

WFIRST STATUS

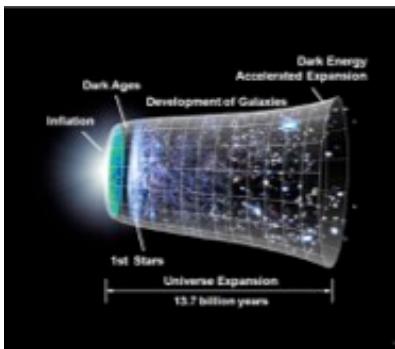
SSB meeting, April 27, 2016

Neil Gehrels/GSFC
Project Scientist

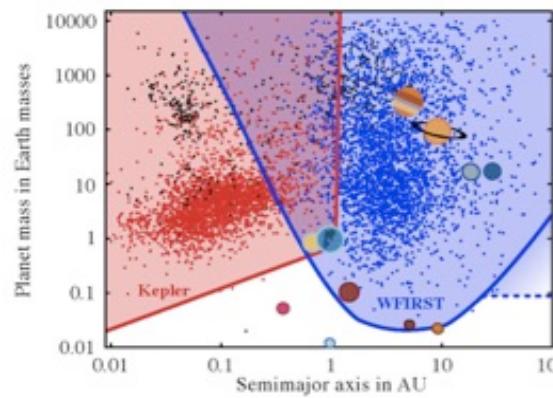


- WFIRST highest ranked large space mission in 2010 Decadal Survey
 - Study Dark Energy, Exoplanet Census, NIR Sky Survey
- Use of 2.4m telescope enables
 - Hubble quality imaging over 100x more sky
 - Imaging of exoplanets with 10^{-9} contrast with a coronagraph

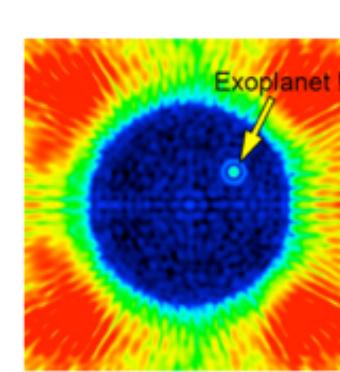
Dark Energy



Exoplanets

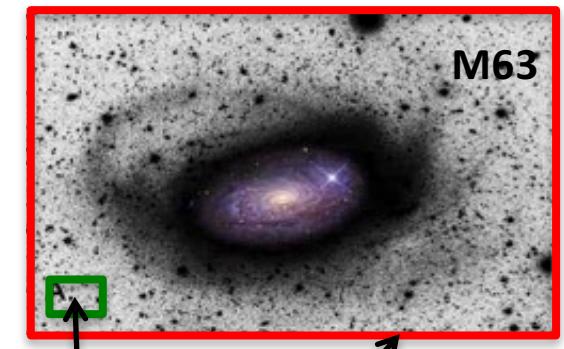


Microlensing



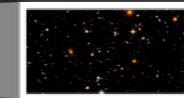
Coronagraph

Astrophysics



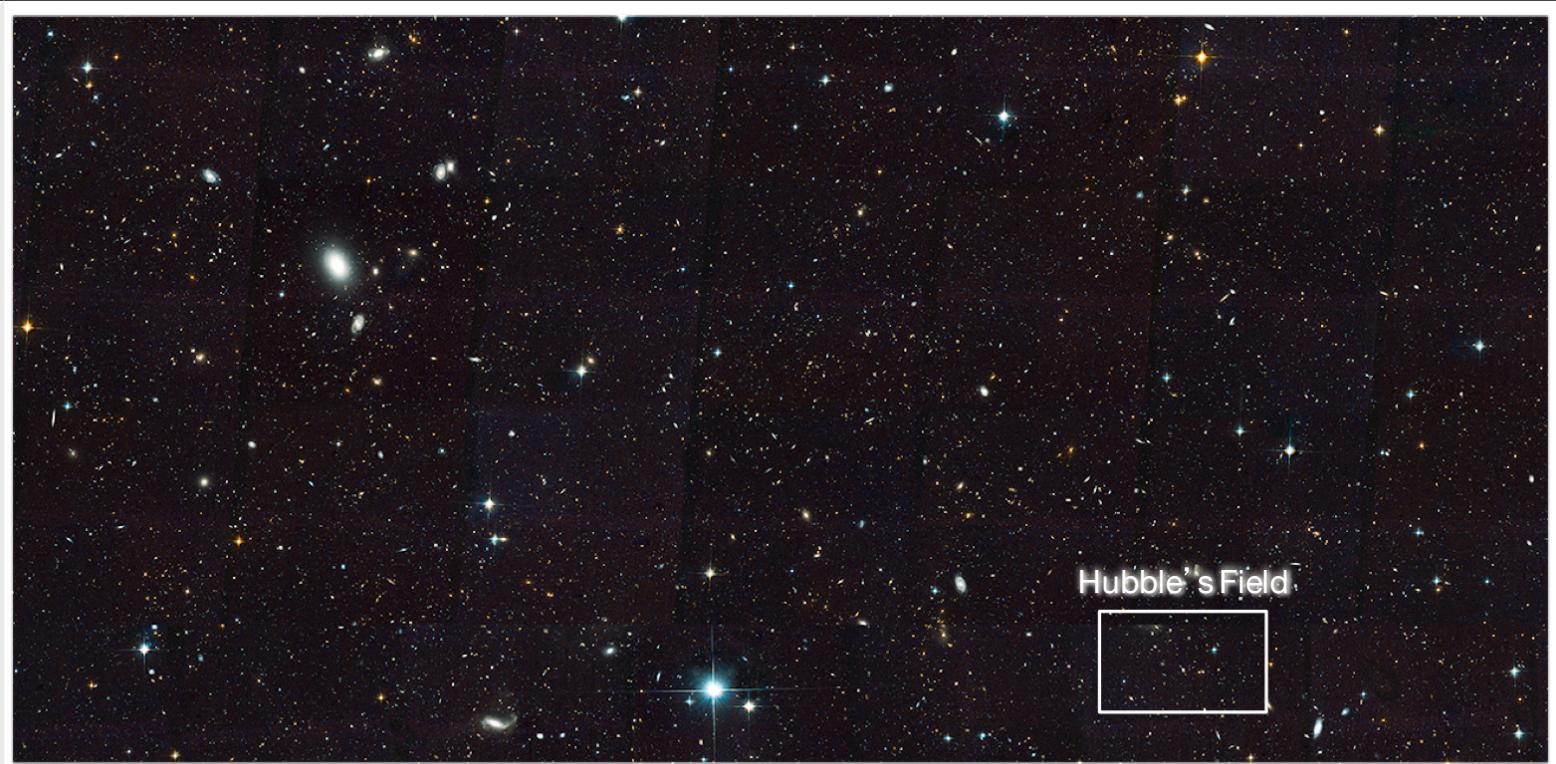
WFIRST

Hubble - A Spectacular Start



The Hubble Ultra Deep Field
seeing the Universe, 10,000
galaxies at a time

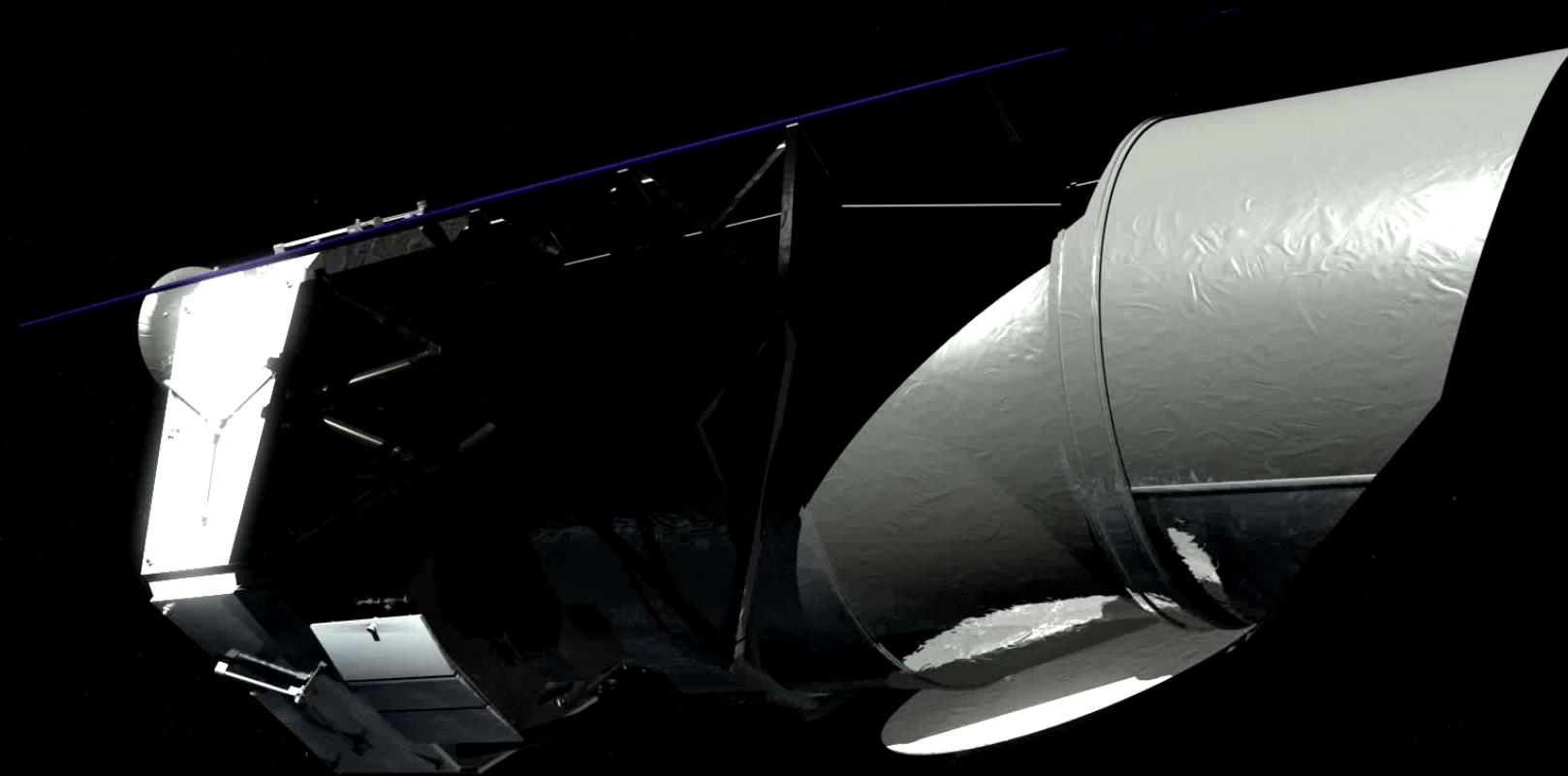
WFIRST - Hubble X 100

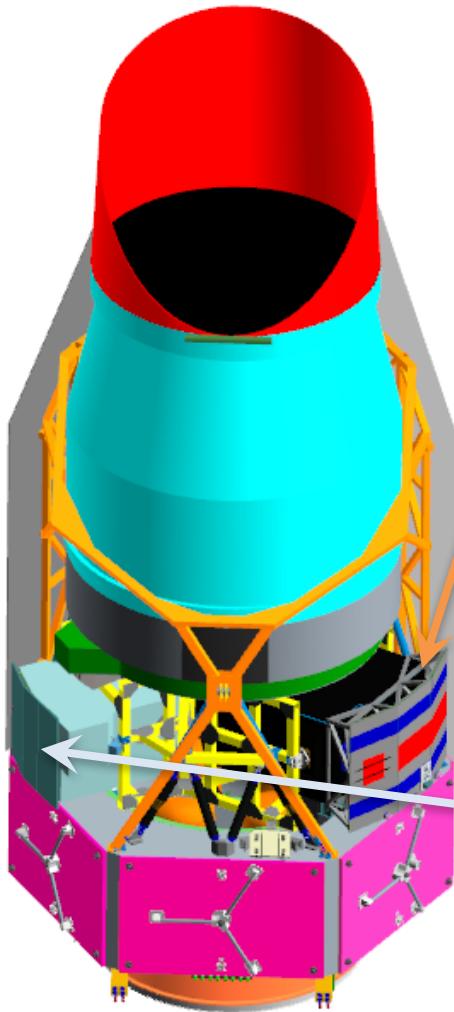


A WFIRST Deep Field
A New Window on the Universe - **1,000,000** galaxies at a time



- 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
- Directly image 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 6 year baseline mission and 100% competed in following years.



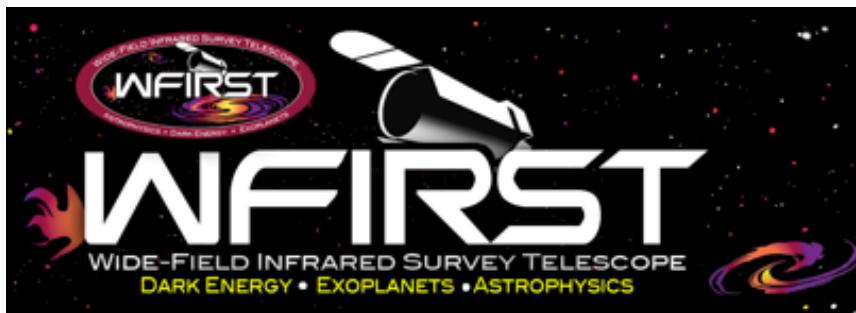


Wide Field Instrument

- *Imaging & spectroscopy over 1000s of sq. deg.*
- *Monitoring of SN and microlensing fields*
- Near infrared bandpass
- Field of view 100 x HST and JWST
- 18 H4RG detectors (288 Mpixels)

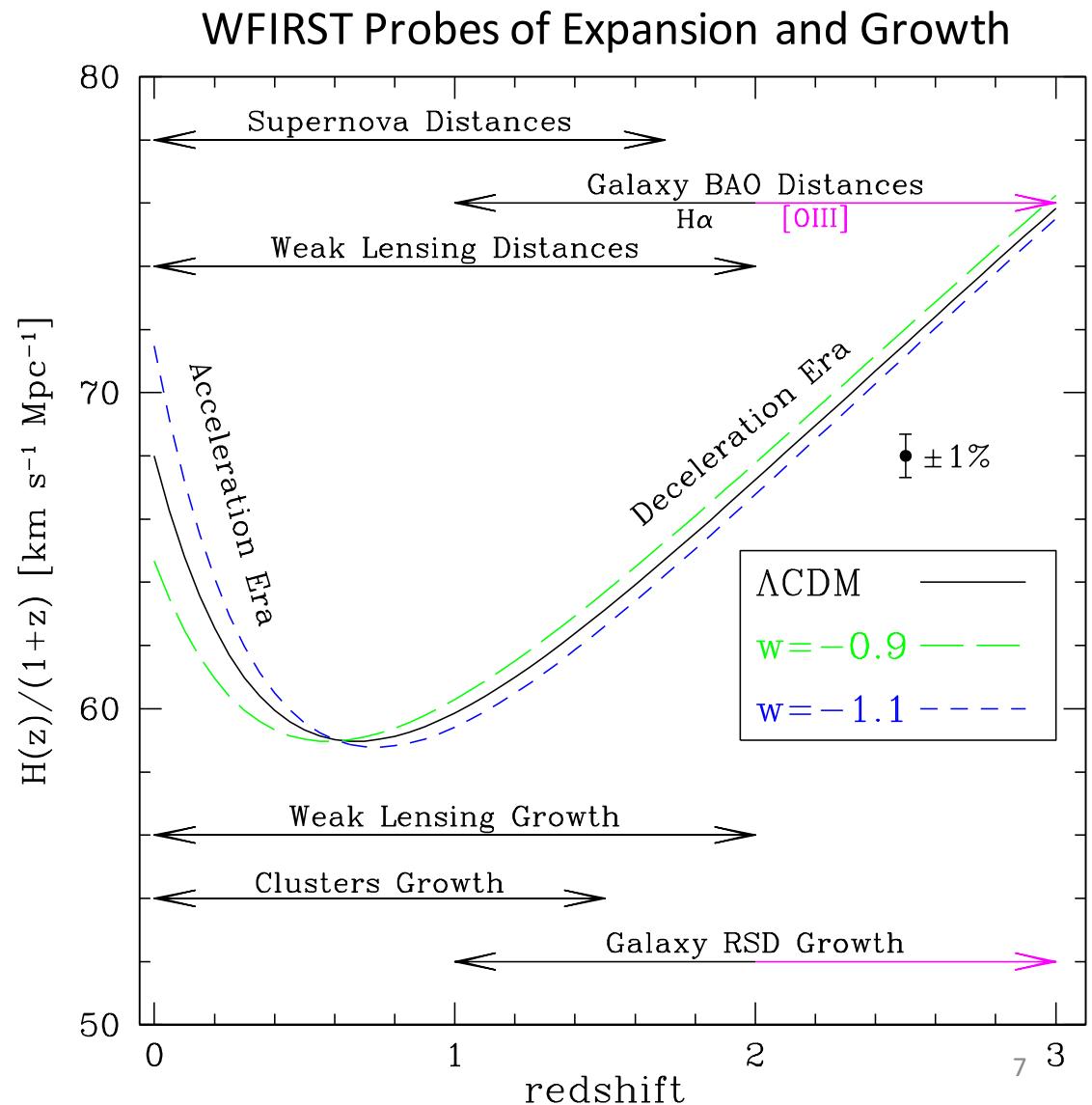
Coronagraph

- *Image and spectra of exoplanets from super-Earths to giants*
- *Images of debris disks*
- Visible bandpass
- Contrast of 10^{-9} or better
- Exoplanet images from 0.1 to 1.0 arcsec



Premier Dark Energy Observatory

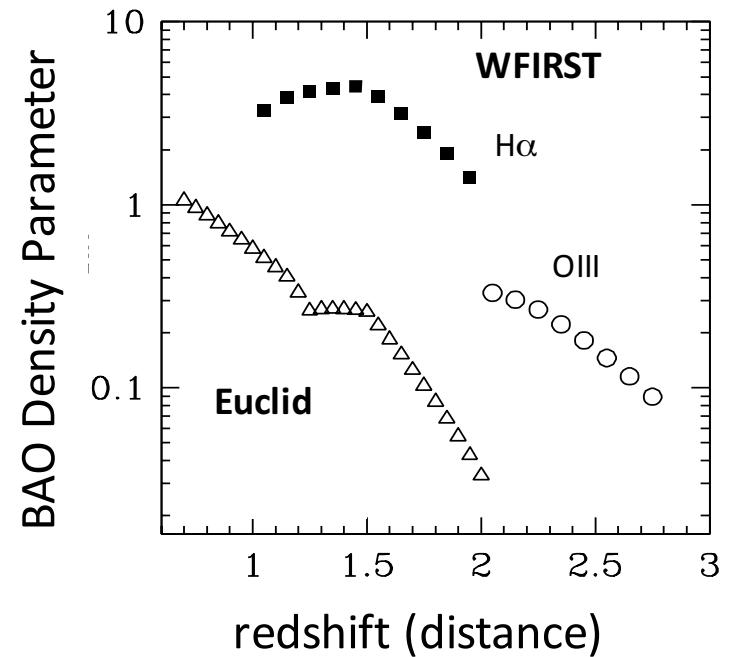
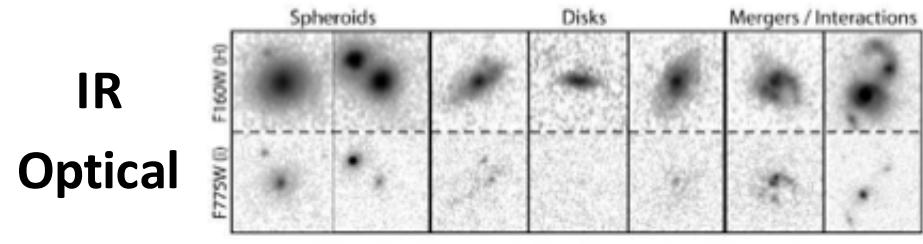
- WFIRST combines all techniques to determine the nature of Dark Energy.
- Only observatory doing such comprehensive observations
- High precision measurements will be optimally combined for the best measurement

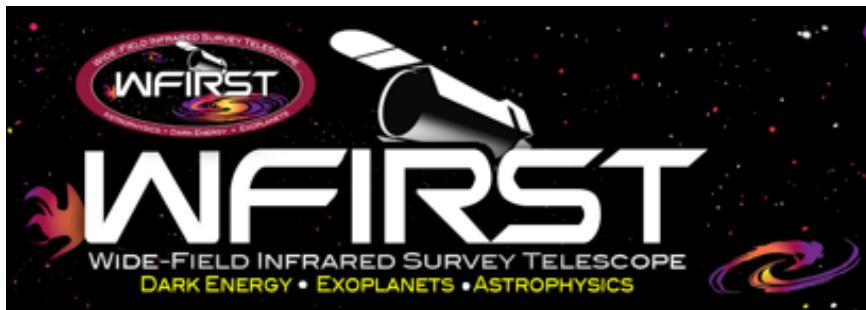




Premier Dark Energy Observatory

- WFIRST will be the first mission to fully exploit the powerful IR band for dark energy measurements.
- It will be much more sensitive and have higher angular resolution than any other dark energy instrument.





Complete the Census of Exoplanets - Microlensing

WFIRST
complements
Kepler, TESS,
Plato

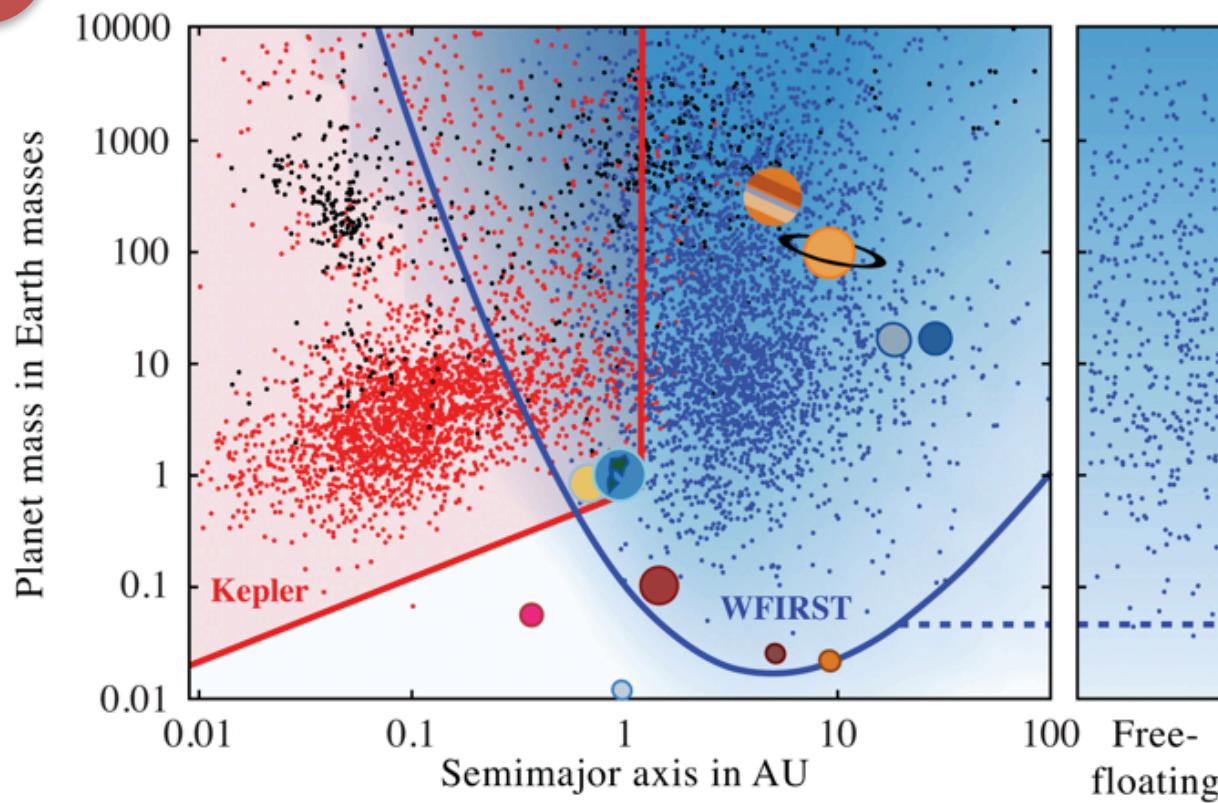


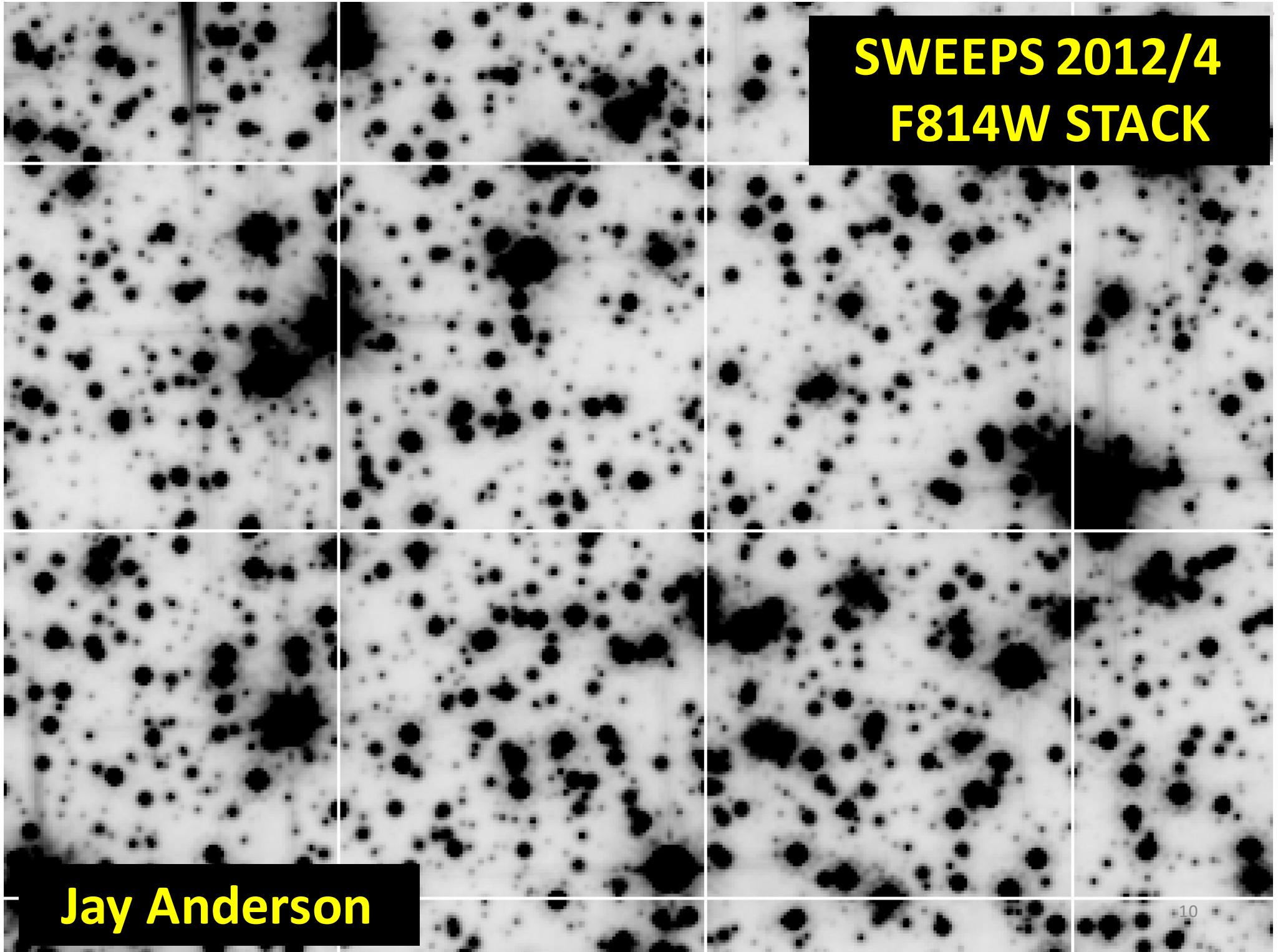
Kepler



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- 2600 planets
- 370 Earth mass & less
- 100's free-floaters

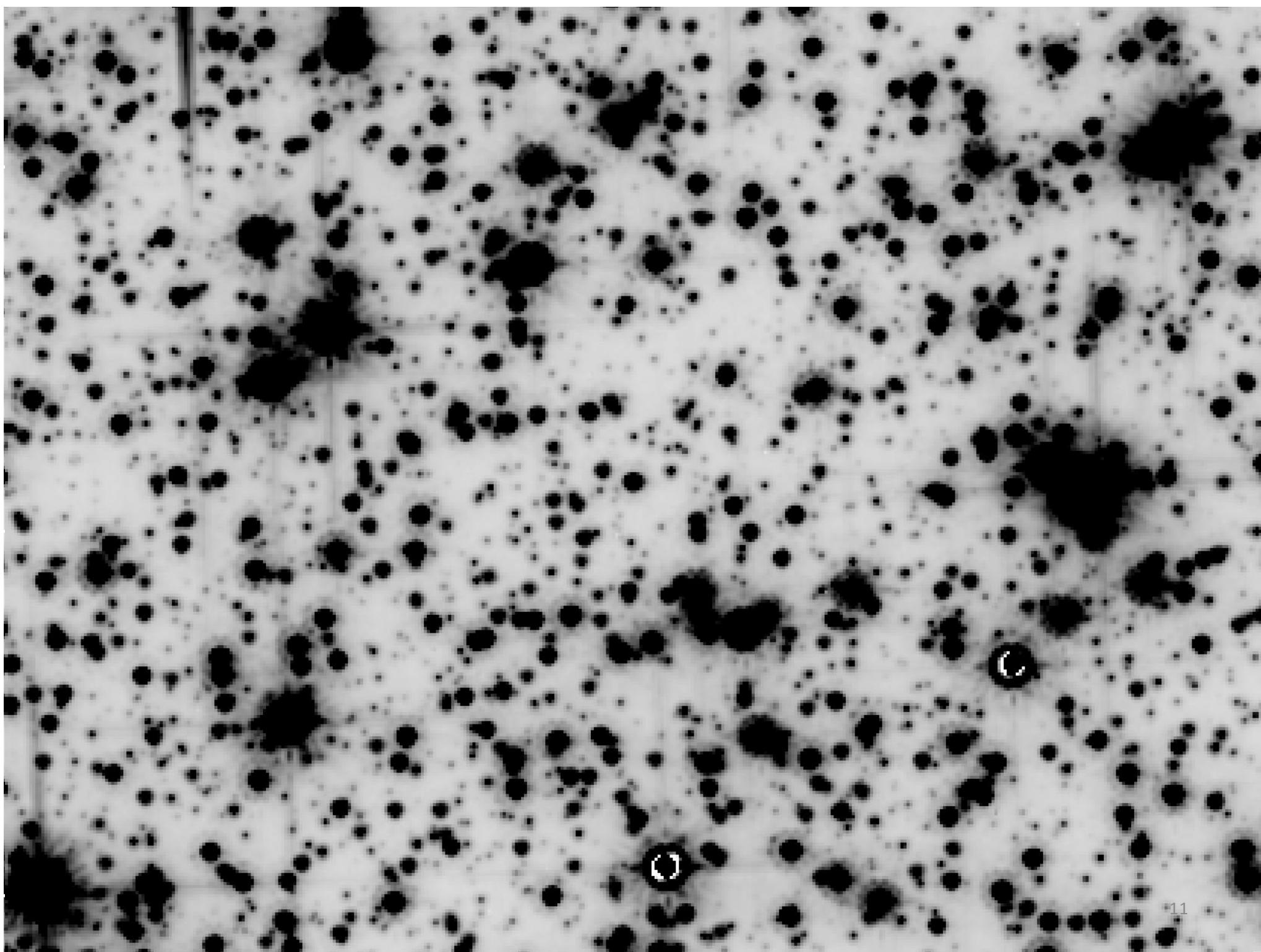




**SWEEPS 2012/4
F814W STACK**

Jay Anderson

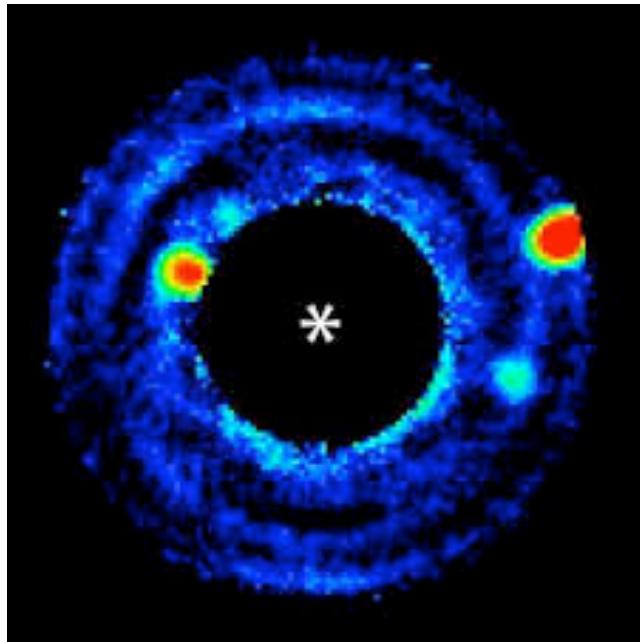
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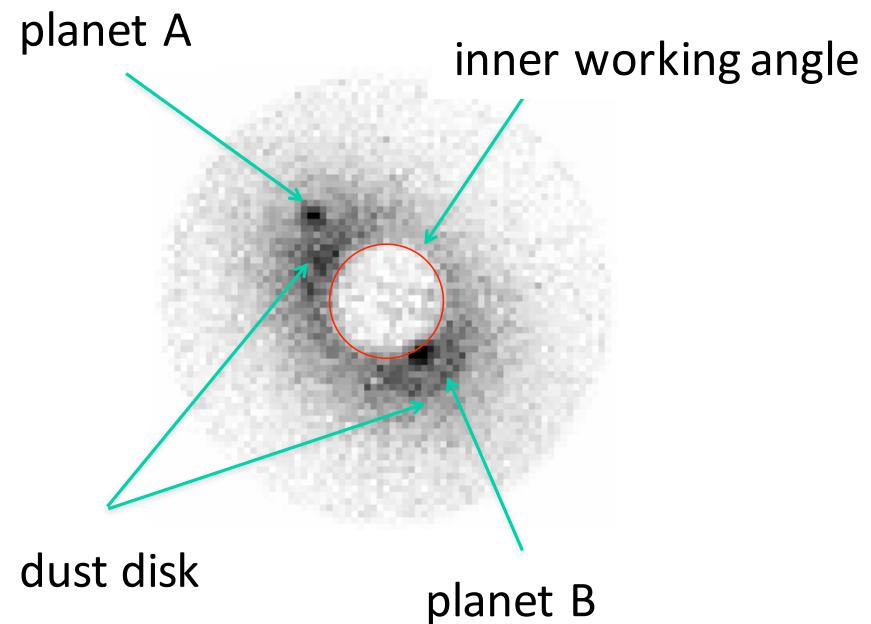
Pioneering High Contrast Exoplanet Coronagraph

- Imaging at high contrast provides for direct detection and spectroscopy (characterization) of exoplanets

Concept

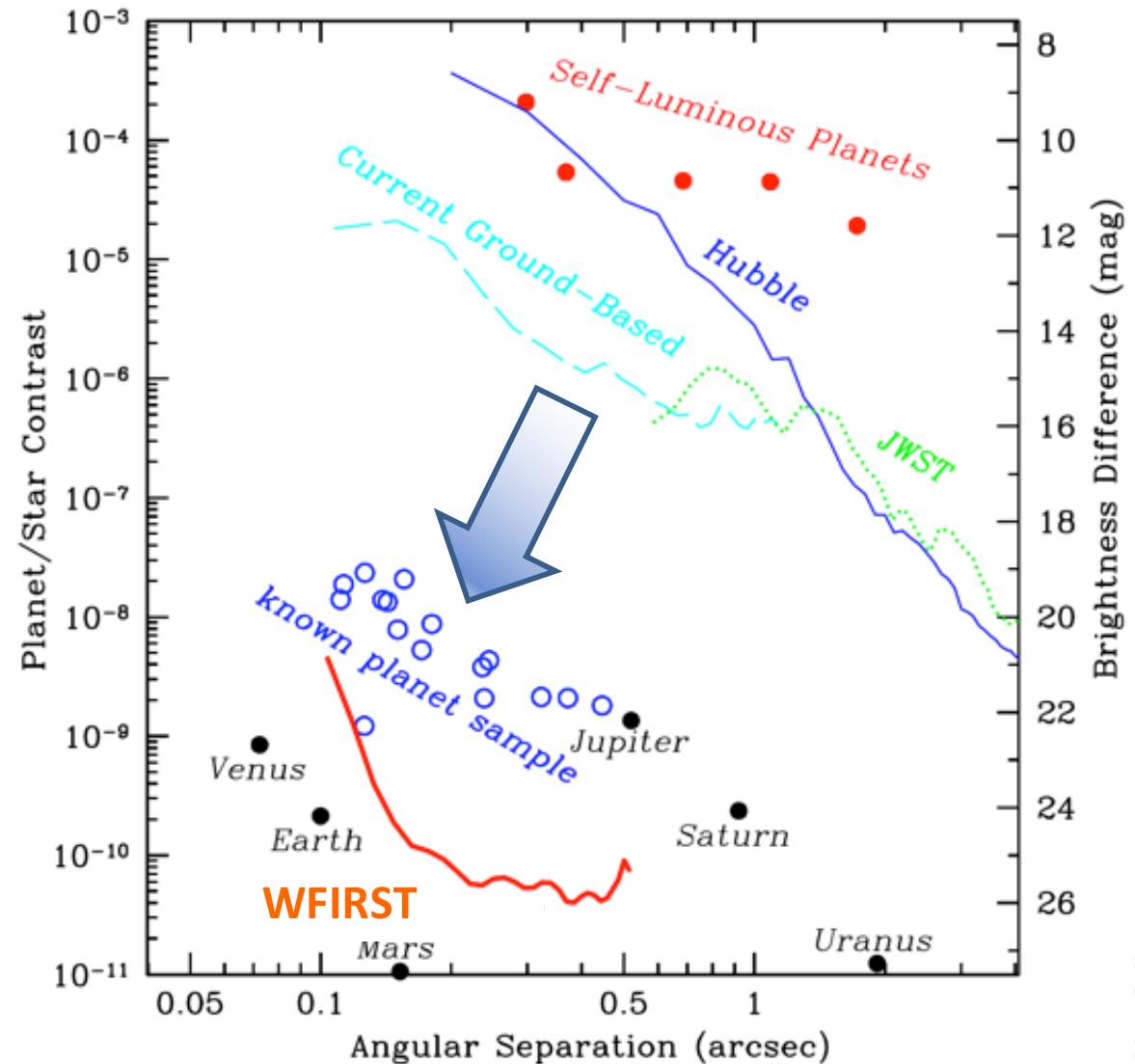


WFIRST Simulation



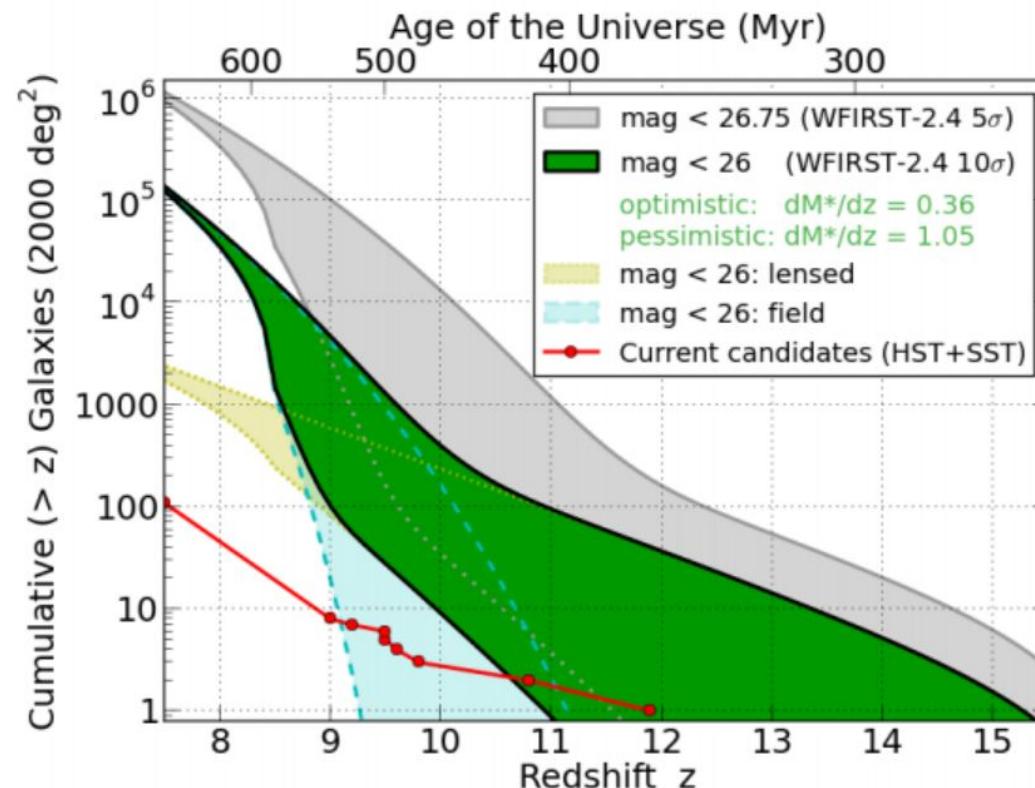
WFIRST Brings Humanity Closer to Characterizing exo-Earths

- WFIRST advances key elements needed for a future coronagraph to image an exo-Earth
 - ✓ Coronagraph
 - ✓ Wavefront sensing & control
 - ✓ Detectors
 - ✓ Algorithms
- WFIRST performance predictions are exciting



Finding the Most Distant Galaxies

- GO Science: 25% of WFIRST observing time in first 6 years and 100% open competition in years 6+
- Example: WFIRST's HLS will yield up to 2 orders of magnitude more high redshift galaxies than currently known





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WFIRST FSWG

Name	Affiliation	Role
Neil Gehrels, Chair	NASA/GSFC	Project Scientist
David Spergel, Deputy Chair	Princeton University	WFI Adjutant Scientist
Jeremy Kasdin, Deputy Chair	Princeton University	CGI Adjutant Scientist
Dominic Benford, <i>ex officio</i>	NASA/HQ	Program Scientist
Dave Bennett	UMBC & GSFC	Microlensing
Ken Carpenter, <i>ex officio</i>	NASA/GSFC	Project science
Roc Cutri, <i>ex officio</i>	IPAC	Science center
Olivier Doré	NASA/JPL	Cosmology: GRS+WL
Ryan Foley	UIUC	Supernova Cosmology
Scott Gaudi	Ohio State U.	Microlensing
Chris Hirata	Ohio State U.	Cosmology: WL
Jason Kalirai	JHU & STScI	GI/GO – Galactic science
Jeff Kruk, <i>ex officio</i>	NASA/GSFC	Project science
Nikole Lewis	STScI	Coronagraph
Bruce MacIntosh	Stanford	Coronagraph
Roeland van der Marel, <i>ex officio</i>	STScI	Science center
S. Perlmutter	UC Berkeley	Supernova Cosmology
James Rhoads	Arizona State	GI/GO – Cosmic Dawn
Jason Rhodes, <i>ex officio</i>	NASA/JPL	Project science
Aki Roberge	NASA/GSFC	Coronagraph
Brant Robertson	UC Santa Cruz	GI/GO – Galaxy evolution
Alexander Szalay	Johns Hopkins	GI/GO – Archival science
Wes Traub, <i>ex officio</i>	NASA/JPL	Project science
Maggie Turnbull	GSI & SETI	Coronagraph
Yun Wang	Caltech/IPAC	Cosmology: GRS
David Weinberg	Ohio State Univ.	Cosmology: Clusters
Benjamin Williams	U. Washington, Seattle	GI/GO – Nearby Galaxies



207 Members on selected WFIRST Science Investigation Teams!

Aldering, Greg	Giardi, David R	Freedman, Wendy L	Hewett, Andy	Law, David R	Mellema, Garth	Ravindranath, Swara	Seth, Anil	Thomas, Rollin C
Anderson, Abigail	Connolly, Andrew	Friman, Joshua	Hsiao, Eric Y	Lemson, Caaid	Menard, Bice	Rejkuba, Maina	Shaklan, Stuart B	Traeger, John Terry
Balay, Charles	Conroy, Charlie	Fuchter, Andrew S.	Hu, Renyu	Levesque, Emily M	Milan-Gabet, Rafael	Rest, Amin	Shapiro, Charles	Tumlinson, Jason
Baibary, Kyle	Crojevic, Denja	Fullanetto, Steven R	Hudson, Michael	Lewis, Nikole K	Miyatake, Hiroyao	Rhoads, James E	Shapley, Alice E	Turnbull, Margaret C
Batalha, Natalie	Dalcanton, Julieanne	Gaudi, Scott	Jain, Bhuvnesh	Line, Michael Robert	Monachesi, Antorella	Riess, Adam	Shet, Tilvi Mital	Van Dyk, Schuyler
Bean, Rachel	Dawson, Rebekah Irene	Ceha, Maita	Jang-Condell, Jamah	Lu, Jessica R	Moley, Caroline V	Roberge, Aki	Shvartzvald, Yosi	von der Linden, Anja
Beichman, Charles A	Debes, John Henry	Giardi, Leo	Jansen, Rob A	Lupton, Robert	Nataf, David	Robertson, Bart	Simon, Amy A	Walker, Matthew
Bell, Eric F	Deustua, Susana E	Coldblatt, Cdin	Jarvis, Michael	Lupu, Roxana E	Newman, Jeffrey A	Robinson, Tyler D	Smith, Kendrick M	Wang, Lian
Benson, Andrew J	Dickinson, Mark E.	Cordon, Kait D	Jensen, Barnes	Macintosh, Bruce	Nugent, Peter	Rodney, Steven A	Snyder, Gregory F	Wang, Yun
Bohlin, Ralph	Dolphin, Andy	Gould, Andrew	Jha, Saurabh W	Maran, Piero	Padmanabhan, Nikhil	Rogers, Leslie A	Soummer, Remi	Wechsler, Risa
Bolatto, Alberto D	Dore, Olivier P	Greene, Jenny E	Johnson, LC	Madhusudhan, Nikku	Papovich, Casey	Roman-Duval, Julia	Sparks, William B	Weinberg, David H
Boyer, Martha L	Dressler, Alan	Greene, Thomas	Johnston, Kathryn V	Malhotra, Sangeeta	Peek, Joshua	Rosenthal, Philip	Speigel, David N	Wheeler, Coral Rose
Braganca, Virgilio M	Duchene, Gaspard	Groff, Tyler D	Jurić, Mario	Mandel, Kasey S	Penarrubia, Jorge	Rozo, Eduardo	Staik, Christopher C	Wheeler, J. Craig
Byrd, Geoffrey	Dvorkin, Coia	Cuhak, Katalin Ruzsa	Kalai, Jason	Mandelbaum, Rachel	Penny, Mathew T	Rubin, David	Staik, Daniel	White, Richard L
Budavari, Tamás	Eilert, Tim Fiedtke	Heap, Sally	Kane, Stephen R	Mandell, Avi M	Perlmutter, Saul	Sako, Masato	Stassun, Keivan	Williams, Benjamin F
Bullock, James	Fall, Michael	Heimann, Katrin	Kassin, Jeremy	Marley, Mark S	Perin, Marshal D	Sales, Laura V	Strader, Jay	Willman, Beh
Burns, Christopher	Fan, Xiaohui	Helou, George	Kelly, Patrick	Mariois, Christian	Phillips, Mark M	Samushia, Ladis	Stolger, Luis Gregor	Windhorst, Roger A
Burrows, Adam S	Ferguson, Henry C	Henderson, Calen B	Kessler, Richard	Martone, Dan	Poleski, Radka	Sand, David	Stubbs, Christopher	Wold, Isaac G
Cahoy, Kei	Filippenko, Alexei	Hinz, Philip	Kissling, Alina	Martin, Nicolas	Pontoppidan, Klaus	Sanderson, Robyn E	Suntzeff, Nicholas	Wood-Vasey, Michael
Calchi Novati, Sebastiano	Finkelstein, Steven L	Hjata, Christopher	Kim, Alex	McConnachie, Alan	Postman, Marc	Sandstrom, Karin M	Szalay, Alexander	Woozley, Stan
Capak, Peter	Foley, Ryan J	Hob, Shirley	Kishner, Robert	McElwain, Michael	Pace-Whelan, Adrian	Saviansky, Dmitry	Takada, Masafiro	Yee, Jennifer C
Cayne, Sean Joseph	Foreman-Mackey, Daniel	Hunsell, Rebekah	Kause, Elisabeth	McGlynn, Thomas	Pueyo, Laurent	Scolnic, Dan	Teplitz, Harry I	Yoshida, Naoki
Chaname, Julio	Fortney, Jonathan J	Howard, Andrew	Lang, Dustin	Meixner, Margaret	Rabinowitz, David	Seifert, Michael	Thakar, Ariudtha R	Zackrisson, Erik



WFIRST Happenings

- Key Decision Point A (KDP-A) completed – February 17, 2016.
 - Phase A to run until KDP-B in October 2017
- WFIRST technology (Coronagraph and IR detectors) continue to make excellent progress. All HQ milestones successfully completed.
- President's Budget Request for FY17 has 90M from SMD and 10M from STMD. Augmented funding (FY14-16, 203M) has enabled significant mission progress.
 - Technology maturation.
 - Increased fidelity in the design reference.
- WFIRST is Category 1 project – Agency Program Management Council (APMC)
- WFIRST designated Class B mission (NPR 8705.4); Coronagraph technology demonstration is designated as Class C.
- L2 orbit (current baseline) launched from Eastern Test Range (ETR).
- 6 ¼ year mission life.
- Modular spacecraft and instrument design to facilitate robotic servicing.
- WFIRST part of Exoplanet Exploration Program (ExEP).



WFIRST Happenings cont.

- Wide Field concept study RFP released Jan 4. Recently awarded concept studies for the Wide Field Optical Mechanical Assembly (WOMA) to Ball and Lockheed.
- Upcoming Project reviews
 - Acquisition Strategy Meeting (ASM) July 21, 2016
 - System Requirements Rev, Mission Definition Rev (SRR/MDR) June 1, 2017
 - Key Decision Point – B (KDP-B) October 2, 2017
- Presentations to NASA committees
 - Mid-Decadal Review panel multiple times in 2015, written input 2015-16
 - NASA Advisory Committee for science (NAC) March 10, 2016
 - Astrophysics Subcommittee (APS) March 14, 2016
 - Space Studies Board (SSB) April 27, 2016
 - Far IR large mission STDT May 13, 2016
- Science Investigation Teams selection made December 17, 2015.
- WFIRST Formulation Science Working Group formed and meeting regularly. Plus numerous working groups with weekly telecons.
 - FSWG #1, Maryland February 2-4, 2016
 - FSWG #2, Pasadena June 13-15, 2016
 - FSWG #3, Maryland October 5-7, 2016



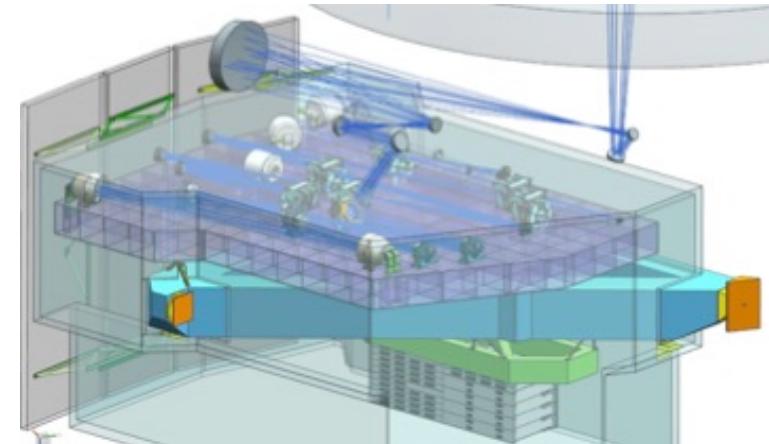
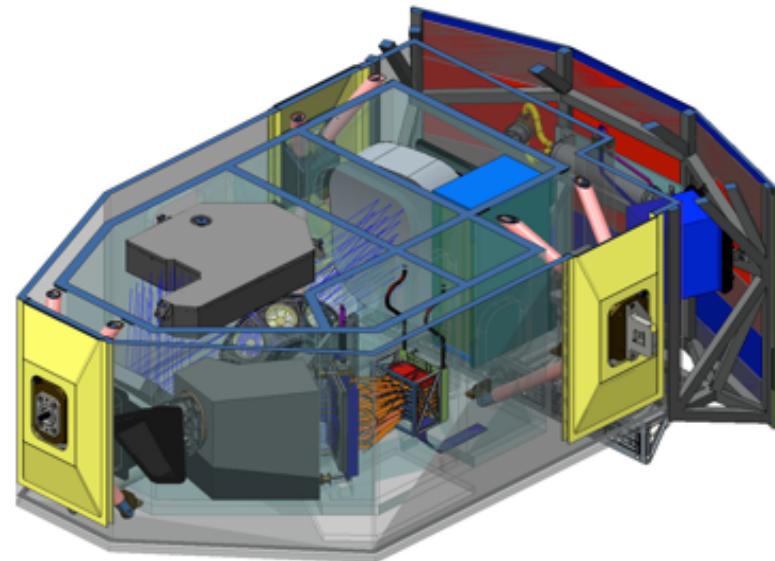
WFIRST Happenings cont.

- Significant foreign interest in contributing to WFIRST
 - Canada: industry studies of IFU and calibration system
 - ESA: Proposals recently submitted for FSWG members, possible hardware
 - Japan: Agency discussion concerning Subaru, ground station, coronagraph
- Hardware design and development is on track by dedicated and growing Project teams at GSFC and JPL, and at Harris telescope contractor
 - detectors
 - coronagraph
 - grism
 - telescope structure, baffling, mirror characterization
 - overall mission design
- Current plan for science operations in Phase E
 - Oversight, mission operations and instrument operations at GSFC & JPL
 - Science center functions shared by IPAC/Caltech and STScI



WFIRST Instruments

- Wide Field Instrument (WFI) – GSFC/Industry
 - Wide-field imaging and spectroscopy in support of the dark energy surveys and the microlensing survey.
 - Integral field spectroscopy in support of the supernova survey and weak lensing photometric redshift calibrations.
 - Guide star data for observatory fine pointing.
 - Developed in partnership with industry. RFP studies underway by Ball and Lockheed.
- Coronagraph Instrument (CGI) - JPL
 - Provides high contrast imaging and integral field spectroscopy in support of exoplanet and debris disk science.





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Mission Schedule – 2024 LRD Overguide Schedule

Task name	CY 16				CY 2017				CY 2018				CY 2019				CY 2020				CY 2021				CY 2022				CY 2023				CY 2024				
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4				
Project Phases	KDP-A					KDP-B				KDP-C															KDP-D												
	◆	Phase A			◆	Phase B			◆	Phase C			◆	Phase D			◆	Phase E			◆	Phase F			◆	Phase G			◆	Phase H							
	3/1/16					10/2/17																															
Mission Milestones	MCR					SRR/MDR				MPDR				MDR											SIR				PSR				LRD				
	◆					◆				◆				◆											◆				◆				◆				
Telescope										PDR				CDR											PSR												
						Phase A				Prelim. Design	◆	Detail Design	◆	Fab. & Int.	◆																						
Widefield Instrument										PDR				CDR											PSR												
										Phase A				Prelim. Design	◆	Detail Design	◆	Fab. & Int.	◆																		
Coronagraph										PDR				CDR											PSR												
										Phase A				Prelim. Design	◆	Detail Design	◆	Fab. & Int.	◆																		
Payload Integration & Test										PDR				CDR											PSR												
										Phase A				Prelim. Design	◆	Detail Design	◆	Fab. & Int.	◆																		
Spacecraft										PDR				CDR											PSR												
										Phase A				Prelim. Design	◆	Detail Design	◆	Fab. Int. & Subsys Test	◆																		
Observatory Integration & Test																																					
Launch Site Activities																																					
Launch Vehicle																																					
Ground System										PDR				CDR		V 0.0								V 1.0									V 2.0		LRD		
										Phase A				Prelim. Design	◆	Detailed Design	◆	Rev 0 Dev.	◆	Rev 1 Dev.	◆	Rev 2 Dev.	◆	Prep.	◆												

Legend:
 KDP- Key Decision Point
 CDR- Critical Design Review
 I&T- Integration & Test
 LRD- Launch Readiness Date
 M- Mission
 MCR- Mission Concept Review
 MDR- Mission Definition Review
 PDR-Preliminary Design Review
 PIL- Payload
 PSR- Pre-Ship Review
 R.R.- Risk Reduction
 SIR- System Integration Review
 SRR- System Requirements Review
 V- Version

- 82 month B/C/D development schedule
- 2024 LRD requires over-guide funding starting FY18

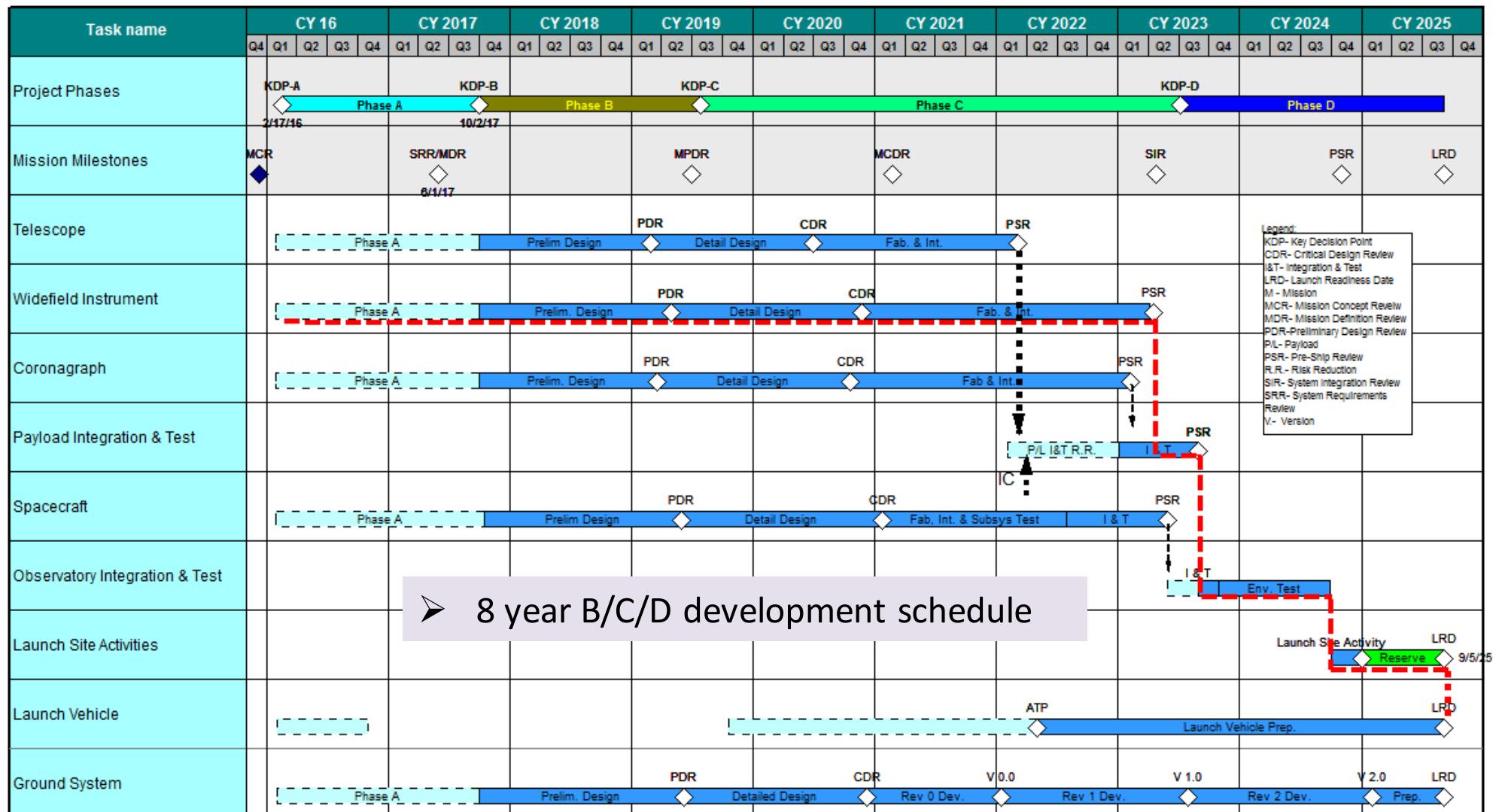
Launch Site Activity LRD
 Reserve 8/5/24



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Mission Schedule – 2025 LRD In-Guide Schedule





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WFIRST KDP-A Budget Estimates

- WFIRST mission life-cycle cost was updated for MCR design configuration and the Key Decision Point A (KDP-A) milestone.
- The current WFIRST budget guidelines are constrained in FY18-20. As a result, the Project is working two development schedule profiles – an overguide 2024 launch date and an in-guide 2025 launch date.
- Mission cost was updated for the following:
 - increased launch vehicle costs,
 - increased science team funding (including number of teams selected),
 - design maturation (L2 changes & maturing design),
 - extended Phase A (KDP-A accelerated),
 - telescope outer barrel assembly configuration changes and
 - funding for Wide Field industry studies.
- The Project's life-cycle estimate over the range of launch vehicles and launch dates is 2.3–2.7B in FY15\$. That equates to 2.7B to 3.2B in RY\$.
- Budget includes STMD funding in FY16/17 for the coronagraph technology. STMD is considering funding portion of coronagraph flight development.
- International contributions – discussions in process for potential contributions from Europe/ESA, Canada and Japan. Contributions include elements of Wide Field instrument, Coronagraph and ground system.



Data Rights Considerations

- Standard of 1 year proprietary time for all data is probably no longer acceptable to NASA or the community
- WFIRST wide field imager has wide FoV that makes proprietary data difficult
- Different science areas for WFIRST have different data needs and processing requirements.
- An open data policy such as that of LSST may be the natural fit for most or all of the WFIRST data
- Rapid public access to broad-use survey data has been demonstrated to maximize scientific output.



Hits 5/6 NASA Strategic Goals

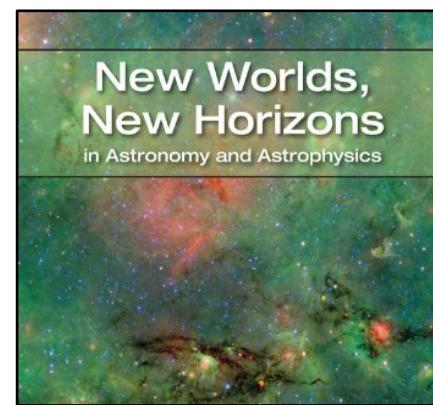


Addresses all 3 APS performance goals



WFIRST Summary

#1 Priority of Astro Decadal Survey



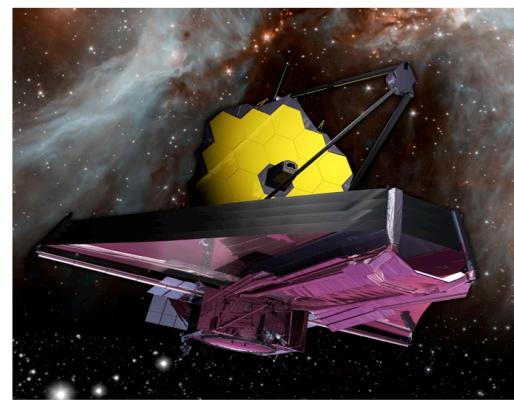
Brings the Universe to STEM education



Foundation for discovering Earth-like planets



Hubble's clarity over 10% of the sky



Complements and enhances JWST science

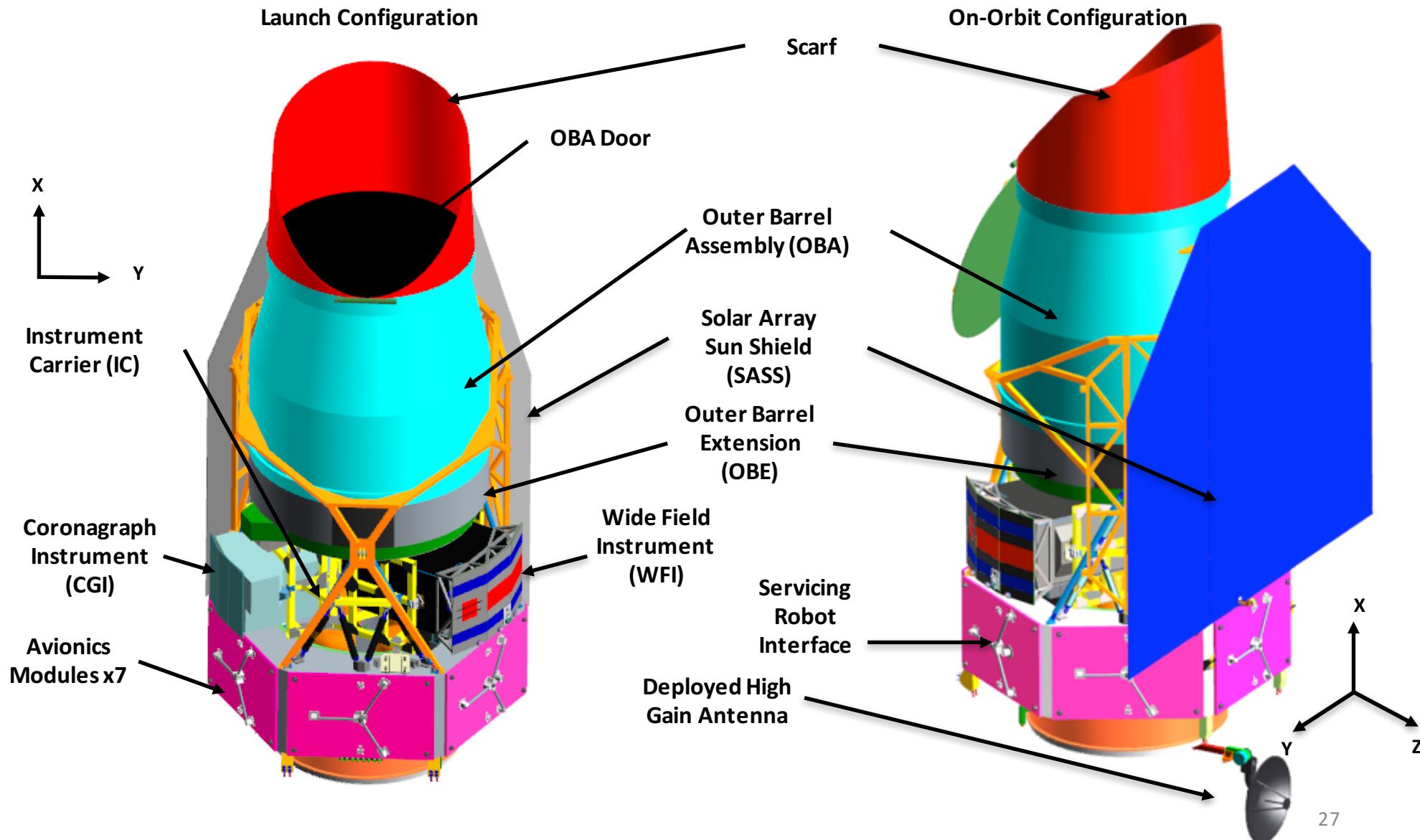


Back-up



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Observatory Configuration





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Example Observing Schedule

- High-latitude survey (HLS: imaging + spectroscopy): 2 years
 - 2227 deg^2 @ ≥ 3 exposures in all filters (2279 deg^2 bounding box)
- 6 microlensing seasons (1 year, after lunar cutouts)
- SN survey in 0.5 years, field embedded in HLS footprint
- 1 year for the coronagraph, interspersed throughout the mission
- GO program 1.5 years

