STScI | SPACE TELESCOPE SCIENCE INSTITUTE

EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

The Nancy Grace Roman Space Telescope

Susana Deustua

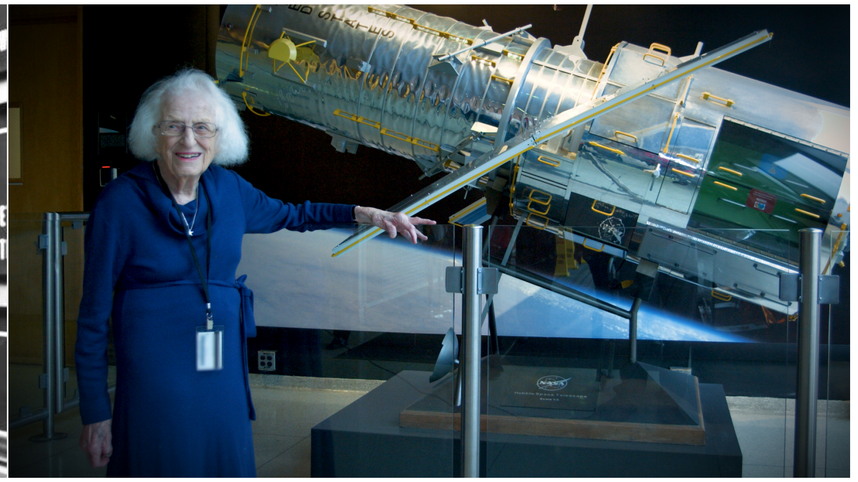
Roman Telescope Branch, Calibration Block Deputy

25 September 2020 XIX Physics Meeting

The Nancy Grace Roman Space Telescope

Nancy Grace Roman – the "Mother of Hubble"
16 May 1925 – 25 Dec. 2018





Scientist

- B.A. Astronomy - Swarthmore College
- Ph.D. - University of Chicago
- Honorary doctorates: Bates, Hood, Russell Sage,
  - and Swarthmore Colleges
- First woman on the astronomy faculty at the University of Chicago
- Recipient of the NASA Exceptional Scientific Achievement Medal
- Numerous scientific awards and recognition

Twitter: *"Nancy Roman took chief astronomer job at NASA because *women couldn't get tenure*, opted to reshape history of astronomy instead #planB."*

NASA Civil Servant

- First Chief of Astronomy and Solar Physics at NASA
- First woman to hold an executive position at NASA
- Driving force behind the OAOs, IUE, Hubble, and experiments on Gemini, Apollo, and Skylab
- Instrumental in establishing a new era of space-based astronomical instrumentation and research
- Namesake for Nancy Grace Roman Technology Fellowship in Astrophysics

Role Model and and STEM Advocate

Volunteer for "Reading for the Blind and Dyslexic"

Dedication to working with schoolchildren

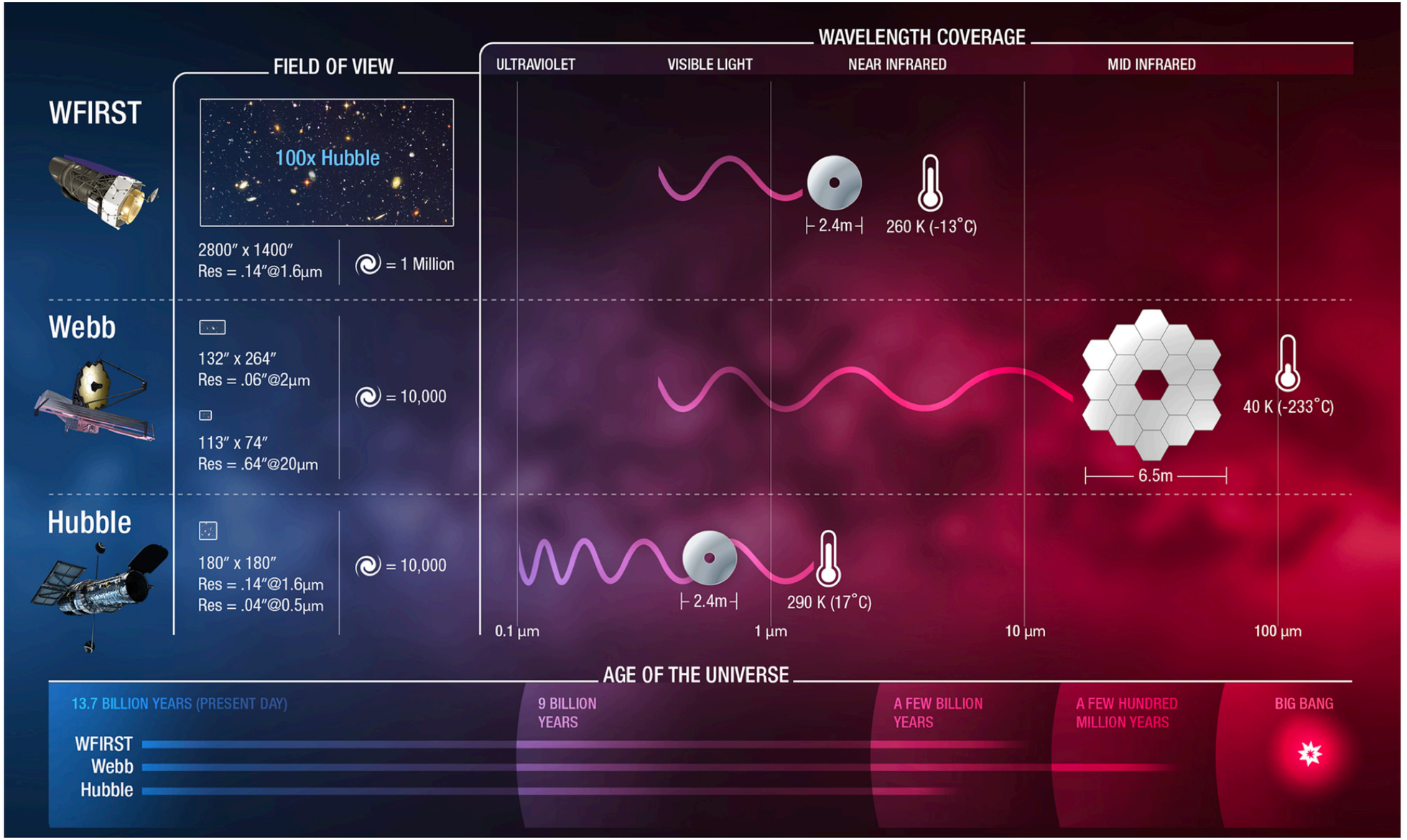
Prolific public speaker on astronomy

Champion of women in astronomy

Inspiration to untold children and adults



Roman is NASA's Next Great Observatory for Optical/IR Astronomy



Survey and Great Observatory Science with Roman

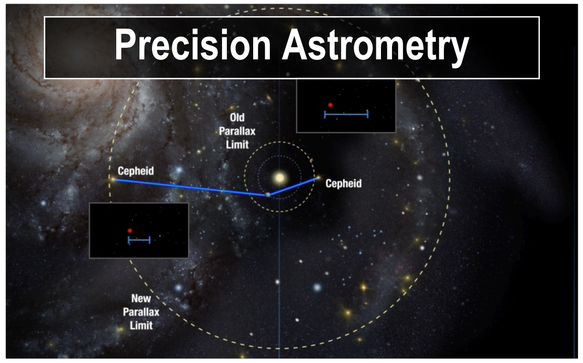
Dark Energy

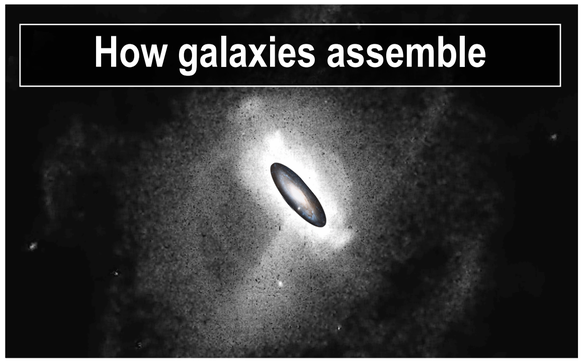


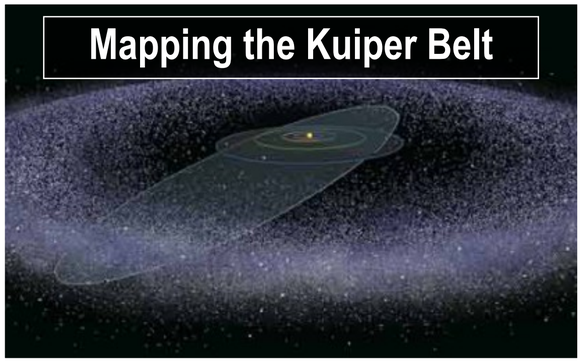


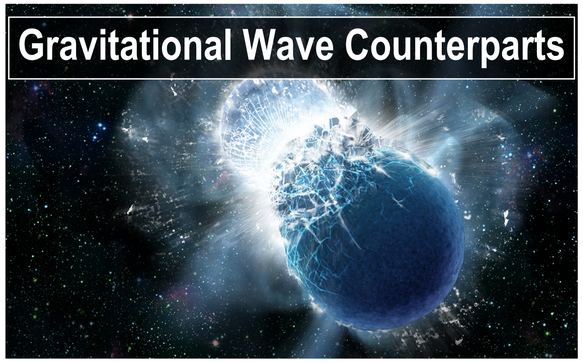


General Astrophysics

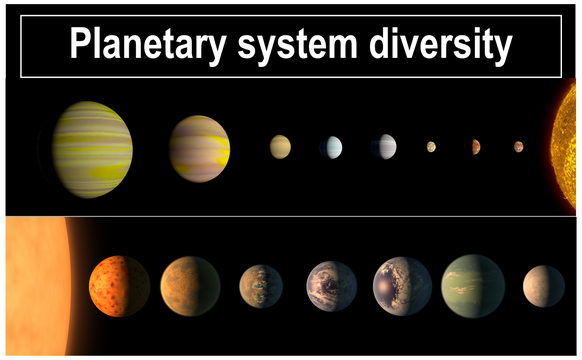


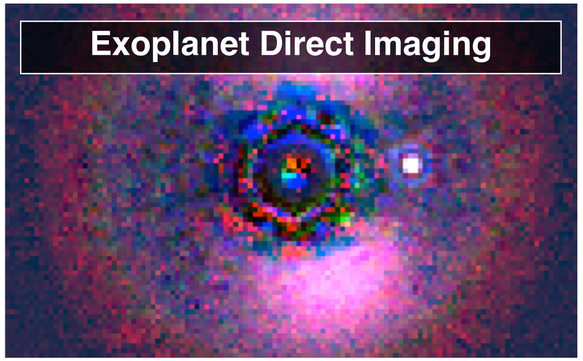


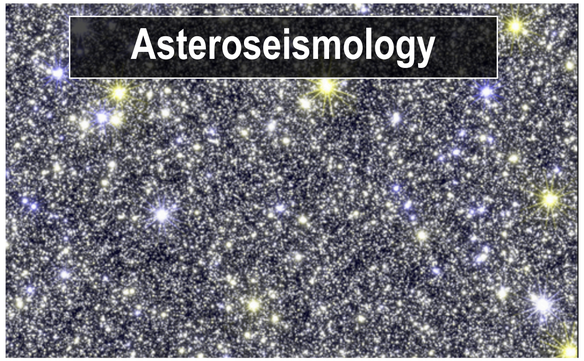




Exoplanets







Roman Mission: Key Features and Timeline

Status: Phase C: Final Design and Fabrication

Mission Life: 5 years (+ ~3 month checkout)

Launch: Mid 2020s

Mission Orbit: Sun-Earth L2 – gravitationally stable

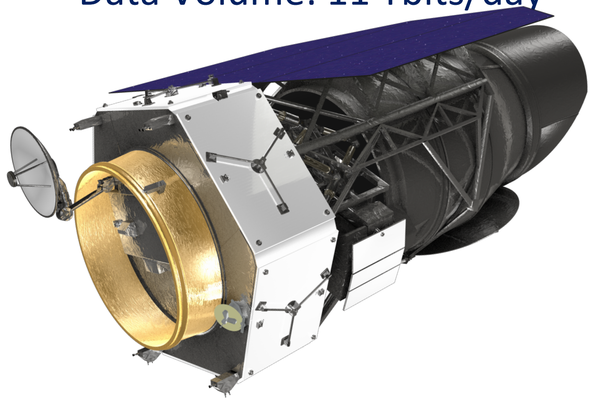
Herschel, WMAP

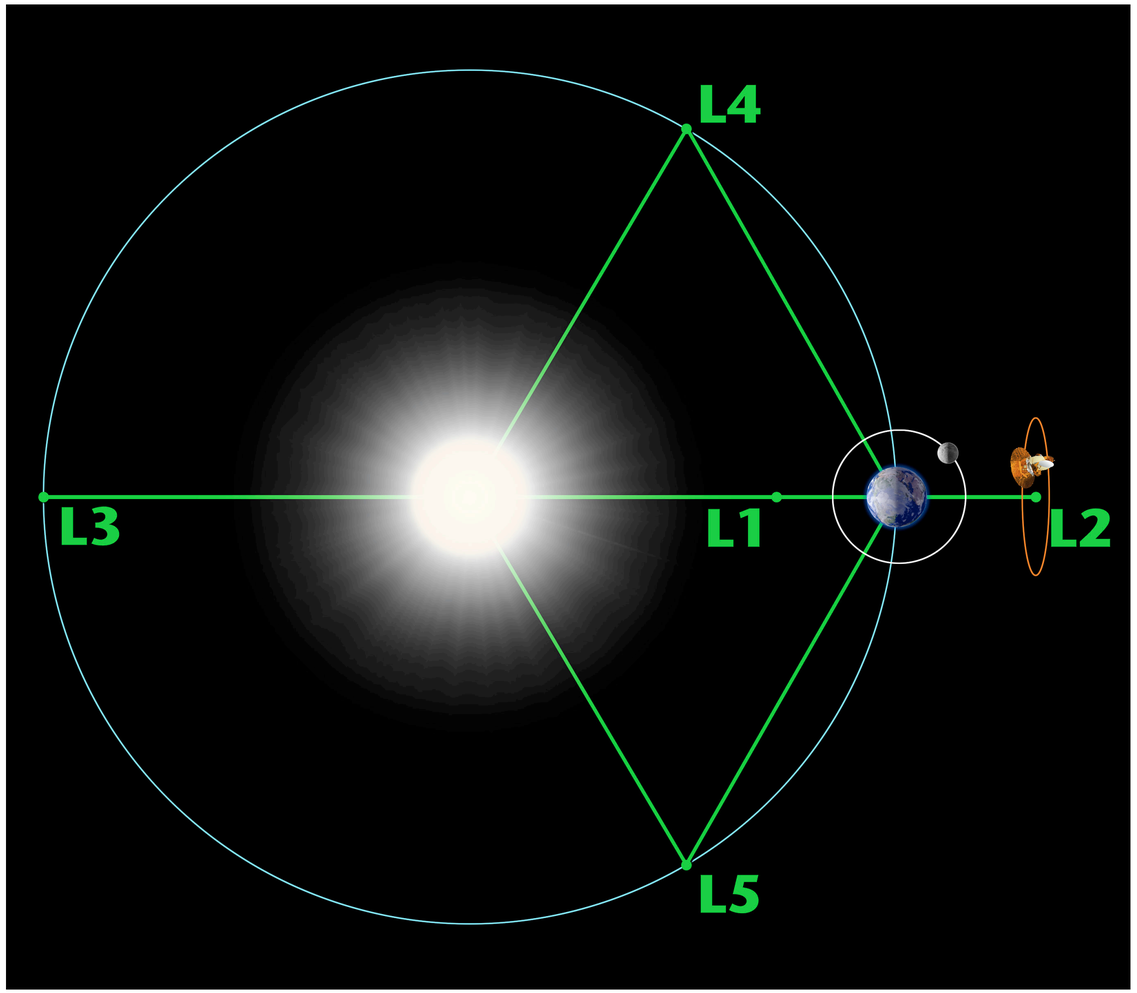
Gaia (active)

in the future JWST and EUCLID

Data Downlink: 290 Mbps

Data Volume: 11 Tbits/day





Earth to L2 = 1.5 million Km

MIRRORS



HUBBLE

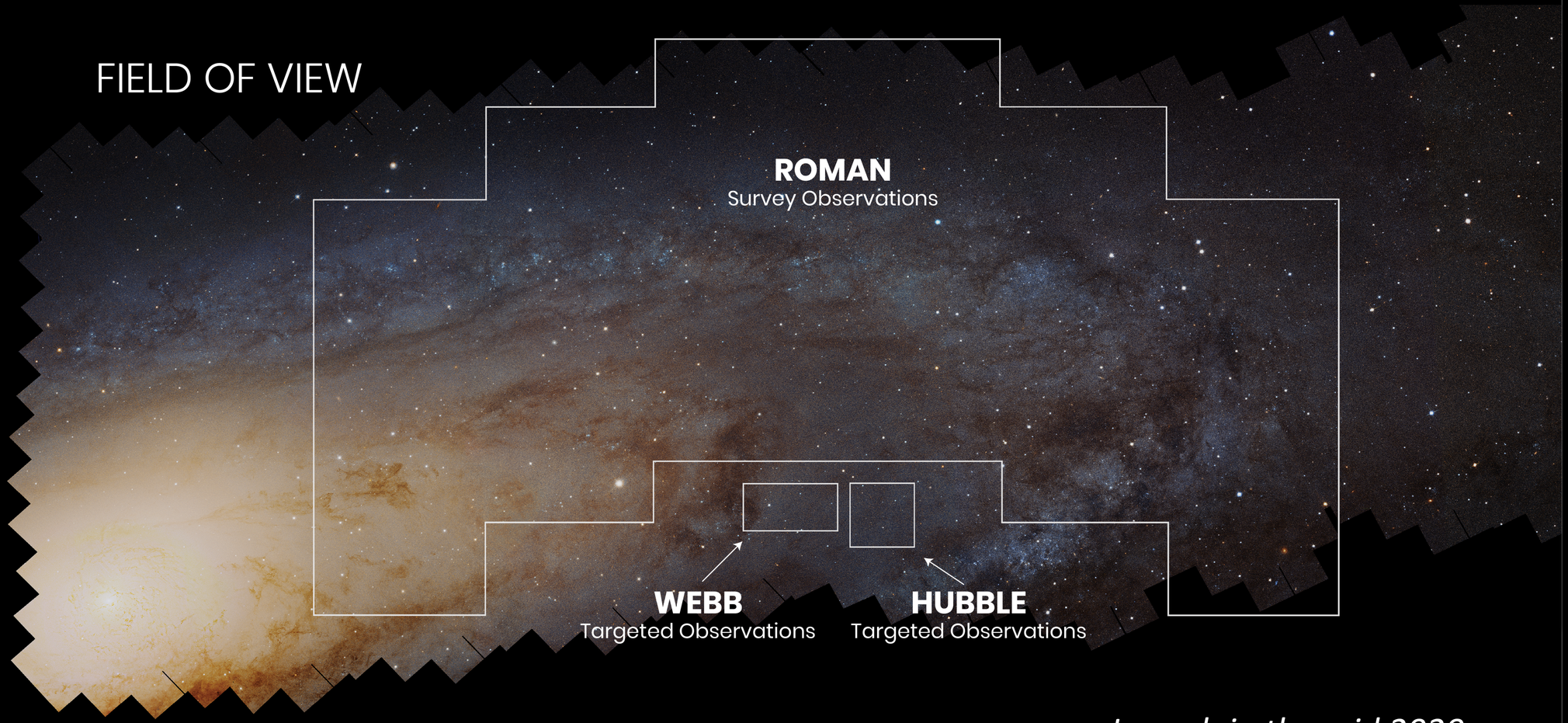


ROMAN



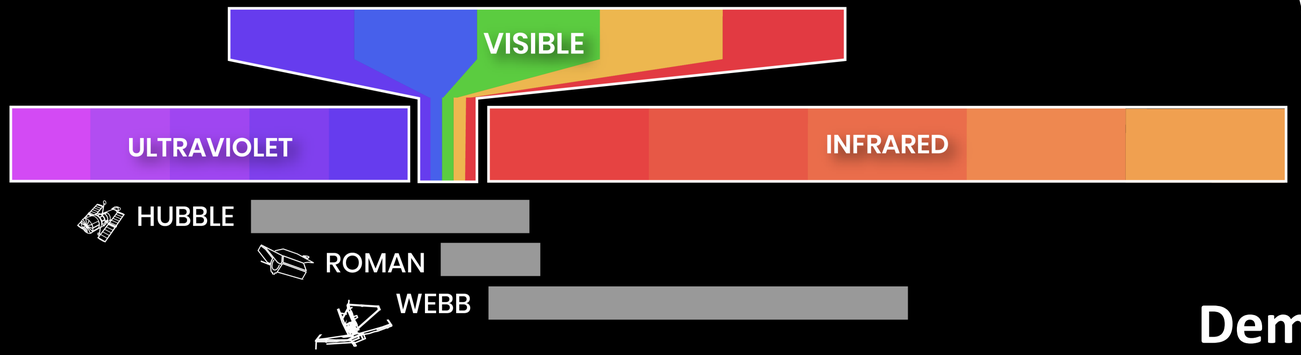
WEBB

FIELD OF VIEW



Launch in the mid 2020s

WAVELENGTH



Wide Field Instrument (WFI)

imaging from 0.5-2 μm

slitless spectroscopy from 0.75-1.93 μm

Coronagraphic Technology Demonstration Instrument (CGI)

MIRRORS



HUBBLE

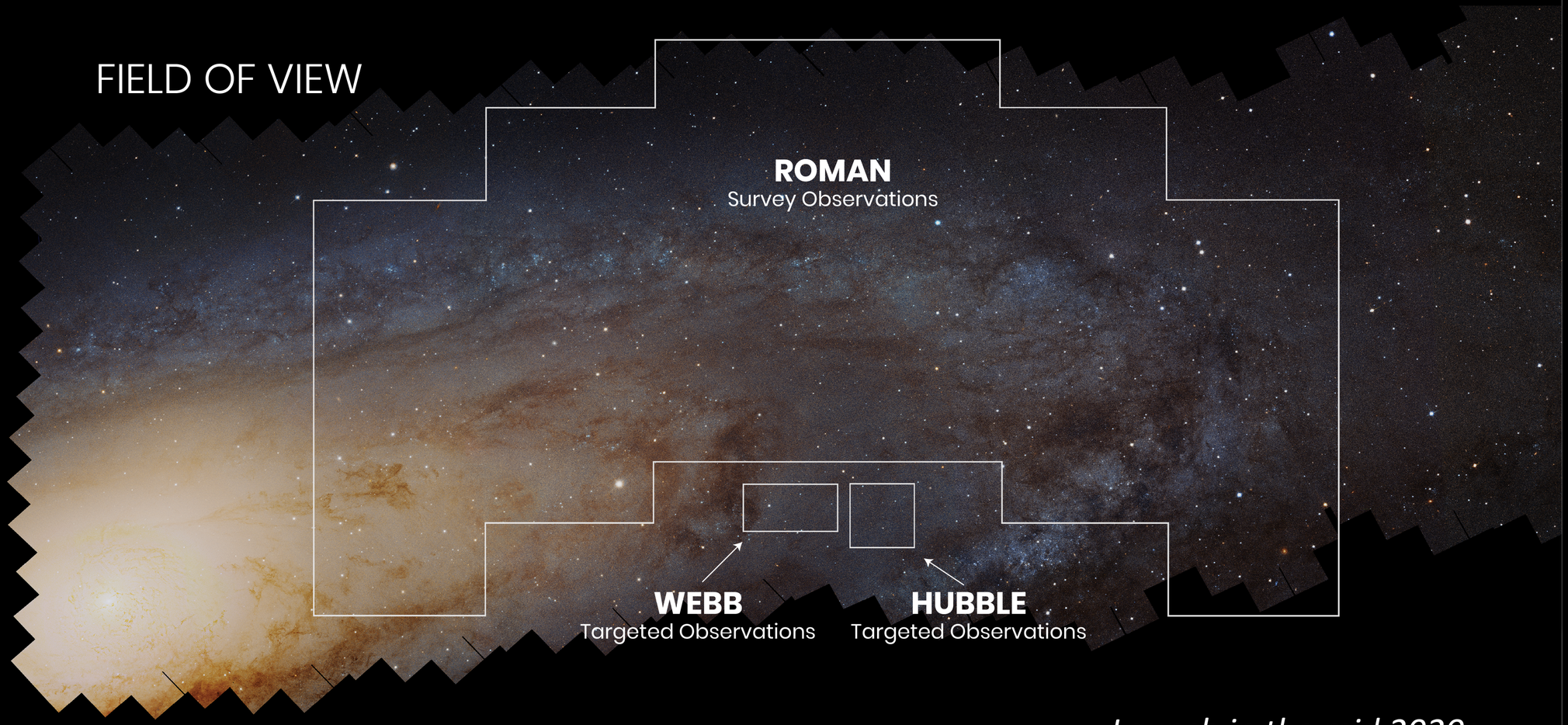


ROMAN



WEBB

FIELD OF VIEW



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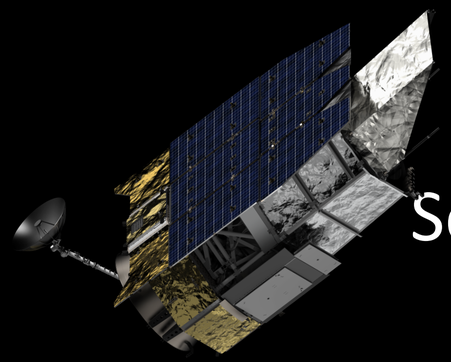


The Partners

Distributed Operations Model

Science Operations Center at STSCI

NASA Goddard SPACE FLIGHT CENTER | JPL Jet Propulsion Laboratory

STScI SPACE TELESCOPE SCIENCE INSTITUTE | ipac

Plus Industry, International, and Academic Partners

Wide Field Imager (WFI)

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

Coronagraphic Instrument (CGI)

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

The Design Reference Mission

Possible Survey Implementations

High Latitude Survey (2000 sq deg at 27th mag in YJHF184 + spectra)
Dark Energy — Cosmic Lensing — High-z Galaxies — Galactic Halo Substructure

Deep Field Surveys (~10 deg^2 fields at 28-29th mag, with high cadence)
Supernova Discovery — First Light — Galaxy Evolution

Guest Observer Surveys (user specified instrument, depth, area, …)
Broad astrophysics from Solar System exploration to cosmology

Galactic Bulge Survey (2.2 sq deg at high cadence)
Exoplanet Census — Free Floating Planets — Stellar Pops — Galactic Structure

Exoplanet (+ Other Objects) Imaging Survey (10^9 contrast ratio direct imaging)
Exoplanet Discovery and Characterization — Disks — Massive Star Atmospheres

Guest Investigator Surveys (funded archival research from survey data)
Broad astrophysics from Solar System exploration to cosmology

Roman Space Telescope is a new NASA facility for the entire astronomical community

The specific implementation of core surveys and all Guest Observer time, as well as associated funding, remain to be competed and selected through peer review

All Roman data will be non-proprietary and publicly available through an archive

Roman Legacy Surveys

The expansive science return of dedicated surveys

Some terms

Redshift: z => 1+z = (1 + velocity of recession / speed of light) x Lorentz factor = $(1+v/c)\boldsymbol{\gamma}$

$z \approx v/c$ when $\boldsymbol{\gamma} = 1$

Age: at z=0 , the age of the universe is ~13.8 x 109 years

at z=1, the age of the universe is ~6 x 109 years

at z=2, the age of the universe is ~3 x 109 years

Magnitude: brightness of an astrophysical object

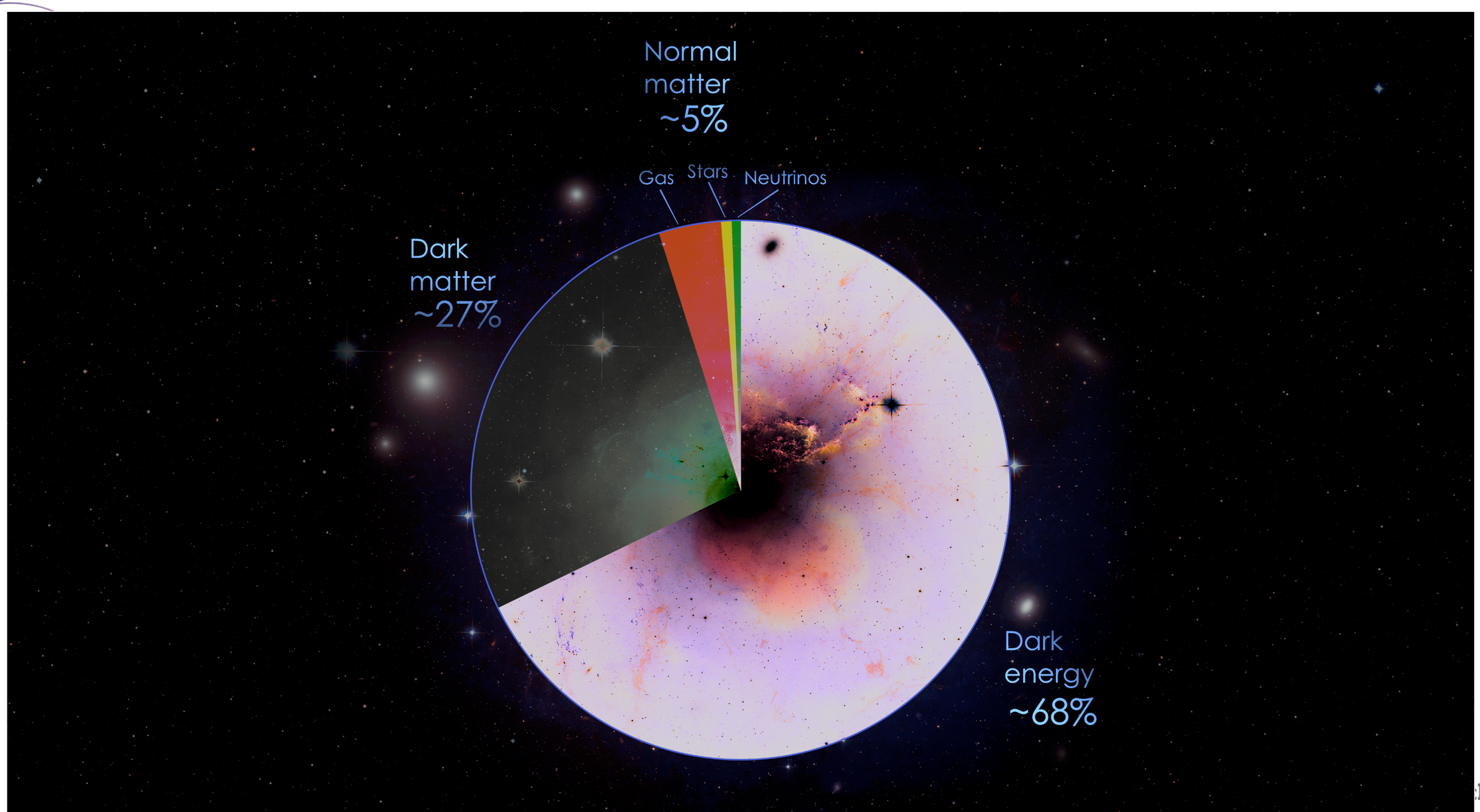
m= -2.5 log (flux) and $\boldsymbol{\Delta}$m=5 is a factor of 100 in brightness.

Type Ia Supernova: thermonuclear explosion of a white dwarf star (in a binary system).

standard candle: class of objects with a known brightness

standard ruler: class of object with a known size

Composition of the Universe



Dark Energy and Cosmology

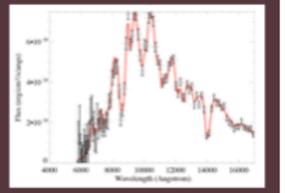
Supernova Survey

wide, medium & deep imaging
+
IFU spectroscopy

2700 type Ia supernovae
z = 0.1 - 1.7

standard candle distances
z < 1 to 0.20% and z > 1 to 0.34%





High Latitude Survey

spectroscopic: galaxy redshifts

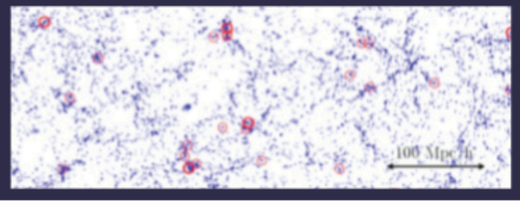
20 million Hα galaxies, z = 1-2
2 million [OII] galaxies, z = 2-3

imaging: weak lensing shapes

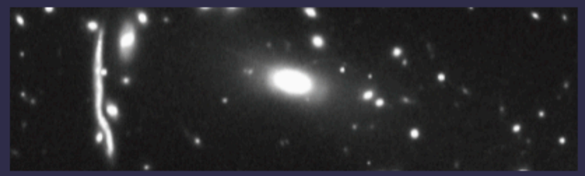
500 million lensed galaxies
40,000 massive clusters

standard ruler

distances	expansion rate
z = 1-2 to 0.4%	z = 1-2 to 0.72%
z = 2-3 to 1.3%	z = 2-3 to 1.8%



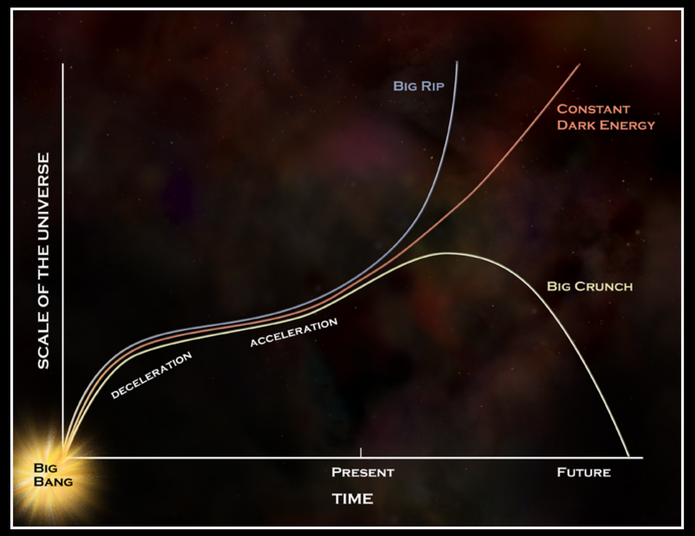
dark matter clustering
z < 1 to 0.18% (WL); 0.14% (CL)
z > 1 to 0.24% (WL); 0.28% (CL)
1.2% (RSD)



history of dark energy
+
deviations from GR

$w(z)$, $\Delta G(z)$, Φ_{REL}/Φ_{NREL}

Dark Energy and Cosmology



Weak lensing

Large scale structure

Photometric Redshifts

Type Ia supernovae

Cluster counts

Roman Cosmology Roadmap

Supernova Survey

wide, medium & deep imaging
+
IFU spectroscopy

2700 type Ia supernovae
z = 0.1 - 1.7

standard candle distances
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High Latitude Survey

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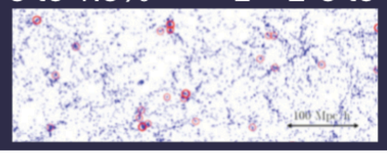

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1.2% (RSD)

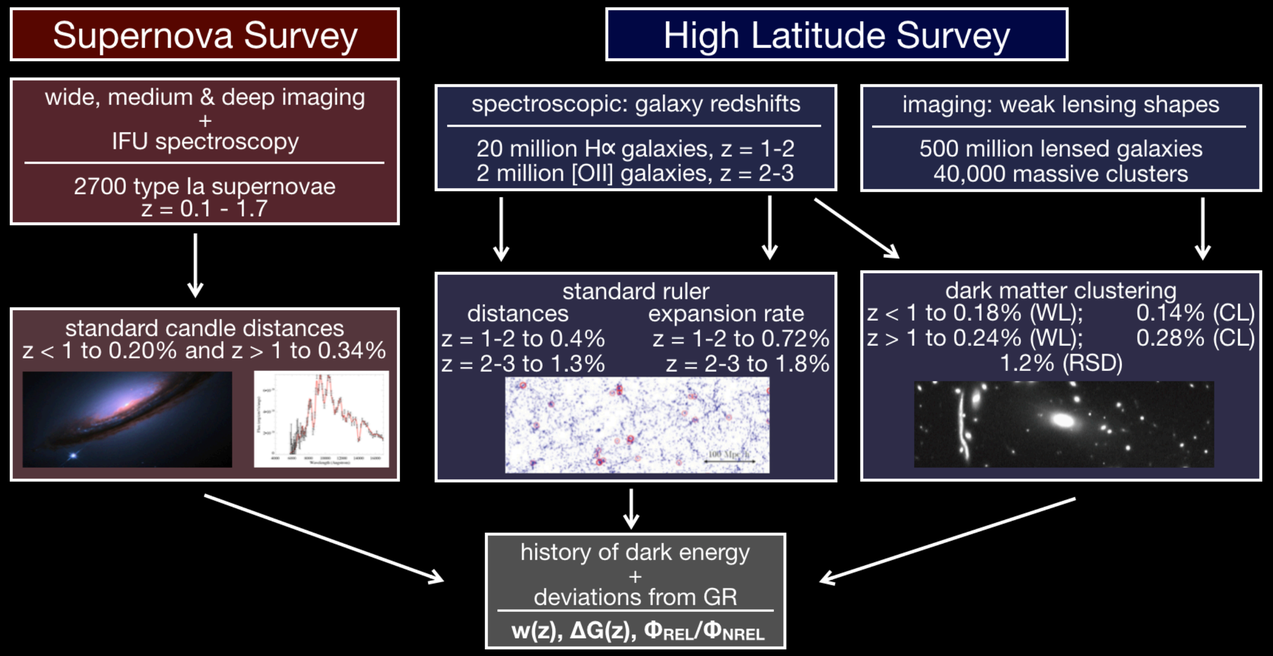


history of dark energy
+
deviations from GR

$w(z)$, $\Delta G(z)$, Φ_{REL}/Φ_{NREL}

Drives requirements for field of view, precise calibration capabilities, and control of systematics

Dark Energy and Cosmology



Dark Energy with Roman

1.) The ultimate supernova cosmology experiment
  – Unique in precision, redshift range, control of measurement and astrophysical systematics
2.) The best controlled weak lensing experiment
  – Unique in depth, detail, and control of measurement and astrophysical systematics
3.) The densest large scale map of structure at z = 1-2
  – Only Roman can map this redshift range at the density needed to reveal details of structure

Large Area High Resolution Galaxy Survey

Per unit time, Roman is the most powerful supernova, weak lensing, and z = 1-2 spectroscopic facility (Roman = 2 yrs, Euclid = 6 yrs, LSST = 10 yrs)

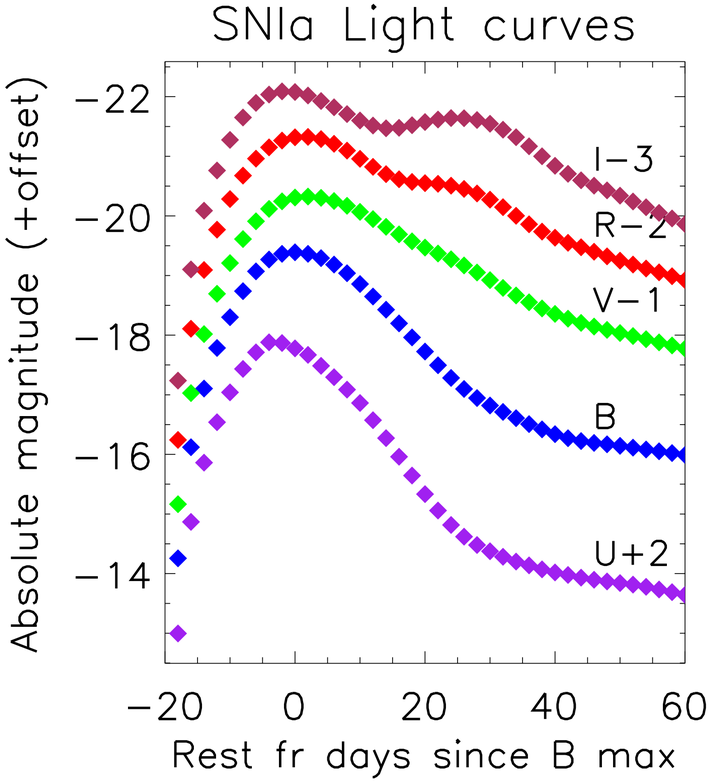
Weinberg 2017

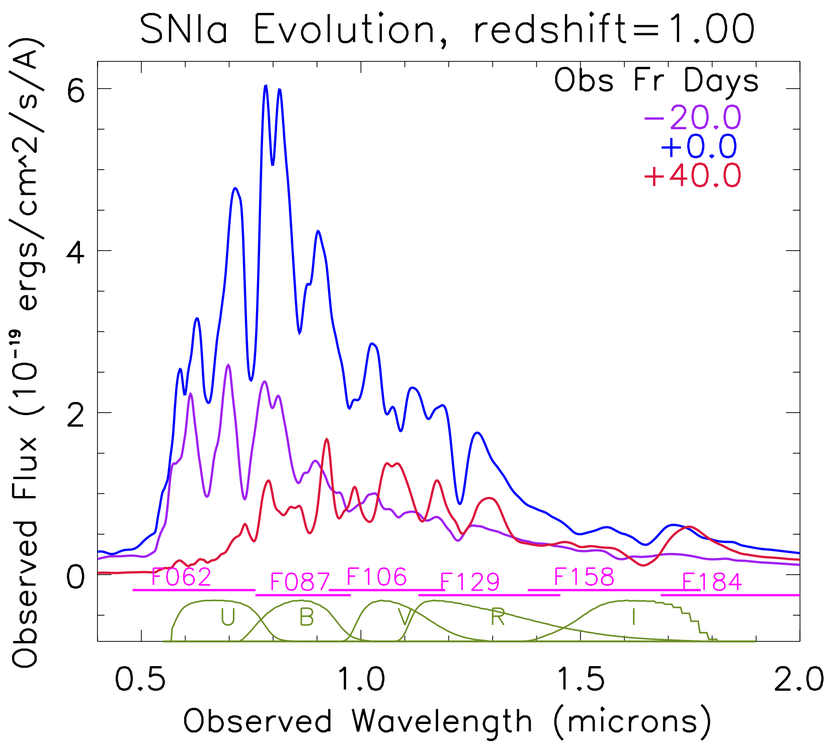
Type Ia supernovae *Observables*

Multi-band imaging for light curves

Spectrum for redshift & confirm type (or host galaxy redshift)

Obtain large sample of SNe Ia: 100 per Δz=0.1 (redshift bin of 0.1) for redshifts between 0.4 and 1.3 (or higher)



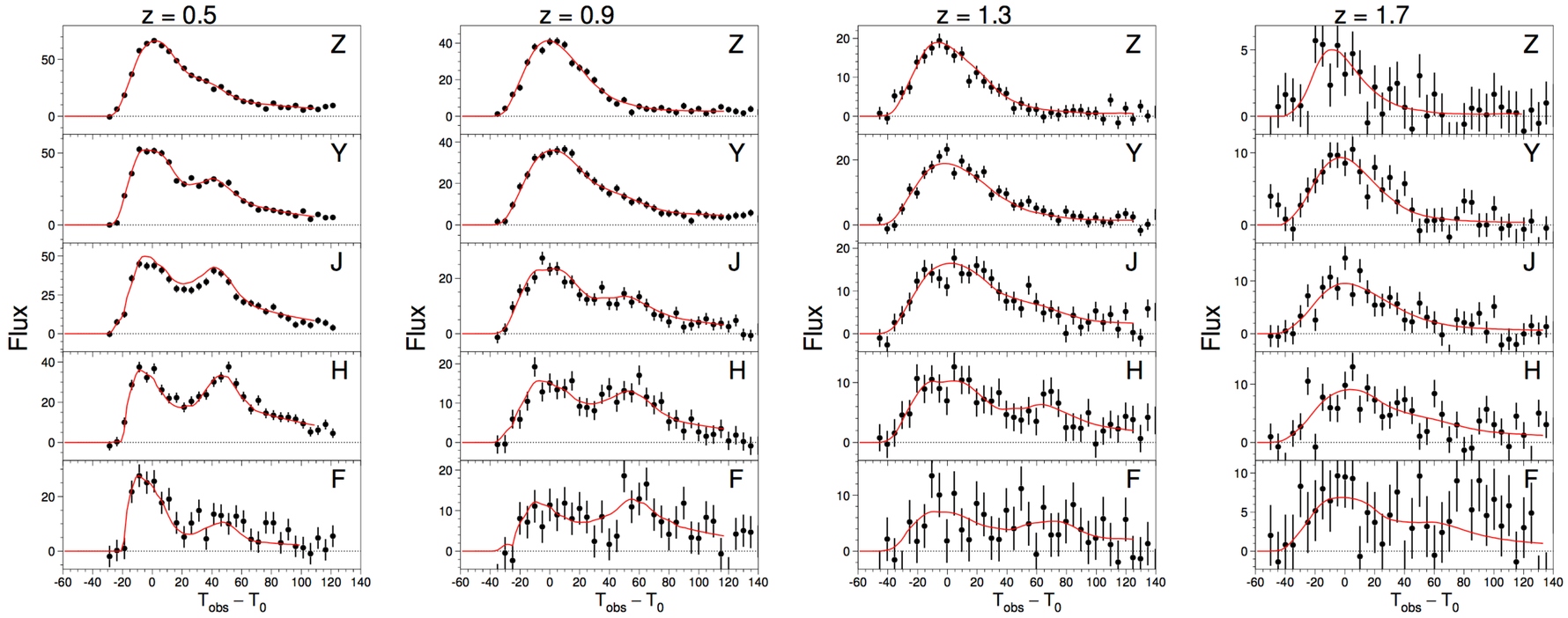


Roman Supernova Survey

An Example three-tier Roman Sne Ia Survey

Survey Tier	Redshift Range	Area (deg^2)	Filters	Depth (mag)
Shallow	$0.1 < z < 0.4$	19.7	R062, Z087 Y106,J129	25.0, 25.1
Medium	$0.4 < z < 0.8$	8.96	Z087,Y106, J129, H158	27.3, 27.2
Deep	$0.8 < z < 1.7$	5.04	Y106, J129, H158, F184	28.9, 28.8

A Roman "Deep Field" including Time Domain



Hounsell et al. (2017)

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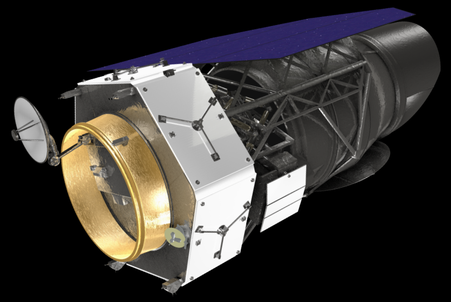
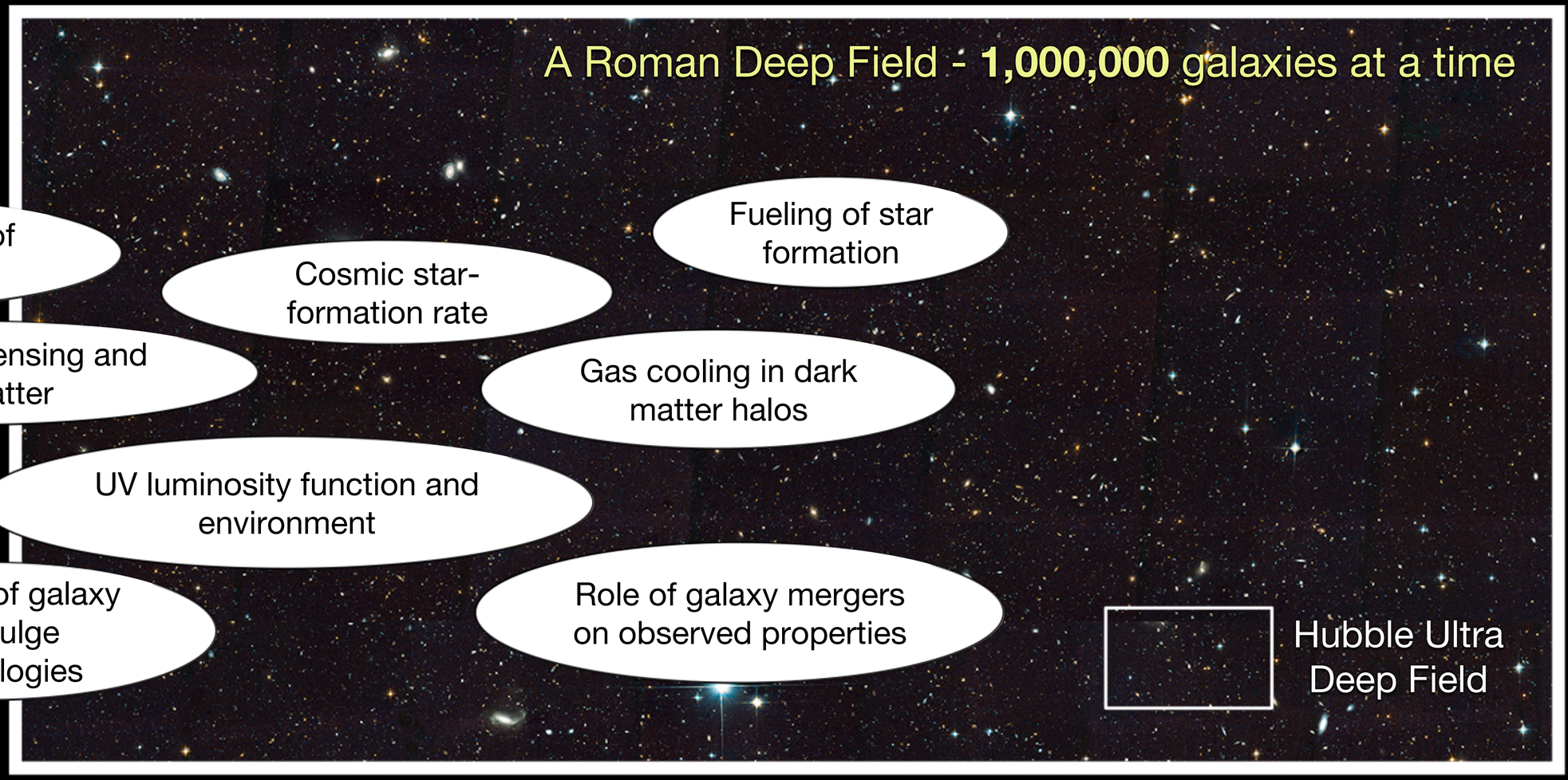
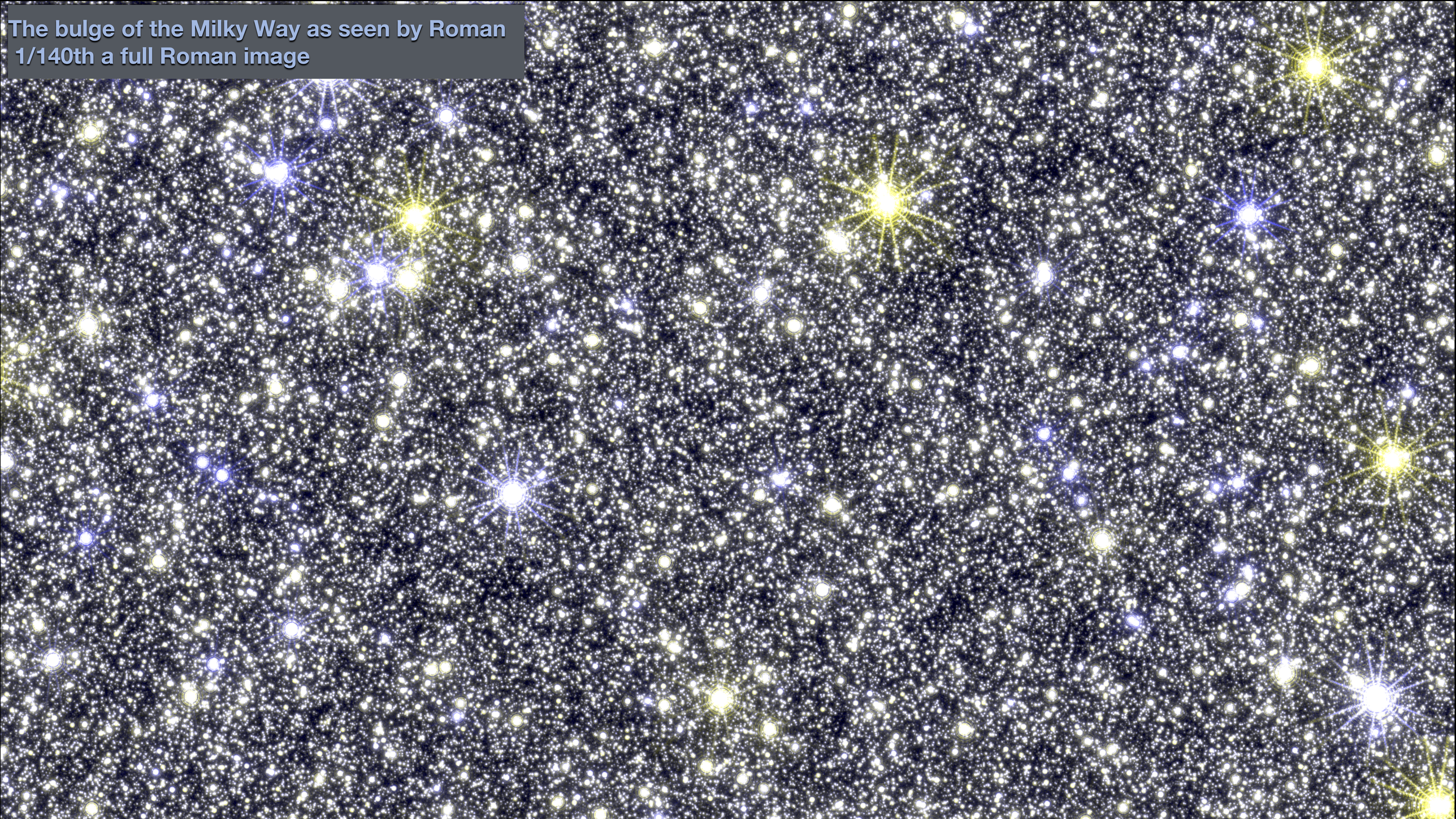
Galaxies



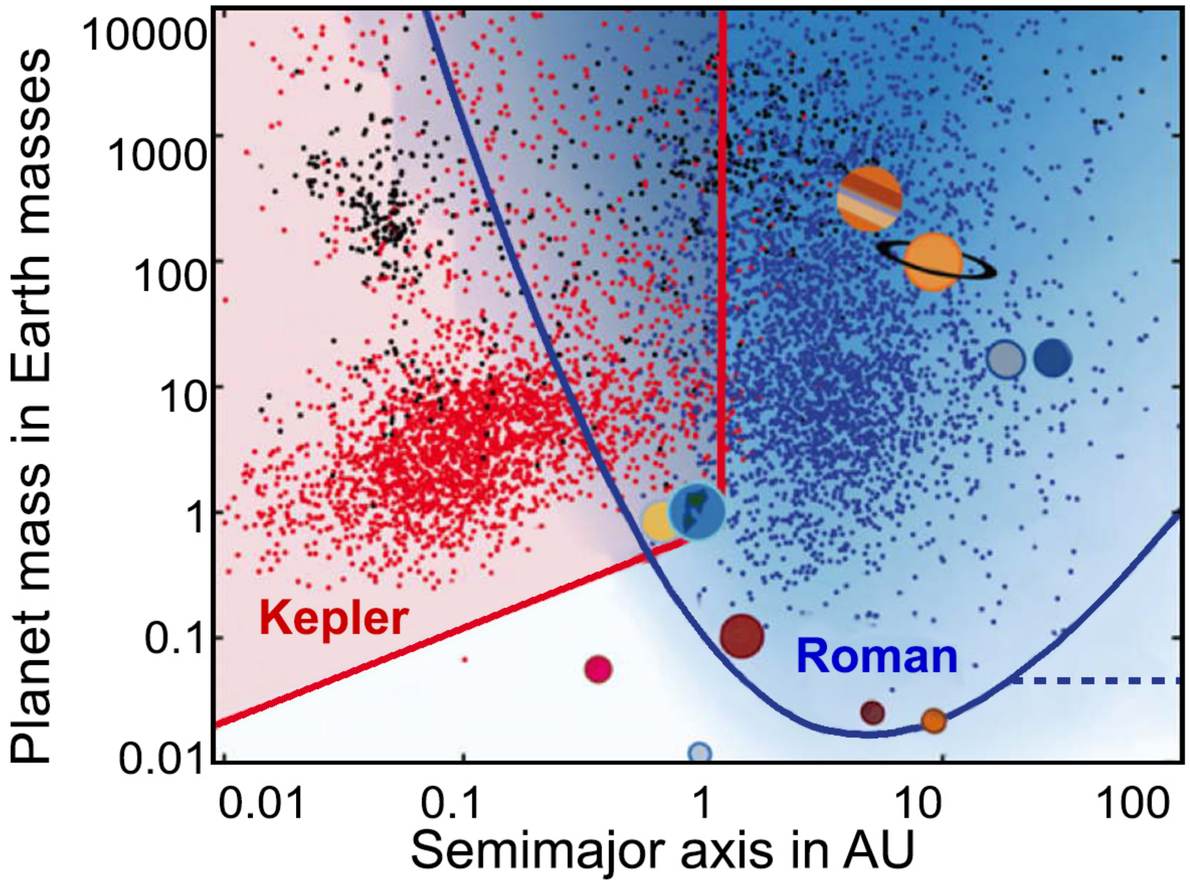


- A High latitude survey (2000 sq deg, 27th mag, 4 filters): measure 10,000 z = 8.5 galaxies
- Roman 0.1” image resolution will distinguish faint structures and shapes of galaxies
- Roman will provide Hubble-like imaging of 100s of gravitational clusters


The bulge of the Milky Way as seen by Roman
1/140th a full Roman image

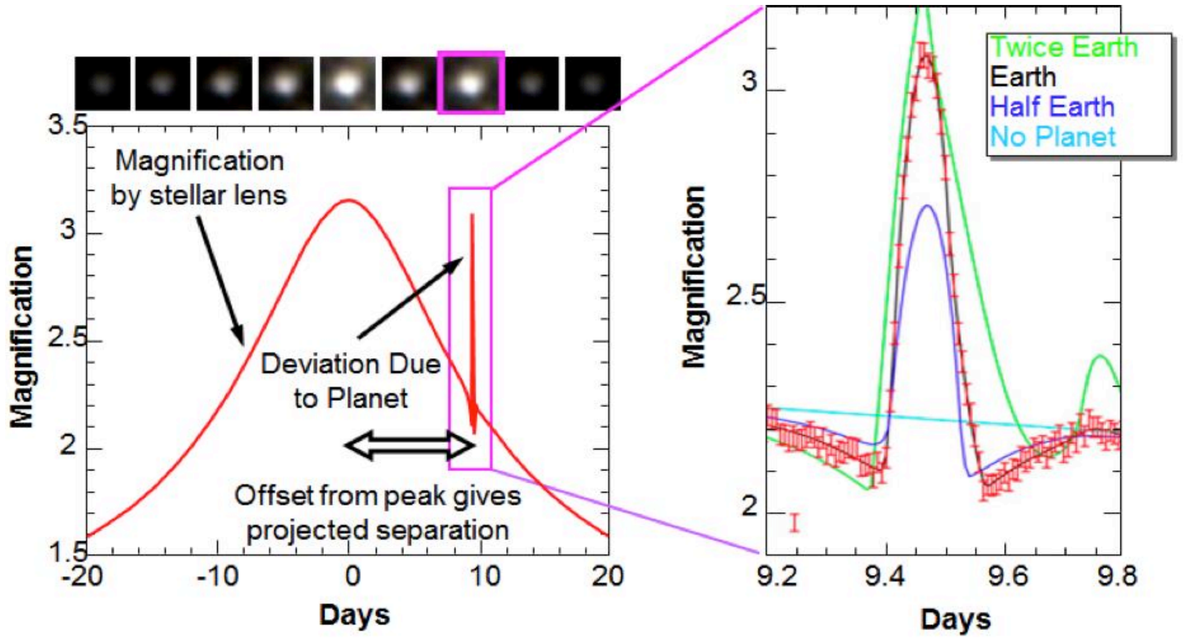
Microlensing Bulge Survey

Complete the Census of Exoplanets



Penny et al. 2018

- A high cadence survey of the bulge of the Milky Way will yield thousands of detections of exoplanets
- Sensitive to analogs of outer solar system planets, complementing Kepler
- Provide tens of thousands of measurements of hundreds of millions of stars in the Galactic bulge enabling studies of stellar variability and other transient phenomena

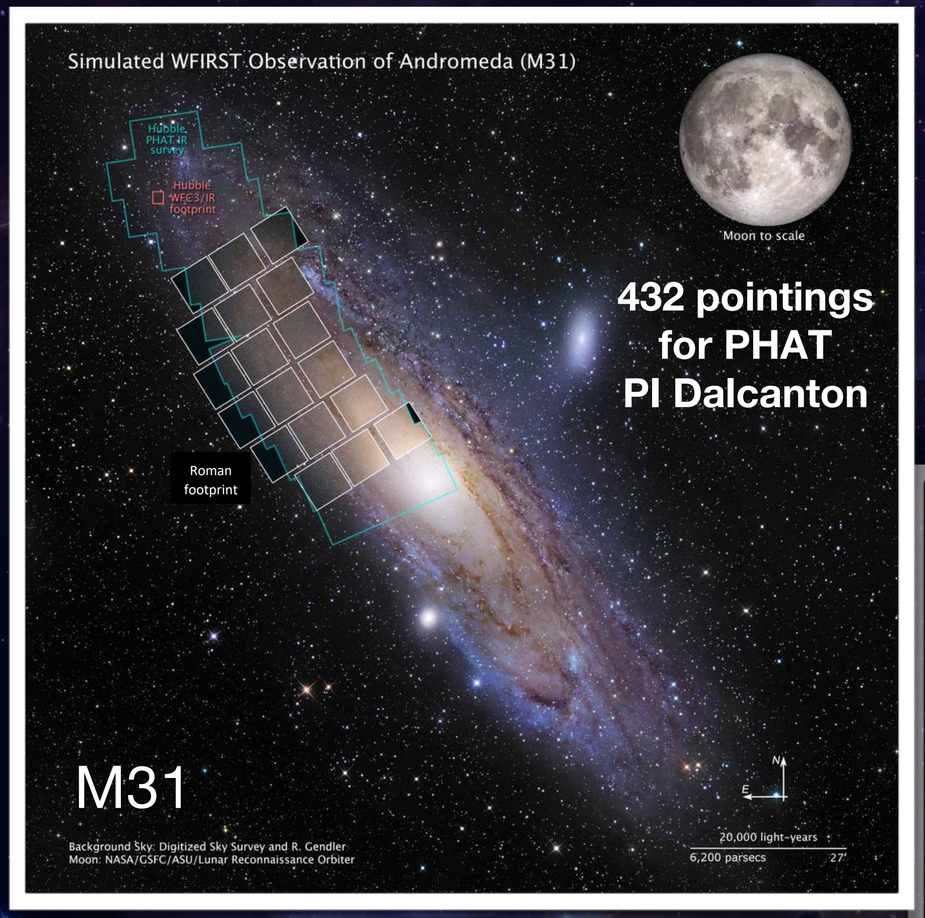


Drives requirements for fast slew and settle times

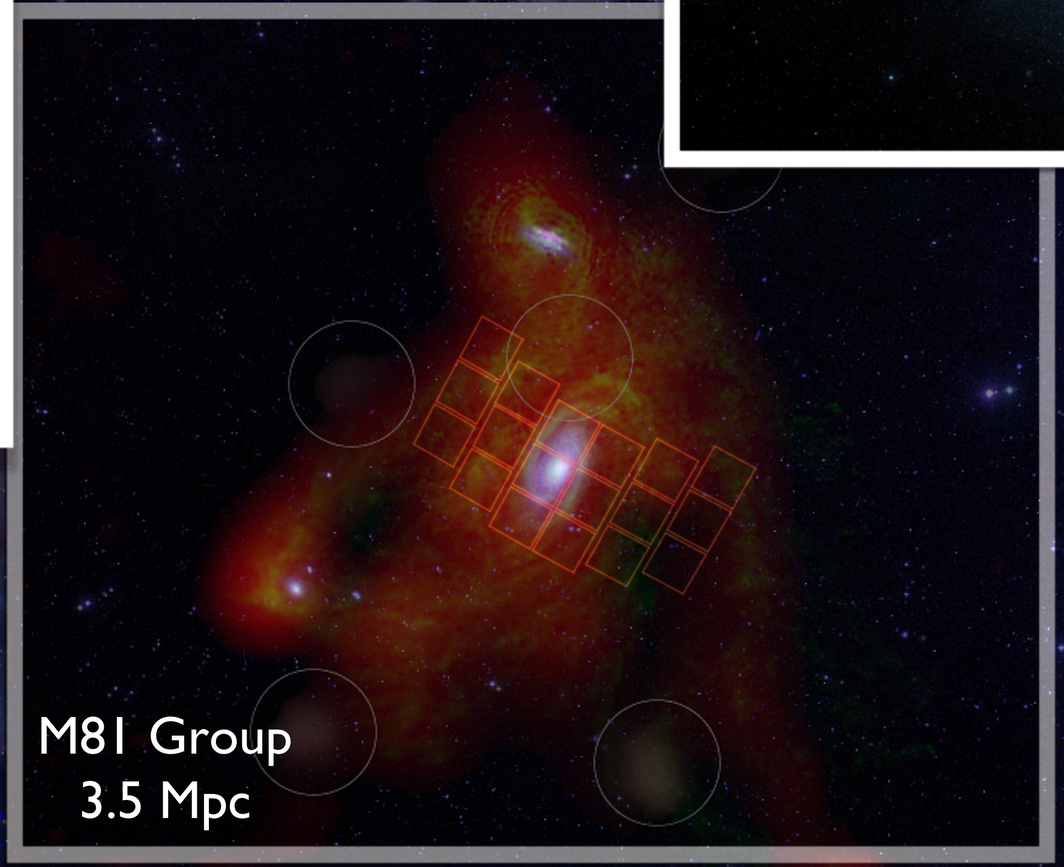
Roman Targeted Surveys

Muli-Cycle Treasury returns from even small General Observer programs

Local Group and Local Volume





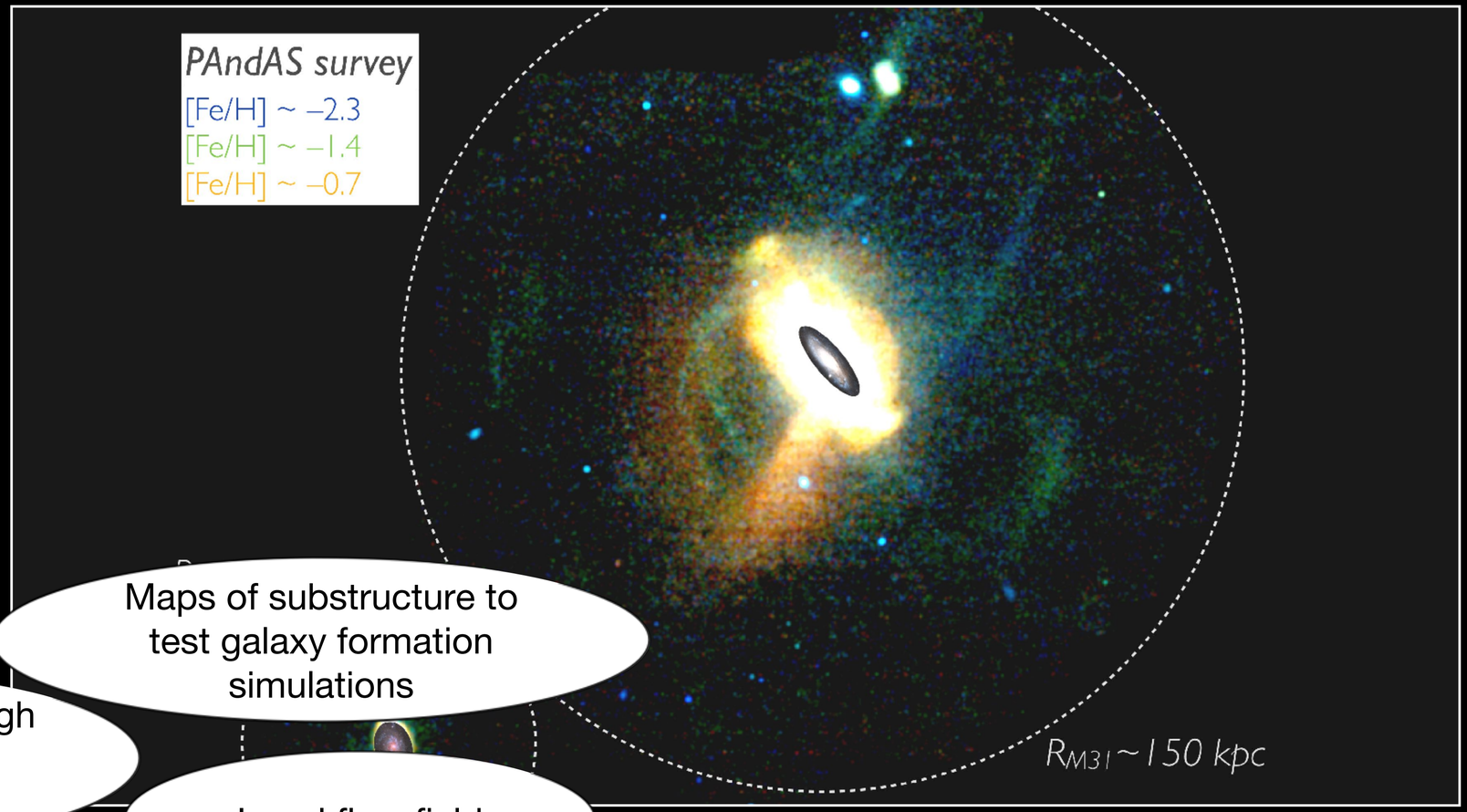


GBT+VLA; Chynoweth et al 2008;
http://www.nrao.edu/pr/2008/m81clouds/

Galactic Halo and Local Volume



A Spiral Galaxy's Resolved Halo - M31



Census of dwarf galaxies in halos

Maps of substructure to test galaxy formation simulations

Accretion history through direct star formation histories

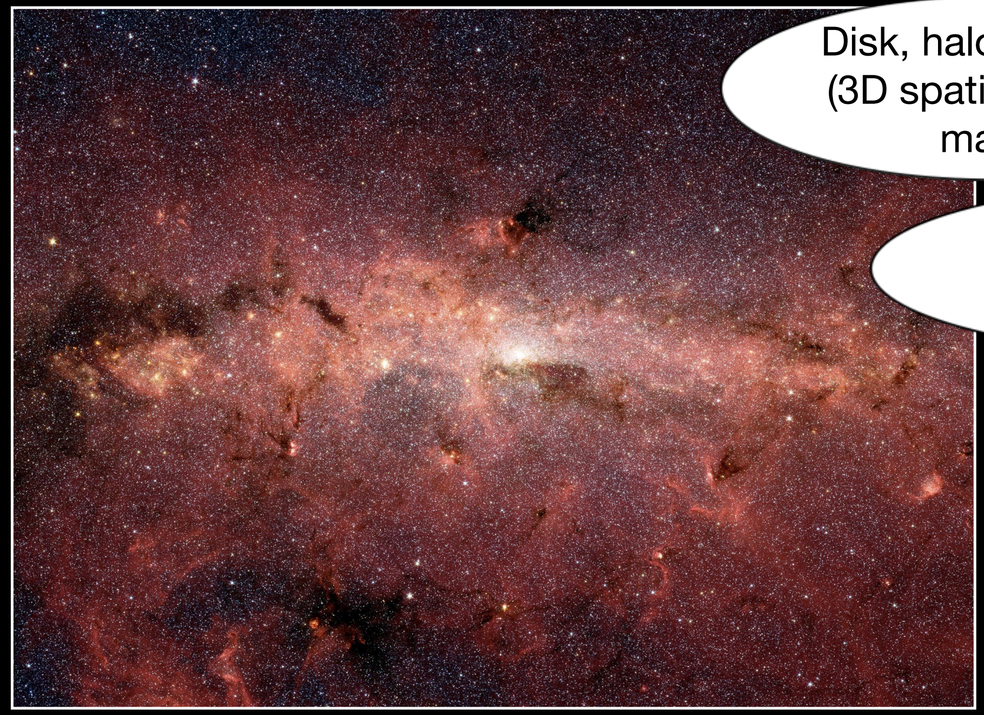
Local flow field

MilkyWay Streams

Calibration of stellar relations to interpret populations in high-z galaxies

galaxy halos

Stars and the Milky Way Galaxy



Disk, halo structure (3D spatial - [Fe/H] maps)

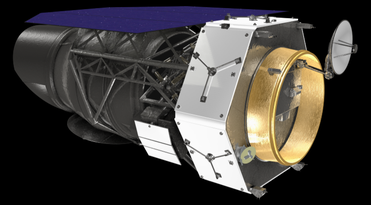
Galactic bar/bulge pops and structure

Rare events, novae, exotic stars

Census of the Solar neighborhood

Structure of the Magellanic Clouds

Wide-field mapping of star clusters and their ejected populations



- GO surveys of key sight lines will separate sources that are blended in ground-based data
- GO pointed observations of star clusters will extend imaging into the crowded centers
- Microlensing survey is really a bulge cadence survey - light curves and asteroseismology of 1 million red giants

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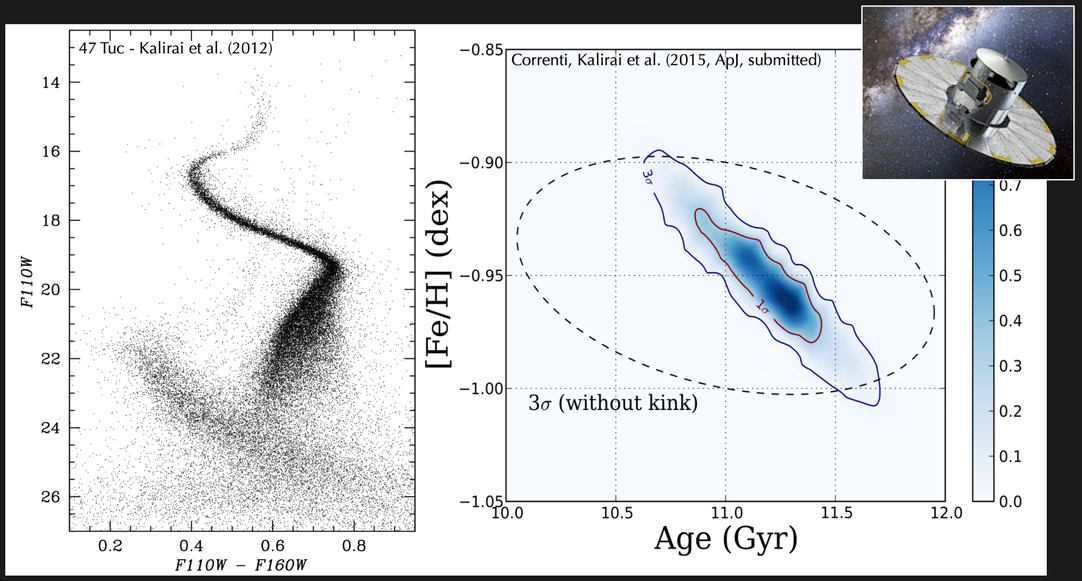
- GO planar surveys will resolve low mass stars in extincted regions to explore the structure of the Galactic center and its populations
- Deep surveys of the Magellanic Clouds will provide “true” luminosity functions free from galaxy contamination

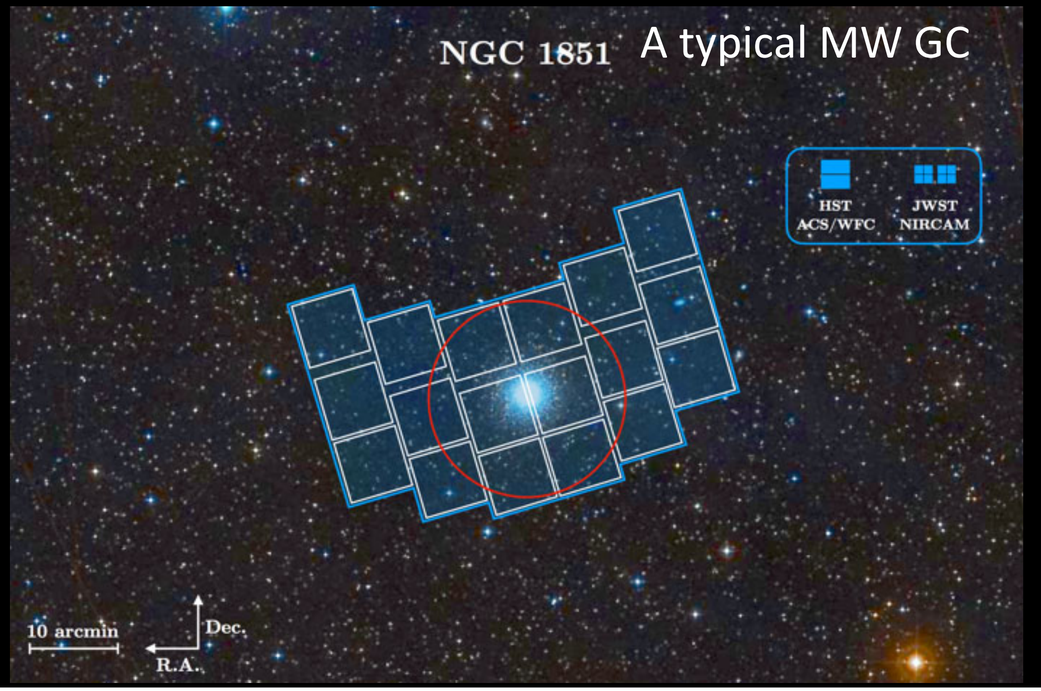
Stars and the Milky Way Galaxy

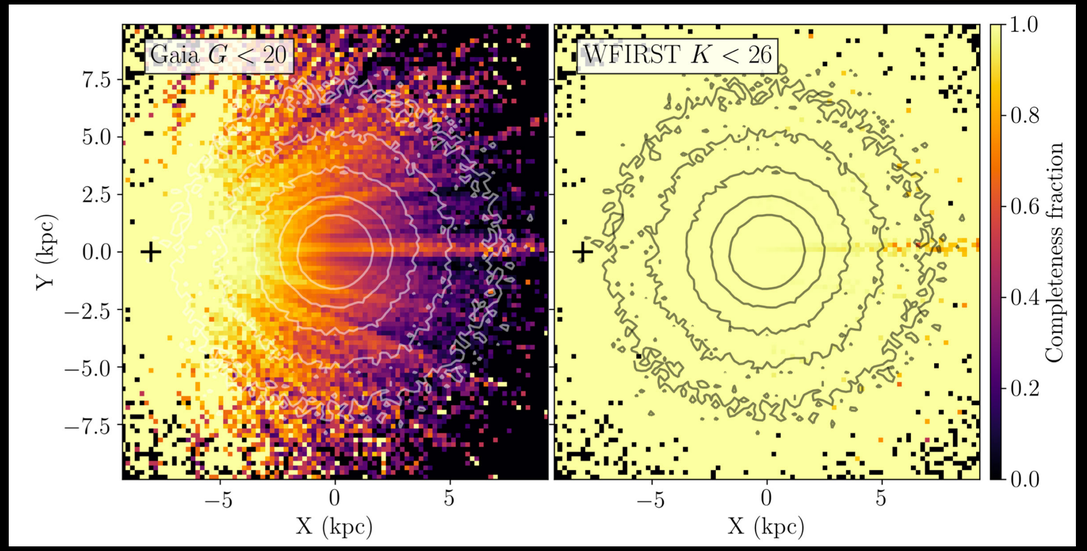
Stellar Populations w/ Precise Distances



Milky Way Field Stars and Star Clusters

- Maps of the galaxy - M dwarfs to edge of MW
- Sub Gyr ages through modeling IR CMD
- IMF through H-burning limit to substellar regime
- Early cluster formation and multiple pops
- Capability of 100% completeness for red clump stars throughout the MW disk





Sanderson et al. 2019

Survey Speeds with Roman

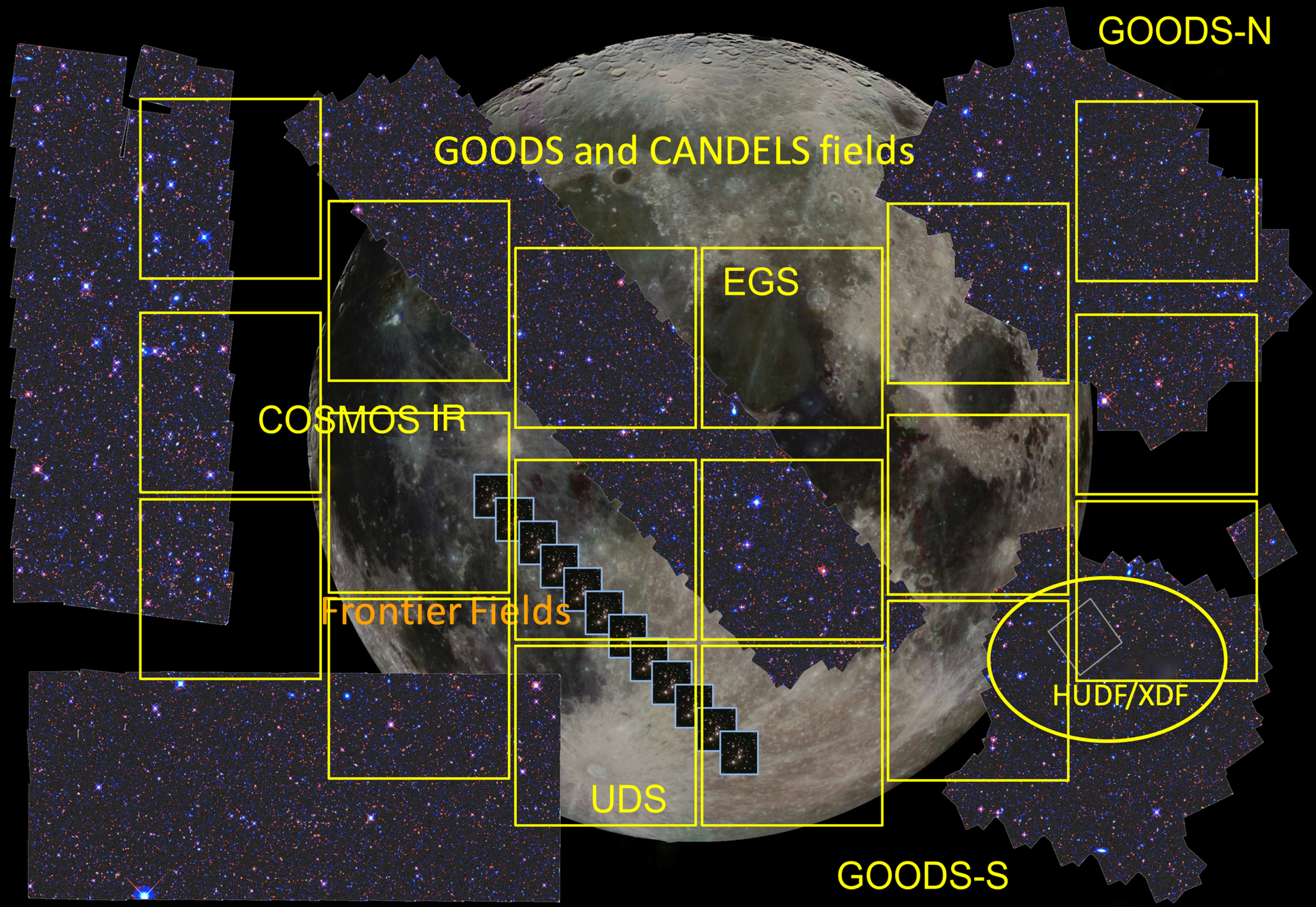
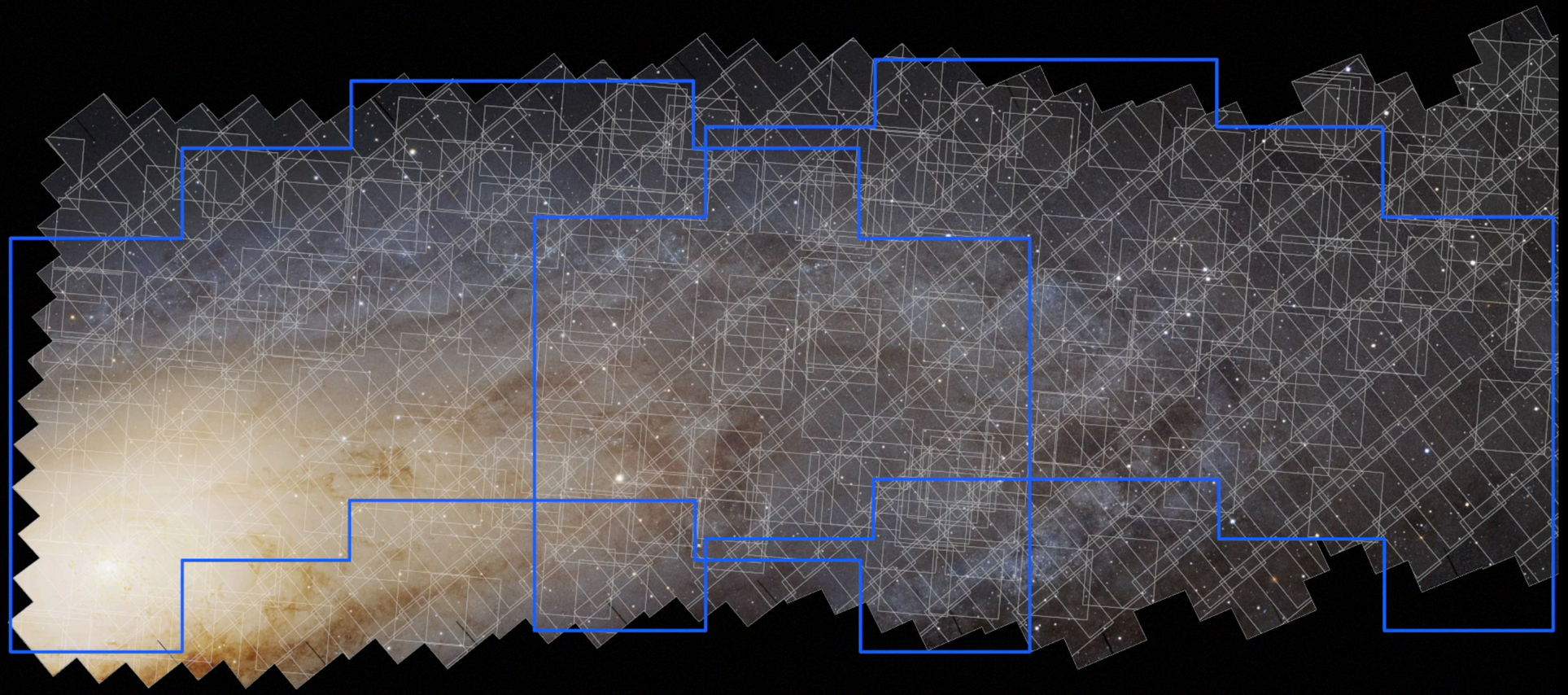


Figure credit: Anton Koekemoer

Roman versus Hubble Field of View

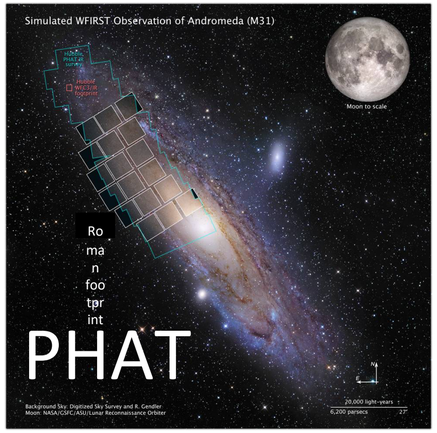
(PHAT Survey of Andromeda Galaxy)



432 Hubble Pointings

2 Roman Pointings!

PI J. Dalcanton



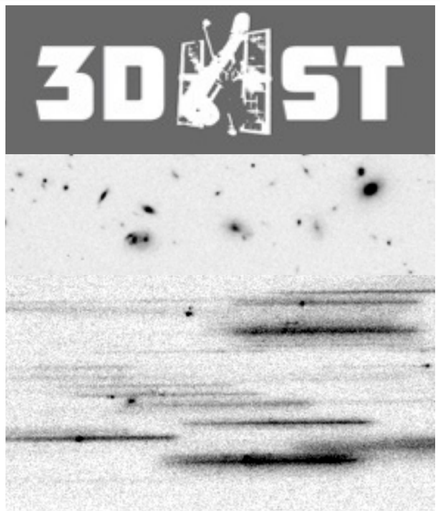


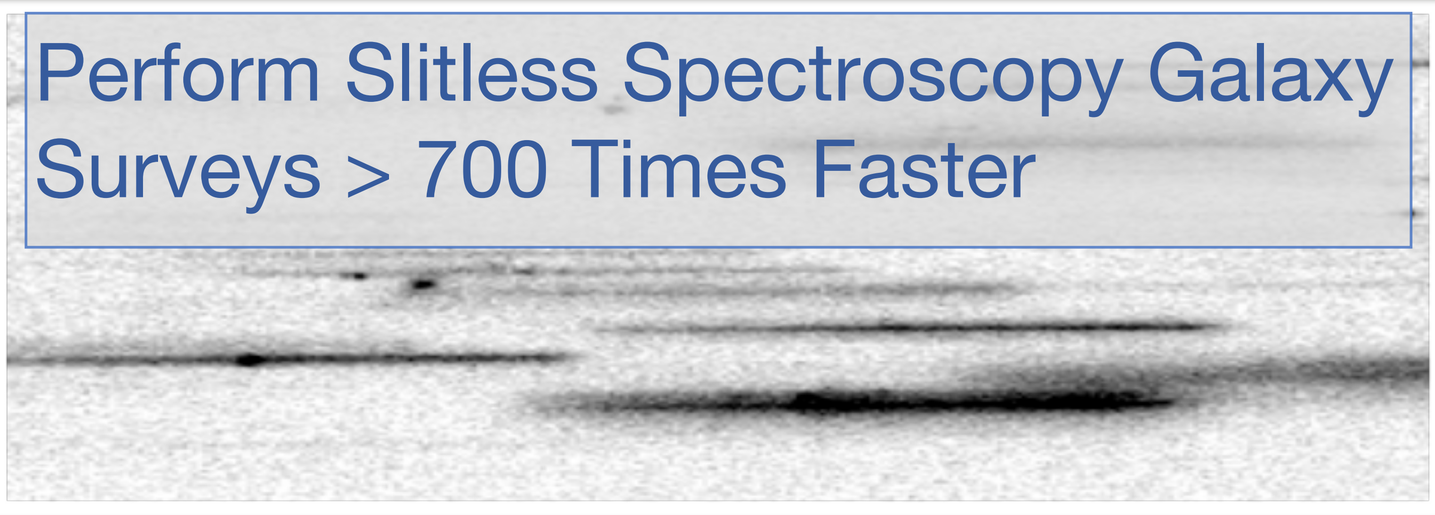
PIs S. Faber, H. Ferguson





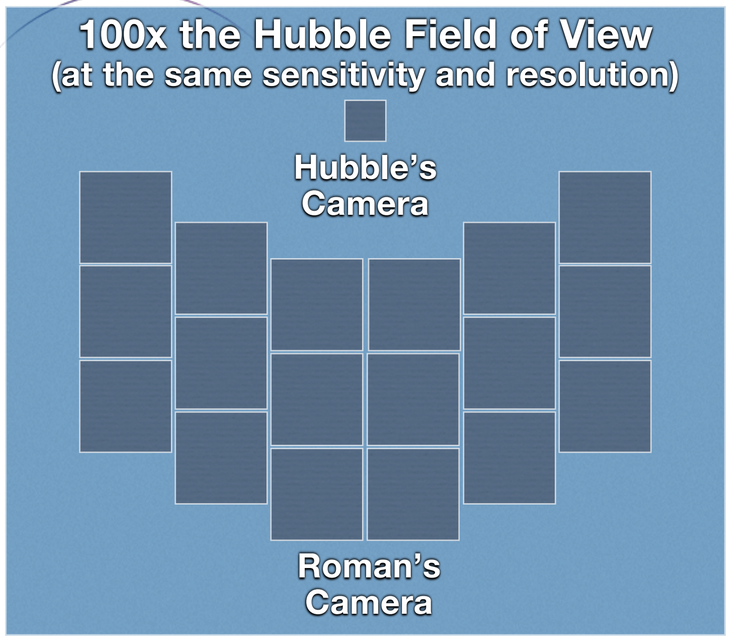
PI P. van Dokkum

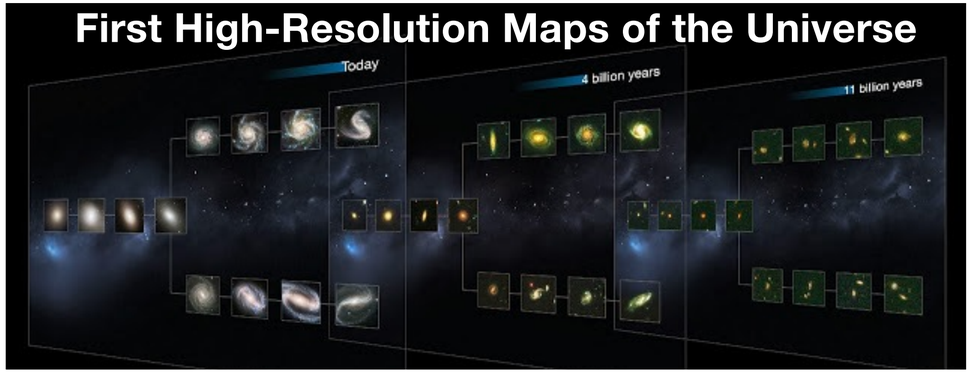


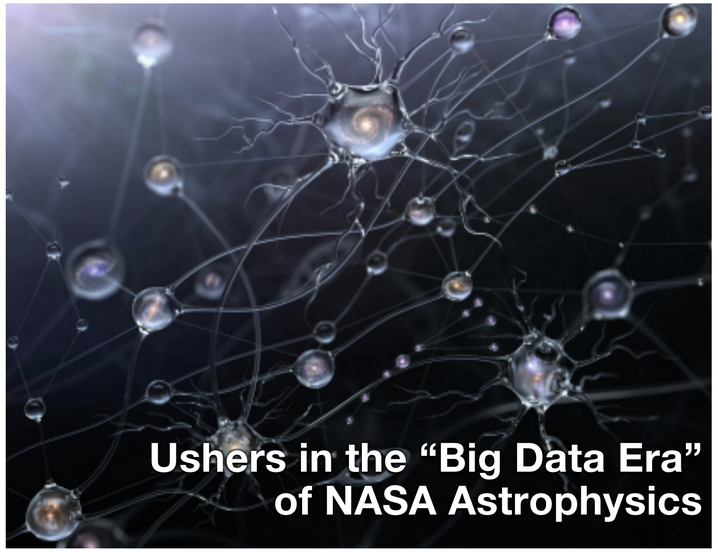


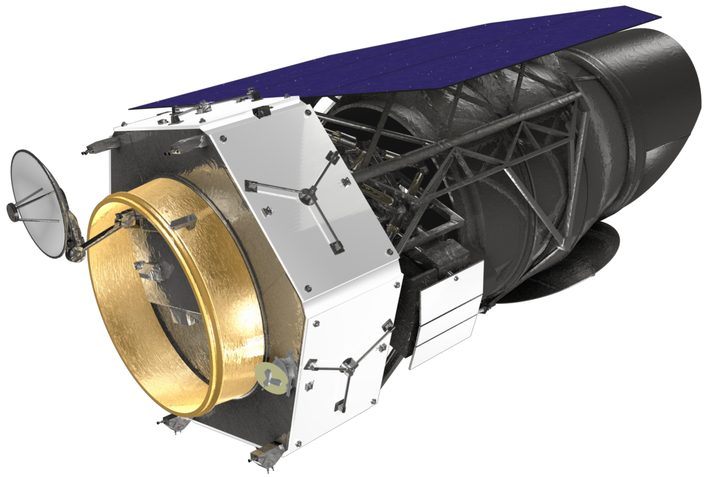
Data, Archives, Community

Guest Observer and Archival Science





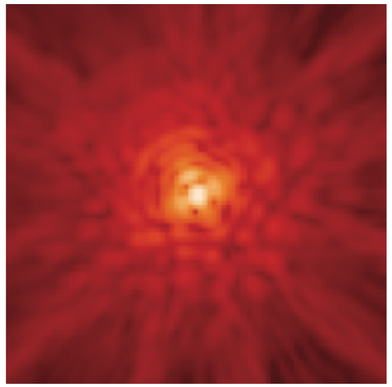




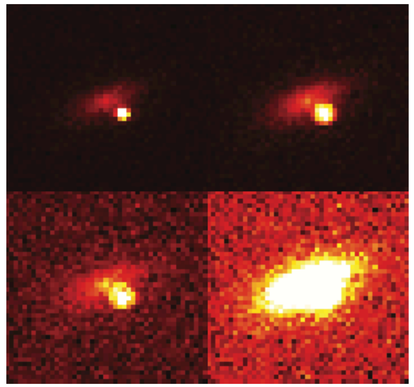
Scale of Roman data will require a modern archive and data processing environment

- STScI will host the Roman archive, which will include MAST-like capabilities and interfaces
- A portable science platform: Operations will include a cloud-based data management framework for high-level data processing
- Common environment accessible to all users

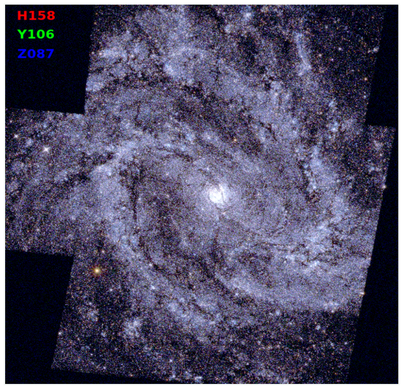
How you can Explore Roman's Capabilities



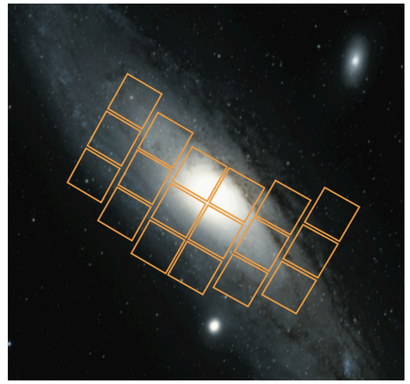
WebbPSF:
Wavelength
Dependent
PSF Simulator



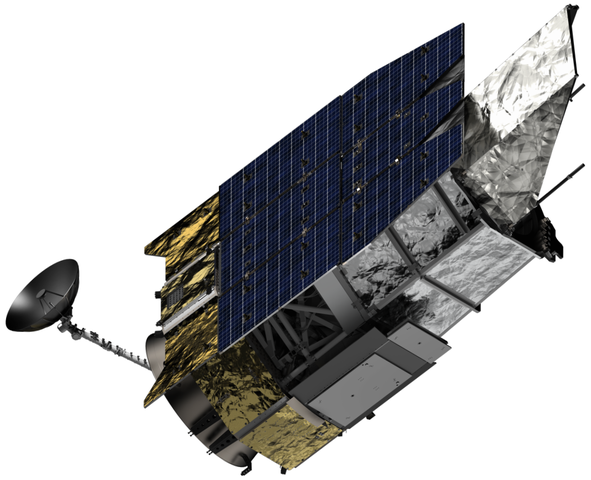
Pandeia:
3-D Exposure
Time
Calculator



STIPS:
Image Simulator



Multi-mission
Field
of View Overlay



Utilize Existing Simulation Tools

STScI has created Roman modules for JWST simulation tools
https://www.stsci.edu/roman/science-planning-toolbox— Science Planning Toolbox

Nancy Grace Roman Space Telescope: Great Observatory Science





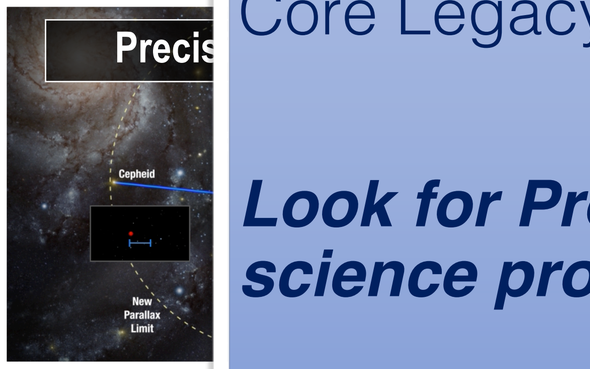




All data will be publicly available with no proprietary period

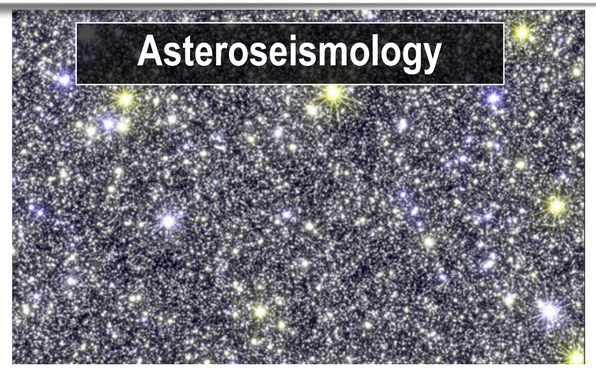
Core Legacy surveys remain to be defined by the community

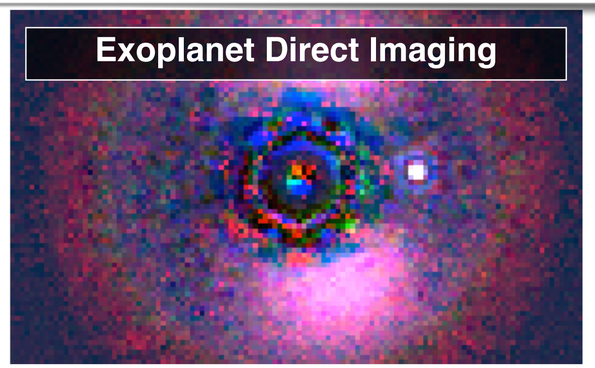
Look for Proposal opportunities for a range of preparatory science programs beginning in 2021

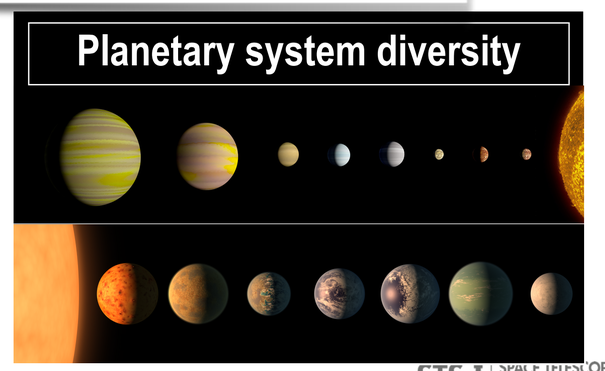












Resources

https://roman.gsfc.nasa.gov/

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

https://wfirst.ipac.caltech.edu/

https://www.jpl.nasa.gov/missions/the-nancy-grace-roman-space-telescope/