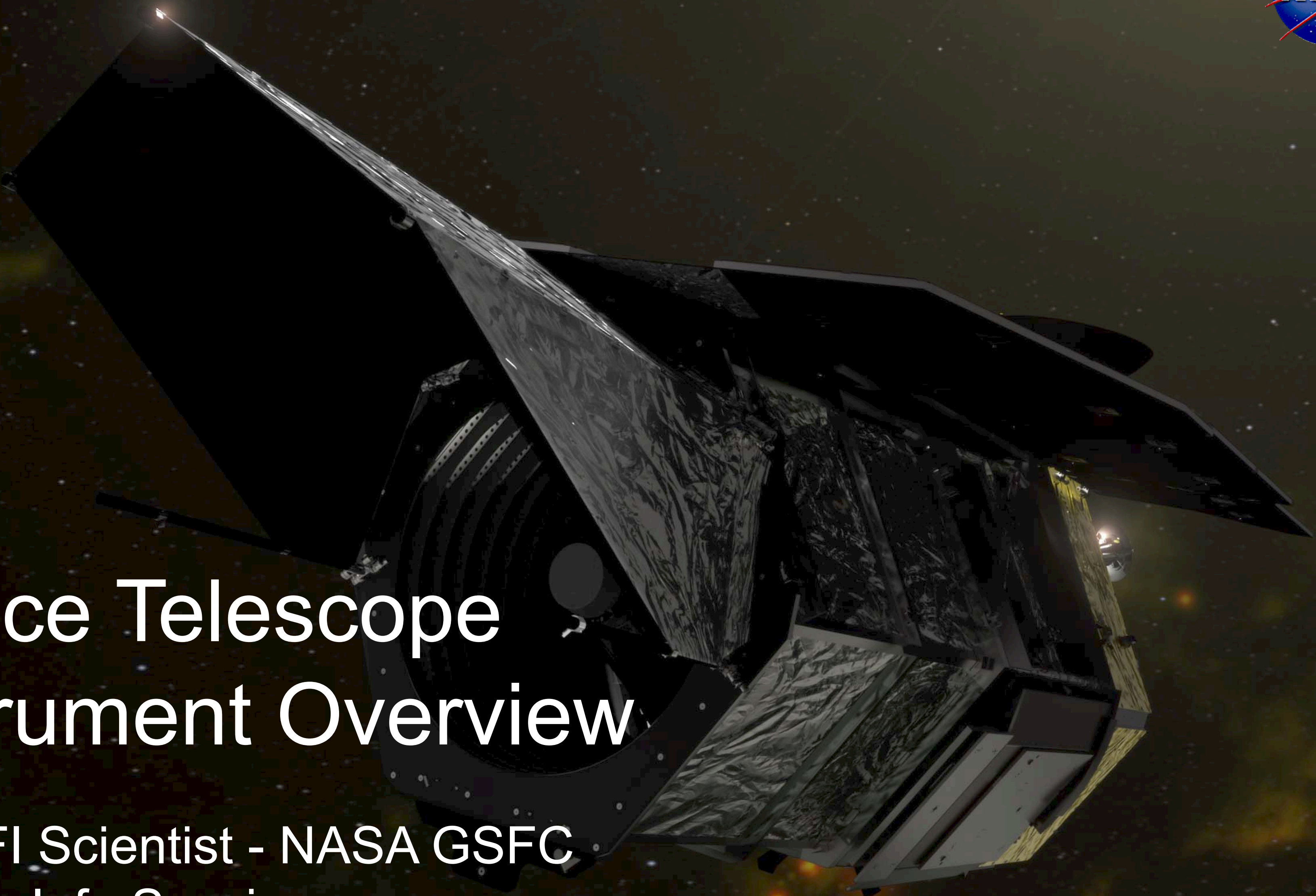


Roman Space Telescope Wide Field Instrument Overview

Joshua Schlieder – WFI Scientist - NASA GSFC

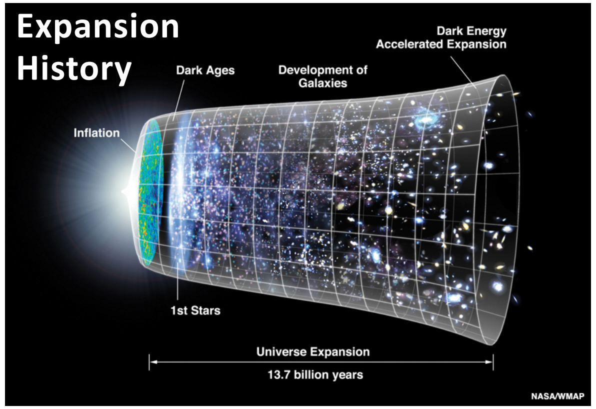
ESA Roman Info Session

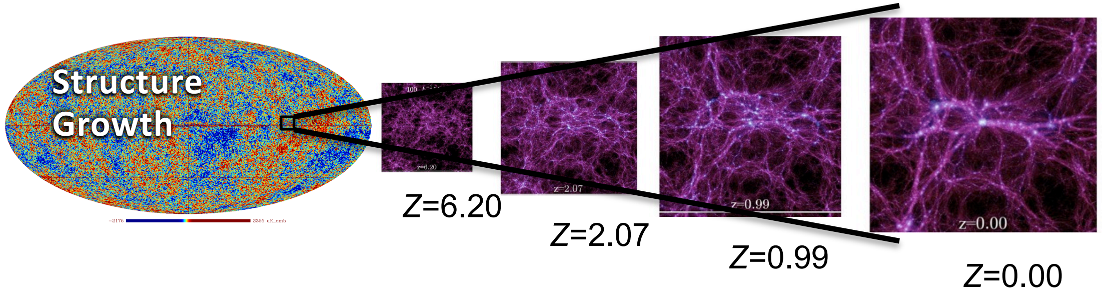
July 6, 2021

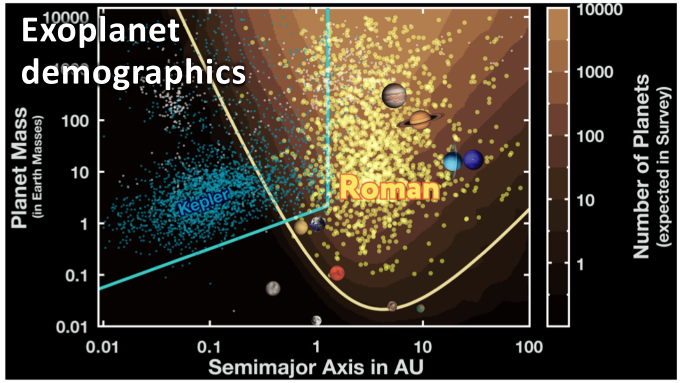
Roman Space Telescope Mission Objectives

- **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 -- <u>This is achieved with the *Wide Field Instrument*</u>







Roman Wide-Field Surveys

Wide-Field Infrared Surveys of the Universe

Large core community surveys and smaller focused surveys

All data to be public immediately

Core Community Surveys under consideration:

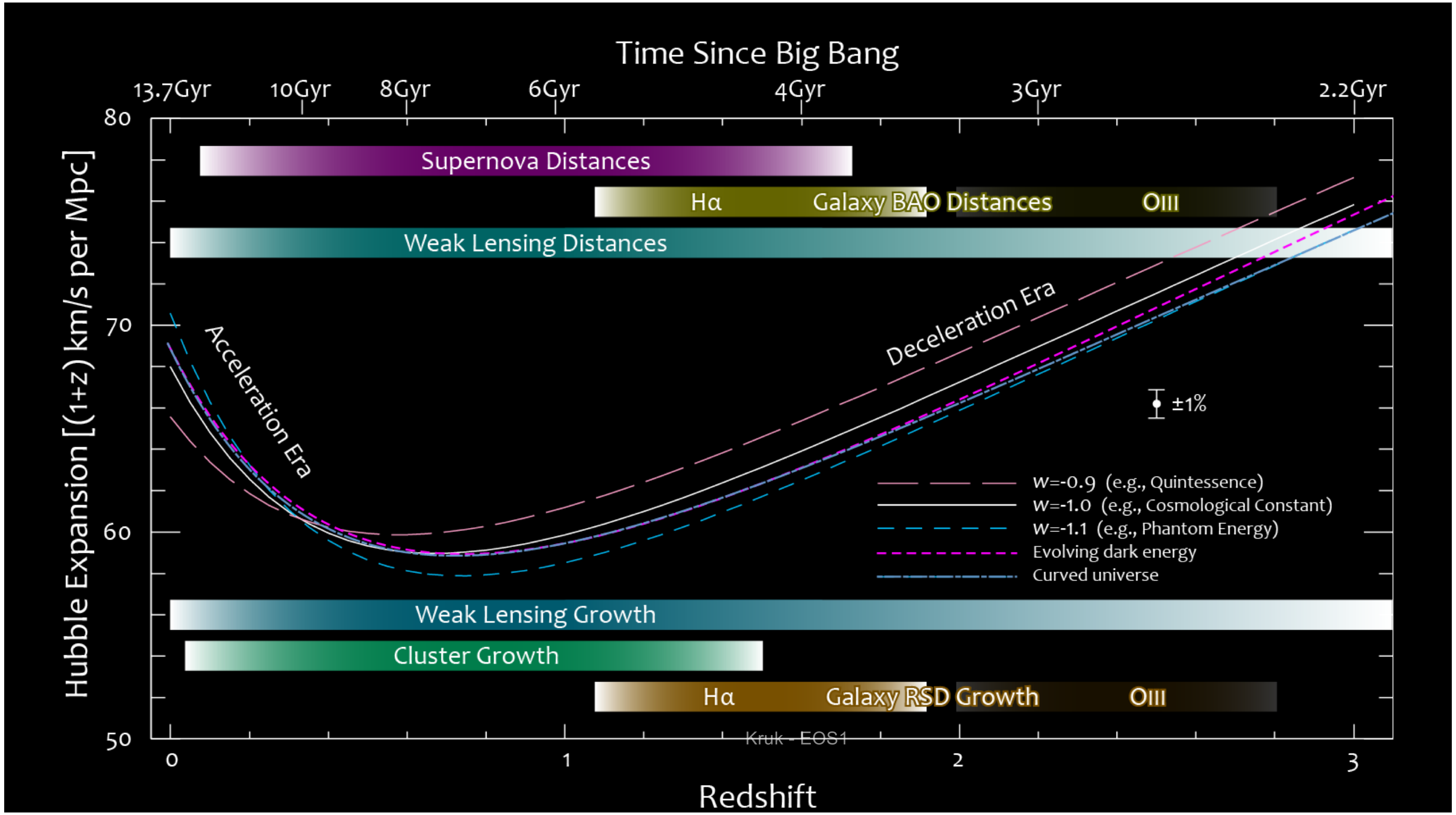
High-latitude imaging and spectroscopic surveys
Enables weak lensing and redshift cosmology investigations

High-latitude time-domain survey
Enables Type Ia supernova cosmology investigations

Galactic Bulge time-domain survey
Enables exoplanet microlensing investigations

Each has a core set of requirements, but potential scope and science return is *much broader*

Roman Cosmology Program



High-Latitude Imaging/Spectroscopy

- Both wide (2000 deg^2) and deep (20 deg^2) surveys
- Imaging - Weak lensing measurements of hundreds of millions of galaxies
- Spectroscopy (grism) - Redshifts of tens-of-millions of galaxies

High-Latitude Time-Domain Survey

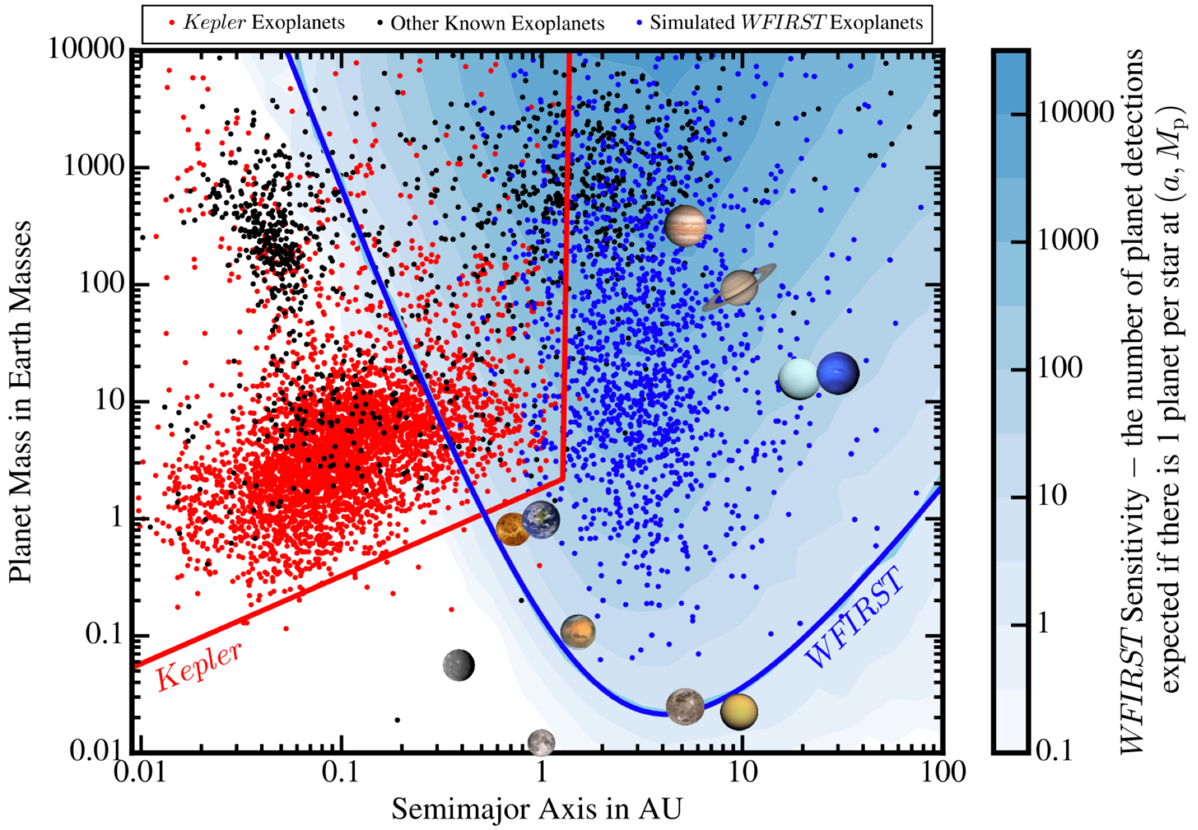
- Light curves for many thousands of SNIa, a subset with prism spectra
- Both wide (16 deg^2) and deep surveys (5 deg^2), 5 day cadence

Cosmology program observations drive key WFI requirements:

Angular resolution, near-IR sensitivity, photometric precision, wave front error and stability

Dore et al. 2019

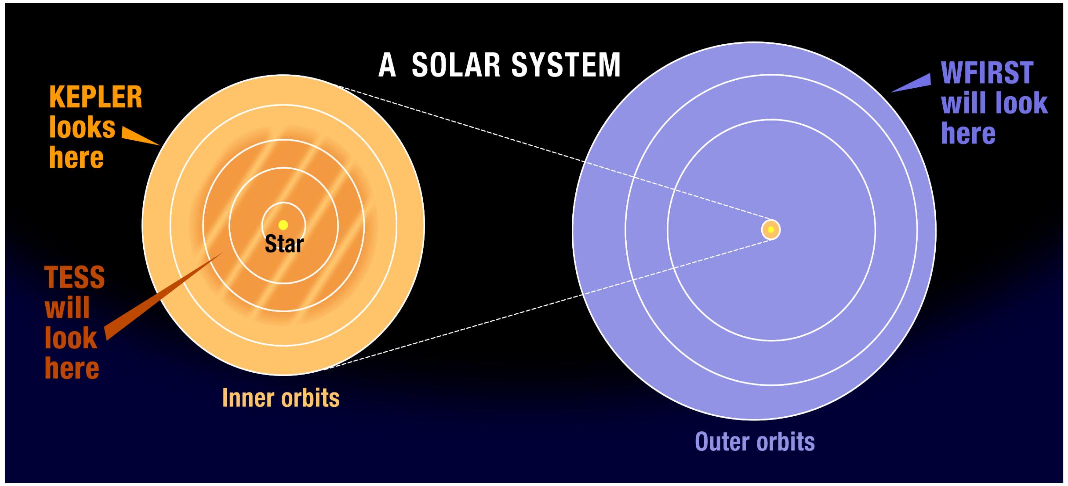
Roman Exoplanet Microlensing Program



Microlensing program observations drive key WFI requirements:
Angular resolution, photometric precision

Galactic Bulge Time-Domain Survey

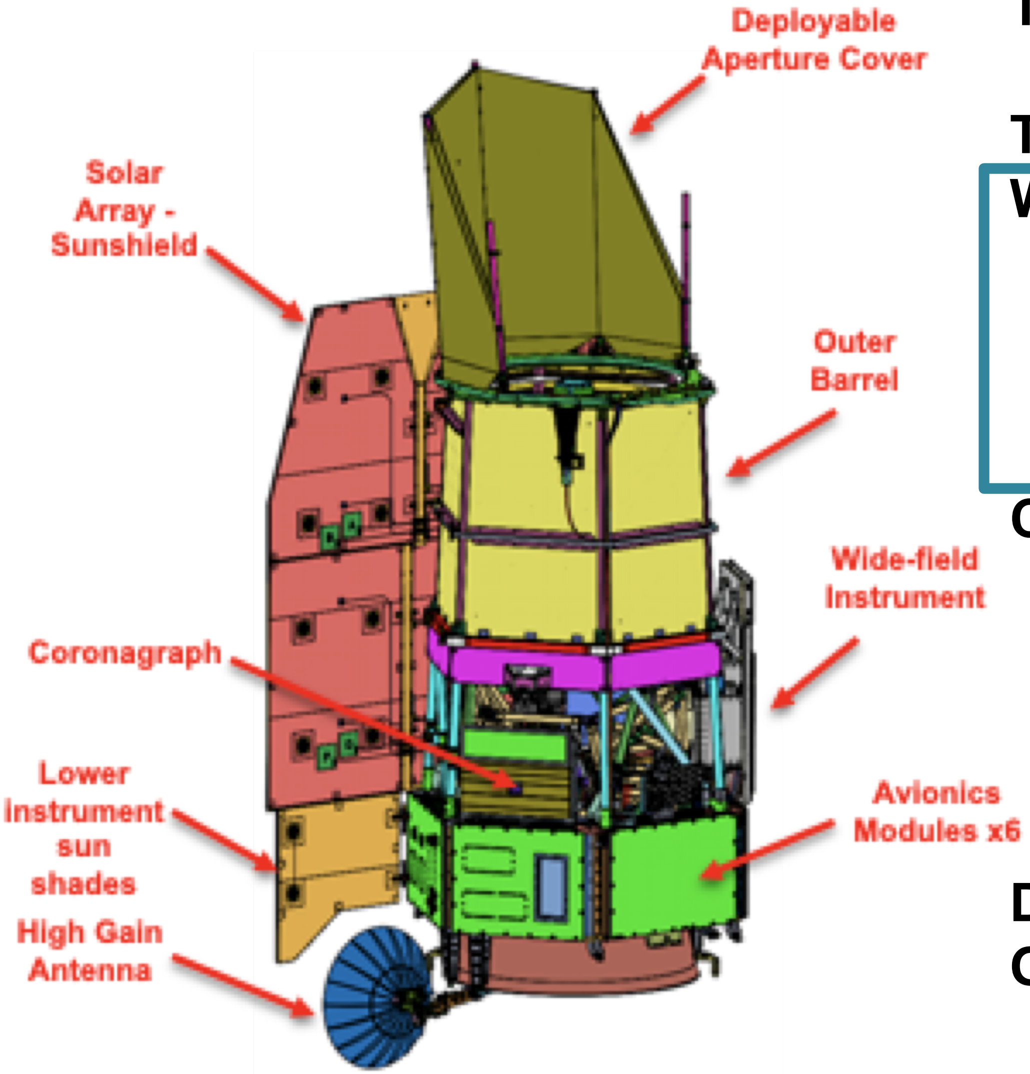
- 2 deg^2 in bulge fields
- Light curves for >100 million stars
- 15 minute cadence over ~60-70 day seasons
- ~1400 bound planets from microlensing
- ~200 free floating planets



[Penny et al. 2019](#)
[Johnson et al. 2020](#)

ROMAN SPACE TELESCOPE

Roman Observatory Overview



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

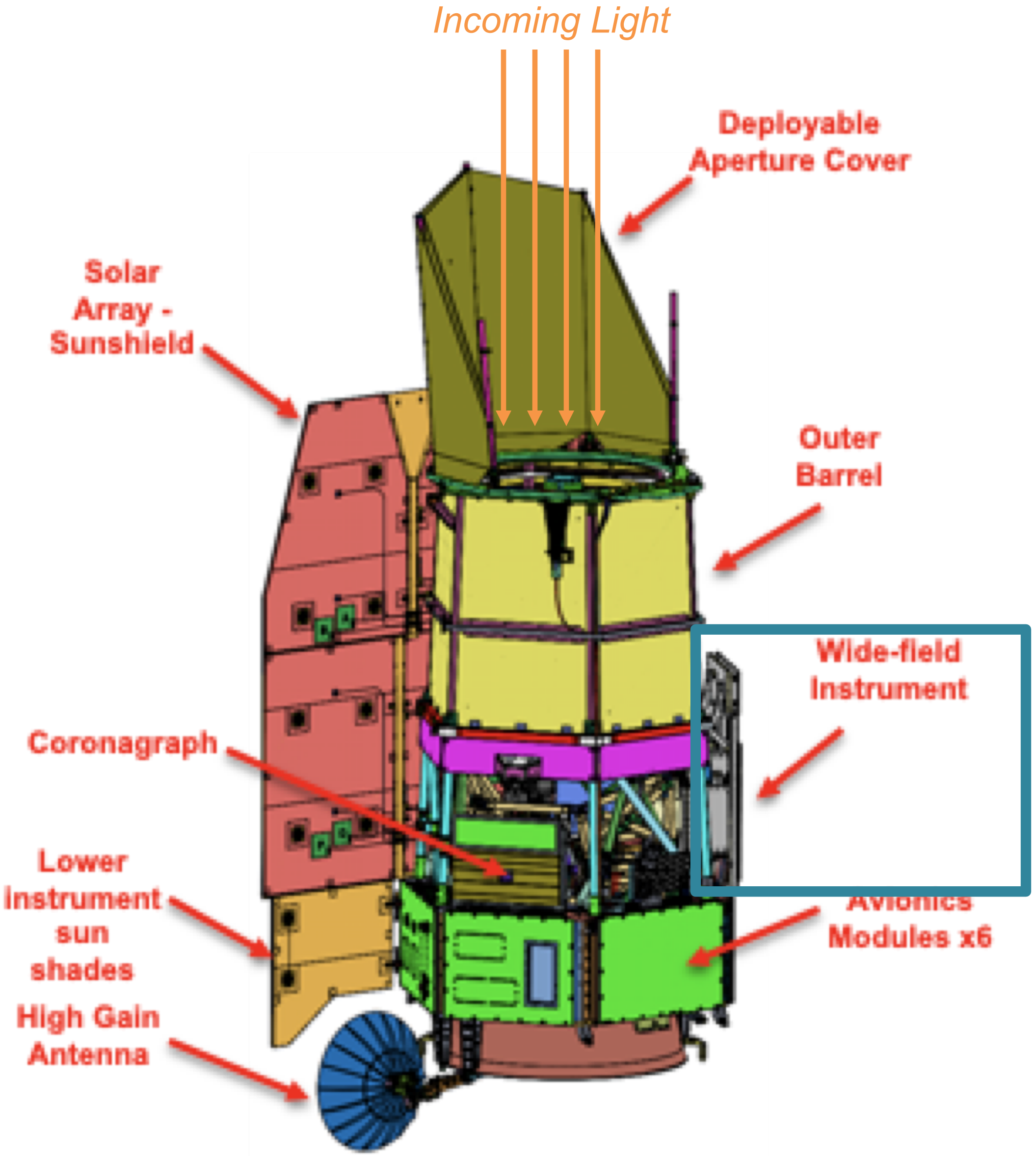
- High contrast imaging technology demo
- First active wavefront control in space
- Vis band imaging, polarimetry, and spectroscopy
- Contrast 10^{-8}-10^{-9}

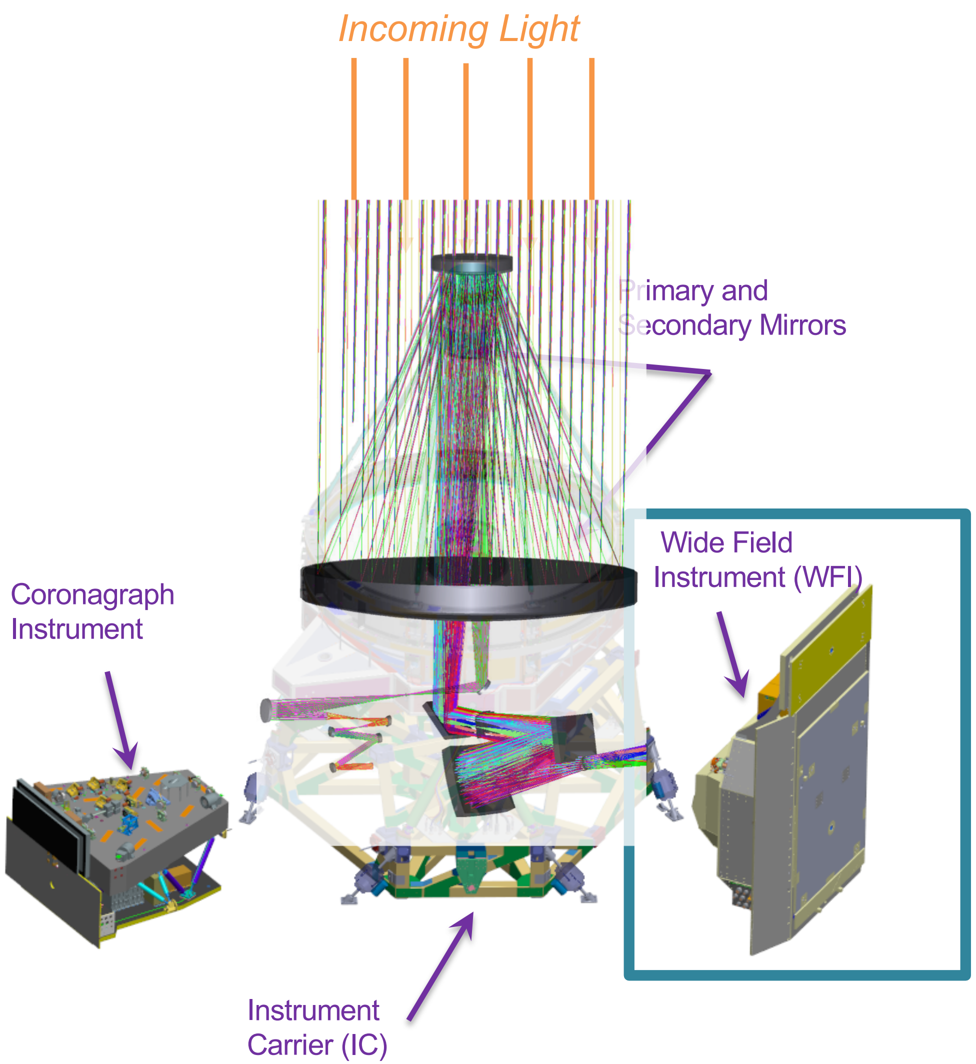
Data Volume: 11 Tb/day
Orbit: Sun-Earth L2

Mission Duration: 5 yr, 10yr goal

Mission parameters
Telescope parameters

Wide Field Instrument – Observatory Context



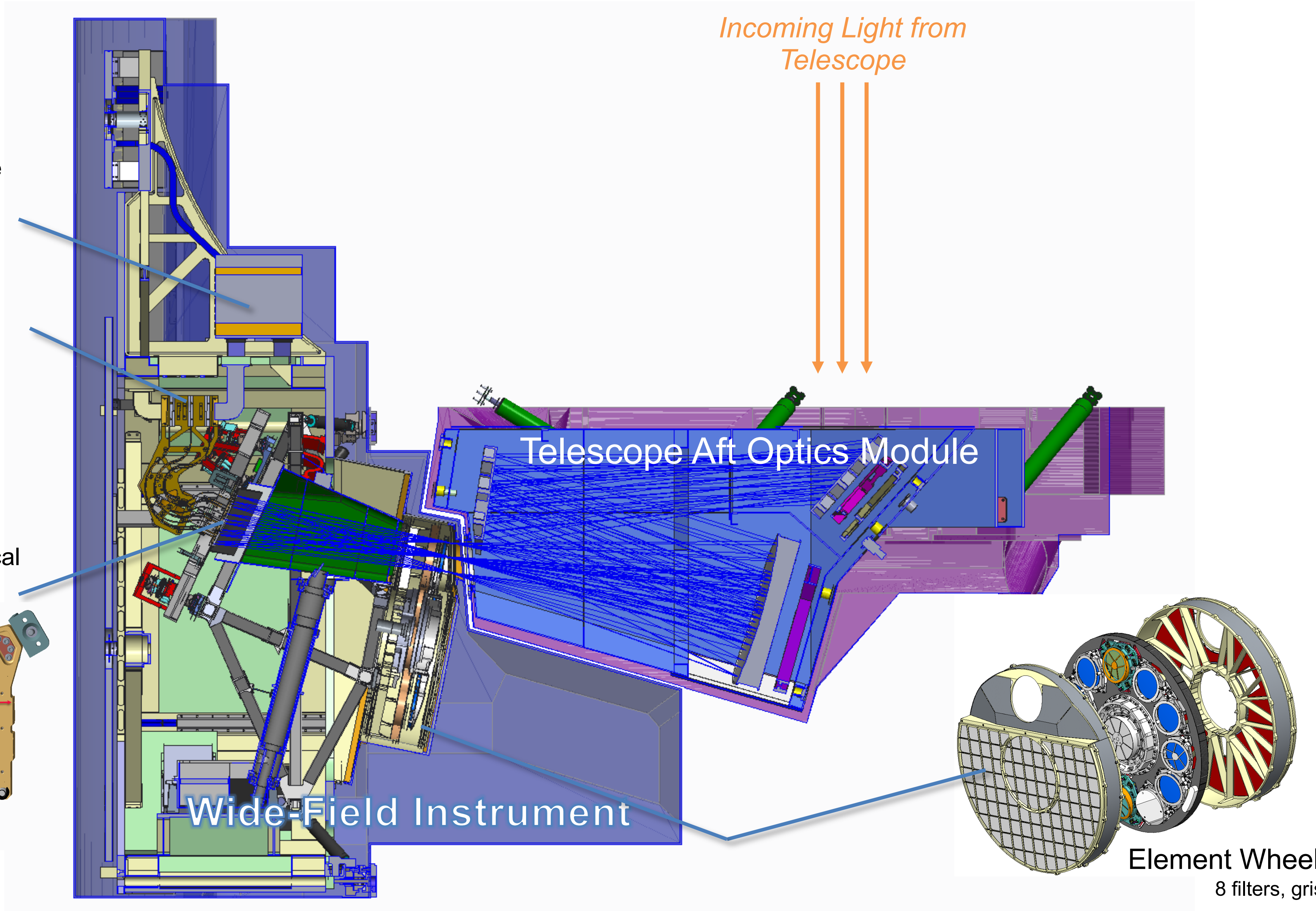


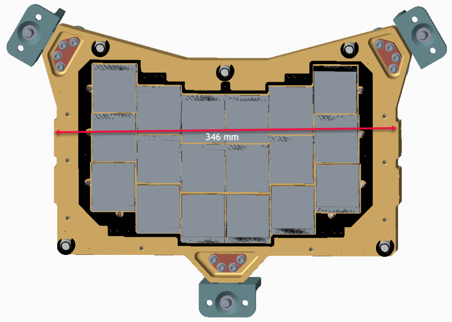
ROMAN SPACE TELESCOPE

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 dark current, flat-field, 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
- Passed Critical Design Review in January 2021

Roman Wide-Field Instrument Overview Schematic





Element Wheel Assembly (EWA)

8 filters, grism, prism, dark

[WFI parameters]

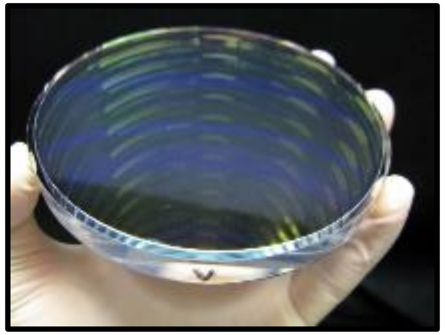
Element Wheel Assembly

- **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**

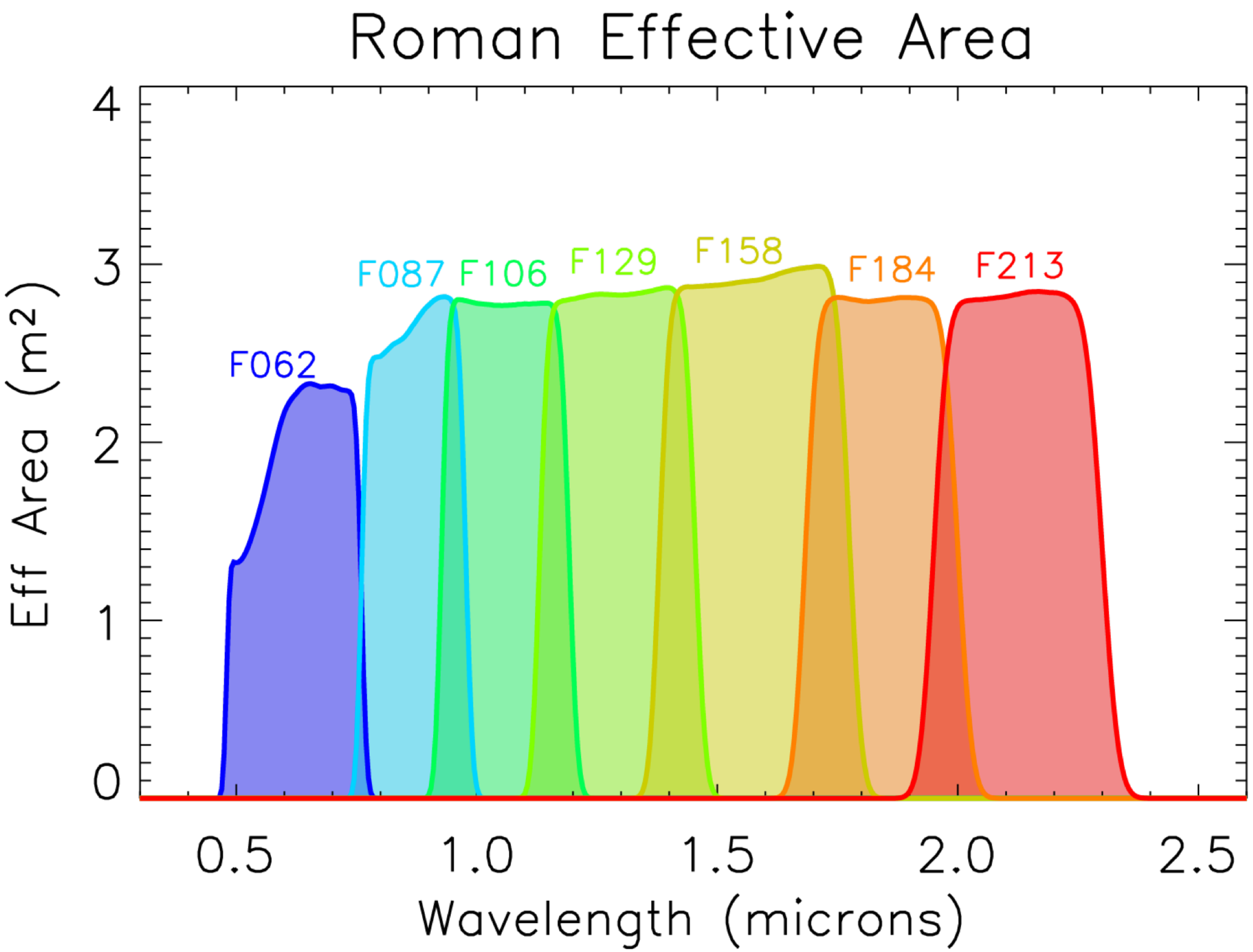
Filters and Dispersing Elements I

- **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	28.6
F087	760 – 977	28.2
F106	927 – 1192	28.1
F129	1131 – 1454	28.0
F158	1380 – 1774	28.0
F184	1683 – 2000	27.5
F213	1950 – 2300	26.2
W146	927 – 2000	28.3



F158 filter Engineering Design Unit (EDU)



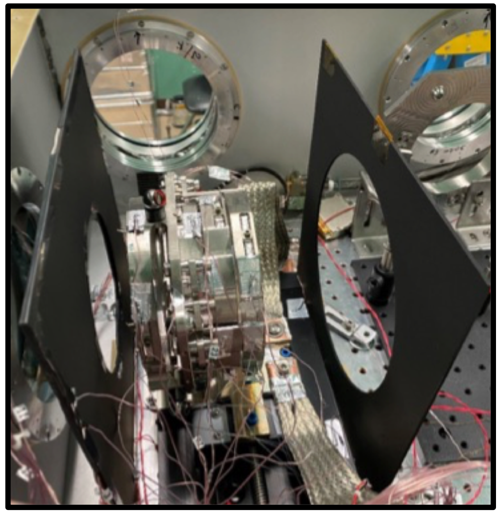
[Akeson et al. 2019](#)
[Filter parameters](#) and [sensitivities](#)
[Filter/Prism/Grism transmission profiles (bottom of page)](#)

Filters and Dispersing Elements II

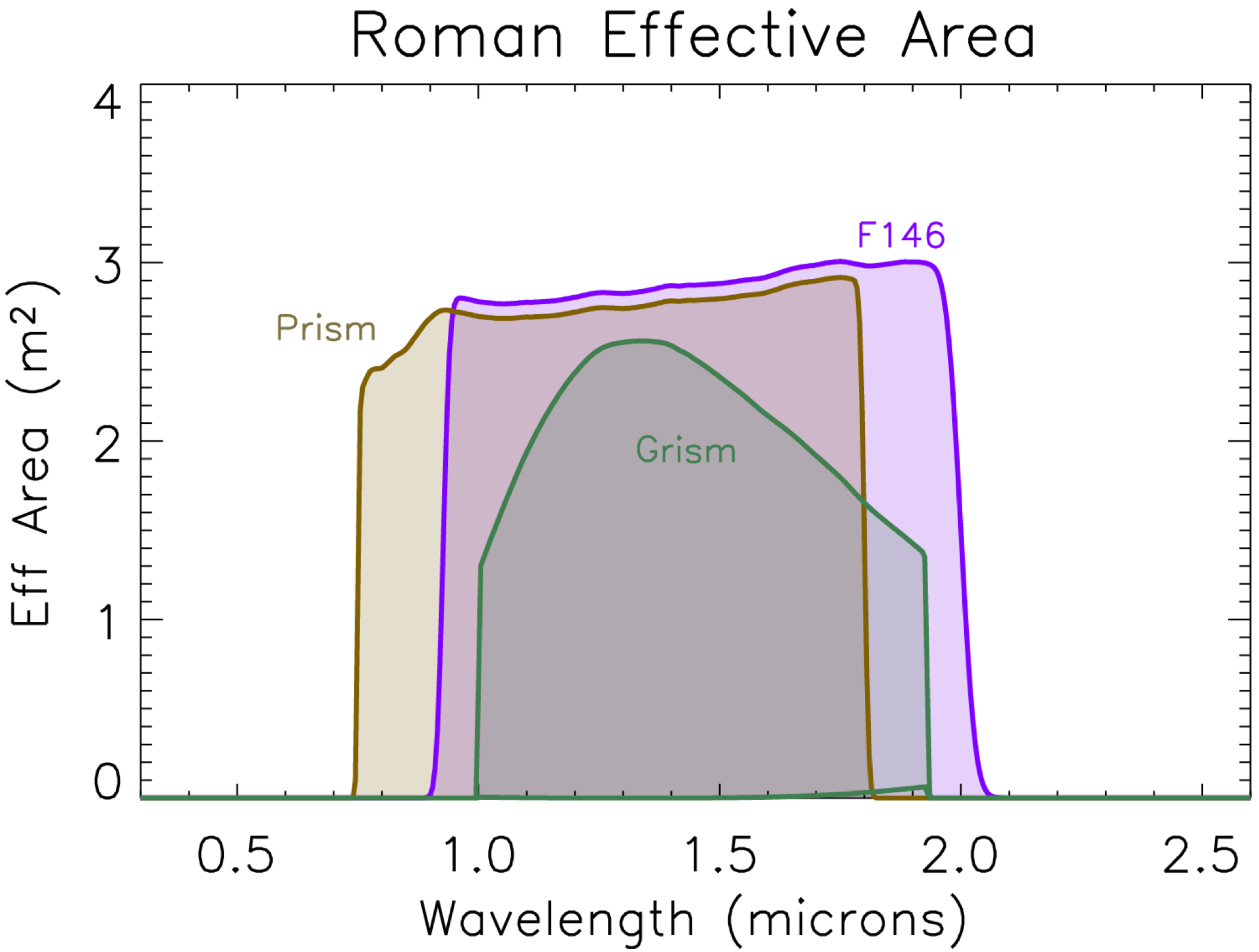
- **WFI Prism and Grism provide slitless spectroscopy from 0.6 – 1.9 μm (600 – 1900 nm)**

Disperser	Bandpass (nm)	Resolution	1 h, 10σ per pixel in continuum
Prism	600 –1800	~100	23.0
Grism	1000 – 1900	~600	21.0

(@1.2 μm)



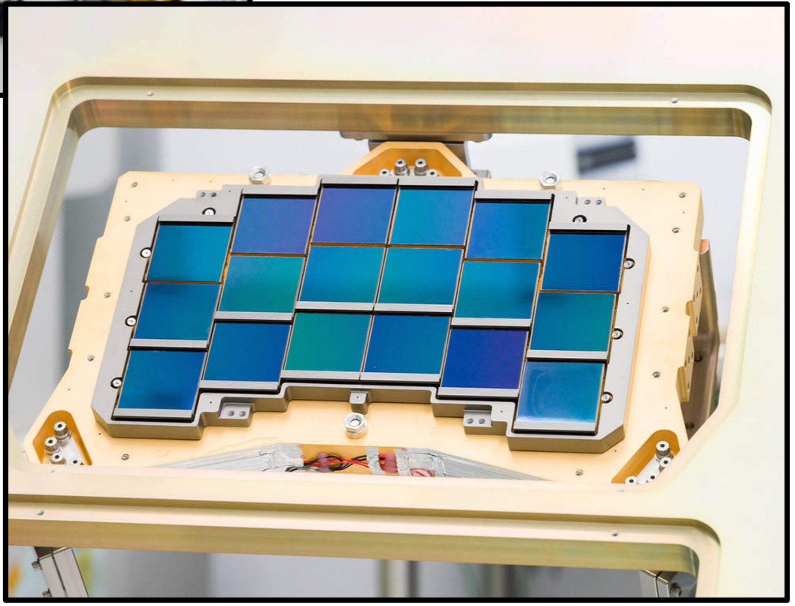
Grism Engineering Test Unit (ETU) in thermal test



Akeson et al. 2019
Disperser parameters and sensitivities
Filter/Prism/Grism transmission profiles (bottom of page)

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 4k x 4k pixels
  - 10 μm/pixel
  - 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 complement* of flight candidate detectors now in hand (*require 18, have 26*), further testing and selection 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 flight candidates

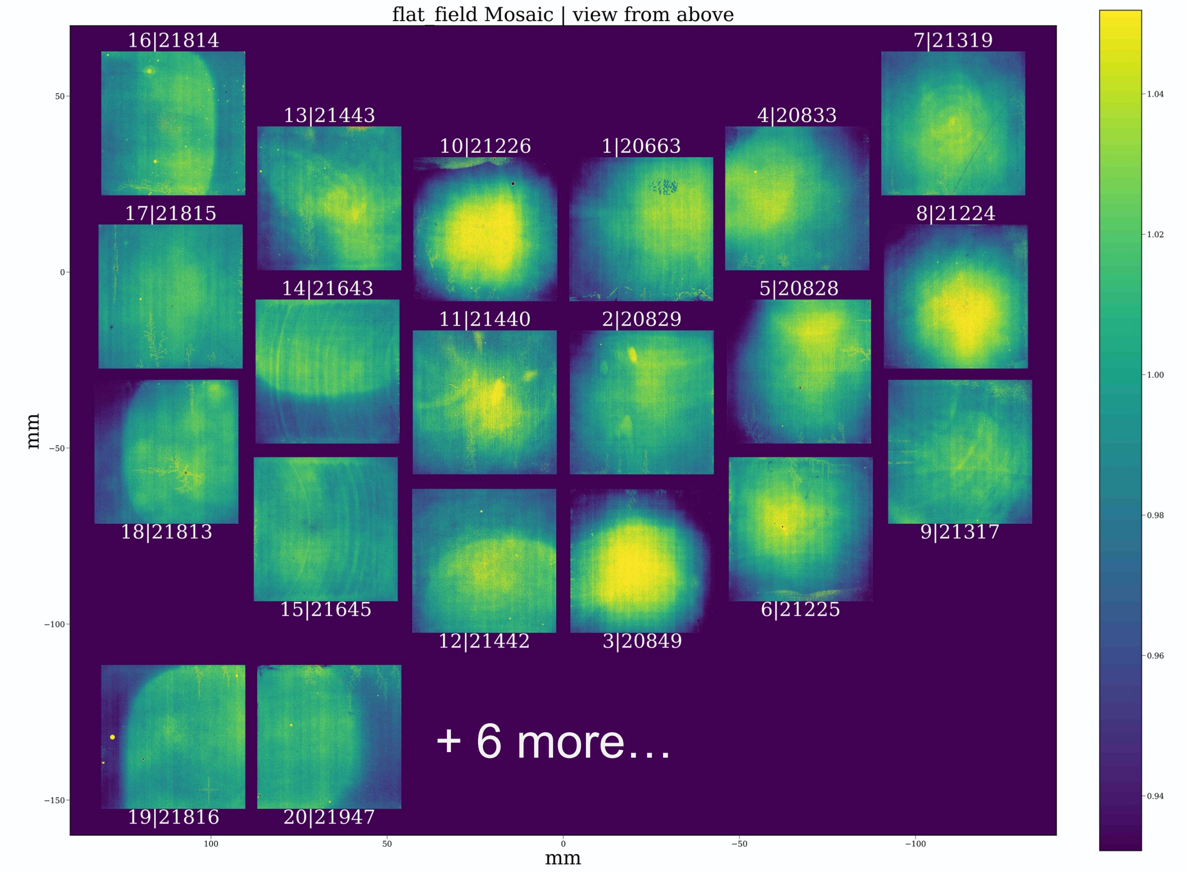
Quantity	Spec. Value	Units	Typical actual
Dark Current	<0.1	e-/sec/pixel	<0.005
CDS Read Noise	<20	e- RMS	15-16
Total Noise in 180s	<6.5	e- RMS	5-6
Quantum Efficiency	>80%	(avg 0.8-2.1μm)	~95%
Quantum Efficiency	>60%	(avg 0.6-0.8μm)	75-80%
Pixel operability	>95%	N/A	>99%
Total crosstalk	<12%	N/A	<8%

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

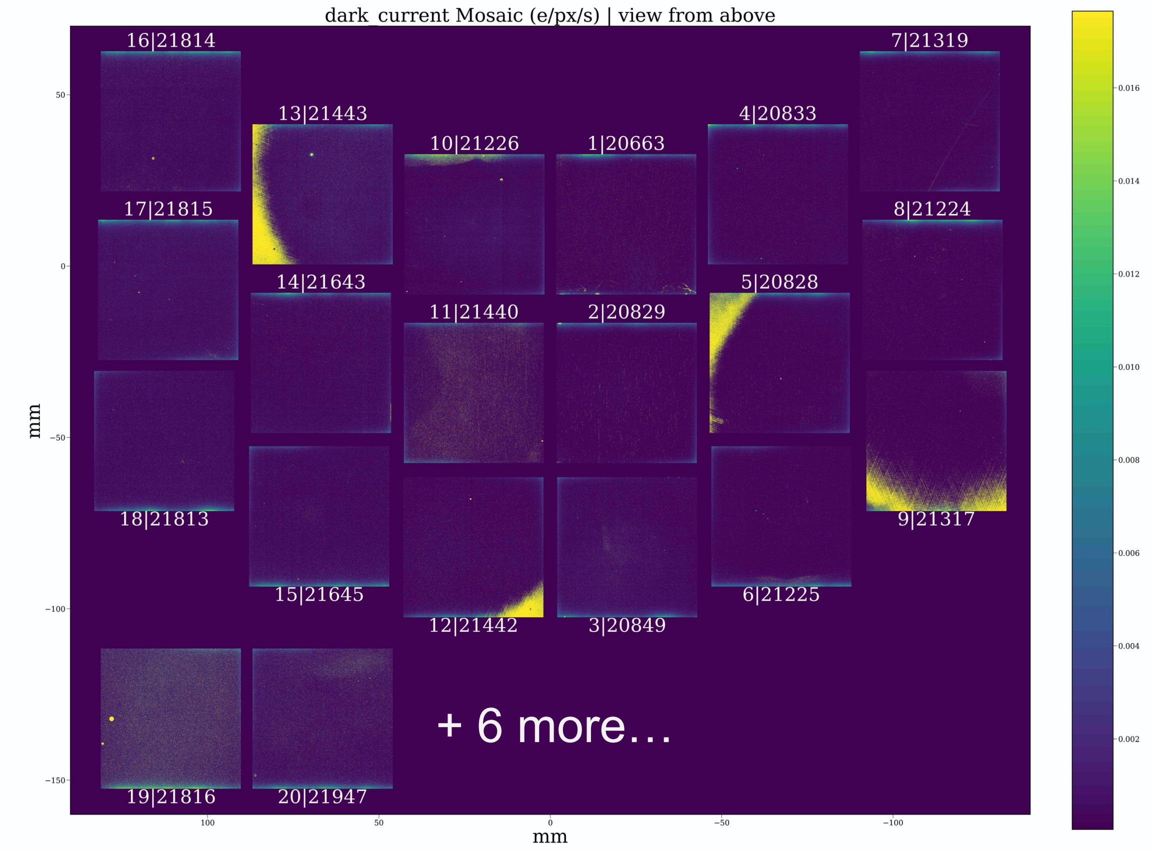
Mosby et al. 2020

Focal Plane Array and Detectors III

Flight candidate detector flat field comparison

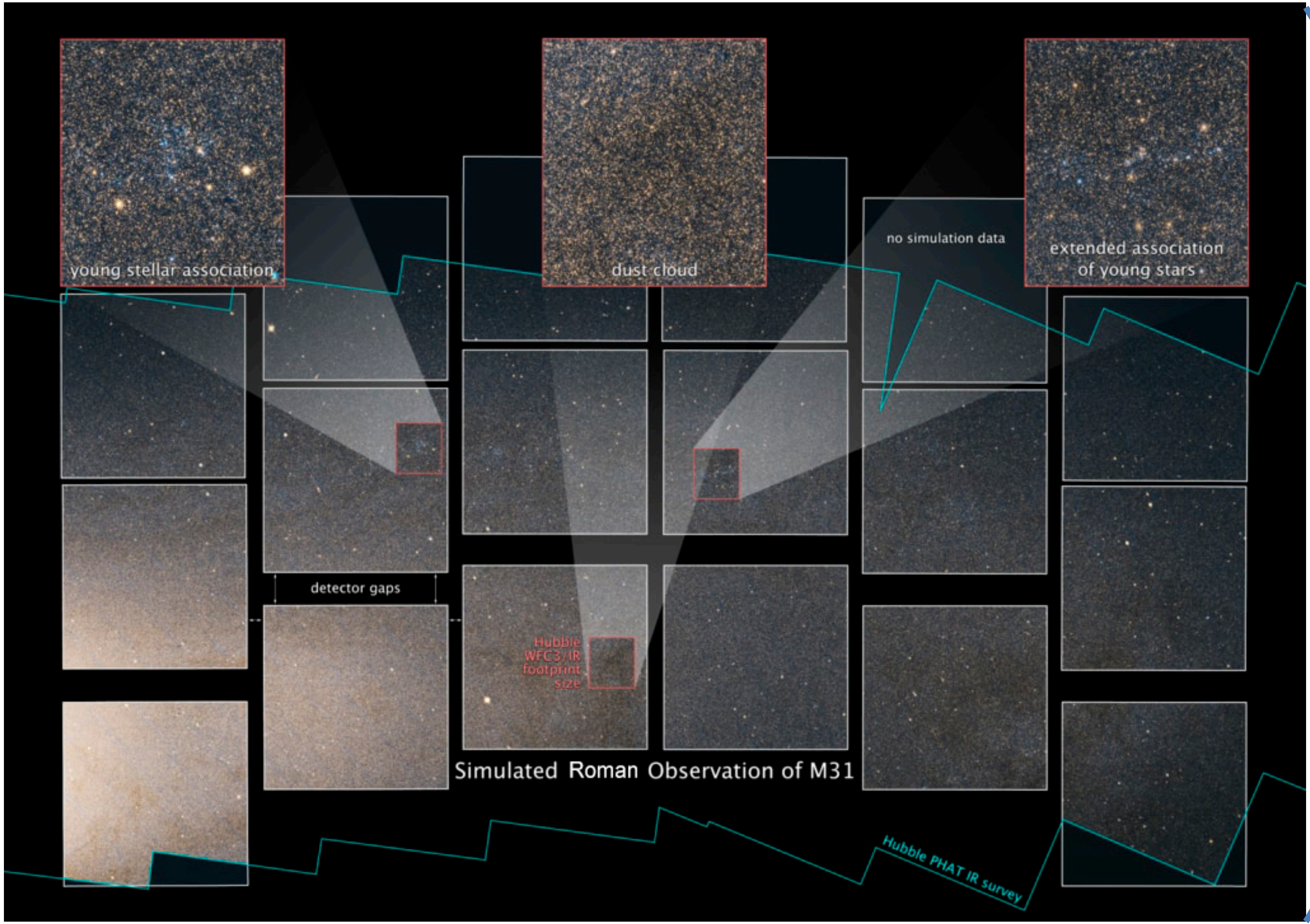


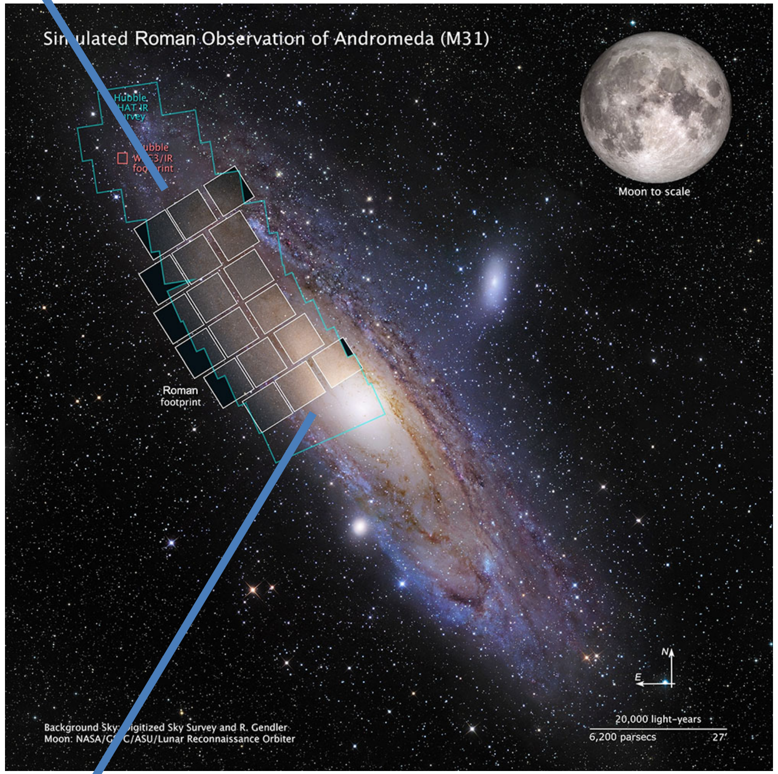
Flight candidate detector dark current comparison



Visual comparisons like these are being used along with operability statistics to prioritize and select the 18 detectors that will be used in the flight Focal Plane Array

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* detector calibration**
- **The WFI is equipped with an on-board calibration system to enable multiple measures of detector non-linearity -- this is the Relative Calibration System (RCS)**
- **The RCS is an instrument that projects smooth flat fields onto the detector focal plane array at a wide range of fluxes at multiple wavelengths**
- **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 hardware has been designed and is currently undergoing component and subsystem level testing, heading toward flight builds**