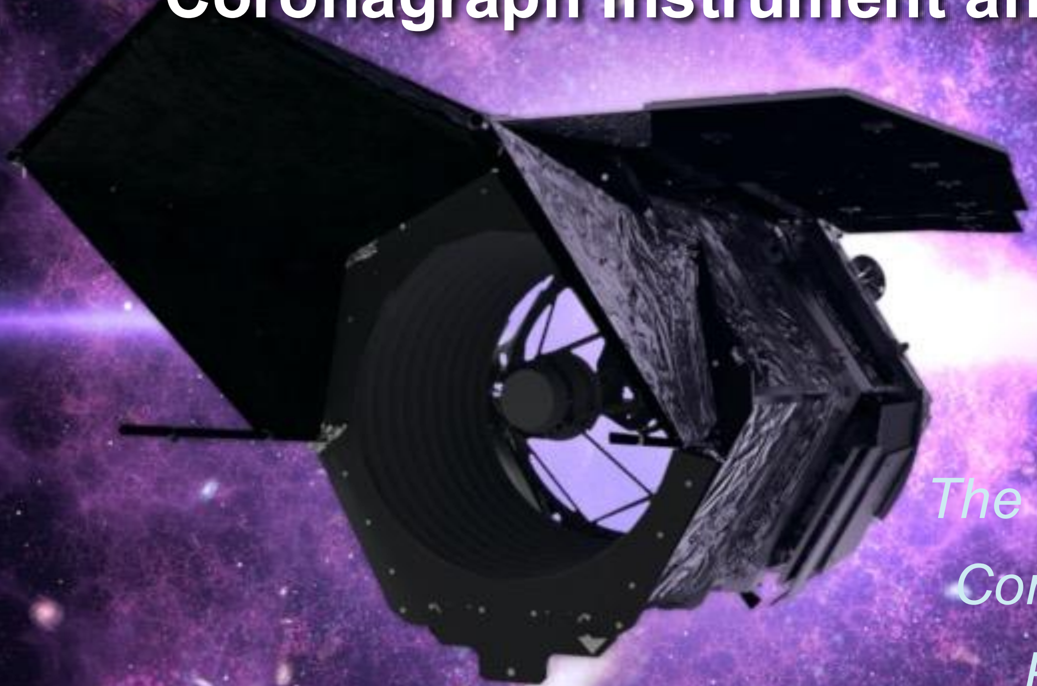
Nancy Grace Roman Space Telescope Coronagraph Instrument and CPP Overview



The Roman Coronagraph Community Participation Program (CPP) Team

Justin Hom (U. Arizona) on behalf of the Roman Coronagraph instrument and science teams

Nancy Grace Roman was NASA’s first Chief Astronomer

appointed 1959

1959 October

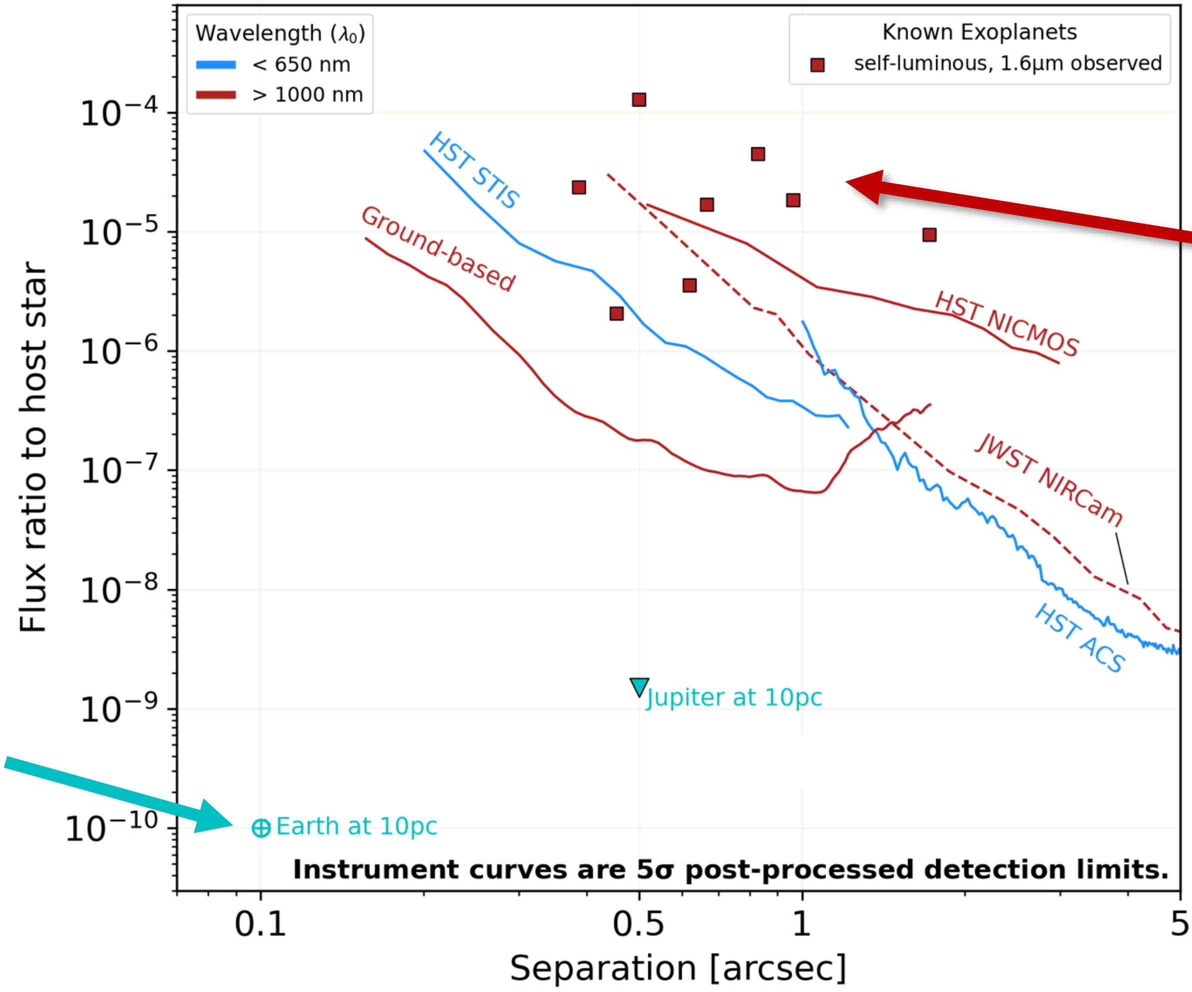
THE ASTRONOMICAL JOURNAL

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).

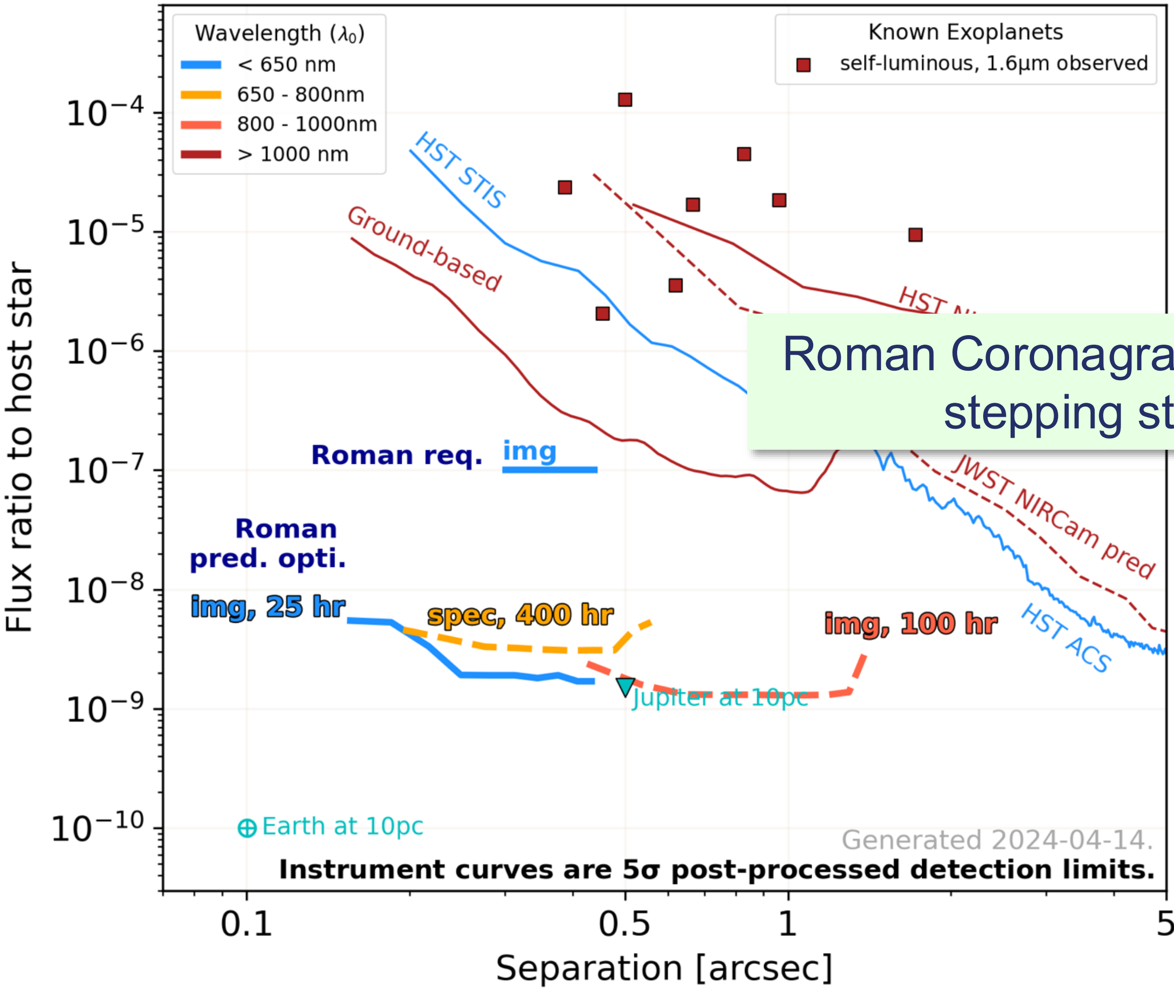
Thus, a similar planetary system around Alpha Centauri would be within the reach of our largest telescopes and our current photoelectric techniques if our terrestrial atmosphere did not limit our resolution. At a separation of more than $2''$, it does not seem to be a serious problem to get rid of the light of the primary in the absence of an atmosphere.

Image credit: NASA, ESA link



IR self-luminous young "super Jupiters"

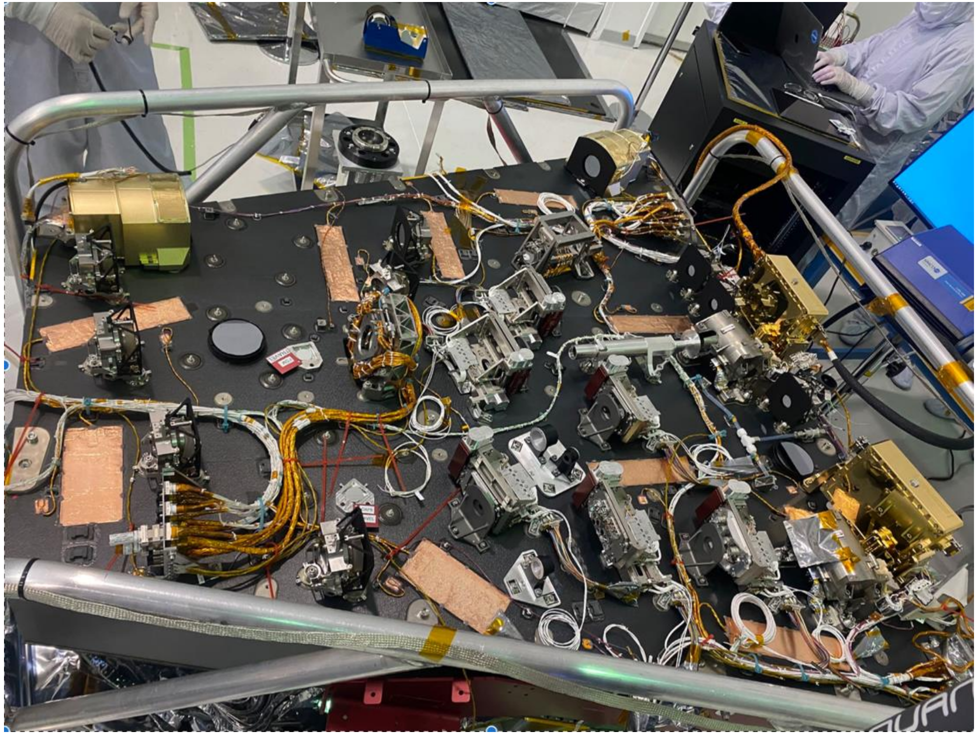
Habitable Worlds Observatory (HWO) mission concept



Roman Coronagraph will be a stepping stone

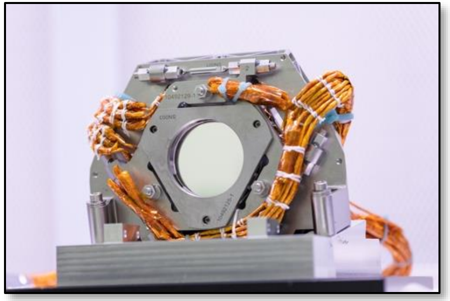
Roman Coronagraph paves the way for Habitable Worlds Observatory

- the first space-based coronagraph with active wavefront control
- a visible light "technology demonstration" instrument
  - "easy" requirement: 10^{-7} detection limit
  - Ambitious goals: few 10^{-9}
- a risk mitigation for HWO
- Delivered May 2024
- Launch to L2 no later than May 2027, Current estimate: Oct 2026

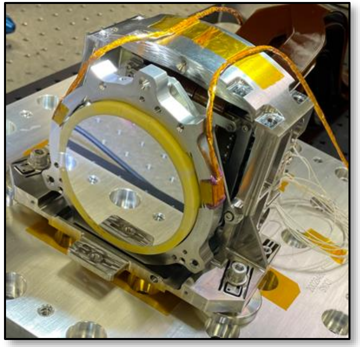


Roman Coronagraph demonstrates multiple technologies at HWO-relevant performance

Ultra-Precise (~10pm RMSE goal) Wavefront Sensing & Control (Ground-In-The-Loop)

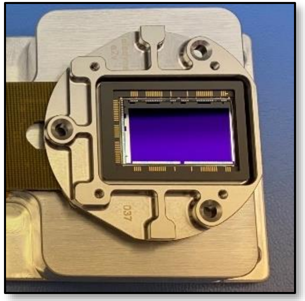


Large-format Deformable Mirrors (48x48)

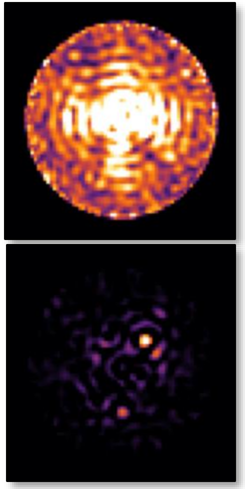


High-contrast Coronagraph Masks for obscured apertures

Ultra-low-noise EMCCDs
Goal: photon-counting flux levels

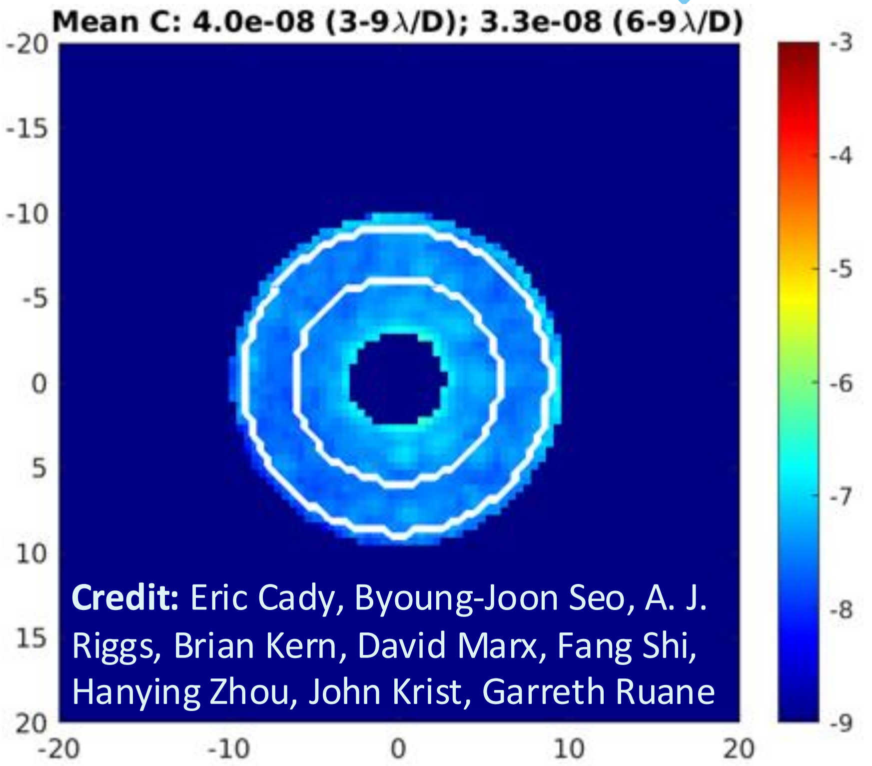


Data Post-Processing
Goal: Photon-counting



Thermal Vacuum (TVAC) lab testing already demonstrates performance beyond requirement

- requirement: 10^{-7} flux ratio 5σ detection limit in a single photometric band
  - Designed to outperform requirement
- Predicted performance ≥4x beyond req
  - Based on end-to-end performance testing



1 fully supported mode

Additional “best effort” modes: spectroscopy & polarimetry

Band	λ_{center}	BW	Mode	FOV radius	FOV Coverage	Pol?	Coronagraph Mask Type	Support
1	**575 nm**	**10%**	**Narrow FOV Imaging**	**0.15” – 0.45”**	**360°**	**Y ****	**Hybrid Lyot**	**Req’d**
1	575 nm	10%	“Wide” FOV Imaging	0.3” – 1.01”	360°	Y	Shaped Pupil	Best Effort
2	660 nm	17%	Slit + R~50 Prism Spectroscopy	0.17” – 0.52”	2 x 65°	-	Shaped Pupil	Best Effort
3	730 nm	17%	Slit + R~50 Prism Spectroscopy	0.18” – 0.55”	2 x 65°	-	Shaped Pupil	Best Effort
4	825 nm	11%	“Wide” FOV Imaging	0.45” – 1.4”	360°	Y	Shaped Pupil	Best Effort

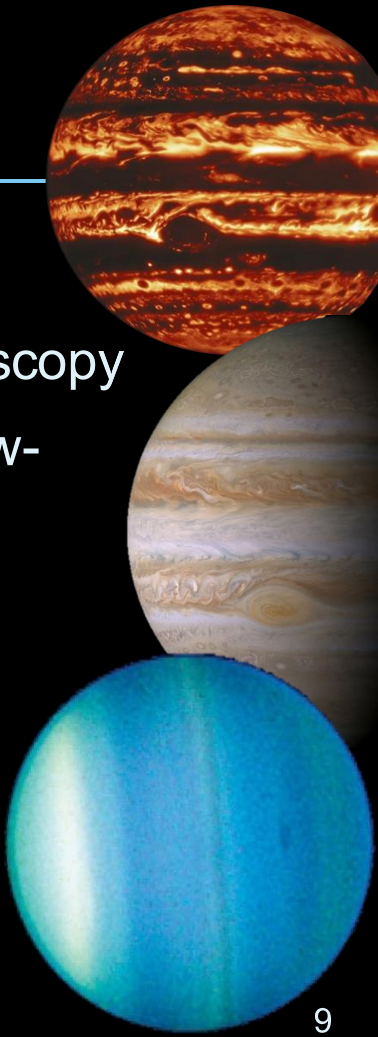
“Best effort” modes will not be end-to-end performance tested prior to delivery & do not have guaranteed support on-orbit.

** Polarimetry in Band 1 is ‘best effort’

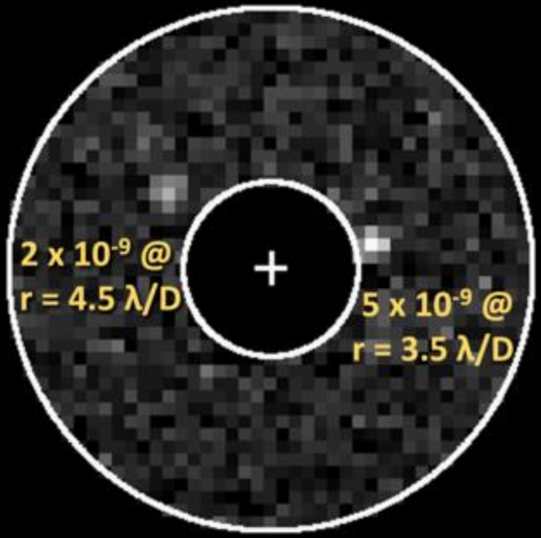
See Riggs et al. 2025 for all possible observing modes

Opportunities in Exoplanet Science

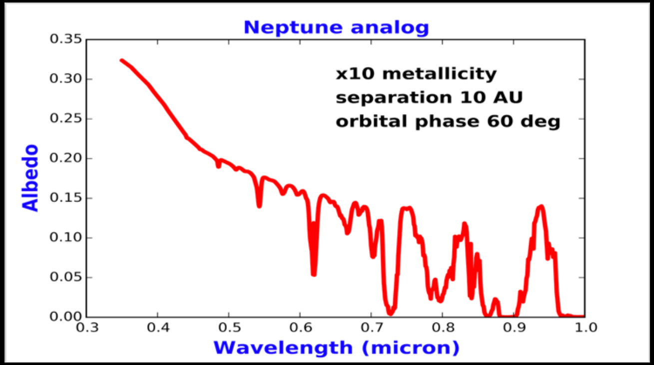
- young, self-luminous super-Jupiters
  - **State of the Art (SOTA)**: Infrared photometry & spectroscopy
  - **Roman Coronagraph**: add visible light photometry & low-resolution spectroscopy (eg: Lacy & Burrows 2020)
- Jupiter analogs:
  - **SOTA**: indirect detection only; no characterization
  - **Roman Coronagraph**: *potential* for 1st images & low-resolution spectrum (eg: Batalha+2018, Saxena+2021)
    - Cloudy or clear?
    - Super-solar or solar metallicity?



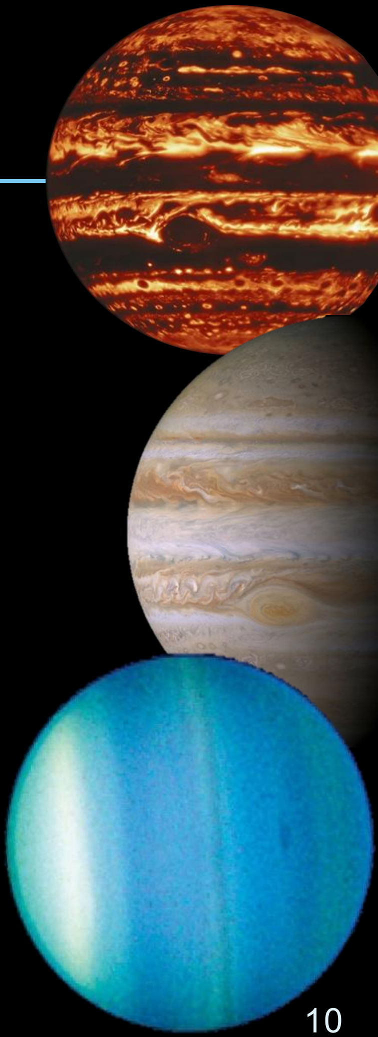
Opportunities in Exoplanet Science



Simulated observation of 47 UMa, using Observing Scenario 11 (J. Krist, 2022)



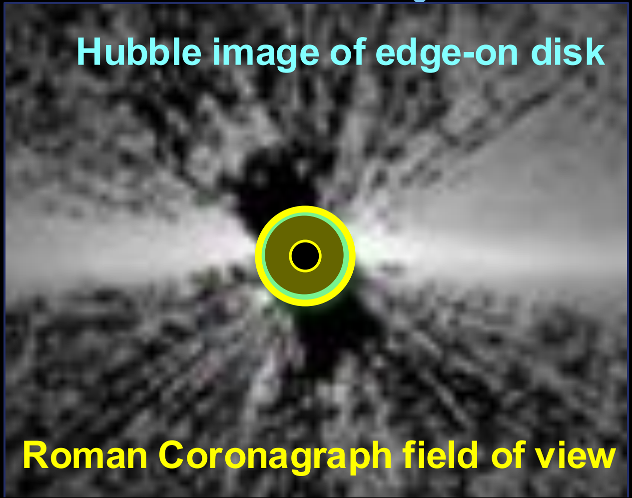
Theoretical albedo spectrum from Cahoy et al. (2010)

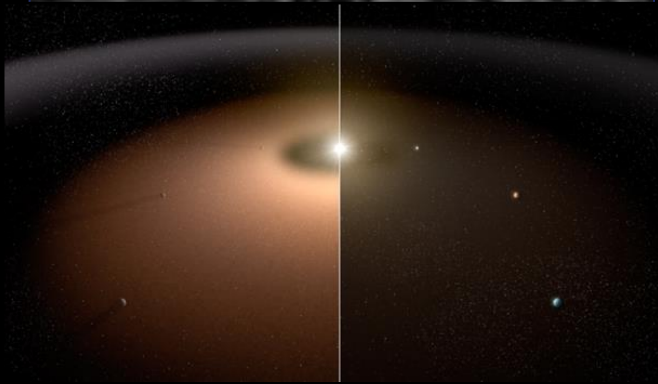


Opportunities in circumstellar disk science

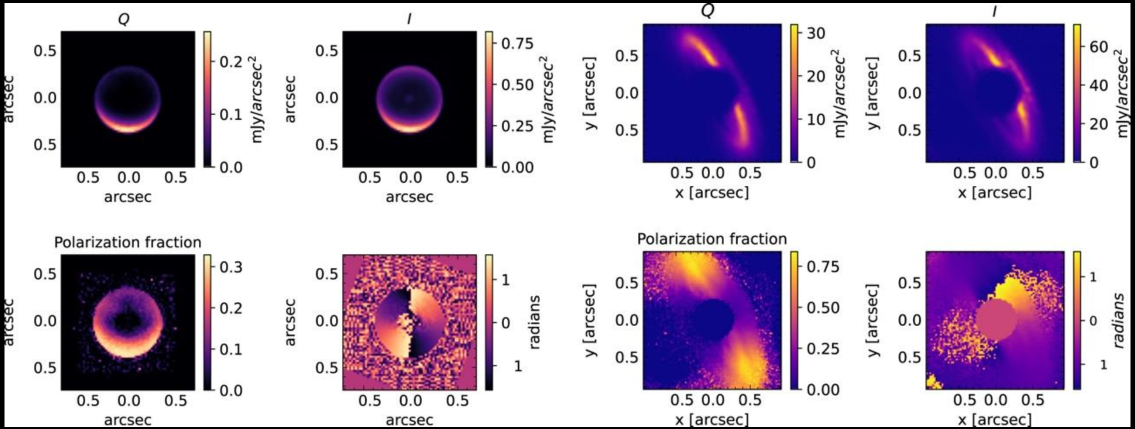
- Debris disks (Kuiper belt analogs)
  - **SOTA:** Hubble imaging
  - **Roman**: Observe closer to the star
    - (Mennesson+2018)

- Exozodi disks (terrestrial zone dust)
  - **SOTA:** IR excesses
  - **Roman**: *potential* for first visible-light image
    - Are any HWO high-priority systems too dusty?
    - (Douglas+2022)

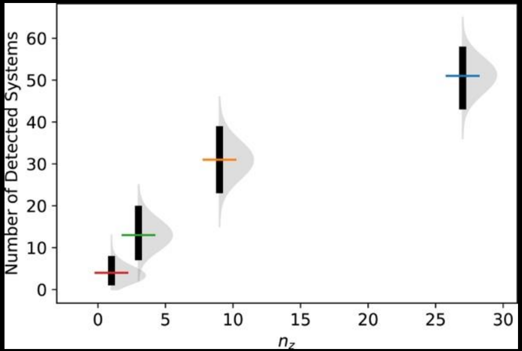




Opportunities in circumstellar disk science



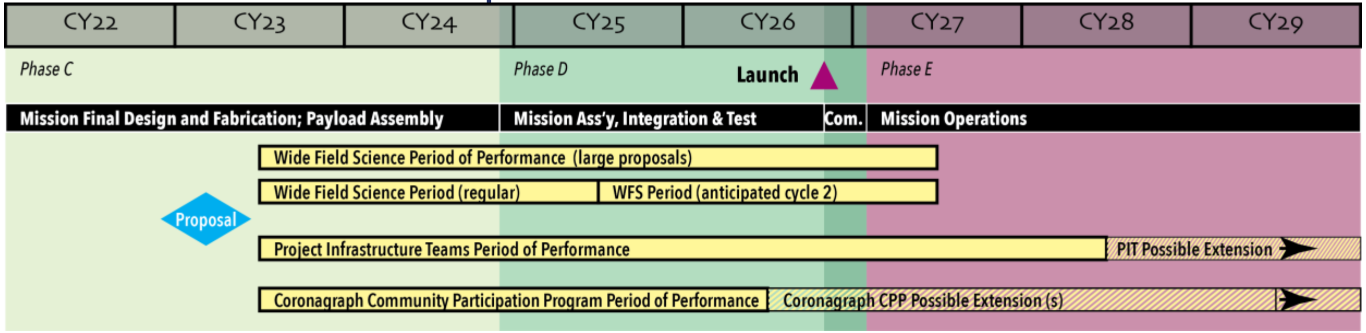
Polarimetric imaging simulations, Credit: Anche et al. (2023)



Exozodi detectability and yield, Douglas et al. (2022)

What is the CPP?

- Established by 2022 NASA ROSES Nancy Grace Roman Space Telescope Research and Support Participation Opportunities program element
  - Solicited proposals aimed at supporting the progress of and exploiting the scientific and technical data from Roman
  - CPP category limited to sole-PI/small-group proposals with intent to form a single, cohesive CPP Team composed of:
    - Selected teams
    - International partners
    - Representatives from Coronagraph science and engineering teams
    - Members of Science Support Center (SSC)



Community Participation Program (CPP) + Project Scientist Responsibilities

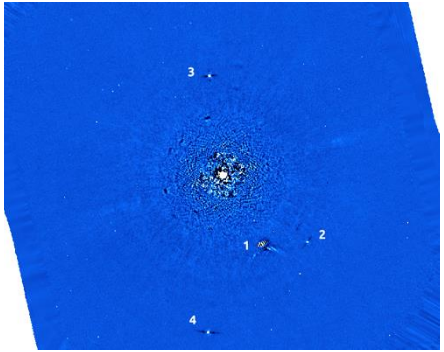
- Data Processing Pipeline
- Observation Planning
  - Target database, precursor observations
  - Internal tools for generating observation plans
- Image & observation simulations
- Best effort: Preparing for beyond-requirements observations
- Prepare for commissioning, and operations of the primary and goal observing modes
  - Research *potential* alternative high-order wavefront sensing and control algorithms

Observation Planning

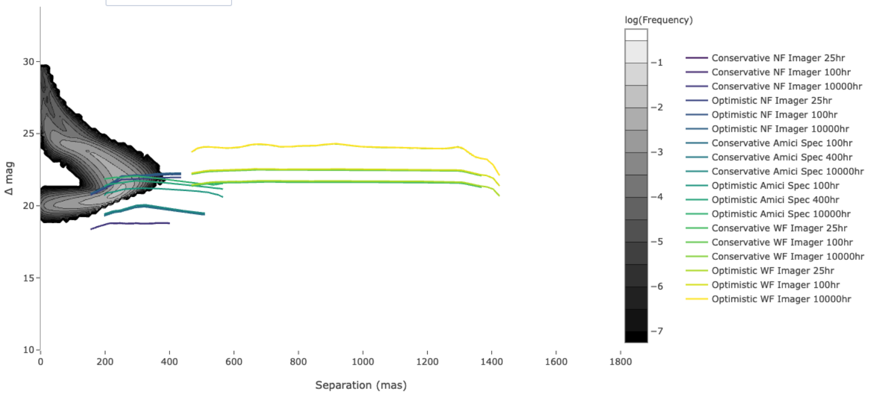
- Lead: Schuyler Wolff, U. Arizona
- Duties, Responsibilities:
  - Developing the observation phase plan
  - Engaging and soliciting community input for constructing the observation phase plan
  - Planning commissioning and calibration activities
  - Precursor observations of wavefront sensing and control reference stars
  - Precursor analysis of potential science targets (known RV exoplanet orbit characterization, radiative transfer modeling of known exoplanet atmospheres, modeling circumstellar disks)

Observation Planning: Current Status

- ETC has been released
- Hundreds of precursor observing hours have been completed, with data analysis ongoing. Effort is on track for completion by the end of this year (sub-lead: Justin Hom)
- Commissioning and calibration activities are being finalized (sub-lead: Bijan Nemati)
- Orbital modeling efforts of known RV planets are nearing completion (sub-lead: Sarah Blunt)
- Atmospheric modeling efforts of known self-luminous planets are ongoing (sub-lead: Zarah Brown)
- Target database is preparing for ingestion of calibration and science target properties (sub-lead: Dmitry Savransky)
- White paper call is out! (sub-lead: Beth Biller)



Precursor Observation of a Reference Star
Credit: Macarena Vega



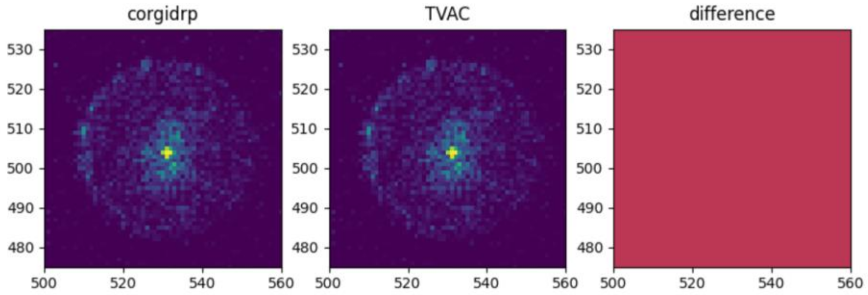
Science Target Completeness; Credit: Dmitry Savransky

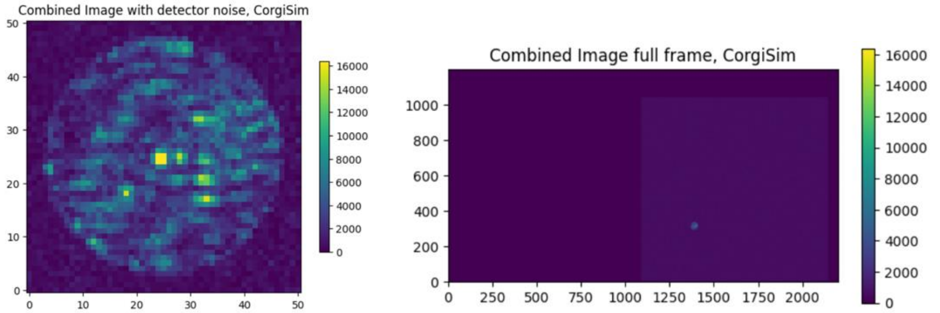
Data Reduction and Simulations

- Leads: Jason J. Wang, Northwestern; Marie Ygouf, JPL; Max Millar-Blanchaer, UC Santa Barbara
- Duties, Responsibilities:
  - Creating the data reduction pipeline for the required and best-effort modes
  - Creating simulated datasets for informing the observation phase plan and testing the data reduction pipeline

Data Reduction and Simulations: Current Status

- V2.2 of the data reduction pipeline is released: https://github.com/roman-corgi/corgidrp/releases/tag/v2.2
- DRP currently supports basic functionality with the required observing mode
- Main goal for the remainder of this year is to develop and implement DRP for best-effort modes





Hardware

- Lead: Dan Sirbu, NASA Ames
- Duties, Responsibilities:
  - Assessing feasibility and implementation of potential alternative wavefront sensing and control algorithms
  - Assist preparation for potential commissioning of additional currently-unsupported observing mode(s)
  - Working with Observation Planning and Simulations groups to implement/mature alternative WFSC algorithms

Hardware: Current Status

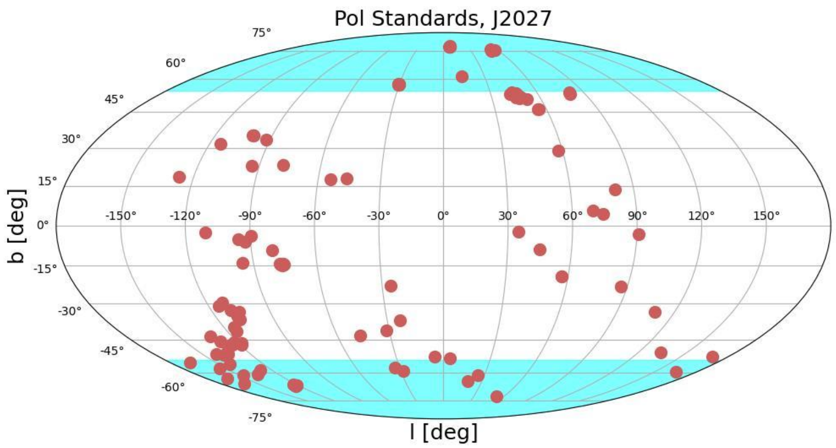
- Coordinating with DRP and Sims WG to implement wavefront sensing and control algorithms into simulation frameworks
- Actively maturing alternative/proposed WFSC algorithms for on-sky use

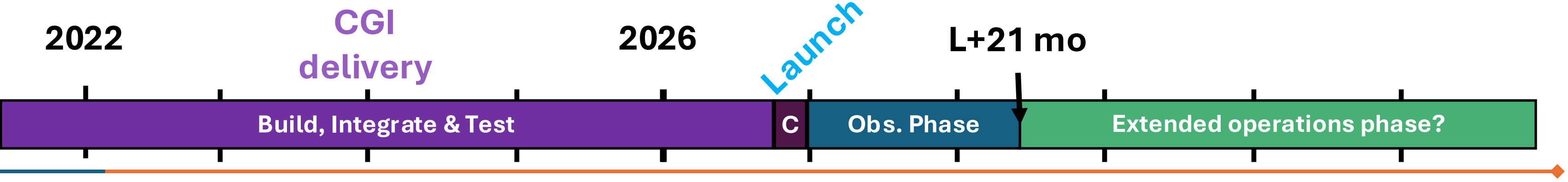
Polarimetry

- Leads: Ramya Anche, U. Arizona; Toshiyuki Mizuki, NAOJ/ABC; John Livingston, NAOJ/ABC
- Duties, Responsibilities:
  - Plan the calibration of the best-effort polarimetry modes
  - Construct the concept of operations for the polarimetry modes
  - Develop the data reduction pipeline formalism for the polarimetry modes

Polarimetry: Current Status

- Conducting precursor observation campaigns for polarimetric standard stars (for calibration)
- Building the description of the polarimetry concept of operations
- Describing the necessary DRP functionality for polarimetric data





May 2024: Instrument delivery to payload integration & test

Launch: no later than May 2027; currently working toward October 2026

Commissioning Phase

450 hr in first 90 days after launch

Observation Phase

~2200 hr (3 months) baselined in next 1.5 years of mission

If successful, *potential* for extended operations phase

- ~10% (order of magnitude) of observing time
- Commission additional currently-unsupported observing modes
- Further community engagement in science and technology observations
- **not guaranteed**; contingent on compelling performance and available resources

Observation Plan for the Coronagraph "Observation Phase"

- Baseline: 2200hr (90 days) during first 18mo of Mission
  - Launch no later than May 2027, currently expected in Oct. 2026
- Top priority: achieve L1 Technology Requirement
  - Flux ratio of at least 10^{-7} on a V~5 star in Band 1
- Then, as time/resources allow, push performance limits and commission additional observing modes
  - Maximize long-term science and technology value
- Prioritize scientifically-interesting targets when possible
  - No GO program; this WP call is intended solicit community input on target selection
  - Roman data has no proprietary period
  - This is the best chance to advocate for impactful observing programs!

1 fully supported mode

Additional “best effort” modes: spectroscopy & polarimetry

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4	**825 nm**	11%	“Wide” FOV Imaging	0.45” – 1.4”	360°	Y	Shaped Pupil	Best Effort

“Best effort” modes will not be end-to-end performance tested prior to delivery & do not have guaranteed support on-orbit.

** Polarimetry in Band 1 is ‘best effort’

See Riggs et al. 2025 for all possible observing modes

Ensuring a Valuable Legacy Dataset: Summer 2025 White Paper Call

What technology demonstration observations, science observations, and observing modes does the community most want to see happen during commissioning, in the baseline observation phase, and beyond?

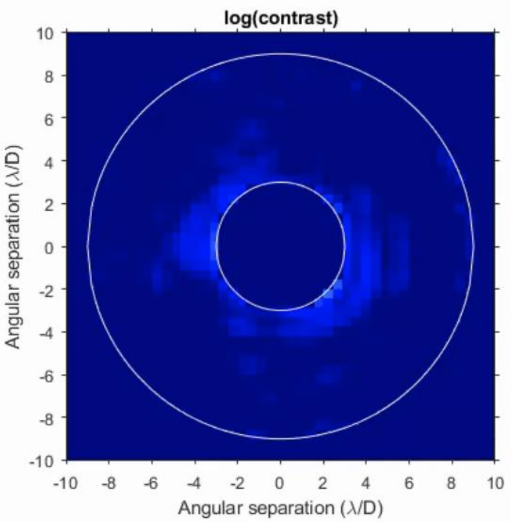
Ensuring a Valuable Legacy Dataset: Summer 2025 White Paper call

- To engage the coronagraph / exoplanet community in the definition of the Roman Coronagraph observing program, the CPP is sponsoring a call for White Papers to define technology demonstration and scientific exploration observations.

- **All members of the community, across all career stages, positions, and types of institutions, are encouraged to submit their technology and science investigation ideas.**
- Deadline: August 7th
- The ExoPAG has set up a website to help with coordination of community white papers: https://exoplanets.nasa.gov/exep/exopag/Roman-CPP/
- See also: https://www.romancoronagraph.space/white-papers-2025

Summary

- Roman Coronagraph is a tech demo for HWO concept
  - Precursor technologies *and system*
  - Several subsystems are "in family," though still work to go
  - Reduces technology & model validation risks
- "goal" capabilities enable exciting disk and exoplanet science
- A white paper submission is the best way to advocate for technology and science observations for the Coronagraph (due Aug 7!)



For more details:

Roman Coronagraph Primer, link to ETC, and template details:

- https://www.romancoronagraph.space/white-papers-2025/resources

Full call for white papers and FAQ:

- https://www.romancoronagraph.space/white-papers-2025

- Any questions? Please email: roman.cpp.wp.submissions@gmail.com

Backup Slides

The White Paper LaTeX template

- Please use this LaTeX template for your white paper:

Roman Coronagraph White Paper

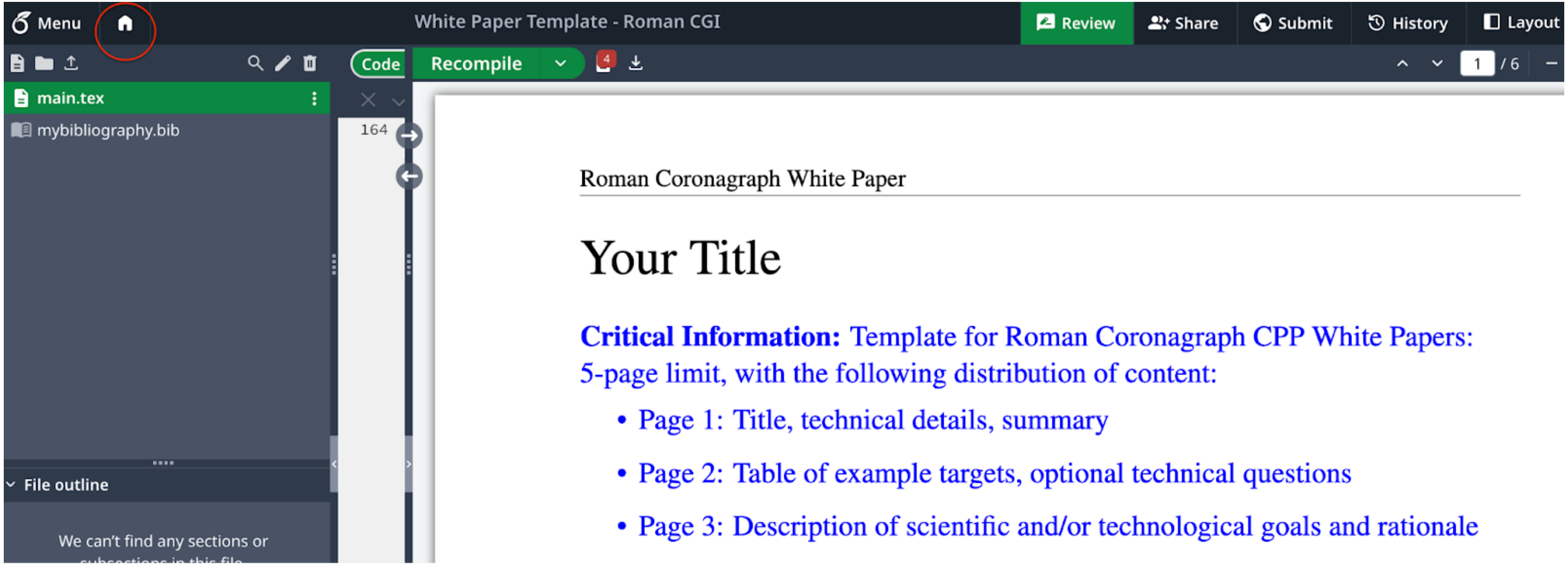
Your Title

Critical Information: Template for Roman Coronagraph CPP White Papers: 6-page limit, with the following distribution of content:

- Page 1: Title, technical details, summary
- Page 2: Table of example targets, optional technical questions
- Page 3: Description of scientific and/or technological goals and rationale
- Page 4: Observing description
- Page 5: Up to 3 figures
- Page 6: References

Please delete the additional guidance text (indicated in blue) before submitting your white paper. More details on how to submit white papers and Roman coronagraph resources are available at the following link: link to resources page.

To start writing your white paper, first click the link to open the document. Then from within the document, click the home button:



From your home menu, you can then click the circled icon (in image below) to duplicate the template and start filling it in:

Page 1: General Technical Details

Type of observation:

☐ Technology Demonstration
☐ Scientific Exploration

Scientific / Technical Keywords: Please choose one or more keywords from the following list: disk, companion (exoplanet), companion (substellar), self-luminous, reflected light, other science, observing strategy, post-processing, control algorithm, high contrast performance

Required Detection Limit: Please estimate the detection limit necessary for your observation. Note: the higher your contrast requirement, the less likely the observation will be feasible in the baseline observing period. Observations that require detection limits better than 10^{-8} may not be possible. Observations requiring detection limits from 10^{-5} to 10^{-6} may be appropriate for "first-look" Coronagraph observations early in the mission, prior to the Coronagraph

What contrast levels are possible during the mission?

- Contrasts of 10^{-5} to 10^{-6} should be achievable throughout the mission and are of particular interest for the “first-look” press release images obtained during commissioning.
- A contrast of $\sim 10^{-7}$ is the baseline requirement of the Roman Coronagraph and should be available early in the Observation Phase.
- Contrasts as deep as a few times 10^{-9} may be achievable but require additional calibration activities and may not be reached until later in the Observation Phase, if at all.

Page 1: Observing Mode and Summary

The LaTeX table in the template is pre-filled with the required and best effort modes; please choose your mode from the table and delete the other options. You can also add rows to the table if your observation idea would use a mode other than the required and best effort modes.

Band	Mode	Mask Type	Coverage	Support
1, 575 nm	Narrow FoV Imaging	Hybrid Lyot	360°	Required (Imaging), Best Effort (Polarimetry)
1, 575 nm	Wide FoV Imaging	Shaped Pupil	360°	Best Effort (Imaging and polarimetry)
2, 659 nm	Slit + R$\sim$50 Prism Spectroscopy	Shaped Pupil	2x65°	Best Effort
3, 730 nm	Slit + R$\sim$50 Prism Spectroscopy	Shaped Pupil	2x65°	Best Effort
4, 825 nm	Wide FoV Imaging	Shaped Pupil	360°	Best Effort (Imaging and polarimetry)

Summary: Please provide a 1-paragraph summary of your observation idea here, including an estimate of the required observing time.

Page 2: Table of Example Targets, Optional Technical Questions

Table of Example Targets: Please provide details on one or more example targets. Target descriptions can remain generic – e.g. if you just need a non-variable star with V = 5, then it is fine just to provide that detail but not provide a specific star. Note: the higher your contrast requirement, the less likely the observation will be feasible during the baseline observation period. Observations requiring detection limits better than 10^{-8} may not be possible. Target stars should in general have $V \leq 5$, although observations of somewhat fainter stars down to $V \sim 7$ may be possible with degraded detection limit performance.

Name	host star V mag.	detection limit	separation (”) (or extent)	description of target

Optional Questions: Please complete only if you have specific targets in mind – fine to skip this if you are proposing for a generic category of targets.

Page 3: Anticipated Technology / Science Objectives

- 1 page to describe the technological or scientific goal of your observation idea
- If your proposed observations would help with the development of technology and science cases for the Habitable Worlds observatory, please detail that here
- Please estimate when in the timeline for the mission your observations would best fit. This will be dependent on required detection limit.

Page 4: Observing Description

- Please include a description (up to 1 page) of the planned observing idea, with an estimate of the observing time necessary to achieve your goals.

- If appropriate for your scientific or technical case, you can use the exposure time calculator (ETC) provided here to estimate the necessary time allocation to achieve your technology / science objectives, then provide your estimate and the details of the calculation here. When relevant, we highly recommend using the ETC for time estimates, but it is not required.

- The ETC is still under development but is fully supported for the optimistic Band 1 imaging case. We welcome feedback!

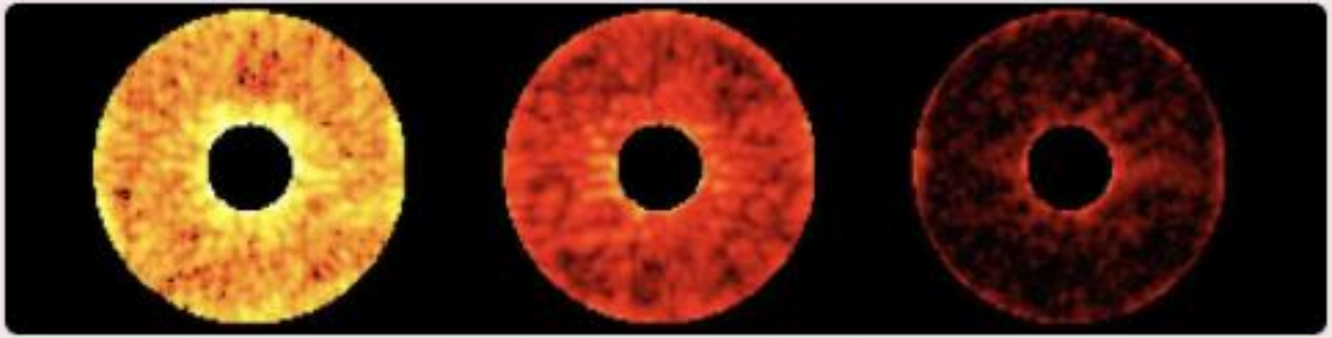
Pages 5 and 6 – Figures and References

- Please include up to 3 figures on Page 5 – all figures must fit on this page.

- Please include references on Page 6 – It’s fine if your references require more than 1 page.

Example White Papers

- Example technological demonstration and scientific exploration white papers are provided on the resources page: https://www.romancoronagraph.space/white-papers-2025/resources



Submission Form for Roman Coronagraph White Papers

Please upload your pdf and provide author information here.

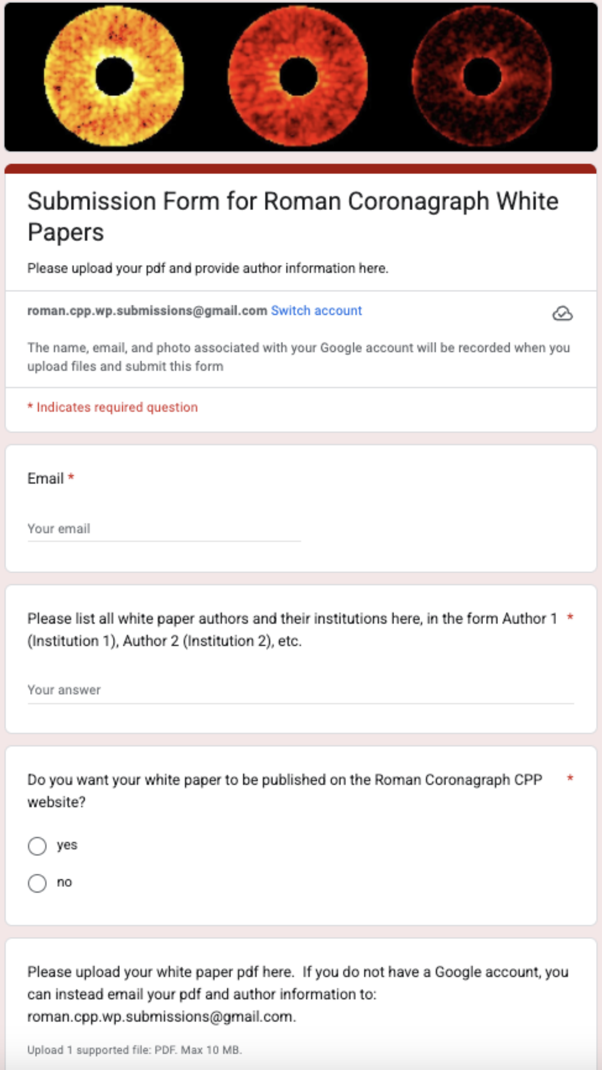
roman.cpp.wp.submissions@gmail.com Switch account

The name, email, and photo associated with your Google account will be recorded when you upload files and submit this form

* Indicates required question

WP submission details

- [Online form for submission]
- To be provided on form:
  - Contact email
  - WP author info
  - Whether you want the WP to be published on the CPP website
- Upload pdf via form or send via email



Submission Form for Roman Coronagraph White Papers

Please upload your pdf and provide author information here.

roman.cpp.wp.submissions@gmail.com Switch account

The name, email, and photo associated with your Google account will be recorded when you upload files and submit this form

* Indicates required question

Email *

Your email

Please list all white paper authors and their institutions here, in the form Author 1 (Institution 1), Author 2 (Institution 2), etc. *

Your answer

Do you want your white paper to be published on the Roman Coronagraph CPP website? *

- yes
- no

Please upload your white paper pdf here. If you do not have a Google account, you can instead email your pdf and author information to: roman.cpp.wp.submissions@gmail.com.

Upload 1 supported file: PDF. Max 10 MB.

The Exposure Time Calculator (ETC)

- Link to the ETC: https://github.com/roman-corgi/corgietc/

corgietc

Roman Coronagraph Instrument Exposure Time Calculator

Using corgietc

The ETC can be run entirely via your browser, with no local installation required. This is recommended for anyone who wants to use the ETC, but not edit it or do other development tasks. Alternatively, you can install everything locally on your own machine, which allows you to run the ETC without an internet connection (although an internet connection is still required for initial runs in order to download additional data required for various calculations).

Two ways to run the ETC: Google Colab

Method 1: Google Colab (No Local Installation)

Navigate to:

https://colab.research.google.com/github/roman-corgi/corgietc/blob/main/Notebooks/00_Google_Colab_Setup.ipynb

Ensure that you are logged in with the Google account you wish to use (data will be written to the Google Drive associated with this account). You can check which account you are logged into by clicking on the user icon in the top right-hand corner of the page.

Two ways to run the ETC: Local Installation

Method 2: Local Installation

If you wish to run the ETC on your own computer, you must first install all required packages and download all relevant data.

We **strongly** recommend use of a dedicated Python virtual environment. The instructions below assume that you have Python (version 3.10 or higher) and pip installed and working on your machine. For help with that, start here: https://wiki.python.org/moin/BeginnersGuide/. We'll assume that Python and pip are executable as `python` and `pip`, respectively, but they might be called `python3` and `pip3` (or something else) on your particular system. These instructions are based on working in a terminal (macOS/Linux) or command prompt/PowerShell (Windows). You also need to have git installed (https://github.com/git-guides/install-git) and executable as `git`.

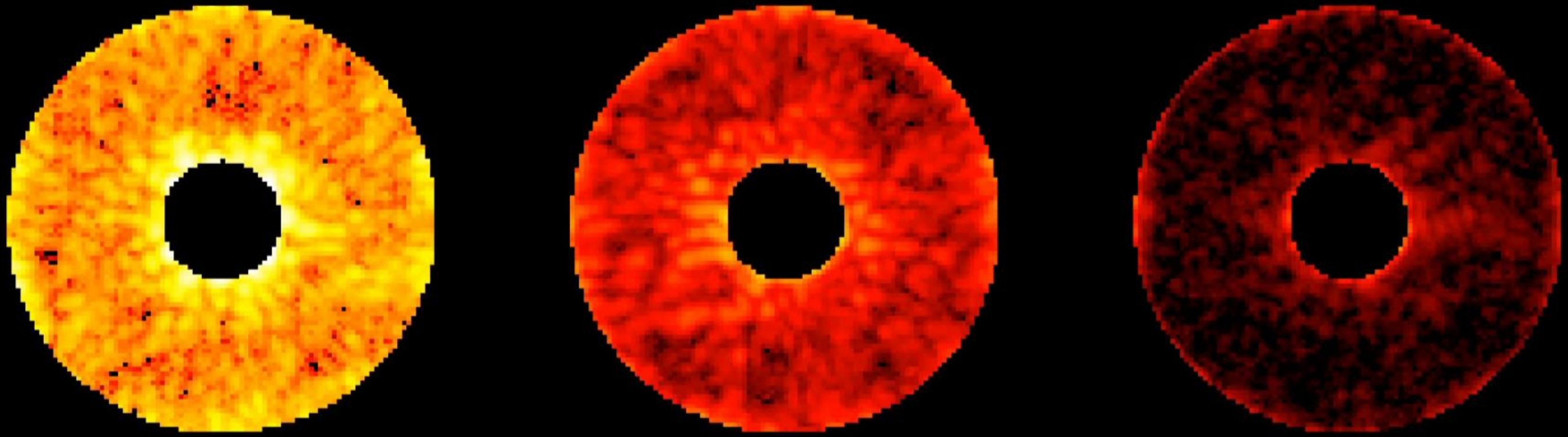
Example Notebooks

- After Colab setup or installation, start with the notebook: 01_Anatomy_of_an_Integration_Time_Calculation.ipynb which steps through the input and output of the ETC model.

Extras

What are the CPP’s top Priorities?

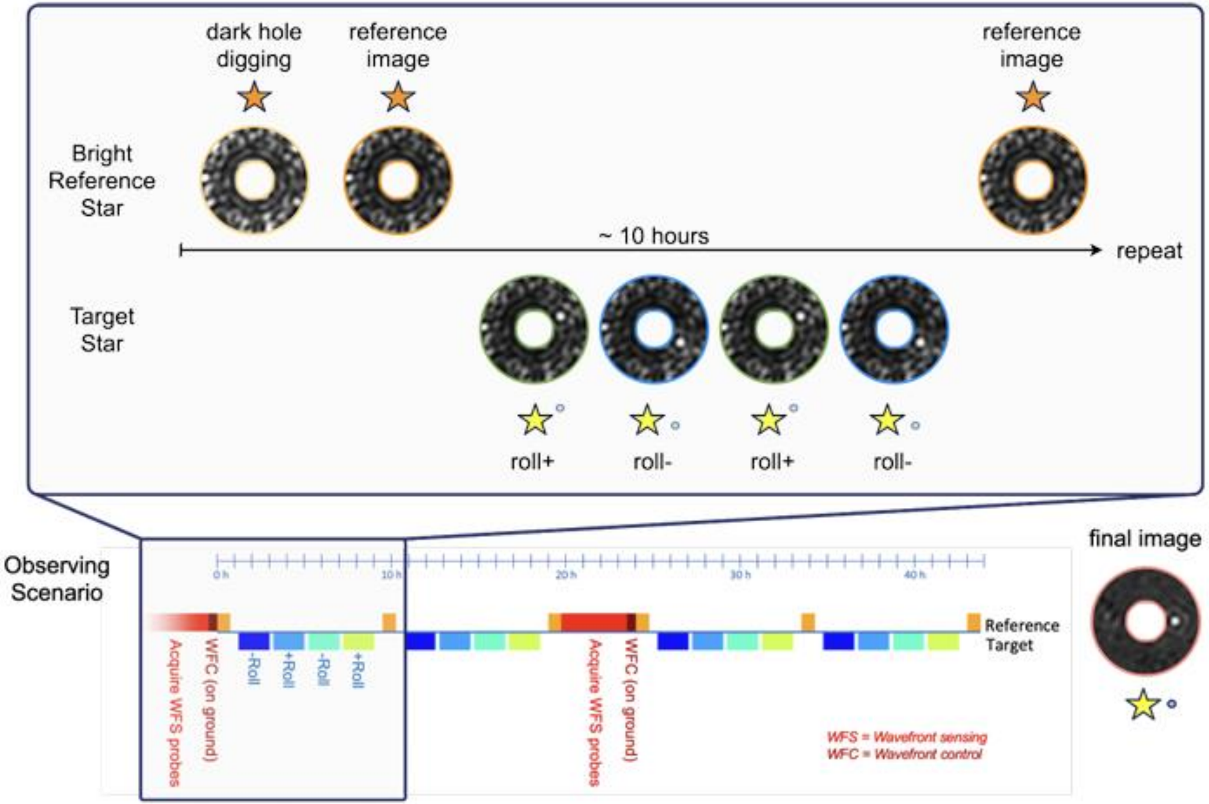
- To make the Roman Coronagraph Instrument as productive as possible
- Near-term high-priority tasks:
  - Development of coronagraph instrument data reduction pipeline (DRP)
  - Development of target and reference star database
  - Vetting programs for reference stars
  - Finalization of instrument calibrations
  - Development of observation scheduling tools
  - Simulating *everything*
- Next: Preparing for beyond-requirements observations



Data from vacuum testing of the Roman Coronagraph Instrument, NASA/JPL-Caltech

Wavefront control techniques will be vital for space-based exoplanet imaging

A typical observing sequence



See Riggs et al. 2025 for all possible observing modes

Table 1 Table of all the designed high-contrast mask configurations in the Roman Coronagraph Instrument. Mask PAM positions reference the labeled mask array layouts shown in later sections. As an example for FPAM, HLC12_C2R1:9 means column 2 and rows 1 to 9 on FPAM substrate HLC12. For the SPC multi-star, the FOV is set by the field stop opening but can be placed anywhere within the listed annular FOV. Abbreviations: Azim., azimuthal (see text for explanation); IWA, inner working angle; OWA, outer working angle.

Mask configuration class	Coro. type	Configuration name	Band number	SPAM position	FPAM position	LSAM position	FSAM position	Azim. FOV (deg)	IWA (λ/D)	IWA (mas)	OWA (λ/D)	OWA (mas)
Required	HLC	Narrow FOV	1	OPEN	HLC12_C2R1:9, HLC12_C3R1:8, HLC12_C4R7:9	NFOV	R1C1, (R1C3), (R6C6), R5C3, R5C4	360	3.0	150.6	9.7	486.8
Best effort	SPC	Wide FOV	1	WFOV	SPC12_R1C1:2, SPC12_R2C1	WFOV	open, R1C5, R6C1, R6C2	360	5.9	296.1	20.1	1008.8
	SPC	Wide FOV	4	WFOV	SPC34_R5C1, SPC34_R8C1, SPC34_R8C3	WFOV	open, R1C5, R6C1, R6C2	360	5.9	424.9	20.1	1447.4
	SPC	Spectroscopy	2	SPEC	SPC12_R3C2, SPC12_-R4C2, SPC12_-R4C4	SPEC	open, R2C5, R3C1, R3C2, R6C5	130	3.0	172.8	9.1	524.2
	SPC	Spectroscopy	3	SPEC	SPC34_R2C2, SPC34_R4C3, SPC34_R6C1	SPEC	open, R1C2, R3C1, R3C2, R4C2, R4C6	130	3.0	191.2	9.1	579.8
Unsupported (high contrast)	SPC	Rotated spectroscopy	2	SPECROT	SPC12_R3C1, SPC12_R3C3, SPC12_R4C3	SPECROT	R4C3, R4C4	130	3.0	172.8	9.1	524.2
	SPC	Rotated spectroscopy	3	SPECROT	SPC34_R2C3:4, SPC34_R4C2	SPECROT	R2C2, R4C2	130	3.0	191.2	9.1	579.8
	SPC	Multi-star	1	MSWC	SPC12_R1C1:2, SPC12_R2C1	WFOV	R4C1	360	5.9	296.1	20.1	1008.8
	SPC	Multi-star	4	MSWC	SPC34_R5C1, SPC34_R8C1, SPC34_R8C3	WFOV	R1C4, (R4C1)	360	5.9	424.9	20.1	1447.4
	HLC	Narrow FOV	2	OPEN	HLC34_R7C1:2, HLC34_R8C2:3	NFOV	R3C3, R2C3	360	3.0	172.8	9.7	558.8
	HLC	Narrow FOV, alternate	2	OPEN	HLC12_C4R1:6, HLC12_C5R1:8	NFOV	R3C3, R2C3	360	3.0	172.8	9.7	558.8
	HLC	Narrow FOV	3	OPEN	HLC34_R5C1:3, HLC34_R6C1:3	NFOV	R3C4, R4C5, R5C1, R5C2	360	3.0	191.2	9.7	618.1
	HLC	Narrow FOV	4	OPEN	HLC34_R3C1:3, HLC34_R4C1:3	NFOV	R3C5	360	3.0	216.0	9.1	655.3
	HLC	Narrow FOV, alternate	4	OPEN	HLC34_R2C1:3	NFOV	R3C5	360	3.0	216.0	9.1	655.3

Who’s leading the CPP?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CPP Chair
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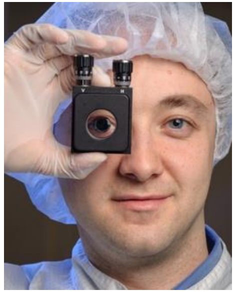
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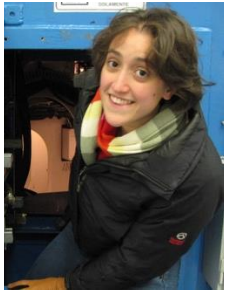
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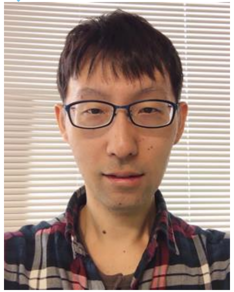
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JPL Roman Project Scientist


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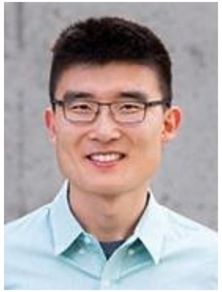
Inaugural CPP co-chair


Arthur Vigan
CNES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