STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

The Nancy Grace Roman Space Telescope

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(Head Science Operations Center)

October 5, 2020

Large NASA Space Missions Recommended by "Decadal Surveys"

THE NANCY GRACE ROMAN SPACE TELESCOPE

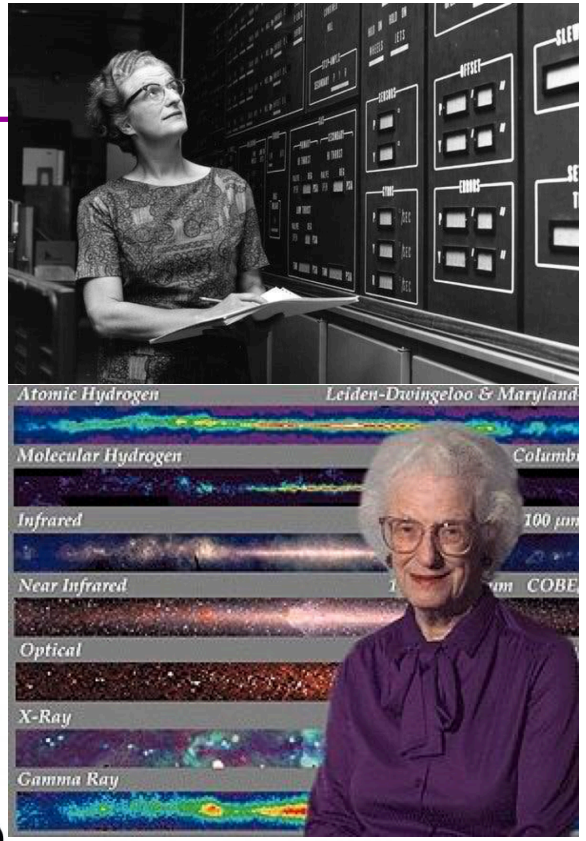
- **2.4 meter telescope (donated)**
  - **Hubble's power and resolution, 100x the FOV**
- **Instrumentation**
  - **Wide Field Camera: imaging, slitless spectroscopy**
  - **Coronagraph Technology Demo: "proof of concept" for high-contrast light suppression**

NASA Goddard SPACE FLIGHT CENTER JPL Jet Propulsion Laboratory

STScI SPACE TELESCOPE SCIENCE INSTITUTE ipac

- Industry: Harris, Ball, Teledyne, ...
- International: ESA, CNES, DLR, JAXA

Nancy Grace Roman (1925-2018): "The Mother of Hubble"

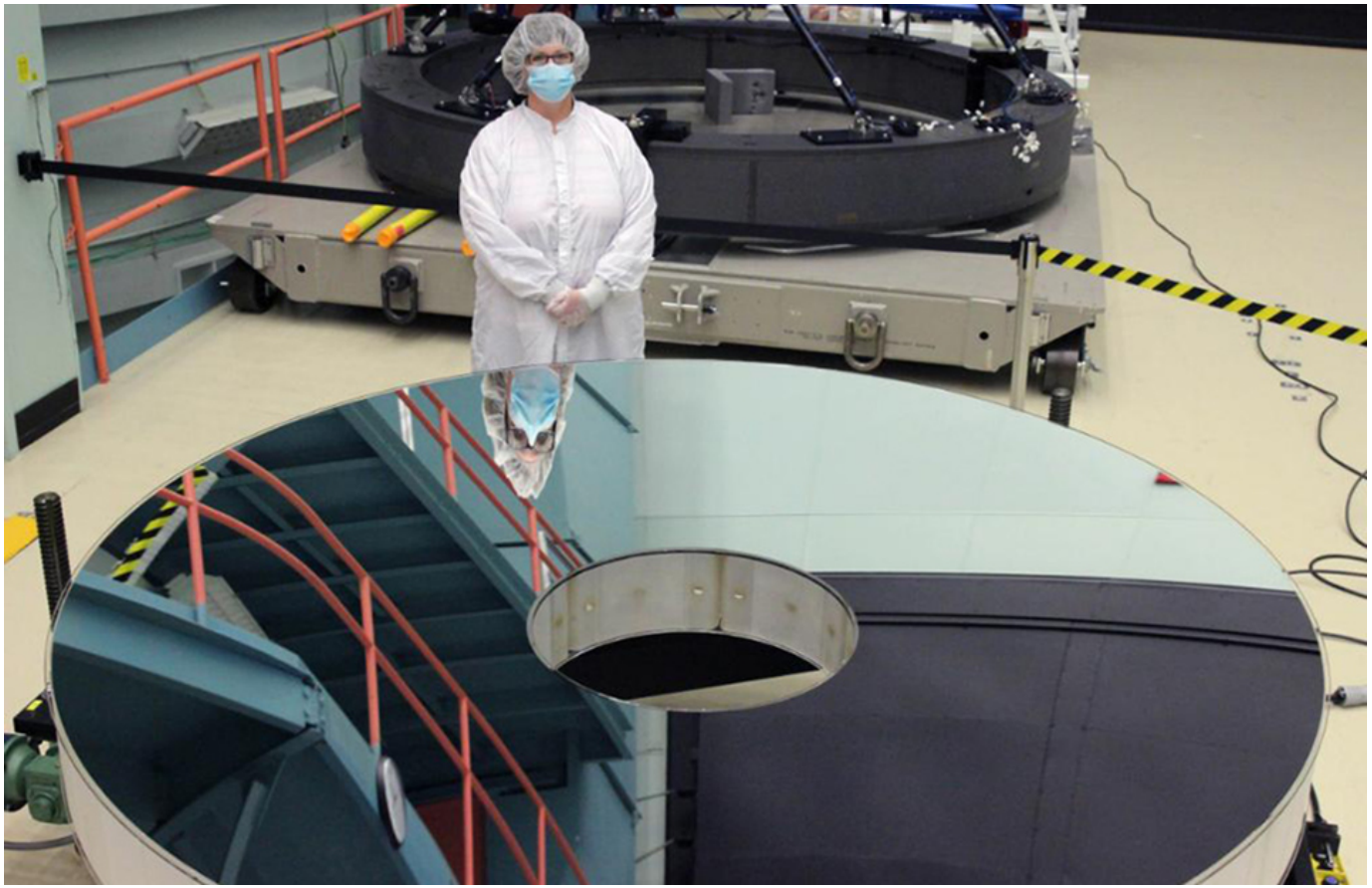


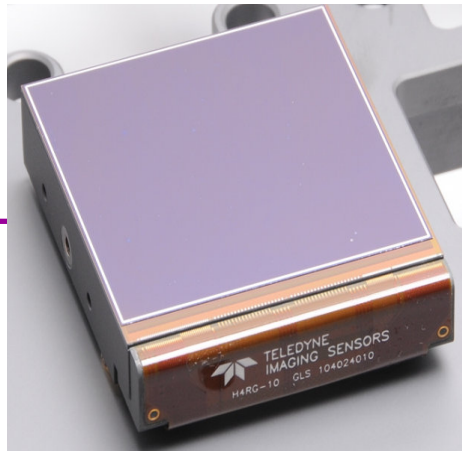
- NASA Leader:
  - First Chief of Astronomy and Solar Physics at NASA
  - First woman to hold an executive position at NASA
  - Instrumental in establishing a new era of space-based astronomical instrumentation and research
- Scientist
  - First woman on astronomy faculty at the University of Chicago
  - Numerous scientific awards and recognitions
- Role Model and STEM Advocate
  - Champion of women in astronomy

"It was Nancy in the old days…who really helped to sell the Hubble Space Telescope, organize the astronomers, who eventually convinced Congress to fund it."
- Ed Weiler

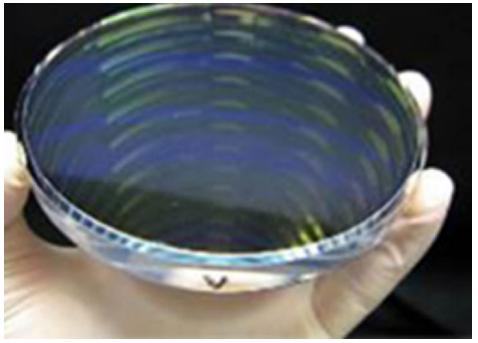
Hardware Status

- Primary Mirror Completed
- Flight Detectors being delivered and tested
- Other Hardware construction well underway





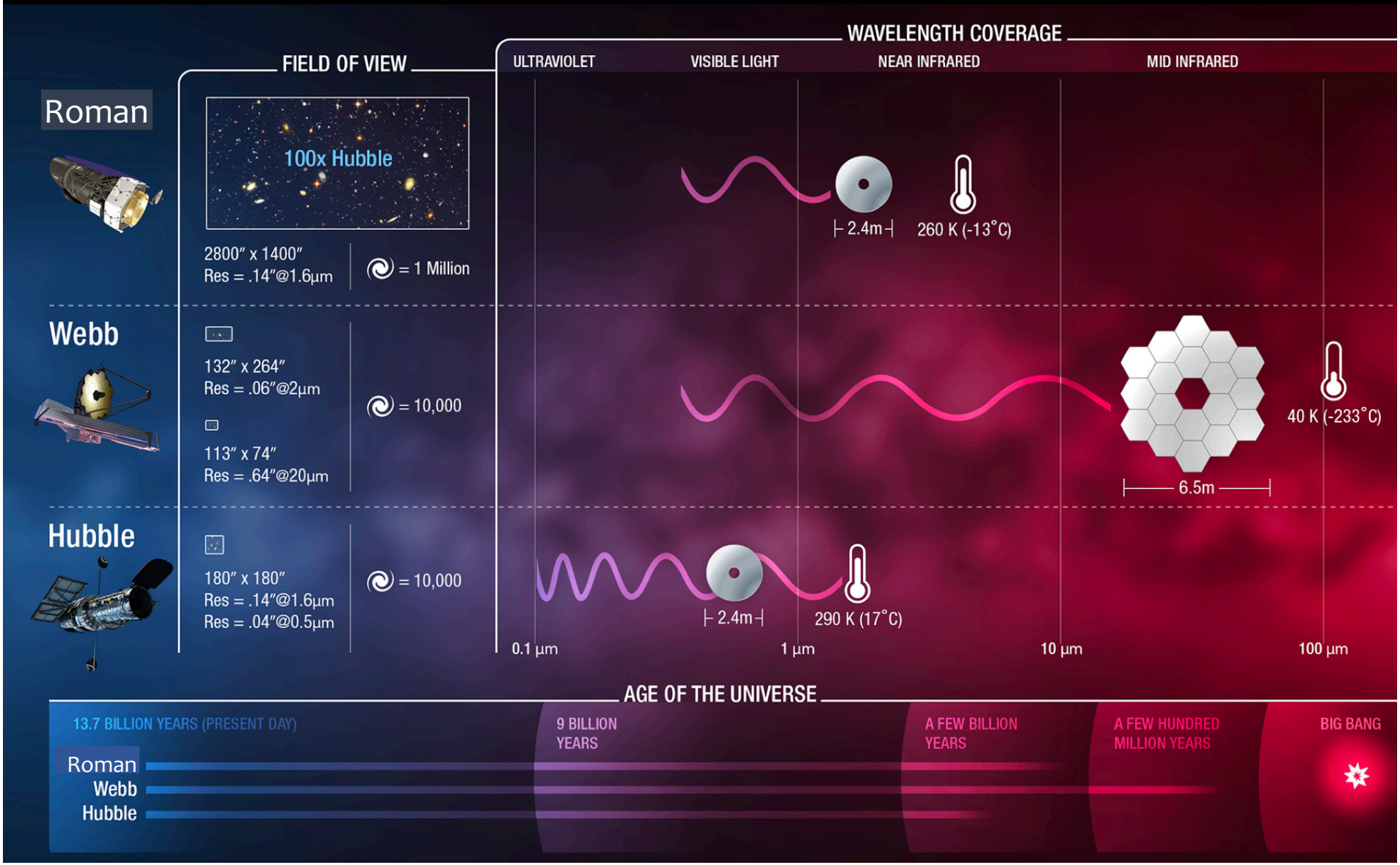
Detector Prototype

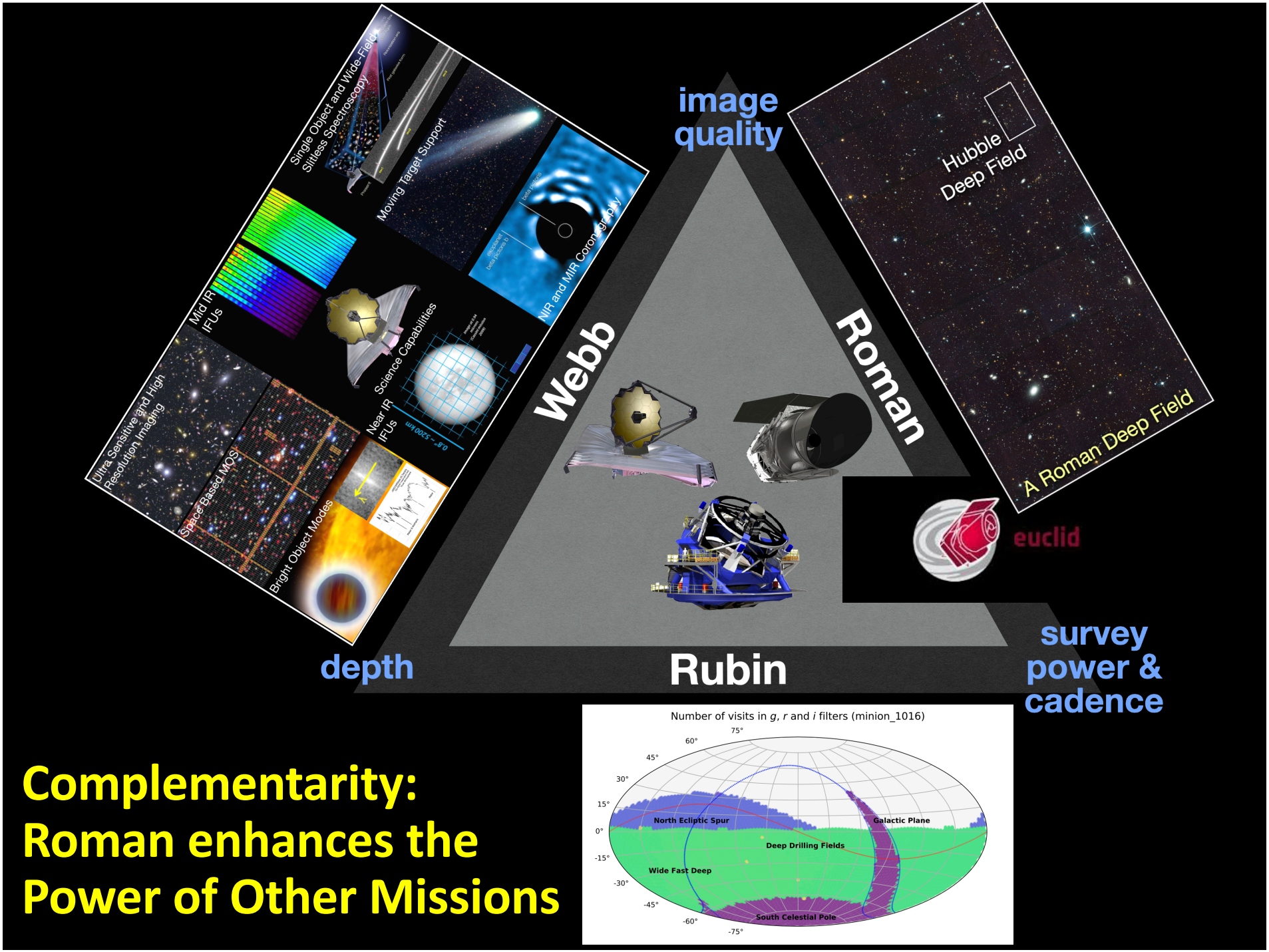


Filter Test Unit

Primary Mirror Assembly

Great Observatory Comparison




Single Object and Wide-Field Slitless Spectroscopy
Moving Target Support
NIR and MIR Coronography
Mid IR IFUs
Science Capabilities
Near IR IFUs
Ultra Sensitive and High Resolution Imaging
Space Based MOS
Bright Object Modes
image quality
Webb
Roman
Hubble Deep Field
A Roman Deep Field
euclid
depth
Rubin
survey power & cadence
Complementarity:
Roman enhances the
Power of Other Missions
Number of visits in g, r and i filters (minion_1016)
North Ecliptic Spur
Galactic Plane
Deep Drilling Fields
Wide Fast Deep
South Celestial Pole

Instrument Capabilities

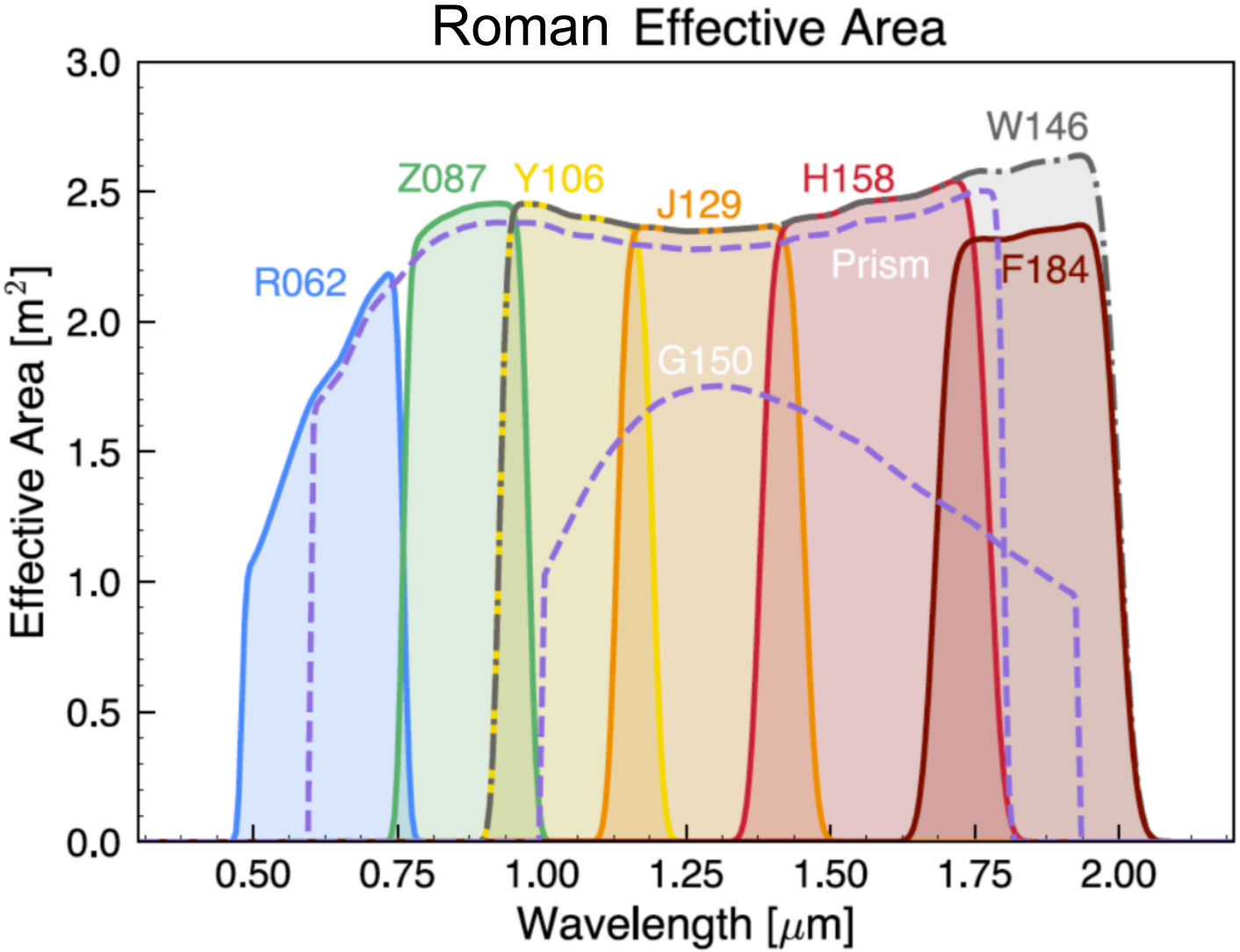
Roman Space Telescope Imaging Capabilities							
Telescope Aperture (2.4 meter)		**Field of View** (45′x23′; 0.28 sq deg)		**Pixel Scale** (0.11 arcsec)		**Wavelength Range** (0.5-2.0 μm)	
Filters	**F062**	**F087**	**F106**	**F129**	**F158**	**F184**	**W146**
Wavelength (μm)	0.48-0.76	0.76-0.98	0.93-1.19	1.13-1.45	1.38-1.77	1.68-2.00	0.93-2.00
Sensitivity (5σ AB mag in 1 hr)	28.5	28.2	28.1	28.0	28.0	27.5	28.3

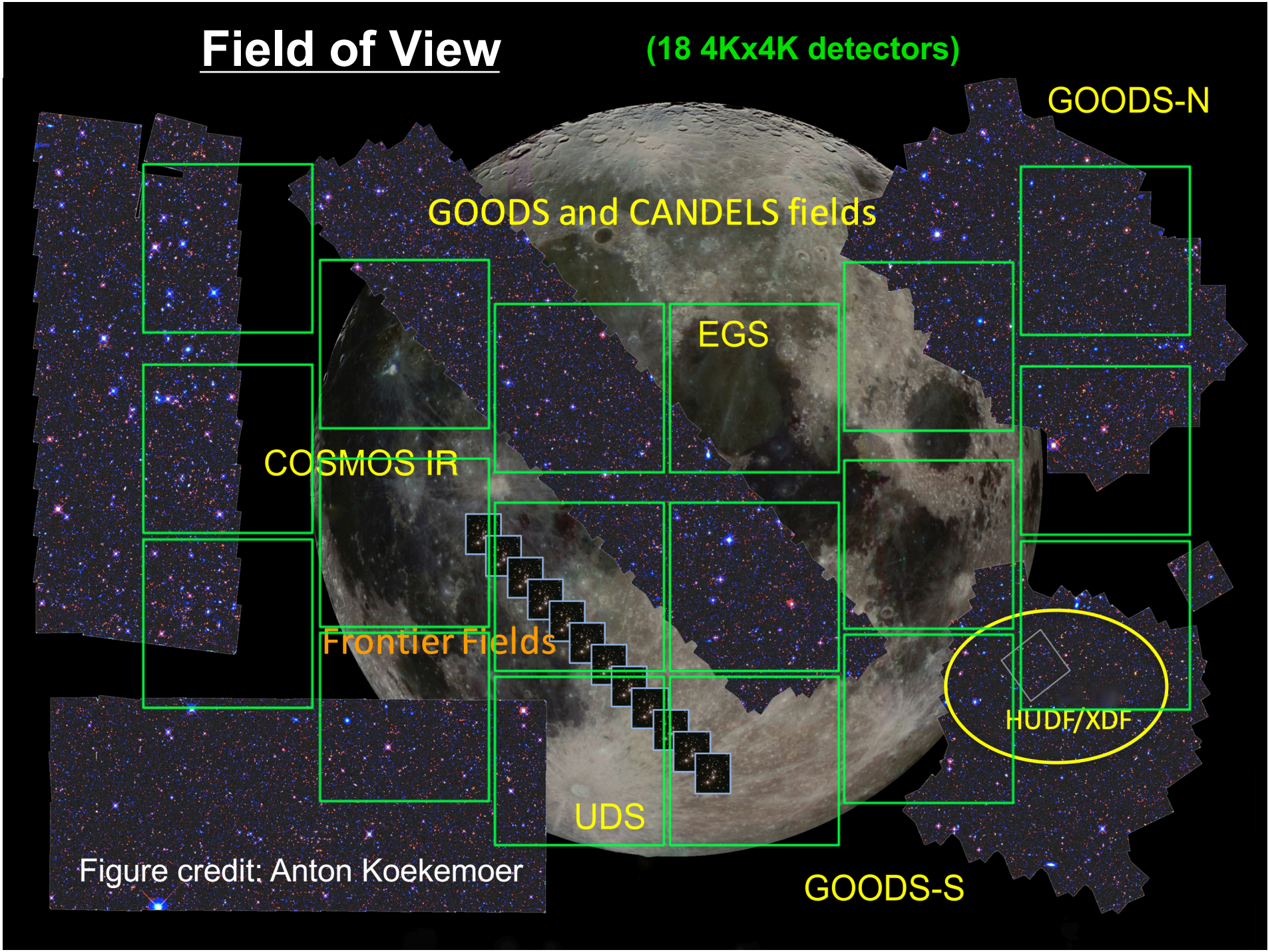
Roman Space Telescope Spectroscopic Capabilities				
	Field of View (sq deg)	**Wavelength (μm)**	**Resolution**	**Sensitivity (AB mag) (10σ per pixel in 1hr)**
Grism	0.28 sq deg	1.00-1.93	461	20.5 at 1.5 μm
Prism	0.28 sq deg	0.75-1.80	80-180	23.5 at 1.5 μm

Roman Space Telescope Coronagraphic Capabilities					
	Wavelength (μm)	**Inner Working Angle (arcsec)**	**Outer Working Angle (arcsec)**	**Detection Limit***	**Spectral Resolution**
Imaging	0.5-0.8	0.15 (exoplanets) 0.48 (disks)	0.66 (exoplanets) 1.46 (disks)	10^{-9} contrast (after post-processing)	47-75
Spectroscopy	0.675-0.785				

https://roman.gsfc.nasa.gov/science/WFIRST_Reference_Information.html

Filters


Roman Effective Area
Effective Area [m^2]
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.50
0.75
1.00
1.25
1.50
1.75
2.00
Wavelength [μm]
R062
Z087
Y106
J129
H158
W146
Prism
F184
G150

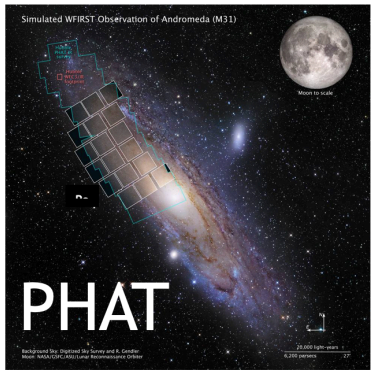

Field of View
(18 4Kx4K detectors)
GOODS-N
GOODS and CANDELS fields
EGS
COSMOS IR
Frontier Fields
HUDF/XDF
UDS
GOODS-S
Figure credit: Anton Koekemoer

Survey Speed

The power of Roman is not *just* that it has a large FOV: it is also very efficient

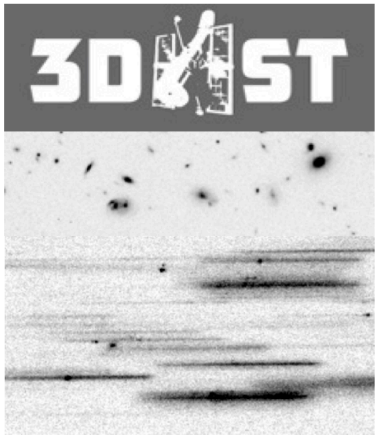
(Rapid slew & settle, no Earth occultations, no South Atlantic Anomaly)

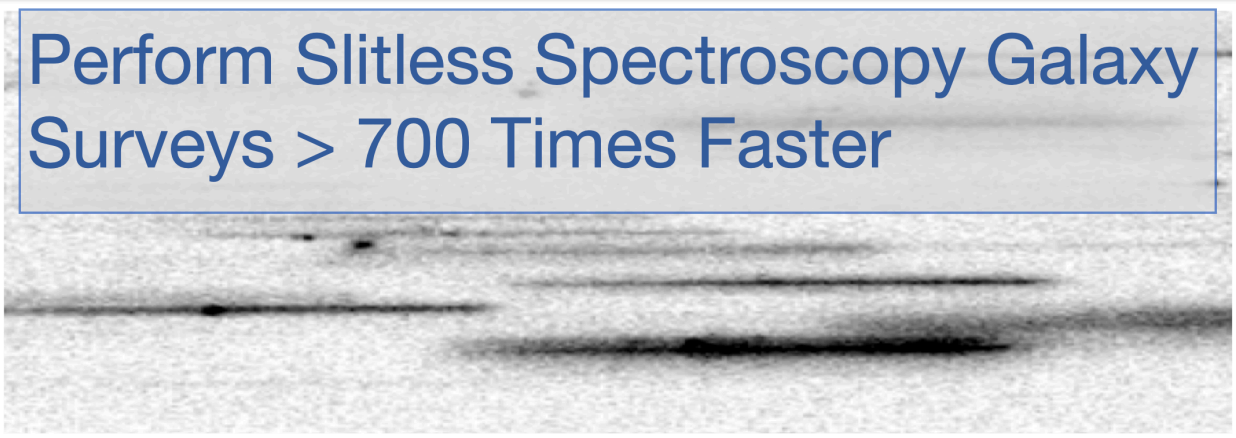
PI J. Dalcanton



PIs S. Faber, H. Ferguson

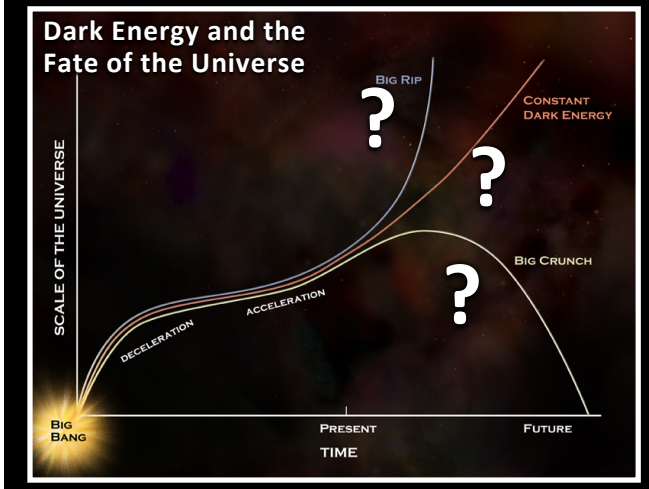
PI P. van Dokkum

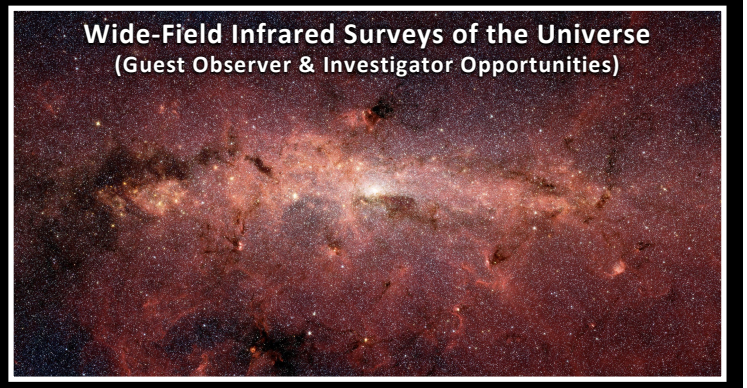




Akeson et al. (2019, arXiv:1902.05569)

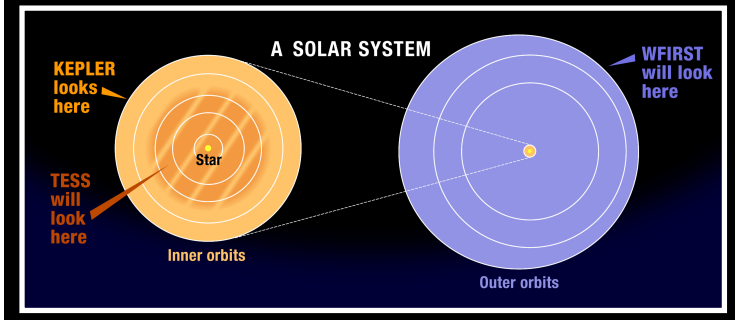
Science Drivers for the Roman Space Telescope from the NRC 2010 Astrophysics Decadal Survey





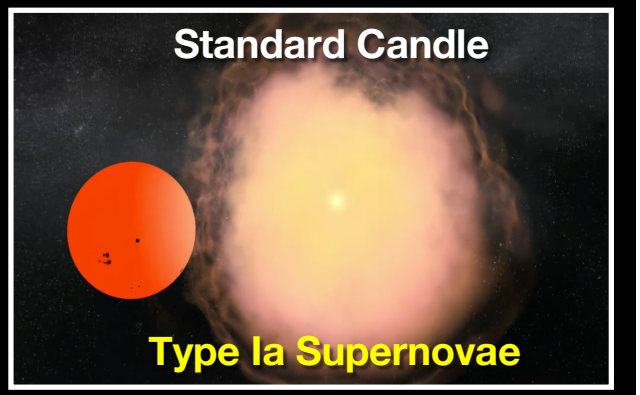
National Academy of Sciences
Astronomy & Astrophysics
Decadal Survey (2010)

The full distribution of planets around stars



Dark Energy, Exoplanets, General Astrophysics

Probe Cosmology using three independent methods



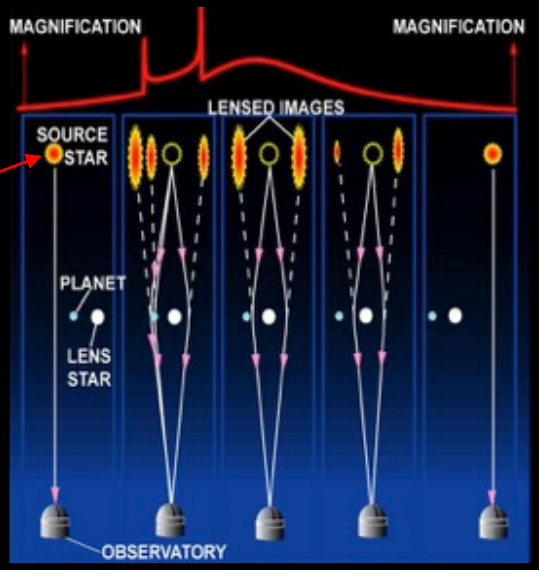
Growth of Structure
(also Expansion History)

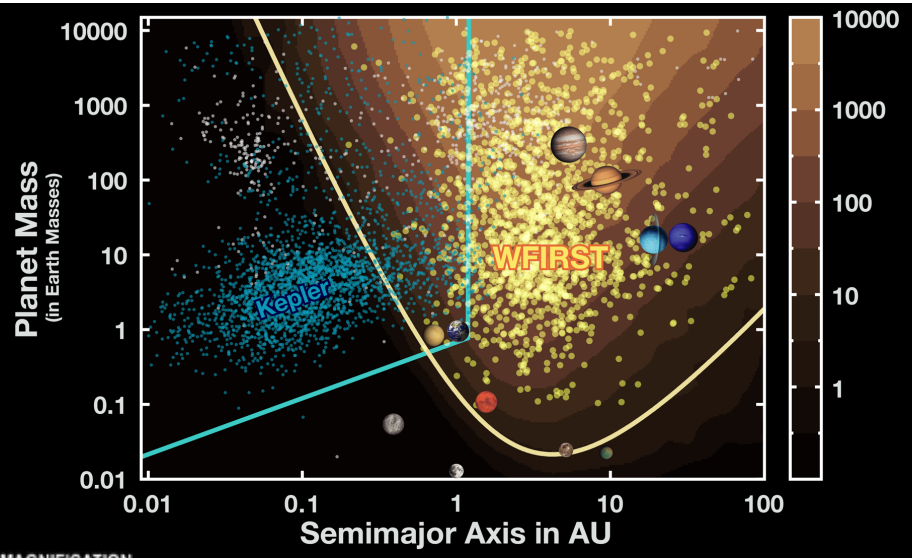
Expansion History
(also Growth of Structure)

Expansion History

Physics of the Universe
Dark Energy, Dark Matter, Modified Gravity

3.5'x2' bulge scene (1/8 Roman detector)





Determine exoplanet mass distribution in habitable zone and beyond using microlensing

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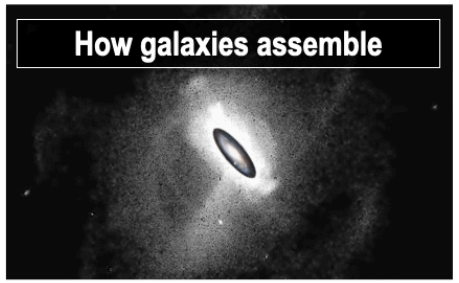
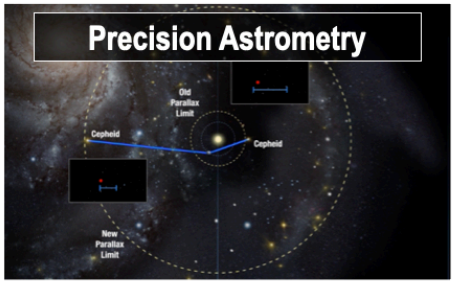
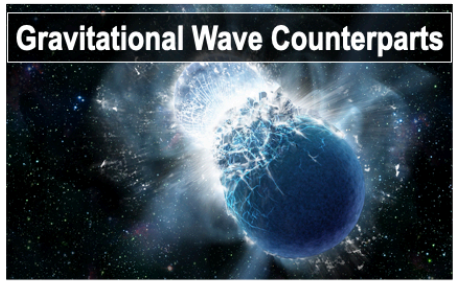
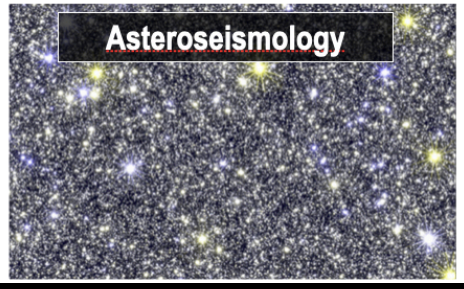
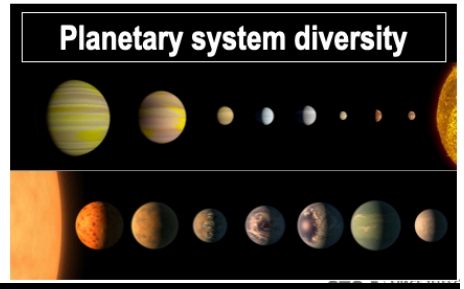
Study key questions in a wide range of astrophysical subject areas







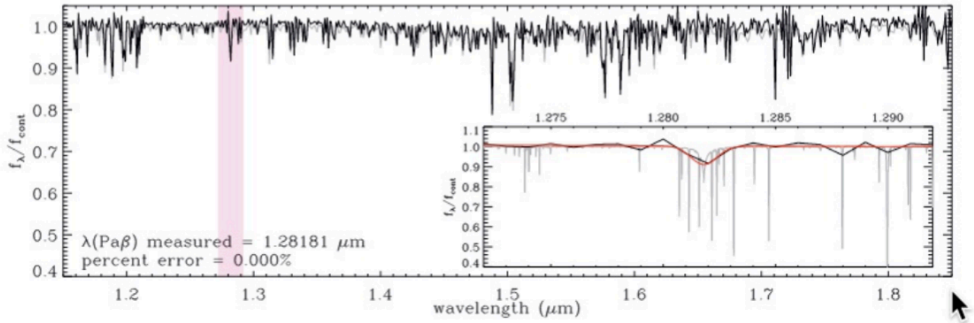




- Community white papers on a wide range of topics available from arXiv
- Recent community questionnaire highlights interests well beyond cosmology and exoplanet science

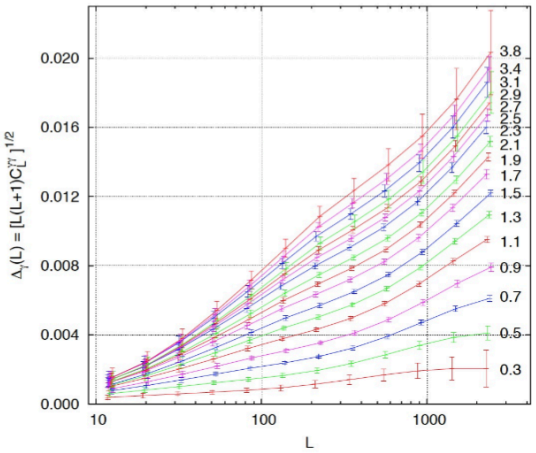
High Quality Calibrations

0.1% wavelength accuracy for BAO (maps to source redshift)



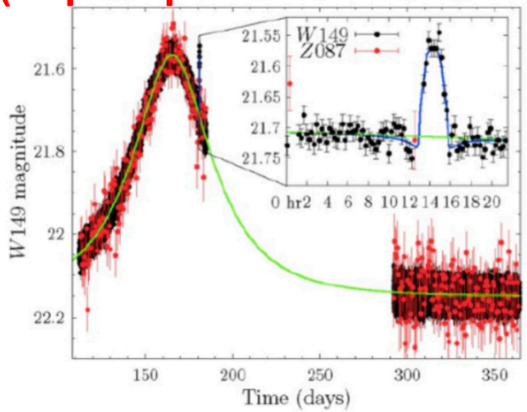
Paβ in simulated stellar spectrum (Ryan+ 2019); 0.027% error

0.05% PSF shape (impacts cosmic shear)



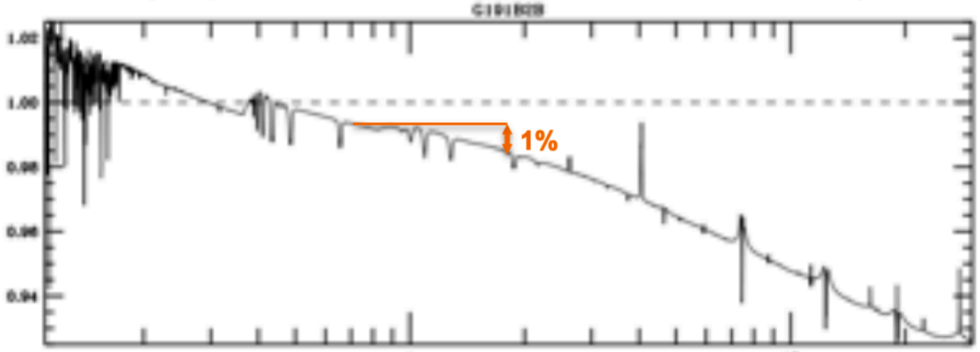
Expected shear power spectrum
(SDT report, Spergel+ 2015)

0.1% Photometric stability for microlensing (maps to planet mass uncertainty)



Simulated microlensing event (S. Carey)

0.5% ABSOLUTE color calibration for SNe (maps to luminosity distance vs redshift)



Ratio between white dwarf spectral models (Bohlin+ 2014)

Observational Program

Wide-Field Infrared Surveys of the Universe

Large core community surveys and smaller focused surveys

All data to be public immediately

Core Community Surveys

- Each has a core set of goals, but potential scientific scope far broader
- Survey designs to be decided through a community process to maximize total science return

High-latitude imaging and spectroscopic surveys	High-latitude time-domain survey	Galactic Bulge time-domain survey
Enables WL and BAO cosmology investigations	Enables SNIa cosmology investigations	Enables exoplanet microlensing investigations

Smaller Focused Surveys

- To be selected through a peer-reviewed GO process (~25% of mission)
- Any extended mission phase (beyond 5 years) could be fully GO

Archival Investigations

- Of varying scope to fund analysis of survey data

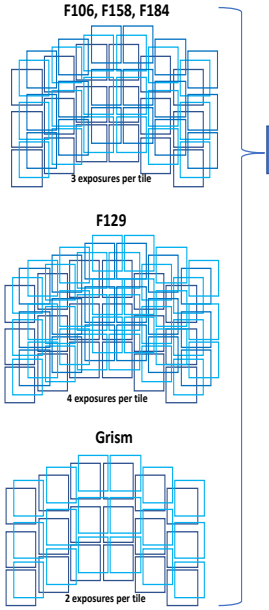
All opportunities for science, funding and involvement remain to be decided

Example Concept: High Latitude Imaging and Spectroscopic Survey

	FRAME		EXPOSURE		TILE / SECTOR					PASS			OBSERVING PROGRAM	
	DURATION (SECONDS)	QUANTITY	DURATION (SECONDS)	FILTER	TARGET	TILE QUANTITY	GAP-FILLED EXPOSURES	SECTOR SIZE (SQ-DEG)	DURATION (HOURS)	SIZE (SQ-DEG)	SECTOR QUANTITY	DURATION (DAYS)	PASS QUANTITY	DURATION (DAYS)
HLIS	2.9	50	144	F106	HIGH LATITUDE REGION	32	3	10.3	5.0	1936	188	39.1	2	337.5
			144	F129			4		6.5			51.3	2	
			144	F158			3		5.0			39.1	2	
			144	F184			3		5.0			39.1	2	
HLSS	3.6	84	299	Grism		32	2	10.3	6.1	1936	188	48.1	4	192.3

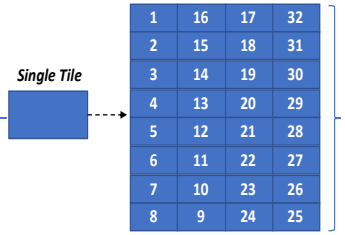
HLS Tile Concepts

(Examples of Single Tiles As A Function Of Optical Element)



HLS Sector Concept

(Example of a Sector Layout)



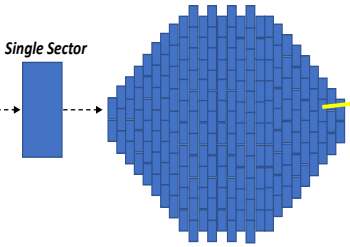
8 x 4 Sector = 10.3 sq-deg
(32 tiles)

HLS sector (T1->T32) performed in each of 4 NIR filters and Grism

EWA rotates at completion of each sector (e.g. T32), and repeats sector in the opposite direction (T32->T1)

HLS Pass Concept

(Notional Pass Layout)

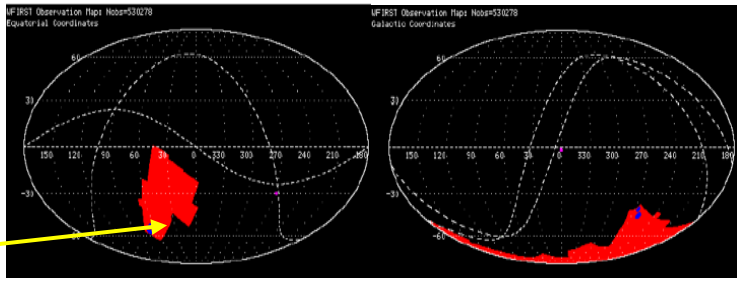


188 Sectors = 1940 sq-deg
(6016 tiles)

At completion of 5 optical element sector (4 NIR filter + Grism), perform slew to adjacent sector and repeat process until pass complete

HLIS requires 2 passes; HLSS requires 4 passes

Approach is to perform 2 passes of HLIS & HLSS together, and then perform 2 separate HLSS passes



Exposure Characteristics

- 144 sec for HLIS (4 filter NIR imaging); 299 sec for HLSS (Grism)

Tile Characteristics

- HLIS: Set of (2-4) exposures following gap-filling slews
- HLSS: Set of 2 exposures following gap-filling slew

Sector Characteristics

- 10.3 deg^2 area using 32 tiles (HLIS & HLSS)
- Sector durations of ~27 hours (4 filters + grism)

Pass Characteristics

- 1936 deg^2 area using 188 sectors (HLIS & HLSS)
- Pass durations are 40-50 days per filter/grism

Program Characteristics

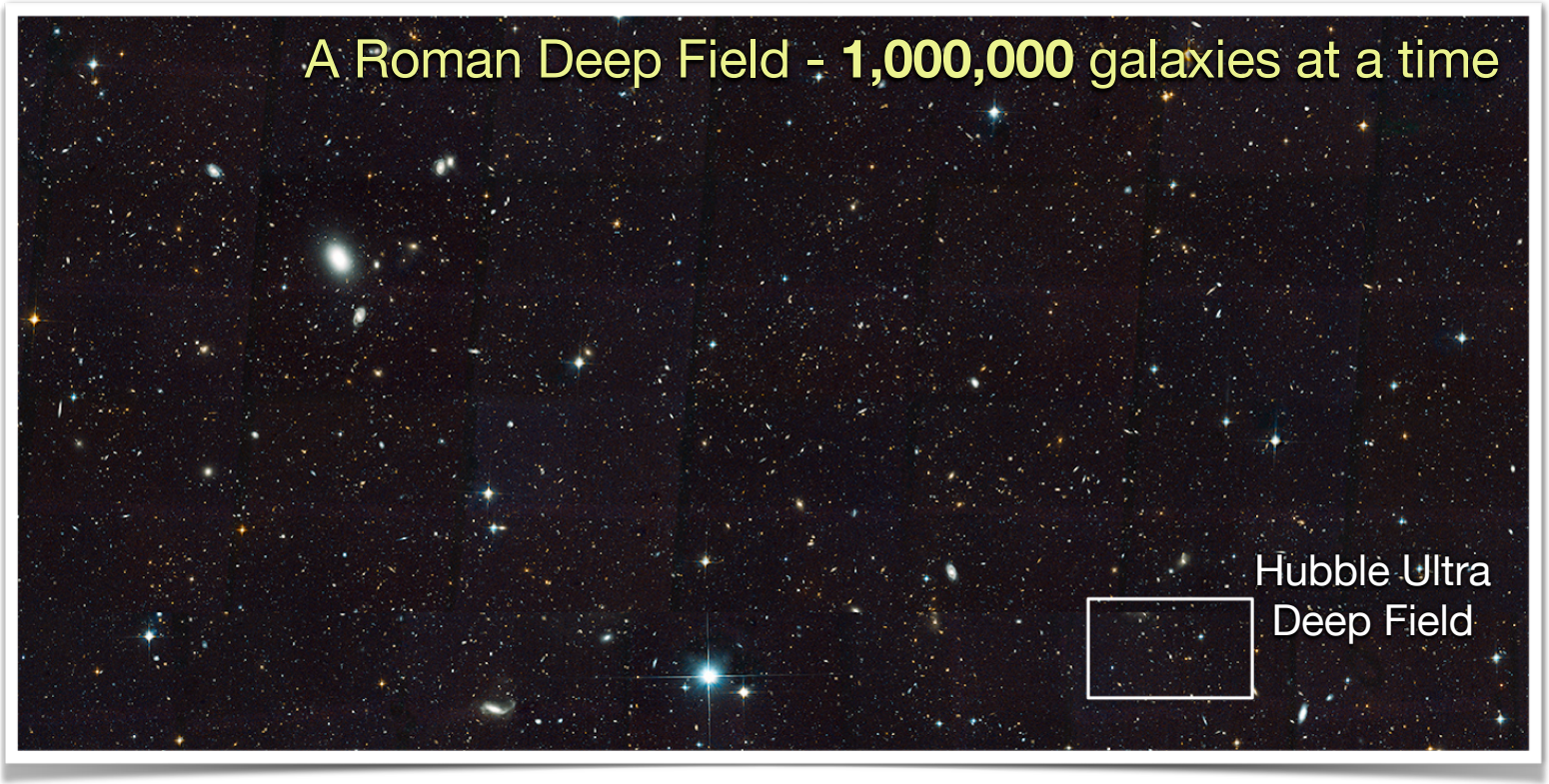
- HLIS: Two passes for each filter (each pass at different roll)
- HLSS: Four passes for grism (each pass at different roll)
- Coverage overlap between HLIS & HLSS passes
- Includes 10% time allocation for Deep-Field Calibration activity

27-hr profile of High Latitude Survey

1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour	1 hour
F106					*F129*							*F158*					*F184*					*Grism*					
HLS Multi-Filter Imagery																						HLS Spectroscopy				

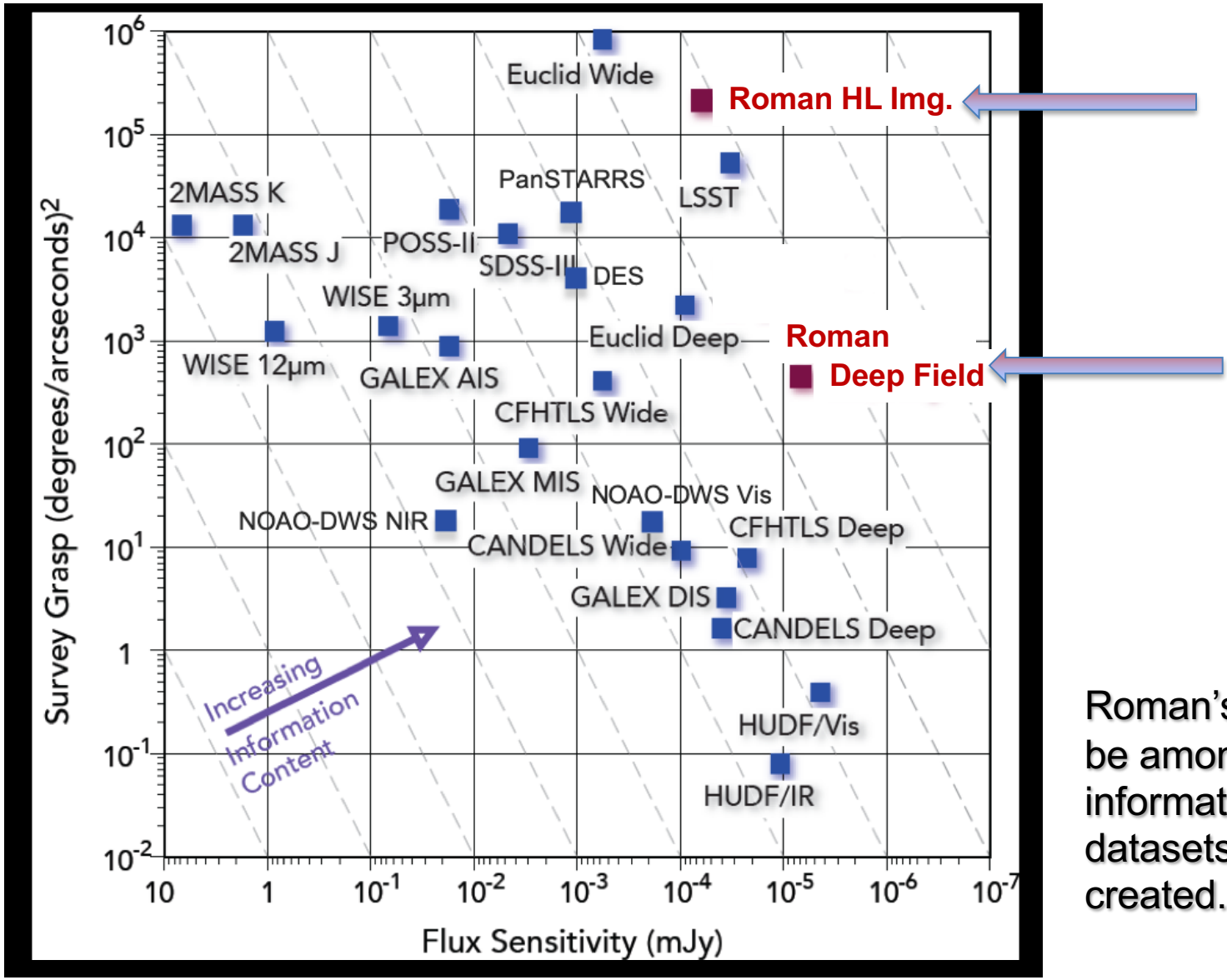
Scientific Potential of a Roman Deep Field

- Roman offers the opportunity to get HST/UDF-like depth over 100x the area
  - Increased survey volume overcomes many current number count limitations
  - Estimated yield of many hundreds of z ~ 9-10 candidates



  - Foley et al. 2019, arxiv:1903.04582; Koekemoer et al. 2019, arxiv:1903.06154
  - *Coordination with the community and other projects required for optimum synergy*

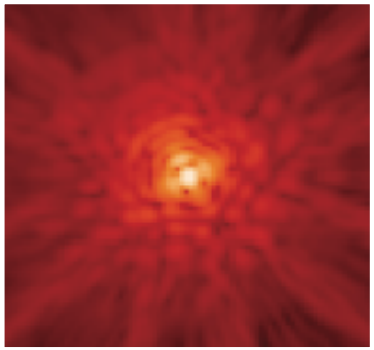
Survey Comparisons



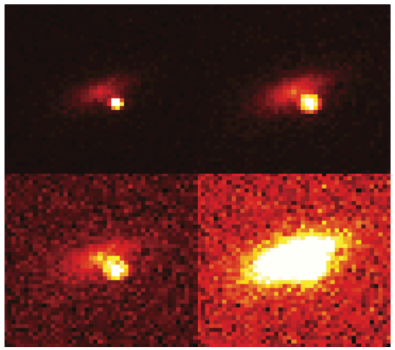
Roman's surveys will be amongst the most information-rich datasets ever created.

Exploring Roman's Capabilities: Simulating Roman Data

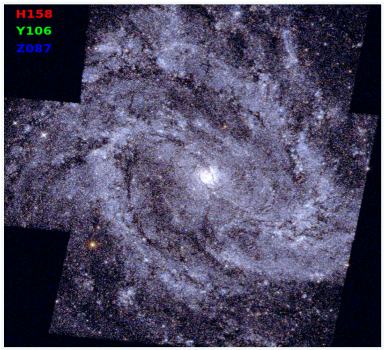
- To support Roman development, Mission partners have produced a large range of simulated data, adding modules to existing packages (GalSim, aXeSIM) and creating new simulation packages
- Roman WFI simulators being developed for the Mission are publicly available from STScI (https://www.stsci.edu/roman/science-planning-toolbox)



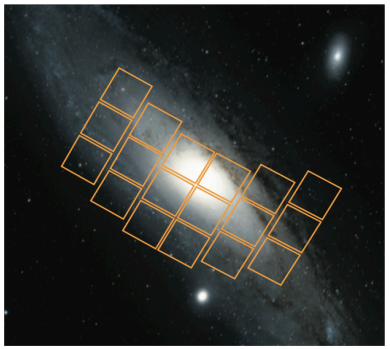
WebbPSF
Wavelength Dependent PSF Simulator



Pandeia
3-D (x,y,λ) Exposure Time Calculator and Image simulator



STIPS
Image Simulator



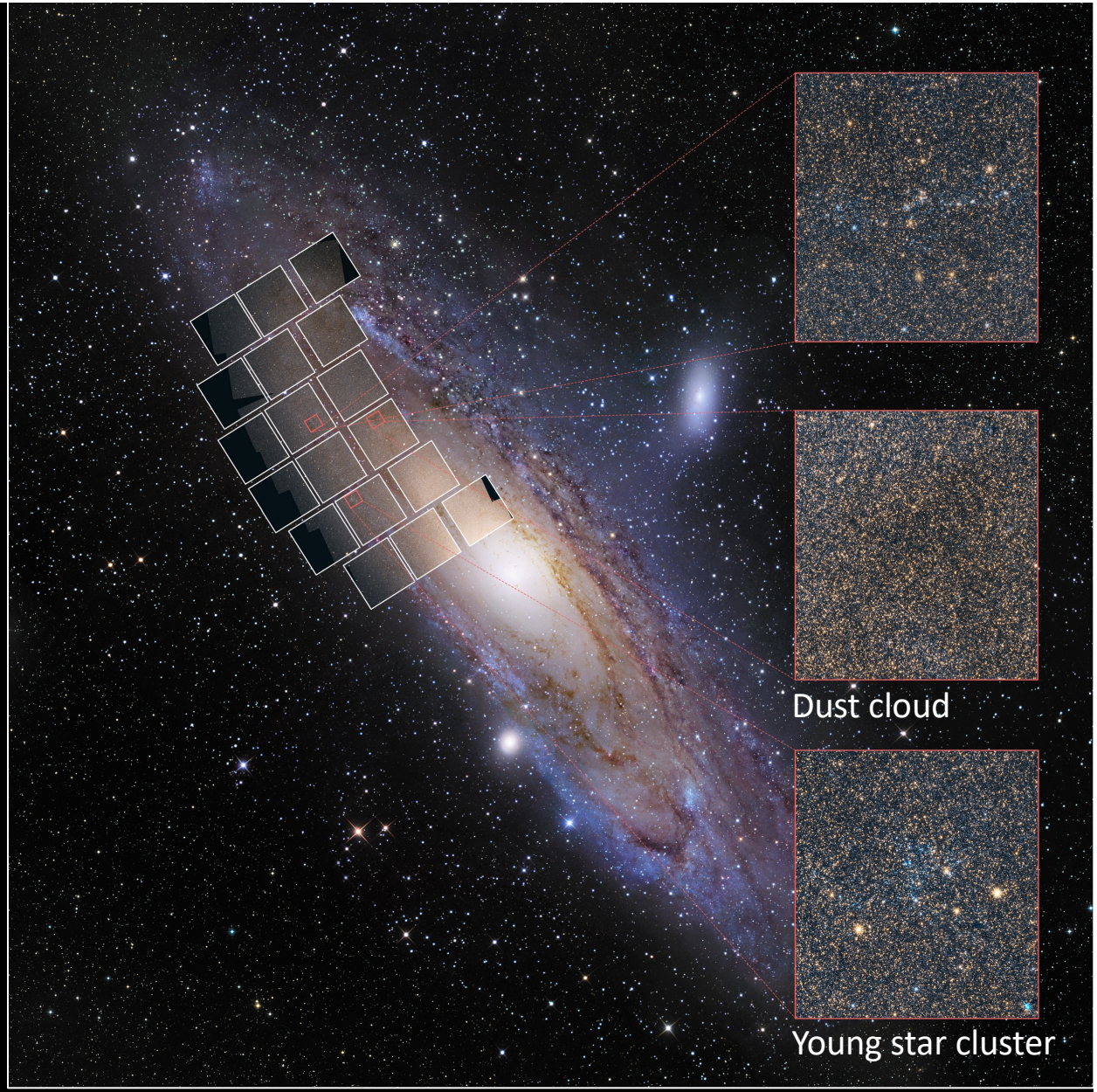
Multi-mission Field of View Overlay

- IPAC maintains an inventory of simulations and instrument models by Roman Mission Partners (https://roman.ipac.caltech.edu)

Simulated Roman Observation of M31

[NASA/STScI, B. Williams]

PHAT:
432 Hubble Pointings
= 2 Roman Pointings



produced using STIPS ,
available on GitHub and PyPI:
https://github.com/spacetelescope/STScI-STIPS

The Roman Data System

- Roman is the first NASA Astrophysics “Big Data” survey mission
  - Both catalogs and pixel-level data sets provide unique science opportunities
  - The capabilities required to download or process very large datasets will exceed what average users can do with standard resources
- Data products will be generated by multiple mission partners
  - Calibrated and mosaiced images, extracted spectra, catalogs, etc.
  - Staged in the cloud and co-located with significant computational resources
  - Open source and modular imaging pipeline (facilitating custom reprocessing)
- The STScI MAST Archive will be the key to Roman Science
  - Most NASA Great Observatory science is already (part) Archival
  - Accessibility & Diversity: 2-4x increase in institutions publishing
- WFI Data Management Environment
  - Cloud-based science platform for high-level data processing
  - Jupyter Lab environments and notebooks to ease access
  - Capability to bring software to Roman’s Big Data, and enable sharing of software by science centers, science teams, and community
  - Users should plan to interact in new ways with such big data sets

Barbara A. MIKULSKI ARCHIVE FOR SPACE TELESCOPES

AWS

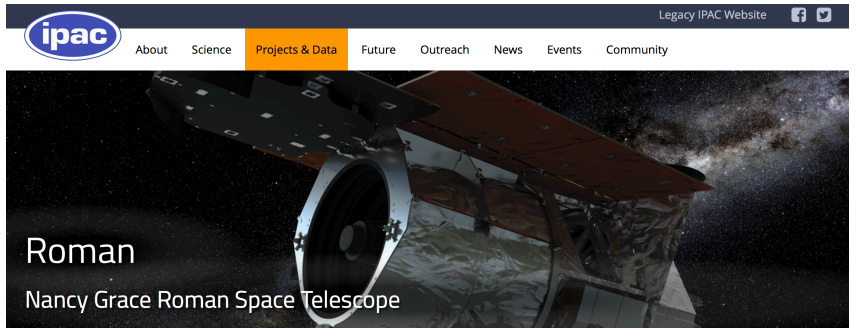
jupyter

Join the Roman Conversation

- Visit web sites of mission partners for observatory and instrument information, science plans and opportunities, operational planning, data simulation tools, documentation, news and events, etc.
- Look for opportunities to influence the core community surveys
- Look for proposal opportunities beginning in 2021 for a range of Roman preparatory science programs. The terms of the current Science Investigation Teams will end in 2021.

https://roman.gsfc.nasa.gov

https://www.stsci.edu/roman/



https://roman.ipac.caltech.edu/

Concluding Remarks

- Roman development is well underway and making great progress
- Roman will provide a wealth of breakthrough science opportunities, both by itself and in combination with other missions/projects
- Get involved! this is an open mission and much of the observing program and analysis plans remain to be decided
- Enjoy the conference, and think about Roman can advance your own science