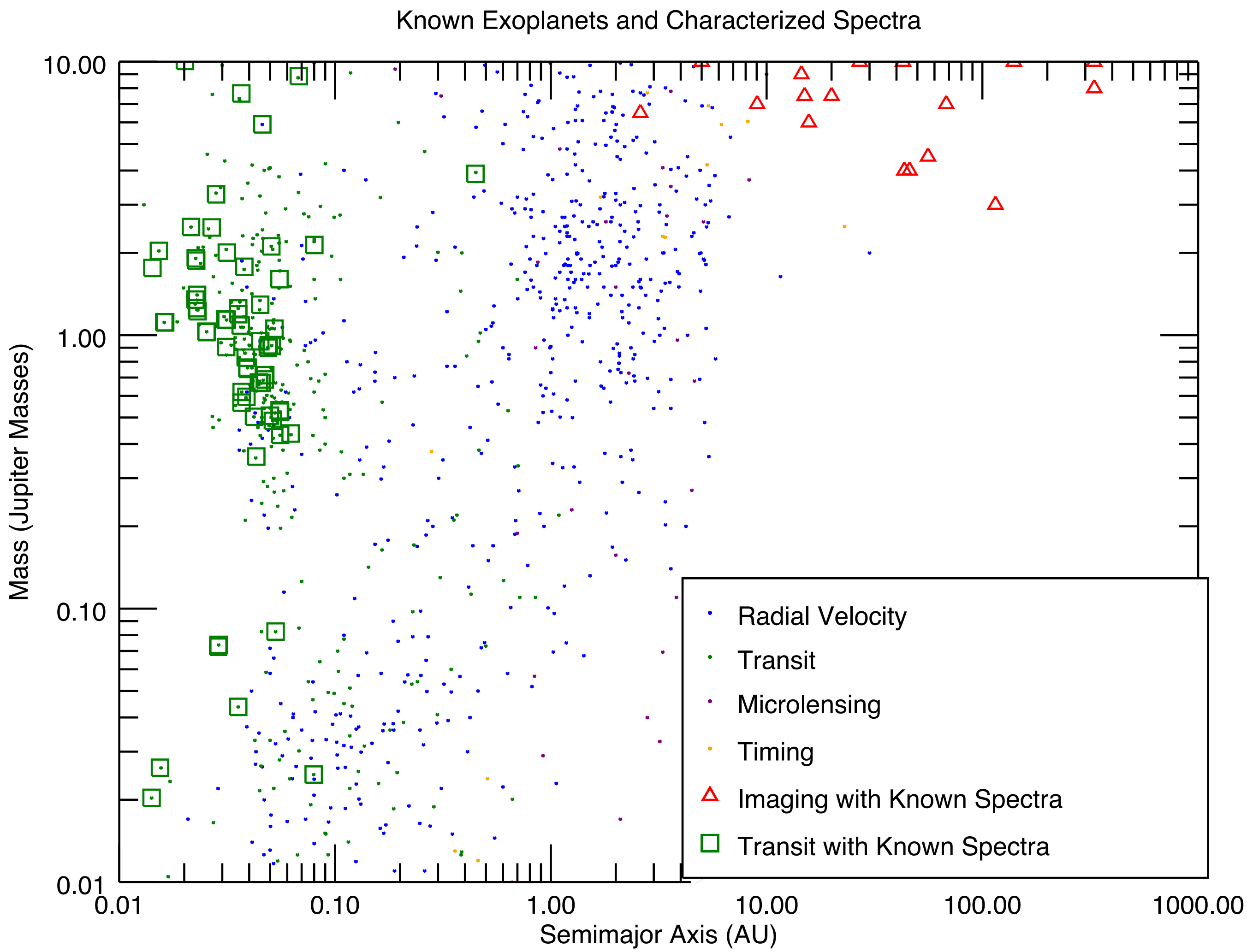
2.4.3.3 Giant planet atmosphere characterization (Greene, Marley)

2.4.3.4 Sub-neptune and super-earth science (Macintosh)

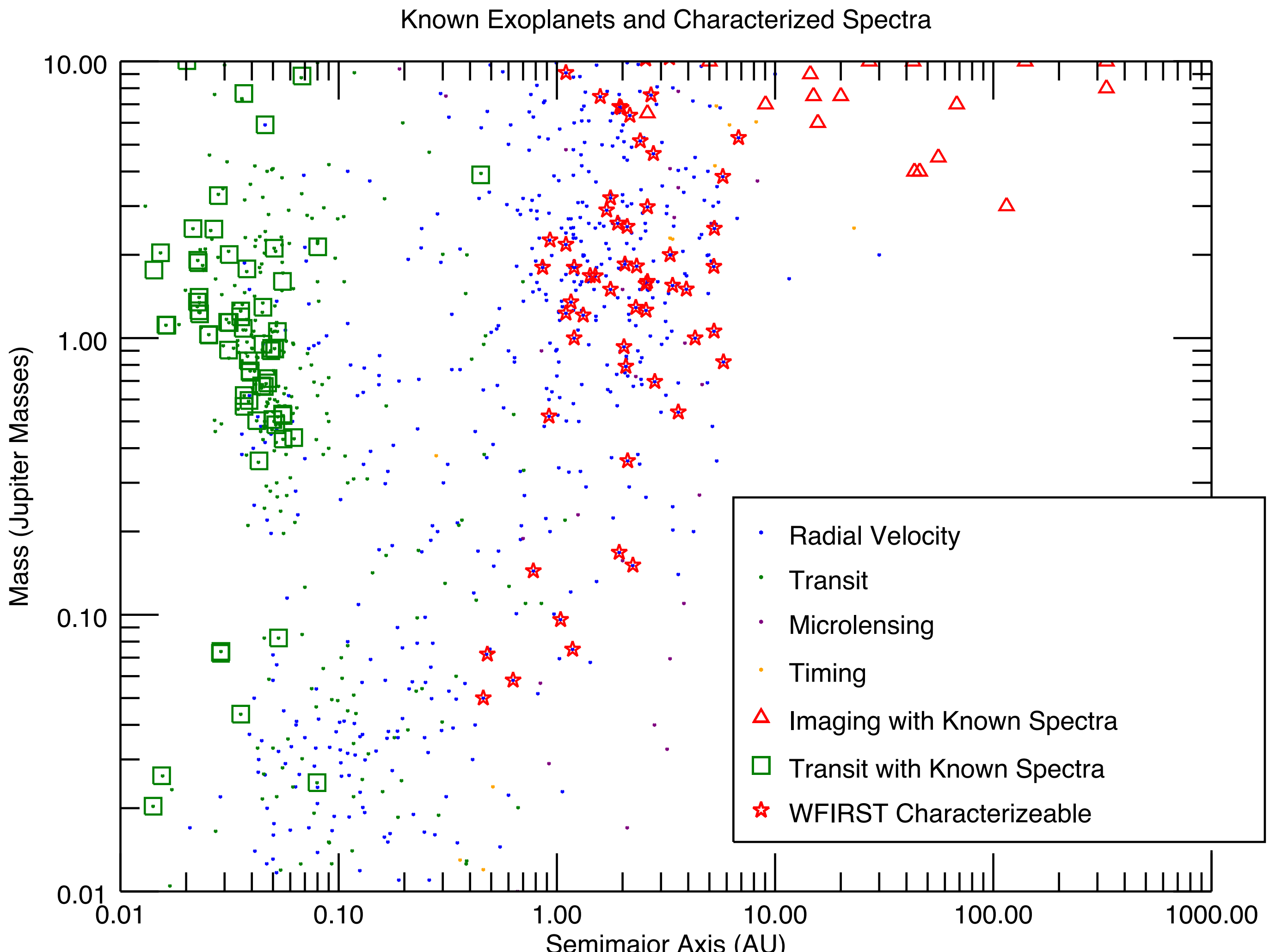
2.4.3.5 Exoplanet science modeling (Traub, Macintosh)

2.4.3.6 Disk science (Greene, Schneider)

2.4.3.1 Intro sections: exoplanet population figure



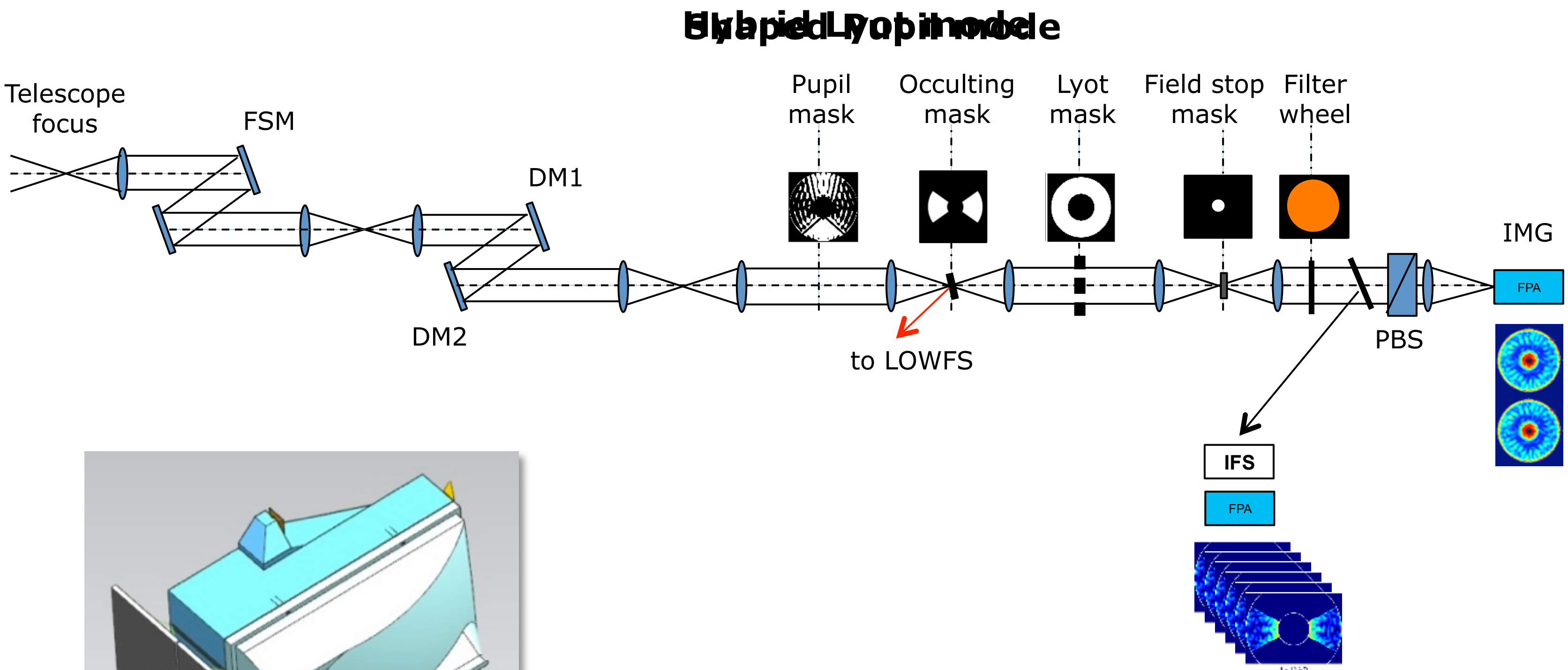
(integrate with Microlensing versions)

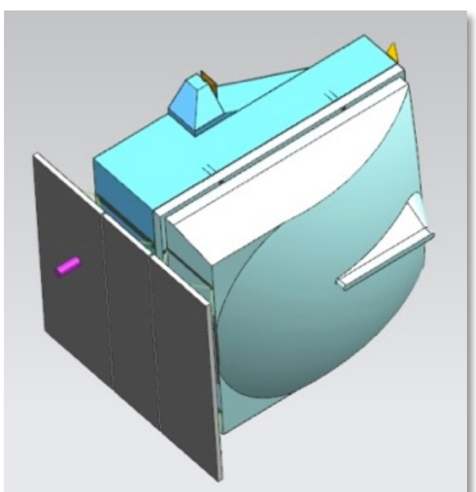


WFIRST Characterizable Doppler planets (PIAACMC case)

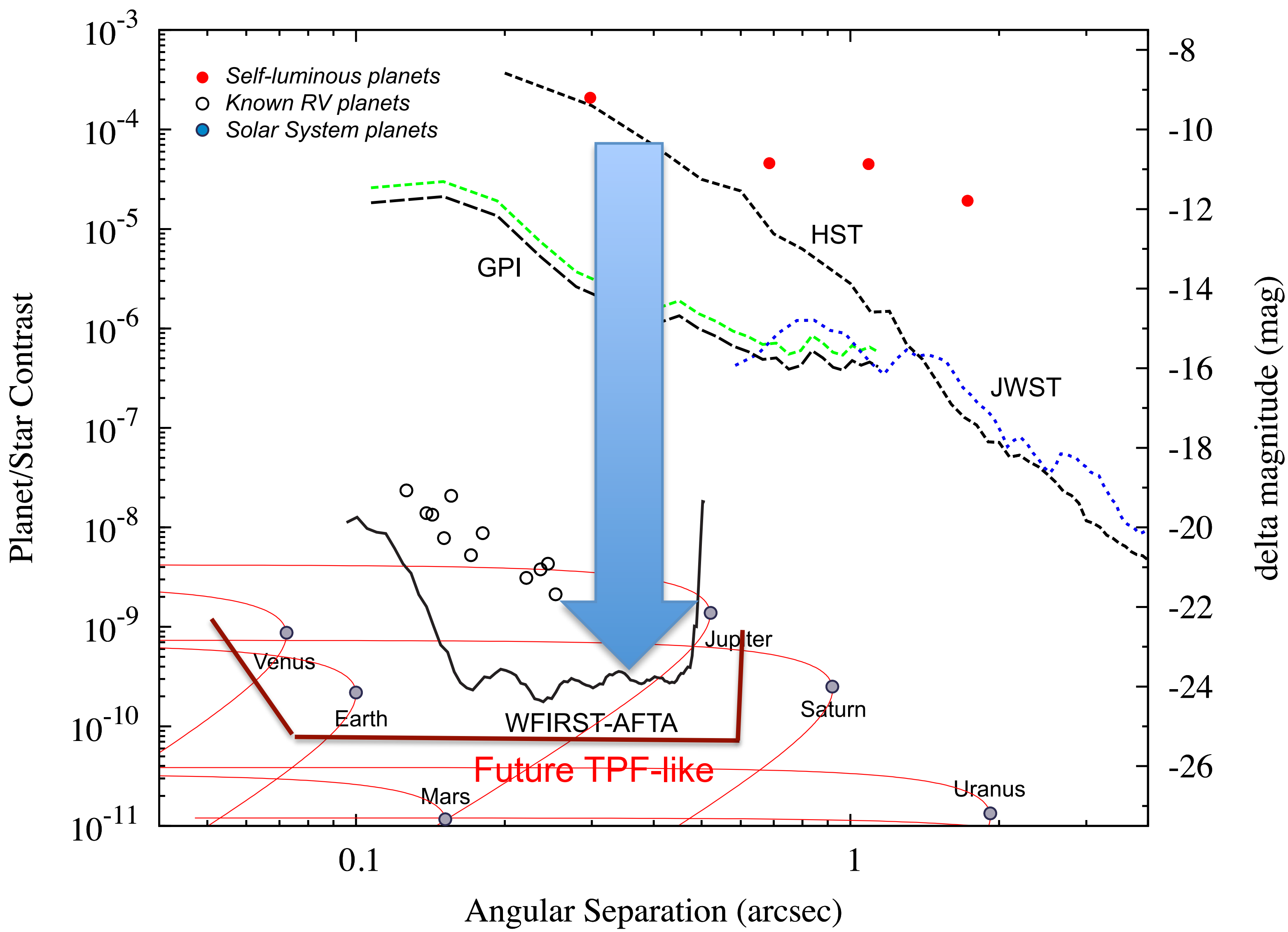
2.4.3.2 Coronagraph architecture

Introduce basic concept of coronagraph



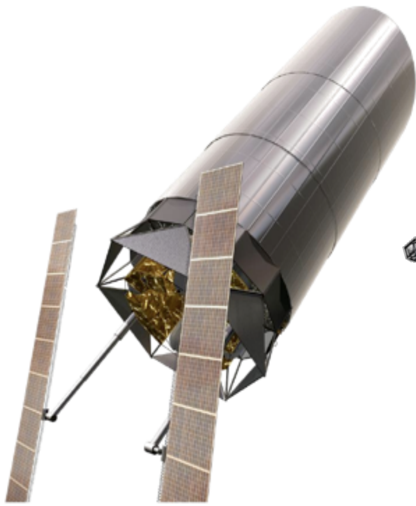


2.4.3.2 – Technology story

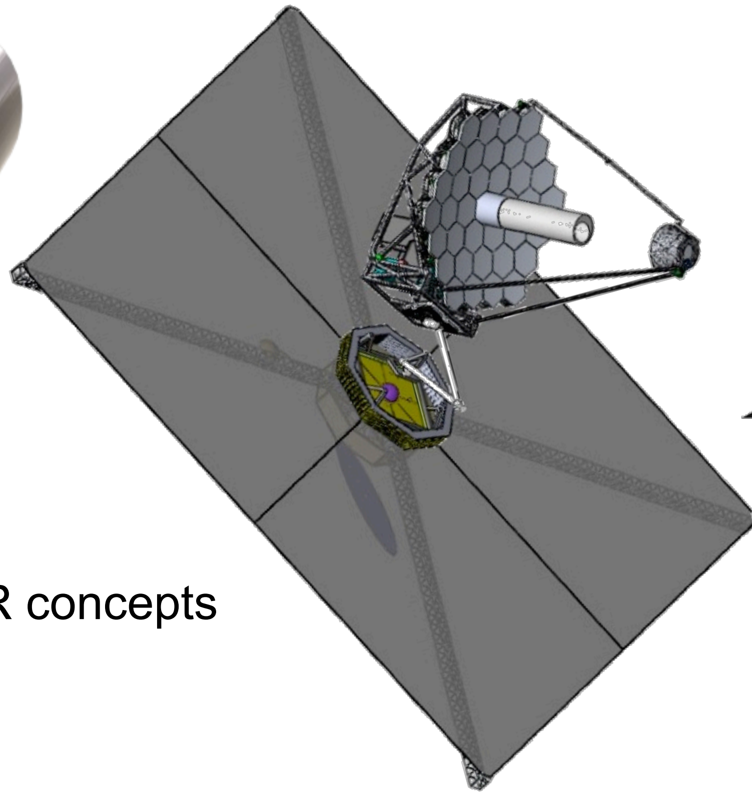


Future space coronagraphs will likely be multipurpose missions

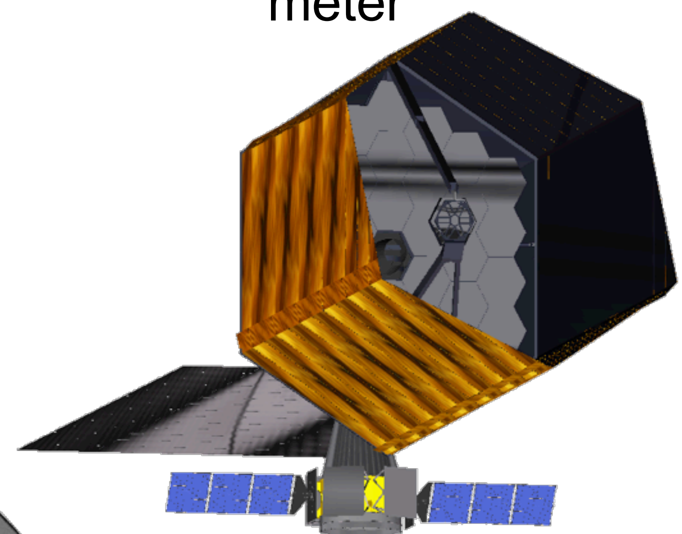
8-meter



9.2-meter



16.8-meter



ATLAST / UVOIR concepts

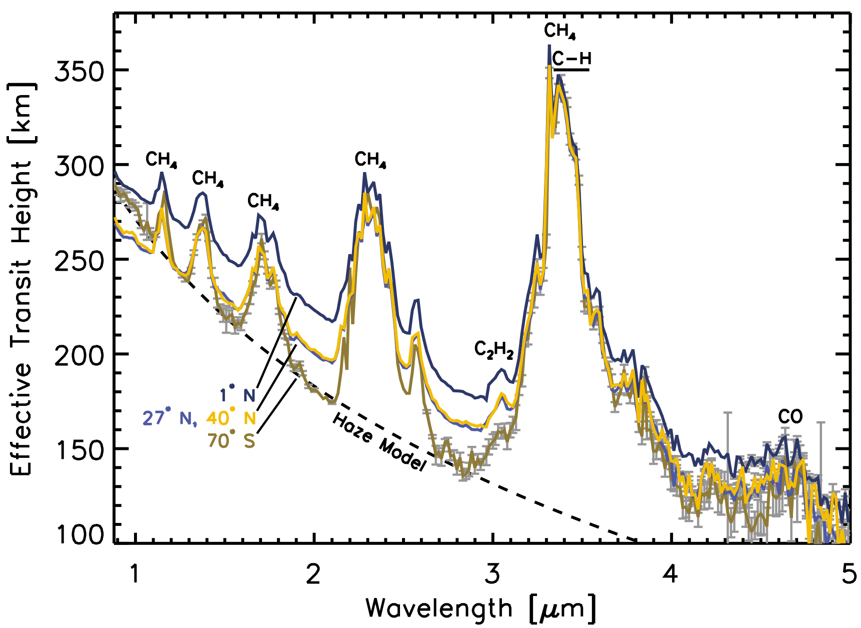
AFTA coronagraph teaches us how to do coronagraphy

2.4.3.3 Giant planet science

- Overview: WFIRST-CGI will be able to probe the physical natures of planets around nearby Sun-like stars with visible light reflected spectra
- - Will primarily target known giant planets with measured projected radial velocities:
- known masses will greatly aid interpretation of spectra
- - AFTA 600 - 970 nm spectra will cover numerous CH4 bands and also H2O.
- Expect to use techniques established with solar system giant planets to study
- the compositions and temperature profiles of exoplanet atmospheres:
- .Bands of different strengths allow measuring temperature and CH4 abundance
- without ambiguities of cloud altitudes.
- - Abundances (CH4, possibly H2O mixing ratios) will constrain C/H and possibly C/O.
- These ratios provide clues to how (late accretion of gas or planetesimals) and where
- (within or beyond ice lines) planets formed.
- - Albedo and color measurements in blue filters probe cloud heights and Rayleigh scattering
- by molecules (right section?)
- - Show the expected quantitative precision of measuring these properties from the
- quick modeling studies that are now underway
- - Conclude: WFIRST-CGI will study the physics of a range giant planet atmospheres
- (hot and cold, different abundances) and reveal how similar they and their formation
- histories are to our solar system's giant planets. WFIRST-CGI will be the only
- instrument to date that can study the planets of nearby, Sun-like stars and is
- therefore best / uniquely suited for providing context to our own Solar System's
- formation and evolution (i.e., lack of giant planet dynamics)

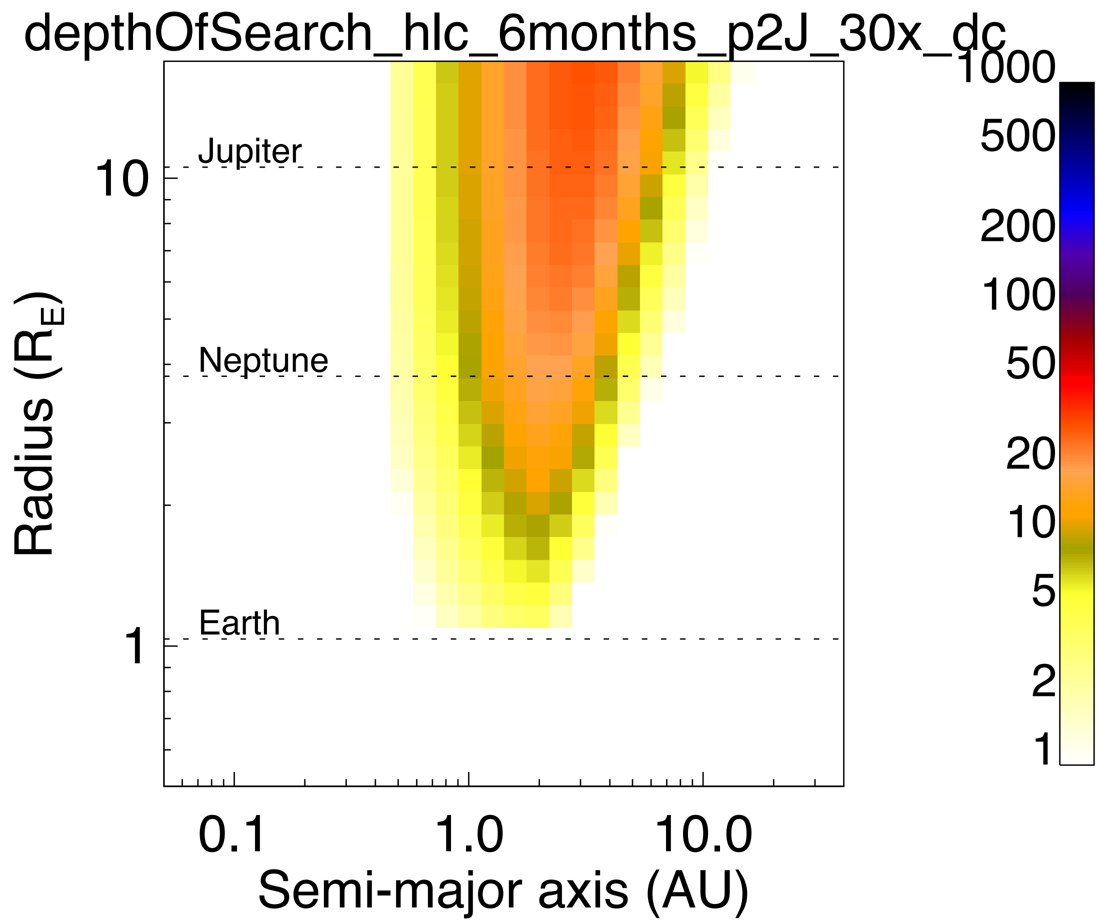
2.4.3.4 "super-earth" science

- Models of directly-imaged super-earths are rare
  - Existing models over-emphasize earthlike planets
- Current modeling focus emphasizes transit atmospheres
- Transit probes different atmosphere regions than imaging
  - Recent paper on Titan transit (Robinson et al) shows sensitivity primarily to stratospheric hazes (compare to directly imaged spectrum#)



2.4.3.4 – 2.4.3.5

- Blind search models (Savransky) showing total completeness
- Need to integrate with Traub modeling, validate (e.g. which Kepler estimate to use)



Summed completeness for 3-month AFTA ~100 star survey

Discuss modeling in Section 2 or 3 (or both?)

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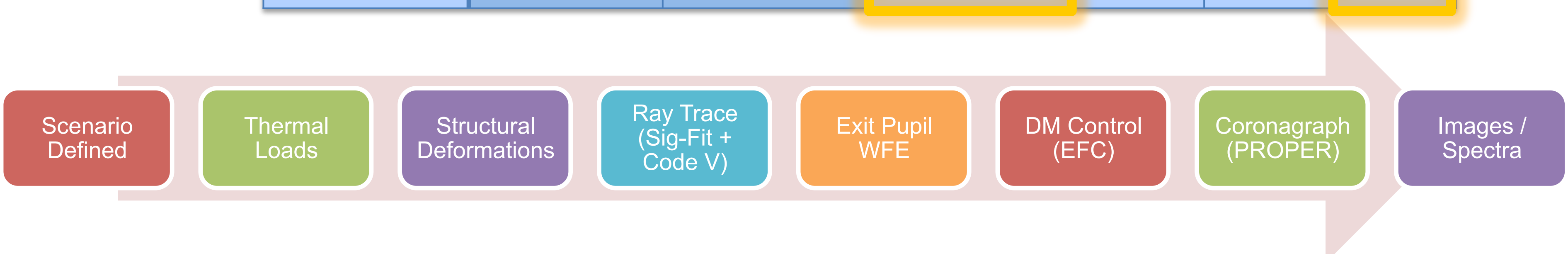
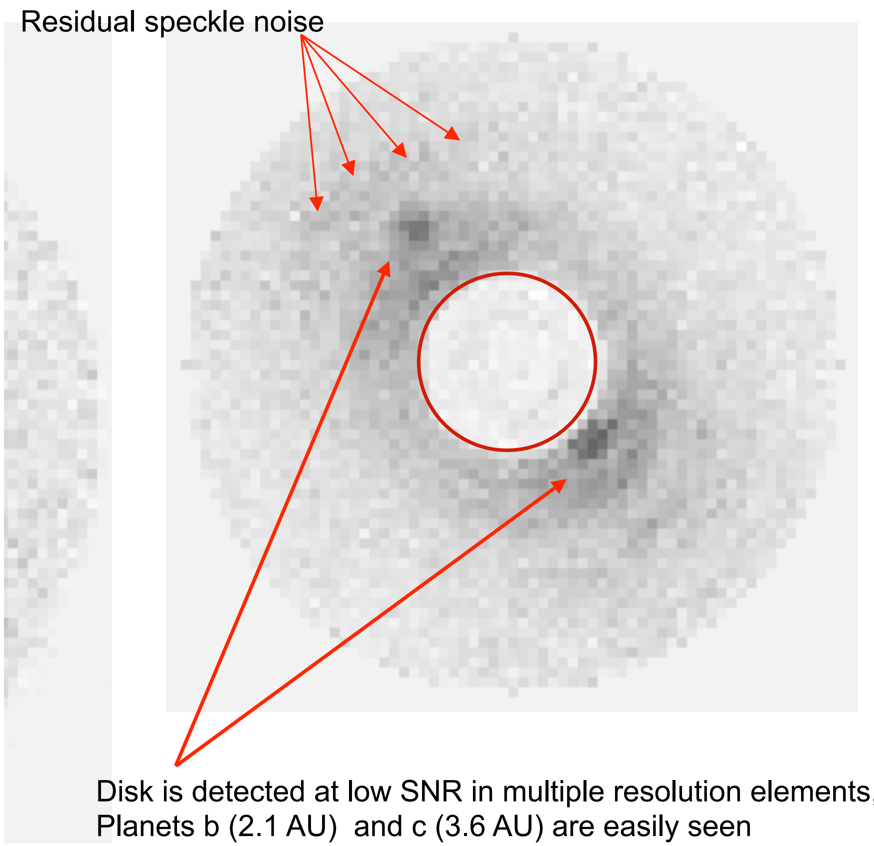
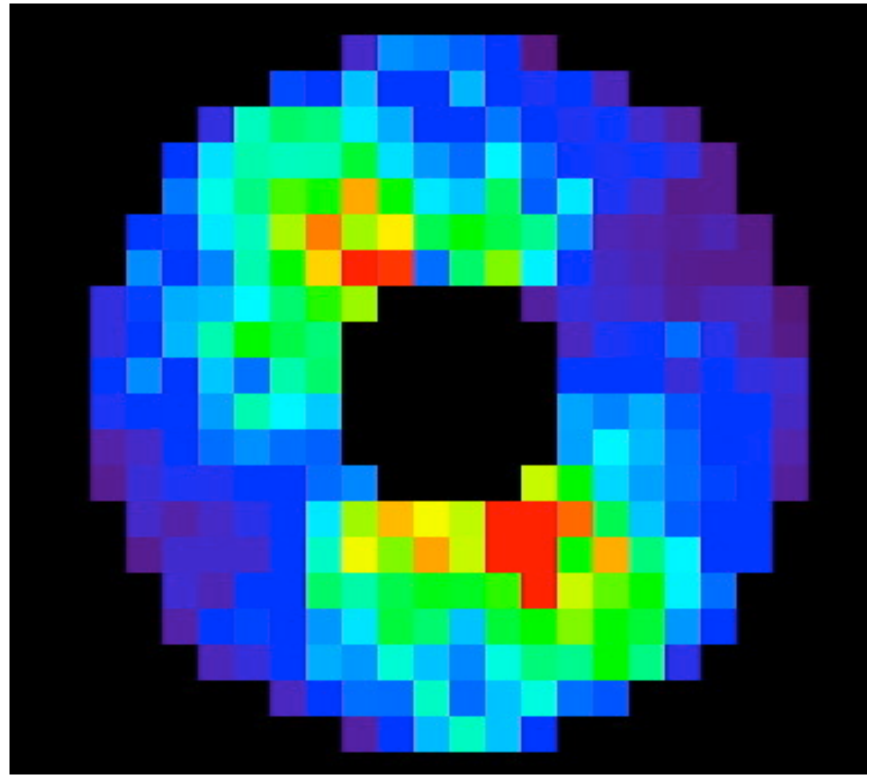


Disk science sim figure: 47 UMa + 30 Zodi disk



PSF-subtracted image

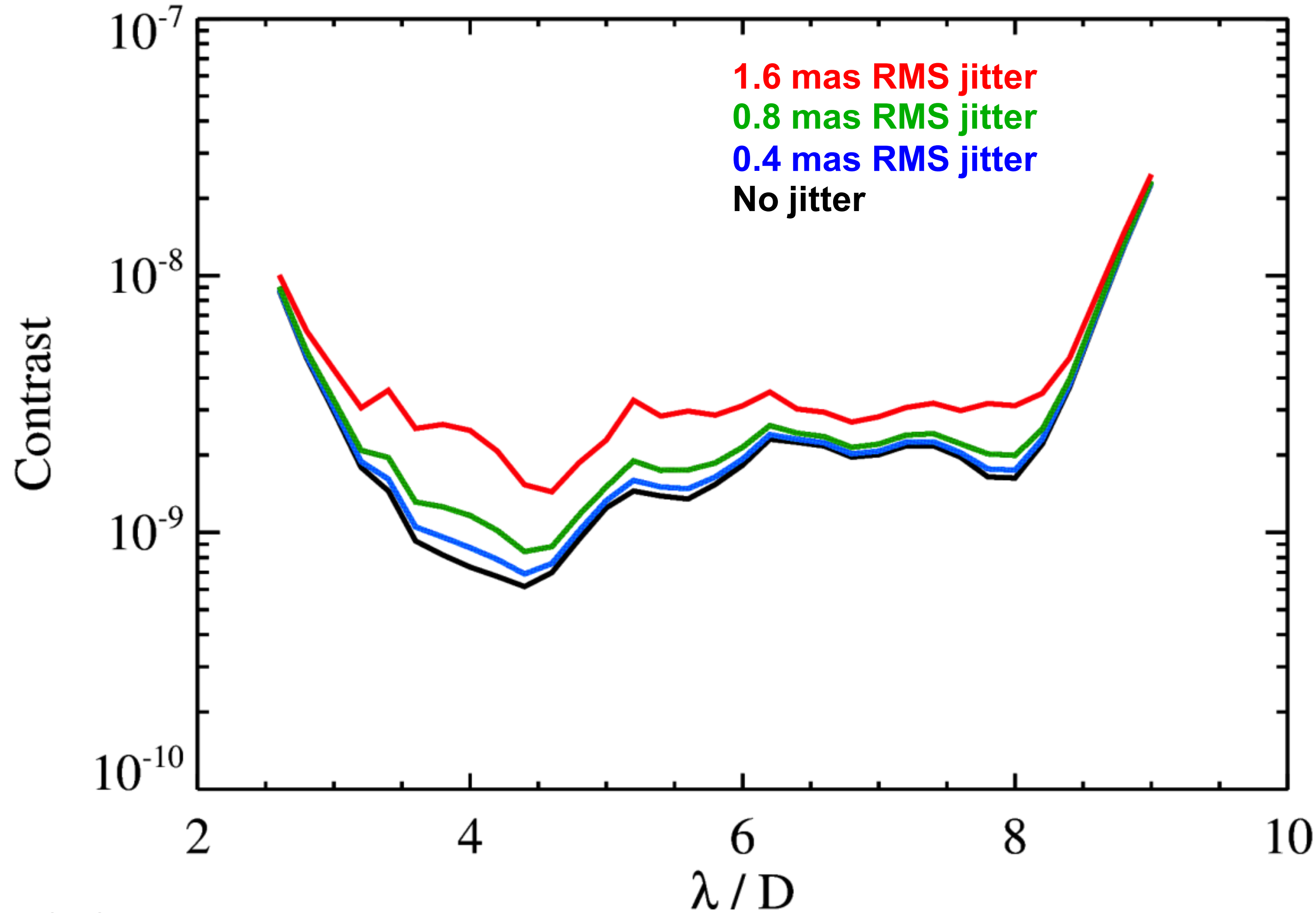


Binned SNR map of disk (peak SNR=15)

Simulations by Tom Greene and Glenn Schneider using 1st-gen HLC

Major uncertainties (technical and political)

Jitter terminology needs to be clarified (telescope jitter 14 mas)



728 – 872 nm

Jitter levels shown here are after coronagraph fast tip/tilt

Major uncertainties (technical and political)

- Jitter story consistency (jitter vs “residual tip/tilt”)
- Nominal mission time allocation (quasi-DRM?)
- Modeling consistency (Kepler realizations, search strategy)
- Show multiple cases for jitter, PSF subtraction?
- Calibration?
- The Starshade Question

- Other areas
  - Non-exoplanet COR science in GO or other?
  - Young systems (cf. Tamura presentation)
  - Polarimetry capabilities

Future tasks

- Wavefront control algorithm development (algorithms need to be addressed in tech development plan)
- DRM-like scenarios
- Polarimetry modes (simple to complex)