Opportunities and Challenges with Coronagraphy on WFIRST/AFTA

Neil Zimmerman and N. Jeremy Kasdin
Princeton University

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WFIRST/AFTA Exoplanet Imaging Science Goals

- Detect and characterize a significant sample of known RV planets

- Study chemical composition, clouds, and atmosphere structure by spectroscopy in reflected visible light

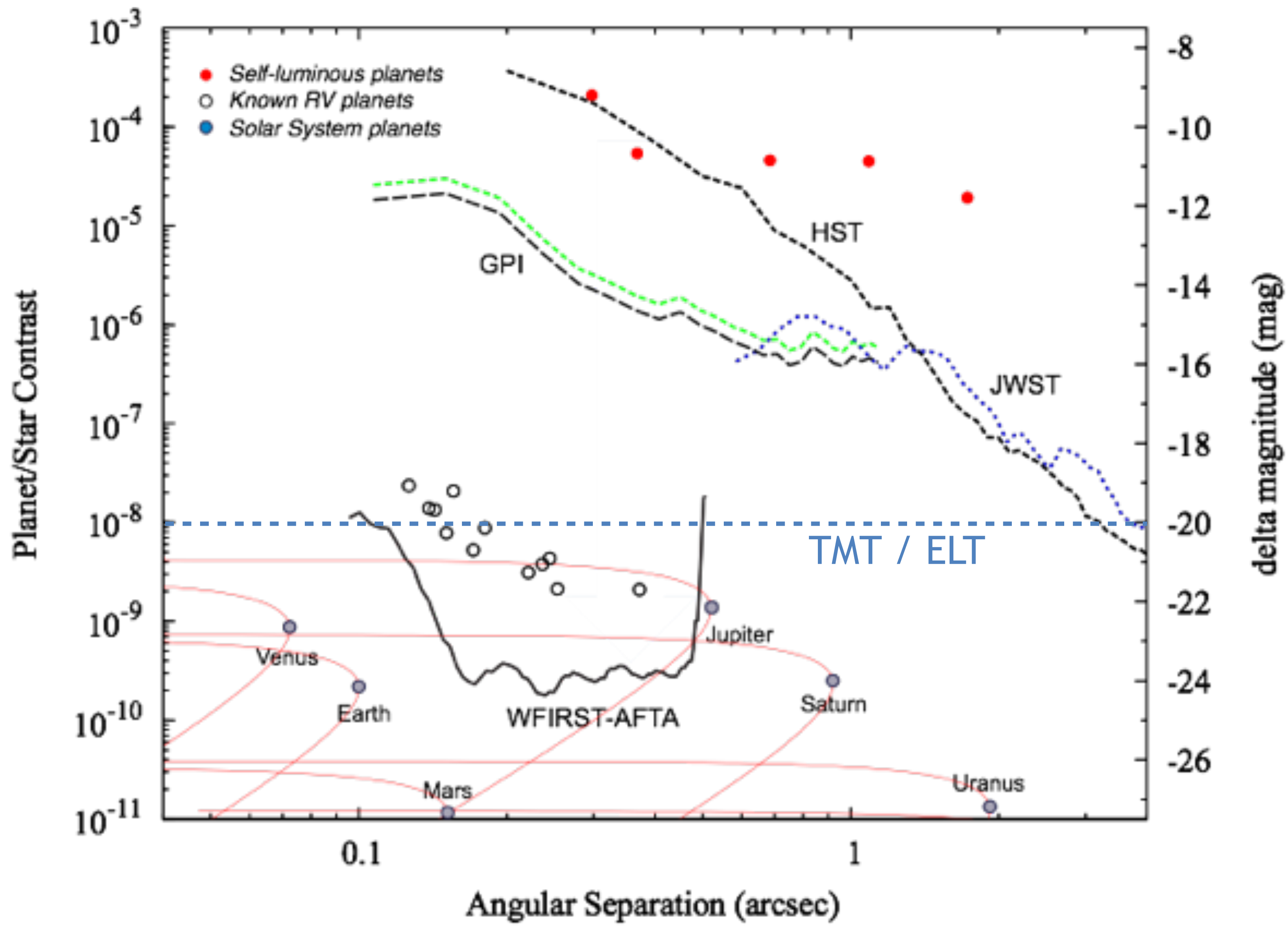
- Broadband colors of a few Neptune-mass RV planets

- Reveal previously undetected, co-eval planets

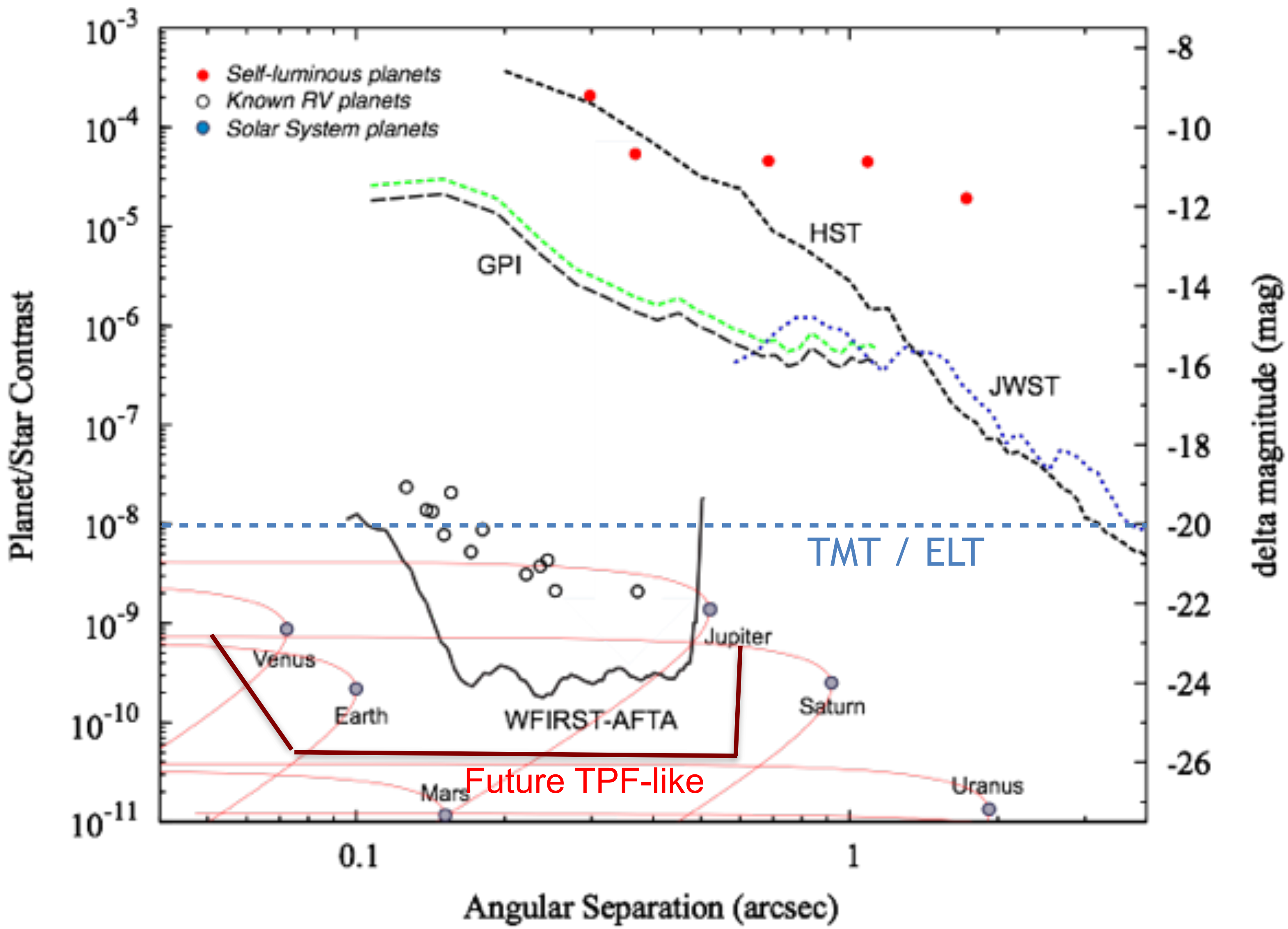
- Spatially resolve 10 zodi debris disks down to 0.5 AU separation

Each of these requires obtaining a very high contrast at a small angular separation.

Complement ground-based, 30-meter class observatories



Bridge the gap to future Earth-finding missions



Challenges

- **Small aperture**

$\lambda/D \sim 40$ mas at 450 nm

—> 0.8 AU at 20 pc

- Pupil obstructions
- Wavefront control
- Long detection times
- Post-processing

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$\lambda/D \sim 40$ mas at 450 nm

—> 0.8 AU at 20 pc

$\lambda/D \sim 80$ mas at 900 nm

—> 1.6 AU at 20 pc

Challenges

- Small aperture
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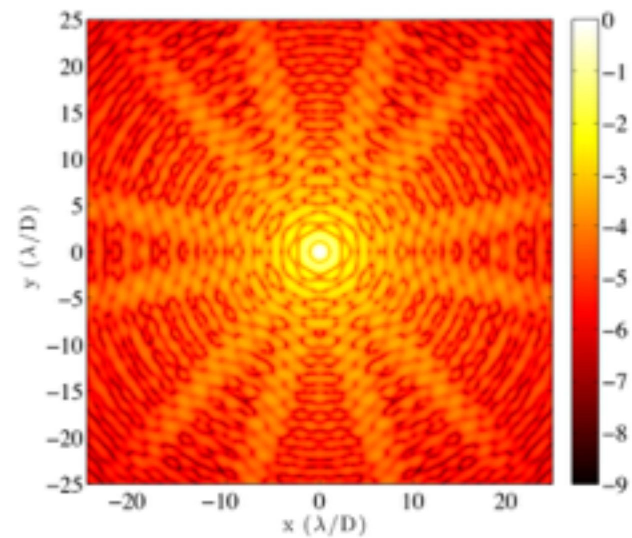
- Post-processing

AFTA pupil

AFTA PSF



Challenges

- Small aperture
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- **Wavefront control**
- Long detection times
- Post-processing

Need to keep phase aberrations stable to within ~ $\lambda/100$

Wavefront estimation with weak signal in "dark hole"

Challenges

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- Post-processing

IFS characterization takes several days per planet

Challenges

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- Wavefront control
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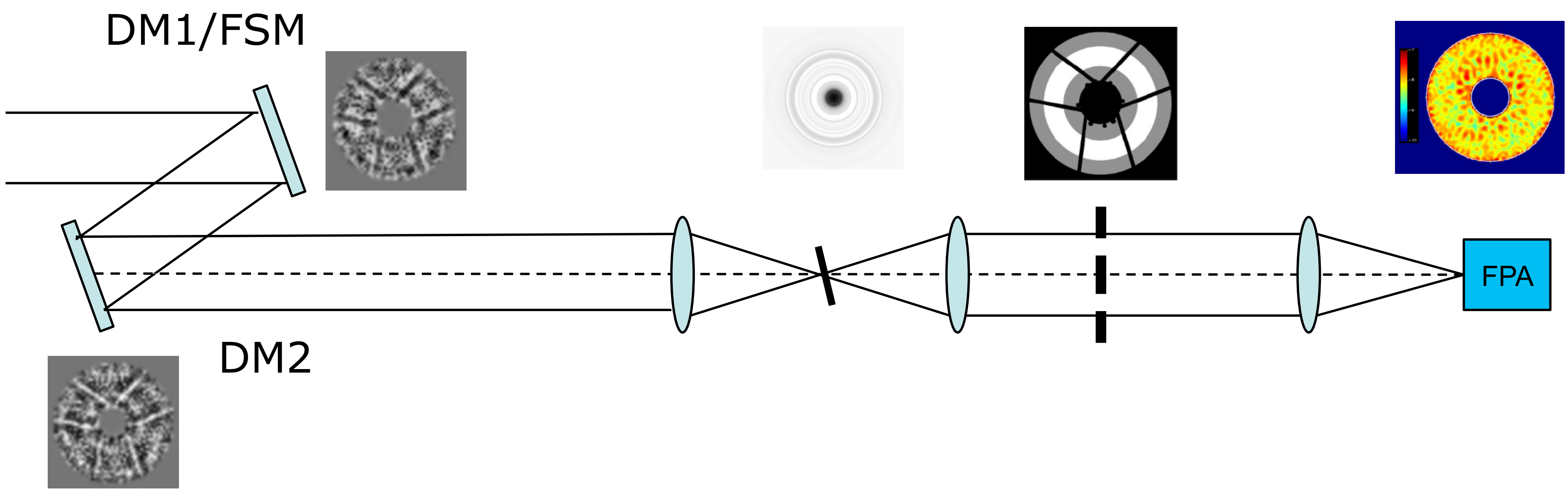
- **Post-processing**

New, untested regime of speckle behavior. How to exploit diversity and build effective reference PSF library?

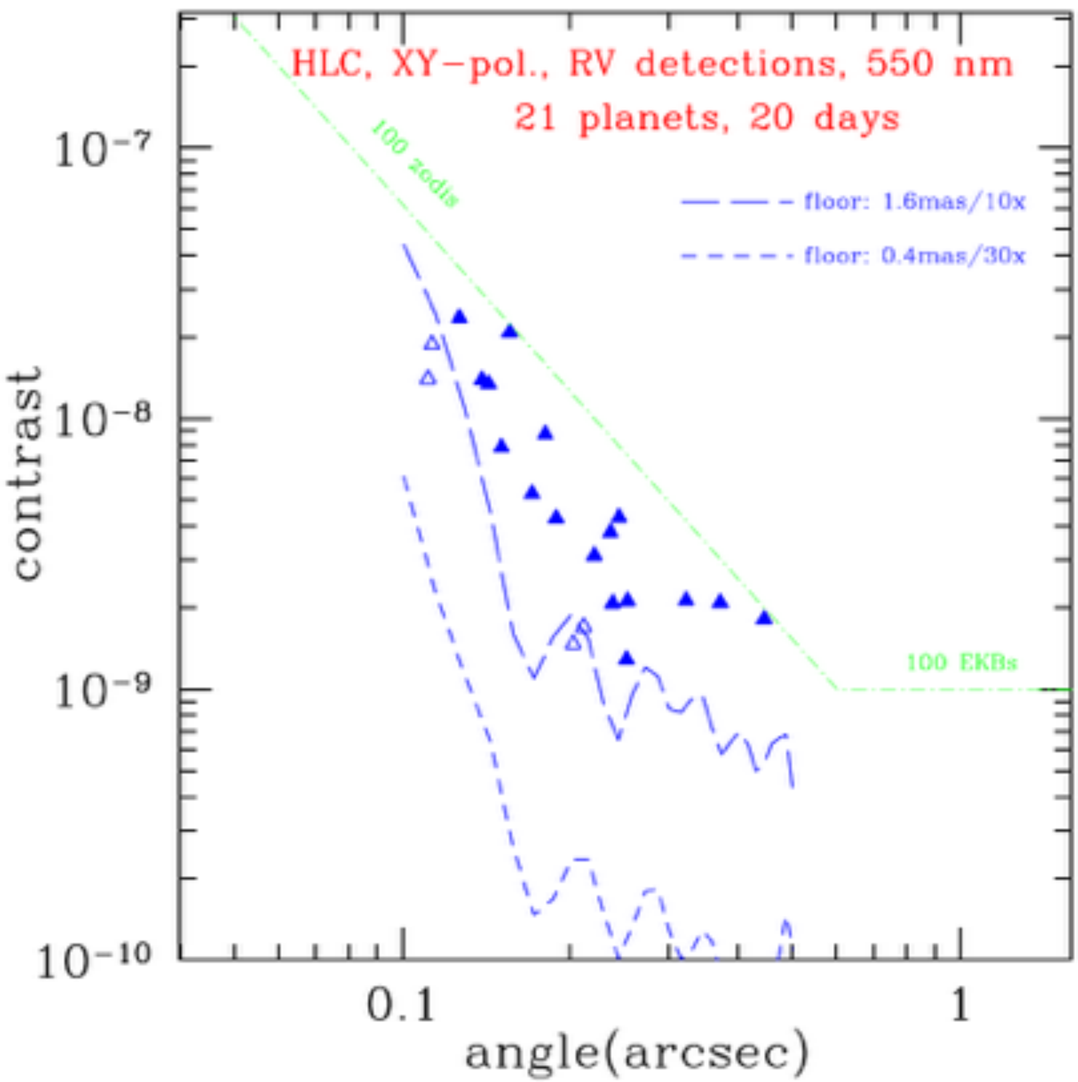
Hybrid Lyot Coronagraph Design

John Trauger and Dwight Moody, JPL

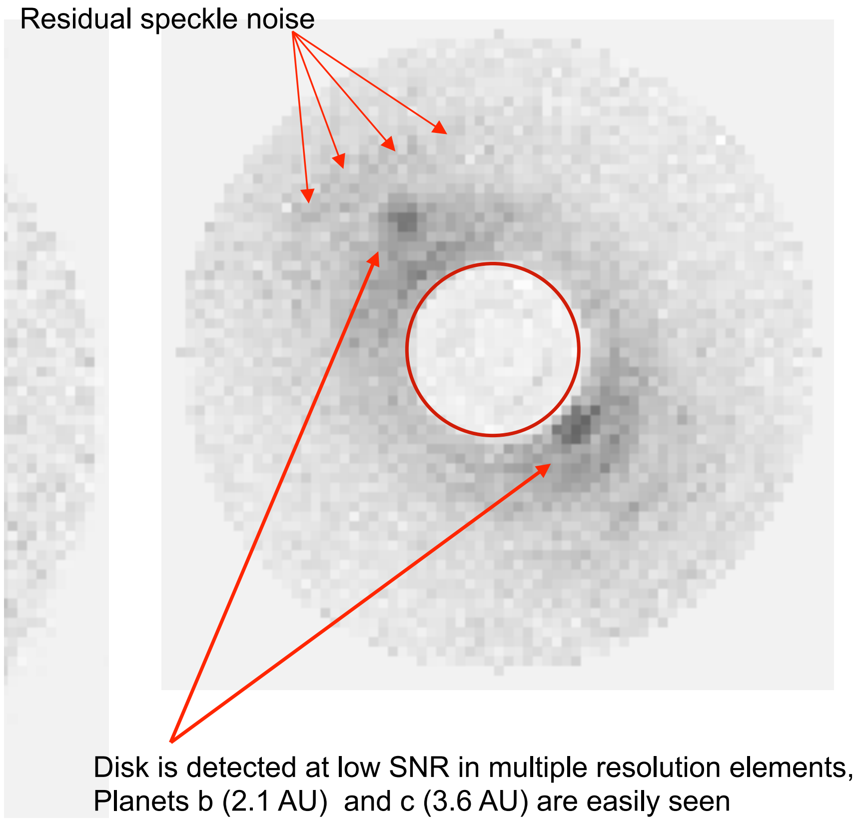


Science yield of HLC in broadband imaging mode

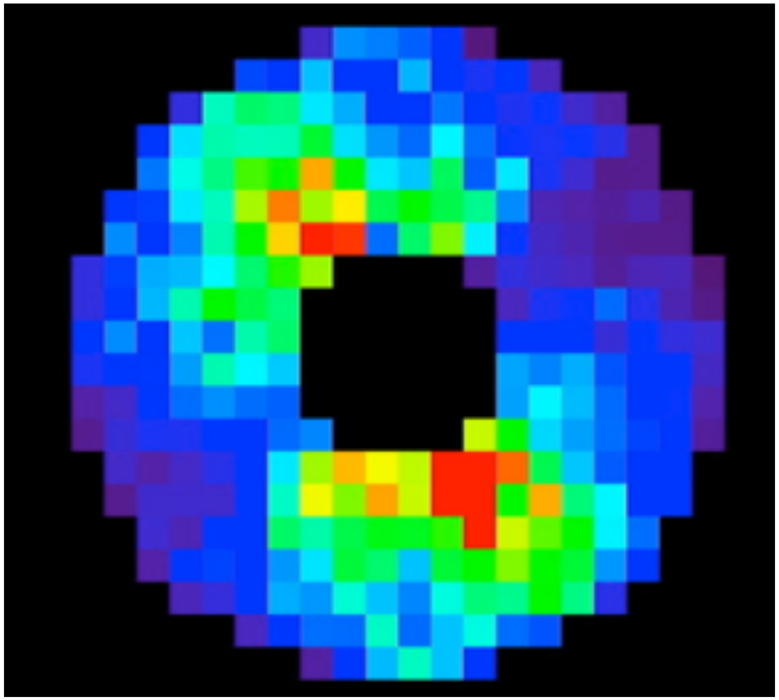
by Wes Traub, JPL



Simulated observation: 47 UMa + 30 Zodi disk



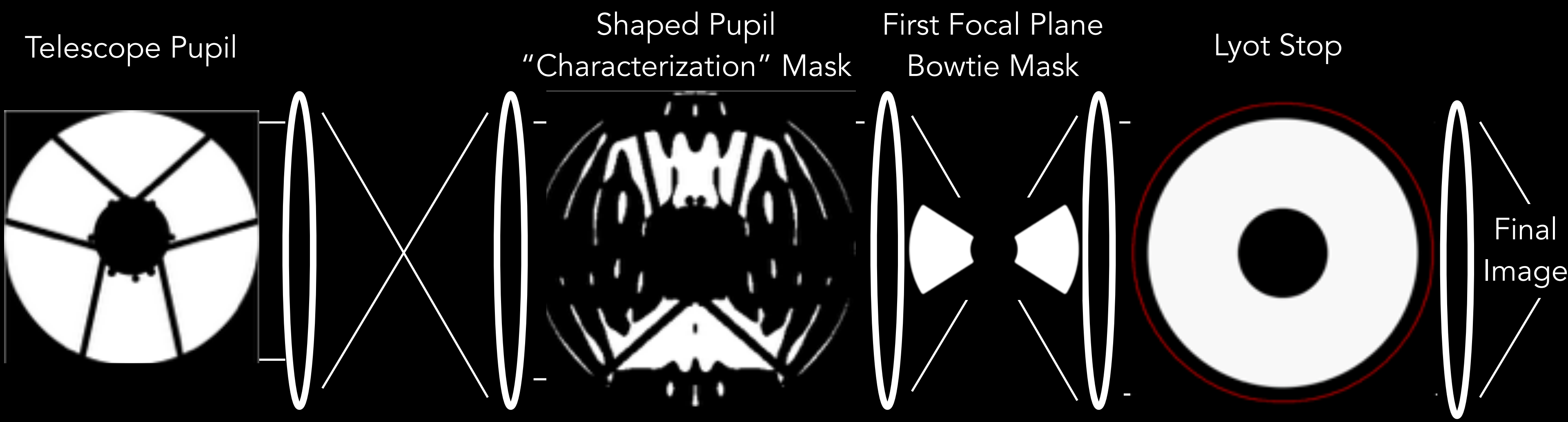
PSF-subtracted image



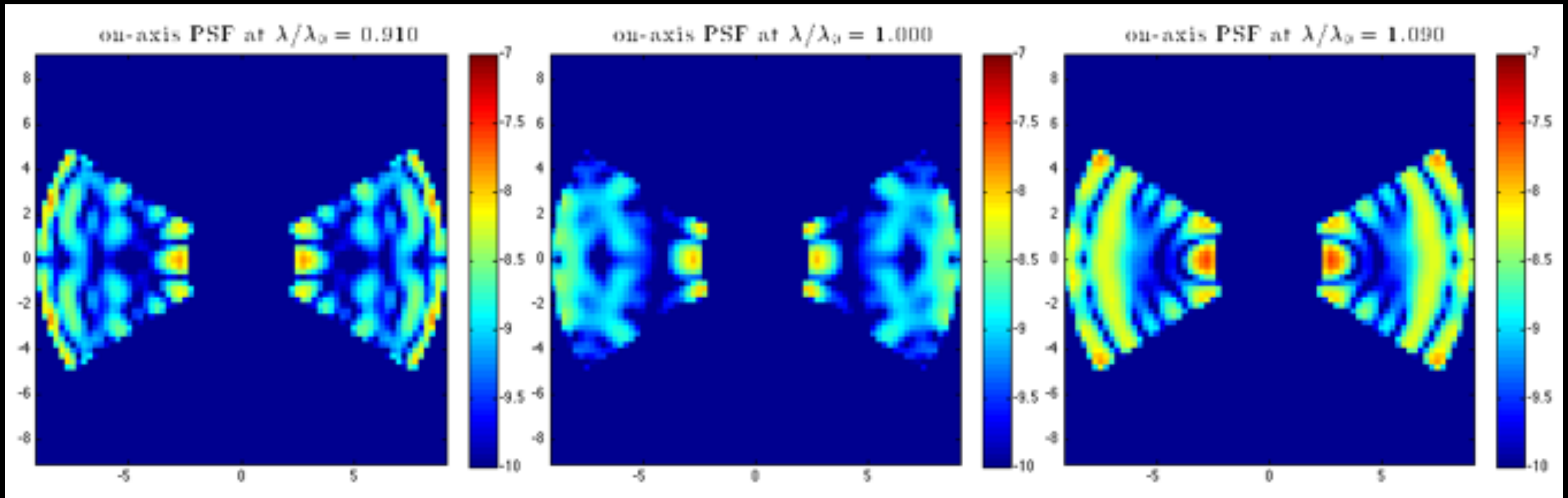
Binned SNR map of disk (peak SNR=15)

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

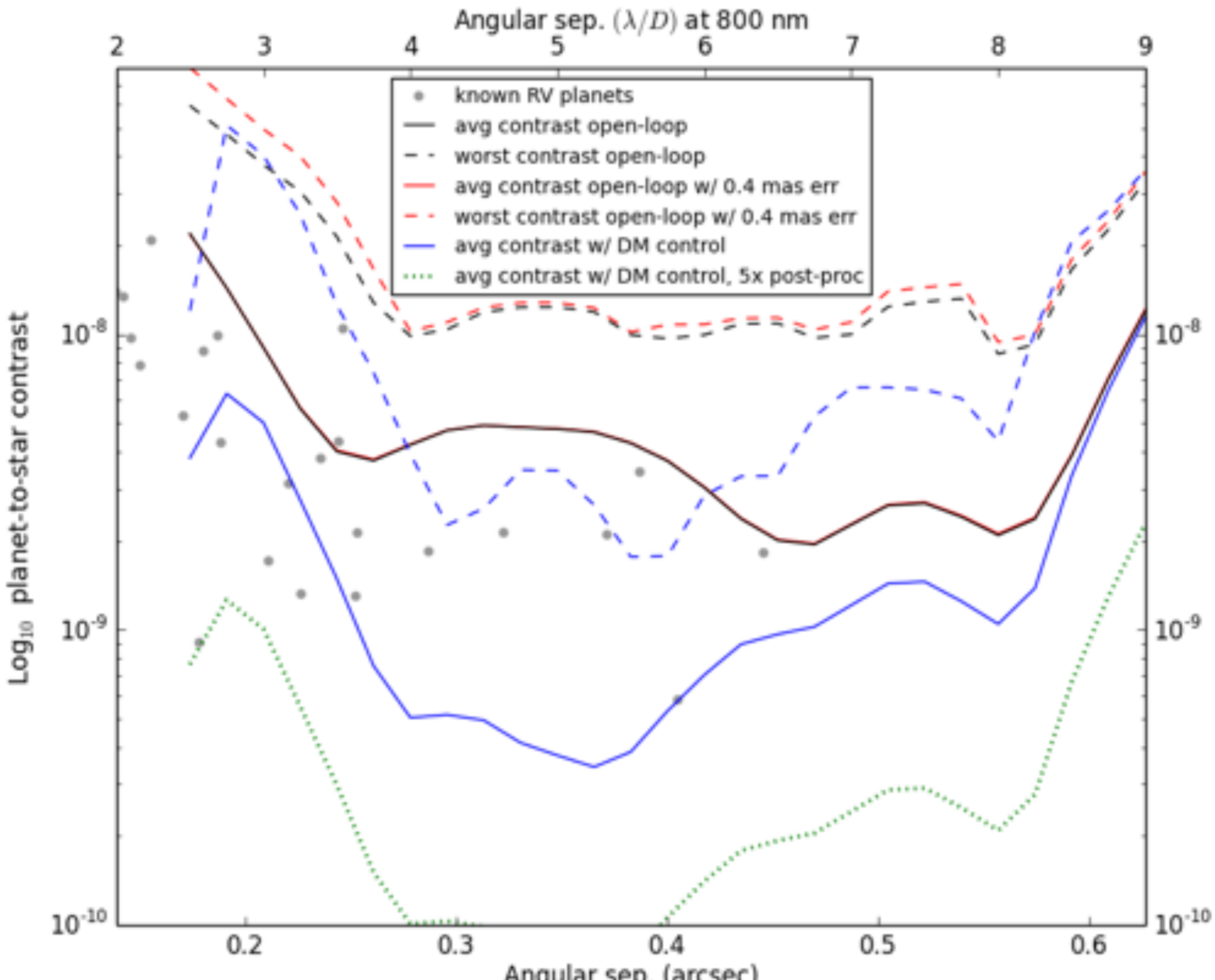
Shaped pupil coronagraph for spectroscopic characterization



Contrast in final image, closed loop



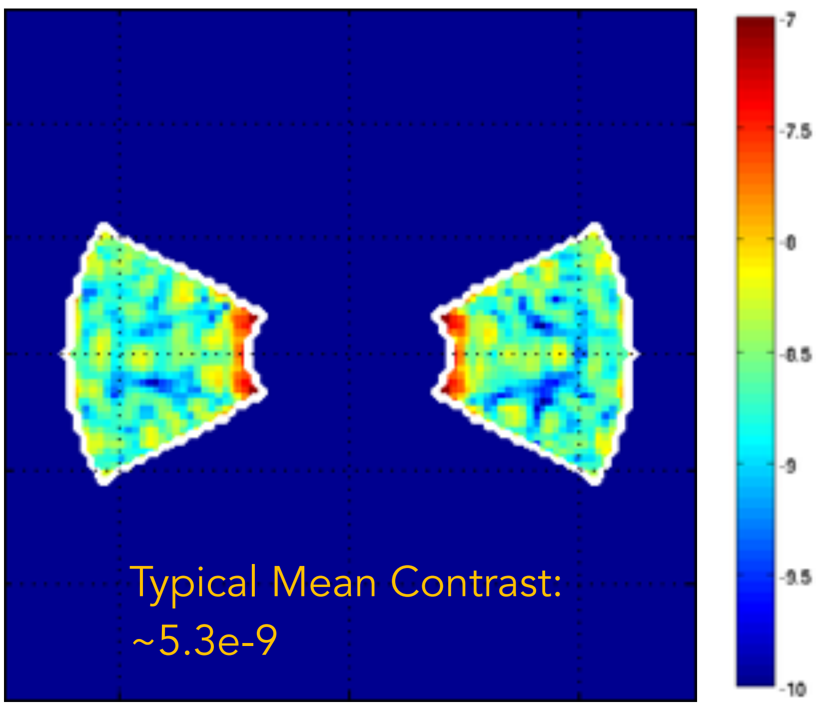
Simulated broadband SPC characterization mask performance



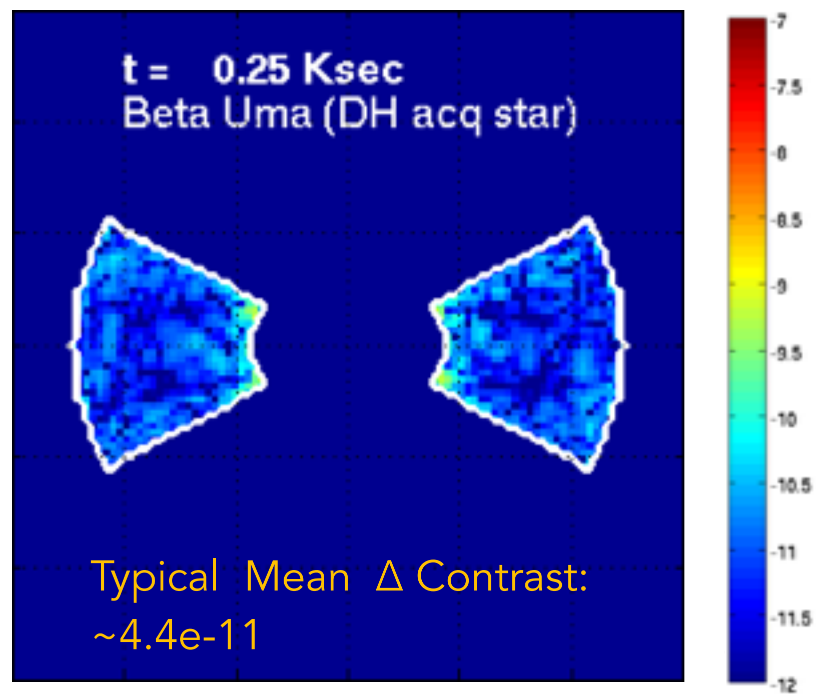
Simulations by JPL show that AFTA wavefront is robust to thermal scenarios

- 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

Raw speckle, S(t)



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



Conclusions

- Teams at JPL, AMES, Princeton, and U. Arizona have converged on designs that solve an array of engineering obstacles for the WFIRST coronagraph.

- Laboratory verification, and end-to-end instrument modeling are in full swing.

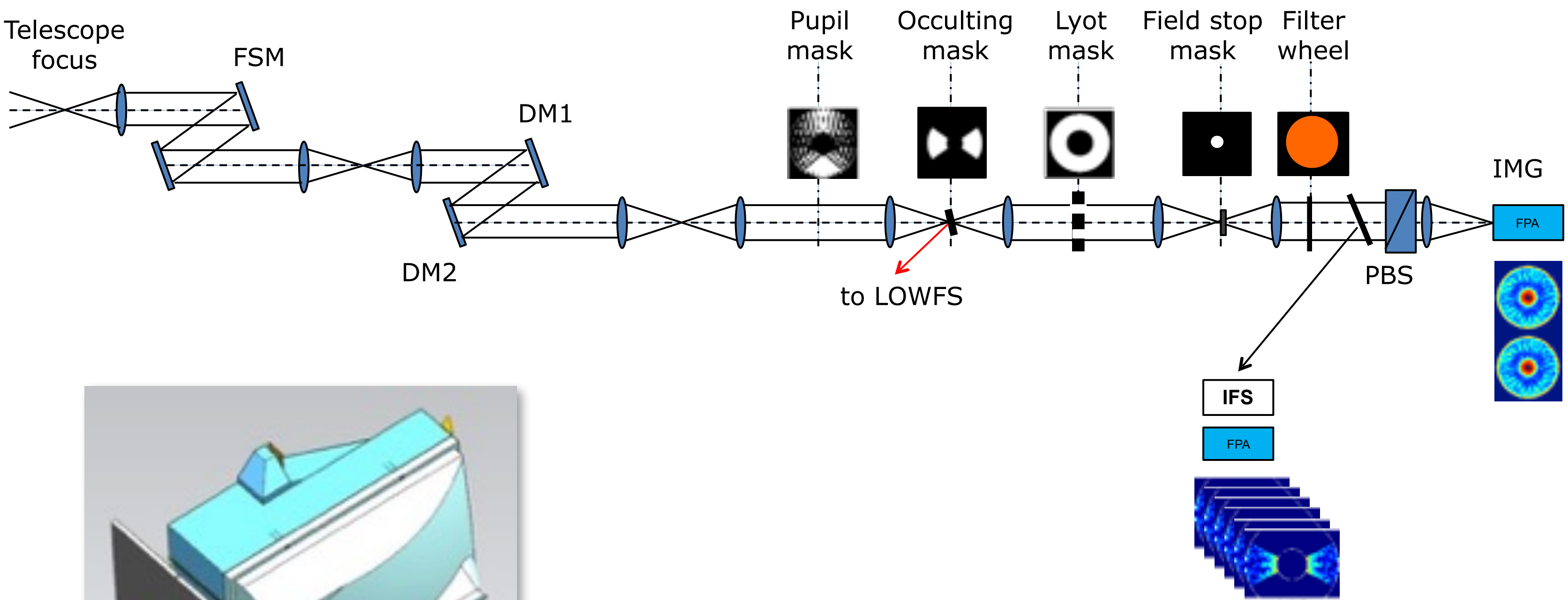
Backup slides

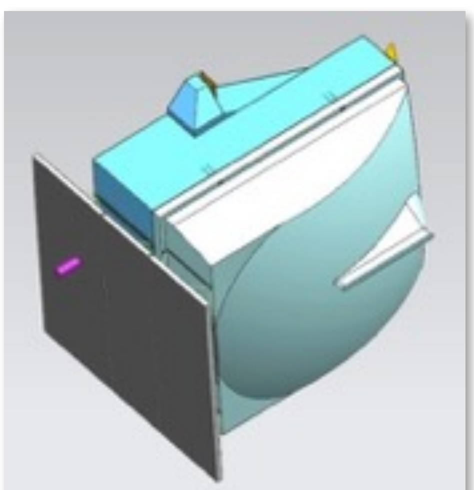
Coronagraph architecture

Baseline coronagraph architecture is flexible combination of hybrid Lyot coronagraph and shaped-pupil apodizer

Shaped Pupil mode

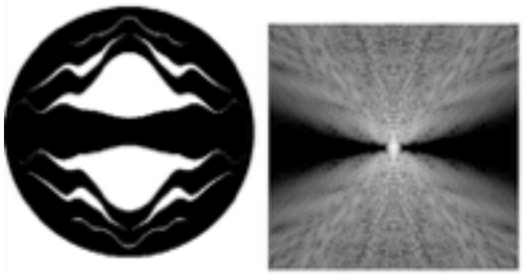
Hybrid Lyot mode





Coronagraph selection based on maturity, robustness, flexibility

SPC



Pupil Masking (Kasdin, Princeton University)

HLC

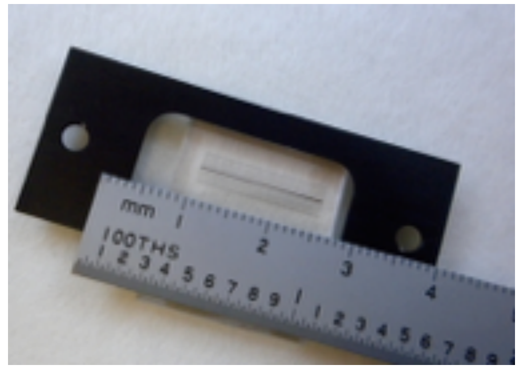
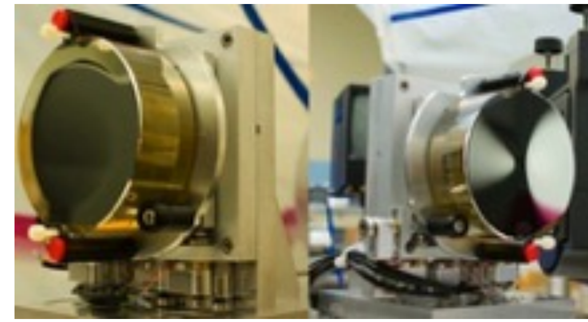


Image Plane Amplitude & Phase Mask (Trauger, JPL)

PIAACMC



Pupil Mapping (Guyon, Univ. Arizona)

VVC

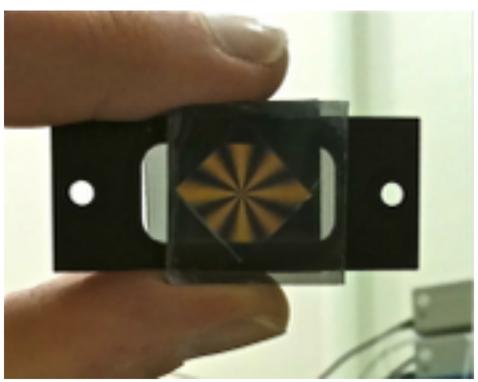
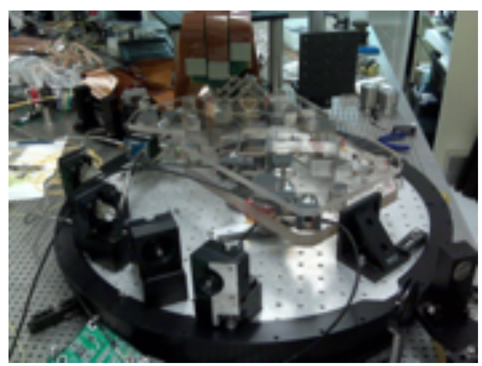


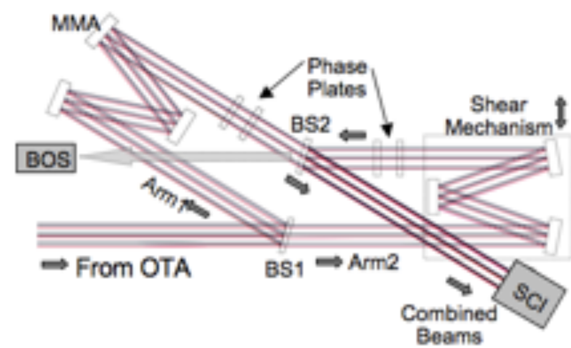
Image Plane Phase Mask (Serabyn, JPL)

VNC - DAVINCI



Visible Nulller - DAVINCI (Shao, JPL)

VNC-PO



Visible Nuller – Phase Occulting (Clampin, NASA GSFC)

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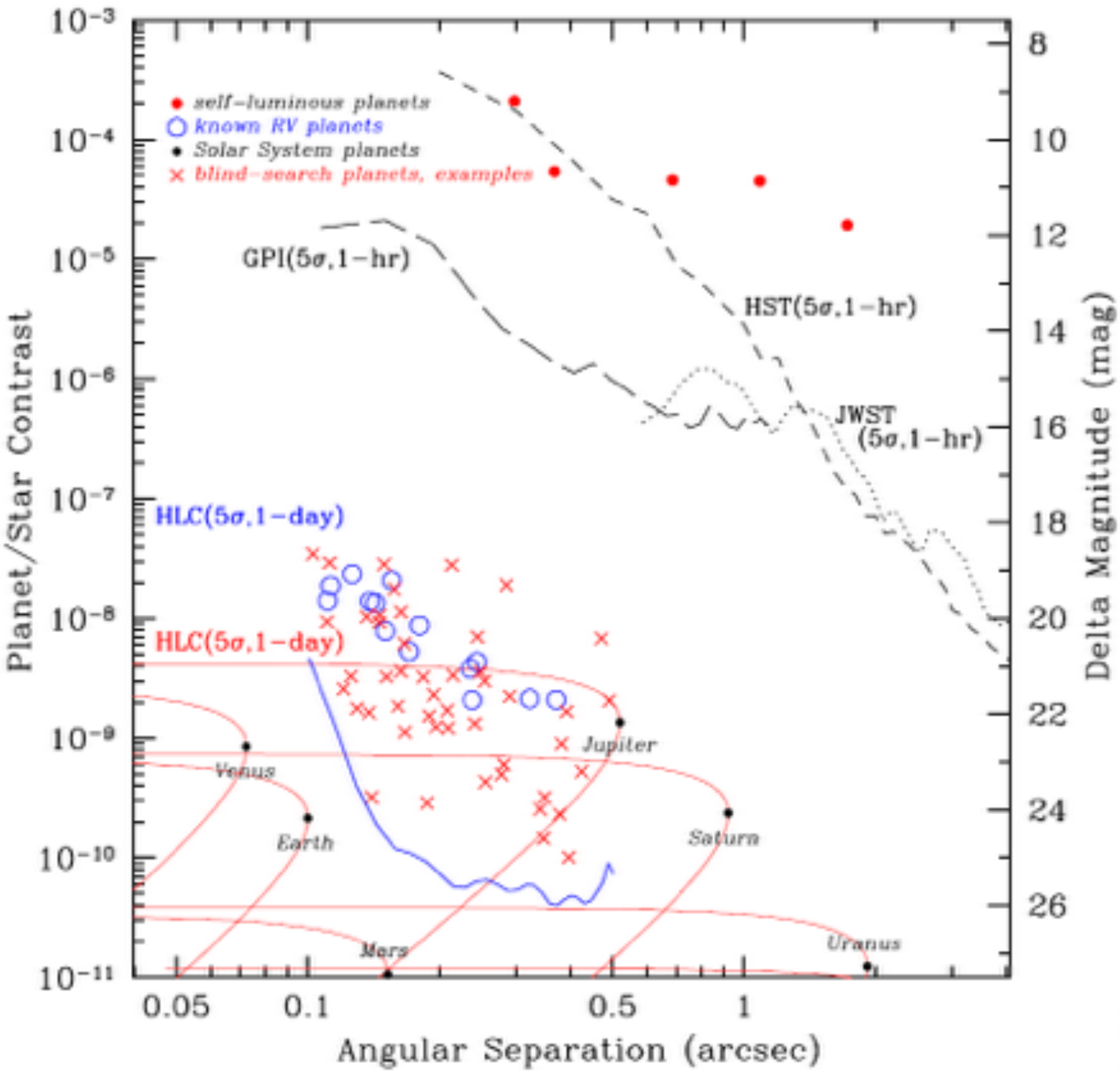
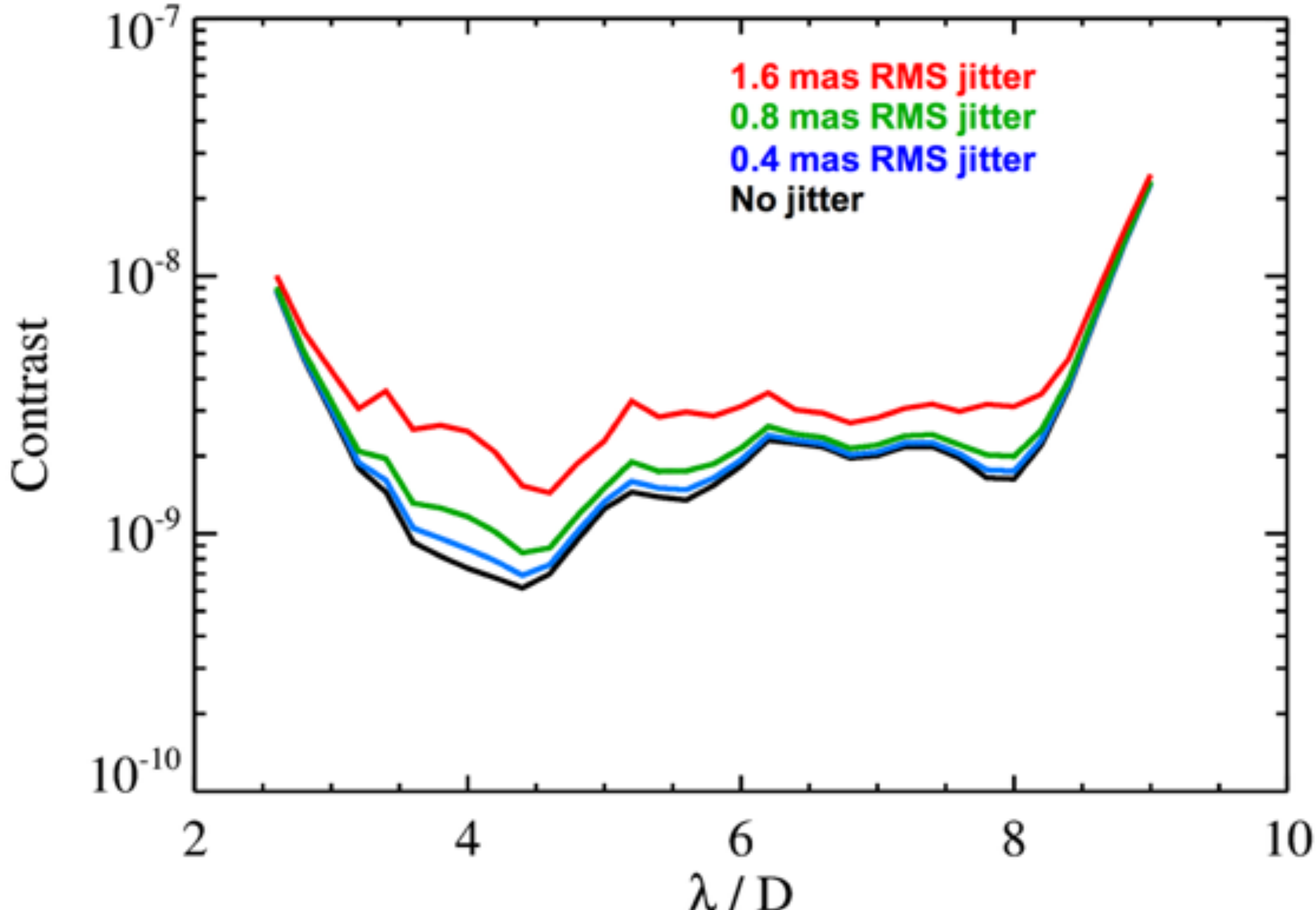


Simulations show e.g. robust performance against jitter

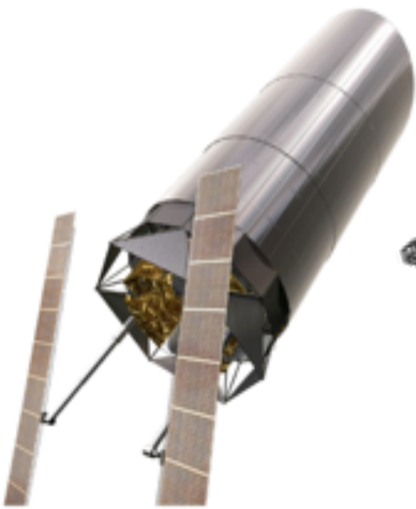


728 – 872 nm

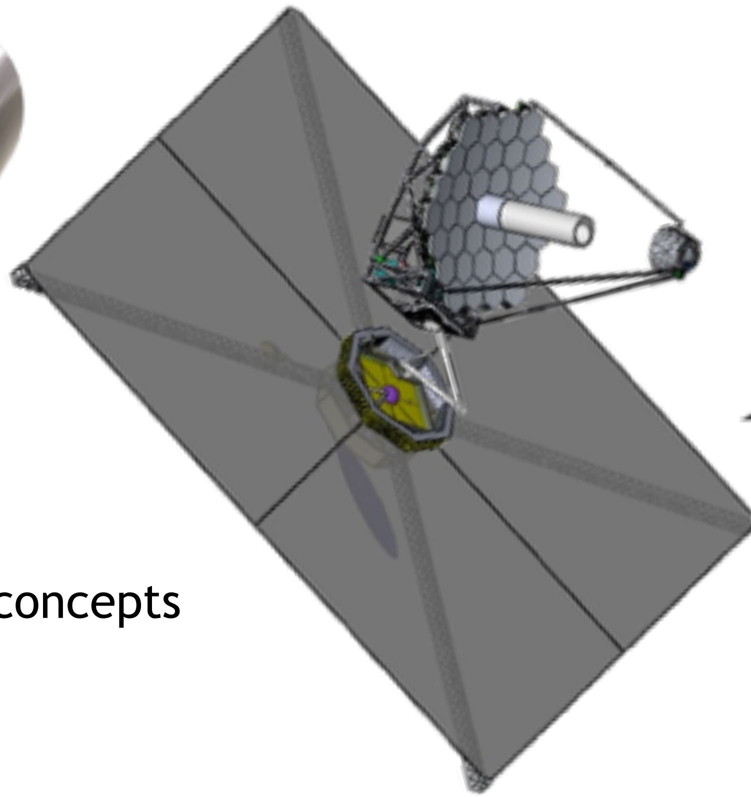
Jitter levels shown here are after coronagraph fast tip/tilt

Future space coronagraphs will likely be multipurpose missions

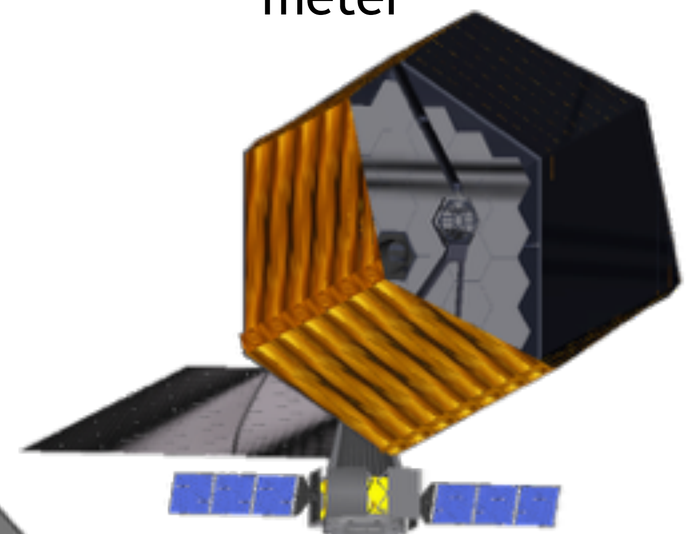
8-
meter



9.2-meter



16.8-
meter



ATLAST / UVOIR concepts