WFIRST: Survey Overview & Mission Status

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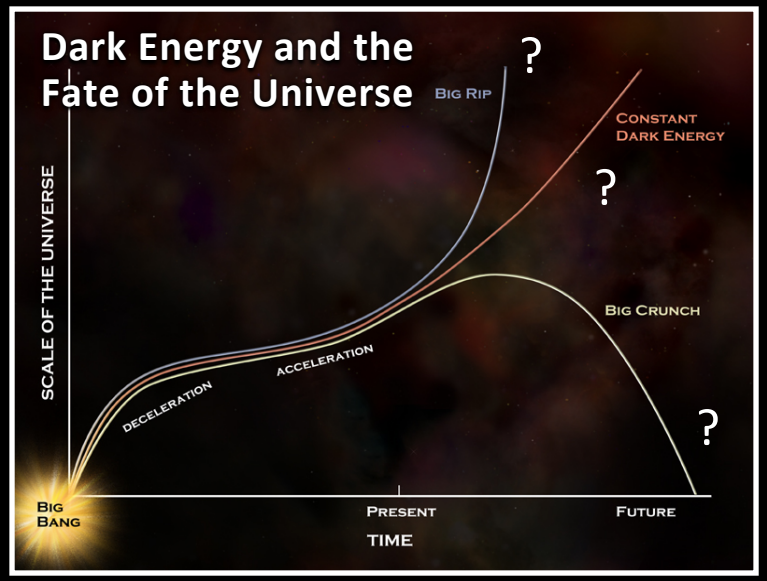
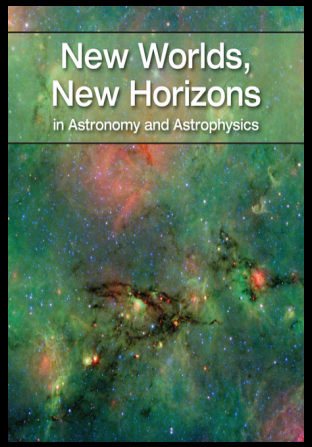
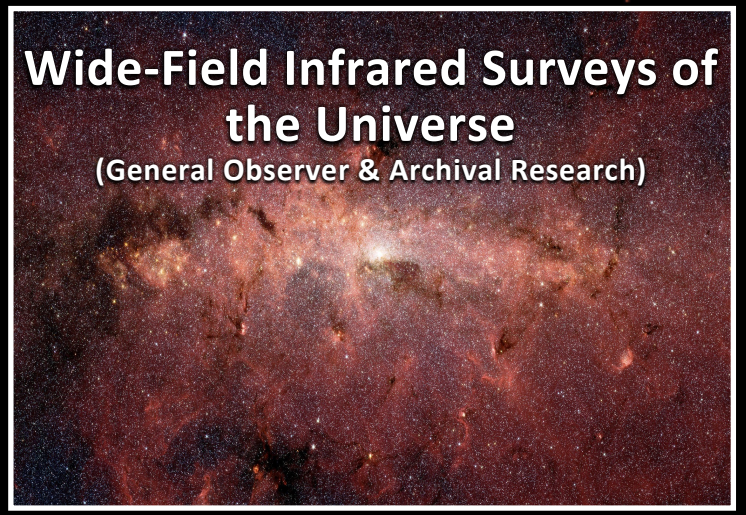
Guidance from NWNH

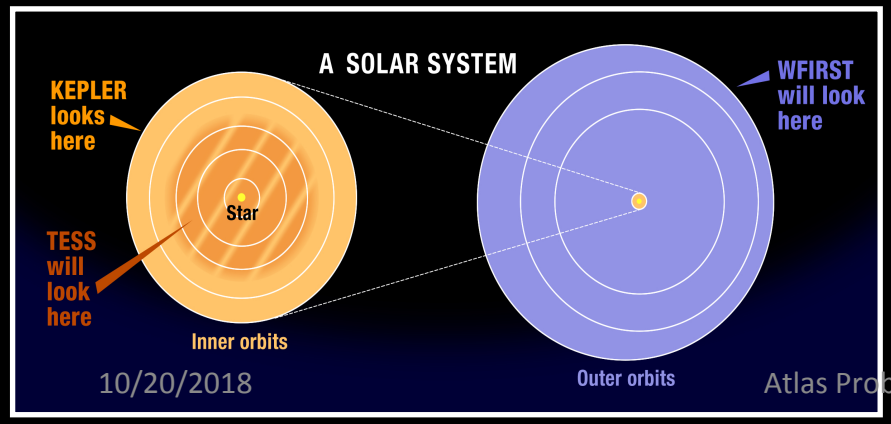
WFIRST
WIDE-FIELD INFRARED SURVEY TELESCOPE
DARK ENERGY • EXOPLANETS • ASTROPHYSICS







The full distribution of planets around stars

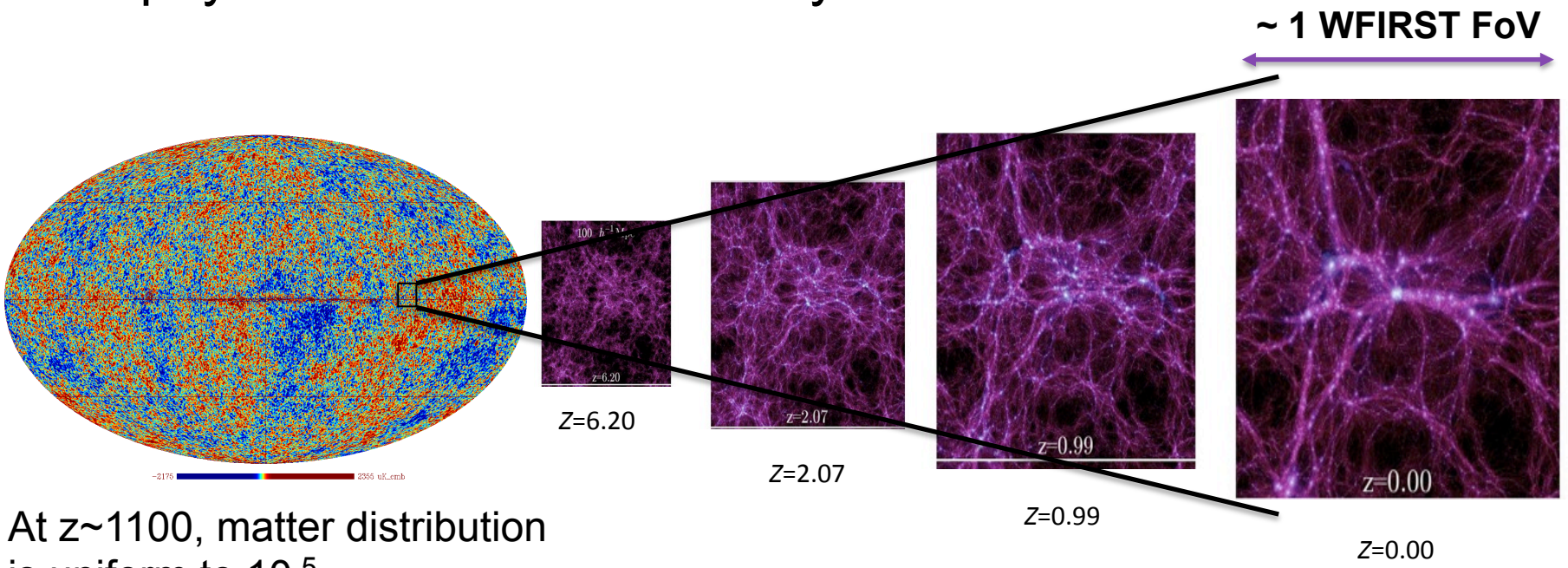


Wide FoV enables study of evolution of the Universe

WFIRST will measure expansion history *and* growth of structure

- If results discrepant -> breakdown of general relativity
- If results agree -> learn about nature of dark energy

WFIRST provides multiple probes, enabling cross-checks for astrophysical and instrumental systematics

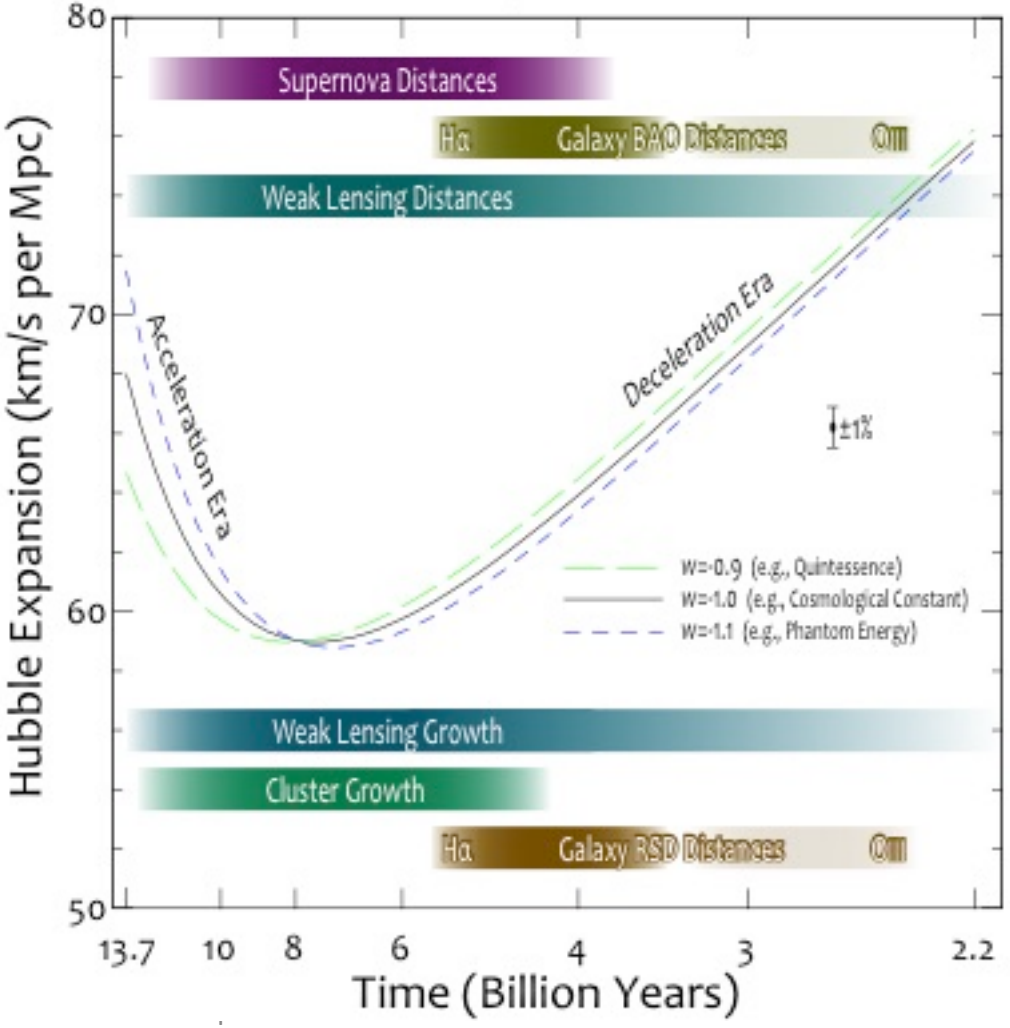


At z~1100, matter distribution is uniform to 10^{-5}

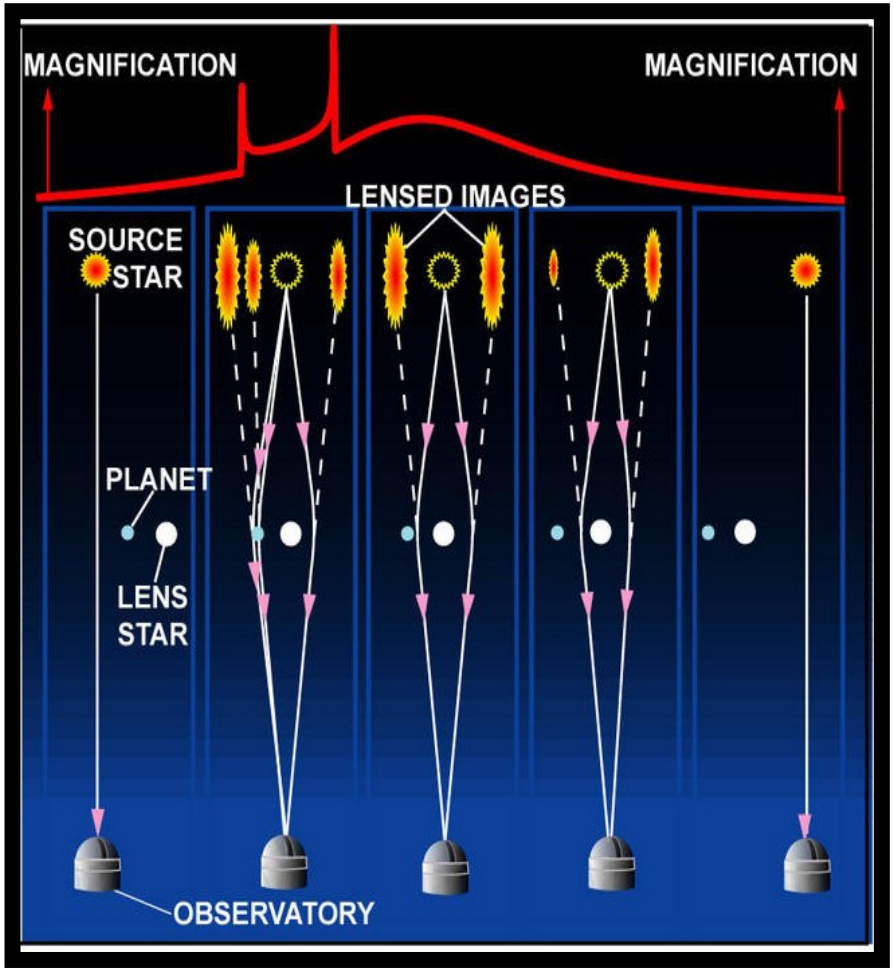
WFIRST Dark Energy Program

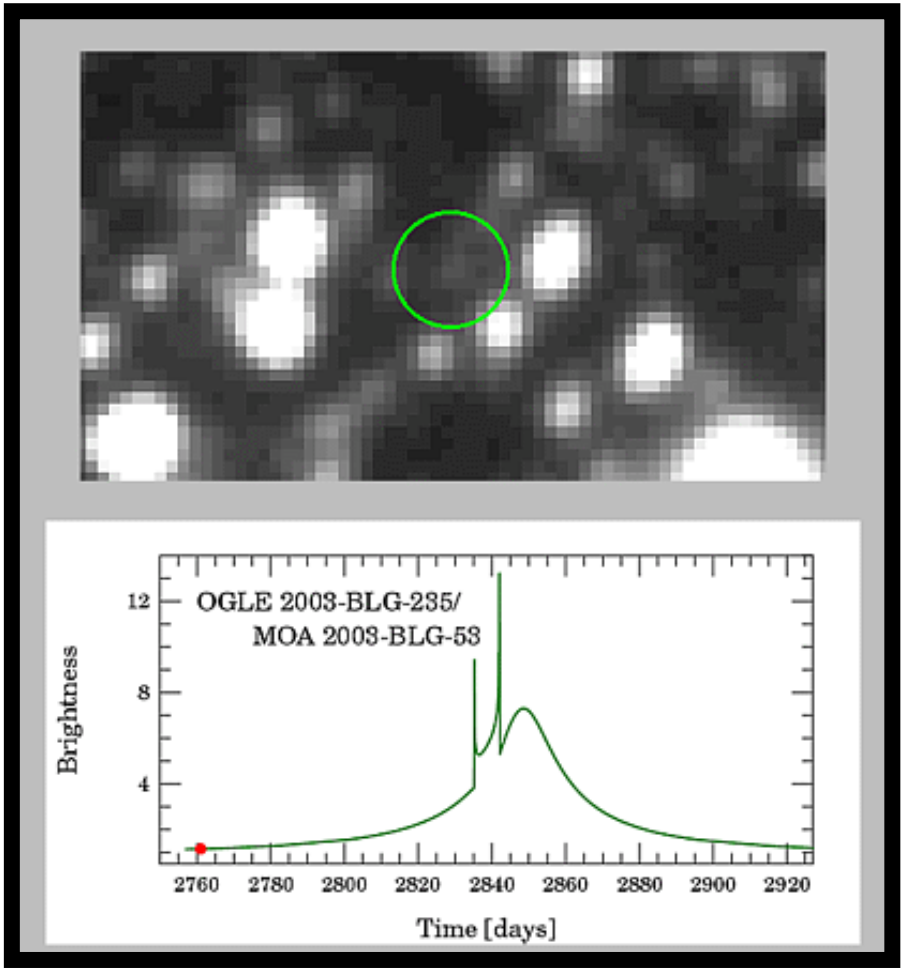
- WFIRST combines all techniques to determine the evolution of the universe and the Dark Energy and Dark Matter.
- WFIRST is the only observatory doing such comprehensive observations

WFIRST Measures Expansion and Growth



Microlensing





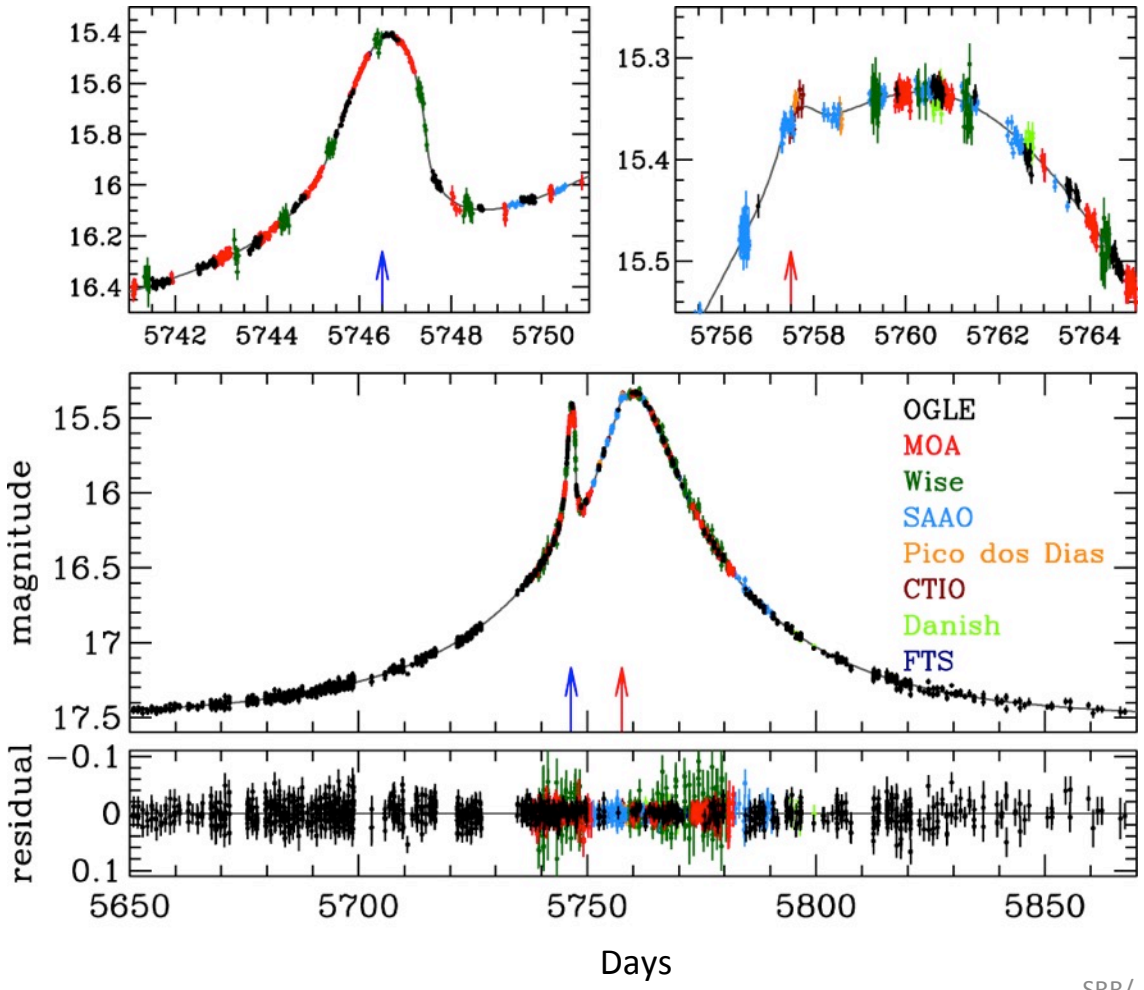
Microlensing
Observables

Microlensing event from Jupiter-mass planet around an M-dwarf (Skowron et al 2015)

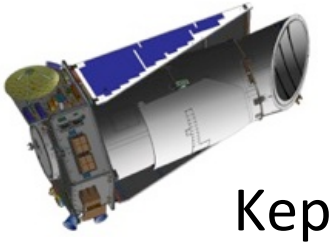
Shape of light curve is governed by changing geometry of source & host stars & planet; motion of Earth about Sun affects shape of star-star light curve.

High-precision relative photometry is essential

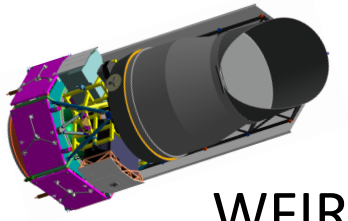
- Flux calibration over time
  - ≤0.1% over a season
- Flux calibration linearity



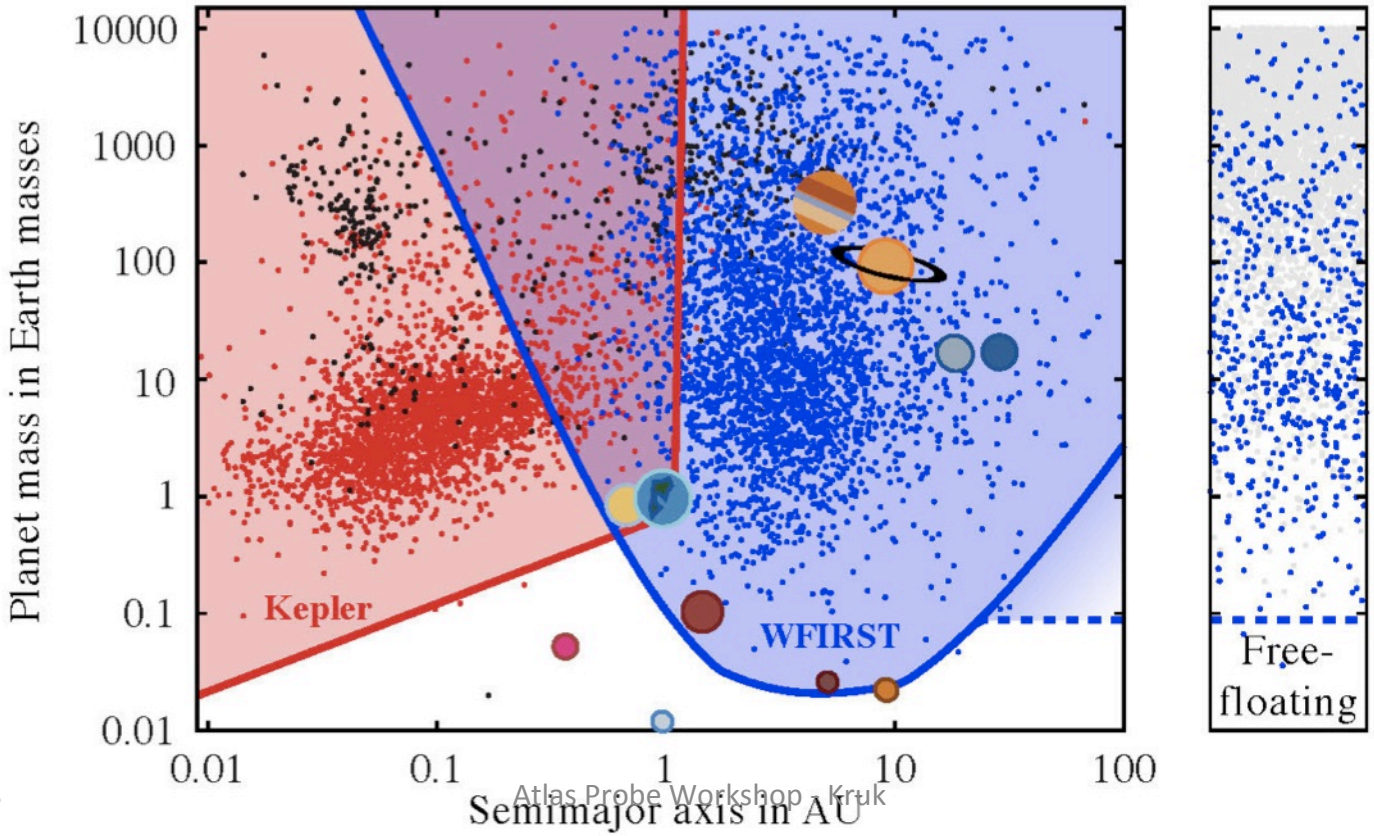
Compete the Census of Exoplanets - Microlensing



Kepler



WFIRST



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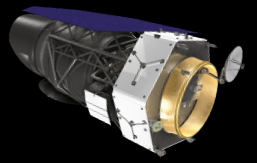
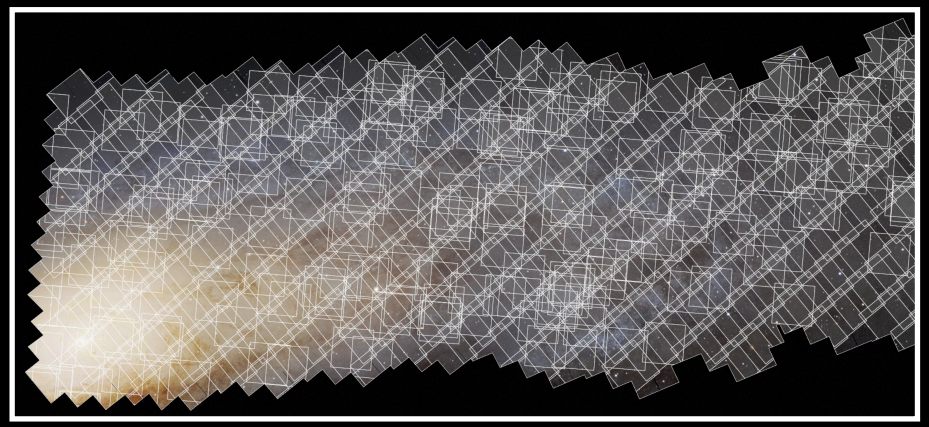
Sample GO Program
Assembly of Galaxies

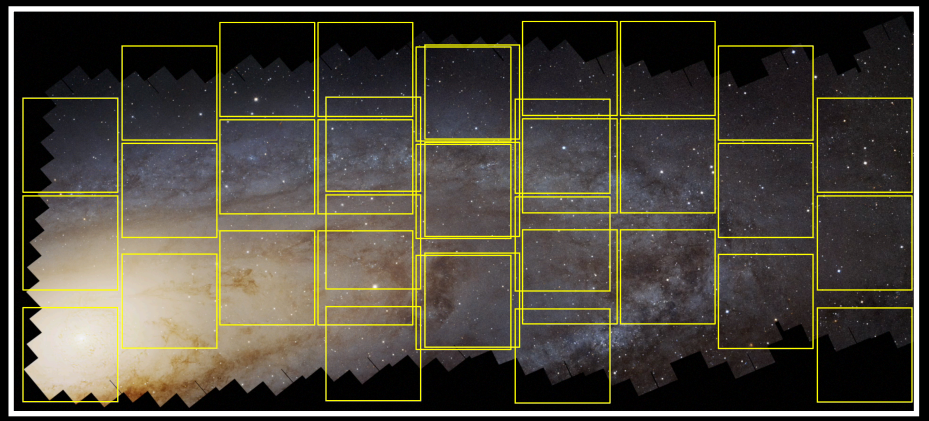
Andromeda - PHAT Survey

The Hubble Way
(400+ individual pointings)

The WFIRST Way
(2 pointings)







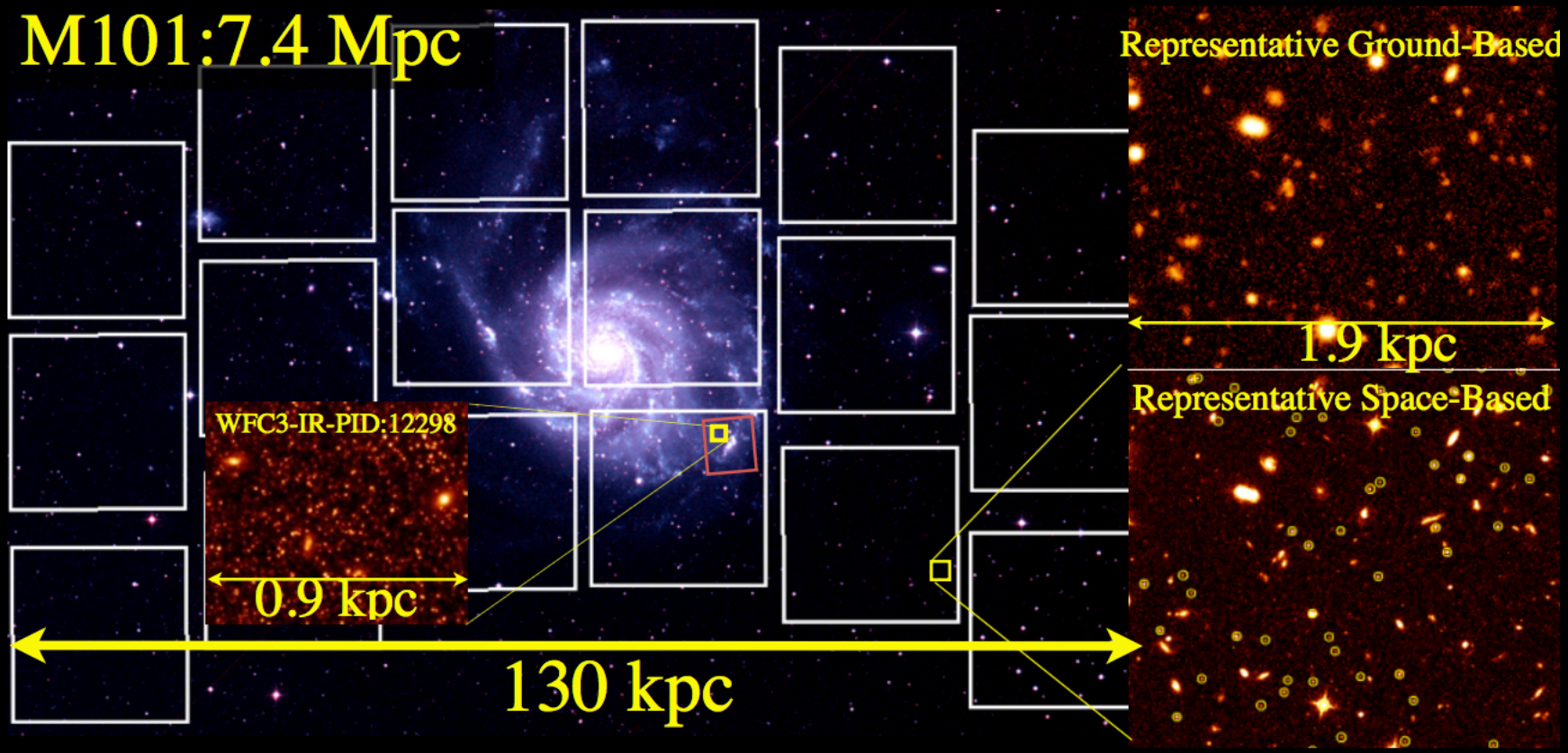
WFIRST will survey nearby galaxies 100x faster than Hubble

Nearby Galaxies - A Bridge to the Distant Universe

WFIRST Survey of Nearby Galaxies - Targets: stellar halos, dwarf satellites, globular clusters

–Age dating as a route to astrophysics
– Star forming regions
– The limits of galaxy and halo formation
– The history of galaxy clusters

–The local flow field
– Dust and ISM
– Stellar evolution



High Contrast Coronagraph as Technology Pathfinder

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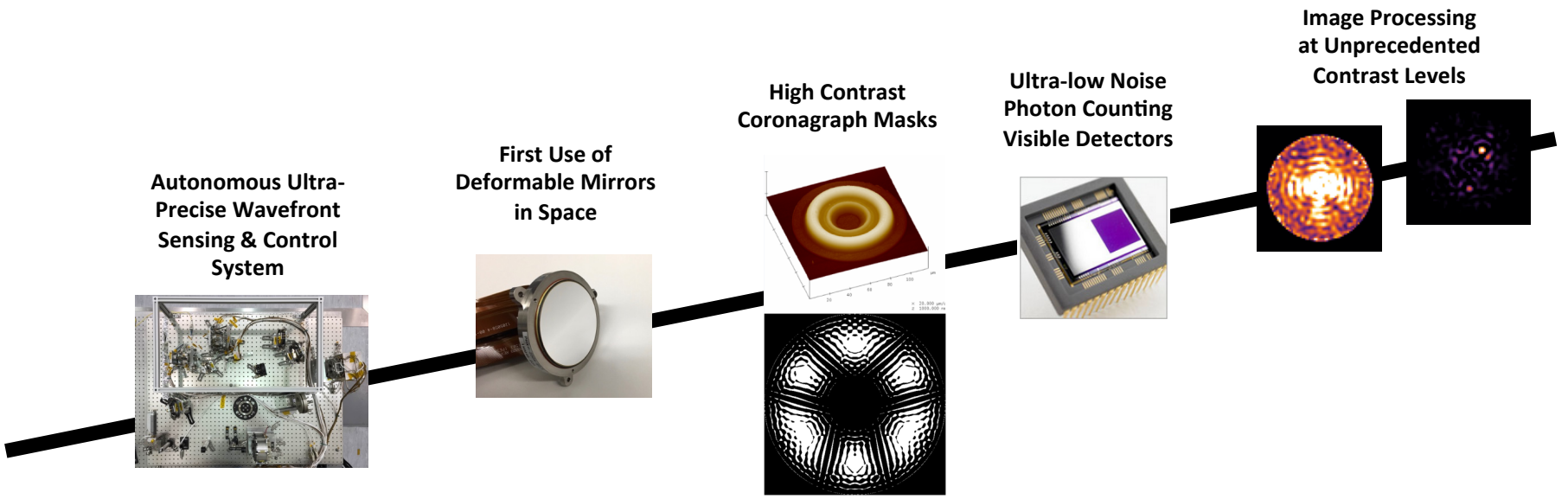
Technology	• Low-order Wavefront Sensing and Control • Deformable Mirrors • Broad-band Coronagraphic Masks for Very High Contrast • Ultra-low Noise Photon Counting Detectors • High Contrast Imaging on Obscured / Discontinuous Aperture • Integral Field Spectrograph at Very High contrast

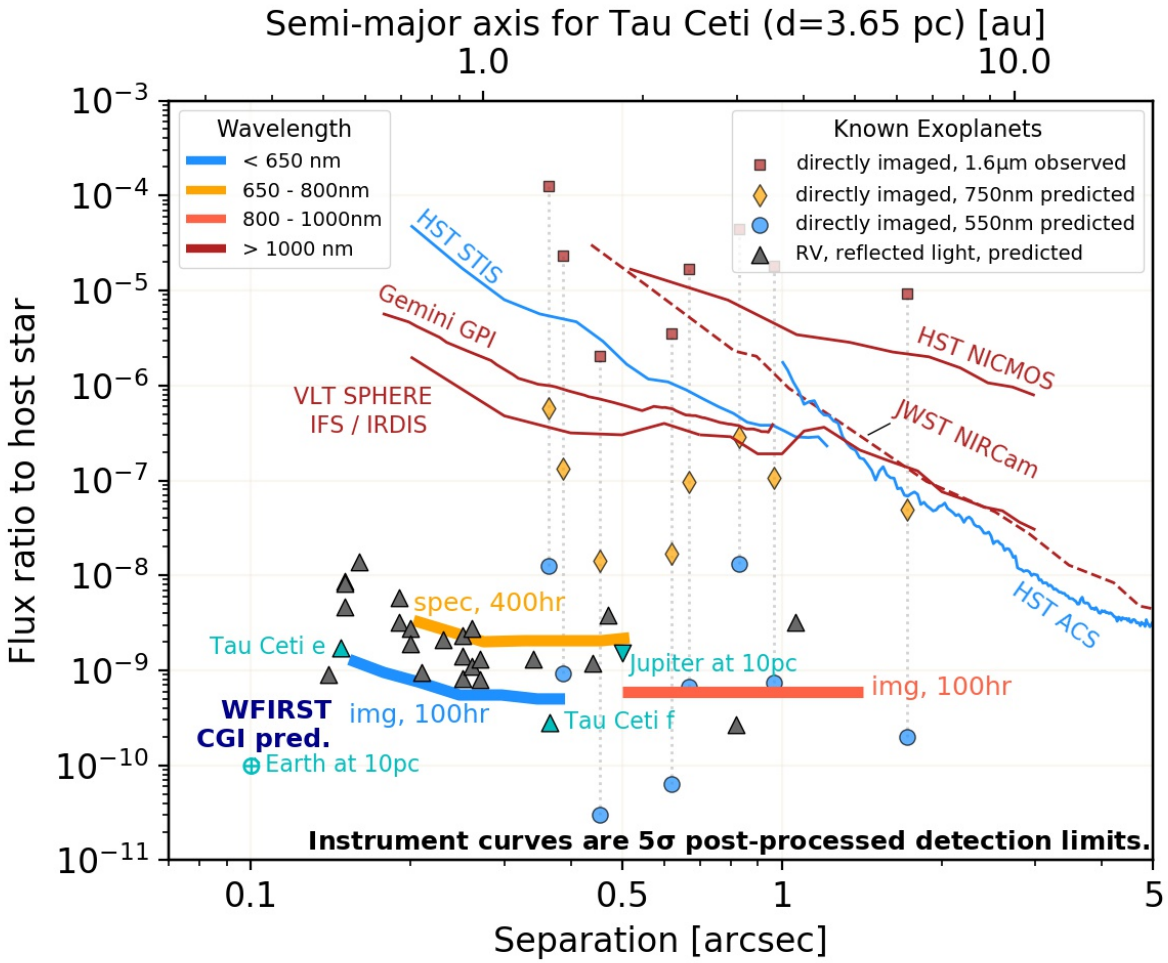


- CGI will premiere in space many key technologies required for the characterization of rocky planets in the Habitable Zone (HZ), significantly reducing the risk and cost of future possible mission concepts such as HabEx and LUVOIR
- CGI is a direct & necessary predecessor to these missions, and is a *crucial* step in the exploration of Sun-like planetary systems

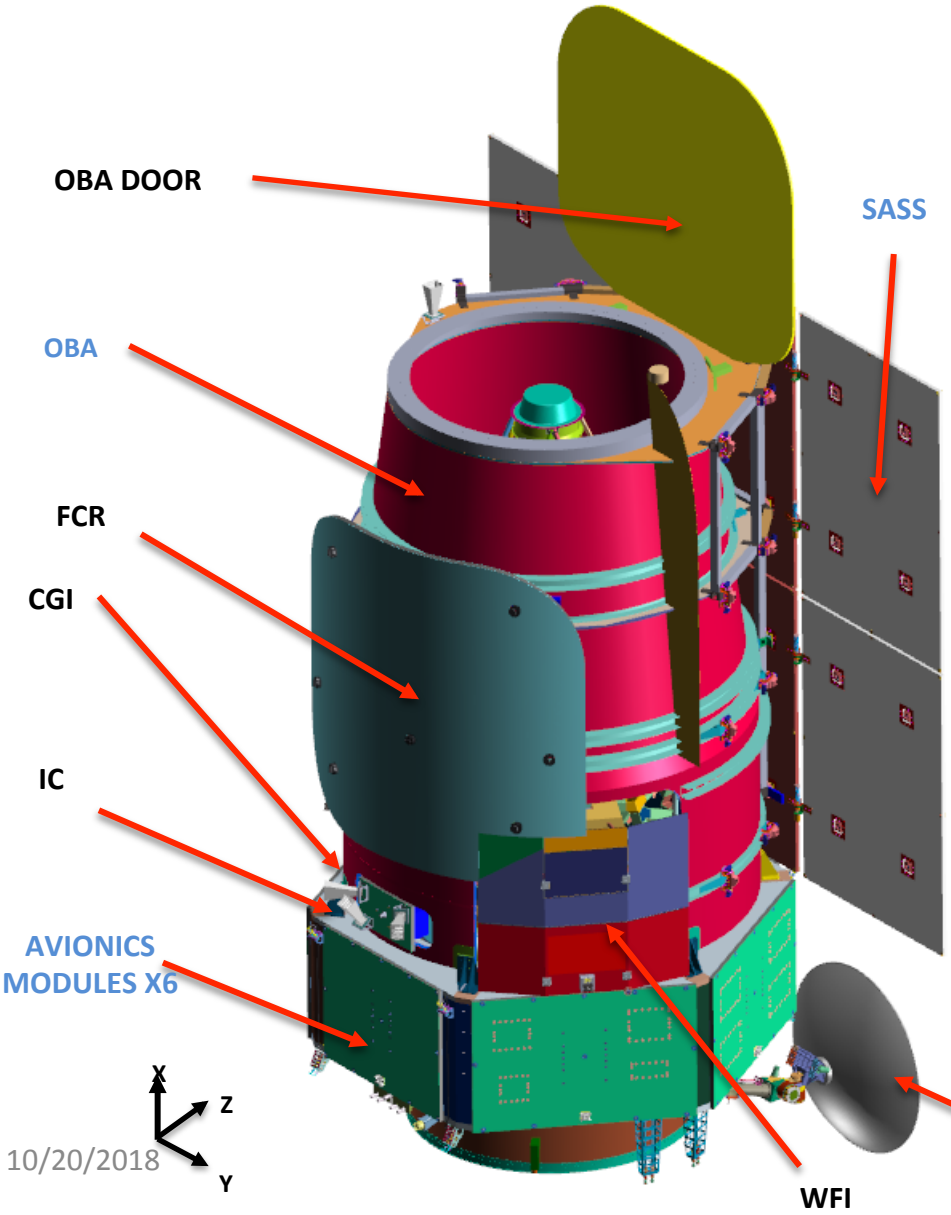
WFIRST Brings Humanity Closer to Characterizing exo-Earths

If present performance predictions are realized, there is potential for:

- 1000-fold improvement over present capabilities.
- Dozens of planets within reach of characterization
- Detection limit can reach super-Earths



WFIRST Observatory Concept



Key Features

Telescope: 2.4m aperture

Instruments:

- Wide Field Imager / Slitless Spectrometer
- Internal Coronagraph with Integral Field Spectrometer

Data Downlink: 275 Mbps

Data Volume: 11 Tb/day

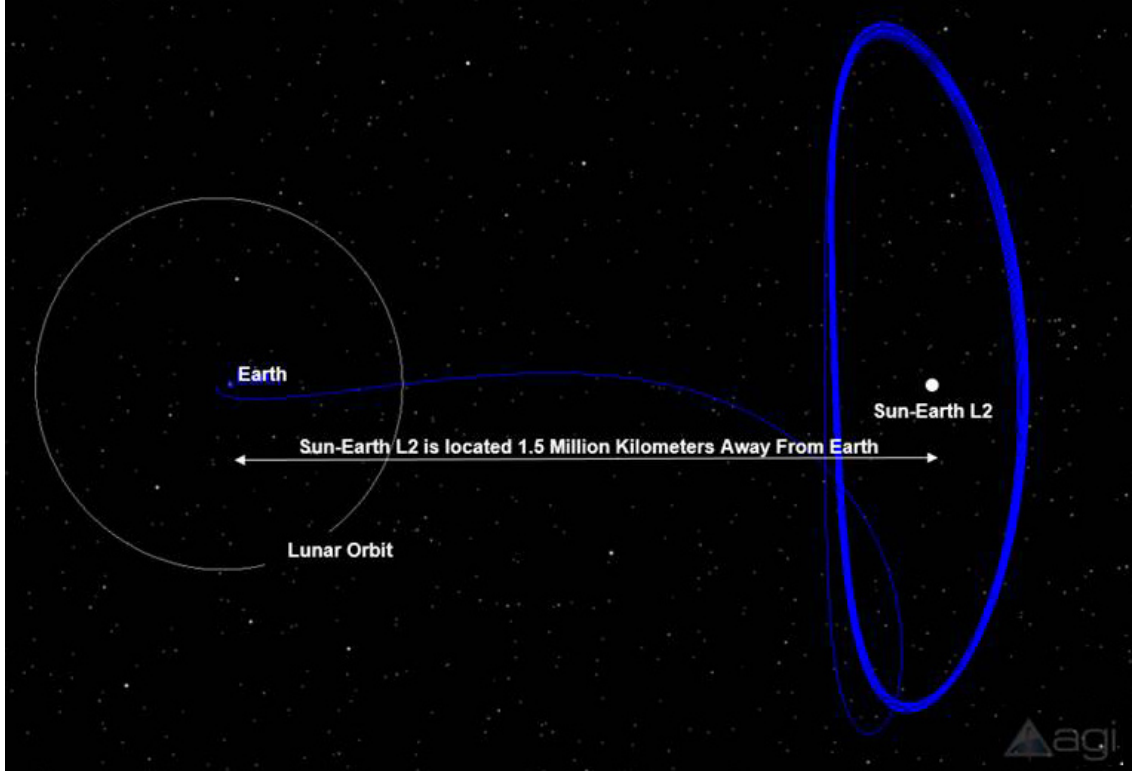
Orbit: Sun-Earth L2

Launch Vehicle: 3 options

Mission Duration: 5 yr, 10yr goal

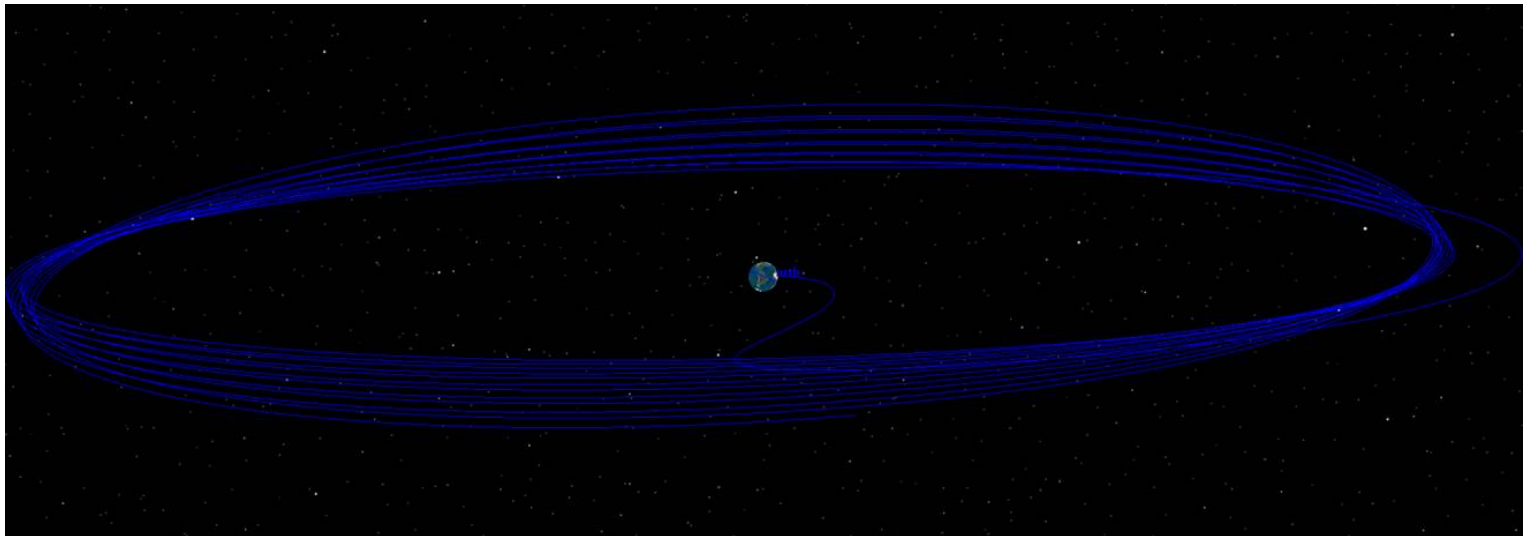
Serviceability: Observatory designed to be robotically serviceable

Starshade compatible



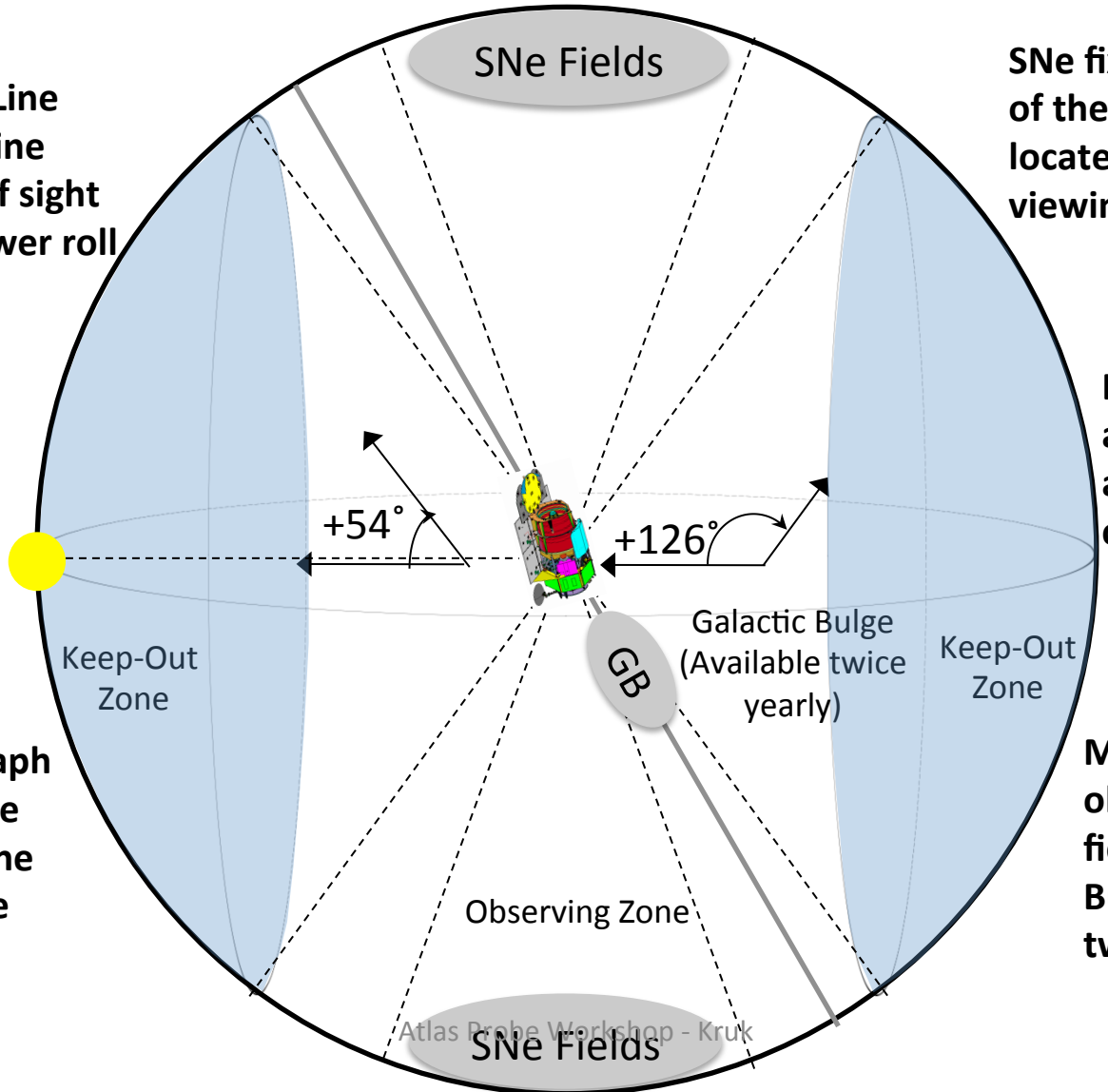
WFIRST orbit seen looking down on ecliptic plane

WFIRST orbit seen looking out from Sun



Field of Regard (FOR)

Observing Zone:
- **54˚-126˚ off Sun Line**
- **360˚ about Sun Line**
- **±15˚ about line of sight (LOS) off max power roll angle**



SNe fixed fields ±20˚ off of the ecliptic poles, located in continuous viewing zone

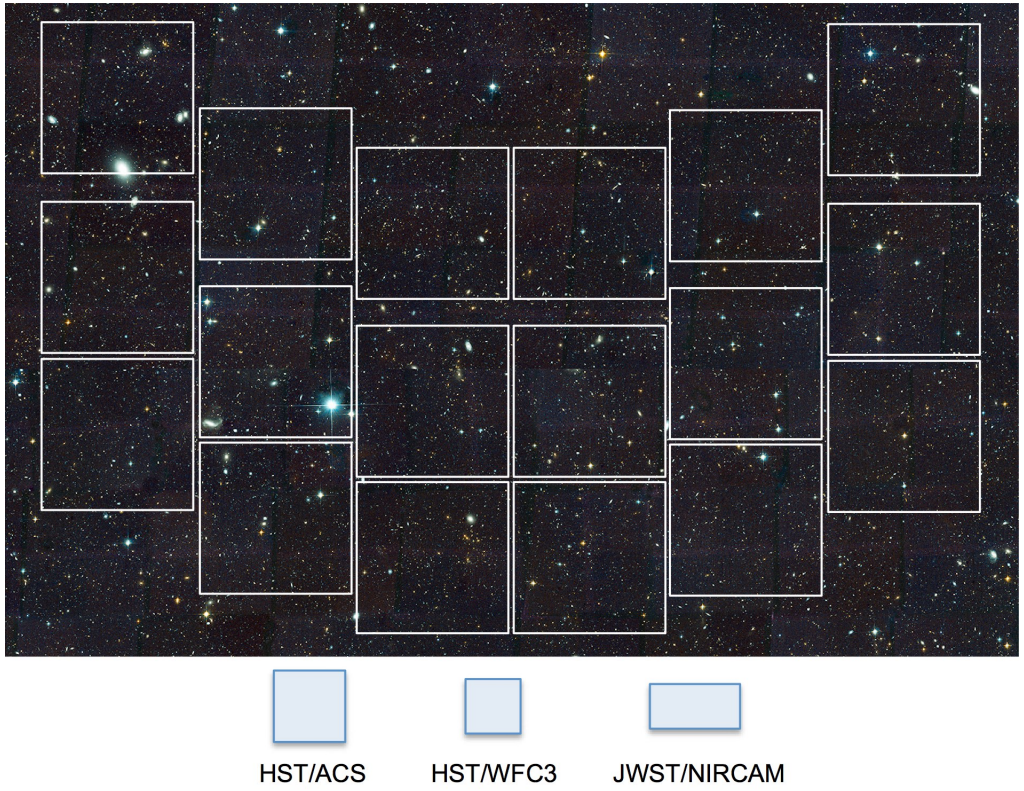
Earth/Moon LOS avoidance angles are a minor sporadic constraint

HLS/GO/Coronagraph observations can be optimized within the full Observing Zone

Microlensing can observe inertially fixed fields in the Galactic Bulge (GB) for 72 days twice a year

Wide-Field Instrument

WFIRST Field of View



Diffraction-limited imaging
0.28 square degree FoV
0.11” pixels
6 R~4 filters spanning 0.48-2.0 μm
1 wide filter 0.93-2.0 μm
Sensitivity: 27.8 H(AB) @5σ in 1hr

Slitless grism:
1.0-1.93 μm
R: 435-865

Representative Surveys

- Actual survey designs won't be chosen until close to launch, but those presently being studied can illustrate the type of data that will be available in the archive.

Representative Surveys

High Latitude Survey 5σ point-source sensitivity (AB mag), 6.5σ line flux						
	Area	Y106	J129	H158	F184	Grism
Wide	2000	26.9	26.95	26.9	26.25	1.0E-16
Deep	20	28.2	28.2	28.2	27.55	2.5E-17

Supernova Survey 5σ point-source sensitivity (AB mag) *5-day cadence*, 146 visits							
	Area	R062	Z087	Y106	J129	H158	F184
Wide	14 sq deg	28.1	27.8	27.8	28.3	28.7	---
Deep	5 sq deg	----	28.7	29.5	29.4	29.6	29.7

Representative Surveys

- Microlensing: 2 sq deg monitored at cadences:
  - 15min W149 filter, 12hr in 2 other filters (R or Z, and Y or J), all filters on occasion (weekly?)
  - 6 seasons of 60-72 days each
  - Excellent temporal sampling
    - asteroseismology , astrometry

What do we get by stacking one season of data?

5σ point-source sensitivity (AB mag) from one season								
Cadence	**Visits/season**	**R062**	**Z087**	**Y106**	**J129**	**H158**	**F184**	**W149**
15 min	**6912**							**>30**
12 hr	**144**	**28.0**	**27.65**	**27.6**	**27.5**			
Week(?)	**10**	**26.55**	**26.2**	**26.1**	**26.0**	**26.0**	**25.55**	

GO Surveys

- We don't know what they will be, but can think about possibilities.

Limiting point-source sensitivity (AB) in 1 hour 5σ imaging, 10σ grism continuum flux							
R062	Z087	Y106	J129	H158	F184	W149	Grism
28.5	28.15	28.1	28.0	28.0	27.5	28.5	20.25

Assuming twice minimum zodiacal light & conservative throughput & instrument background properties

Project Status

- System Requirements Review / Mission Definition Review held February 27 – March 1
  - Do we have the right requirements? / Does the mission design meet those requirements?
- KDP-B completed May 22, 2018
  - **WFIRST now in Phase B!**

- White House FY2019 budget proposed termination of WFIRST to fund other priorities
- Direction from HQ is to proceed while Congress deliberates
  - *Preliminary indications are that WFIRST will be fully funded in FY2019*

SMD/APMC Direction

- Mission technical baseline unchanged, except:
  - Integral Field Channel descoped – 4/27/2018
  - Will likely to add a slitless prism optimized for SNIa
    - R~70-100, 0.8-1.6 (2.0) um
- Phase A-E cost remains at $3.2B (50% CL)
  - APD to provide "optimal" funding profile
- Present schedule:
  - PDR: late 2019
  - CDR: mid 2021
  - **Launch: 3rd quarter 2025**

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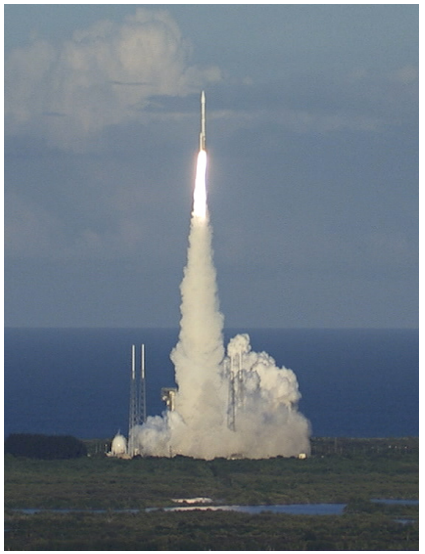
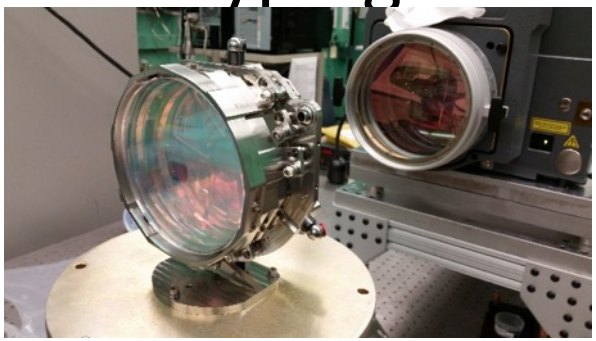
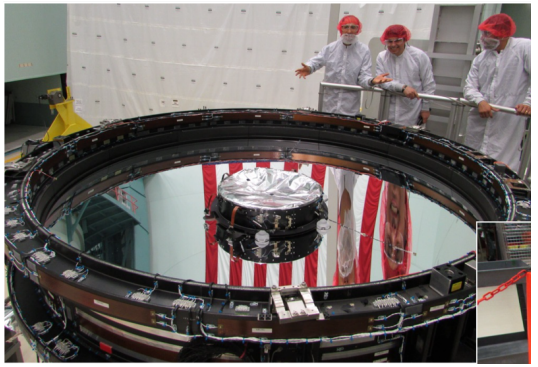


Hardware status

- First flight detectors to be delivered Dec 2018
- Complete prototype signal chain electronics tested, including new ASIC
  - Will start flight production of ASICs early 2019
- Primary mirror ion figuring starts next week
- Prototype grism built, testing starts next week





Partnerships

JAXA	Coordinated, contemporaneous ground-based observations on Subaru Ground station for telemetry and tracking Polarization optics for the CGI Microlensing data from the MOA project
DLR	Precision mechanisms for the CGI
ESA	Star trackers, possibly other S/C components EMCCD detectors for the CGI Ground station for telemetry and tracking
CNES	Superpolished optics for the CGI Grism data processing Cosmology simulations

Science Investigations

- All observing time to be selected competitively
  - Some close to launch, the rest periodically thereafter
- All data will be public immediately
  - Archival research will be funded on a par with GO programs
- Scientific priorities to be updated throughout mission, based on landscape at the time
- Coronagraph available through a Participating Scientist Program
- Changes under consideration:
  - Models for time allocation to large programs
  - Models for structure of teams for large programs
  - Have begun consultations w/FSWG and will be seeking community input on both topics
  - Deep Field workshop held August 30-31


WIDE-FIELD
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QUESTIONS?

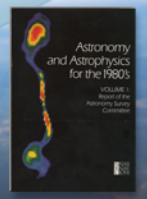
ASTROPHYSICS

Decadal Survey Missions

1972
Decadal Survey
Hubble

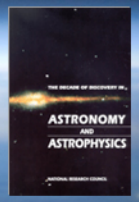
1990

1999



1982
Decadal Survey
Chandra

2003

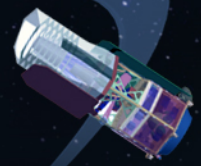


1991
Decadal Survey
Spitzer

LRD: 2019

2001
Decadal Survey
JWST, SOFIA

LRD: 2020s



2010
Decadal Survey
WFIRST

Science Goals

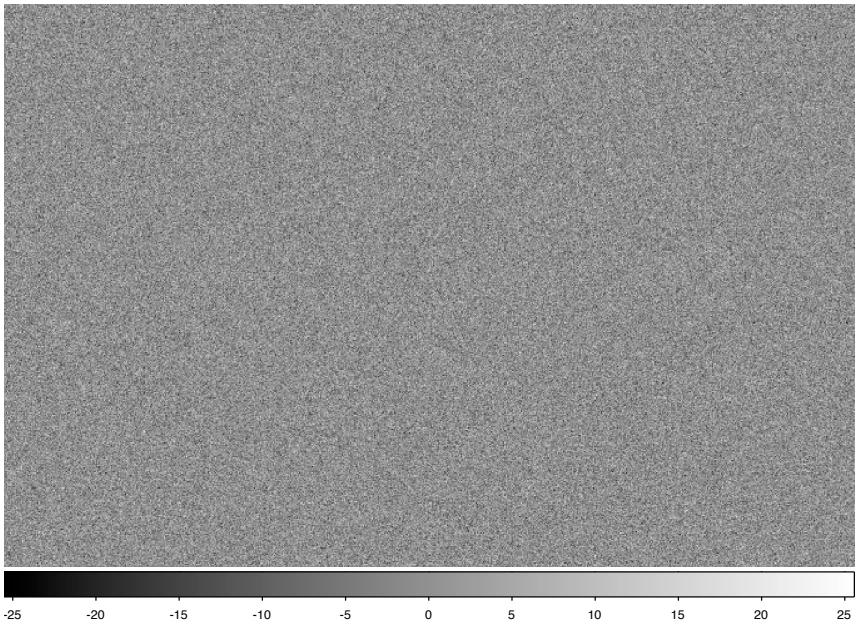
- **Produce Hubble quality infrared sky images and spectra over 1000's of square degrees of sky**
- **Determine the expansion history of the Universe and the growth history of its largest structures in order to test possible explanations of its apparent accelerating expansion including Dark Energy and modifications to Einstein's gravity.**
- **Complete the statistical census of planetary systems in the Galaxy, from the outer habitable zone to free floating planets**
- **Demonstrate new technologies enabling direct imaging & spectroscopy of giant planets and debris disks from habitable zones to beyond the ice lines and characterize their physical properties.**
- **Provide a robust guest observer program utilizing a minimum of 25% of the time over the 5 year baseline mission and 100% in following years.**
- **Provide a robust archival research program with access to all data from the mission.**

An aside on noise

- Detector readnoise is comparable to zodi for imaging on WFIRST, smaller by factor of a few for slitless spectrocsopy
- Substantial R&D failed to make much improvement to readnoise
  - Order of magnitude improvements to persistence
- Slits on Atlas will help a lot, but readnoise will limit the gains

When Good noise turns Bad

What goes into S/N models:



What noise should look like.
Measuring RMS noise tells you what variance to assign to a given pixel.
No bias on measurements.

When Good noise turns Bad

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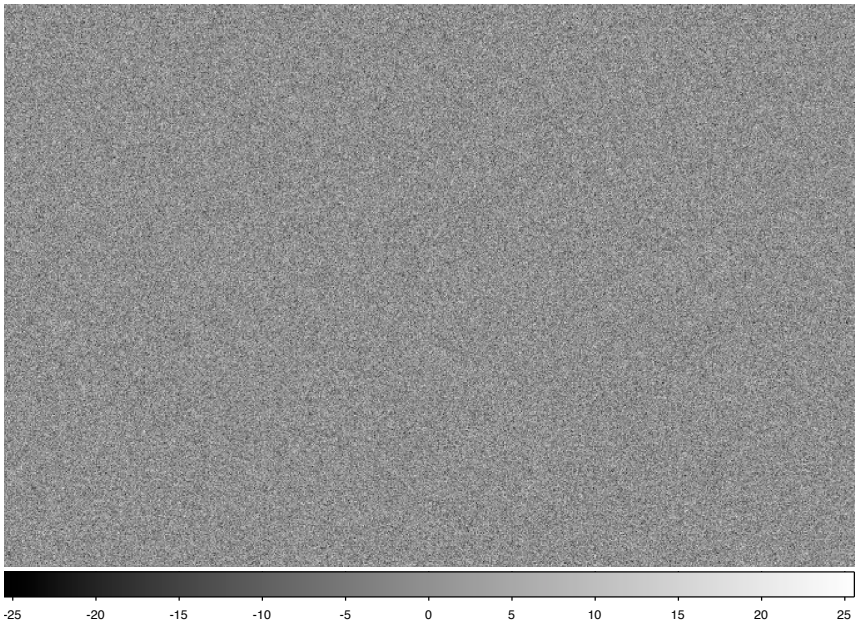

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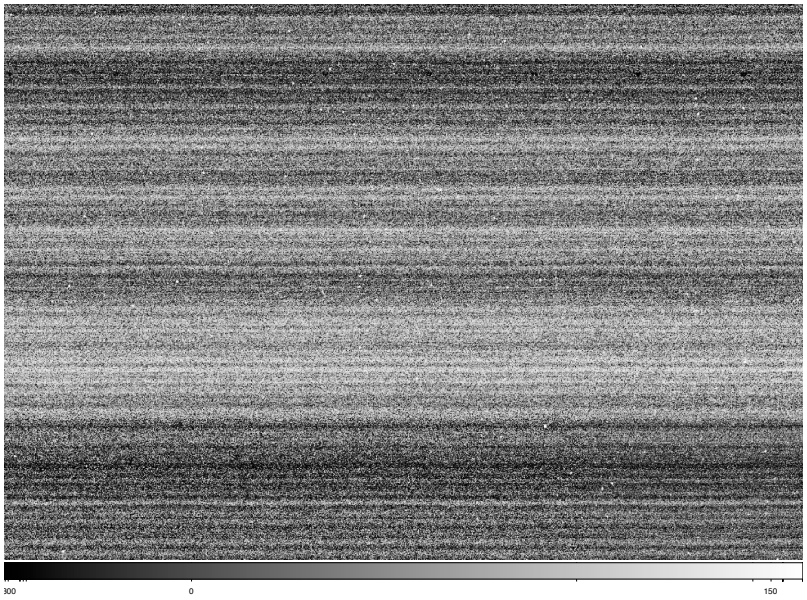
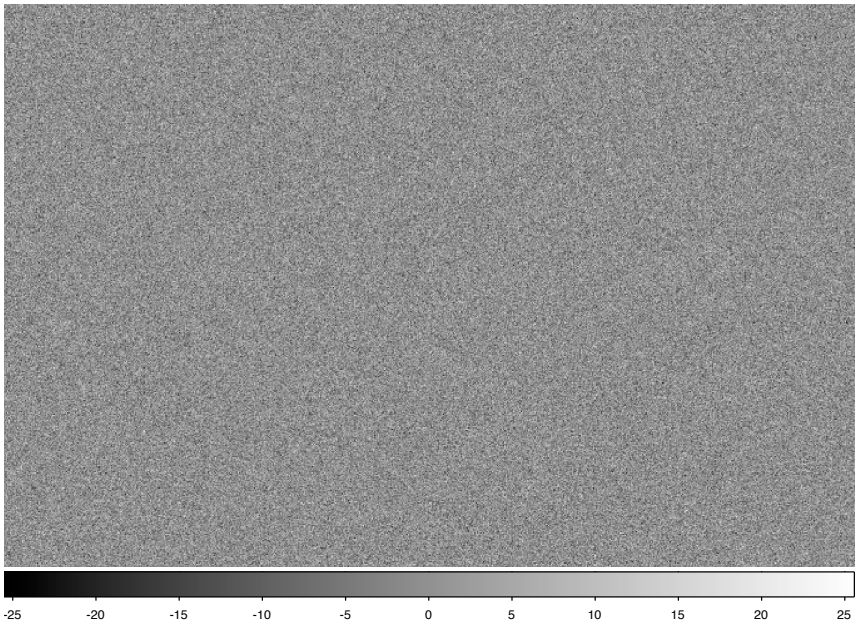
What you actually get:



H4RG 17634 with SIDECAR.
Measuring RMS noise doesn't tell you what is affecting any given pixel or group of pixels. Effects are systematic as well as random; ellipticity systematically biased.

When Good noise turns Bad

What goes into S/N models:



WFIRST R&D has not improved CDS noise, but has greatly improved readout electronics. Now expect uniformity much closer to expectation.

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Measuring RMS noise tells you what variance to assign to a given pixel.
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