National Aeronautics and
Space Administration

HABITABLE WORLDS OBSERVATORY

The Roman and HWO Coronagraphs

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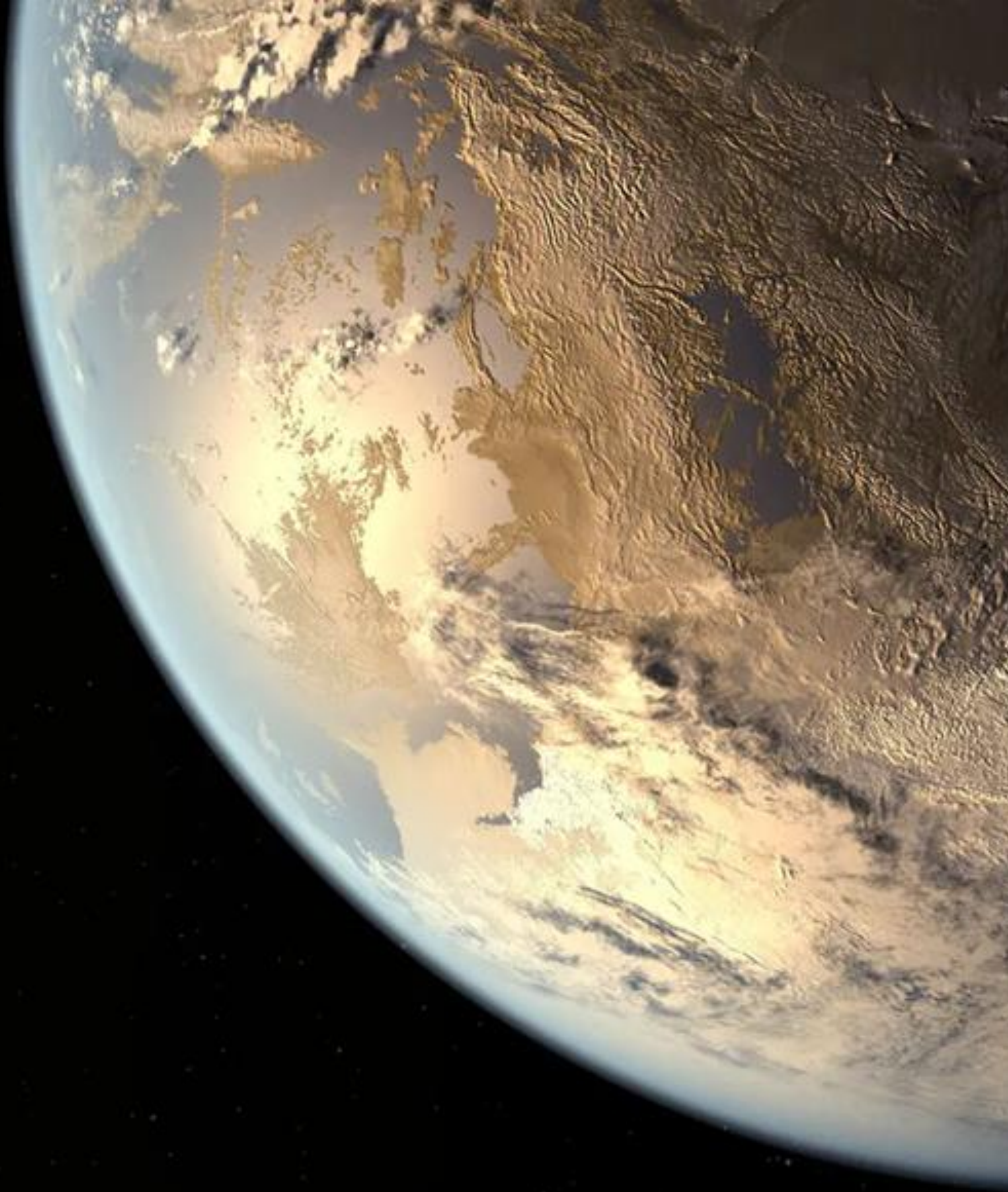
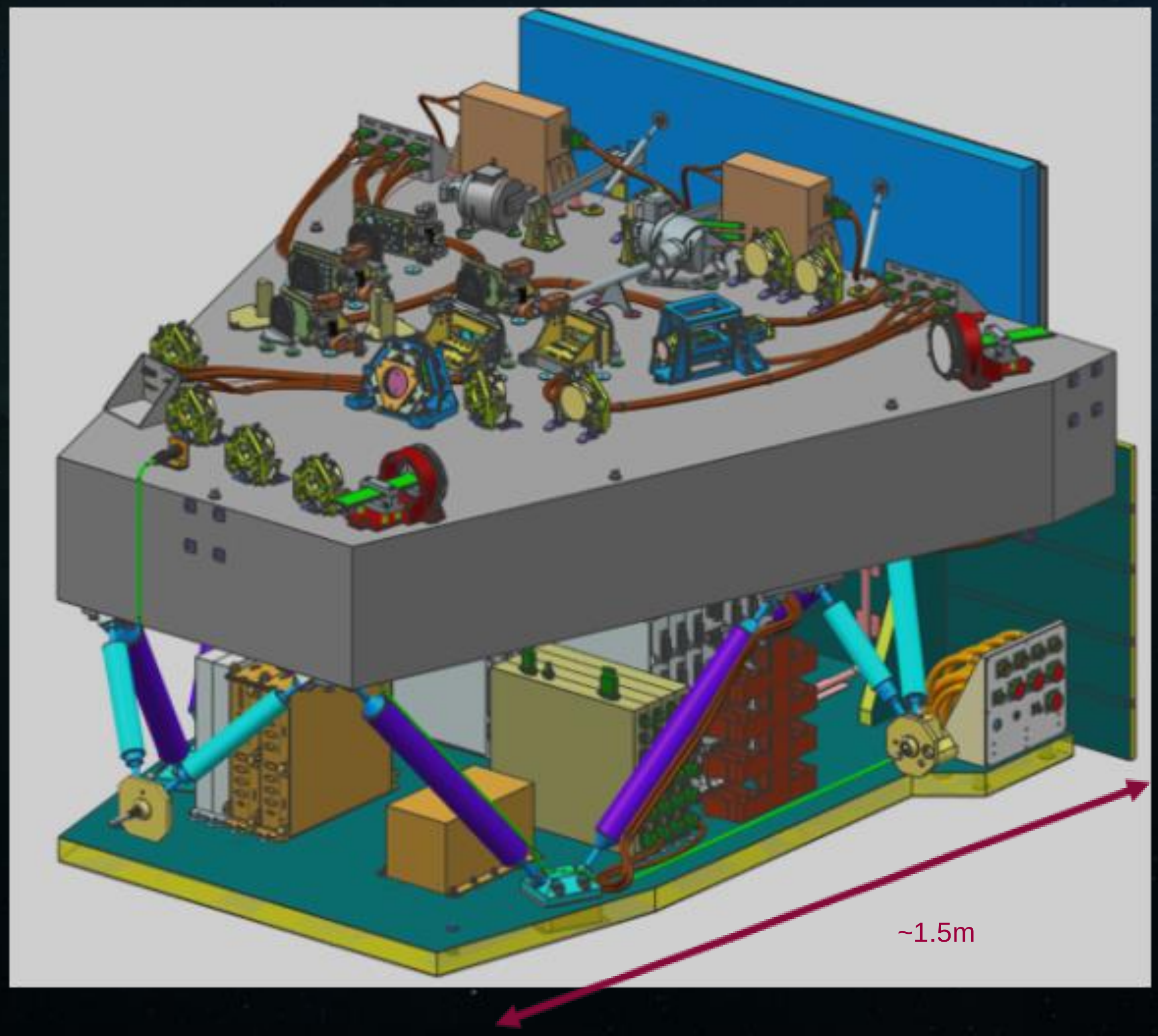
Habitable Worlds Observatory Special Session
AAS Meeting # 245, January 15, 2025



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 Roman Coronagraph Instrument in a Nutshell

- A visible-light, high-contrast "**technology demonstration**" instrument for HWO
- The first space-based coronagraph with active wavefront control
- A visible light (545-865nm) imager, polarimeter, and R~50 slit spectrograph
- Requirement: 10^{-7} flux ratio 5σ detection limit at $6\lambda/D$ in a single photometric band
- Designed to outperform requirement
- Predicted performance ≥4x beyond req
  - Based on end to end performance testing



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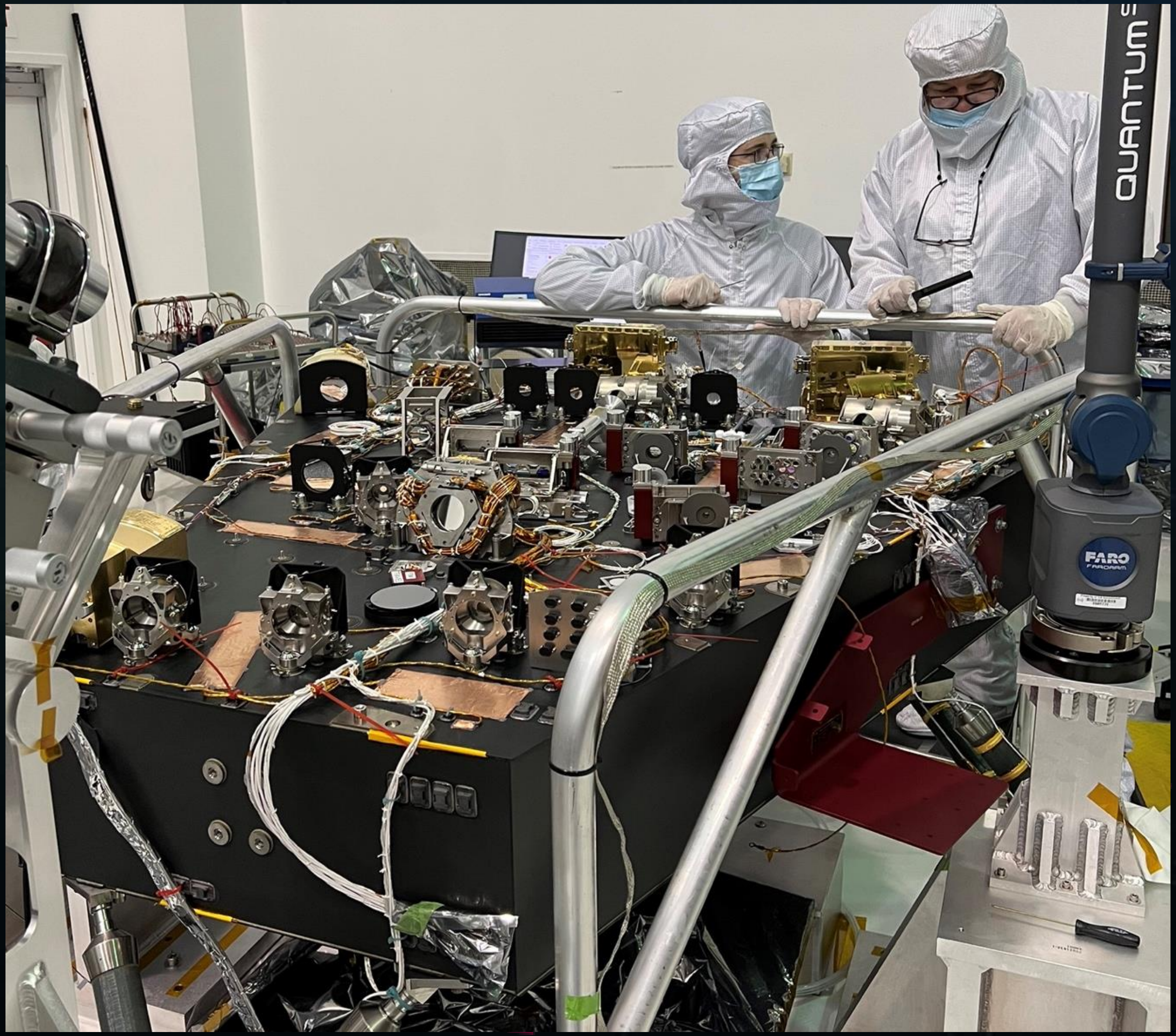
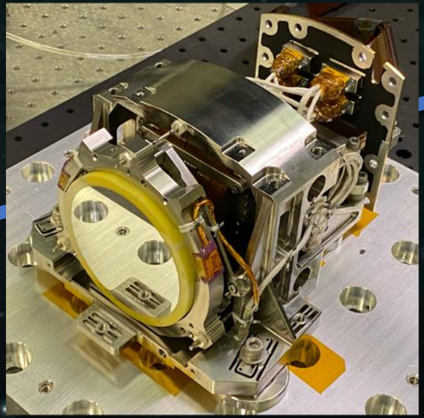


Aligned optical bench during I&T, JPL Jan 2024

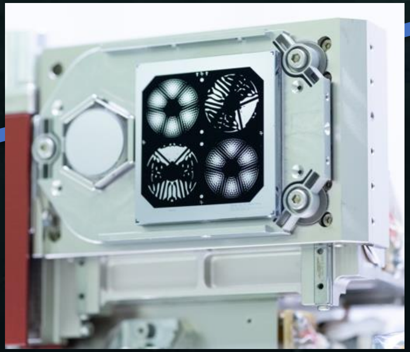
The Roman Coronagraph includes most of the key functionalities and subsystems anticipated for HWO's coronagraph(s)

Ultra-Precise Wavefront Sensing & Control

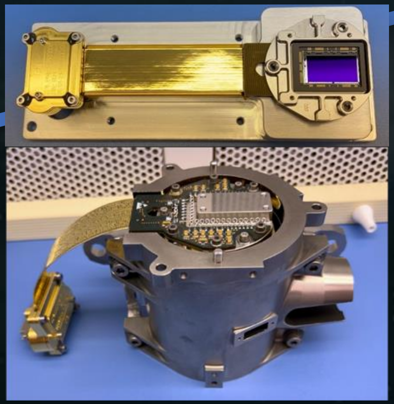
Large-Format Deformable Mirrors



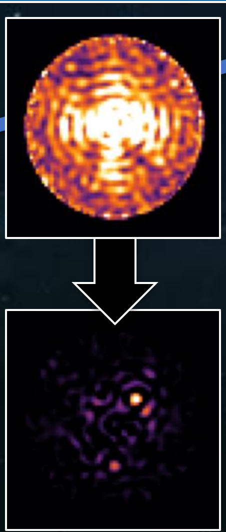
High-Contrast Coronagraph Masks



Ultra-Low Noise Photon Counting Detectors

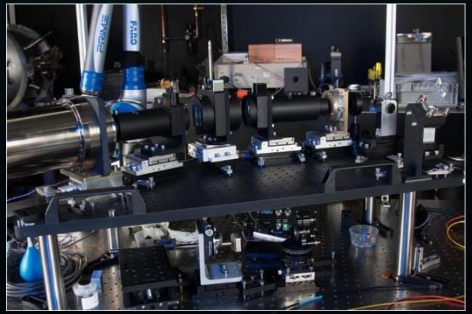


High Contrast Data Processing



HWO

IFS / MOS

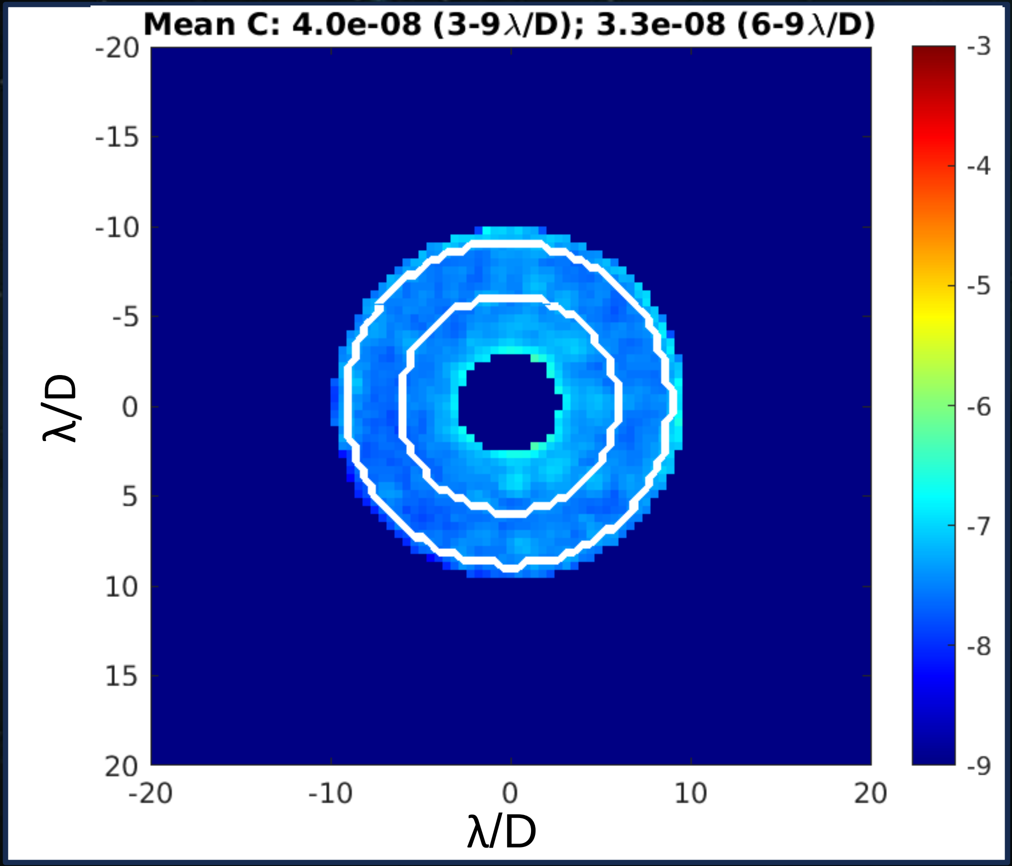


Exceptions: multi-planet spectroscopy, dichroic and polarization splitters

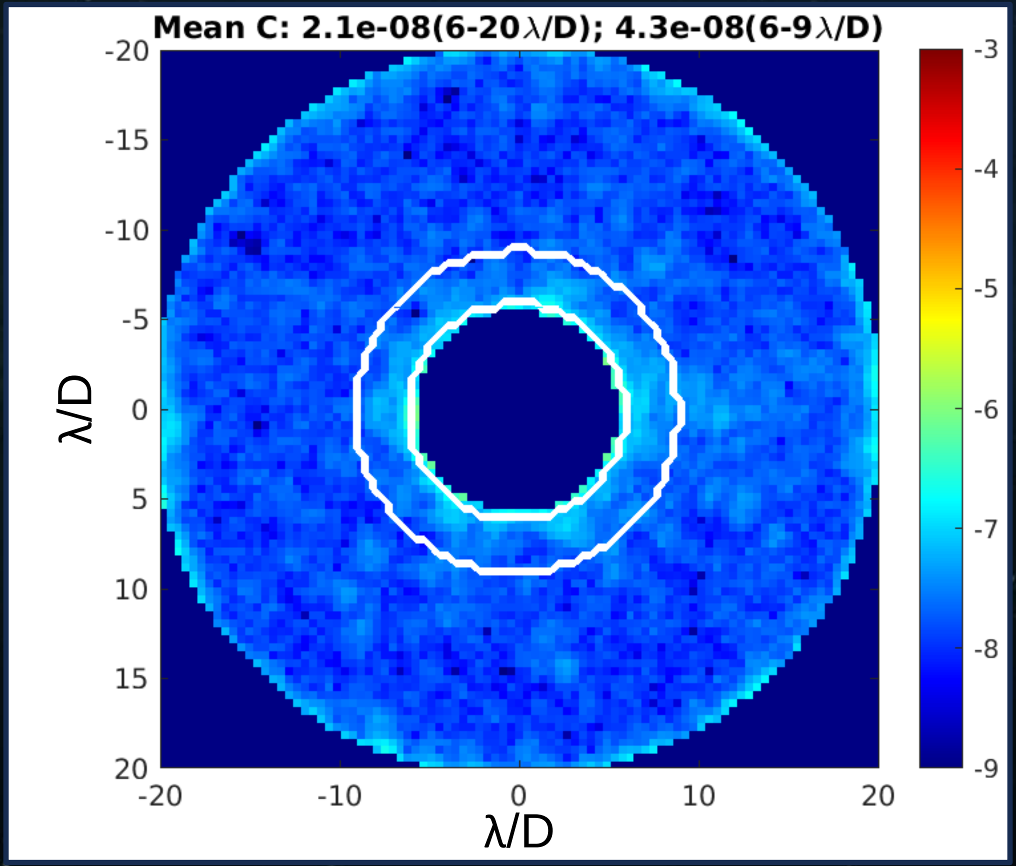
(as required to get simultaneous spectra of multiple planets at different wavelengths & polarization states with HWO)

Roman Coronagraph TVAC Raw Broadband Contrast Results (Dual polarization, 10% BW around 575 nm)

Narrow Field-of-View (Hybrid Lyot)



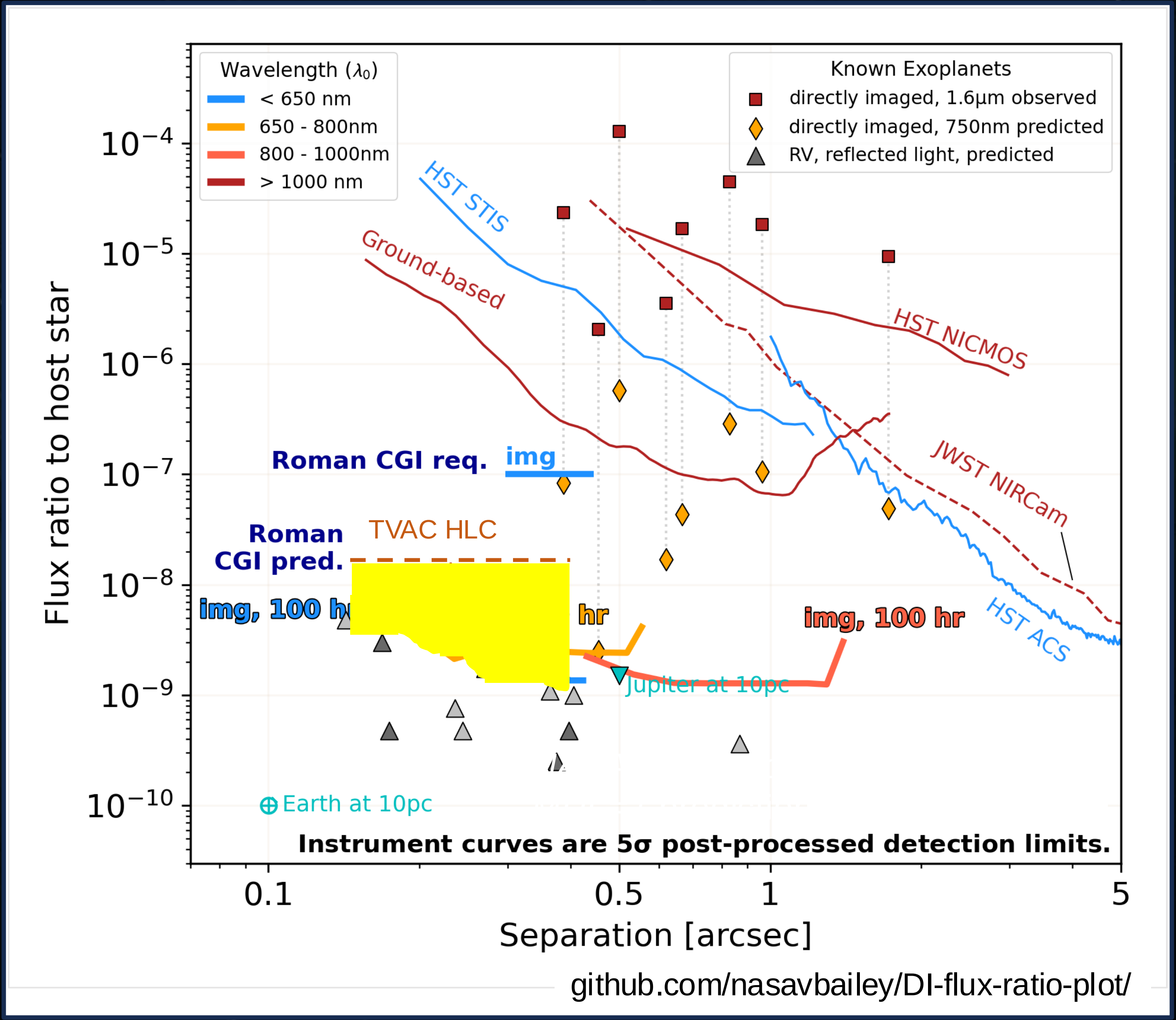
Wide Field-of-View (Shaped Pupil)



- Contrast not at a hard physical limit: Stopped after meeting requirements with margin and running out of allocated time

Credit: Eric Cady *(lead), Byoung-Joon Seo, A. J. Riggs, Brian Kern, David Marx, Fang Shi, Hanying Zhou, John Krist, Garreth Ruane*

The big picture of CGI's technical and scientific relevance to HWO

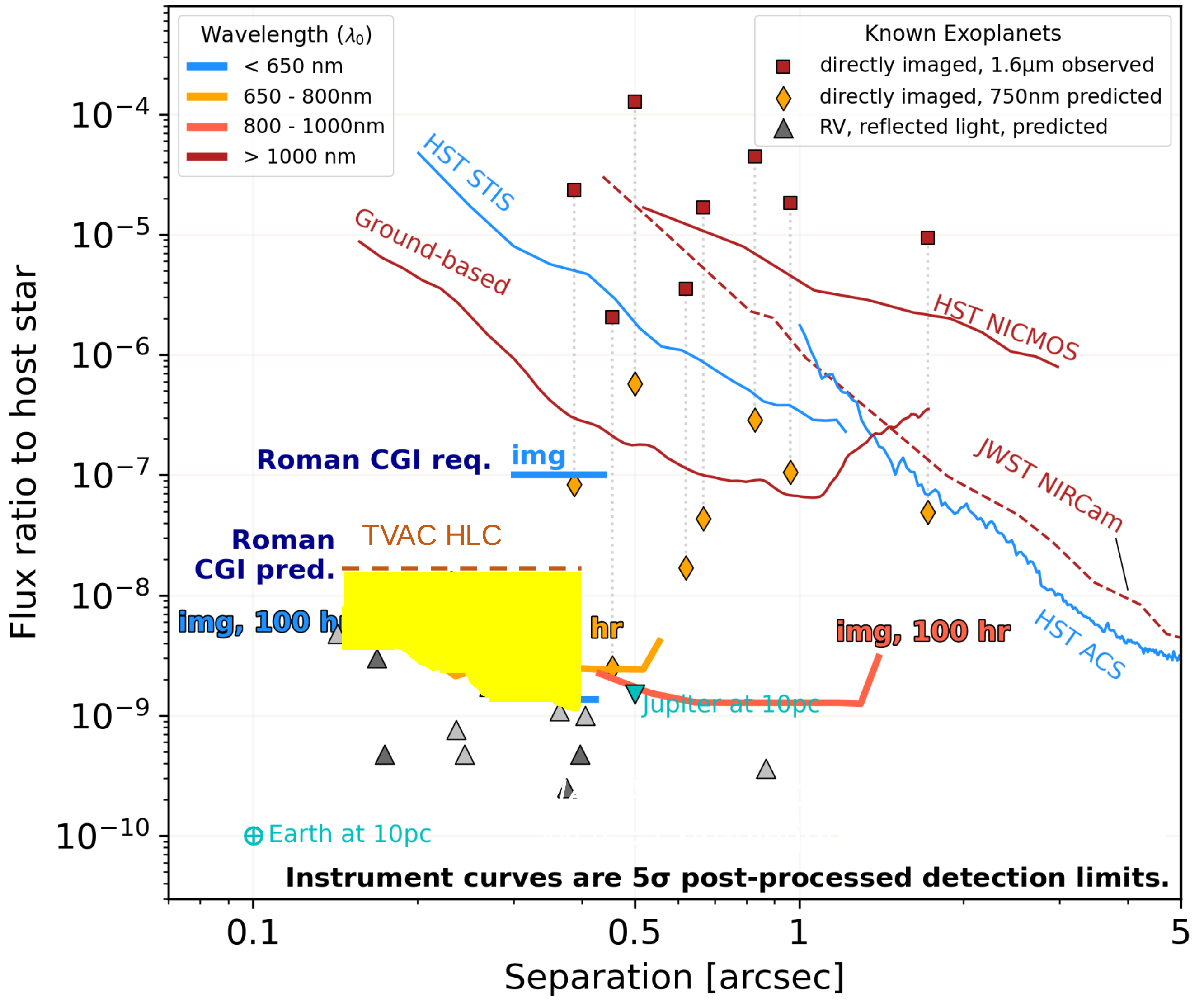


Technology:

- Predicted detection limit 100-1000x better than current capabilities
- Will test speckle calibration methods applicable to HWO (ADI, RDI) in a relevant contrast regime
- Still 10-100x away from HWO detection limits needs
- But most functionalities and subsystems with predicted performance in family with HWO's technical needs
- Ultimate contrast performance limited by heavily obscured telescope geometry rather than by coronagraph itself or the exquisite telescope stability

See Mennesson et al. 2020 for more details https://arxiv.org/pdf/2008.05624

The big picture of CGI’s technical and scientific relevance to HWO



github.com/nasavbailey/DI-flux-ratio-plot/

Science:

- Will barely skim the top of the exoplanet population around ***mature*** stars
- But capable of detecting habitable zone exozodiacal dust at low enough density levels to inform HWO’s target list and architecture

Mennesson et al. 1997, 2010, 2018, 2019, Beichman et al. 1997, Defrère et al. 2010, Douglas et al. 2022

Roman Telescope and Coronagraph Integrated, Dec 2024

HWO Coronagraph(s) Architecture Exploration

- HWO Science Working Groups and Project Science team are still gathering the full breadth of exoplanet science objectives

- Will next quantify implications for HWO's coronagraph(s) observational requirements ("DISRA")

- Will explore:
  - Coronagraph instruments covering the visible (~0.35 to ~1um) and near infrared ranges (~1 to ~1.7um)
  - High contrast near UV instrument (~0.25 to ~0.35 um), either a coronagraph or starshade

- HWO key differences from the Roman coronagraph:
  - Even higher contrast ~10^{-10} vs ~10^{-8} detection limits
  - Integral field spectroscopy capability
  - Probably multiple parallel channels

- On-going HWO coronagraph architecture exploration trades and parameter studies include:
  - Coronagraph key performance parameters
    - e.g., raw contrast, detection floor, core throughput, outer working angle, bandpass, see Mennesson et al. 2024, JATIS
  - Optimal coronagraph masks per telescope aperture geometry
  - Simultaneous channels with dichroic and/or polarization beam splitters
  - Spectroscopy spectral resolution
  - Coronagraph concept of operations and post processing techniques
  - ***Telescope Aperture Geometry***

HWO Coronagraph Architecture Exploration: looking at different notional telescope designs

- Roman coronagraph main performance limitation is the entrance aperture, which could not be changed

- HWO coronagraph performance improvement over Roman's will come from the joint optimization of the telescope and coronagraph, the overall *starlight suppression system*

→ *Exploring different types of segmentation (hexagons vs keystones) and aperture (off-axis vs on-axis)*