An Introduction to the Nancy Grace Roman Space Telescope

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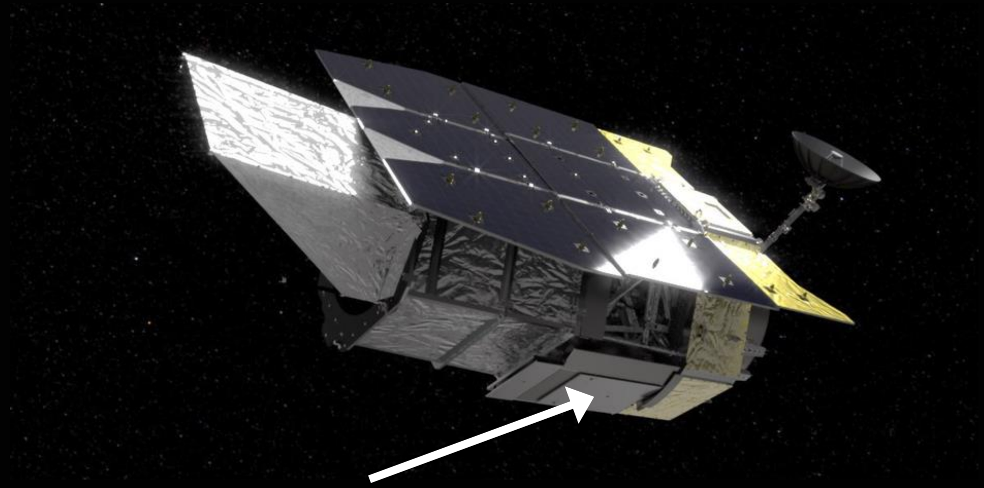
NASA Goddard Space Flight Center

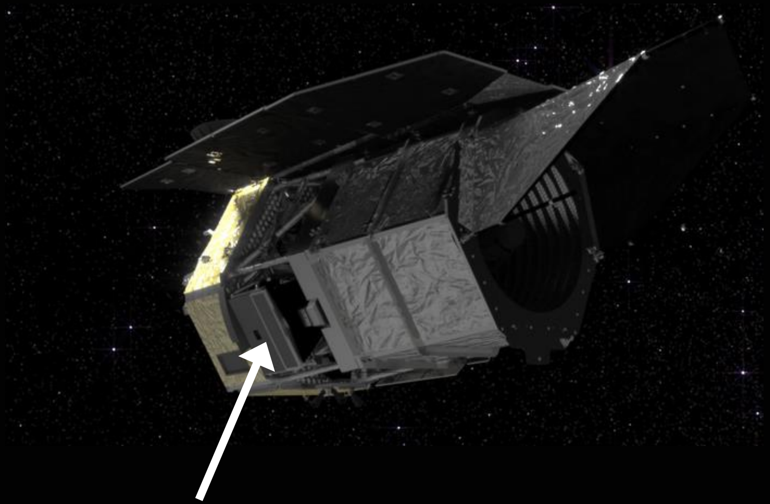
Sagan Summer Workshop

July 20, 2026

Roman Objectives, Instruments, and Surveys



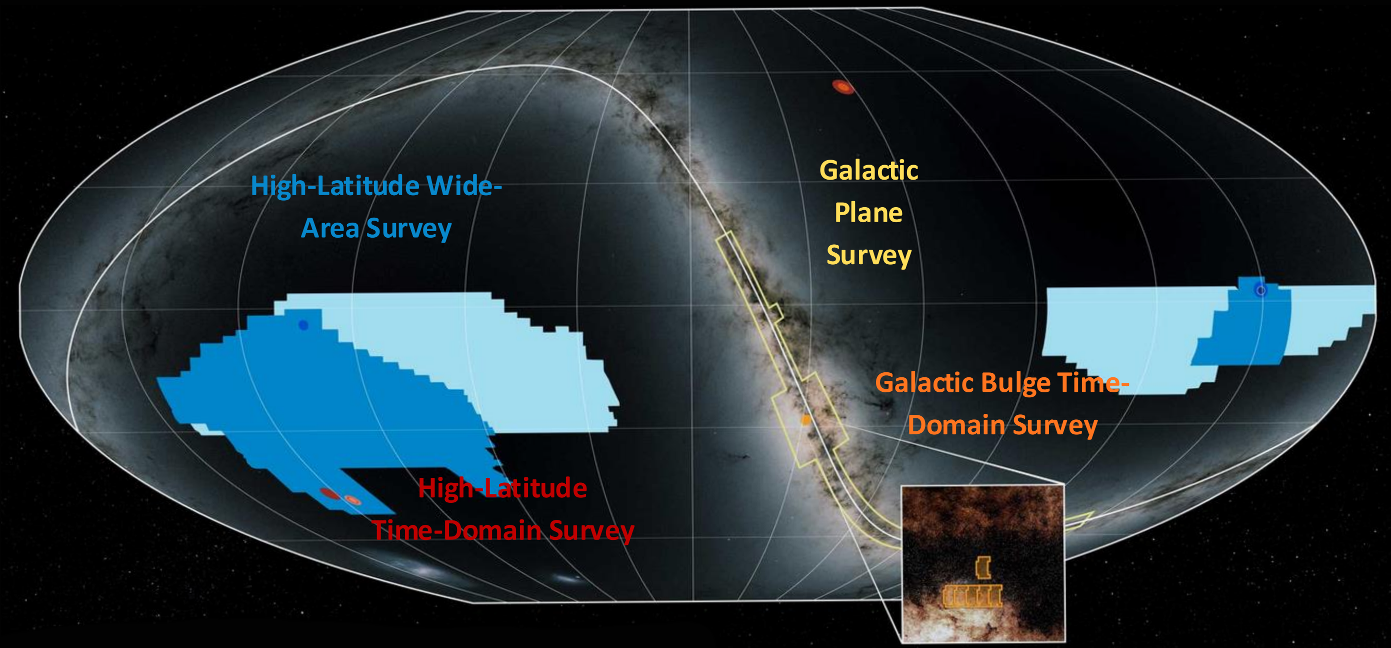
Wide Field Instrument



Coronagraph Instrument

Primary Goal is to Perform Astrophysics Surveys

High level science objectives focus on cosmology and exoplanets



Wide-area survey supports cosmology objectives and a broad range of astrophysics

Galactic bulge time domain survey enables exoplanet discovery and characterization and a broad range of astrophysics

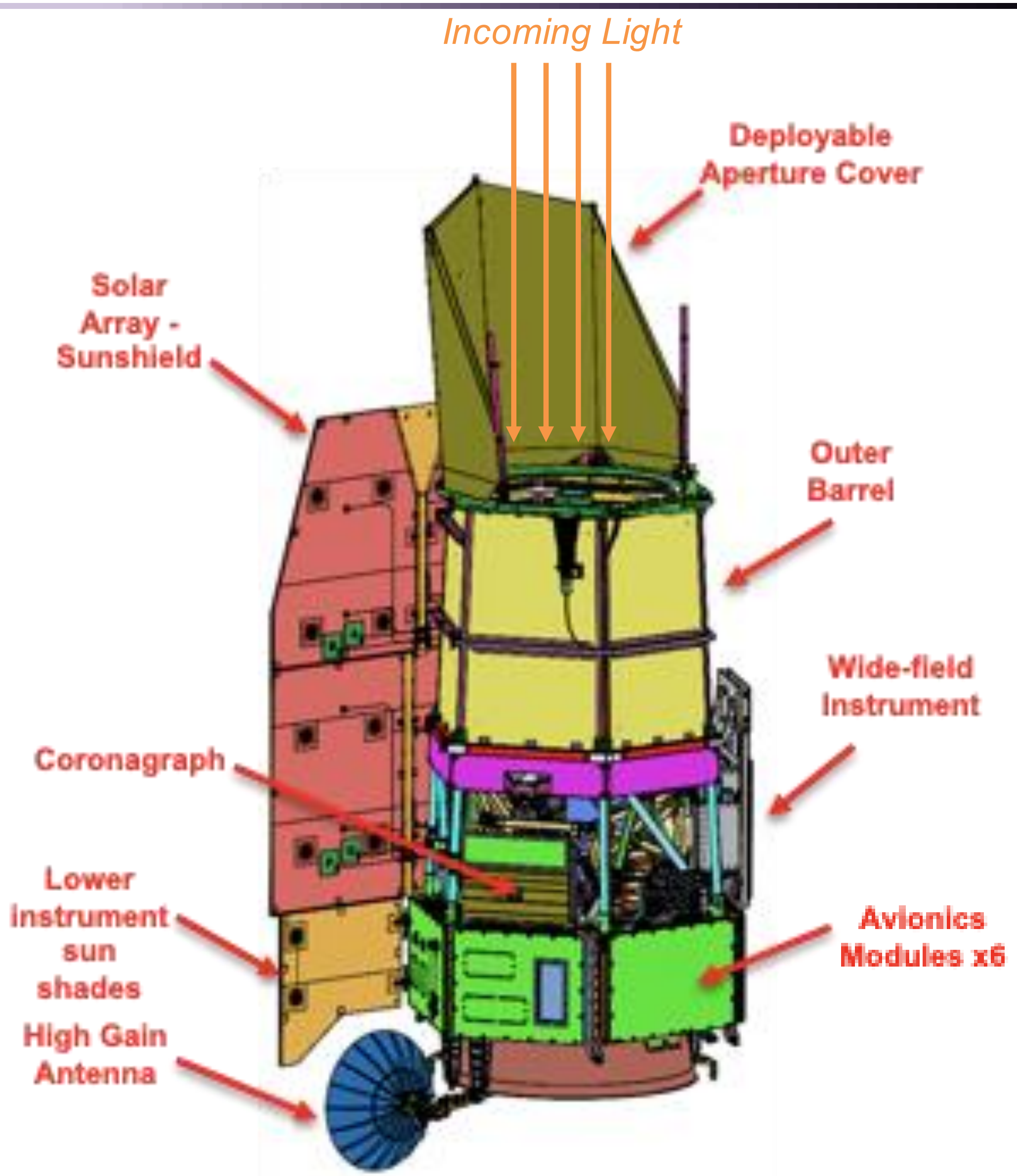
High-latitude time-domain survey supports cosmology objectives and reveals the evolution of Galactic and extragalactic transient and variable sources

General Astrophysics Surveys focus on broad science and produce broadly useful data

Coronagraph demonstrates technology advancement for direct exoplanet imaging

Roman Technical Information

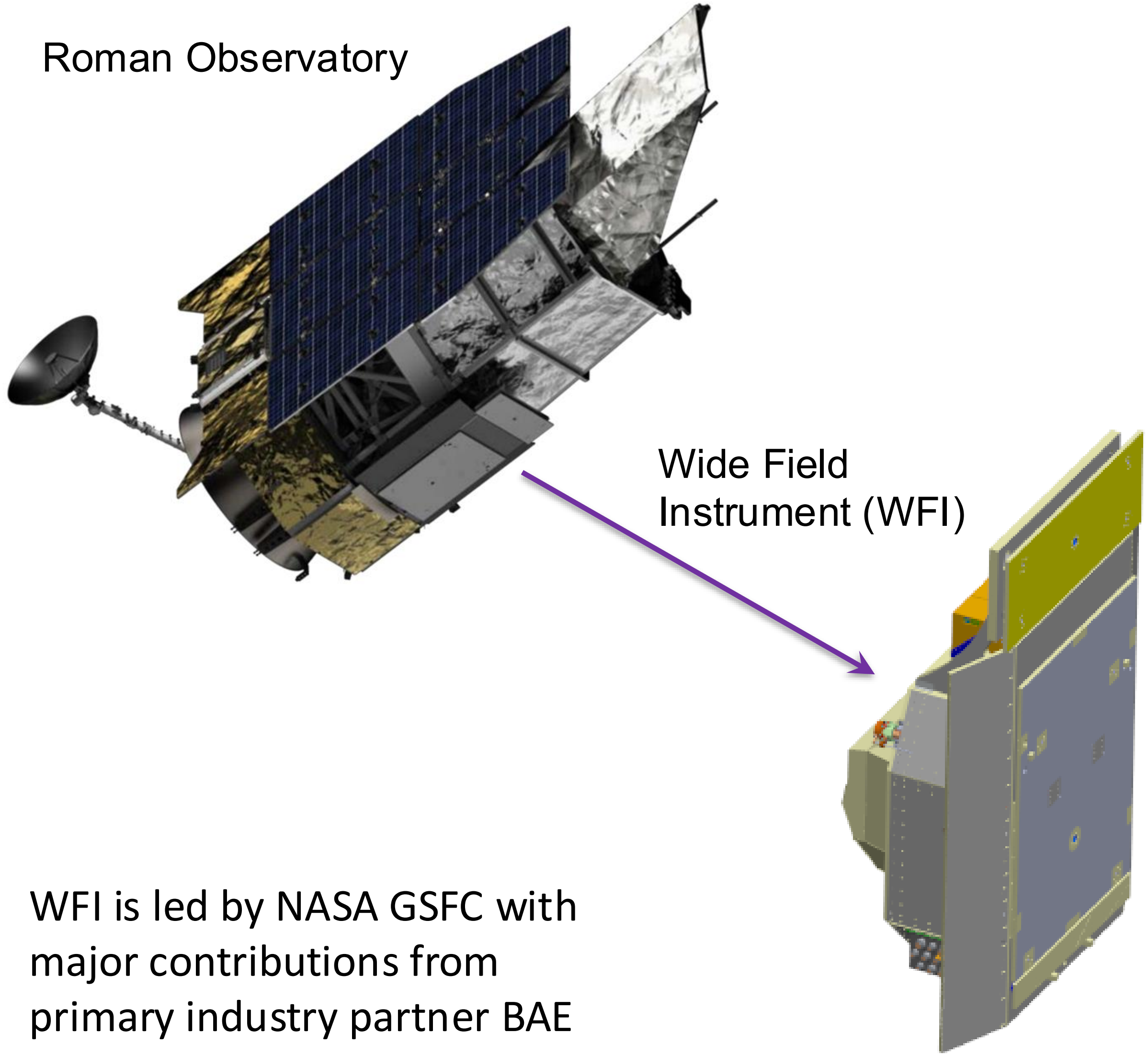
Roman Observatory Facts and Figures



Observatory Overview

- **Telescope**: 2.4m aperture
- **Instruments:**
  - Wide Field Imager and Slitless Spectrometer
  - Coronagraph Technology Demonstration
- **Orbit**: Sun-Earth L2
- **Data Volume**: 11 Tb/day
- **Launch Vehicle**: Falcon Heavy from Cape Canaveral
- **Launch Date**: August 30, 2026 (41 days!)
- **Mission Duration**: 5 yr nominal, 10 yr goal

Roman Wide Field Instrument (WFI)

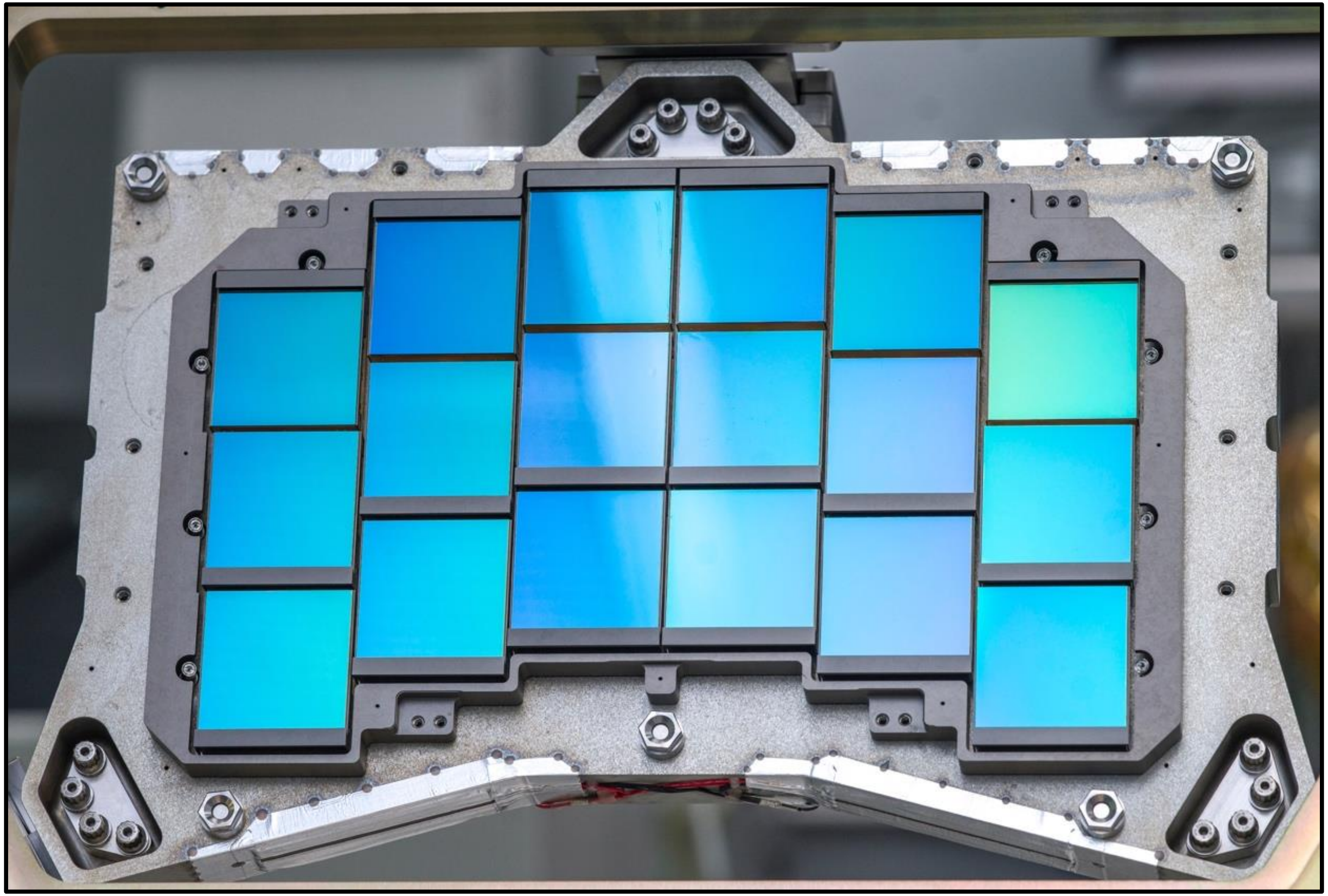


WFI is led by NASA GSFC with major contributions from primary industry partner BAE Systems

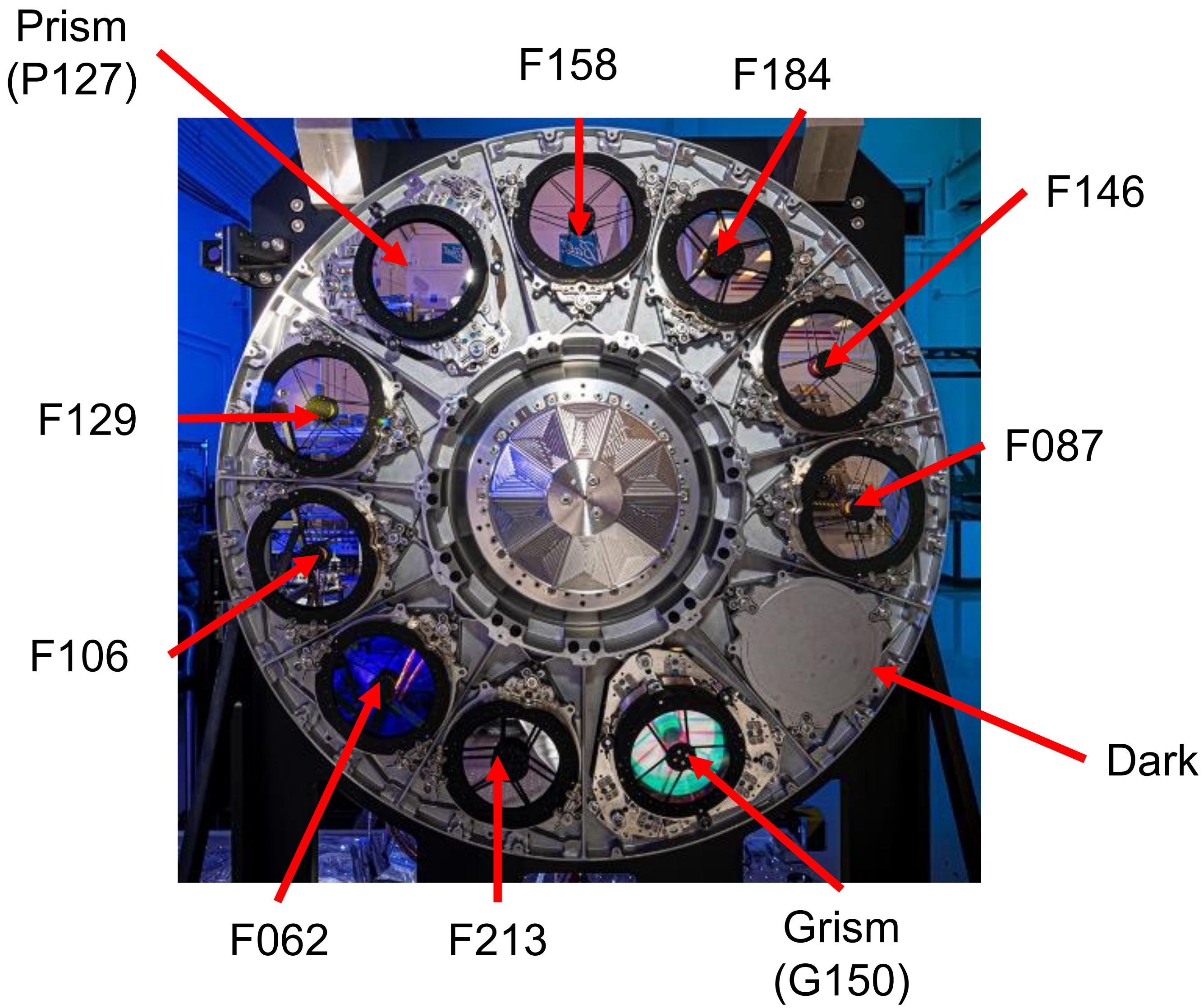
- **Primary science instrument for surveys**
- Focal plane array of 18 4k × 4k detectors
  - Large FOV – 0.8 x 0.4 deg (0.281 deg^2)
  - 300,000,000 pixels with 0.11”/pix
  - Image stability: 1.0 nm RMS wave front error (WFE) variation in 180 sec
  - Guide star sensing interleaved with science data collection
- Element wheel enables imaging and spectroscopy spanning 0.48 to 2.3 μm
  - 8 imaging filters
  - Prism and grism for full-field, slitless spectroscopy
  - Blank position for darks, flat fields, and other calibrations
- Internal relative calibration system
- Detectors passively cooled to ~90 K

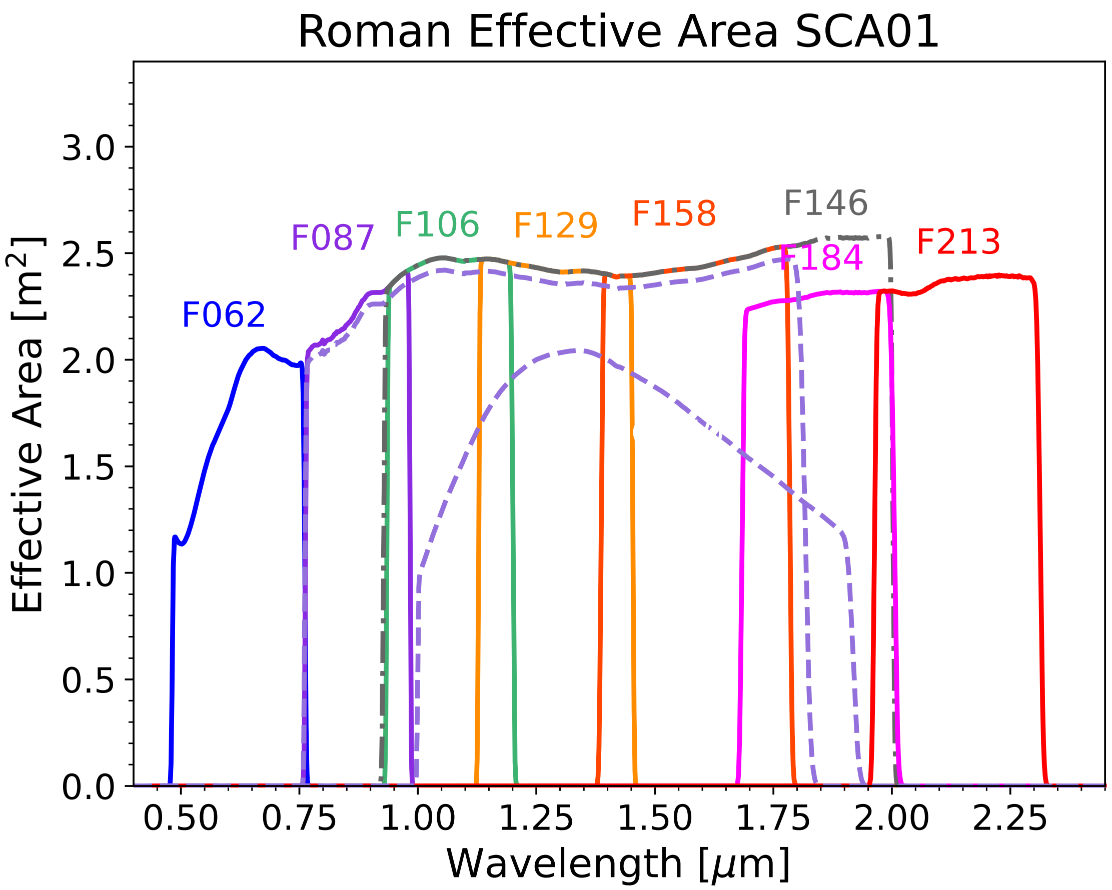
WFI technical info, WFI paper

WFI Focal Plane Array



WFI Element Wheel

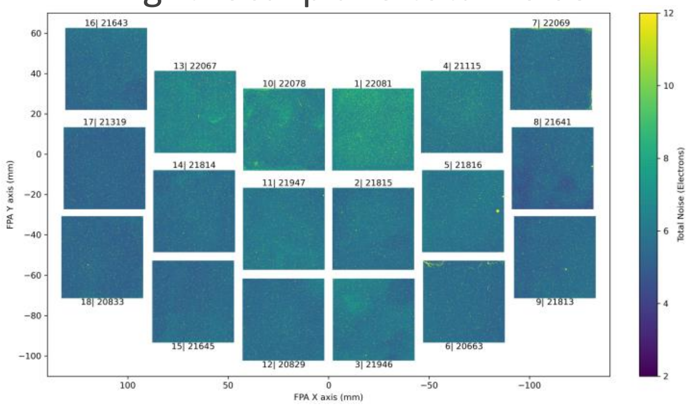




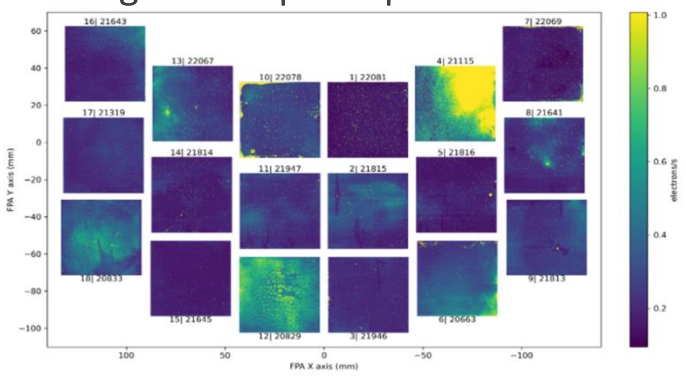
Key Information on WFI Performance

- **WFI meets or exceeds requirements ☺, *but there are key things to know***
- WFI reaches saturation on a ~17 mag source in one frame (~3 s) of integration
- WFI has 18 detectors, each one is an individual with its own performance and properties
- The wide FOV leads to angle of incidence effects that change properties as a function of location
  - PSF shape changes from center to edge
  - Filter band passes shift from center to edge
- WFI has an internal calibration system to characterize and trend detector performance throughout the mission

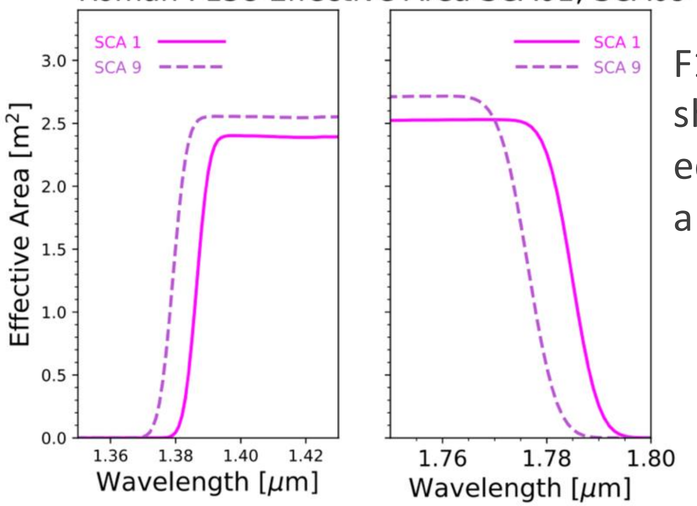
Flight focal plane total noise



Flight focal plane persistence



Roman F158 Effective Area SCA01, SCA09

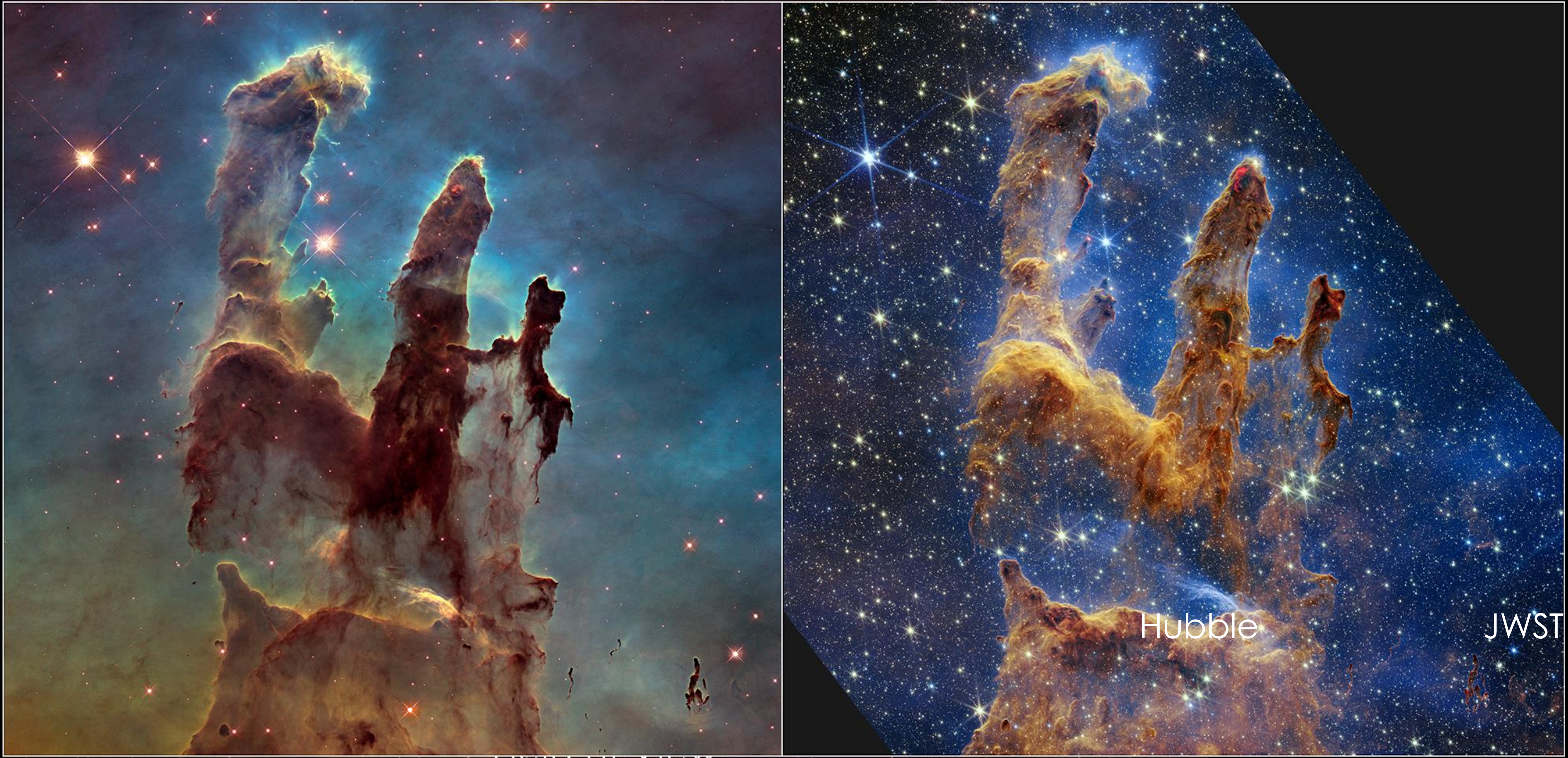


F158 filter bandpass shift from center to edge of focal plane array

[WFI technical info]
[WFI resources/papers]

Roman Space Telescope and WFI – Built for Surveys

Hubble / JWST / Roman Comparison



www.nasa.gov

Hubble WFC3 JWST NIRCam

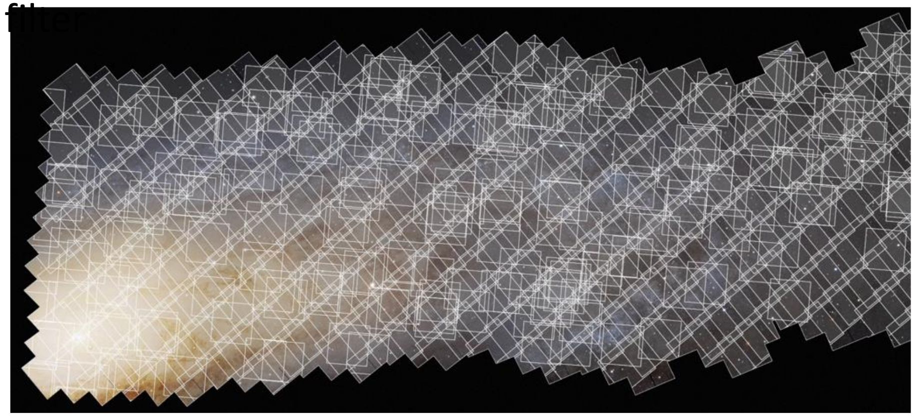
The Eagle Nebula, M16, in the constellation Serpens, containing the "Pillars of Creation," in the Milky Way Galaxy, 5,700 light-years from earth

Slide Credit: Art Whipple
Image credit: NASA/Hubble/JWST

Roman + WFI – Built for Surveys

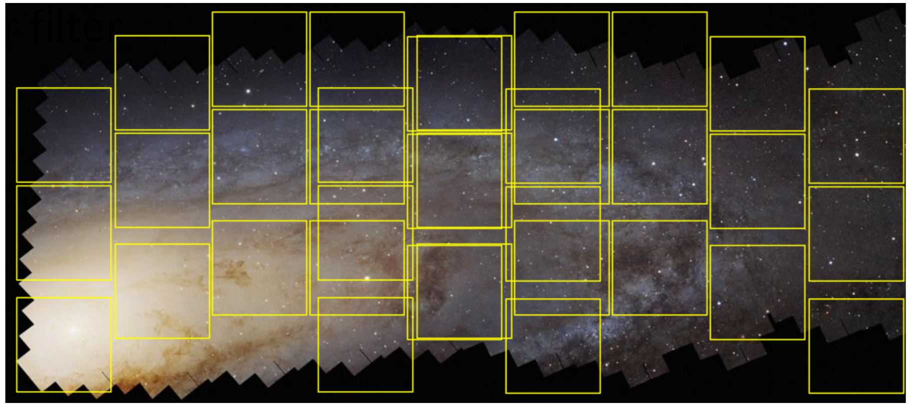
- **The power of Roman for surveys is not *only* in the WFI field-of-view**
  - **Very efficient observations from L2**
  - **Rapid slew and settle**
  - **Well understood and stable PSF**
  - **Excellent flux calibration**
- **Larger FOV + efficient and stable operations yields *survey speeds ~1000x faster than Hubble***

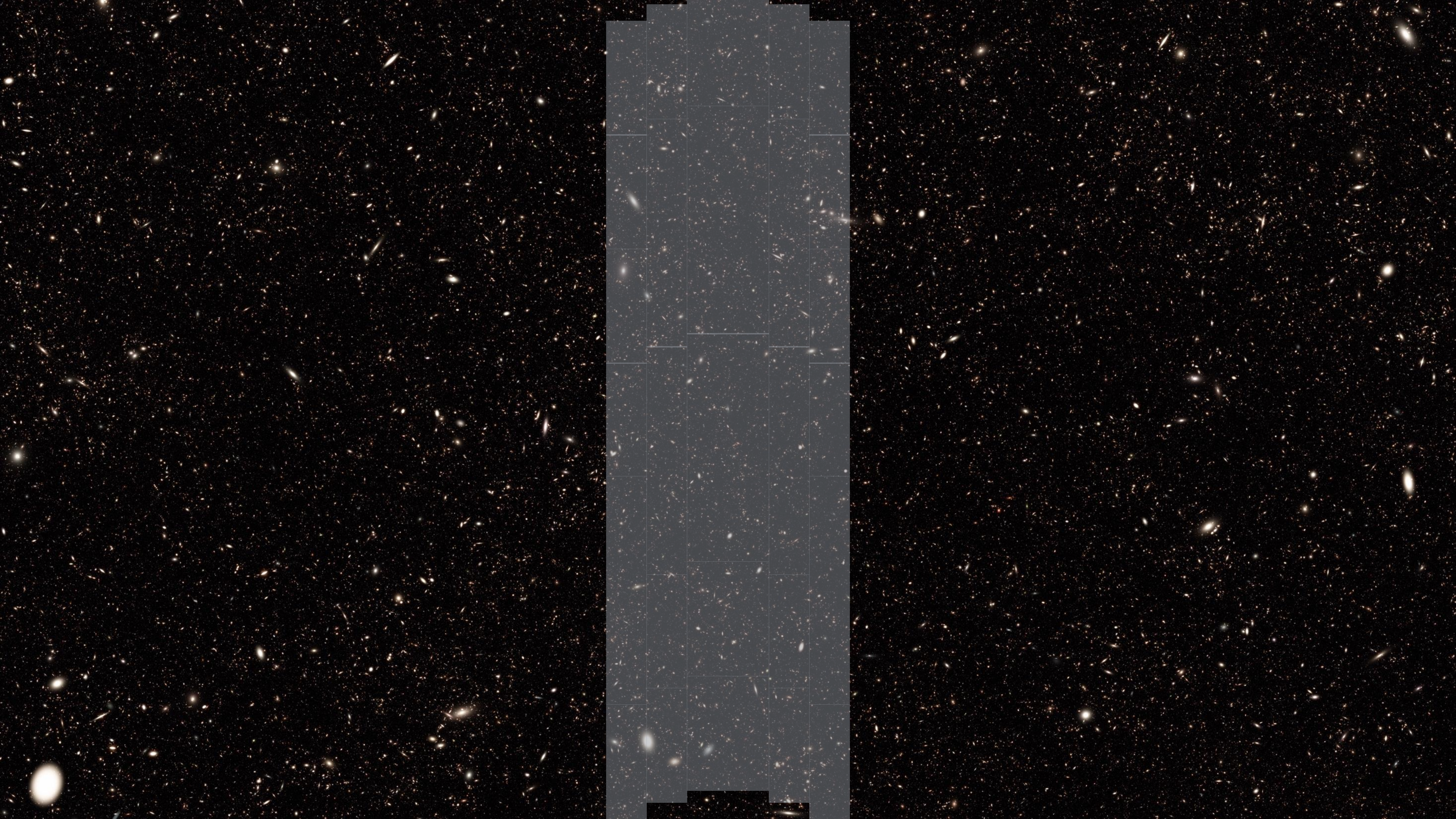
HST PHAT survey of M31 - >400 observations per filter

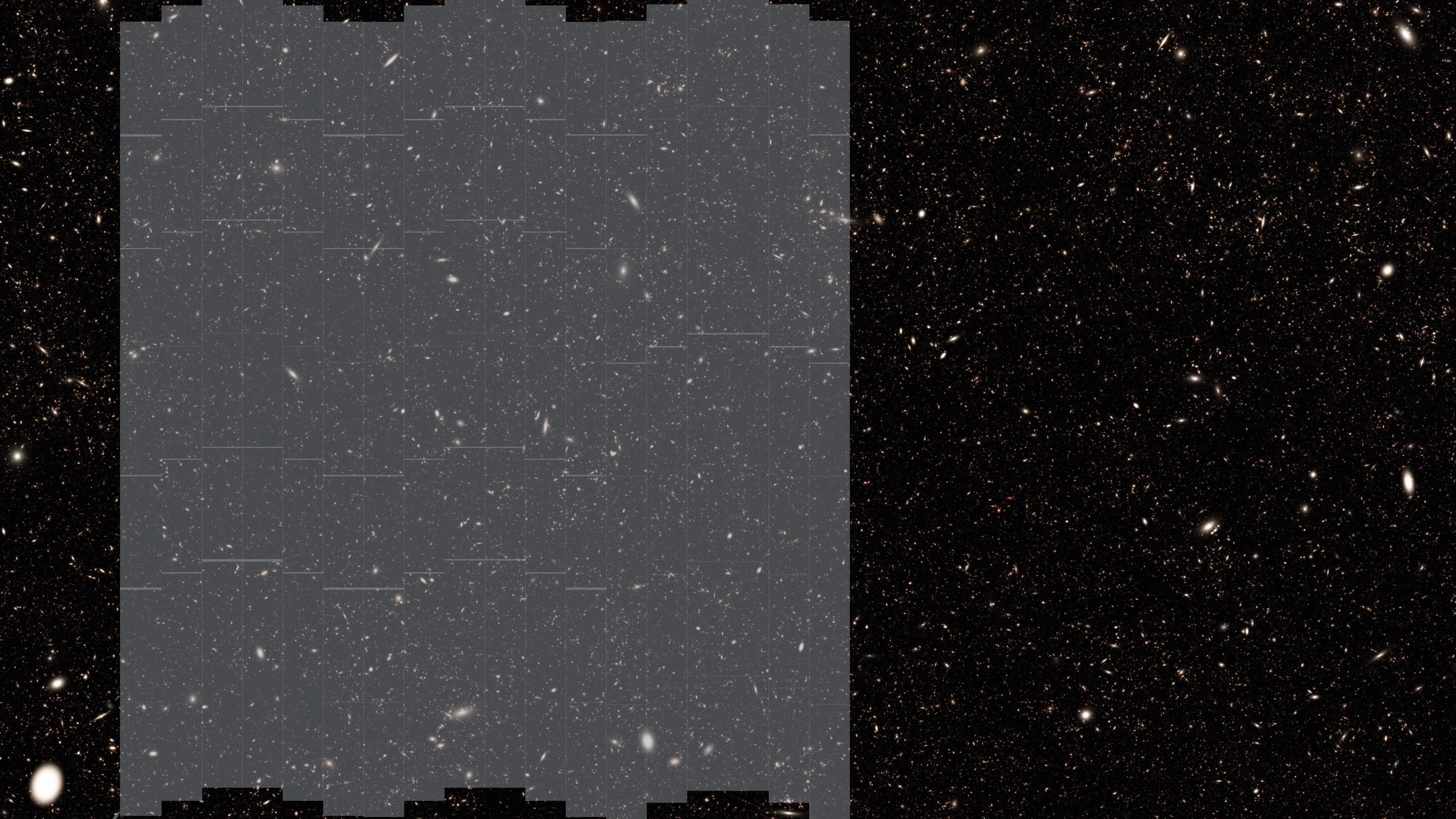


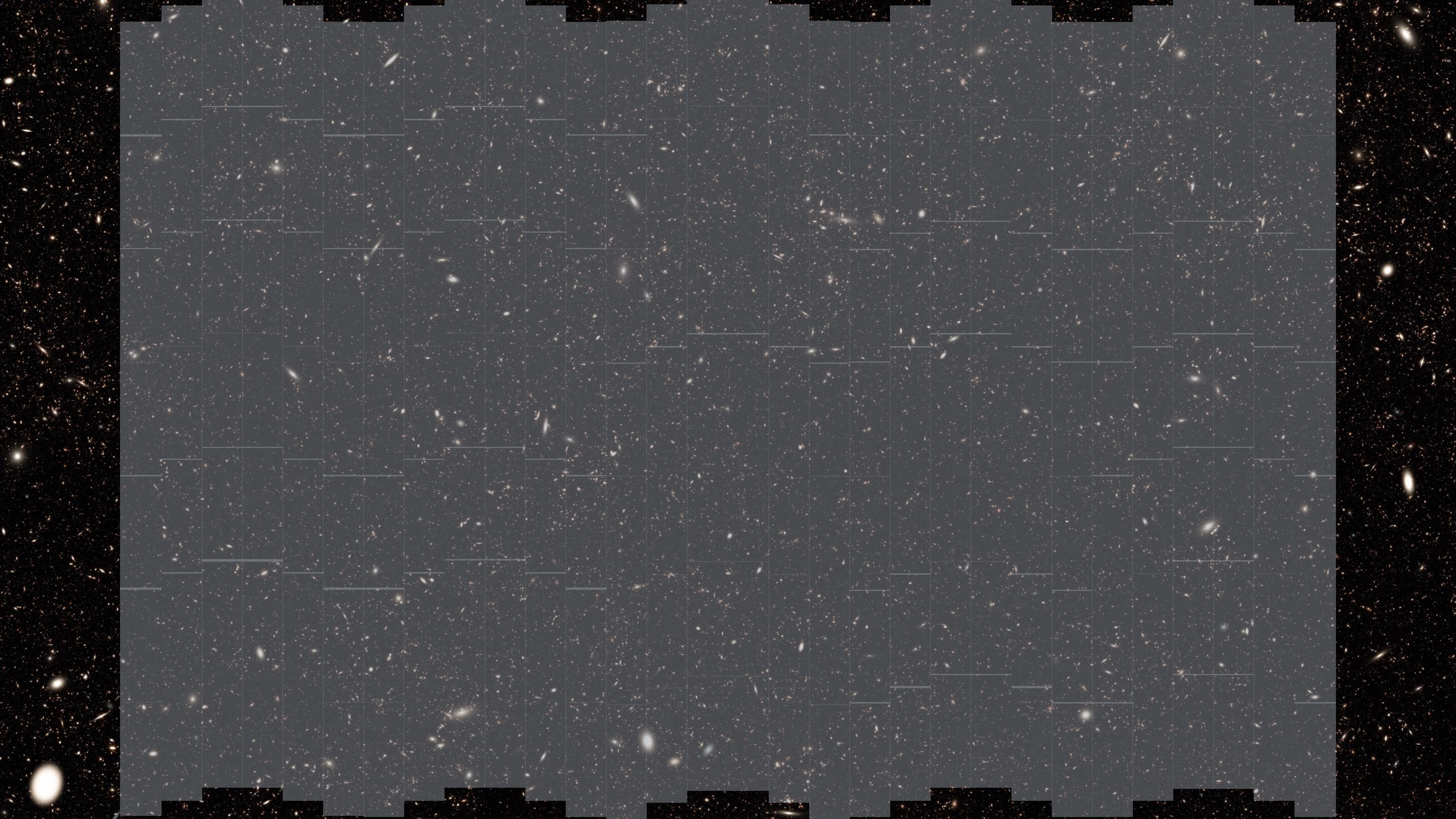
(Dalcanton et al. 2012)

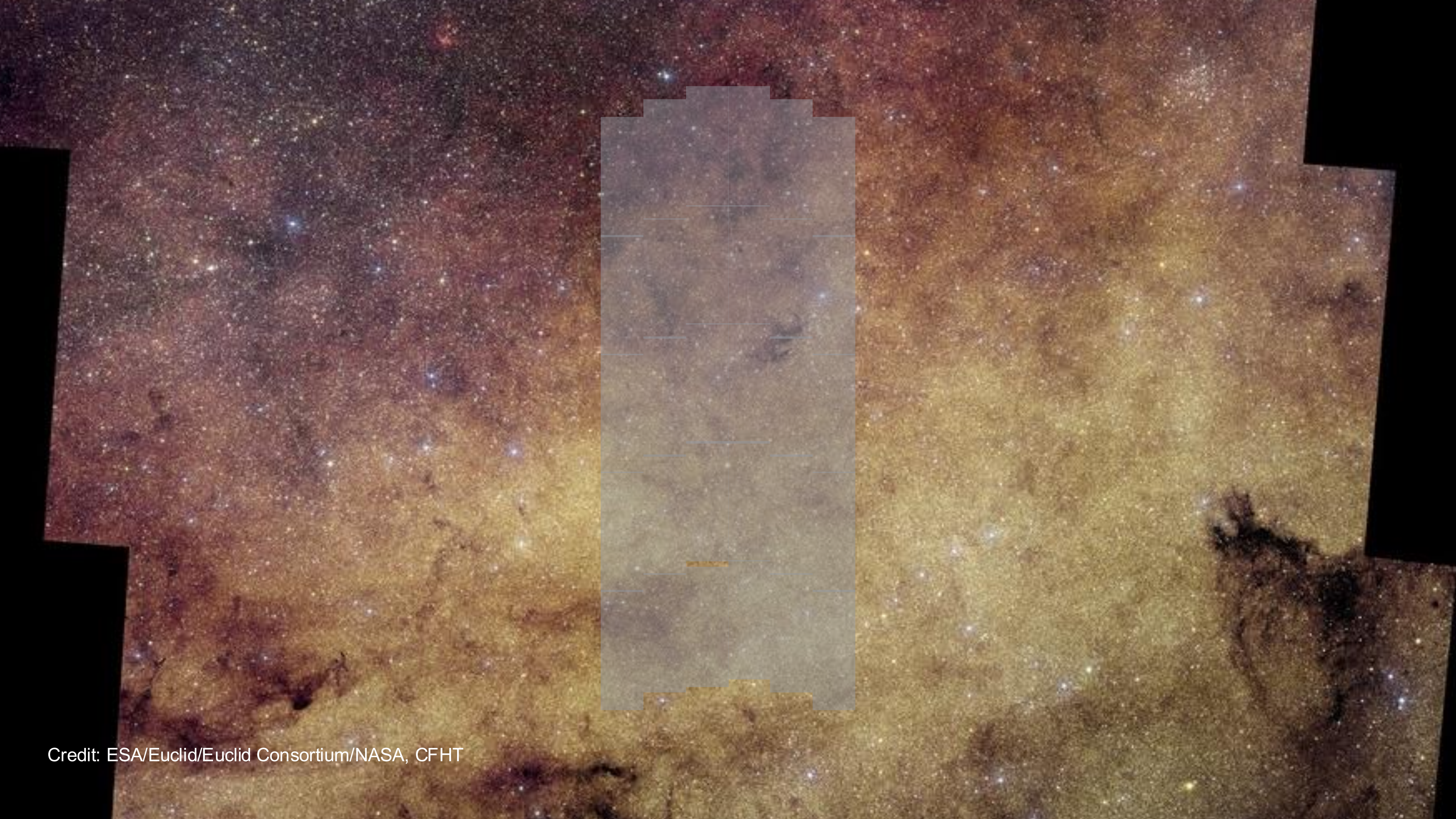
Roman WFI covers similar sky area in 2 observations per filter











Credit: ESA/Euclid/Euclid Consortium/NASA, CFHT

Simulated Roman WFI Image of a Field Near the Galactic Center

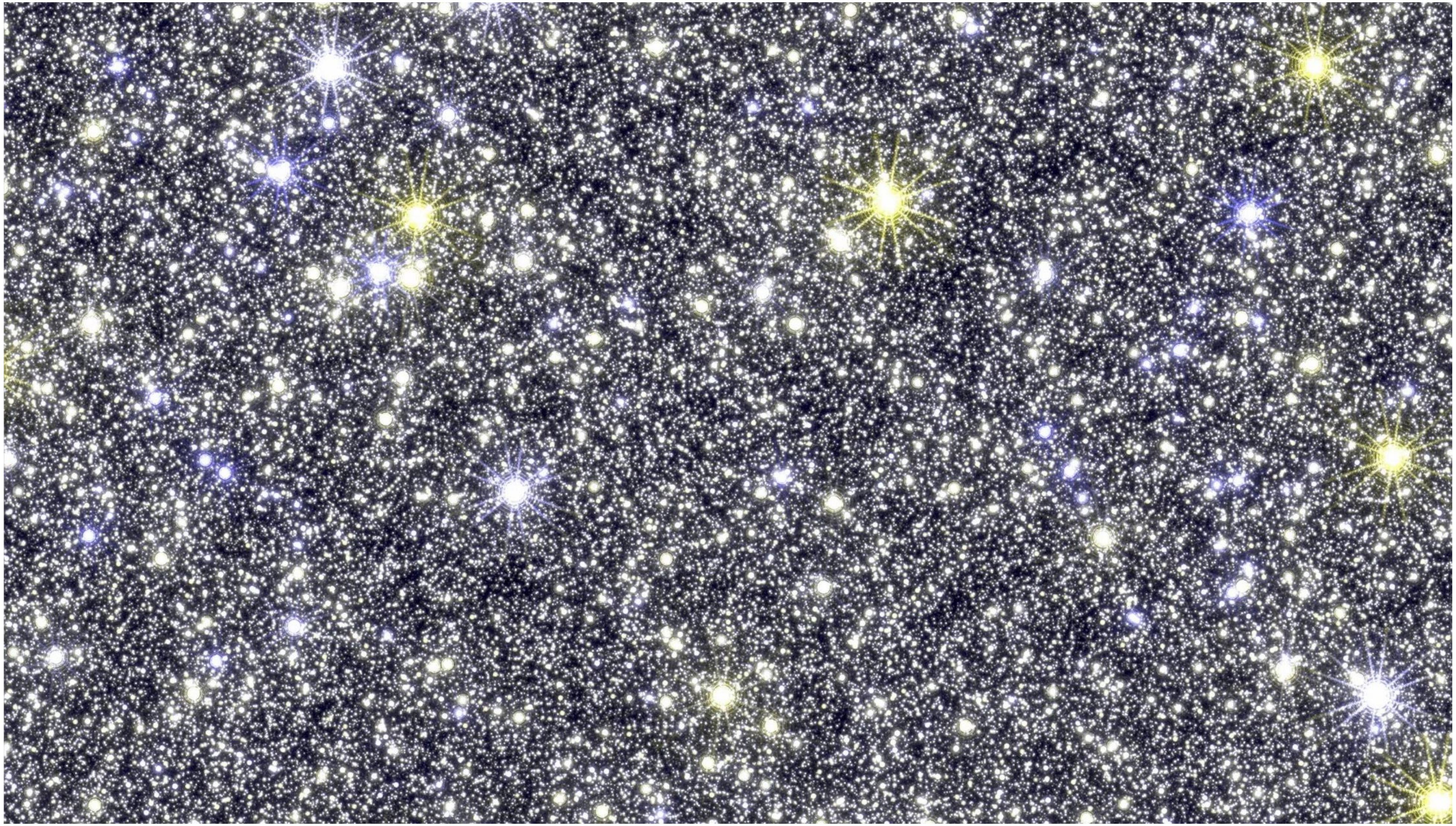
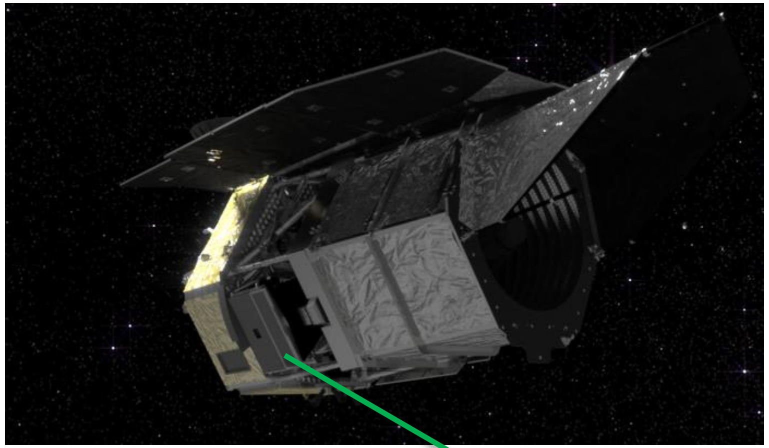


Fig: Penny et al. 2019

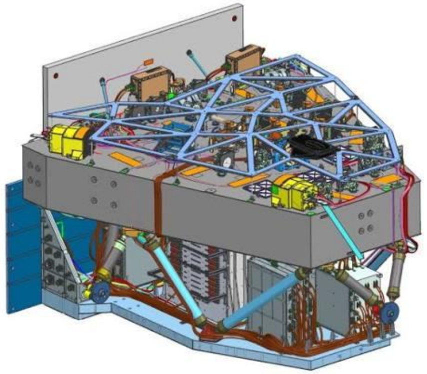
A small portion of the full WFI FOV

Roman Coronagraph Instrument

Roman Observatory



Coronagraph Instrument

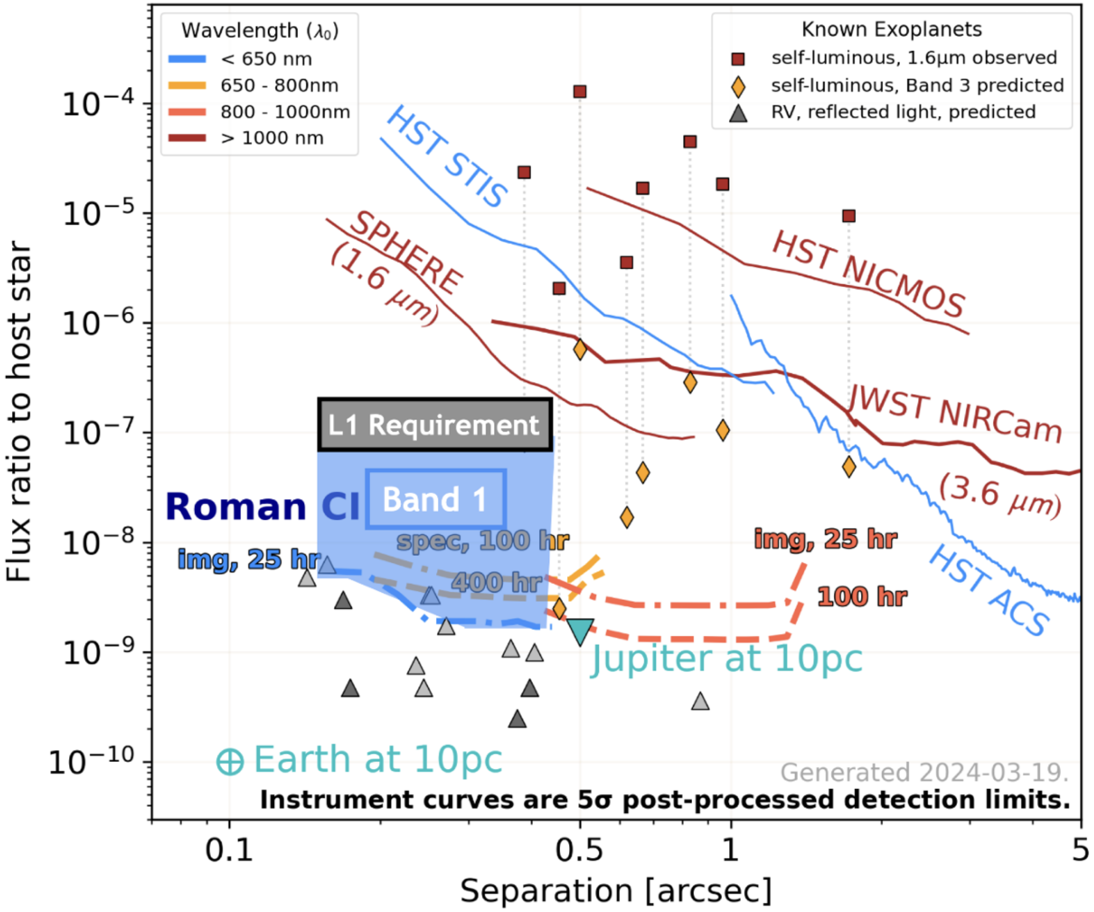


- **Technology demonstration instrument**
- Designed to suppress starlight and diffraction to reveal faint signals close to bright stars
- 10^{-7} contrast on a bright star in visible light, ~10^{-8} -10^{-9} as a goal
- Technologies demonstrated:
  - novel coronagraphic masks
  - wavefront sensing and control
  - photon counting detectors
  - advanced image post-processing
- Multiple observing modes in visible light from 575 – 825 nm
  - Narrow field imaging (required), wide field imaging (goal), polarimetry (goal), spectroscopy (goal)
- 90 days of observations in the first 18 months of the Roman mission

The Coronagraph is led by NASA JPL

Coronagraph overview paper

Roman Coronagraph – A New Contrast Regime



For V~ 5 stars

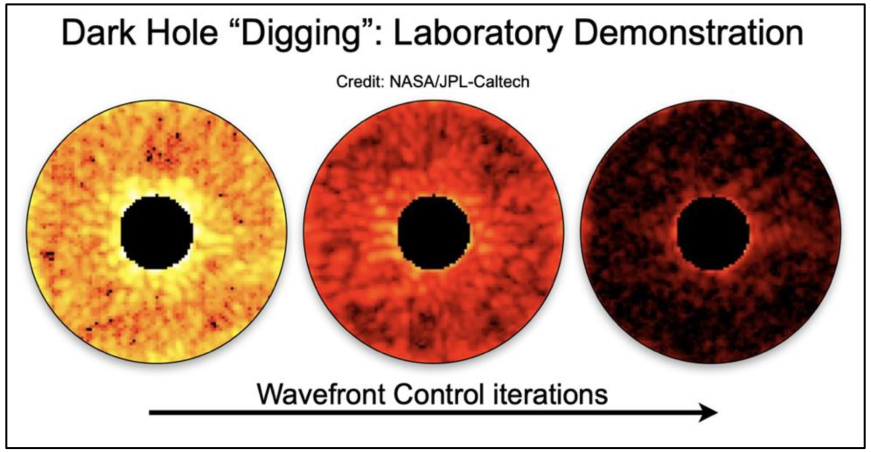
The expected contrast is

< 10^{-7} (L1 requirement)

~ 10^{-8} - 10^{-9} (predicted/goal)

100 to 1,000 times better than current facilities. Optimistically, image mature "Jupiters"

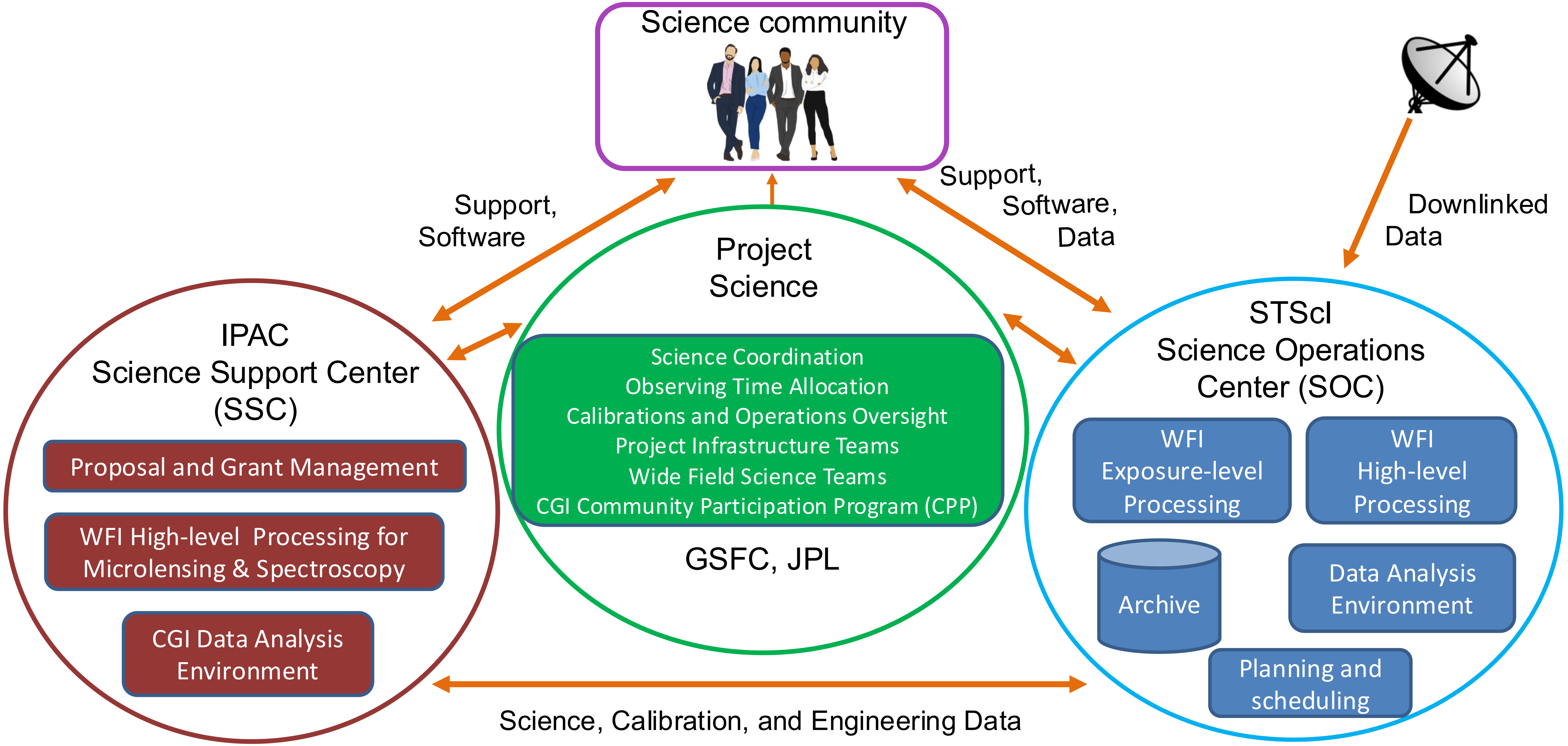
@ 10-50pc in reflected light!



Credit: V. Bailey, Coronagraph team

Roman Observations

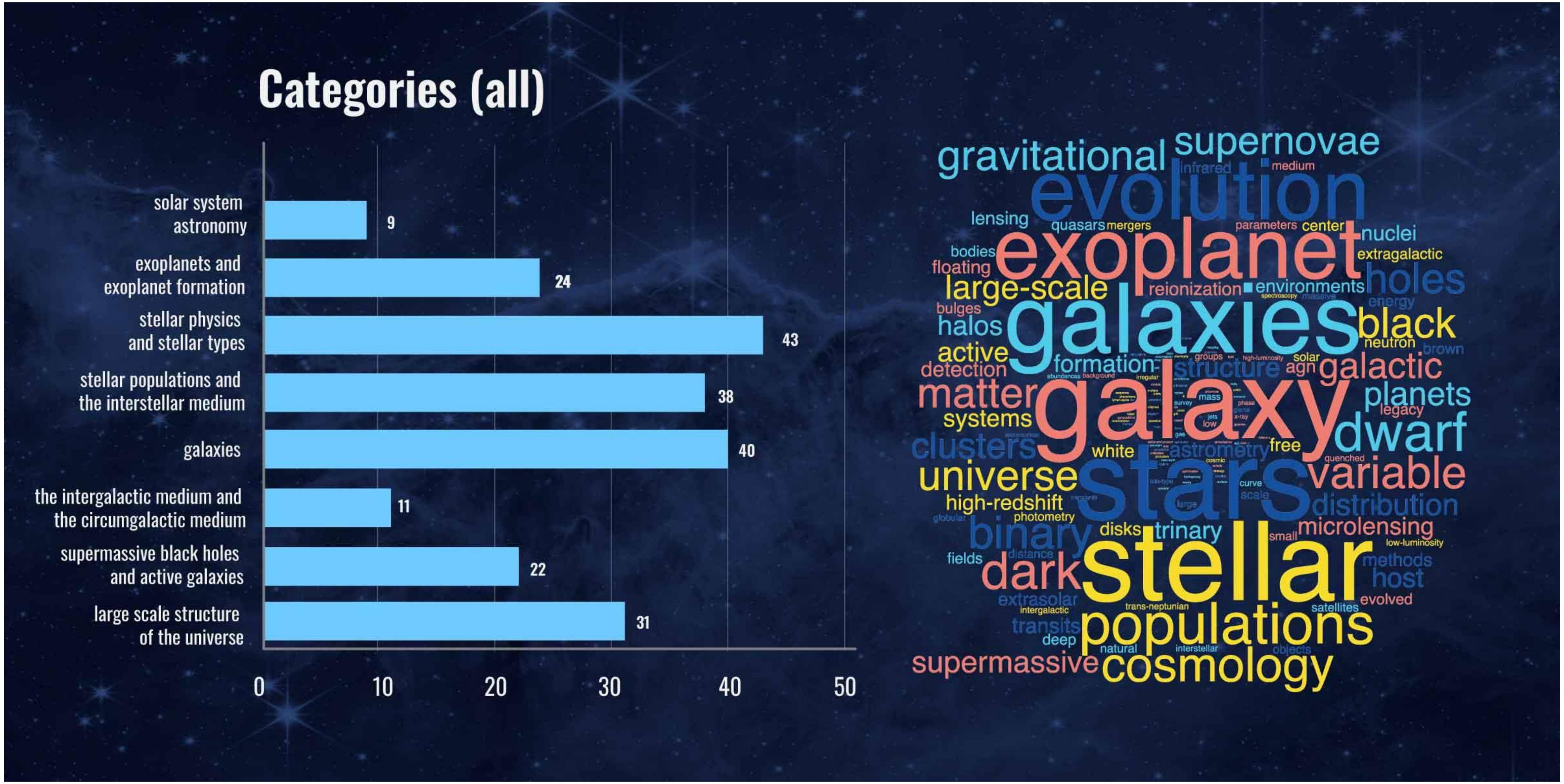
Roman Partners and Community



Credit: J. McEnery

Roman Core Community Surveys

Astrophysics with WFI for the Community, by the Community



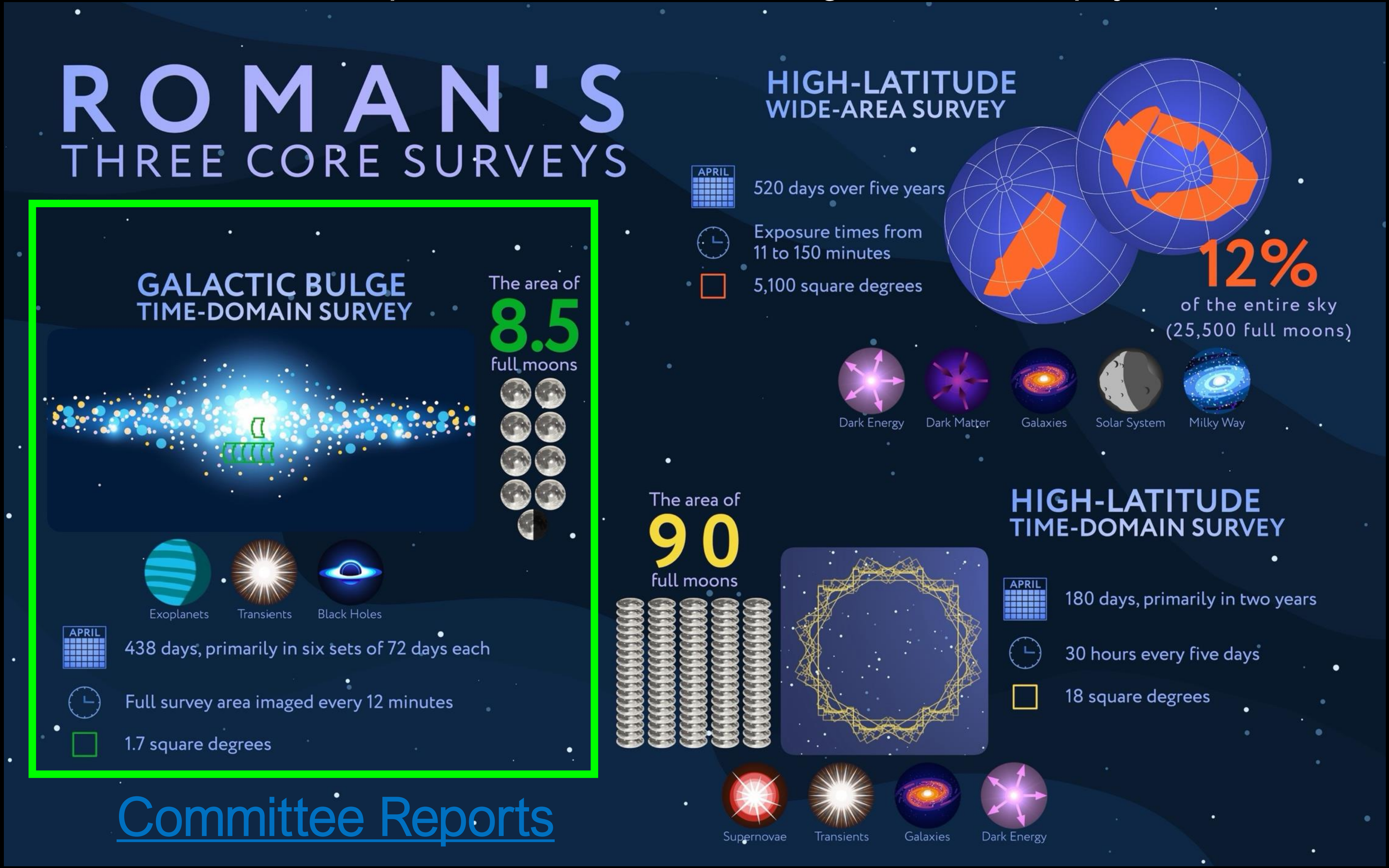
- [Community Science Pitch submissions]
- [Community White Paper submissions]

Input was reviewed alongside mission objectives by community committees to develop survey recommendations

Fig: STScI

Roman Core Community Surveys

Address Science Requirements While Maximizing General Astrophysics with WFI



[Committee Reports](#)

Roman Core Community Surveys

Address Science Requirements While Maximizing General Astrophysics with WFI

High-latitude wide area survey (HLWAS)

Cosmic expansion/acceleration and structure growth using >10^8 galaxies

- **Medium tier** - 2400 deg^2 3-band imaging to 26.5 mag, Grism spectroscopy
- **Deep tier**– 19 deg^2 7-band imaging to 27.5 mag, deep Grism spectroscopy
- **Ultra deep tier** - 5.5 deg^2 3-band imaging to 28 mag
- **Wide Tier** – additional 2700 deg^2, 1-band imaging to 26 mag

HLWAS details

like 2MASS, SDSS, DES and other wide-field surveys

High-latitude time-domain survey (HLTDS)

Cosmic expansion/acceleration using Type Ia supernovae, >10^4 transients

- **Multiple fields -** North and south, wide and deep, imaging and Prism spec.
- **Pilot tier** – 16 d cadence, eight observations per field, imaging and Prism spec., early in the mission
- **Core tier** – 5 d cadence, all fields, one anchor filter with others alternating for colors, Prism spec., 2 year duration
- **Extended tier** – long (65-85 day) cadence observations in deep fields
- Area and depth, see details below

HLTDS details

like ZTF, ASAS-SN, and other time domain surveys for transients

Galactic Bulge time-domain survey (GBTDS)

Exoplanet demographics using microlensing, LCs for >10^8 stars

- Repeat observations over 1.7 deg^2 in five bulge fields and Galactic center spanning ~70-day seasons
- **High cadence** – 12.1 min in wide NIR filter, 6 h in 2 bands, over six seasons
- **Low cadence** – 5 days in 3 bands, over four seasons
- **Snapshots** – 35 days in 5 bands and Grism, over all seasons
- Imaging sensitivity to ~24 mag (crowding dependent)

GBTDS details

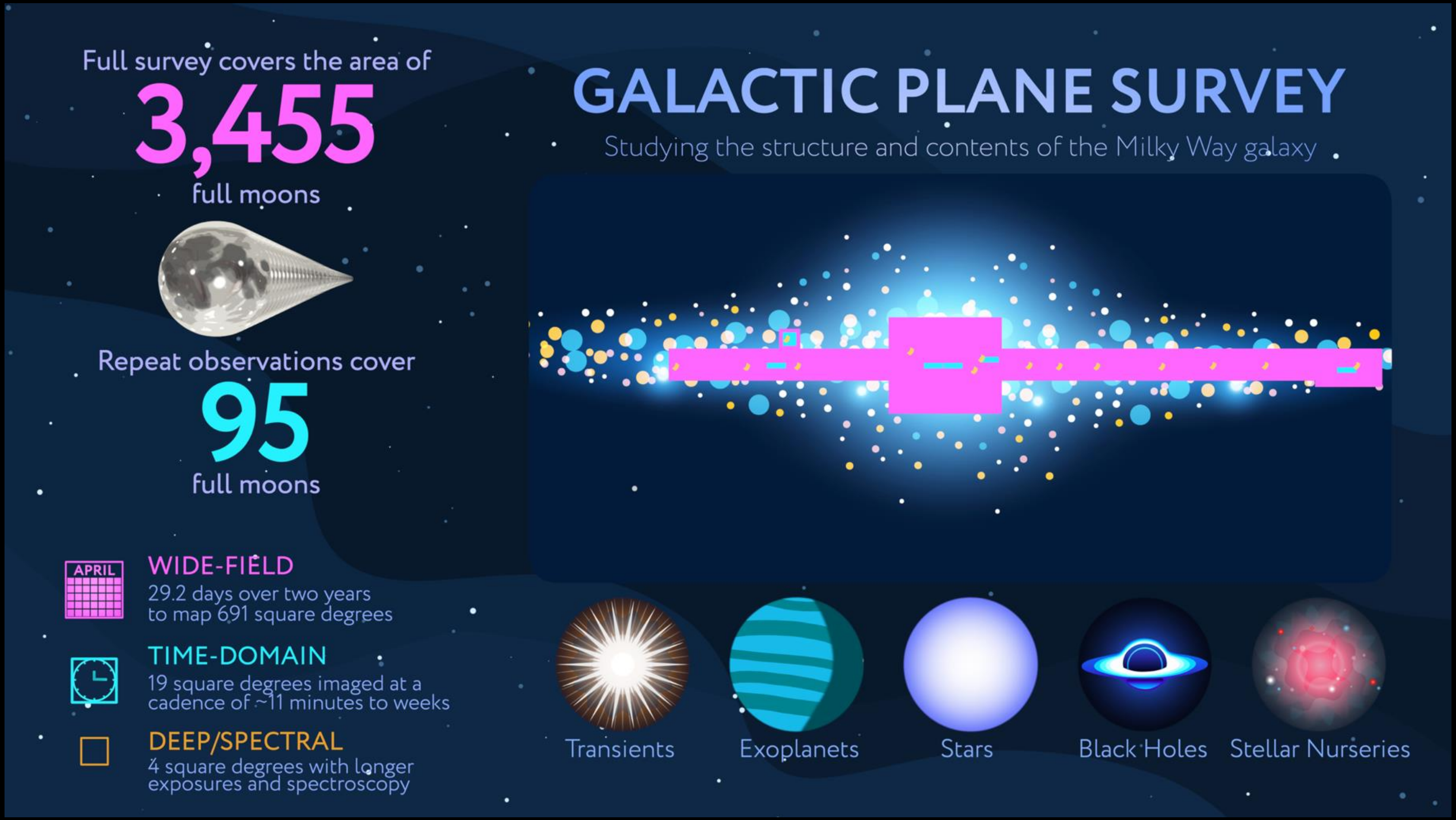
like previous microlensing, *Kepler,* and TESS exoplanet surveys

Roman General Astrophysics Surveys

What can Roman do for you?

- General Astrophysics includes both science with core survey data and additional WFI surveys that are defined by the community. Allocated via community processes and proposal calls

Galactic Plane Survey – Defined by a Community Process



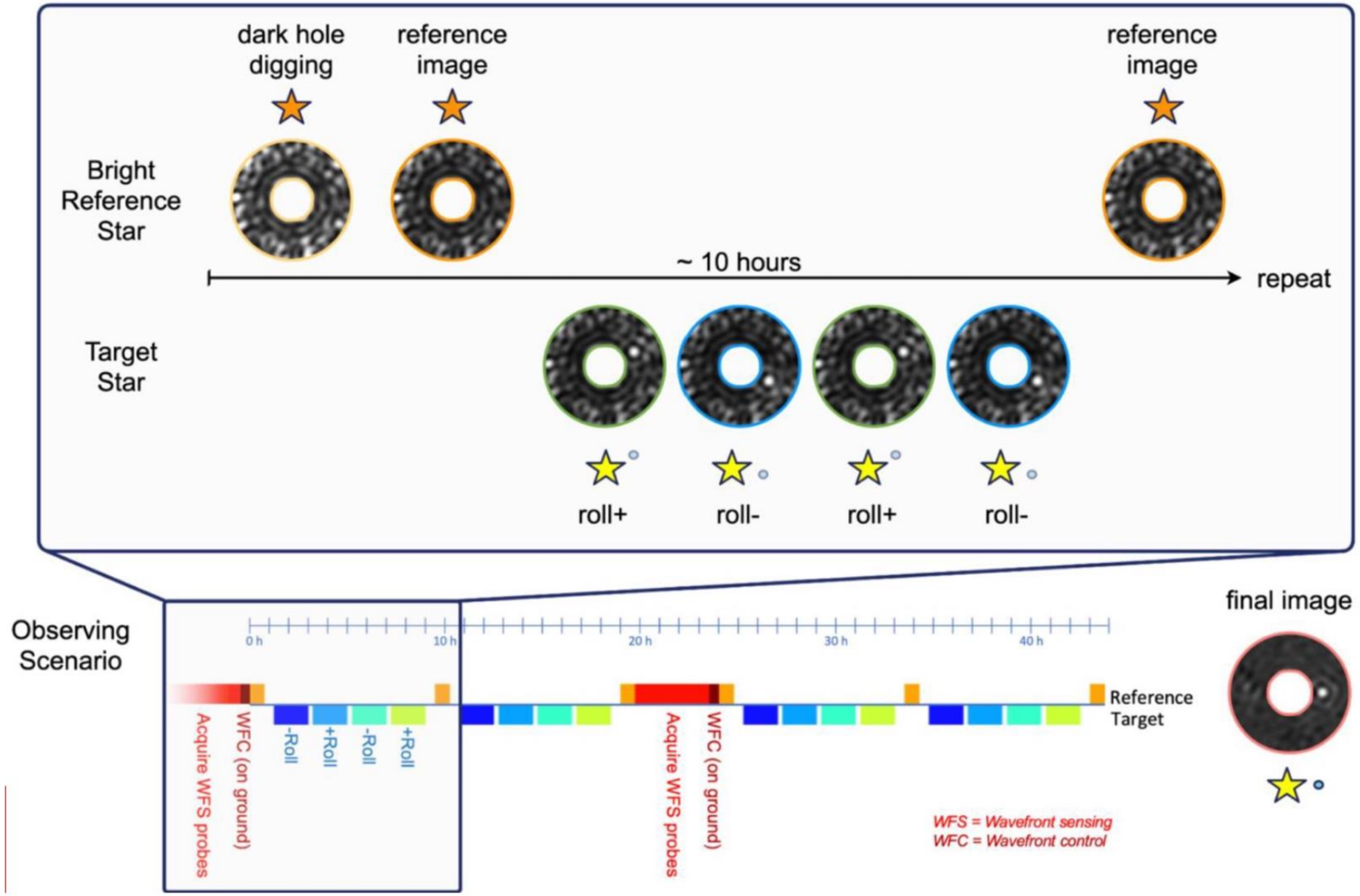
New Surveys Selected in Cycle 1 Call for Proposals

- The Roman-Kepler Legacy Survey
- Roman eXtreme Deep Field
- GRACE: The Grism Reionization and Cosmic Evolution Survey
- The First Complete Census of Stars in Key Globular Clusters
- A Legacy Survey of Andromeda and Triangulum with Roman

Approved Cycle 1 programs

ROMAN SPACE TELESCOPE

Roman Coronagraph Observations



Credit: V. Bailey, J. Wang, Coronagraph team

- Establish deep contrast through iterative observations of reference star → Slew to science target, observe at multiple rolls →Back to reference → Postprocessing
- First 6 months of Coronagraph observations planned
- Developed through a community process
  - Tech demonstration using science targets
  - Attempt first reflected light images of Jupiter analogs
  - Target known, self-luminous planets
  - Imaging/polarimetry of debris disks
- WFI acts as guiding camera during Coronagraph sequences, obtains parallel observations in adjacent field
  - WFI parallels memo

Roman Data

BIG DATA

172

Terabytes

Hubble's data archive

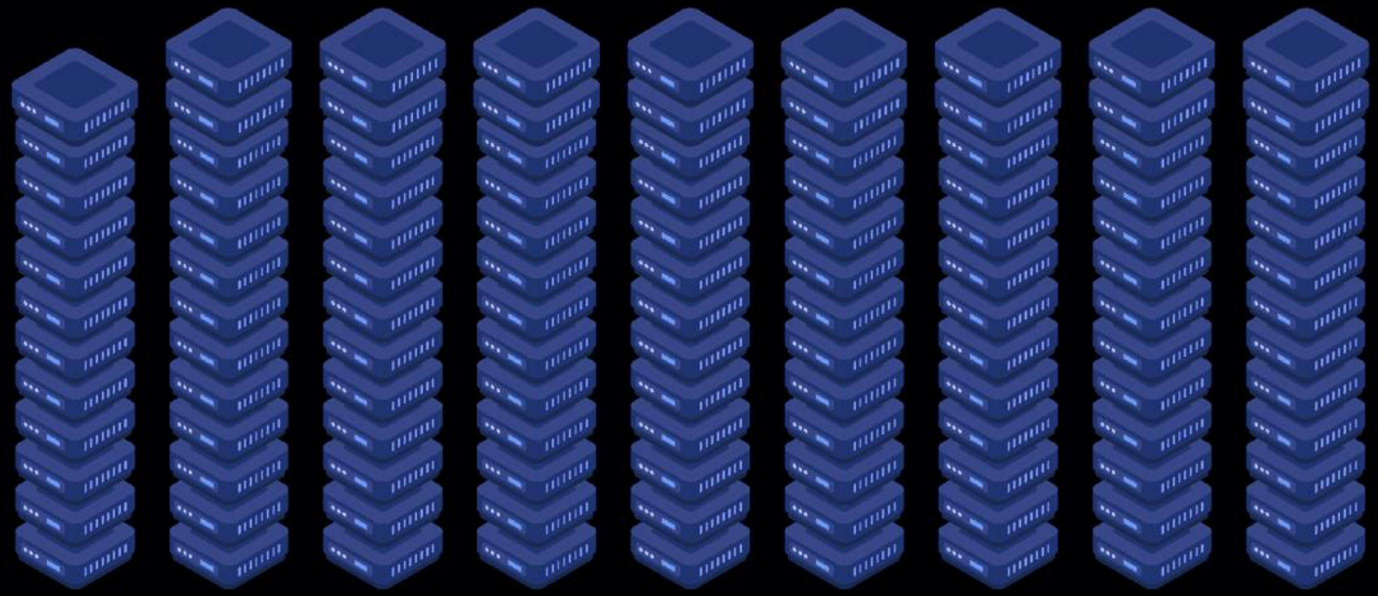
30 years (1990–2020)

20,000

Terabytes

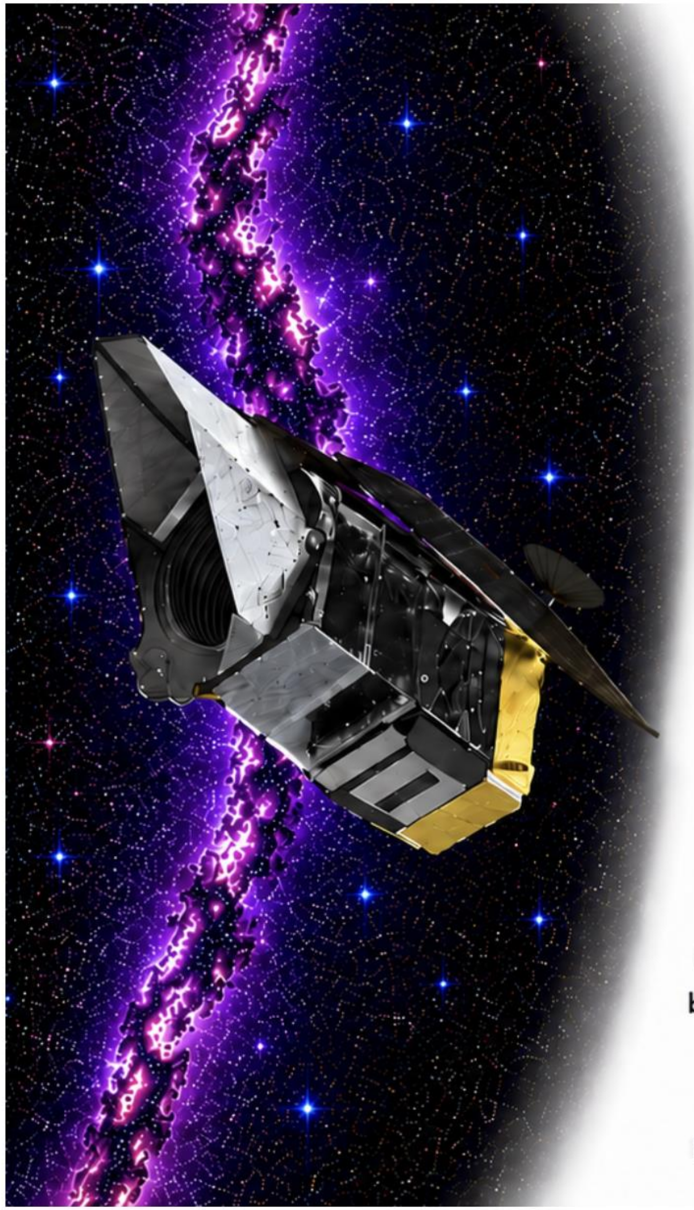
Roman's data archive

5 year primary mission (projected)



All Roman data will be publicly available

Roman Data – What to Expect



The Roman Data Philosophy

Roman data are available immediately, improve in quality throughout the mission, and are packaged into comprehensive Data Releases along the way.

LAUNCH & EARLY OPS

Day 1 science prompt products available following commissioning.

Prompt data products will be available immediately on the MAST archive and Nexus. Pre-launch test products already available.

PROMPT PRODUCTS & UPDATES

Prompt products offer fast, simple data products ideal for early exploration.

Calibrations and pipeline are continuously improved. We update prompt products when it is of scientific benefit.

DATA RELEASES

Data Releases will be uniformly processed and offer more comprehensive products ideal for thorough analysis.

Official Data Releases ensure consistency. The high cost of large scale data processing precludes independent processing.

CONTINUOUS JOURNEY

Improvements continue throughout the mission.

Each release builds on the last, enabling new discoveries and more powerful science.

Credit: H. Ferguson, STScI

Roman Data Access

- The Roman Research Nexus is the primary venue to access and analyze Roman data
- A cloud-based data analysis environment:
  - Roman specific software and analysis tools
  - Access to simulated and test data sets
  - Scalable compute resources
  - Science workflows and tutorials
  - Team collaboration and shared workspaces
- Will provide direct access to Roman science data
- Develop and run analyses on the data, in the cloud, where the data is
- Individual and team accounts
- **Early access open now!**

Ask the Help Desk!

Credit: G. De Rosa, STScI

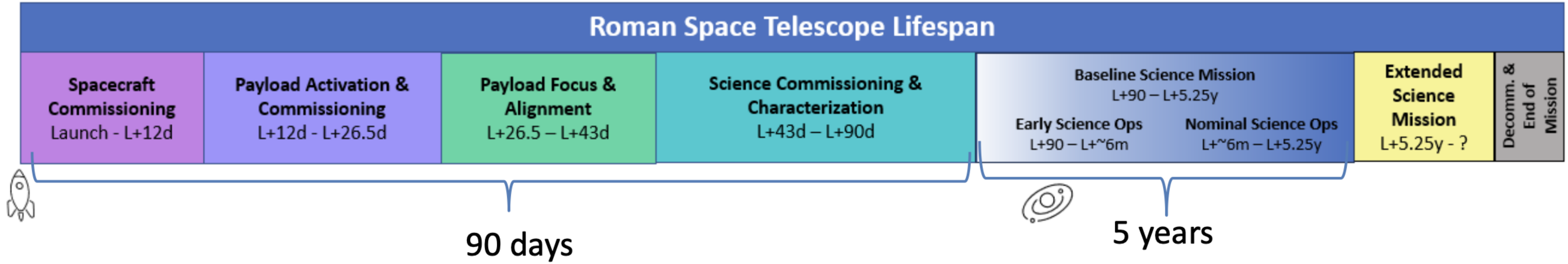
Roman Status

Roman Travels by Barge to Kennedy Space Center

ROMAN
SPACE TELESCOPE

Roman Undergoes Post-shipping Checkout and Tests

What's Next for Roman?



- **Commissioning** (L – L+~90 days) - Ready the observatory, instruments, and ground system for science. Establish a calibration and performance baseline
- **Baseline Science Mission**
  - ***Early Science Operations*** (L+~90 – L+~6 months)
    - Prompt data available to the community
    - Flight calibrations continue with dedicated observations and collection of survey data
    - Anticipate frequent updates to calibration and pipelines
    - Regular community communication to share status and inform expectations
  - ***Nominal Science Operations*** (L+~6 months - L+5.25 years)
    - Stable calibration and pipelines
    - Prompt products and curated releases
- **Extended Science Mission** (L+5.25y – TBD)

How to Get (More) Involved

Working Groups

- Calibration
- Software
- Simulations
- Photo-Z
- Time Domain
- External Synergies
- …

Science Collaboration

- Milky way and Stellar Astrophysics
- Exoplanets and Solar System
- Nearby Galaxies (< 15 Mpc)
- Galaxy and Quasar Evolution
- Explosive Transients
- Cosmology

General Investigator Program

- Call for proposals each year

Roman is Ready to Go!

- ✓ **Observatory built, tested, and delivered to the launch site**
- ✓ **Observations defined**
  - ✓ Community process for bulk of WFI observations and Coronagraph program
  - ✓ Cycle 1 selections of additional WFI surveys announced
- ✓ **Commissioning plans in place**
- ✓ **Calibration plan completed**
- ✓ **Observations and calibrations implemented into mission plan**
  - ✓ Planning and scheduling implementation tested in Mission Readiness Tests
- ✓ **Pipelines implemented and tested**
  - ✓ Code freeze last month
  - ✓ Pipeline details discussed/reviewed in calibration and software groups
- ✓ **Roman Research Nexus analysis environment deployed**
  - ✓ Accounts publicly available (includes tools, simulated/test data, and tutorials)
- ✓ **Launch and commissioning rehearsed through many Mission Readiness Tests**
- ✓ **The community is engaged and ready to pursue breakthrough science**

Dr. Nancy Grace Roman

NASA’s First Chief of Astronomy

Visionary behind NASA’s space astronomy program

1925–2018


UNITED STATES

Back-up Slides

Survey Astronomy – A Legacy of Discovery

- **Astronomy surveys target large numbers of astronomical sources**
- **Surveys can cover wide areas of the sky, differing time cadences, or both**
- **Surveys often focus on answering key questions where large samples are necessary**
- **Also produce community resources in the form of images, spectra, source catalogs, source variability, and legacy calibrations**
- **Surveys have *enormous* discovery potential**
- **Legacy surveys have led to groundbreaking science and continue to deliver through archival data**
- **The Nancy Grace Roman Space Telescope will perform next generation surveys and deliver breakthrough results**

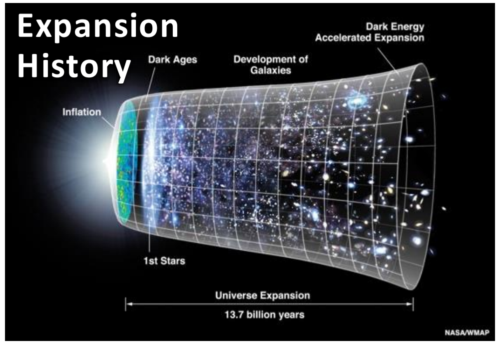
Roman Space Telescope Mission Objectives

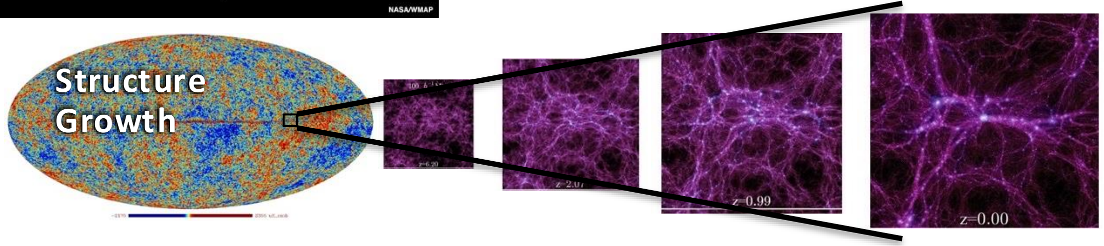
- **NASA's next Astrophysics Flagship mission**
  – Will address outstanding questions in astrophysics through wide field and time domain surveys

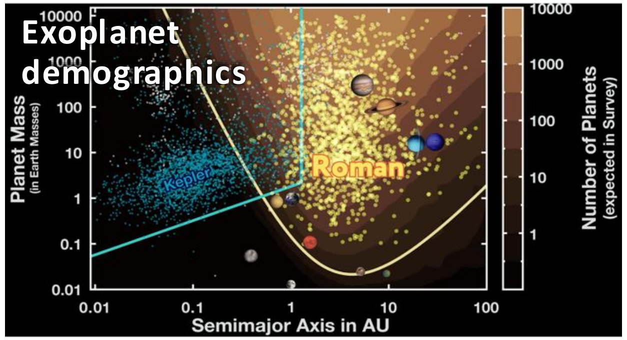
- **Cosmology and Exoplanets drive requirements and core surveys**
  – Expansion history of the Universe
  – Growth of structure in the Universe
  – Exoplanet Demographics

- **General Astrophysics**
  – Broad range of science enabled by:
    - Core Community Survey data
    - Additional surveys selected via peer review, allocating *at least* 25% of Roman observing time

- **Coronagraph Technology Demonstration**
  – Paper 13092-304 – 19 June 2024



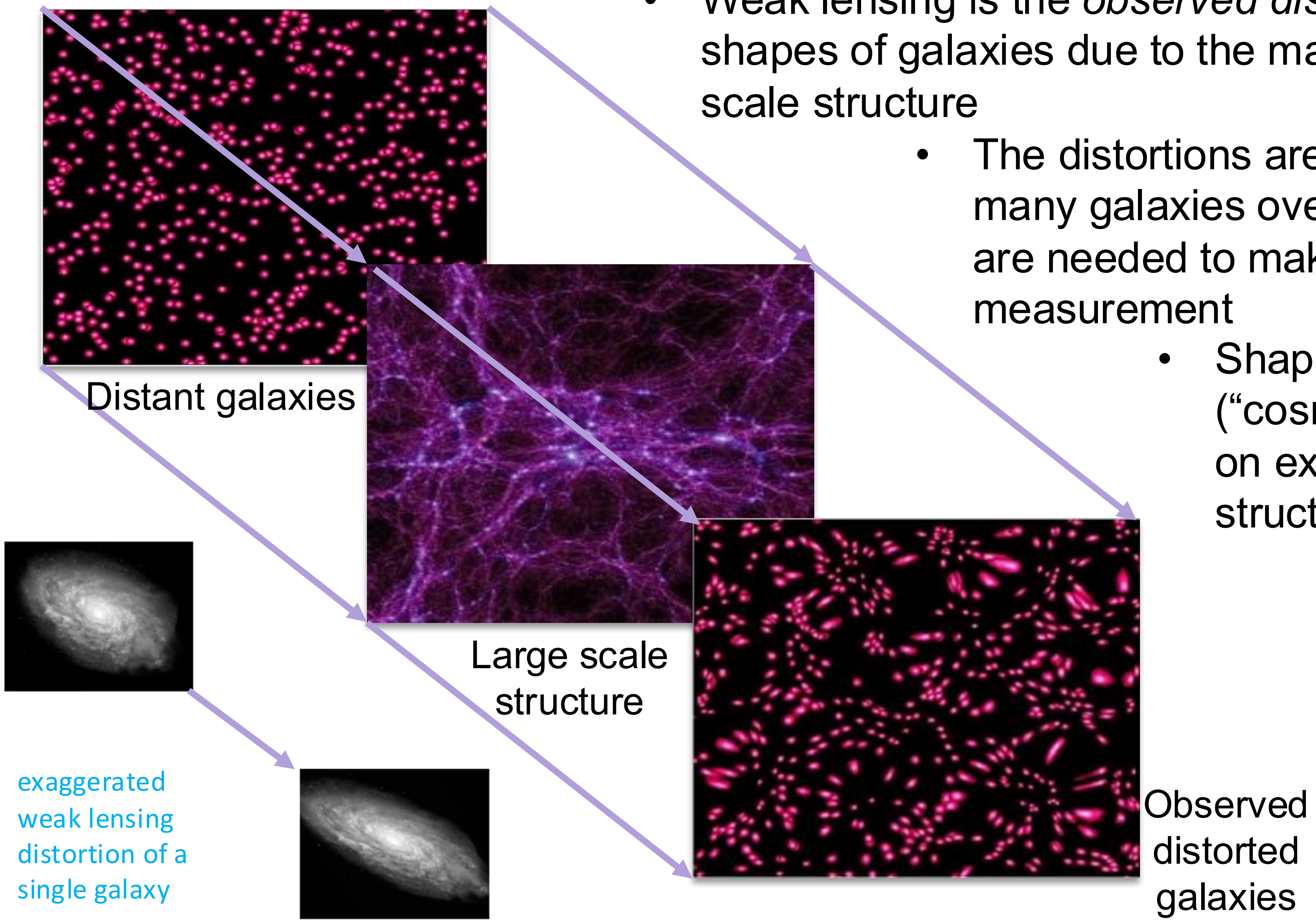




General Astrophysics

Expansion History and Growth of Structure - Weak Lensing

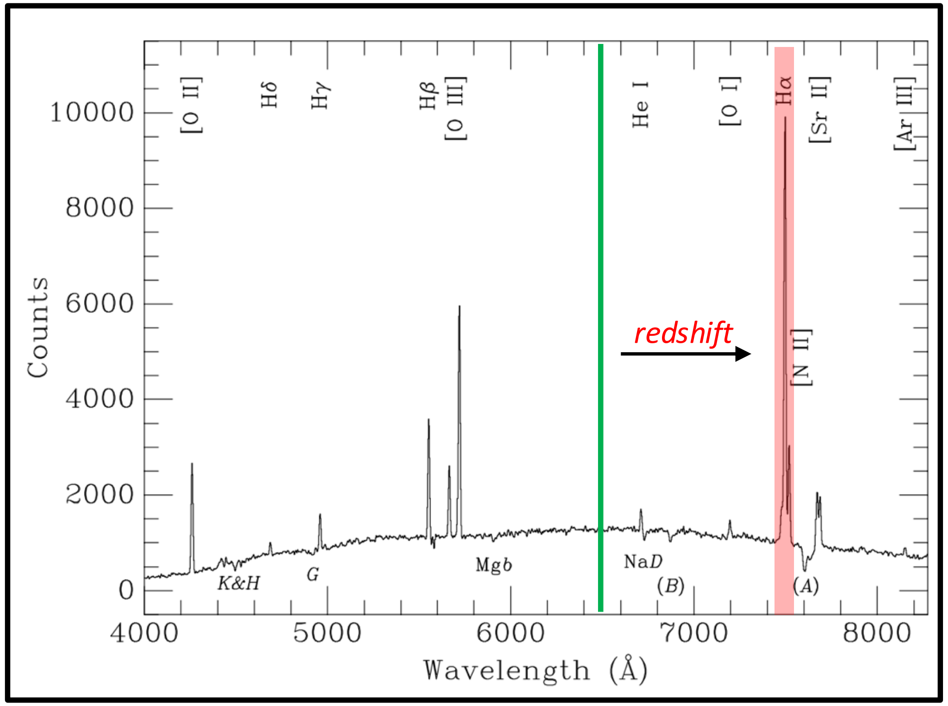
- Weak lensing is the *observed distortion* in the shapes of galaxies due to the mass of large-scale structure
  - The distortions are subtle (<1%), so many, many galaxies over a large portion of the sky are needed to make a significant measurement
    - Shapes correlated over many galaxies ("cosmic shear") provides constraints on expansion and the growth of structure over cosmic history



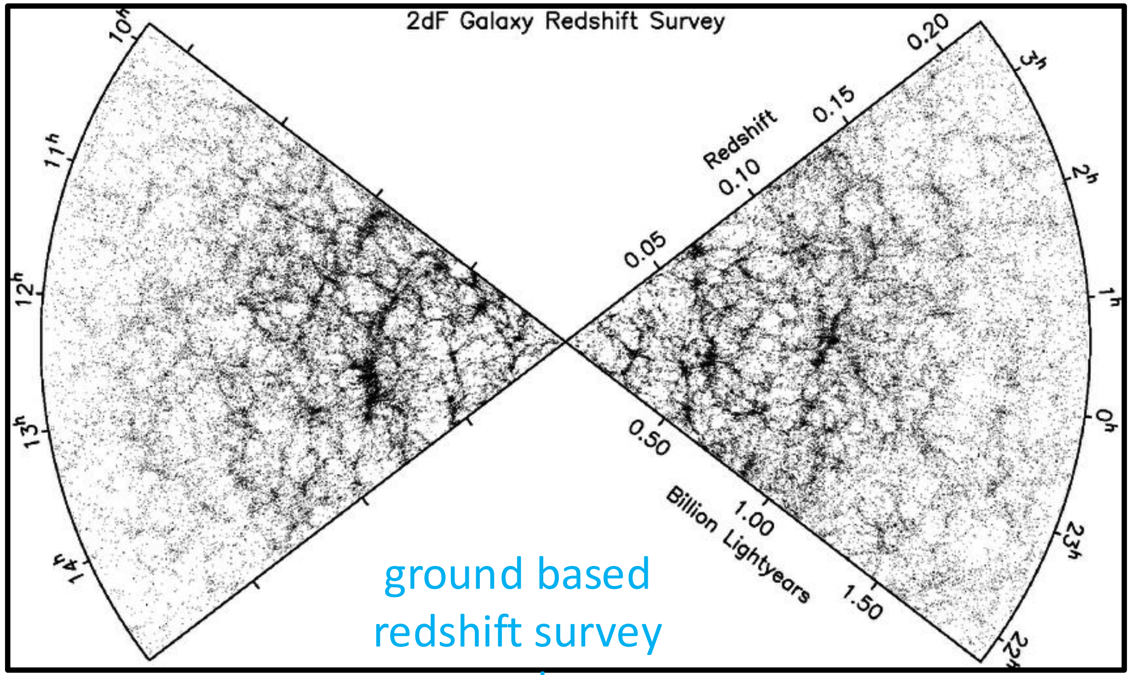
- **Next Gen Survey Needs:**
  - **many galaxies**
  - **sensitive NIR imaging**
  - **high angular resolution**
  - **well controlled PSF**
  - **precise calibration**

Expansion History and Growth of Structure - Galaxy Redshifts

- The expansion of the universe causes the light from distant sources to be shifted to redder wavelengths → *redshift*



- Redshifts and positions of many galaxies provides → new constraints on the 3D distribution of structure (dark matter) and the expansion history of the universe (dark energy)



- **Next Gen Survey Needs:**
  - **many galaxies, sensitive NIR imaging/spectroscopy, precise calibration**

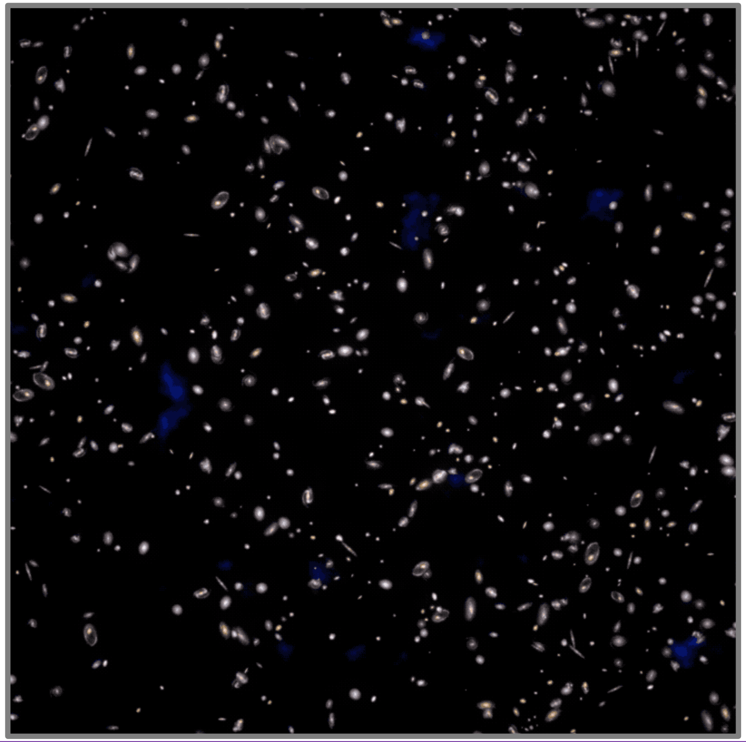
Figs: Blakeslee et al. 2007; 2dF Survey

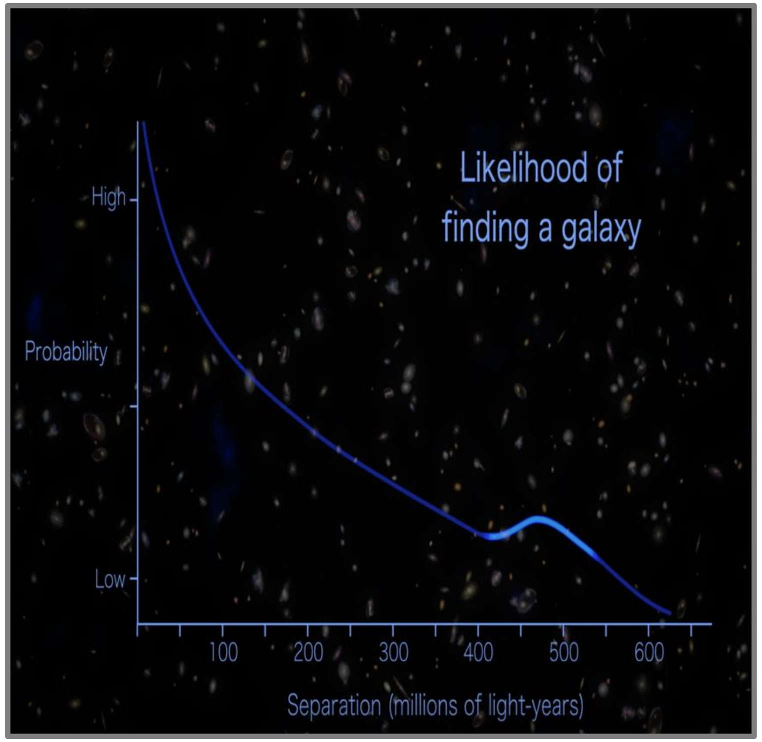
Expansion History and Growth of Structure – Baryon Acoustic Oscillations

Acoustic oscillations in the early universe lead to matter over-densities where galaxies form.

Imprint in galaxy distributions grows with the expansion of the universe…

Leads to an excess in the separation of galaxies that can be measured in large scale surveys



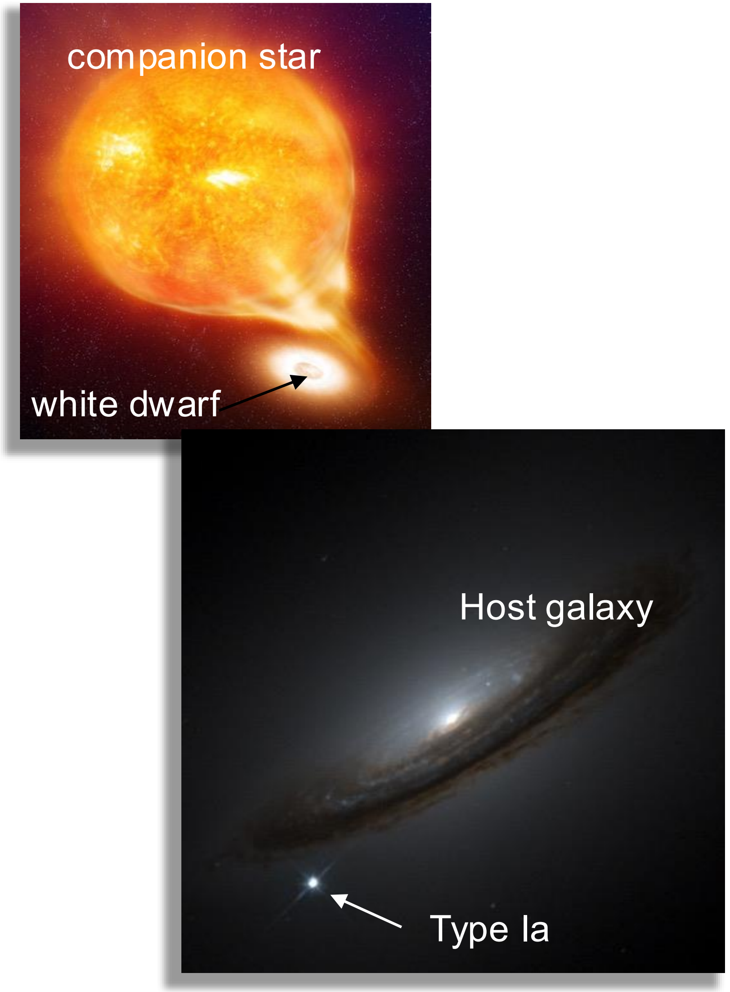


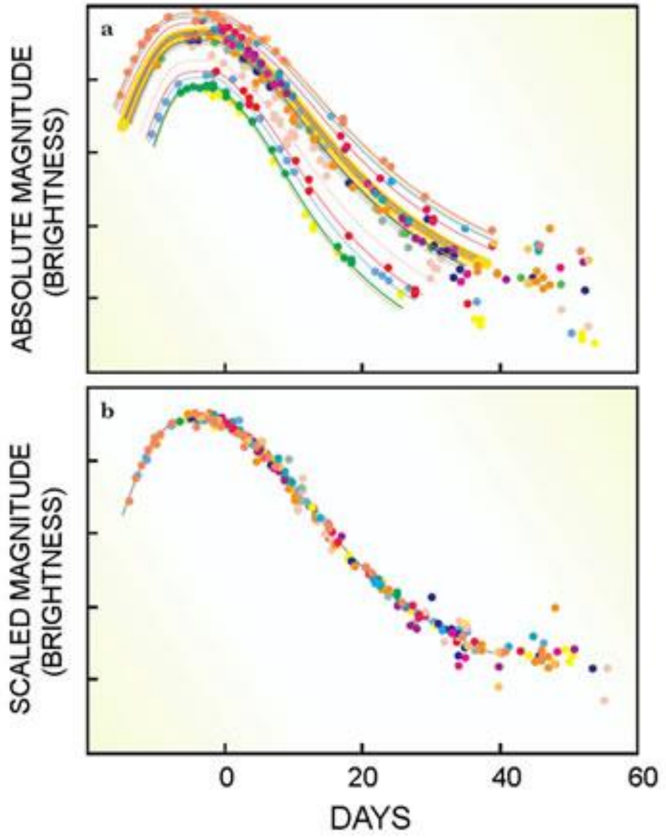
- **Next Gen Survey Needs:**
  - **many galaxies, sensitive NIR imaging/spectroscopy, precise calibration**

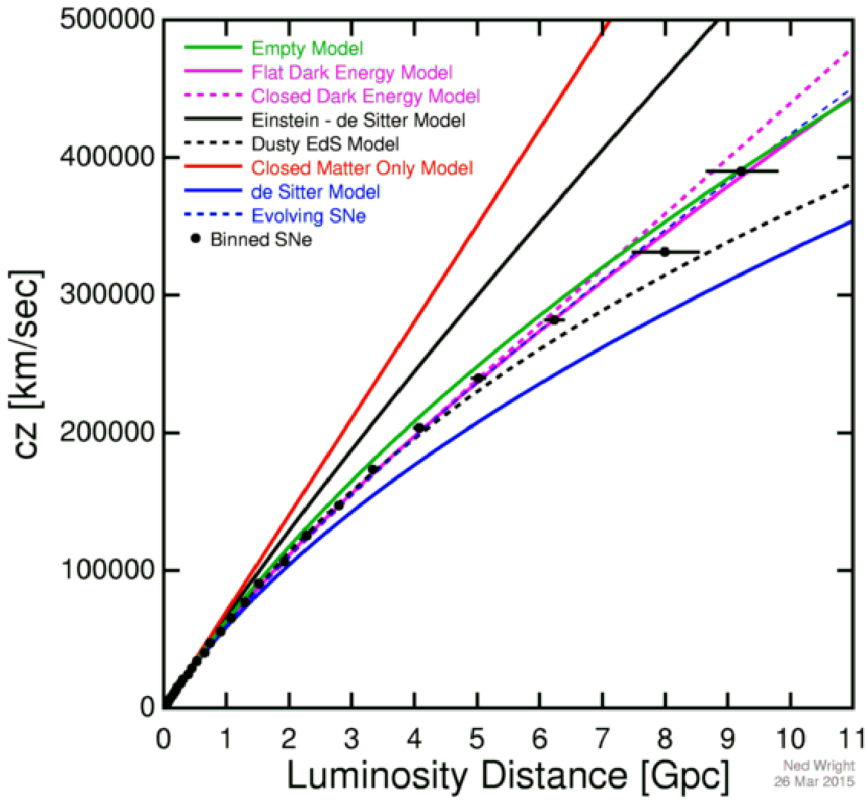
Image Credit: NASA SVS

Expansion History – Type Ia Supernovae I

- **A “Type one-A” Supernova is the runaway thermonuclear detonation of a white dwarf**







- **Next Gen Survey Needs:**
  - **many supernovae, sensitive NIR imaging/spectroscopy, photometric precision, precise calibration**

Figs: NASA/Hubble; Perlmutter 2012, RevModPhys; N. Wright

Exoplanet Demographics – Microlensing

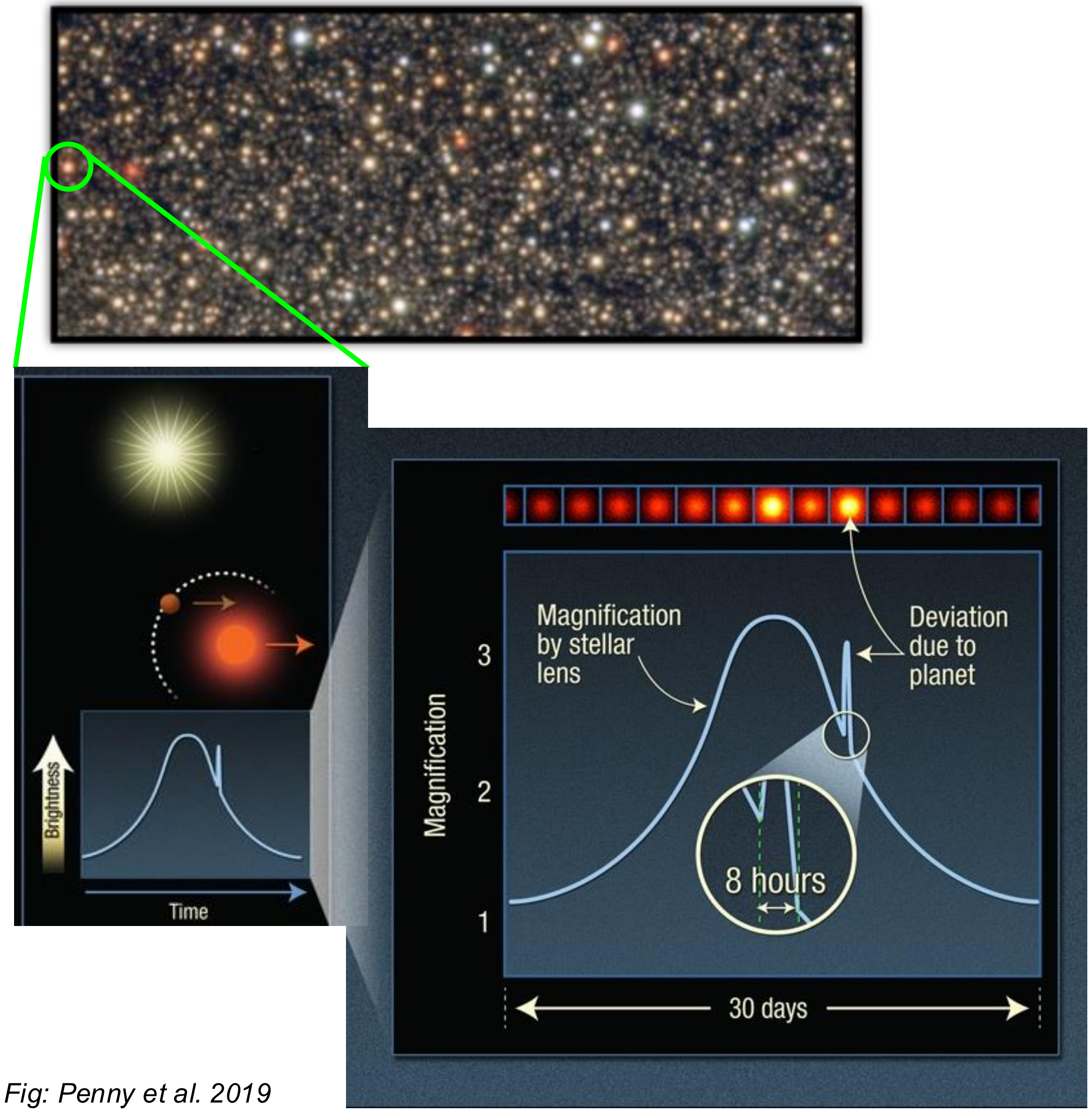
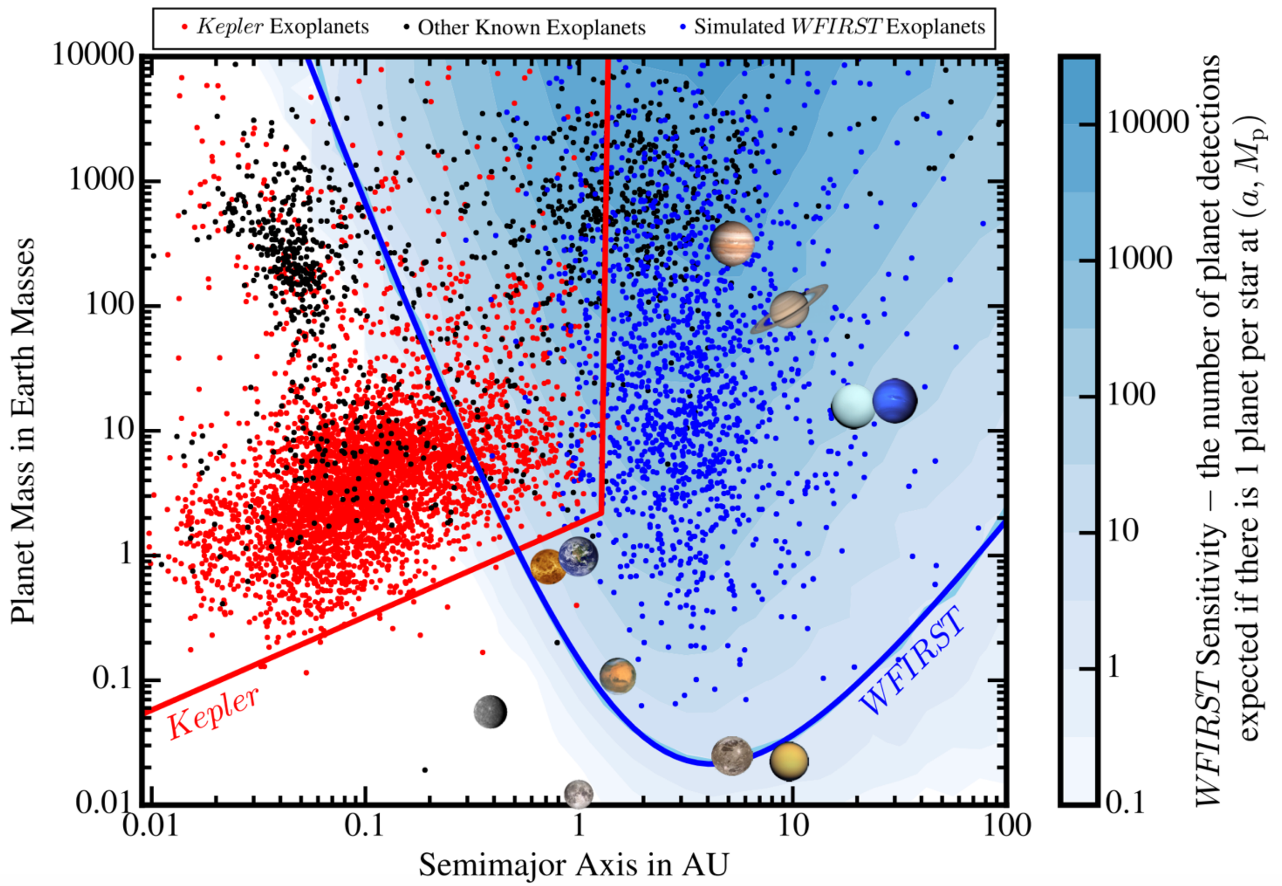


Fig: Penny et al. 2019

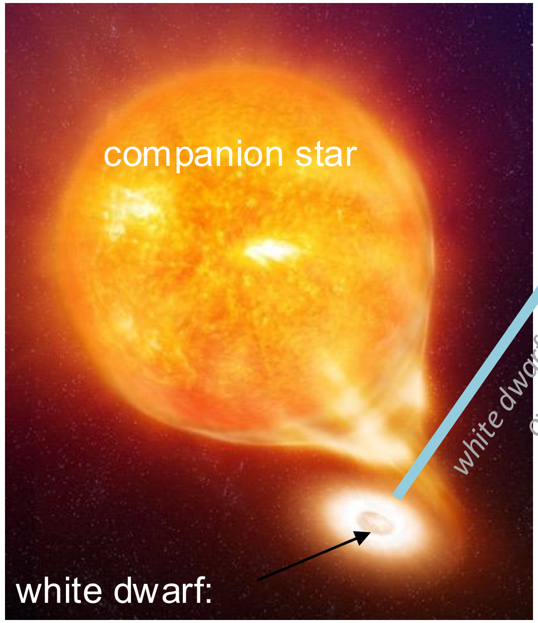


- **Next Gen Survey Needs:**
  - **many stars, sensitive NIR imaging, high angular resolution, photometric precision**

Expansion History – Type Ia Supernovae I

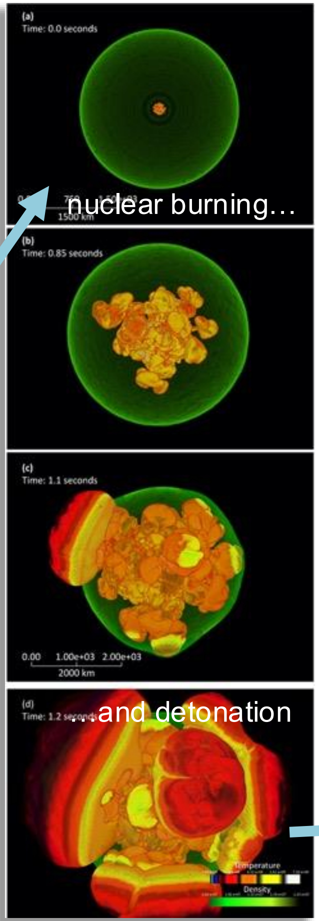
- **A "Type one-A" Supernova is the runaway thermonuclear detonation of a white dwarf**
  - They are used as standardizable candles to measure the expansion history of the universe
  - Their detection and characterization is a core cosmological probe

Thermonuclear detonation of a white dwarf?

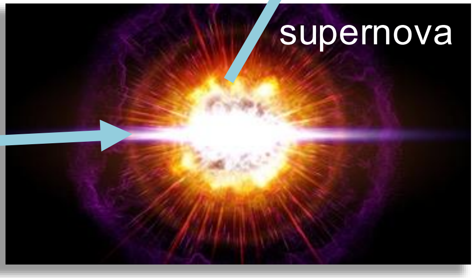


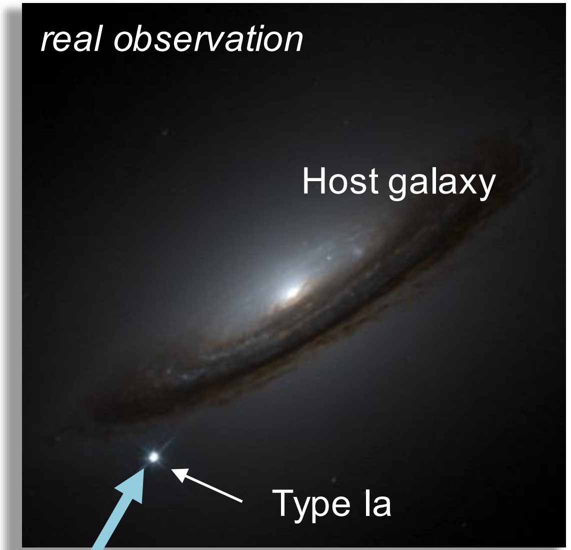
The remnant core of a star like the Sun, a ball of carbon and oxygen the size of Earth but ~300,000 times more massive

white dwarf builds up too much mass over a long period of time



a few seconds

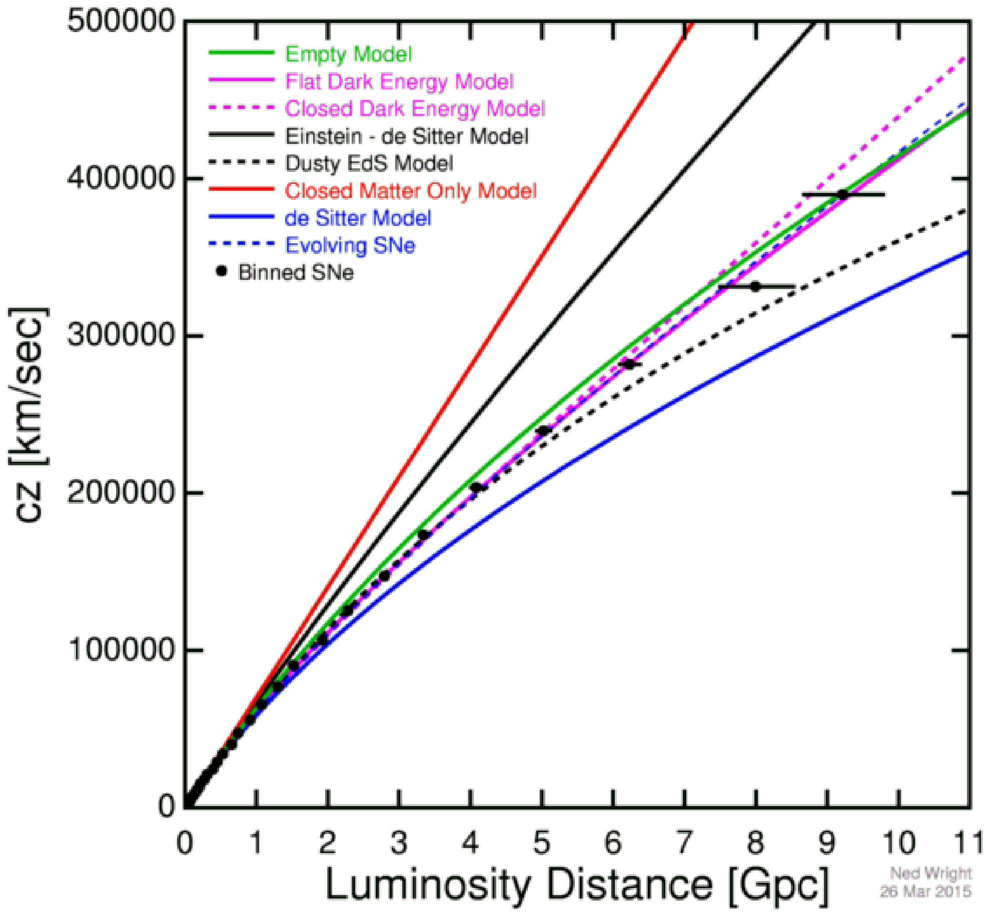




Supernovae are *extremely* bright (about *5 billion times* brighter than the Sun) and can be detected at extreme distances with sensitive surveys

Expansion History – Type Ia Supernovae II

- **A "Type one-A" Supernova is the runaway thermonuclear detonation of a white dwarf**
  - They are used as standardizable candles to measure the expansion history of the universe
  - Their detection and characterization is a core cosmological probe



Supernova distances from light curves are compared to redshifts from spectra/SEDs

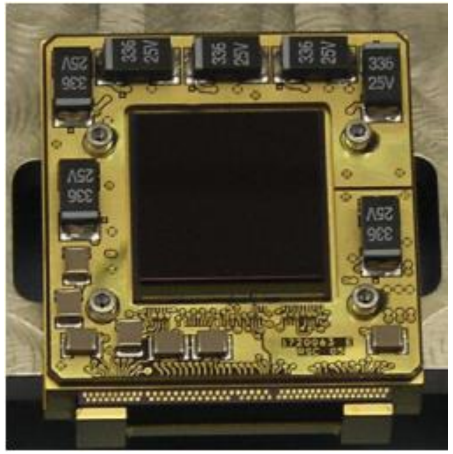
Different cosmological models are fit to the data to constrain the nature of the universe (acceleration, dark energy)

Roman WFI Detectors

The Next Generation from Teledyne Imaging Sensors

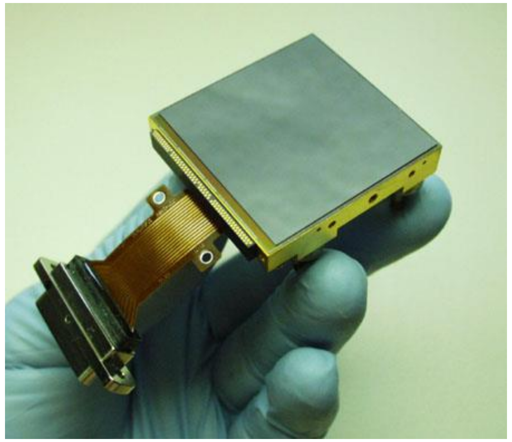
H1R
(Hubble WFC3 IR)

- 1024 x 1024 pixels
- 18 µm pixels
- QE ~ 90% (1.0 – 1.7 µm)
- Dark current <0.05 e^{-}/s/pix
- Noise – 12 e^{-} RMS (16 reads)



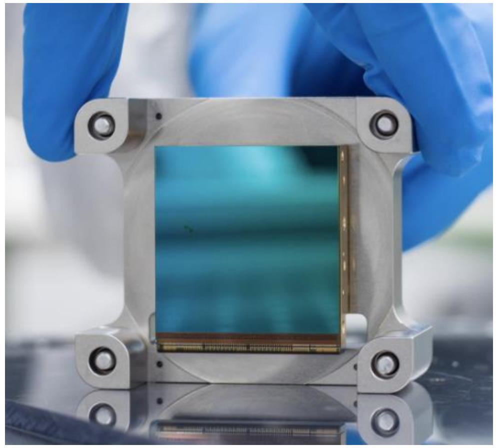
H2RG
(JWST, Euclid)

- 2048 x 2048 pixels
- 18 µm pixels
- QE ~ 90% (@2 µm)
- Dark current <0.01 e^{-}/s/pix
- Noise – 6e^{-} RMS (1000 s)



H4RG - 10
(Roman WFI)

- 4096 x 4096 pixels
- 10 µm pixels
- QE ≳95% (0.8 – 2.1 µm)
- Dark current <0.005 e^{-}/s/pix
- Noise – 5 - 6 e^{-} RMS (180 s)

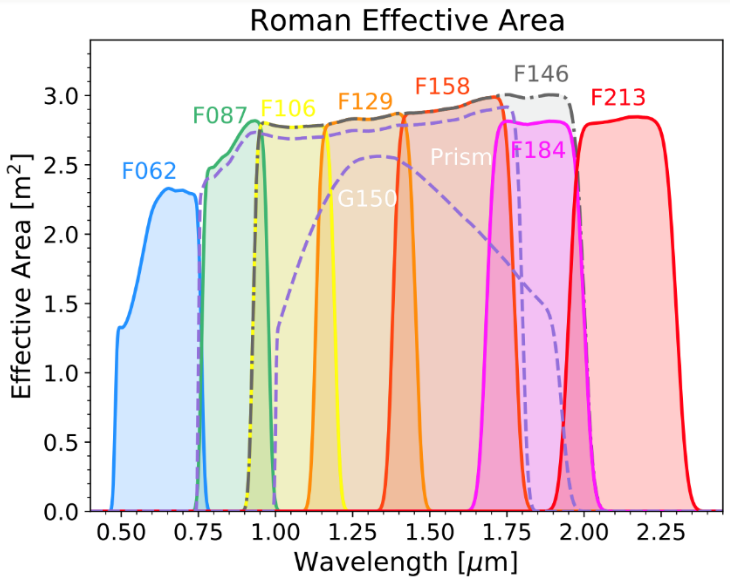


Teledyne H4RGs Enable Roman Survey Science

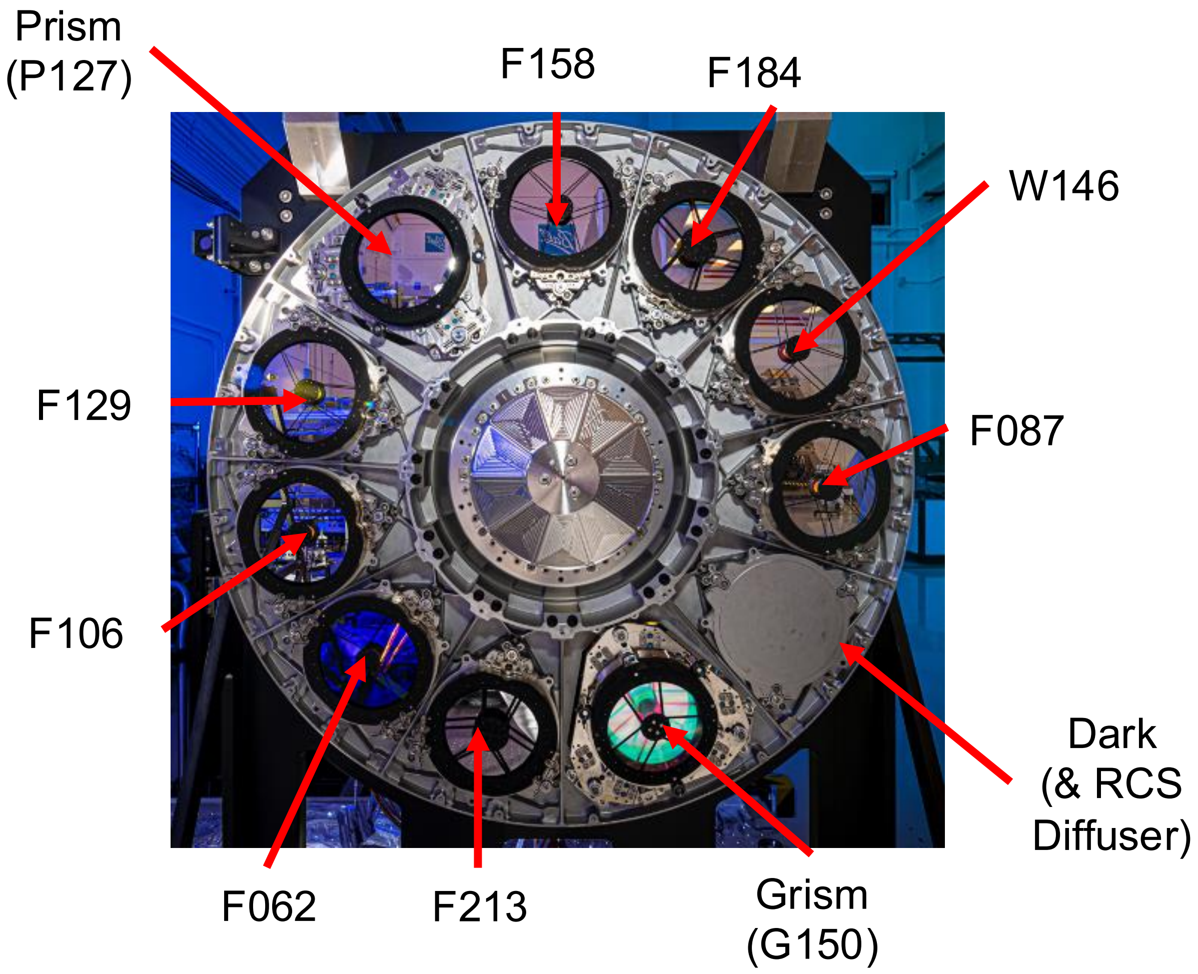
high angular resolution, high sensitivity, low noise, low persistence

WFI Capabilities – Filters, Grism, and Prism

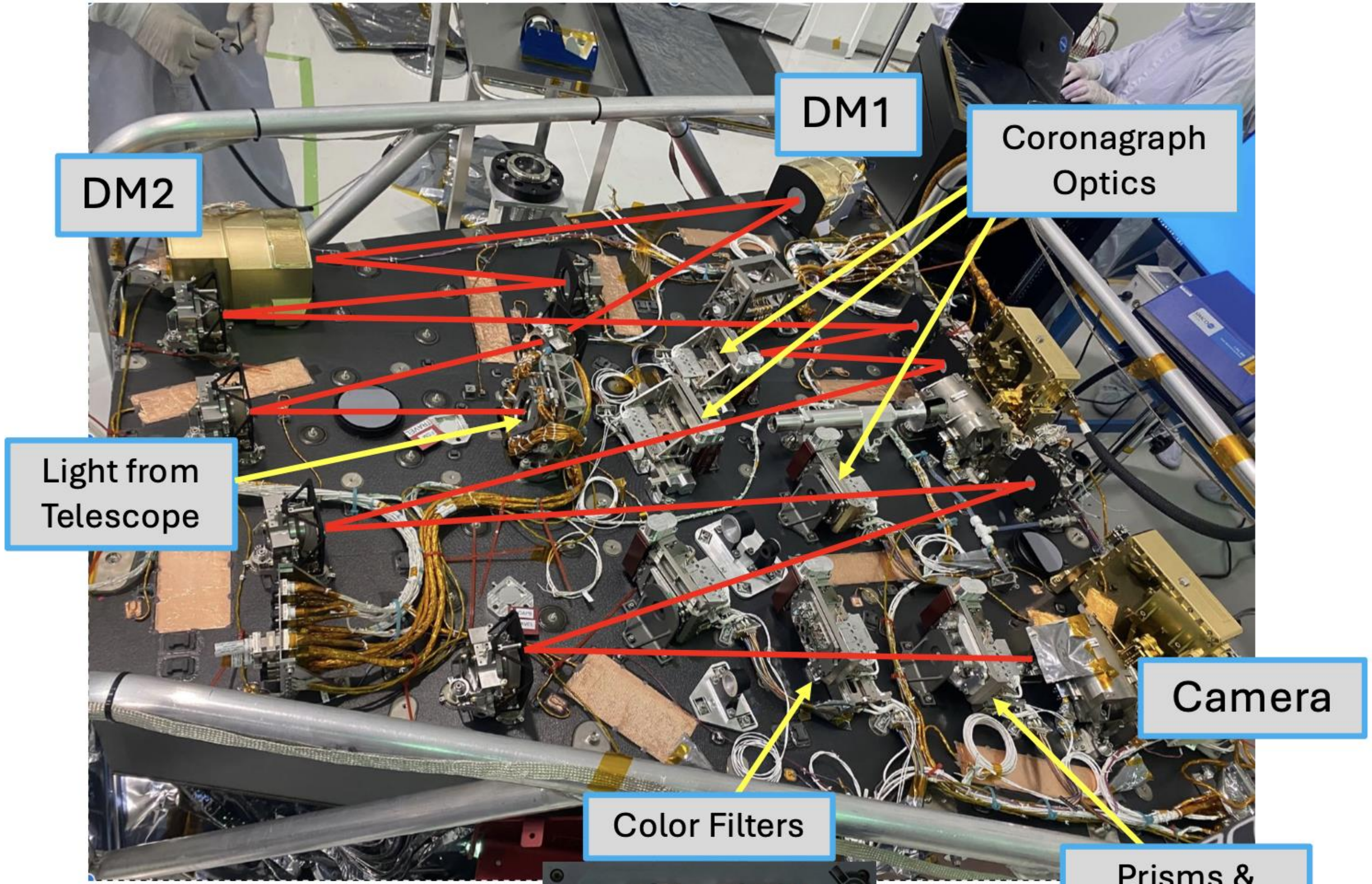
Element name	Min (µm)	Max (µm)	Center (µm)	Width (µm)	R
F062	0.48	0.76	0.620	0.280	2.2
F087	0.76	0.977	0.869	0.217	4
F106	0.927	1.192	1.060	0.265	4
F129	1.131	1.454	1.293	0.323	4
F158	1.380	1.774	1.577	0.394	4
F184	1.683	2.000	1.842	0.317	5.81
F213	1.95	2.30	2.125	0.35	6.07
F146	0.927	2.000	1.464	1.030	1.42
G150	1.0	1.93	1.465	0.930	461λ(2pix)
P127	0.75	1.80	1.275	1.05	80-180 (2pix)



*Effective Area is the area of the telescope multiplied by the efficiency factor for detecting a photon that strikes the telescope



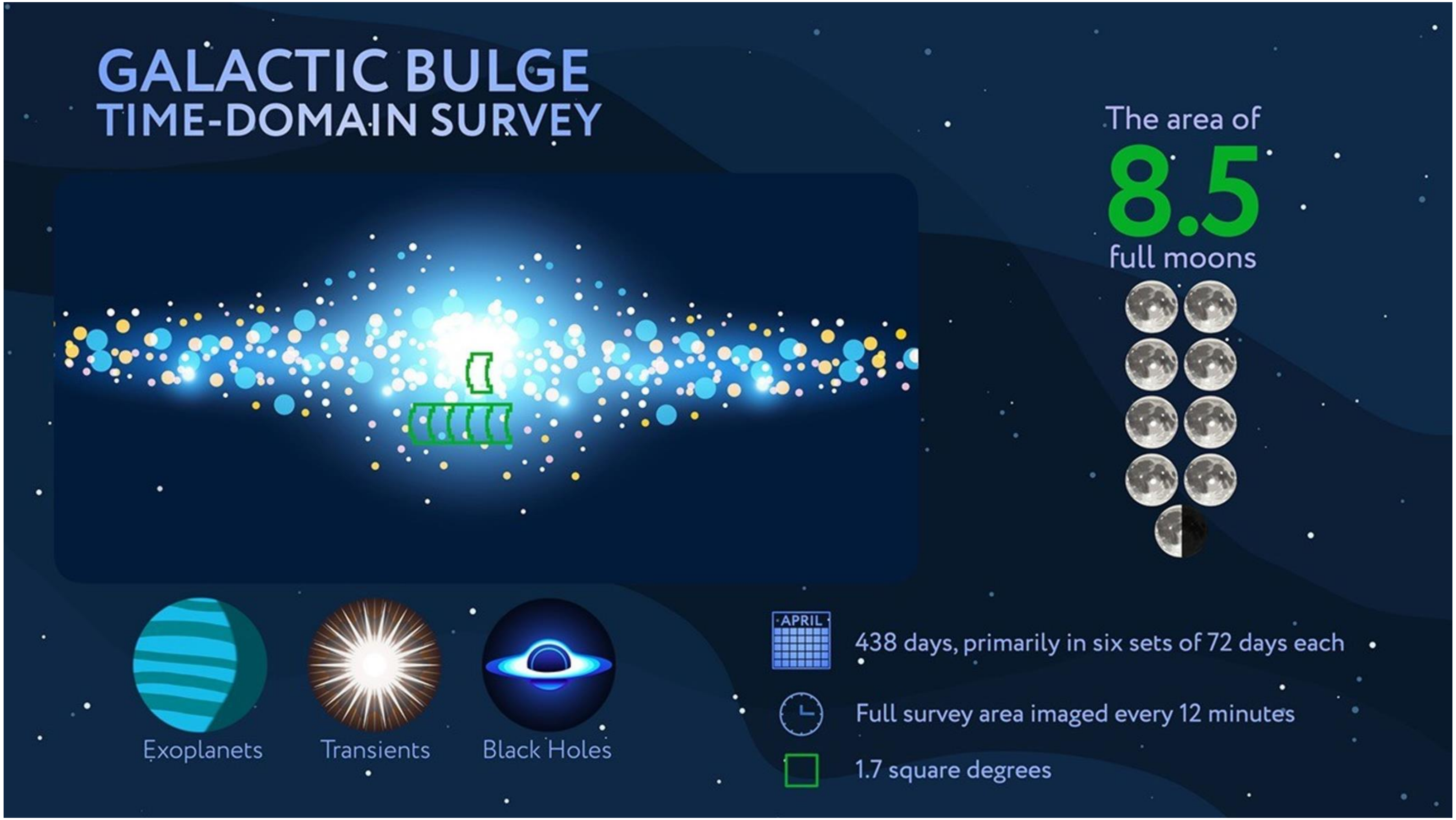
Coronagraph Optical Bench with Components



Credit: J. Wang

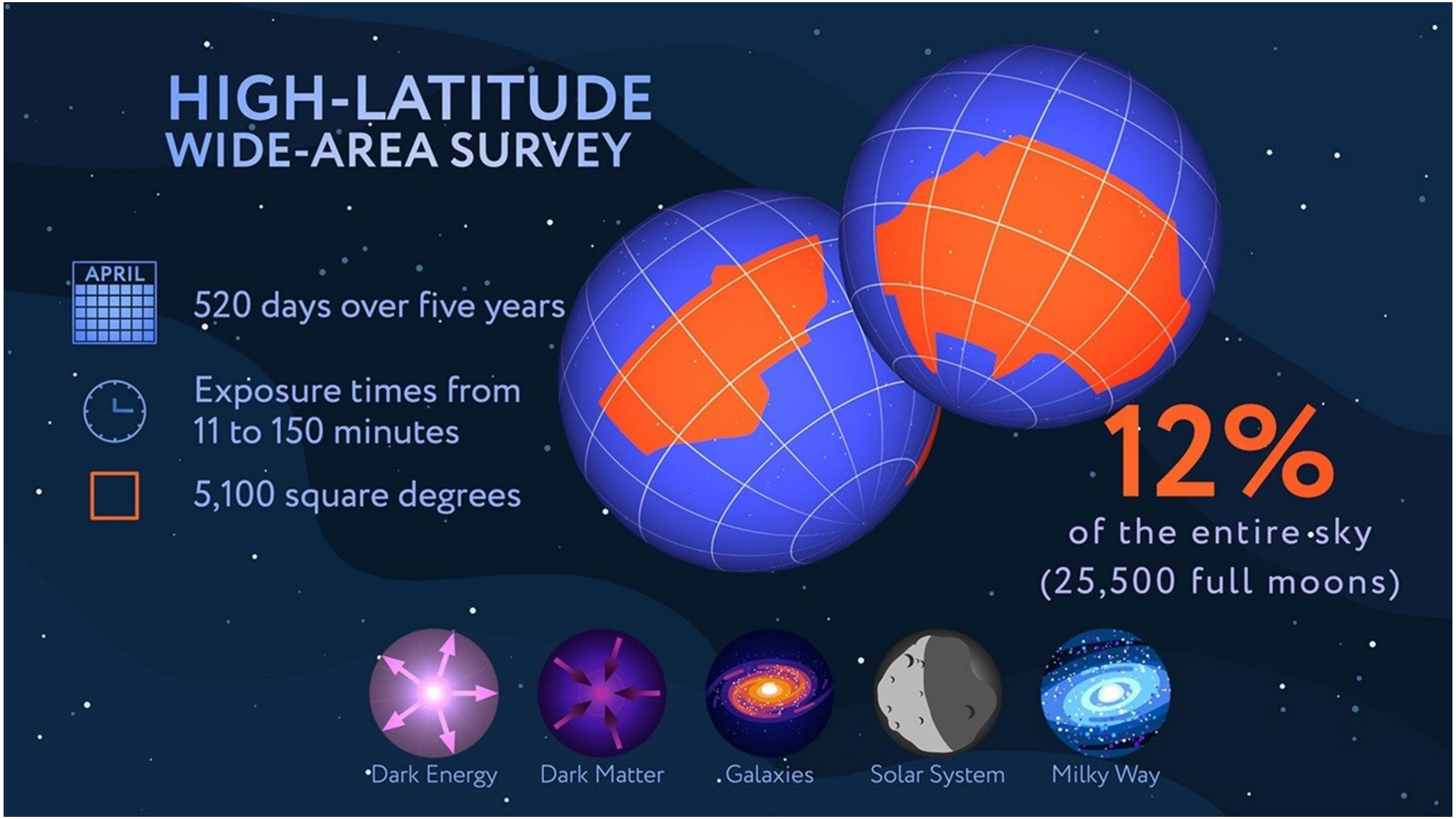
Roman Core Community Surveys

Address Science Requirements While Maximizing General Astrophysics



Roman Core Community Surveys

Address Science Requirements While Maximizing General Astrophysics



Roman Core Community Surveys

Address Science Requirements While Maximizing General Astrophysics

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