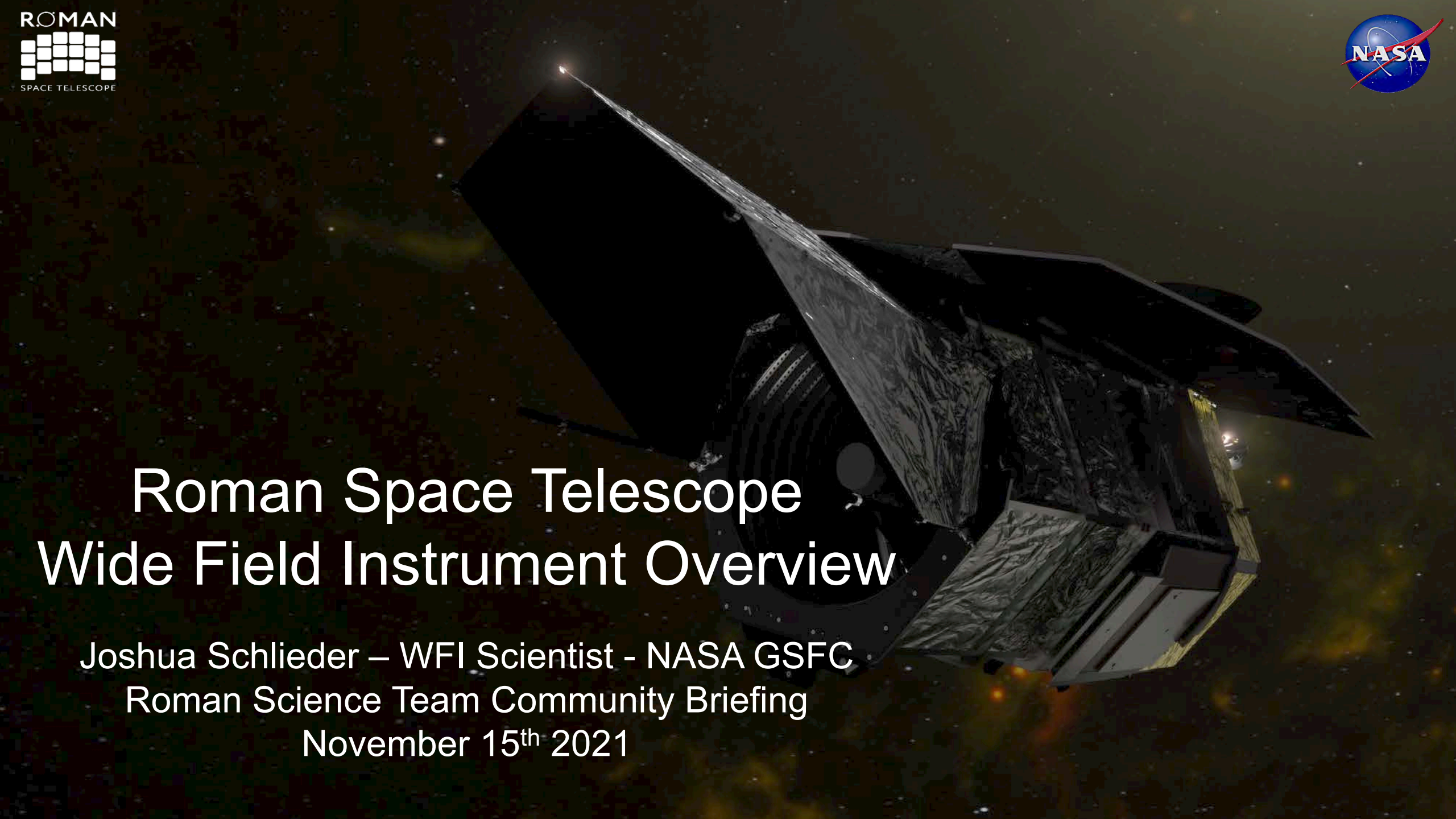


# Roman Space Telescope
# Wide Field Instrument Overview

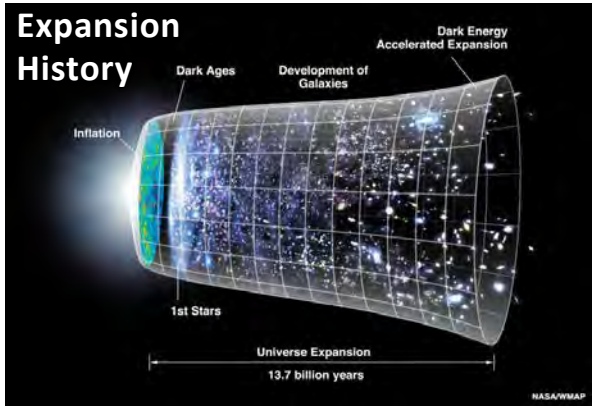
Joshua Schlieder – WFI Scientist - NASA GSFC

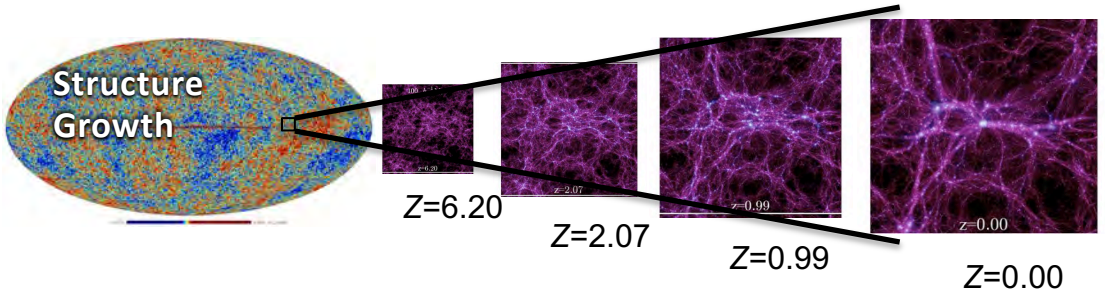
Roman Science Team Community Briefing

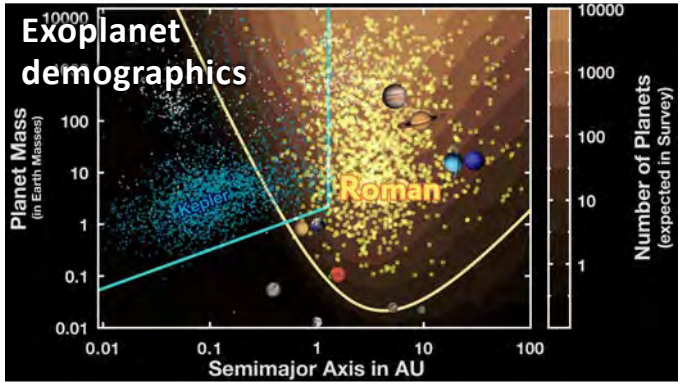
November 15th 2021

# Roman Space Telescope Mission Objectives

- **Wide-Field IR Surveys**
- **Expansion history of the Universe**
  - Using Type Ia supernovae, weak lensing, and galaxy redshift surveys
- **Growth of Structure in the Universe**
  - Using weak lensing, redshift space distortion, and galaxy clustering techniques
- **Exoplanet Census**
  - Microlensing census of cold exoplanets
- **General Astrophysics Surveys**
  - Devote substantial fraction of mission lifetime to peer reviewed program
- **Coronagraph technology demonstration**
  - Demonstrate exoplanet coronagraphy with active wavefront control

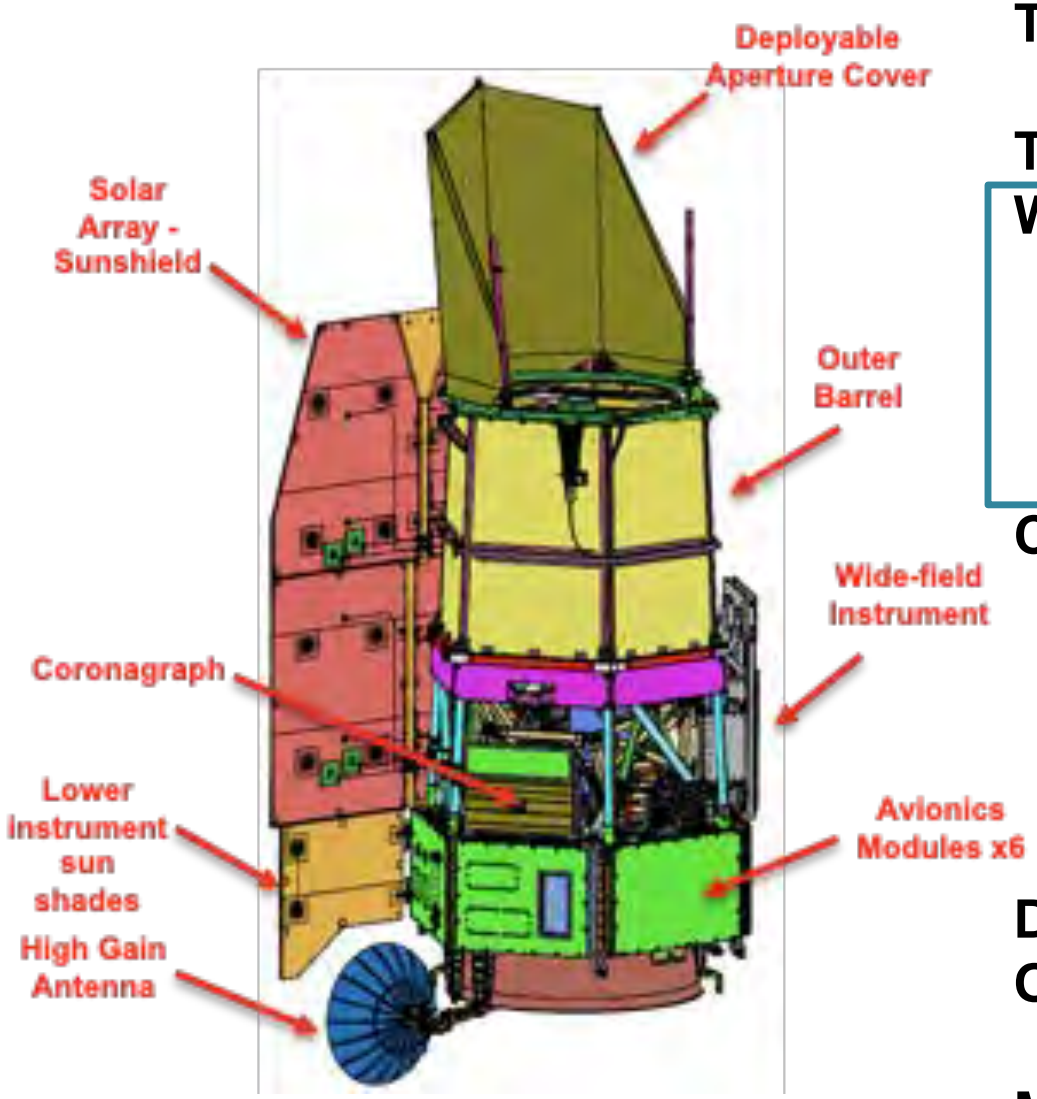



**Core Roman science requires highly sensitive, wide-field, multi-wavelength survey capability with very well controlled systematics --** This is achieved with the *Wide Field Instrument (WFI)*

# Roman Observatory Context




**Telescope**: 2.4m aperture

**Two Instruments:**

**Wide Field Instrument (WFI)**

- Imaging and Slitless Spectroscopy
- Vis/Near IR bands (0.48 – 2.3 micron)
- Field-of-view 0.281 deg$^2$ (~200× HST WFC3-IR)
- 18 4k × 4k detectors (~300 Mpix)

**Coronagraph Instrument**

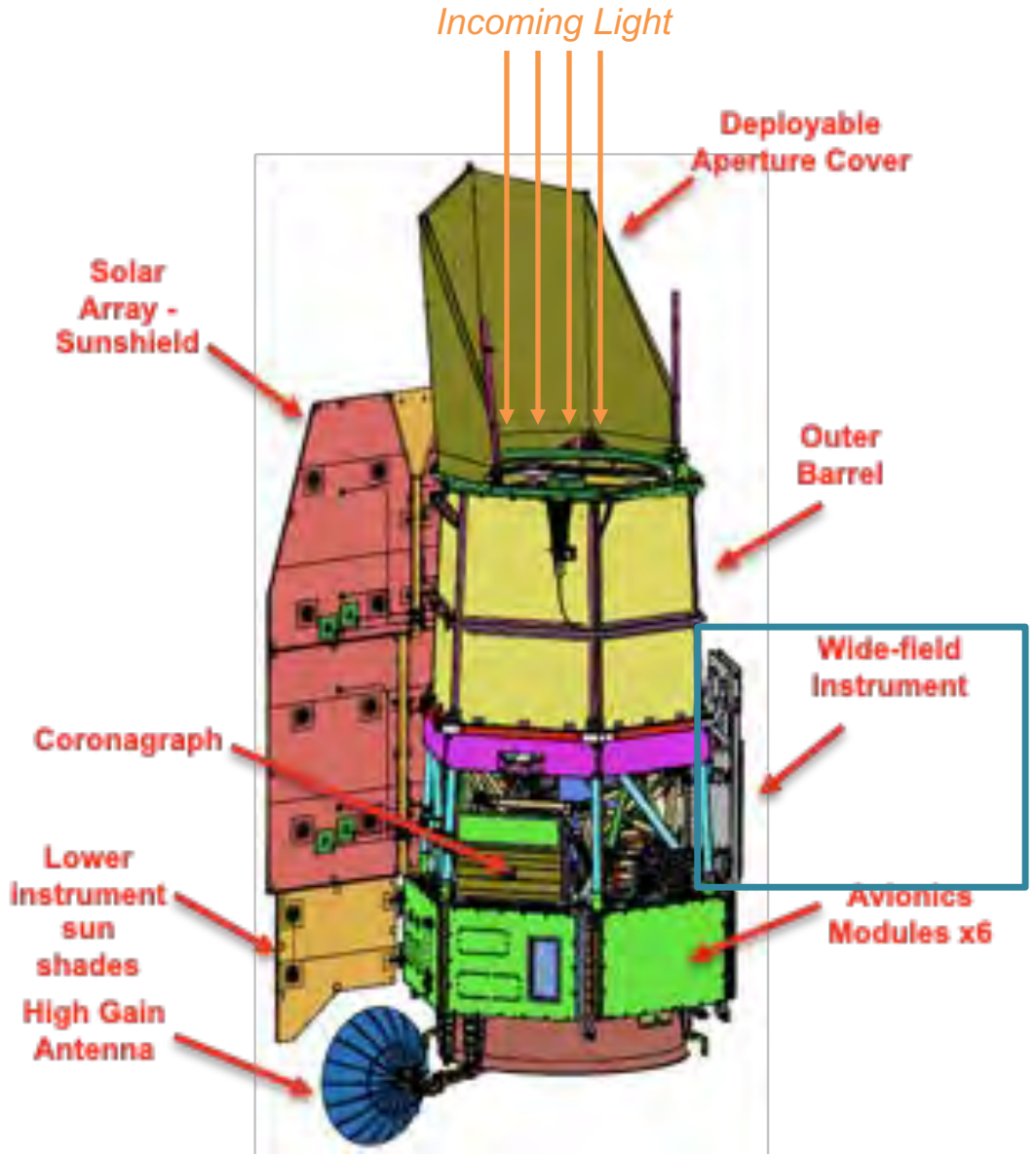
- High contrast imaging technology demo
- First active wavefront control in space
- Vis band imaging, polarimetry, and spectroscopy
- Contrast $10^{-8}$-$10^{-9}$

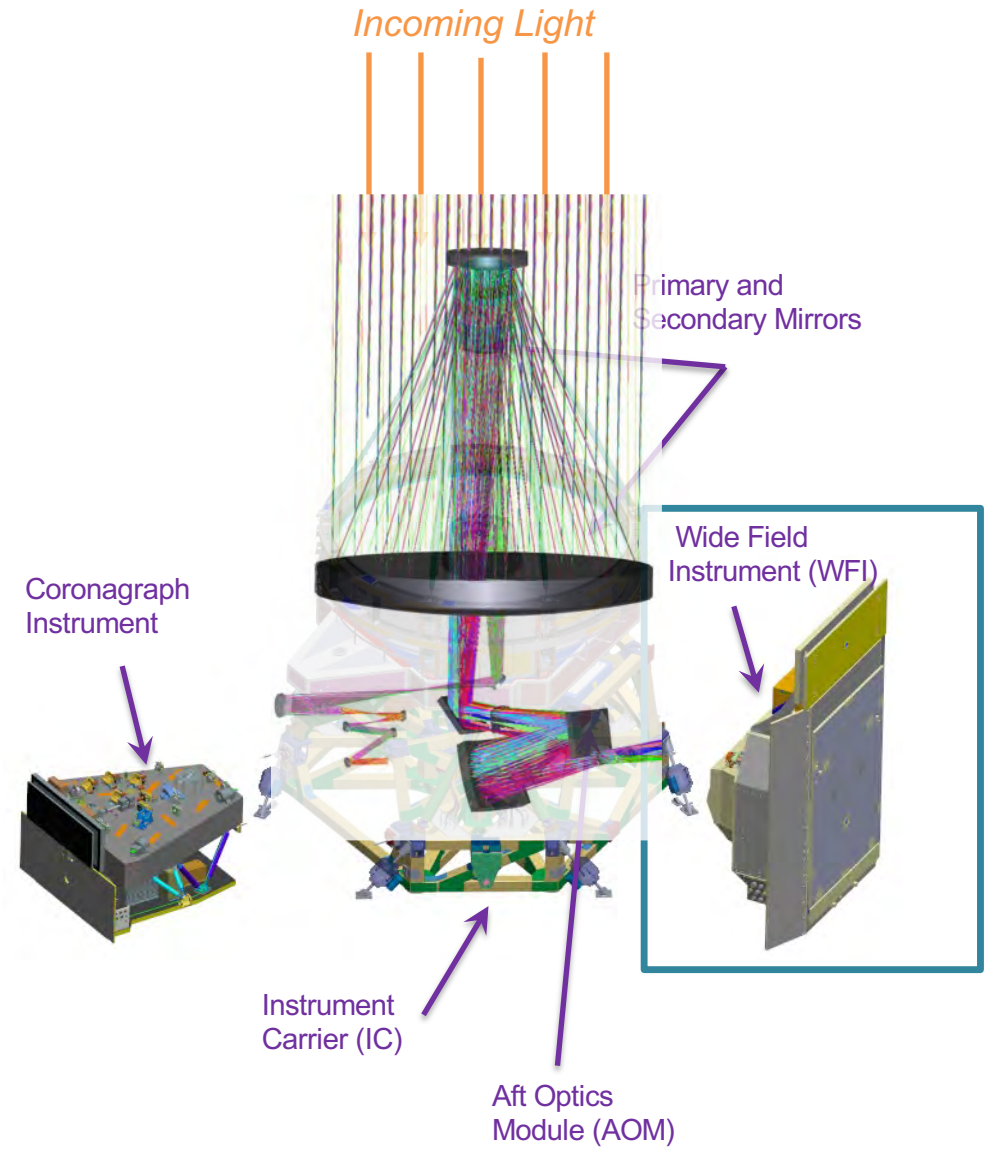
**Data Volume**: 11 Tb/day
**Orbit**: Sun-Earth L2

**Mission Duration**: 5 yr, 10yr goal

Mission and telescope overview

# Wide Field Instrument in Context



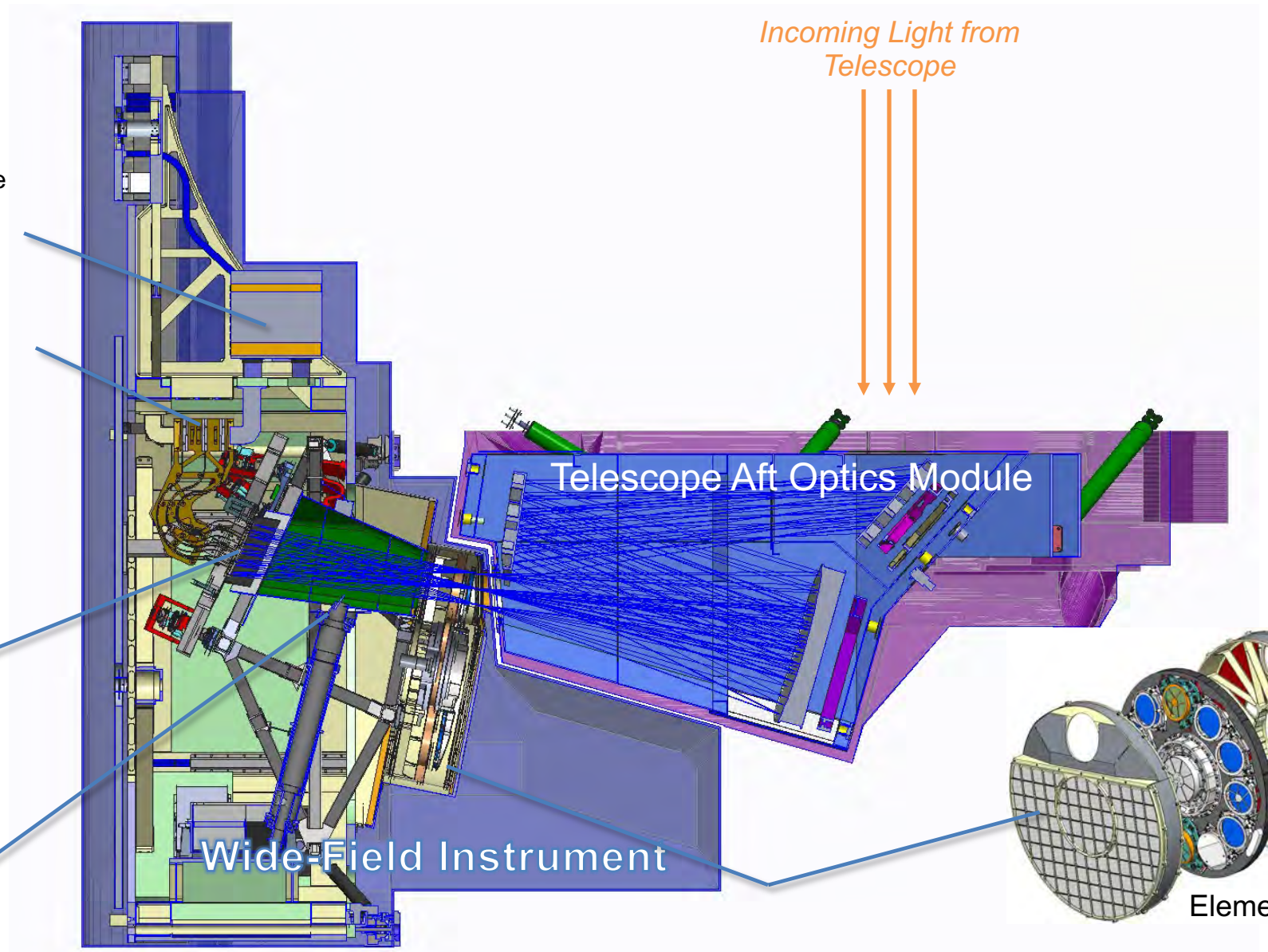



# Roman Wide-Field Instrument Overview

- Large field-of-view (FOV) – 0.8 x 0.4 deg (0.281 deg$^2$, excluding gaps)
- Spatial sampling: 0.11 arcsec/pixel
- Image stability: 1.0 nm RMS wave front error (WFE) variation in 180 sec
- Visible to Near-infrared (NIR) bandpass (0.48 to 2.3μm)
  - 8 imaging filters
  - Blank position for darks, flat-fields, and other calibrations with internal light source
  - Grating+prism (Grism) for multi-object spectroscopy at medium spectral resolution
  - Prism for multi-object spectroscopy at lower resolution
- Guide star sensing interleaved with science data collection
- WFI passed Critical Design Review in January 2021
- Led by NASA GSFC and Ball Aerospace

WFI Technical Overview

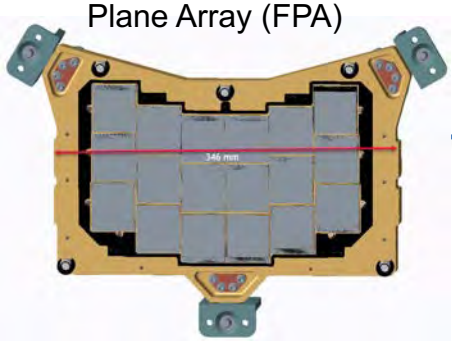
# Roman Wide-Field Instrument Overview Schematic



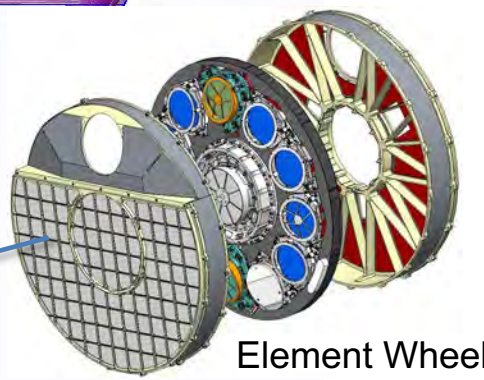

Focal Plane Electronics (FPE)

Sensor Control Electronics Assembly (SCEA)

Mosaic Plate Assembly (MPA) with detector Focal Plane Array (FPA)



Relative Calibration System (RCS)



Element Wheel Assembly (EWA)
8 filters, grism, prism, dark

# Element Wheel Assembly

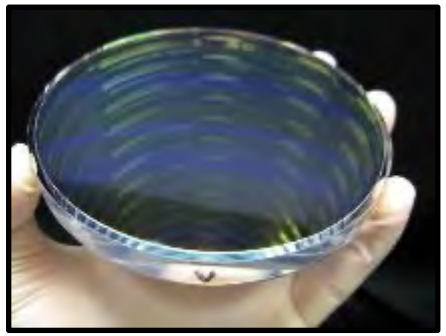
- The element wheel carries:
  - 8 imaging filters
  - Prism for low-dispersion multi-object spectroscopy
  - Grism for medium-dispersion multi-object spectroscopy
  - Blank position for darks and flat-fields

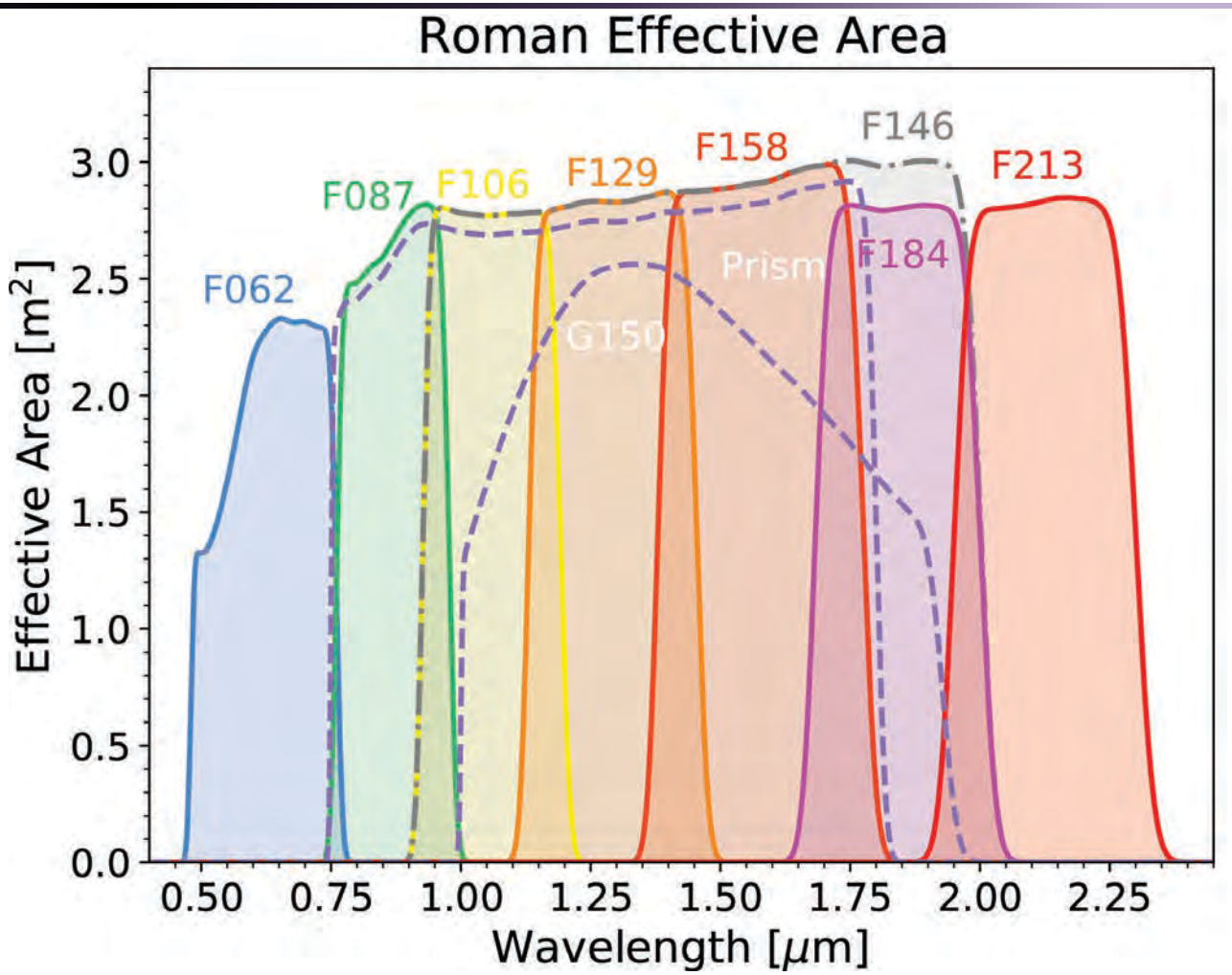
# Filters and Dispersing Elements I

- **WFI filters provide imaging from 0.48 – 2.3 μm (480 – 2300 nm)**

| Filter | FWHM Passband (nm) | 1 h, 5σ limiting AB mag |
|---|---|---|
| F062 | 480 – 760 | 28.5 |
| F087 | 760 – 977 | 28.2 |
| F106 | 927 – 1192 | 28.1 |
| F129 | 1131 – 1454 | 28.0 |
| F158 | 1380 – 1774 | 28.0 |
| F184 | 1683 – 2000 | 27.4 |
| F213 | 1950 – 2300 | 26.2 |
| W146 | 927 – 2000 | 28.4 |

F158 filter Engineering Design Unit (EDU)






*Flight filters in hand and undergoing characterization and test*

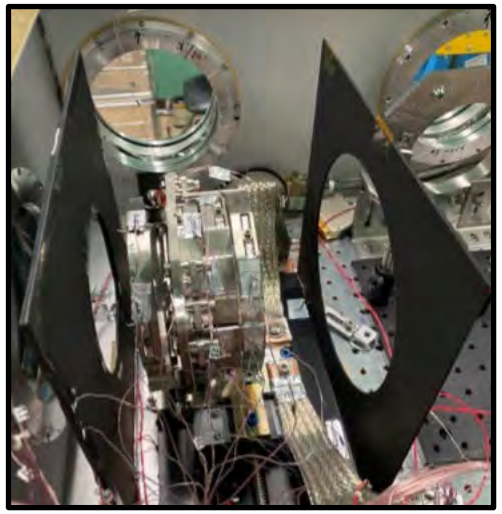
Akeson et al. 2019
Filter and Imaging parameters

# Filters and Dispersing Elements II

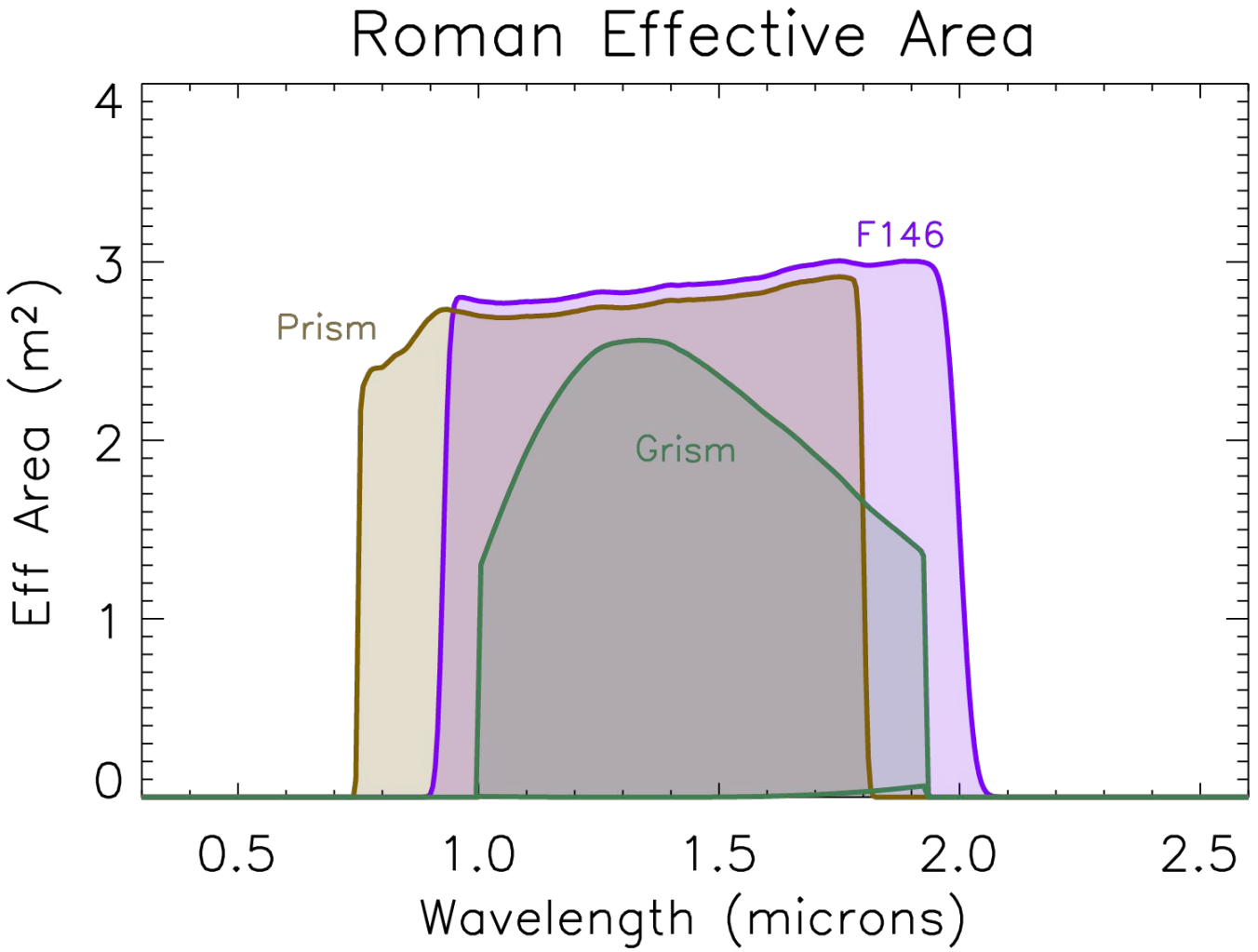
- **WFI Prism and Grism provide full field, slitless spectroscopy from 750 – 1930 nm**

| Disperser | Bandpass (nm) | Resolution | 1 h, 5σ (2 pix) continuum |
|---|---|---|---|
| Prism | 750 –1800 | 80-180 | 23.8 |
| Grism | 1000 – 1930 | 461*λ (in μm) | 21.7 |

(@1.2 μm)



Grism Engineering Test Unit (ETU) in testing

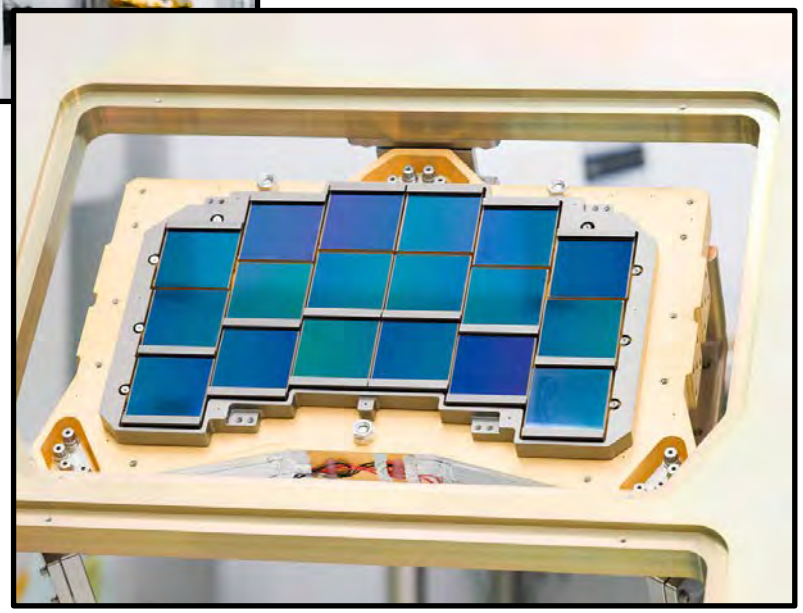



*Flight grism assembly is complete, entering characterization and test. Flight prism assembly is in progress.*

Akeson et al. 2019
Prism and Grism Parameters

# Focal Plane Array and Detectors I

Roman detector compared to typical cell phone camera



Engineering Test Unit (ETU) focal plane array and mosaic plate

- 18 H4RG-10 detectors
  - 6 x 3 mosaic arrangement
  - Each detector has 4096 x 4096 pixels
  - 10 μm/pixel
  - 3.04 s readout time
  - On sky:
    - 0.11 arcsec/pixel
    - 0.281 deg$^2$ FOV
- A 300 million pixel, wide-field survey camera
- Excellent detector characterization, stability, and calibration

*Full set of flight detectors (and spares) now in hand, prep for flight focal plane integration ongoing*

Mosby et al. 2020
Flight candidate press release

# Focal Plane Array and Detectors II

Roman detectors undergo detailed characterization to ensure they meet strict requirements. Below are representative values *for detectors selected for flight*

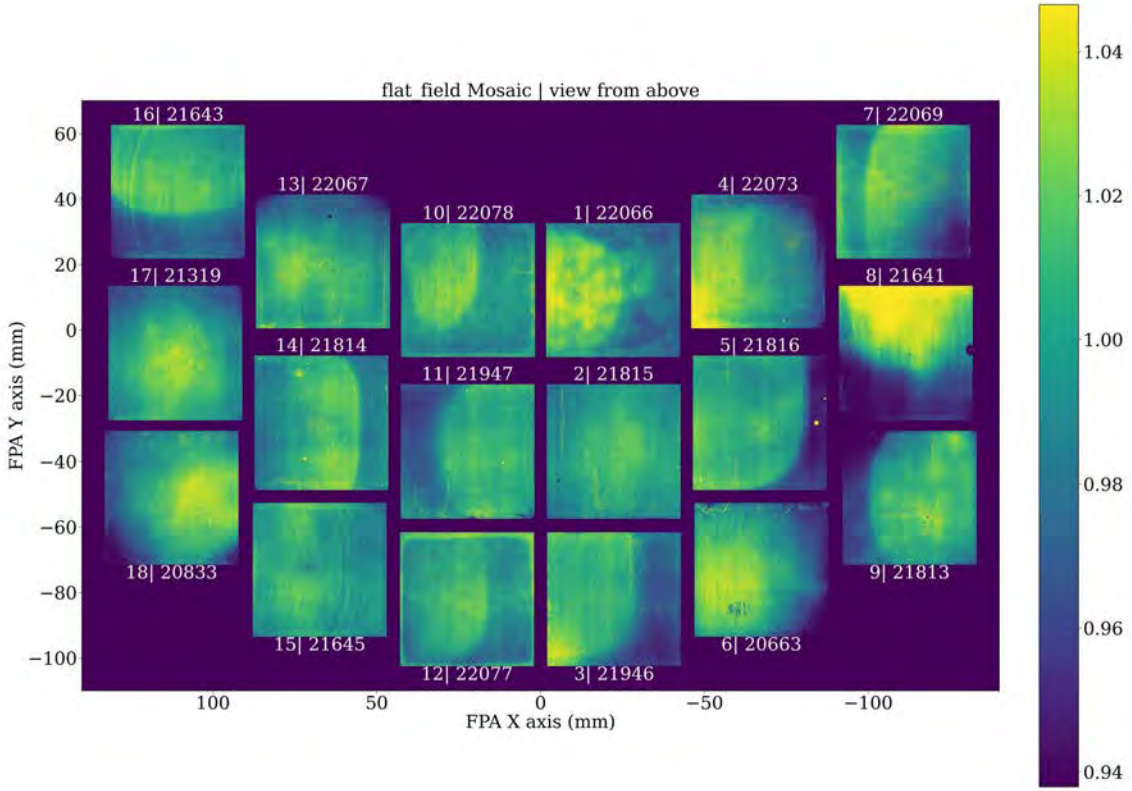
| Quantity | Spec. Value | Units | Typical actual |
|---|---|---|---|
| Dark Current | <0.1 | e-/sec/pixel | <0.005 |
| CDS Read Noise | <20 | e- RMS | 15-16 |
| Total Noise in 180s | <6.5 | e- RMS | 5-6 |
| Quantum Efficiency | >80% | (avg 0.8-2.1µm) | ~95% |
| Quantum Efficiency | >60% | (avg 0.6-0.8µm) | 75-80% |
| Pixel operability | >95% | N/A | >99% |
| Total crosstalk | <12% | N/A | <8% |

CDS noise is the RMS noise from the difference of two successive detector readouts
Total noise is uncertainty on slope fit for an exposure time of 180 sec

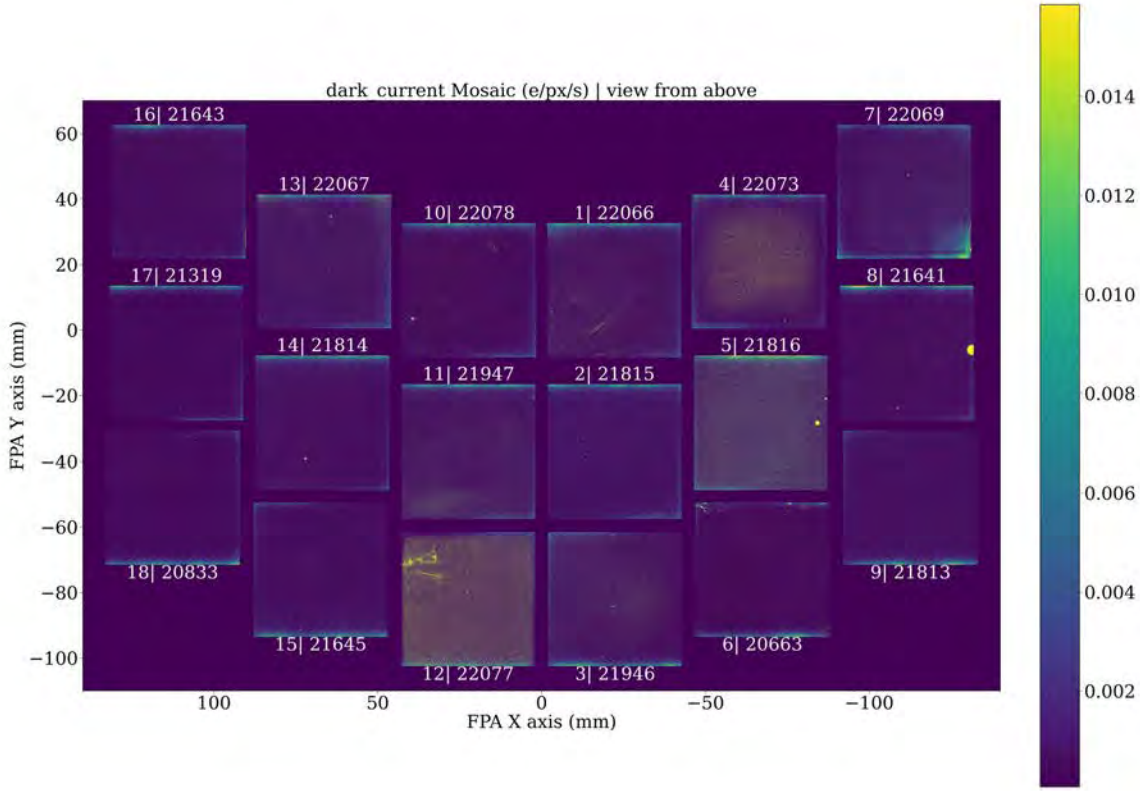
Mosby et al. 2020

# Focal Plane Array and Detectors III

Flight detector flat field comparison

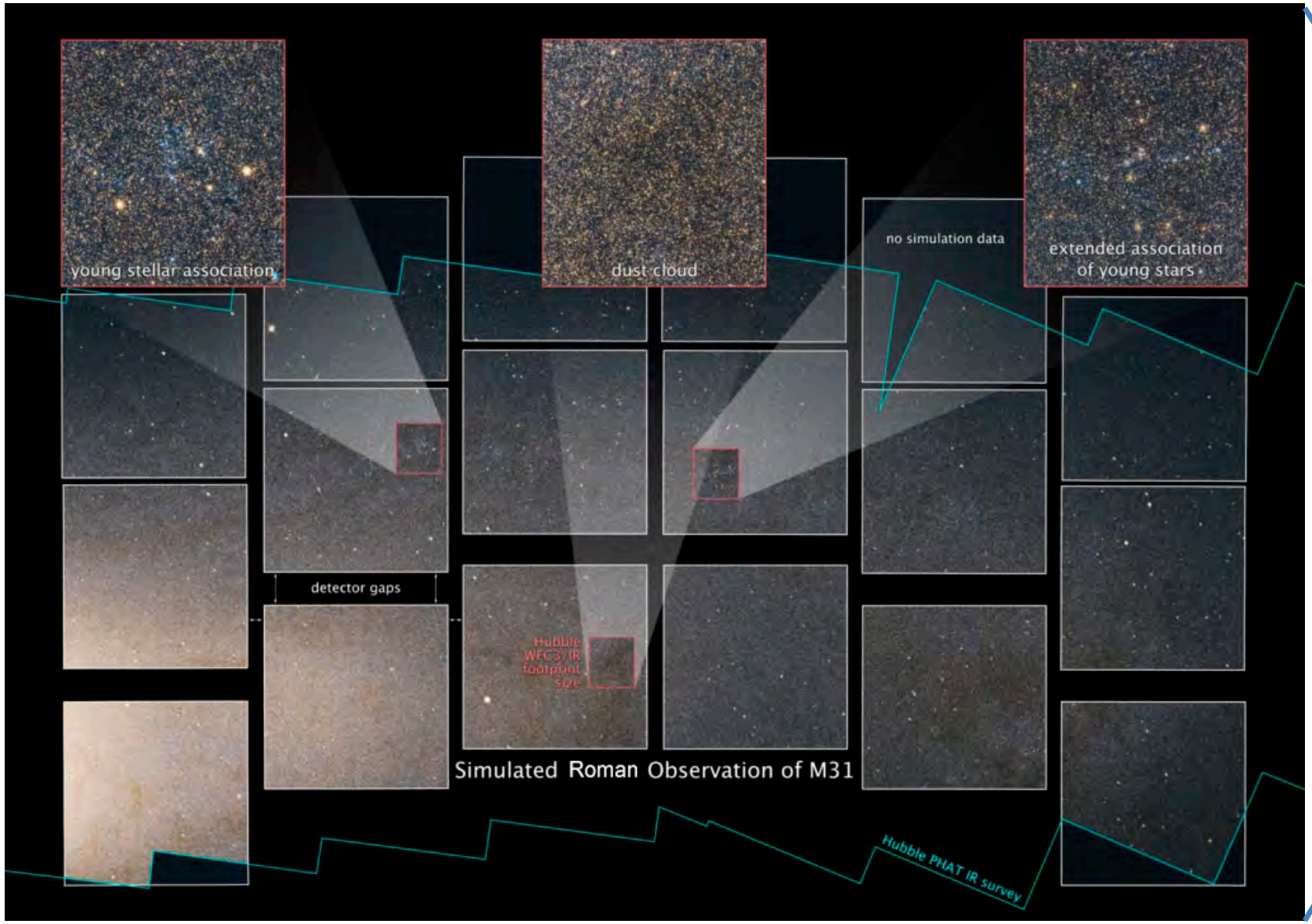


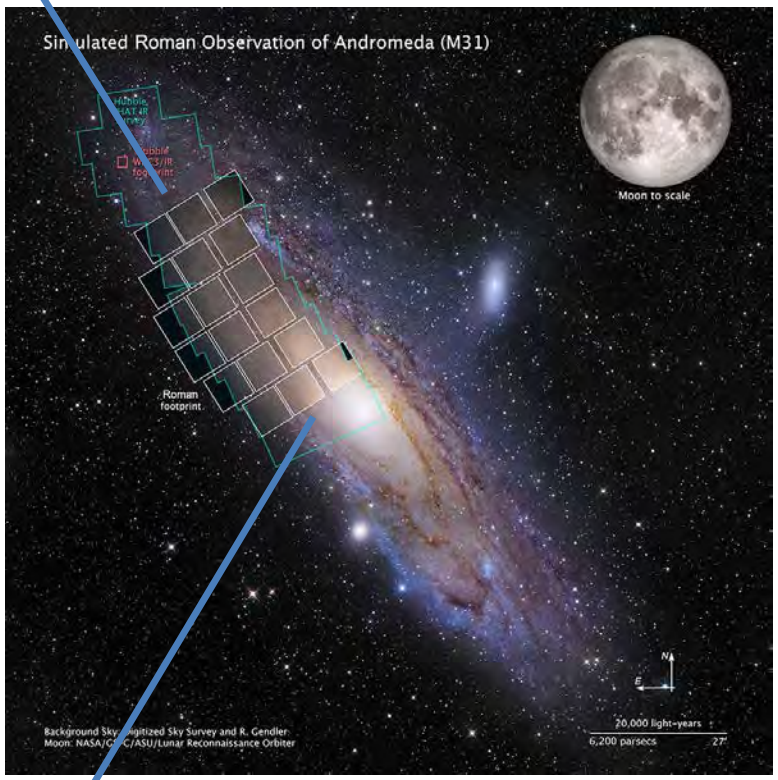

Flight detector dark current comparison




18 detectors selected for flight all *exceed requirements*, color scale presented to highlight small differences in performance.

# Focal Plane Array and Detectors IV

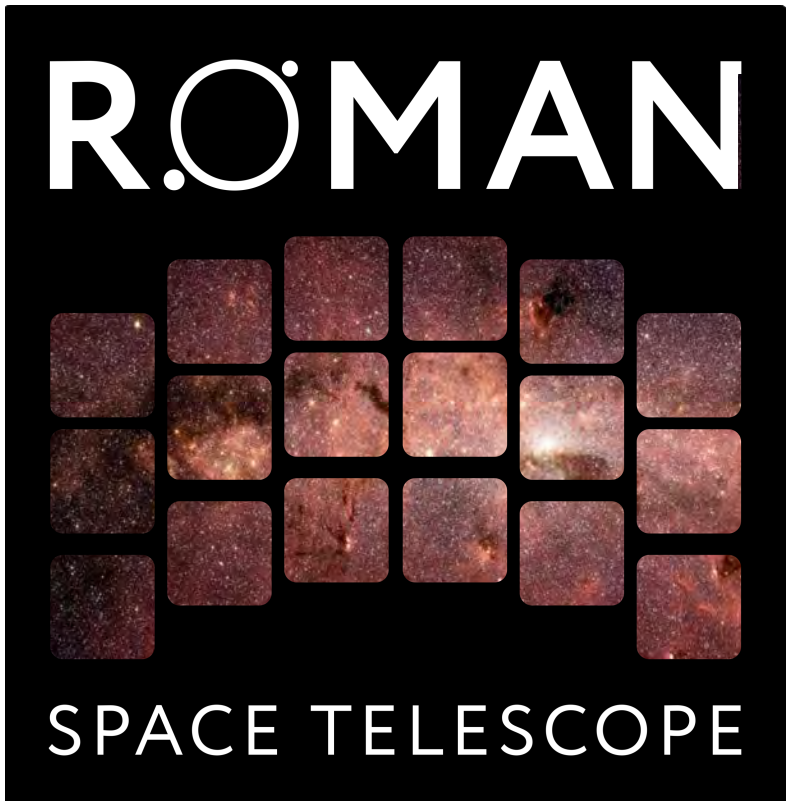



The WFI focal plane provides Hubble's resolution and sensitivity over >200x larger FOV – *flagship level survey capability*

# Relative Calibration System (RCS)

- **Roman science requirements lead to the necessity for *very precise* flux calibration**
- **The WFI is equipped with an on-board calibration system to enable multiple measures of detector non-linearity and other systematics -- this is the Relative Calibration System (RCS)**
- **The RCS is an instrument that projects smooth flat fields onto the detector focal plane array at wavelengths matched to the WFI filters across a wide range of fluxes**
- **RCS calibration measurements are repeated throughout the mission to trend systematics over time**
- ***The RCS is integral to the WFI*, not a part of the telescope or spacecraft**

# Roman Wide Field Instrument Summary

- **Roman science objectives lead to the need for a sensitive, wide-field instrument with multi-wavelength imaging/spectroscopy and well controlled systematics**
- **The Wide Field Instrument (WFI) provides these capabilities through several key subsystems**
- **WFI flight hardware is solidly in the build and test phase!**