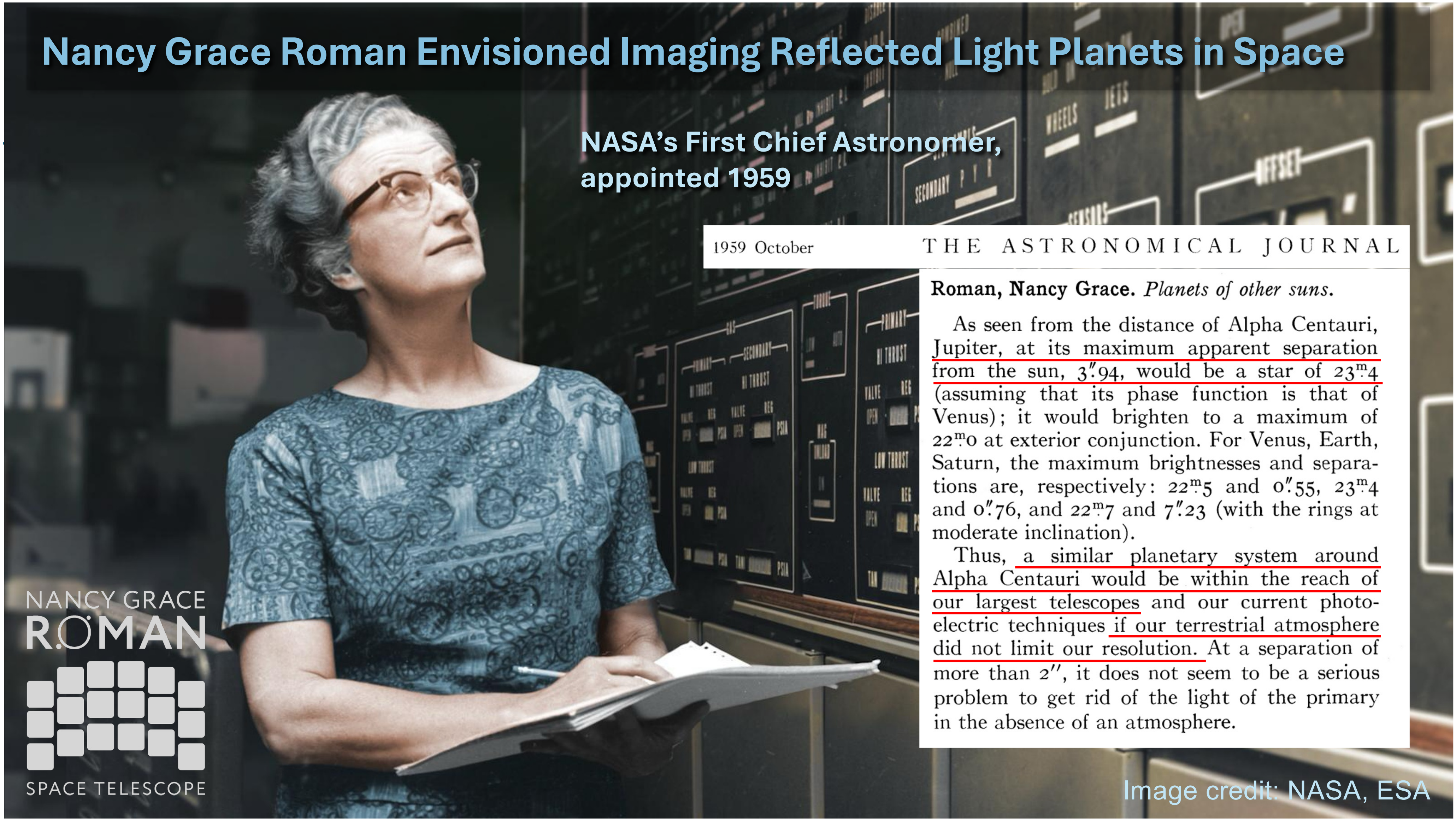
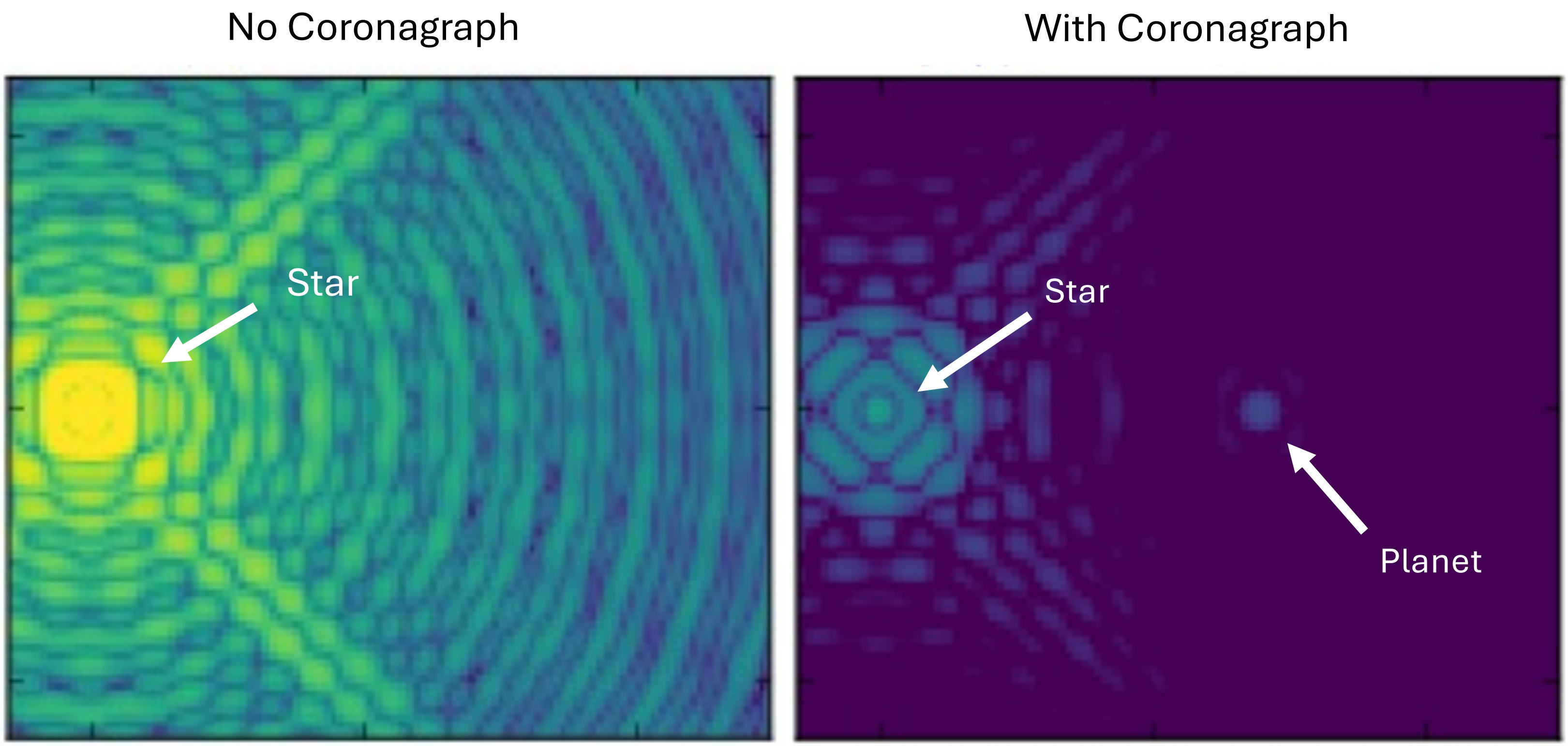
The Roman Coronagraph Instrument

Pathway to Imaging Reflected Light Planets and Habitable Worlds

Jason Wang, on behalf of the Roman Coronagraph Team


Nancy Grace Roman Envisioned Imaging Reflected Light Planets in Space
NASA's First Chief Astronomer, appointed 1959
1959 October
THE ASTRONOMICAL JOURNAL
Roman, Nancy Grace. *Planets of other suns.*
As seen from the distance of Alpha Centauri, Jupiter, at its maximum apparent separation from the sun, $3''.94$, would be a star of $23^{m}.4$ (assuming that its phase function is that of Venus); it would brighten to a maximum of $22^{m}.0$ at exterior conjunction. For Venus, Earth, Saturn, the maximum brightnesses and separations are, respectively: $22^{m}.5$ and $0''.55$, $23^{m}.4$ and $0''.76$, and $22^{m}.7$ and $7''.23$ (with the rings at moderate inclination).
Thus, a similar planetary system around Alpha Centauri would be within the reach of our largest telescopes and our current photoelectric techniques if our terrestrial atmosphere did not limit our resolution. At a separation of more than $2''$, it does not seem to be a serious problem to get rid of the light of the primary in the absence of an atmosphere.
NANCY GRACE ROMAN
SPACE TELESCOPE
Image credit: NASA, ESA

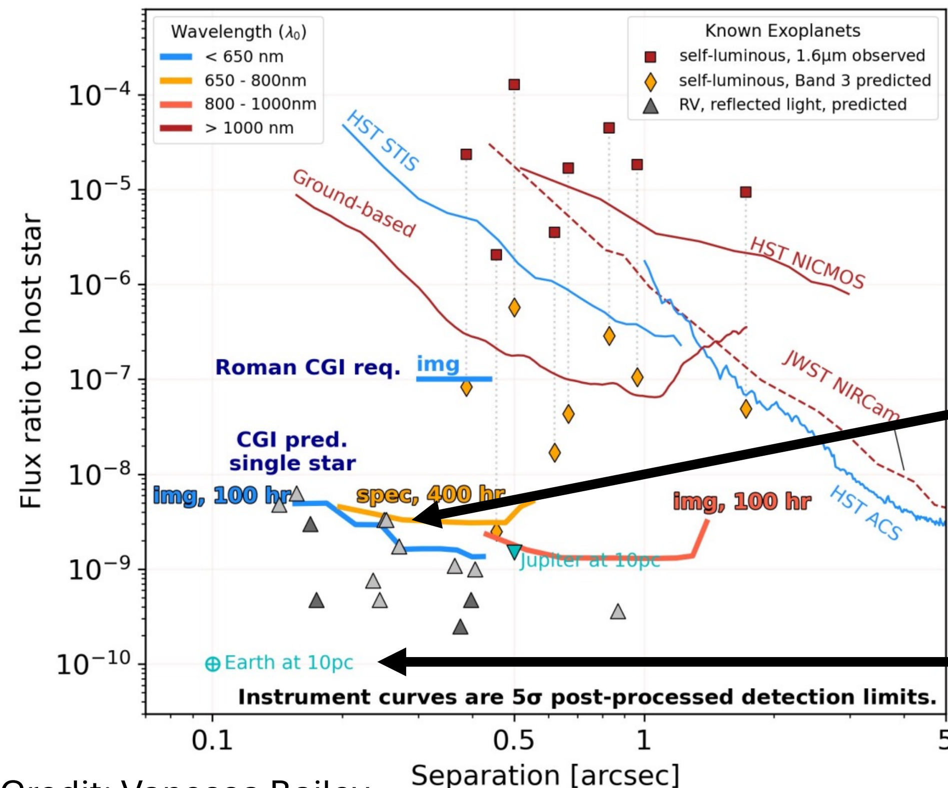
Imaging Planets Requires Suppressing Diffraction



Credit: Rob De Rosa

Towards Imaging of Habitable Worlds

Orders of Magnitude Improvement in Sensitivity



Credit: Vanessa Bailey

Roman Coronagraph

(Performance Limited by Telescope Architecture)

Roman COROnaGraph Instrument Overview

(capitalization and coloring is Jason's personal choice)

Visible Light
550 – 875 nm

Top goal is technology demonstration, but pick scientifically interesting targets when possible

~2200 hours (3 months) of observations in the first 18 months of Roman

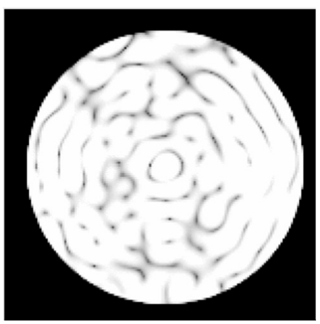
Not the logo

"Dark hole digging" to reach 10^{-7} (req) to 10^{-9} (goal) contrast

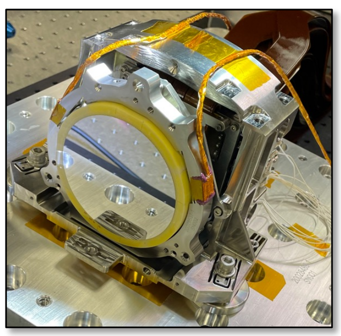
Novel coronagraphs, wavefront control, photon-counting detectors

Roman Coronagraph Will Demonstrate Key Technologies for Exo-Earth Imaging

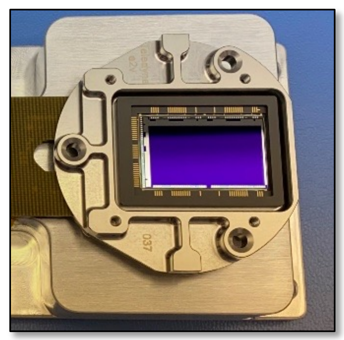
Dark Hole Digging with Ultra-Precise (~10pm RMSE goal) Wavefront Sensing and Control



Large-format (48x48) Deformable Mirrors with ~10pm stroke resolution

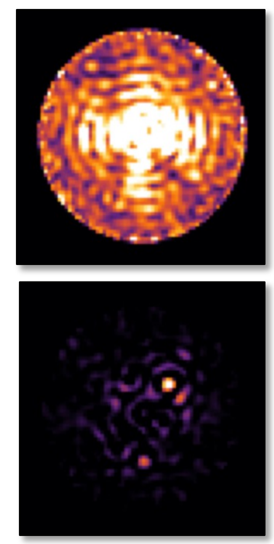


Ultra-low-noise EMCCDs for photon-counting flux levels

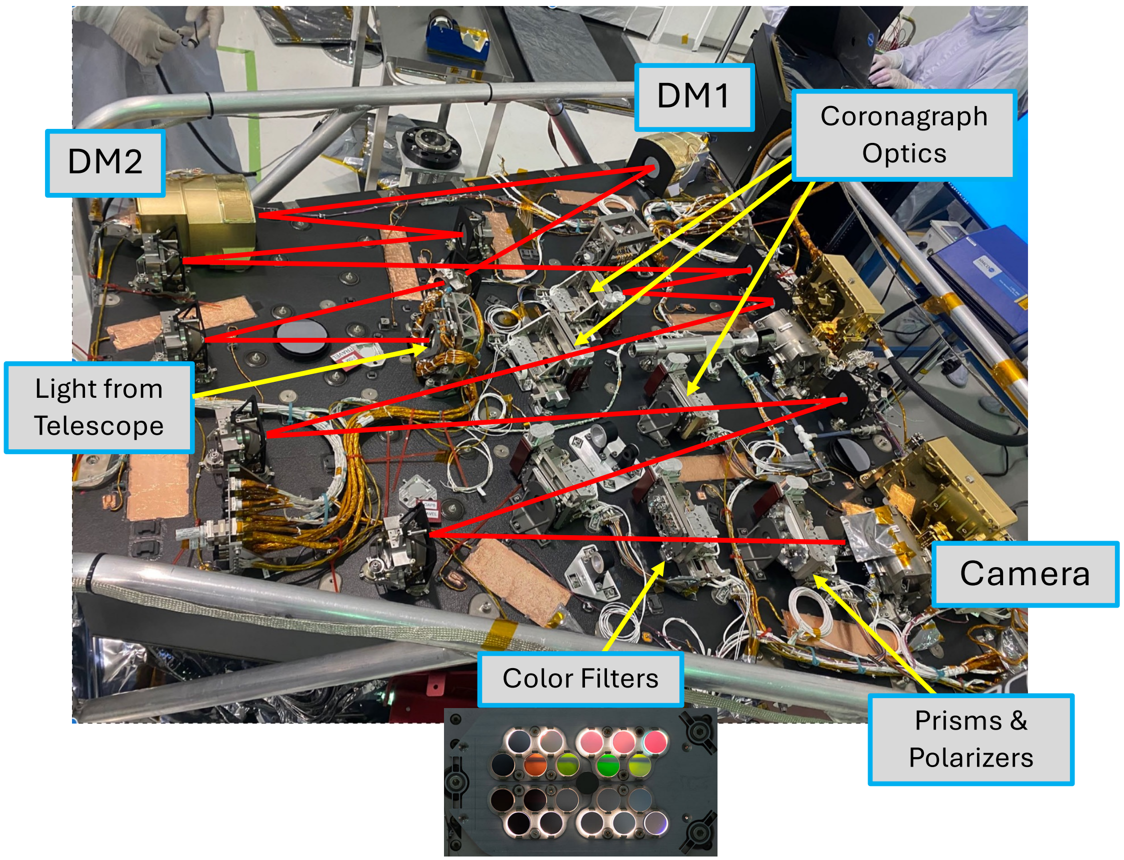


High-performance Coronagraph Masks for obscured apertures

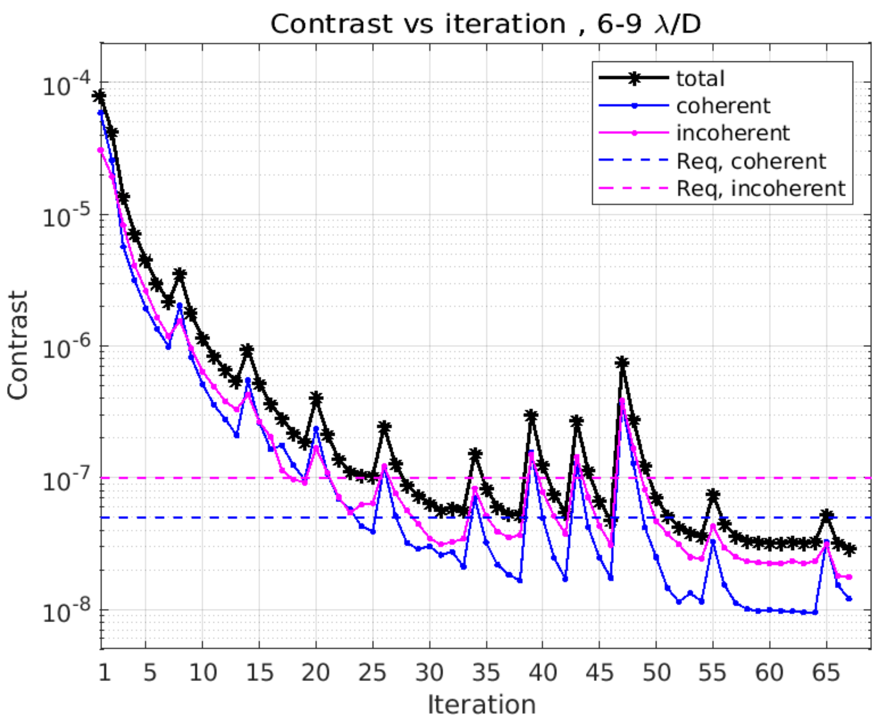
Data Post-Processing in a New Contrast Regime



Coronagraph Instrument @ JPL

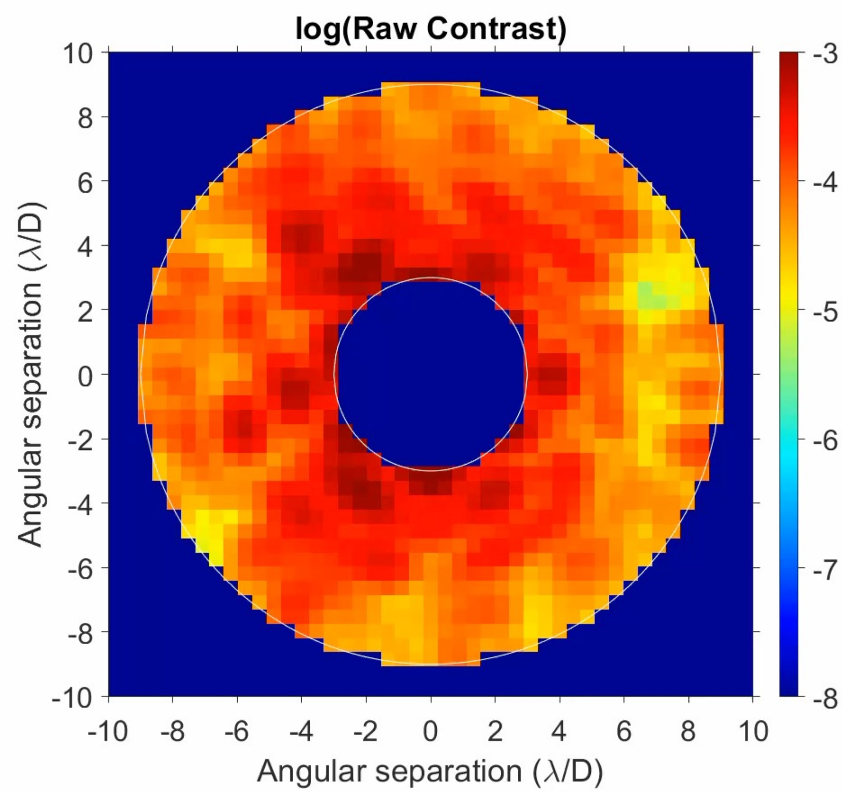


Dark Hole Digging



“Beta bumps” represent purposeful changes in control regularization

Real vacuum chamber data

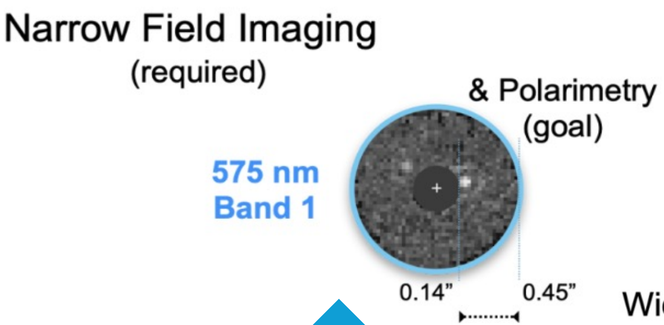


Credit: wavefront sensing and control team

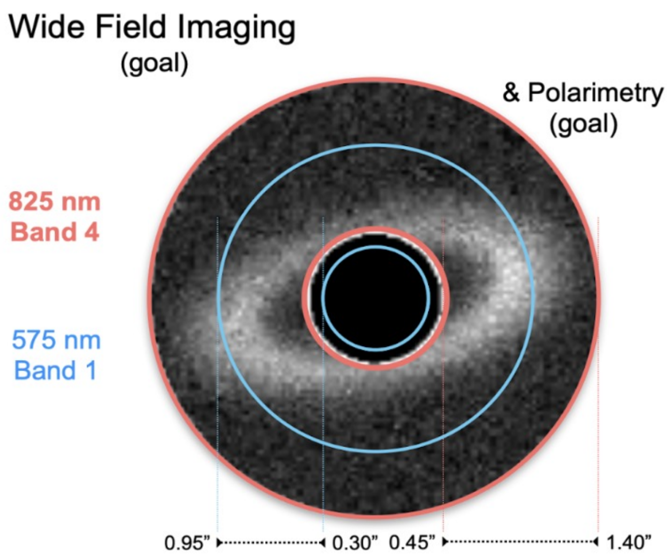
Community Participation Program (CPP)

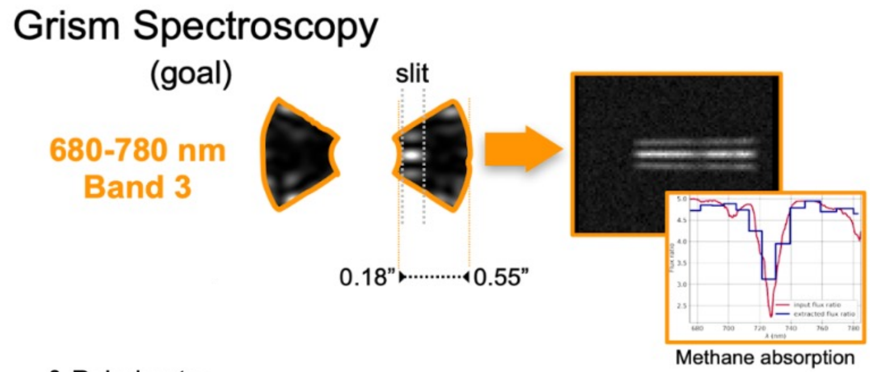
- 11 US-based and funded teams, Roman Project team members (e.g., from JPL, IPAC), international partner teams from ESA, JAXA, CNES, and MPIA, and interested community members
- Planning, calibrating, commissioning, executing, and analyzing the Coronagraph observations

Observing Modes



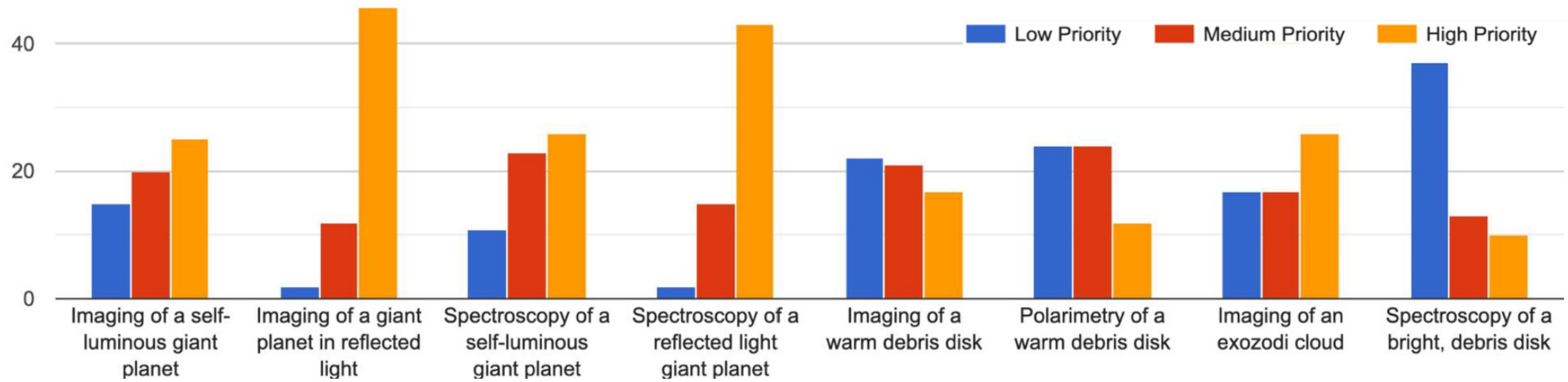
Tech Requirement:
Reach < 10^{-7} contrast on a V ~ 5 star in Band 1 at 6-9 λ/D





Community input has been valuable

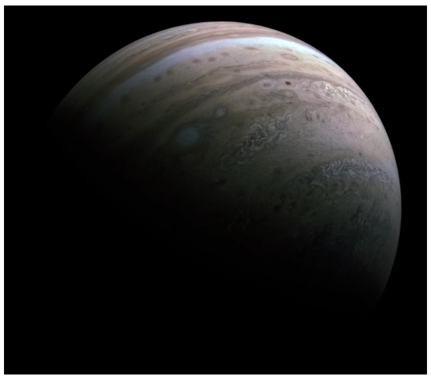
- Jan. 2025 community interest survey



- Summer 2025 white paper call
  - Received 80 white papers spanning science and technology demonstration
  - Target selections (planets + disks), possible AGN/transient science cases, tech validation avenues, wavefront control algos

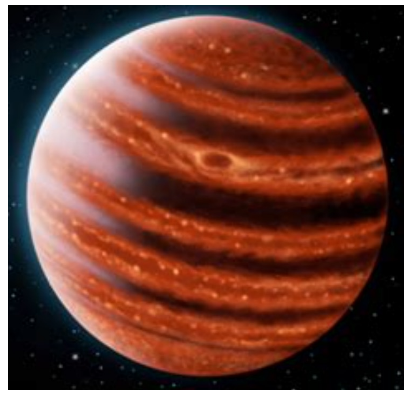
White papers published to Zenodo

The First 6 Months of Observations Planned



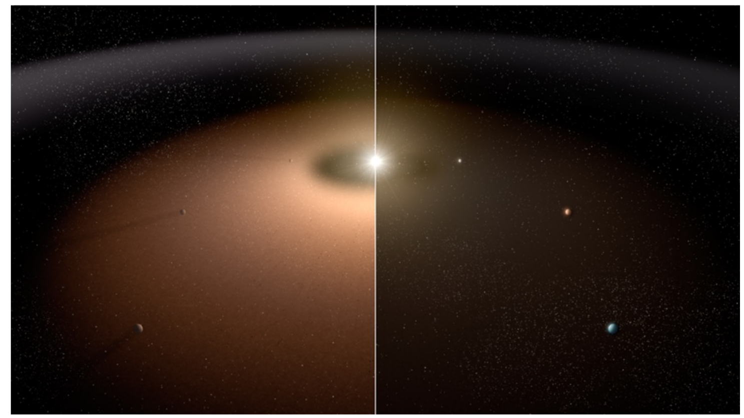
Try to obtain the first images of planets in reflected light and study the albedos of typical Jupiters

Ups And d, eps Eri b, 14 Her b



Imaging and spectroscopy of self-luminous planets and brown dwarf companions

HR 8799 cd, kap And b, HR 2562 b, HIP 54515 b, HIP 71618 B

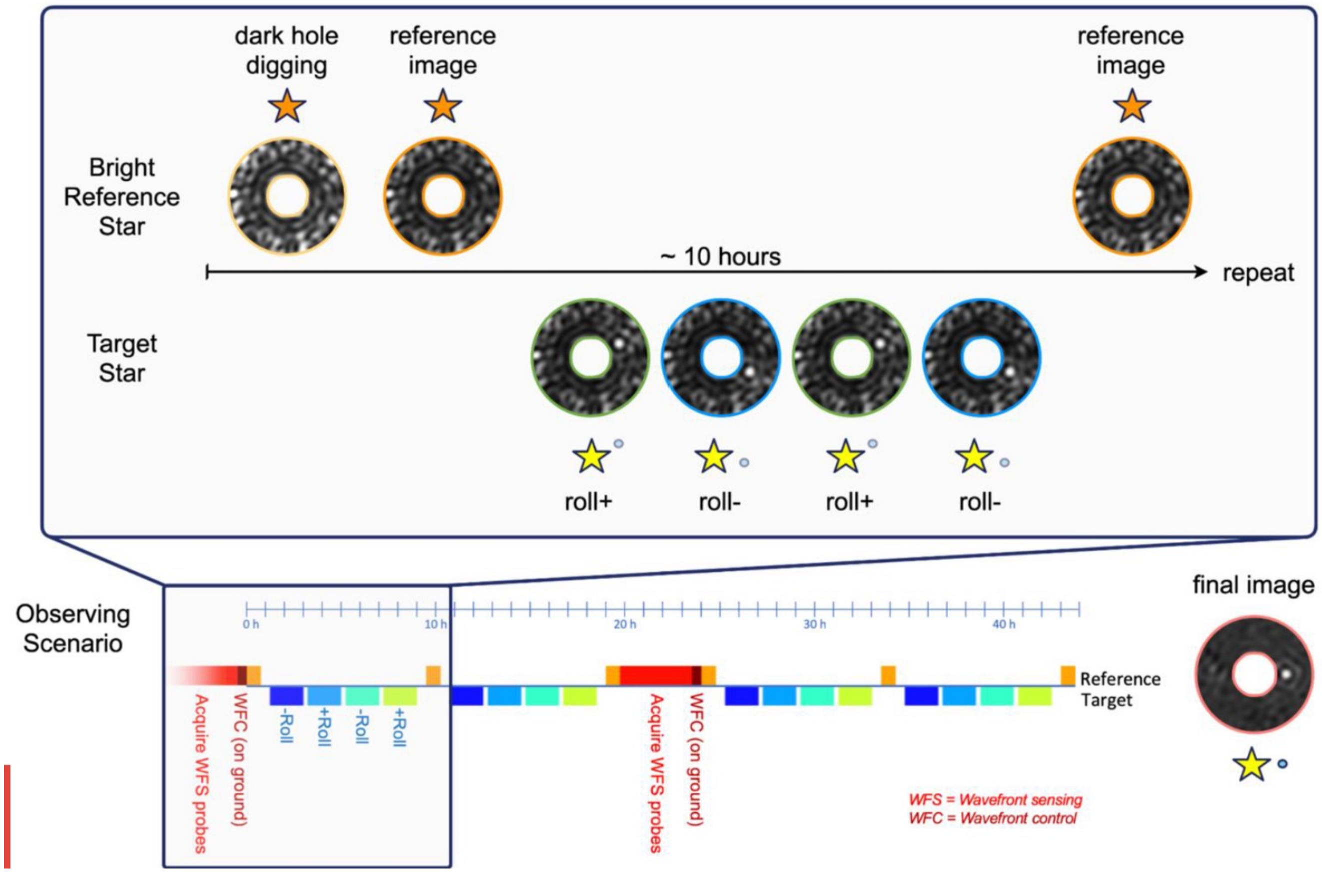


Images/polarimetry of debris disks and an exozodi survey

Eps Eri, eta Crv, HR 4796, among others

Thanks to the community for observing ideas and target suggestions!

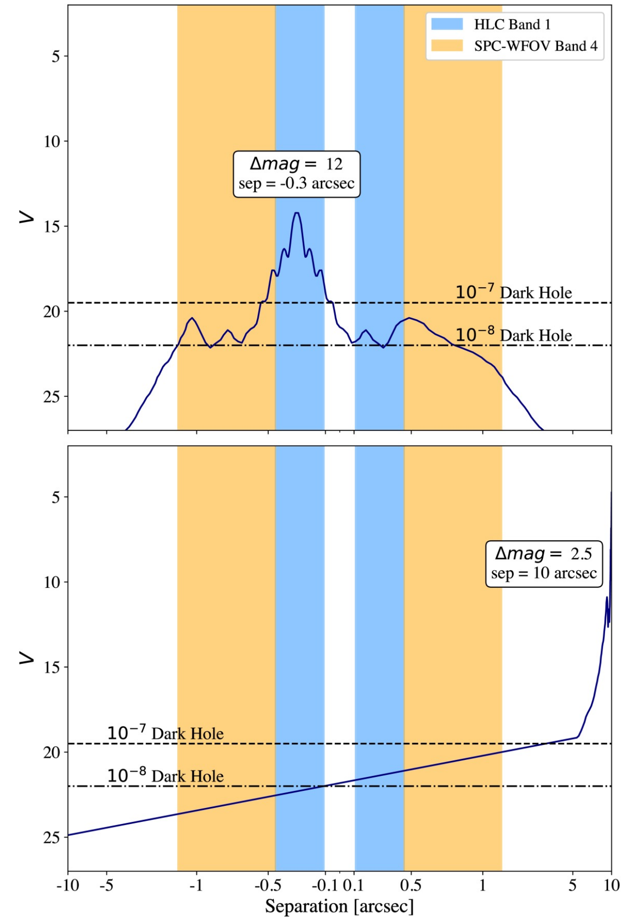
Typical Observing Sequence



- Dig dark hole on bright reference star
- Telescope rolls + ref star images to model changing speckles
- Can have simultaneous WFI observation during long stares

The Reference Star Problem

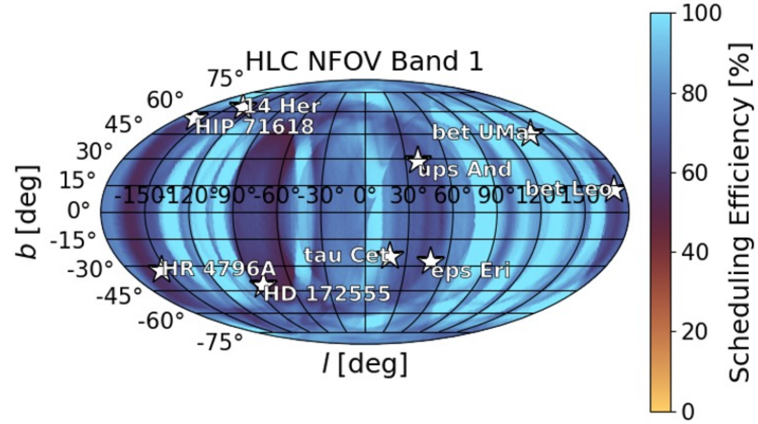
- Requirements:
  - V < 3 (B1), I < 1.25 (B3/B4)
  - Angular diameter < 2 mas
  - Single (no companions)
  - Within 5 degrees from science target in observatory pitch
- For Band 1 (tech demo), the only stars are high-mass stars
- HWO will have the same problem or increase time digging dark holes!

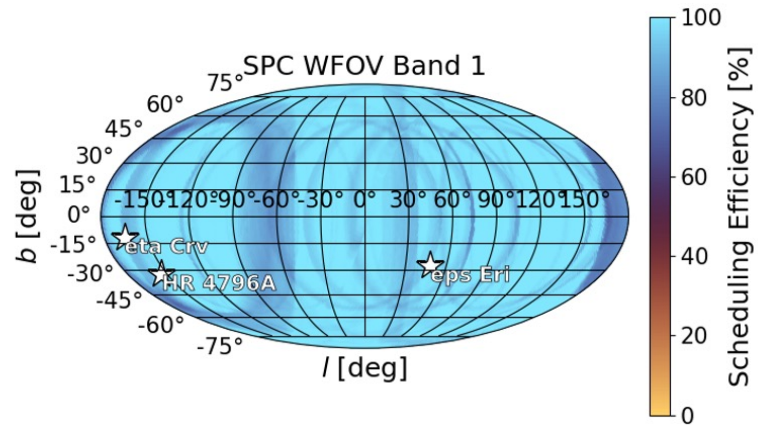


Justin Hom et al. (2026a)

The Reference Star Problem

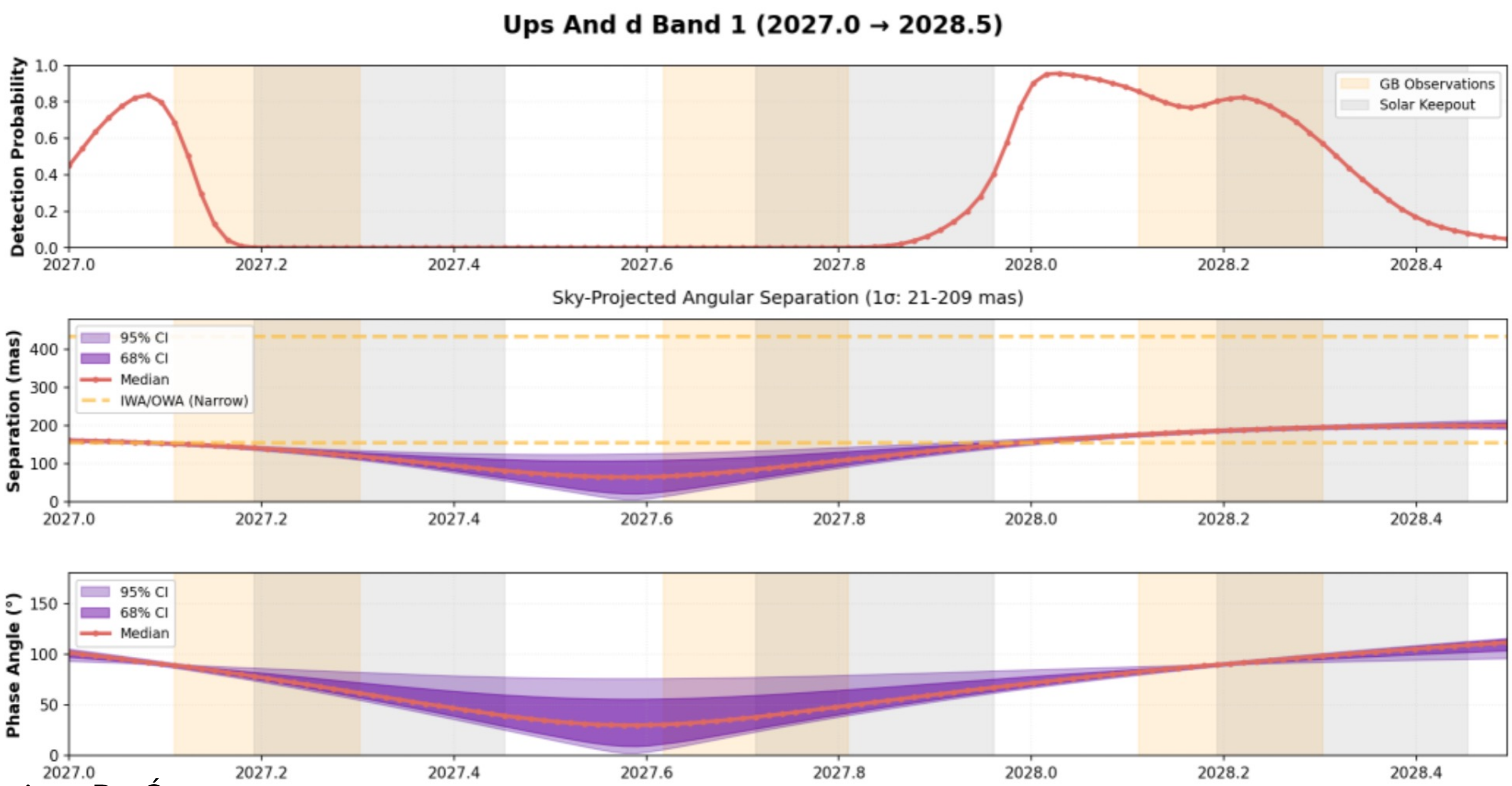
- Exhaustive reference star vetting that combines speckle imaging, AO imaging, coronagraphic imaging, optical interferometry, radial velocity, astrometry observations
- Hundreds of telescope hours over the last two years
- Stars ranked “A” or “B”:
    - 20 Stars in narrow field of view mode
    - 40 Stars for wide field of view mode





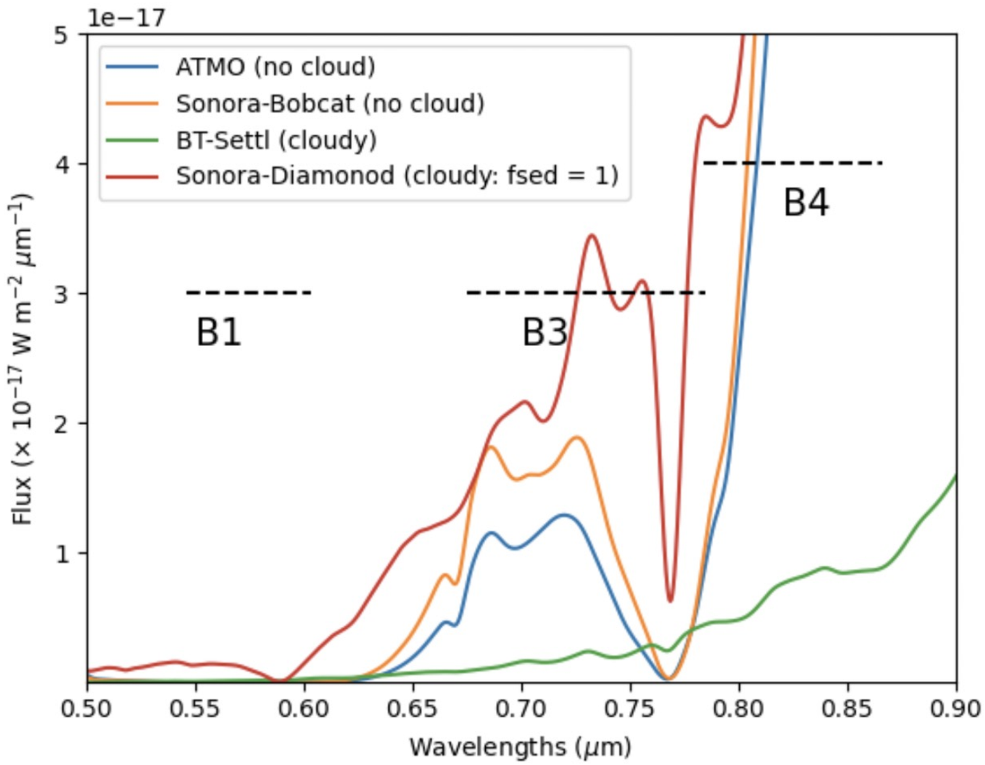
Justin Hom et al. 2026b

Reflected Light Planet Scheduling Constraints

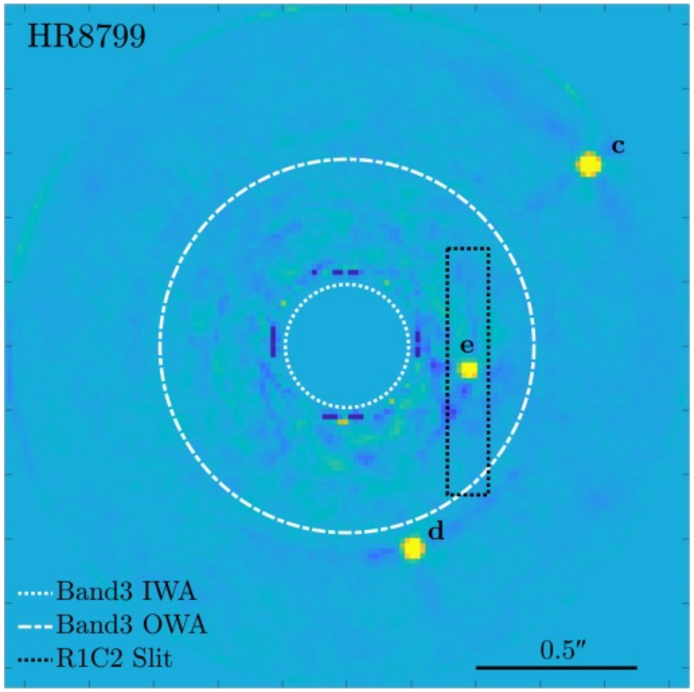


Credit: Clarissa Do Ó

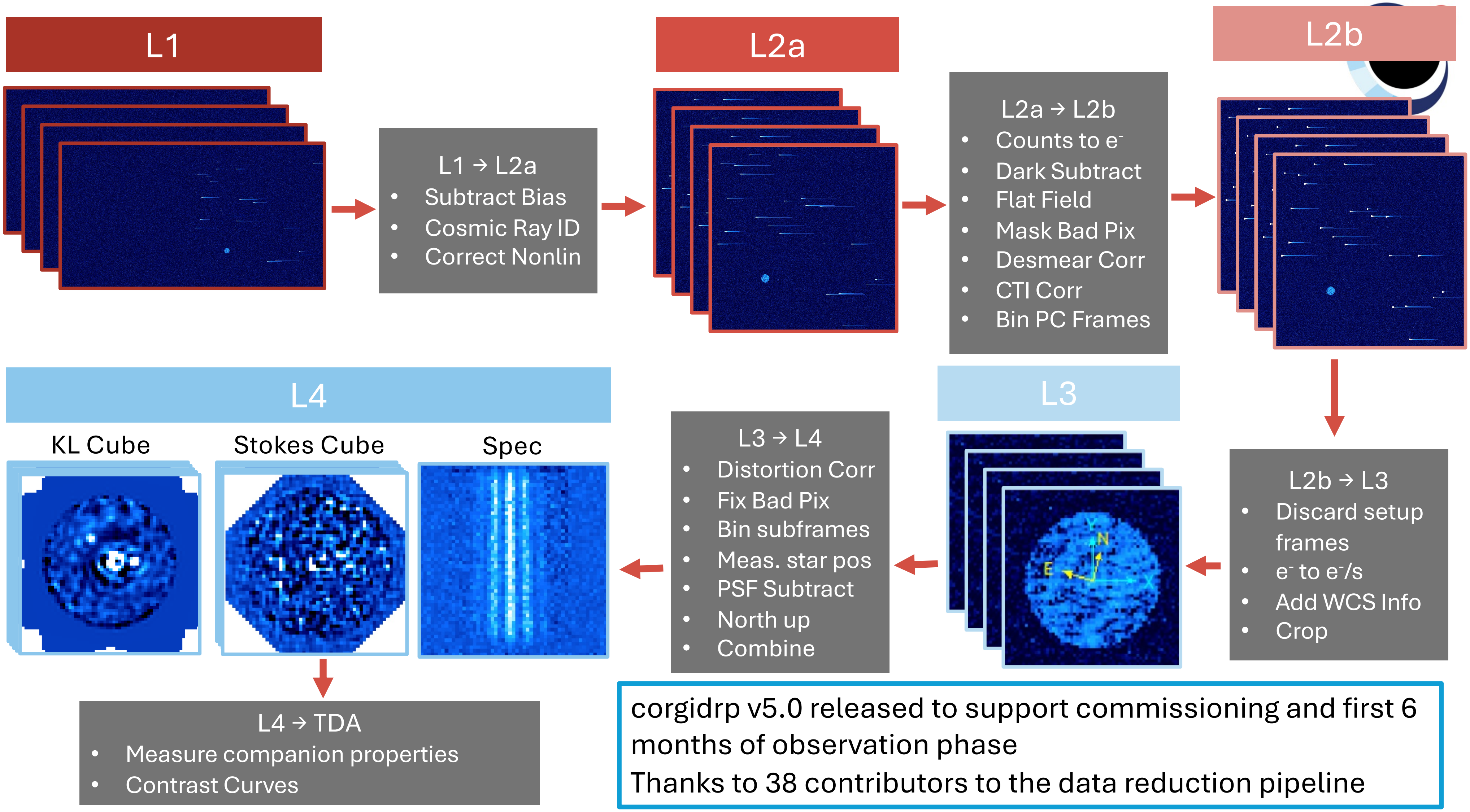
Self Luminous Planets are Faint



Credit: Masayuki Kuzuhara



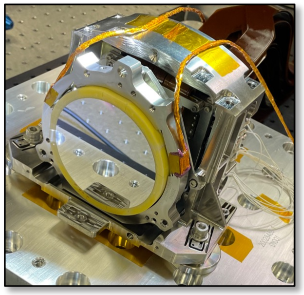
Groff et al. 2025



L1
L1 → L2a
Subtract Bias
Cosmic Ray ID
Correct Nonlin
L2a
L2a → L2b
Counts to e-
Dark Subtract
Flat Field
Mask Bad Pix
Desmear Corr
CTI Corr
Bin PC Frames
L2b
L2b → L3
Discard setup frames
e- to e-/s
Add WCS Info
Crop
L3
N
E
Y
X
L3 → L4
Distortion Corr
Fix Bad Pix
Bin subframes
Meas. star pos
PSF Subtract
North up
Combine
L4
KL Cube
Stokes Cube
Spec
L4 → TDA
Measure companion properties
Contrast Curves
corgidrp v5.0 released to support commissioning and first 6 months of observation phase
Thanks to 38 contributors to the data reduction pipeline

What are we hoping to do after the first 6 months

- Faint star performance (go from V < 5 to V < 9) will open many science cases
  - Protoplanet and protoplanetary disk systems
  - New giant planets discovered by Gaia
  - Non-exoplanet science cases?
- Additional modes (see Riggs+ 2025)
- Improved observing efficiency: stability, dark hole digging speed
- Alternative wavefront control algorithms
- **New community ideas to be solicited Summer ‘27**
  - With published on-sky instrument performance

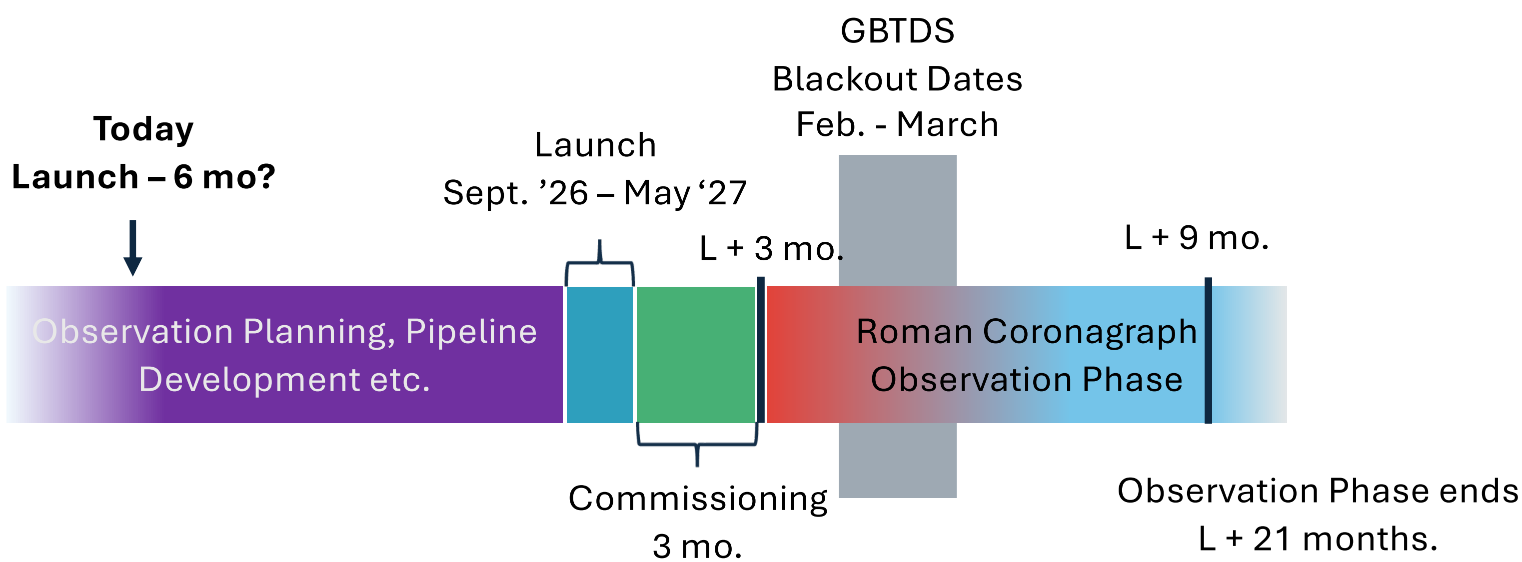


The Roman Coronagraph Instrument will demonstrate key technologies to enable Habitable Worlds Observatory

Credit: Andrea Luck/NASA/
JPL-Caltech/SwRI/MSSS

The orders of magnitude improvement in sensitivity may enable the first reflected light images of exoplanets and exozodical dust

Where are we now?



~2200 hours of Coronagraph observations in Observation Phase