Coronagraph Technology Gaps

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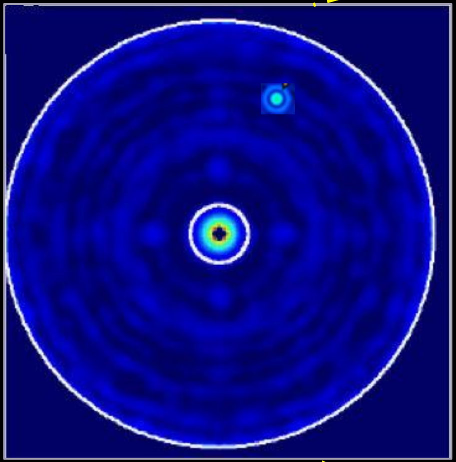
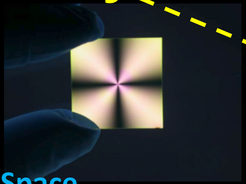
Towards Starlight Suppression for the Habitable Worlds Observatory Workshop
August 8, 2023

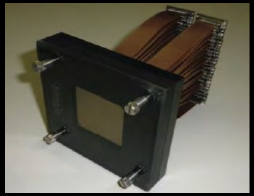
V-NIR Coronagraph/Telescope Technology Gaps

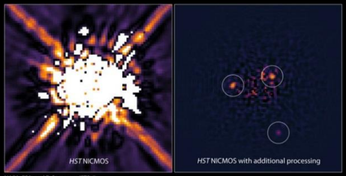


Coronagraph Contrast and Efficiency



- Coronagraph Architectures
- Deformable Mirrors
- Coronagraph Efficiency
- Computational Throughput in Space
- High Bandwidth Optical Comm
- Autonomous On-board WFSC Architectures

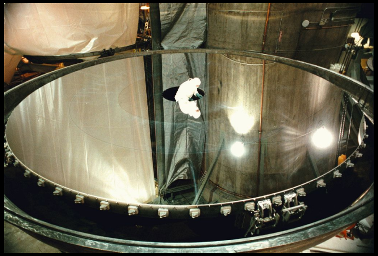




NASA, ESA, and R. Soummer (STScI)

Mirror Technologies for High Angular Resolution

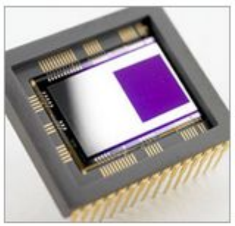
- Mirror Substrate and Structures
- Mirror Finishing
- Mirror Positioning Actuators
- Gravity Sag Offload
- CTE Characterization
- UV Coatings: Wavefront Effects

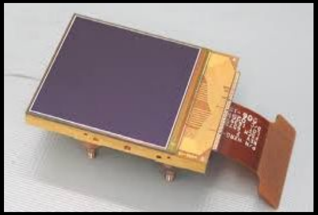


Coronagraph Stability

- Wavefront Sense/control
- Precision Pointing Stability
- Disturbance Reduction and Observatory Stability
- Segment Relative Pose Sense/Control
- Telescope Thermal Sense/Control
- Vibration Isolation
- Laser Gauges
- Integrated Modeling of Coronagraph/Telescope System

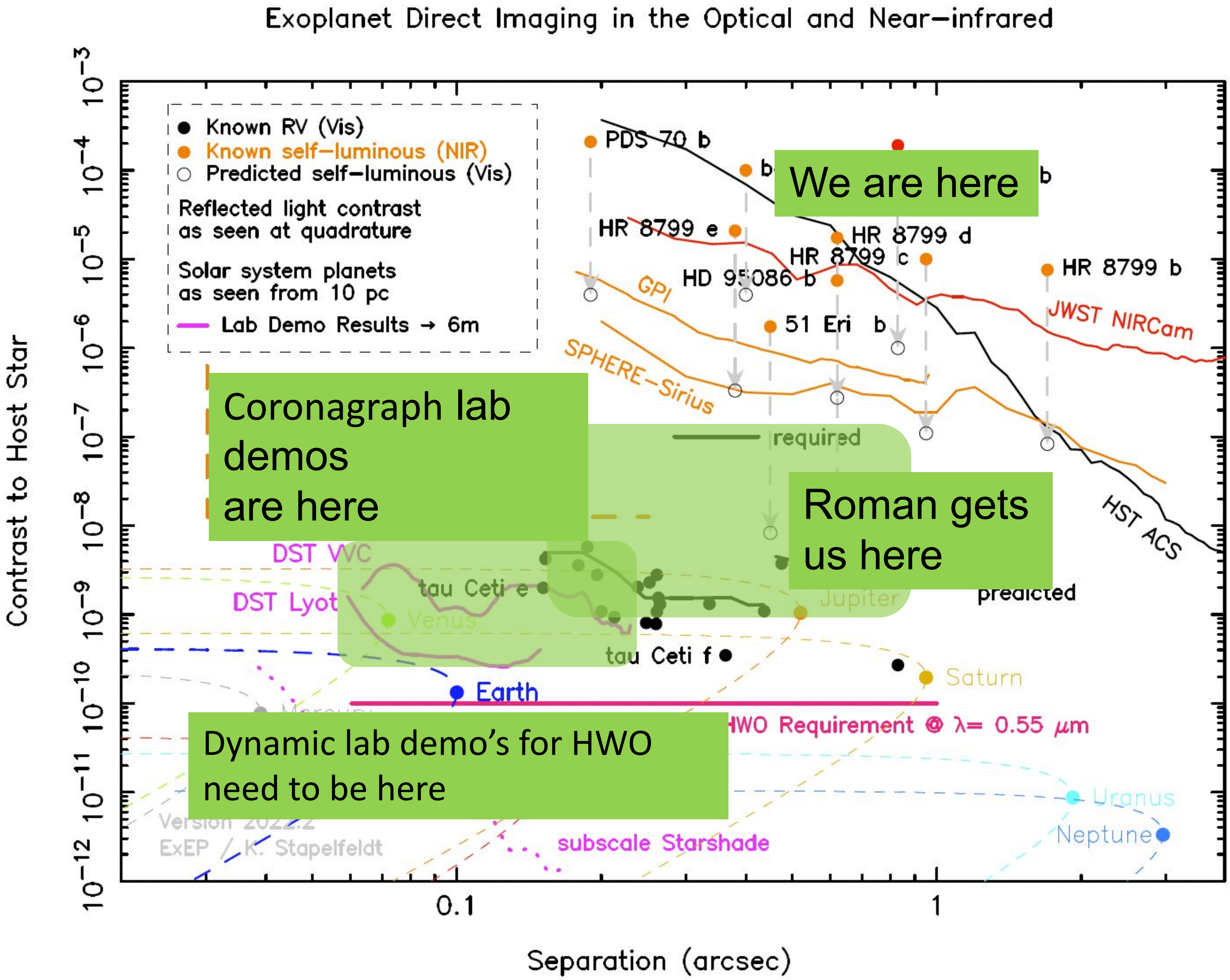
Vis/NIR Detection Sensitivity





- NIR Detectors
- UV/Vis Detectors
- Photon-counting energy-resolving detectors

Contrast Requirements



Exoplanet Direct Imaging in the Optical and Near-infrared

We are here

Coronagraph lab demos are here

Roman gets us here

Dynamic lab demo's for HWO need to be here

Coronagraph Contrast and Efficiency

- **Goal performance**
  - ≤ 10^{-10} raw contrast
  - >=20% instantaneous bandwidth; 200-1800 nm [TBD]
  - inner working angle ≤ 3 λ/D, outer working angle >45 λ/D [TBD] – deformable mirrors with 96 x 96 actuator count
  - > 10% [TBD] throughput
  - **segmented** pupil
- **State of the Art**
  - **unobscured** pupil: 4×10^{-10} raw contrast **at 10% bandwidth** at 550 nm, angles of 3–9 λ/D (classic Lyot coronagraph demo in High Contrast Imaging Testbed (HCIT))
  - **obscured** pupil: 1.6×10^{-9} raw contrast at **10% bandwidth** across angles of 3–9 λ/D (Roman Coronagraph lab demos)
  - **segmented/unobscured** pupil: 2.5×10^{-8} raw contrast in **monochromatic** light across 6–10 λ/D (Lyot coronagraph demo in High-contrast imager for Complex Aperture Telescope (HiCAT))) Static segmented pupil 4.7×10^{-9} in 10% BW averaged from 3-10 λ /D (VVC). Static obstructed/segmented pupil 1.8e-8 in 10% band (PIAACMC)
  - Roman coronagraph flight qualified AOX 48x48 actuator deformable mirrors

See upcoming talks this session, in particular Bertrand Mennesson, Emiel Por, Garreth Ruane

Coronagraph Stability

- **Goal Performance**
  - Contrast stability on time scales needed for spectral measurements (possibly as long as days).
  - Requires an integrated approach to the coronagraph and observatory: wavefront sense/control, metrology and correction of mirror segment phasing, vibration isolation/reduction
  - This stability is likely to require wavefront error stability at the level of 10–100 pm per control step (of order 10 minutes - TBD).

- **State of the Art**
  - Roman Coronagraph demonstrated 6.5×10^{-9} contrast in a simulated dynamic environment using Low-Order Wavefront Sense and Control (LOWFS) (obtained 12 pm focus sensitivity)
  - nm accuracy and stability demonstrated with laser metrology
  - Capacitive gap sensors demonstrated at 10 pm 80 dB vibration isolation demonstrated
  - Gaia cold gas microthrusters and LISA pathfinder colloidal microthrusters can reduce vibrations

See upcoming talks this session: Emiel Por, Olivier Guyon;
Thursday session on Ultrastable Observatory: Mike McElwain

UV/Vis/NIR Detection Sensitivity

- **Goal Performance**
  - The capability to detect single photons in the Near **UV** (200-400 nm), **Vis** (400-900 nm) and **Near Infrared** (NIR; 900-1800 nm)
  - Read noise: < 1e- RMS
  - Spurious count rate (dark current) < 0.001 e-/px/s
  - Lifetime in L2 radiation environment 5–10 years
  - may need 2k x 2k format

- **State of the Art**
  - **Vis**: Roman coronagraph 1k x 1k Electron-Multiplying Charge Coupled Device (EMCCD) detectors meet requirements, longer lifetime desirable. Photon counting also demonstrated in Quanta Image Sensor (QIS) and Skipper CCD
  - **NIR**: Linear Mode Avalanche Photodiode (LMAPD) HgCdTe close to photon-counting
  - **UV**: Delta-doping process to enhance UV efficiency demonstrated on EMCCDs, could apply to other silicon detectors
  - Demonstrated Cryogenic superconducting photon-counting Superconducing Nanowire Single Photon Detectors (SNSPDs), energy resolving in Microwave Kinetic Induction Device (MKID),Transition Edge Sensor (TES)); < 1k x 1k format size

For More Details

Astrophysics Biennial Technology Report (ABTR) - 2022

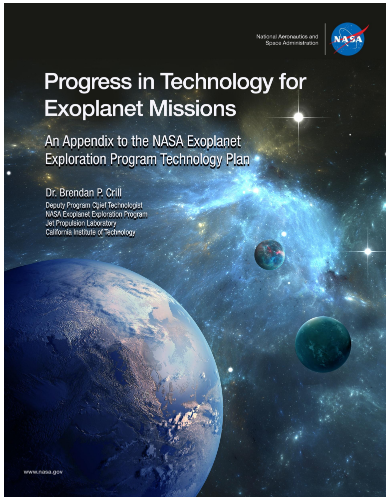
Astrophysics Biennial Technology Report

2022

Astrophysics Division

SCIENCE MISSION DIRECTORATE

Progress in Technology for Exoplanet Missions - 2022



National Aeronautics and Space Administration

Progress in Technology for Exoplanet Missions

An Appendix to the NASA Exoplanet Exploration Program Technology Plan

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www.nasa.gov