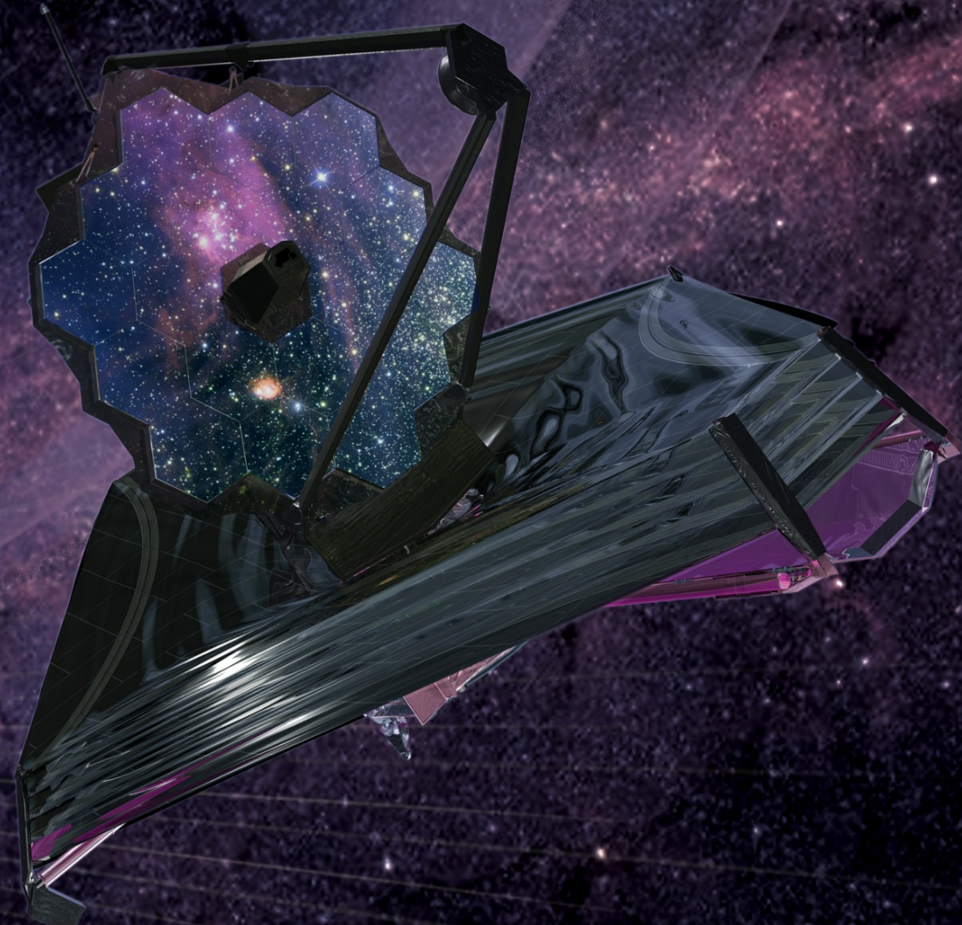
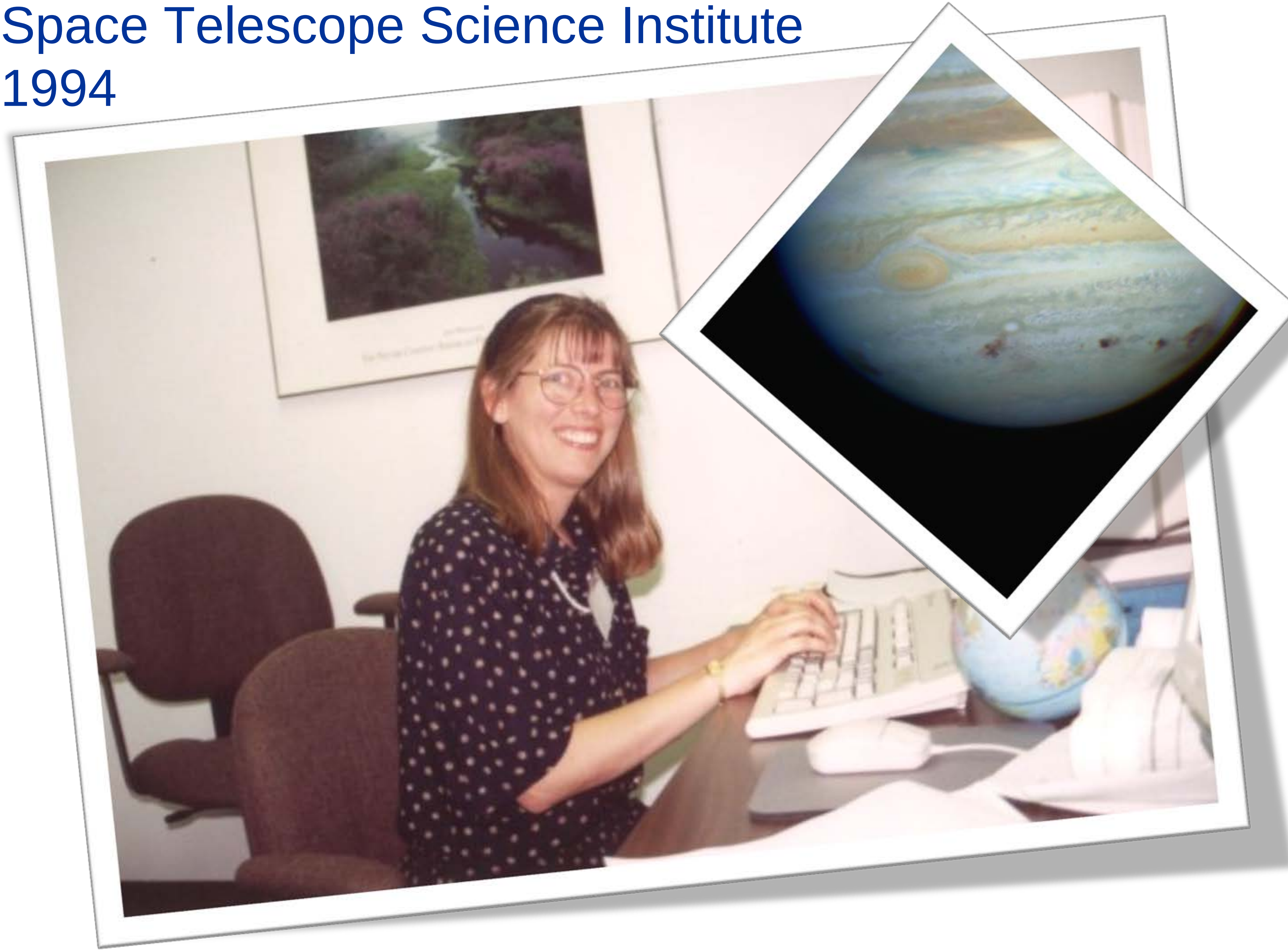
James Webb Space Telescope



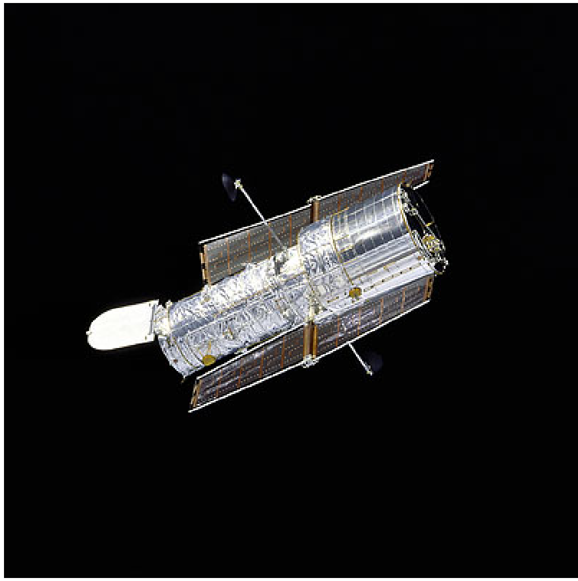
Heidi B. Hammel
JWST Interdisciplinary Scientist
and
Executive Vice President
AURA, Washington, DC

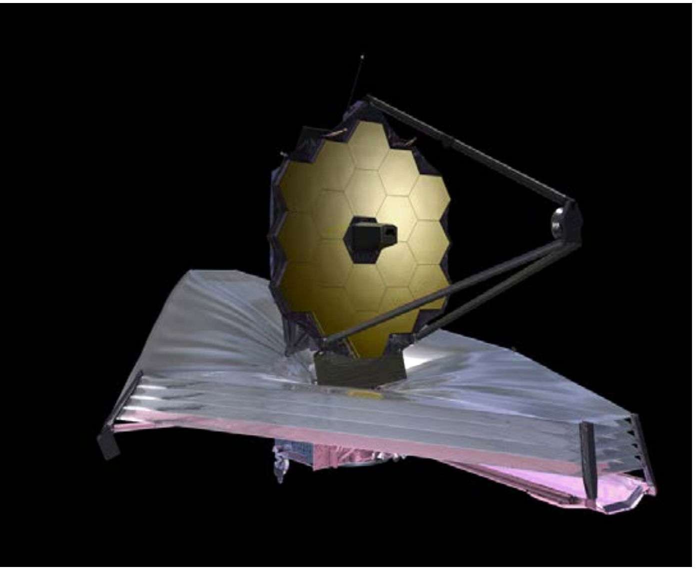
with significant help from
***Jason Kalirai**, Space Telescope Science Institute,*

Space Telescope Science Institute
1994



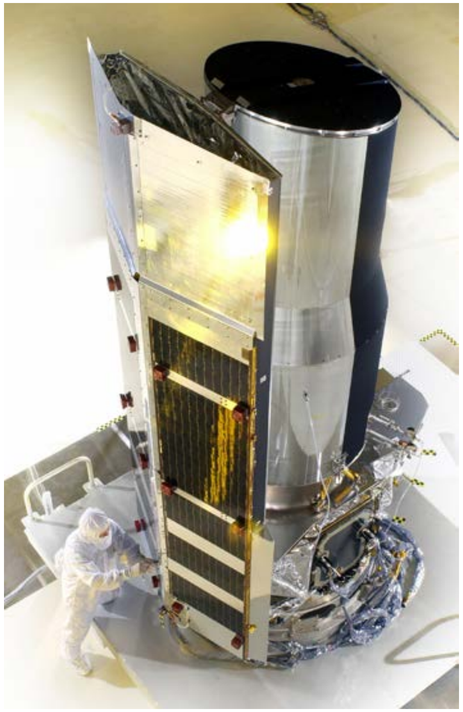
after my own experience
with the
Hubble Space Telescope



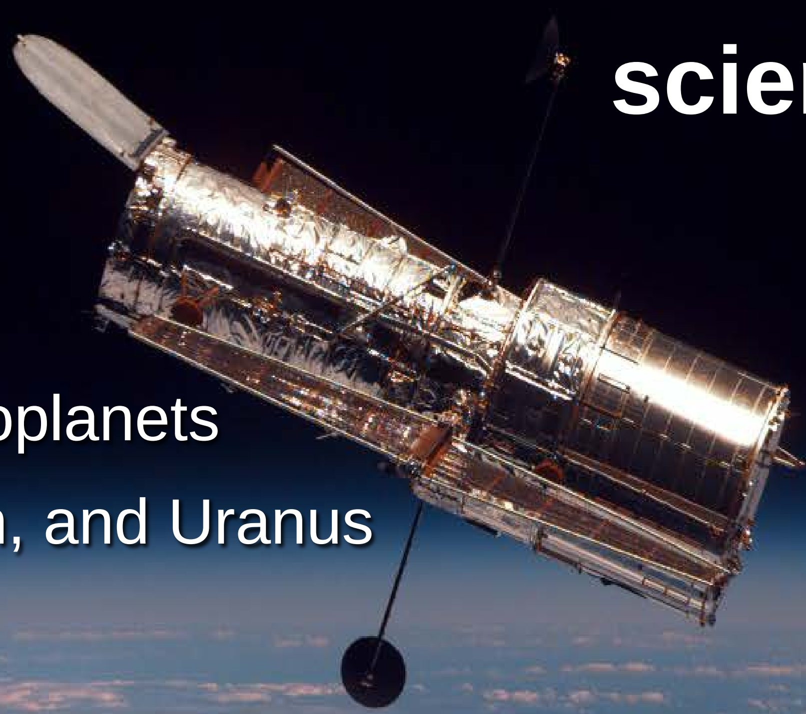


i wanted to help build the
Next Great Observatory
for future young scientists

great observatories



Hubble science



Dark energy and the expansion of the Universe
Supermassive black holes
New moons of Pluto
Age of the Universe
Gravitational lensing
Dark matter
Images and spectra of exoplanets
Aurorae on Jupiter, Saturn, and Uranus
Sources of GRBs
Intensities of supernovae
Ages of stellar populations beyond the Milky Way
Precise measurements of the Hubble Constant
and much much more…..

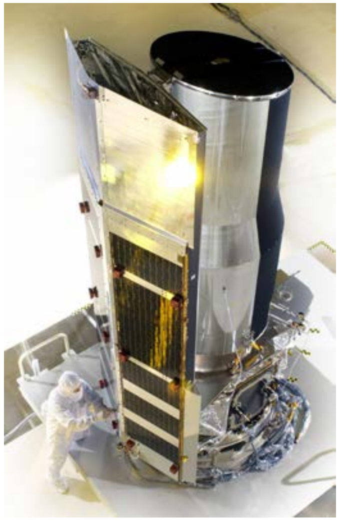
Frontiers of Astronomy

Seek the first stars and galaxies that formed in the early Universe, and follow the ionization history

Determine how galaxies evolve from the early Universe to the present day (stars, gas, metals, dark matter)

Solve the mysteries of star formation and birth of protoplanetary systems

Probe the chemical properties of planetary systems to constrain the building blocks of life



these frontiers require the best of Hubble and

"Wish List" for an Exoplanet Spectroscopy Platform

Dr. David Charbonneau (CfA/Harvard), January 2012, AAS Meeting in Austin, TX

Orbit that assures thermal stability and low background

Orbit that assures long dwell times

Stable PSF and excellent pointing

Infrared sensitivity (planetary temperatures; molecules)

Aperture sufficient to permit medium resolution spectroscopy

i.e., a large-aperture cryogenic telescope placed at L2, with a detailed error budget and careful instrument characterization prior to launch

or, as David Charbonneau himself said, "JWST is an excellent platform for exoplanet spectroscopy"

JWST

Answering the Challenges

100x more power than Hubble

10x image sharpness of Hubble in the infrared

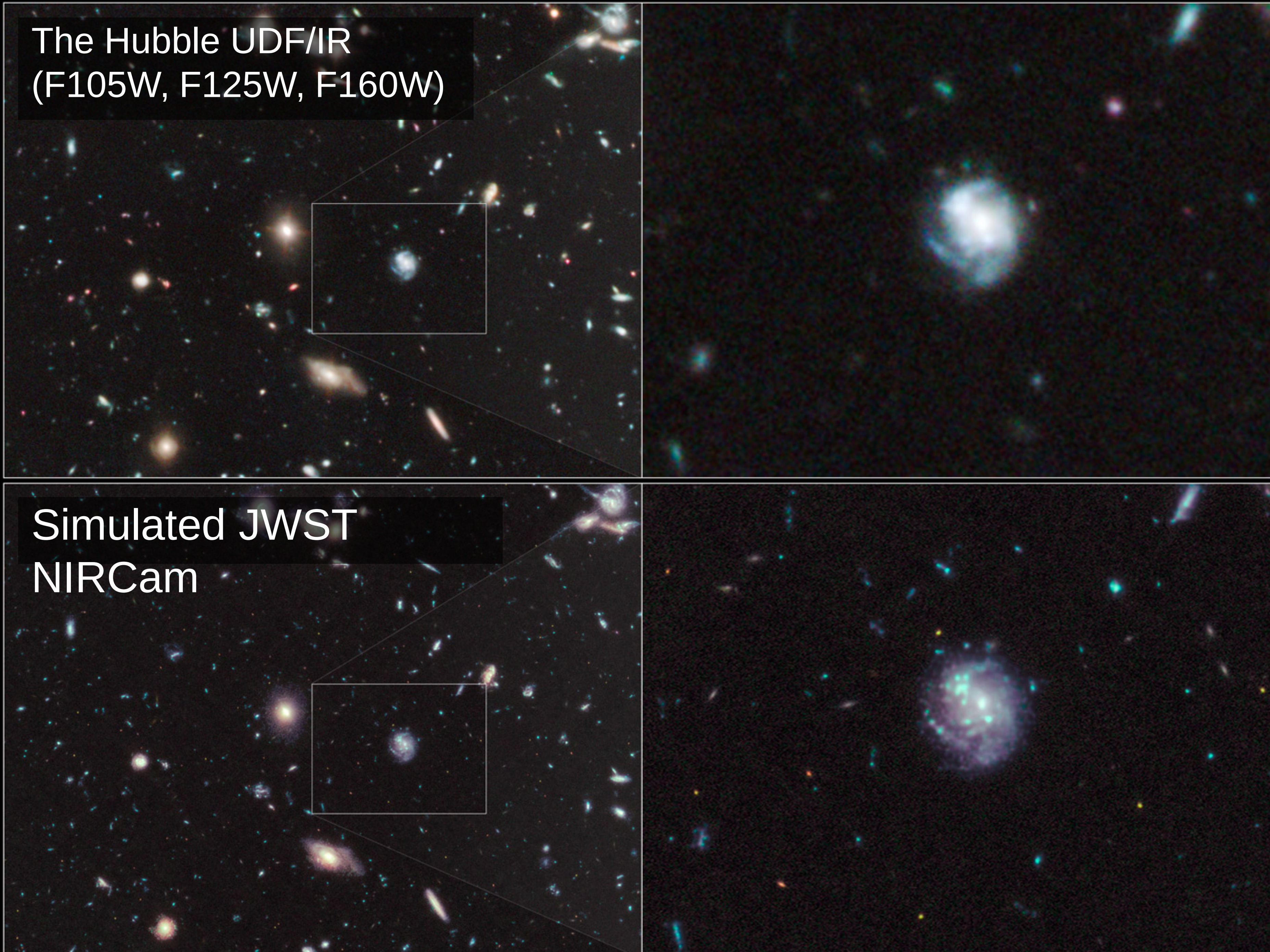
Comparable in size to the largest ground-based telescopes yet light weight

Operate at cryogenic temperatures to cover wavelengths to 27 microns

Place a million miles away at L2

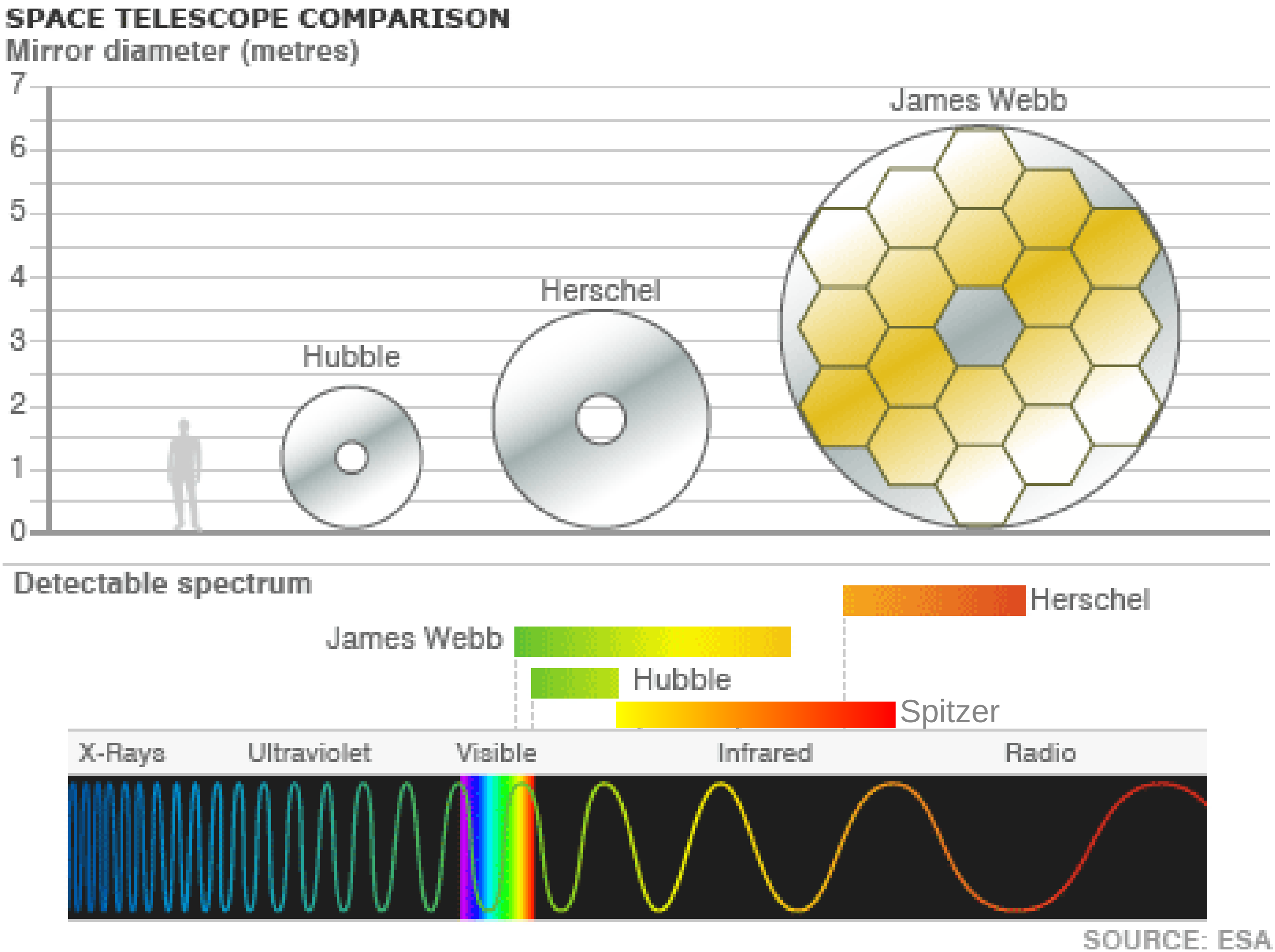
New generation of complex instrumentation to ensure diverse modes of operation without servicing

JWST science preparation


The Hubble UDF/IR
(F105W, F125W, F160W)
Simulated JWST
NIRCam

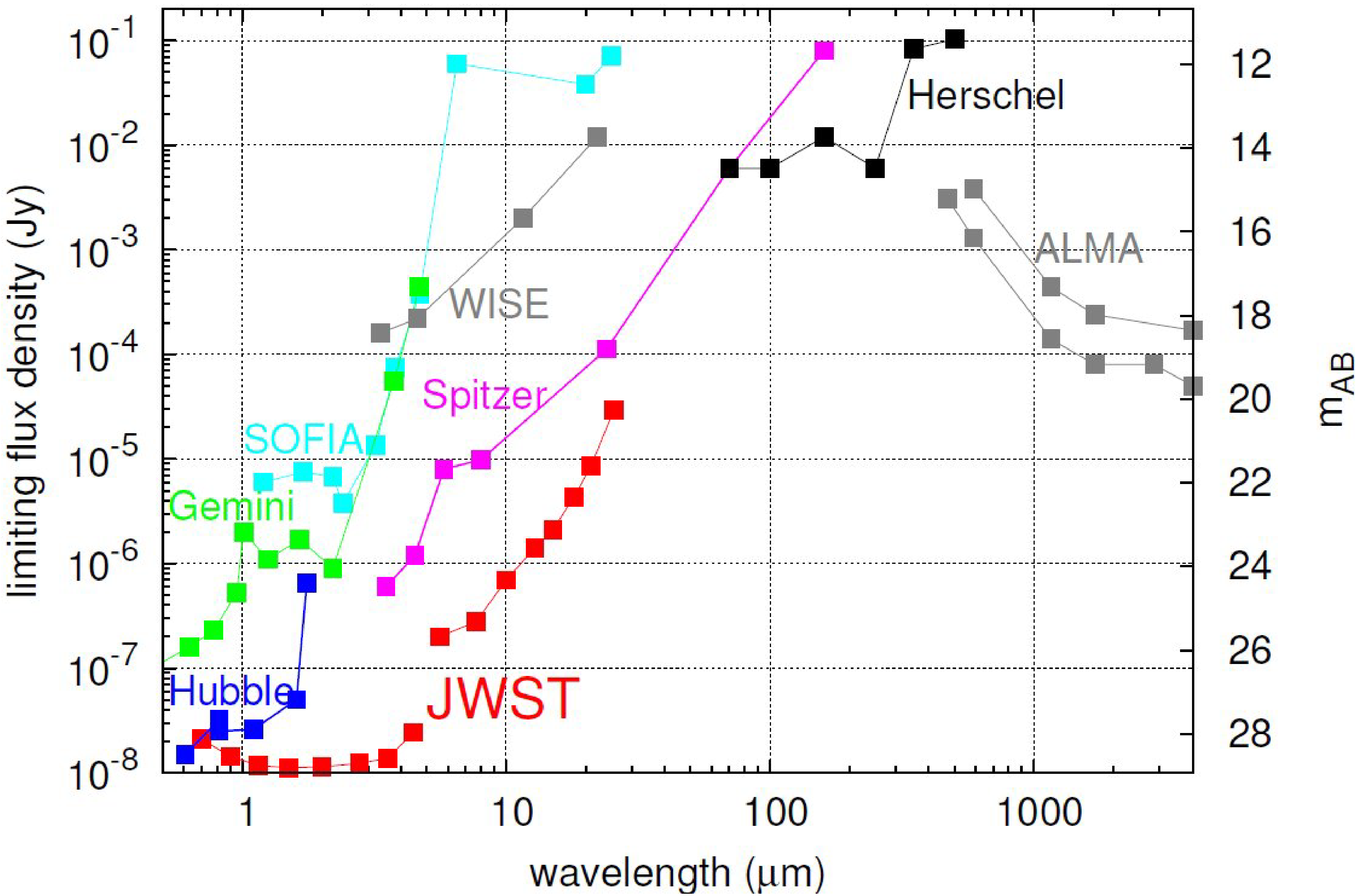
JWST: largest cryogenic telescope ever built

*(JWST is **BIGGER** and **COLDER** than Hubble)*

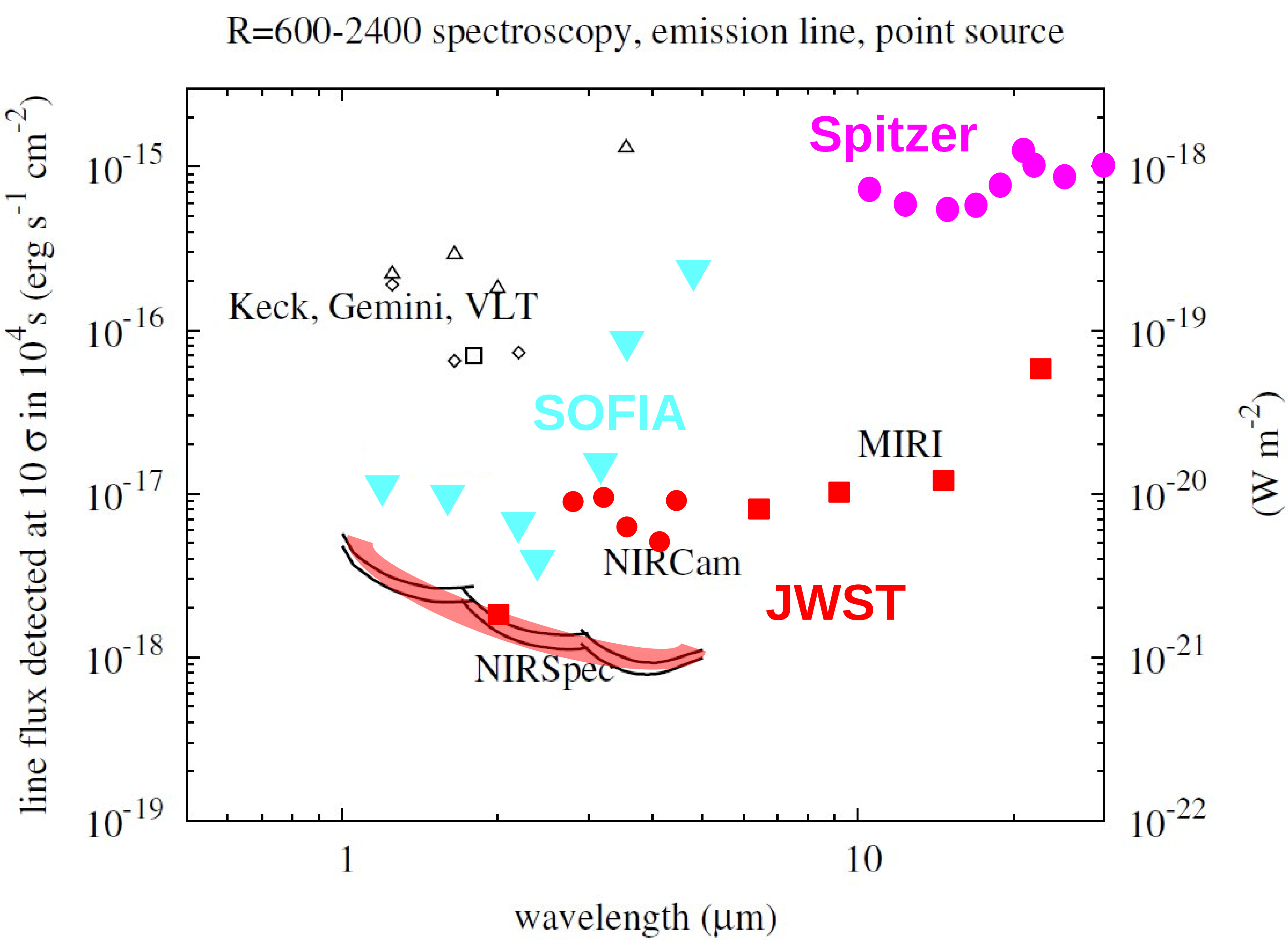


JWST Imaging Sensitivity

photometric performance, point source, 10σ in 10^4s

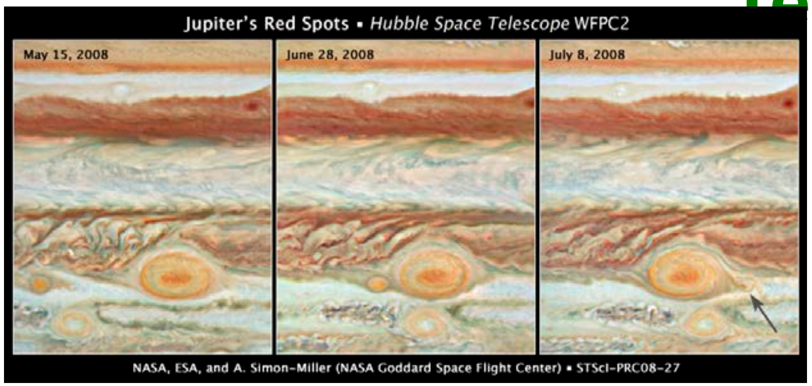


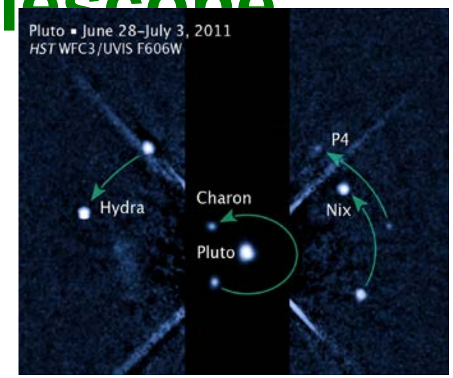
JWST Spectroscopic Sensitivity

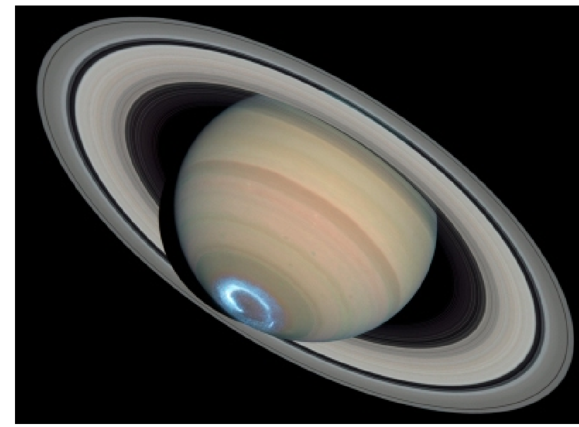


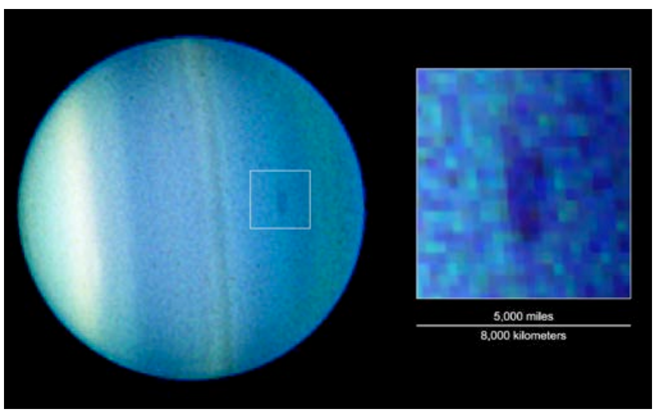
Vision and Voyages for Planetary Science in the Decade 2013-2022

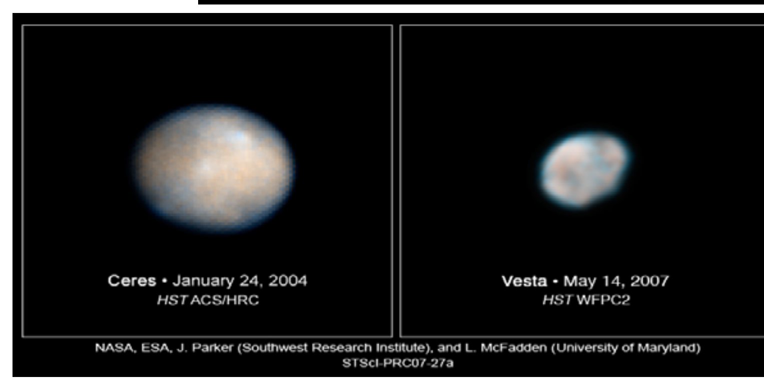
"**Hubble Space Telescope** has a long history of successful planetary observations, and this collaboration can be a model for future telescopes such as the **James Webb Space Telescope**."











JWST can track rates of motion up to 0.03 arcsec per second
i.e., **can track all planets and asteroids beyond Earth's orbit**

Solar System Science with JWST

Kuiper Belt Objects (KBOs) and Dwarf Planets

Image all known KBOs in the mid infrared

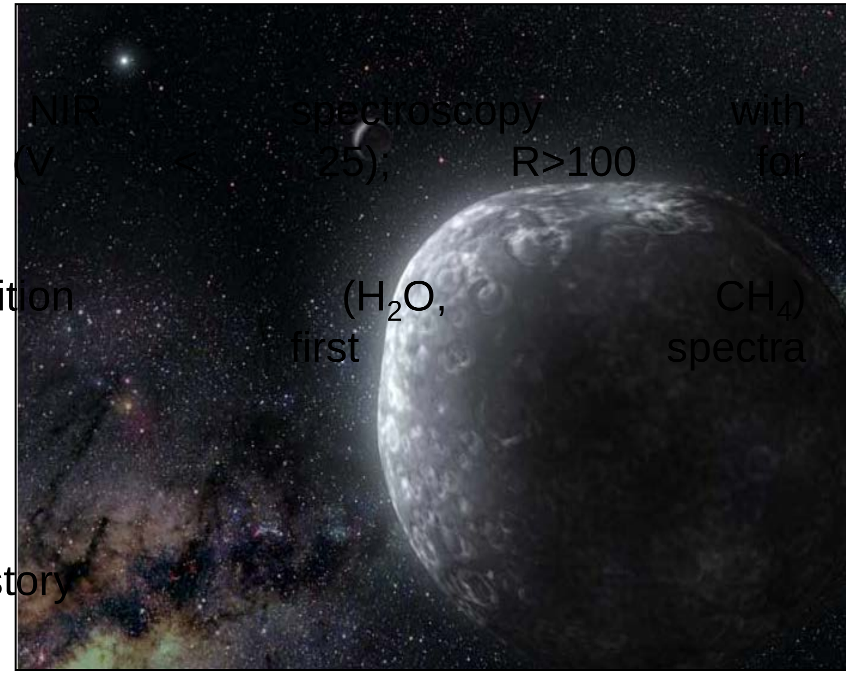
Conduct R = 100 NIR spectroscopy with S/N = 20 in 3 hours (V < 25); R>100 for bright KBOs

Constrain surface composition (H_2O, CH_4) & volatile inventories; first spectra at 2.5–5 microns

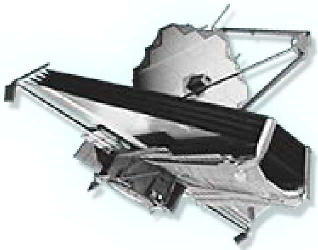
Discover new organic molecules/ice

Address the dynamical and chemical history of the solar system; test formation theories

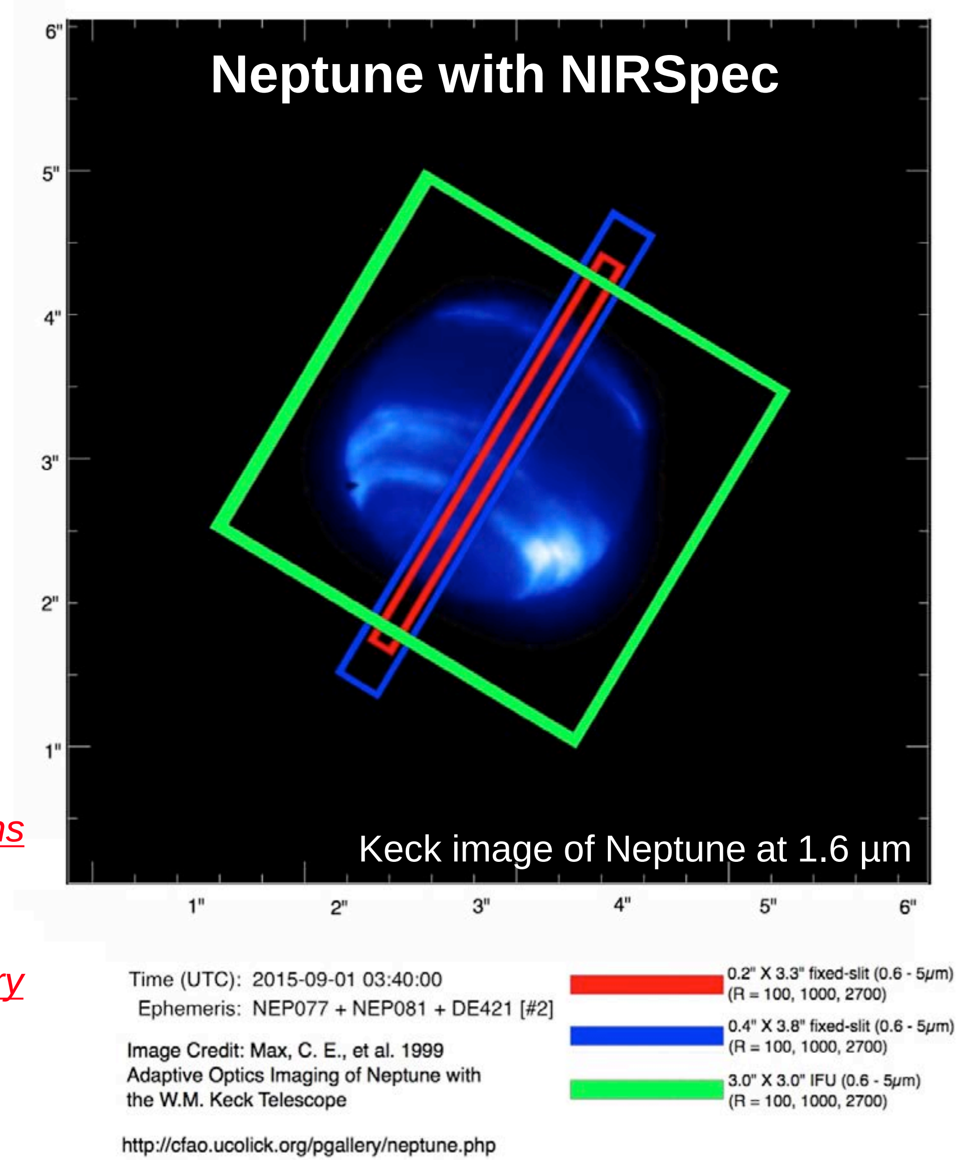
Reveal seasonal behaviors and surface compositions of Pluto, Eris, Sedna and other dwarf planets



Artist's impression of a binary KBO



Solar System Science with JWST



Uranus and Neptune

spectral characterization of H_3^+, CO in fluorescence…

Jupiter and Saturn

phosphine and methane fluorescence which link to vertical dynamics and thermal structure of stratosphere…

Mars

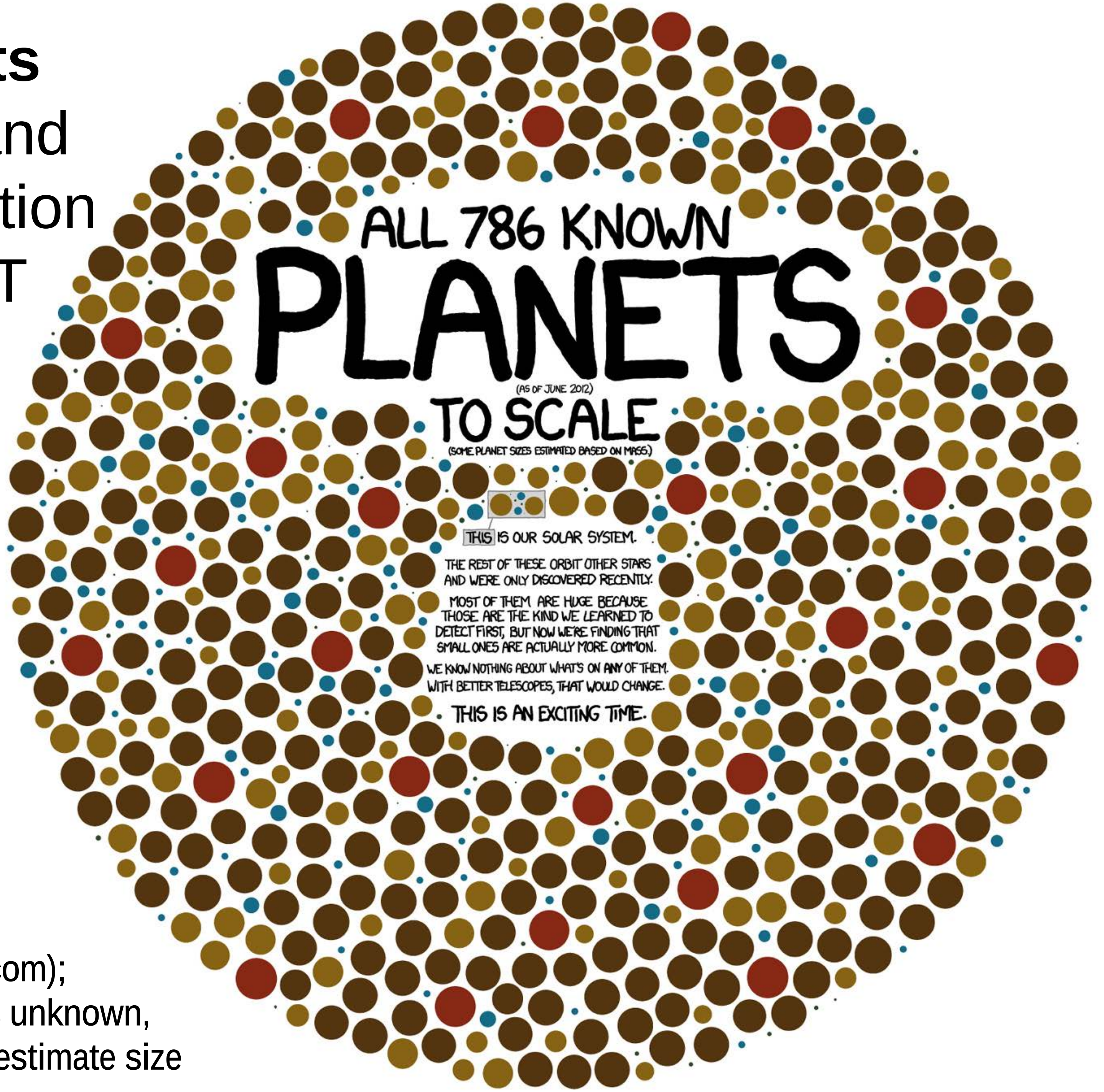
variability of atmospheric species including CO_2, CO, and H_2O…

Lunine, J. et al. (2010) *JWST Planetary Observations within the Solar System*"

Sonneborn, G. et al. (2009) *JWST Study of Planetary Systems and Solar System Observations*"

Planetary Science with JWST Flyer
http://www.stsci.edu/jwst/news/2011/DPS2011_JWSTFlyer.pdf

exoplanets
discovery and characterization with JWST



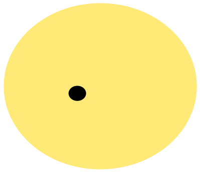
all planets as of
June 2012 visualized by
Randall Munroe (XKCD.com);
when a planet's size was unknown,
its mass was used to to estimate size

Exoplanet Discovery and Characterization with JWST

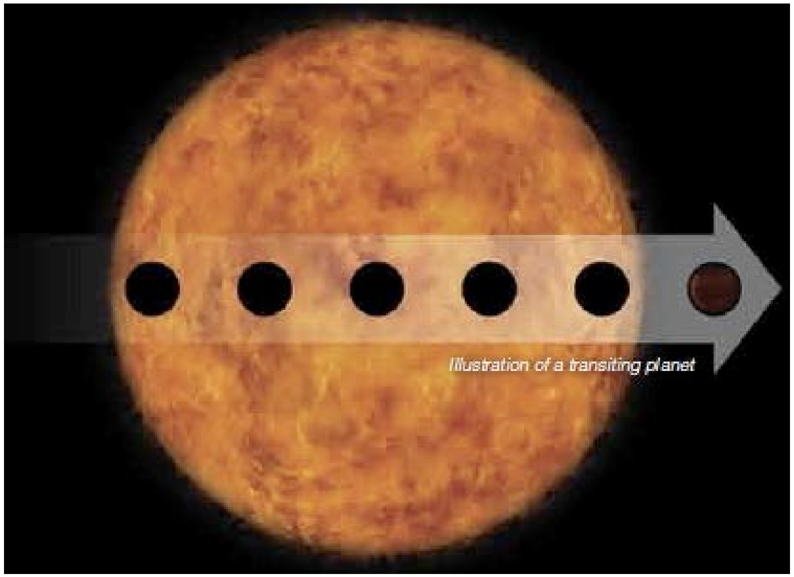
Application	Planet Type	Res.	JWST Scientific Investigations
Transit Light Curves	Gas Giants Intermediate Mass Super Earths Terrestrial Planets	5 5 5 5	- Planet prop. w/ RVs (mass, radius) → physical structure - Detection of terrestrial transits - Transit timing: detection of unseen planets
Phase Light Curves	Gas Giants Hot Neptunes	5 5	- Day to night emission mapping - Dynamical models of atmospheres
Transmission Spectroscopy	Gas Giants Intermediate Mass Super Earths	3000 100-500 <100	- Spectral line diagnostics - Atmospheric composition measurements (C, CO_2, CH_4) - Follow up of survey detections
Emission Spectroscopy	Gas Giants Intermediate Mass Super Earths	3000 100-500 <100	- Spectral line diagnostics - Temperature measurements - Follow up survey detections

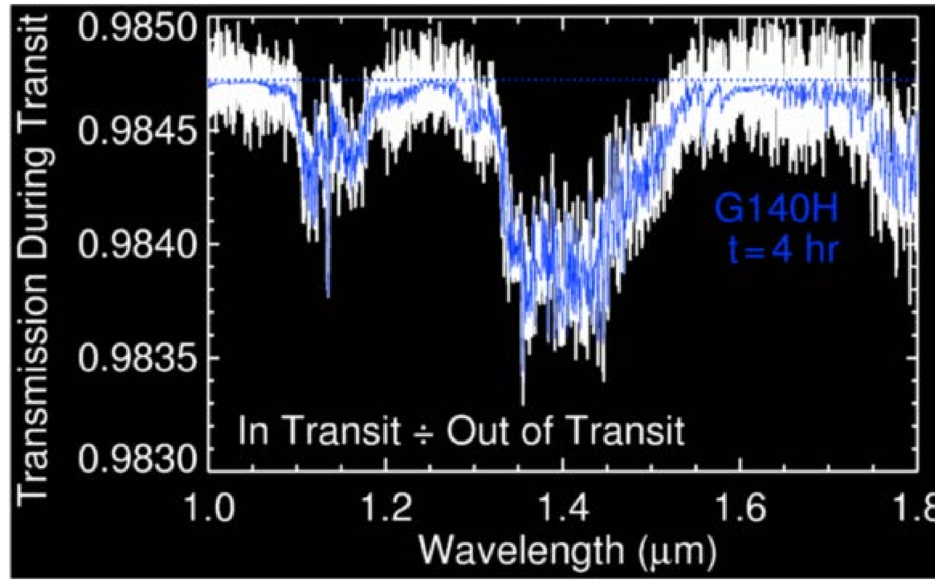
M. Clampin et al. (2009), JWST White Paper,
"Comparative Planetology: Transiting Exoplanet Science with JWST"

JWST/NIRSpec will measure **phase curves** of exoplanets around nearby M dwarfs **in 1 hour**



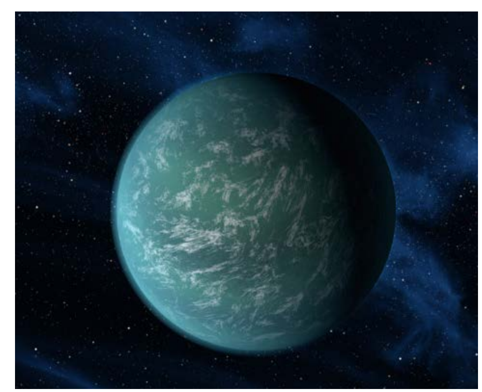
Exoplanet Discovery and Characterization with JWST





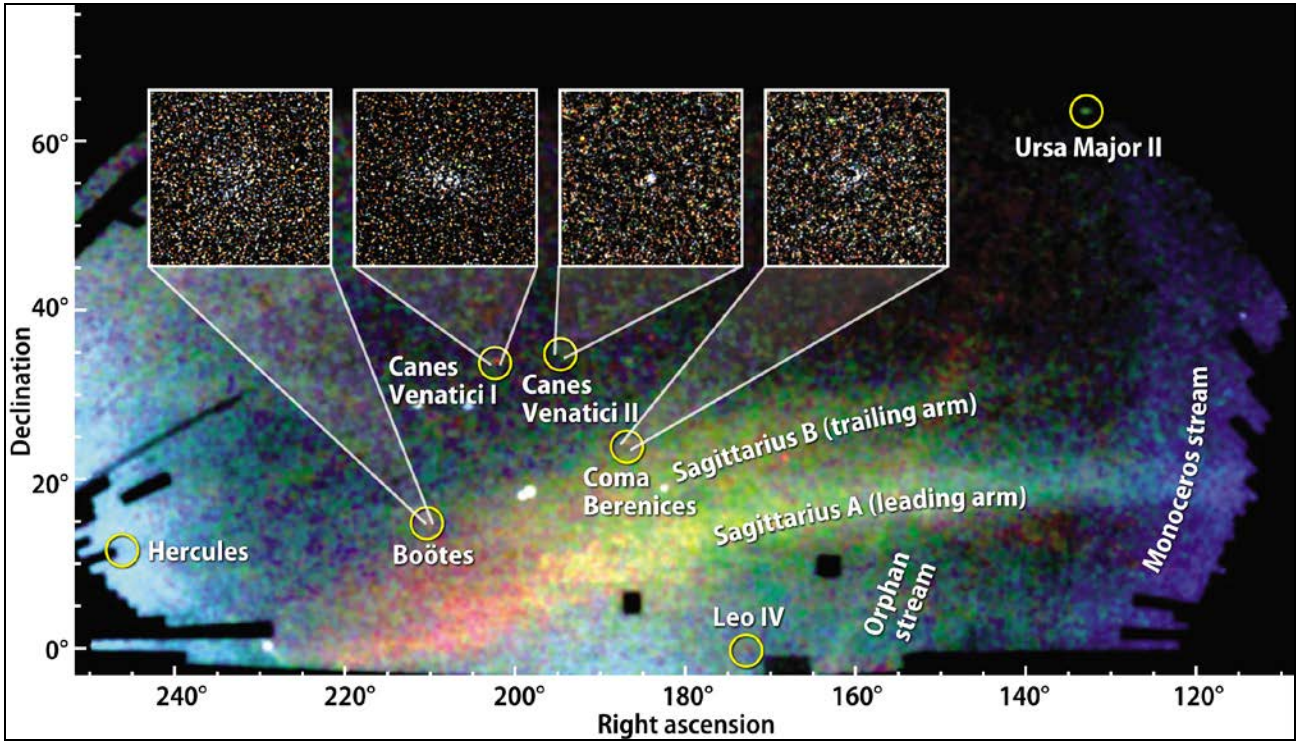
Atmospheric transmission spectrum (4 hours) for HD209458-like Kepler source
using NIRSpec (R=3000). Simulation from J. Valenti

JWST/NIRSpec can detect **water**
in a super-earth's **habitable zone**

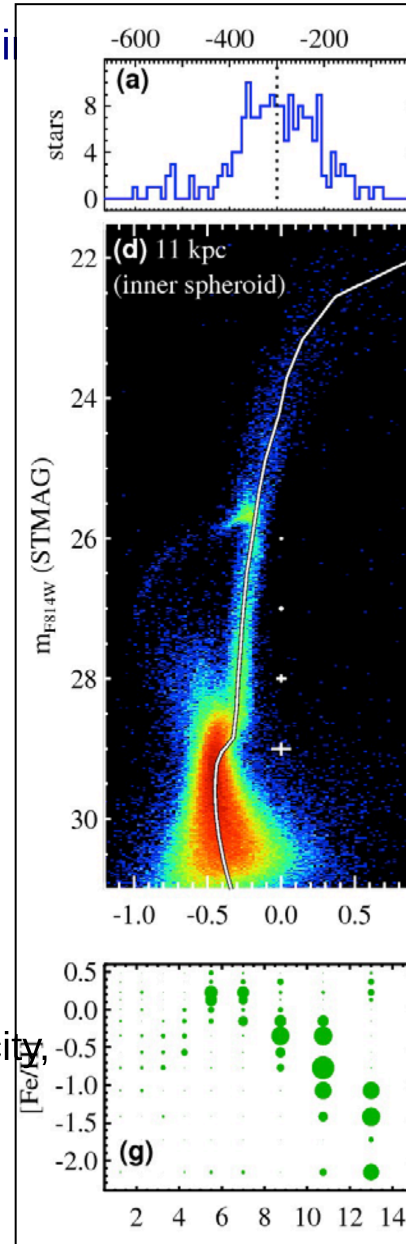


JWST and Resolved Local Stellar Populations

Synergy between wide-field ground based imaging, HST ultra-deep imaging and 10-m spectroscopy



SDSS Field of Streams



SDSS, HST, & Keck work together to yield substructure maps, metallicity, ages, and kinematics of nearby Local Group galaxies.

Brown et al. (2008)

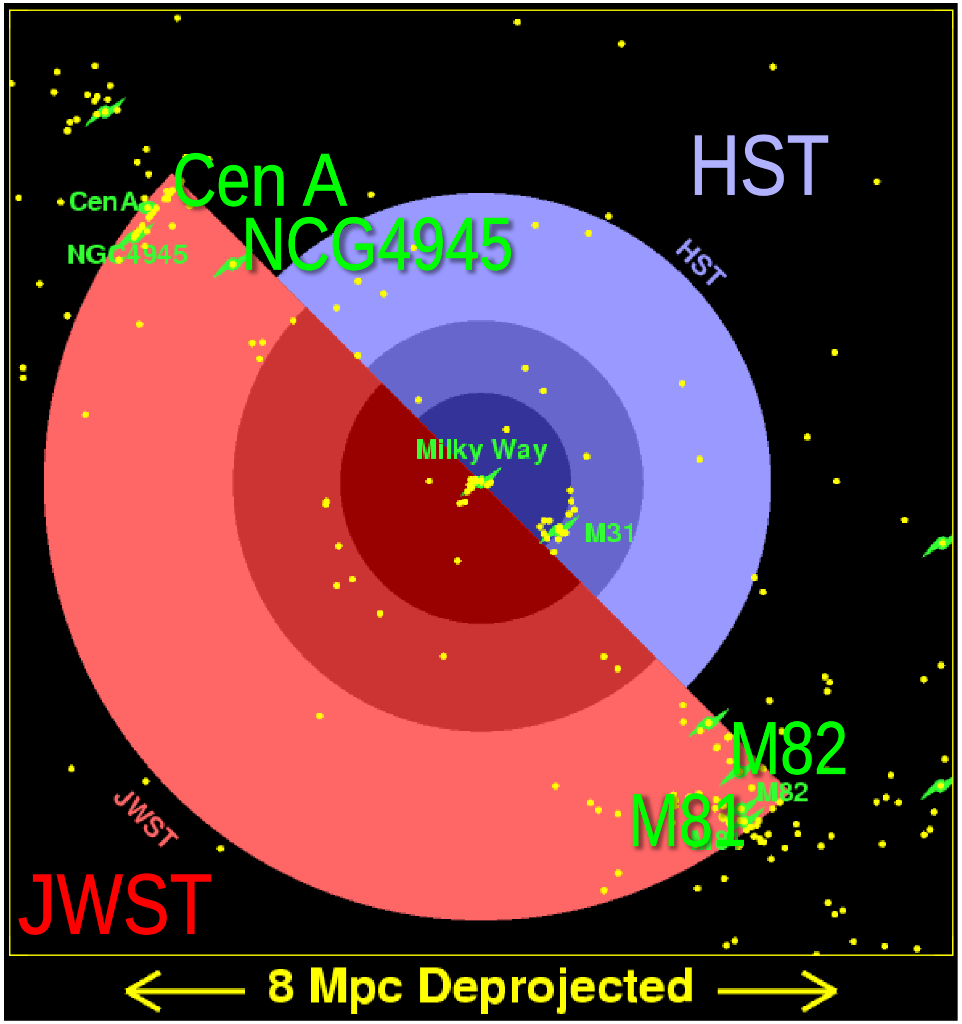
JWST and Resolved Local Stellar Populations

JWST will push beyond the Local Group, and probe sensitive age variations.

Extended Star Formation History will be efficiently measured with filters well-separated in wavelength and with larger FOVs than Hubble

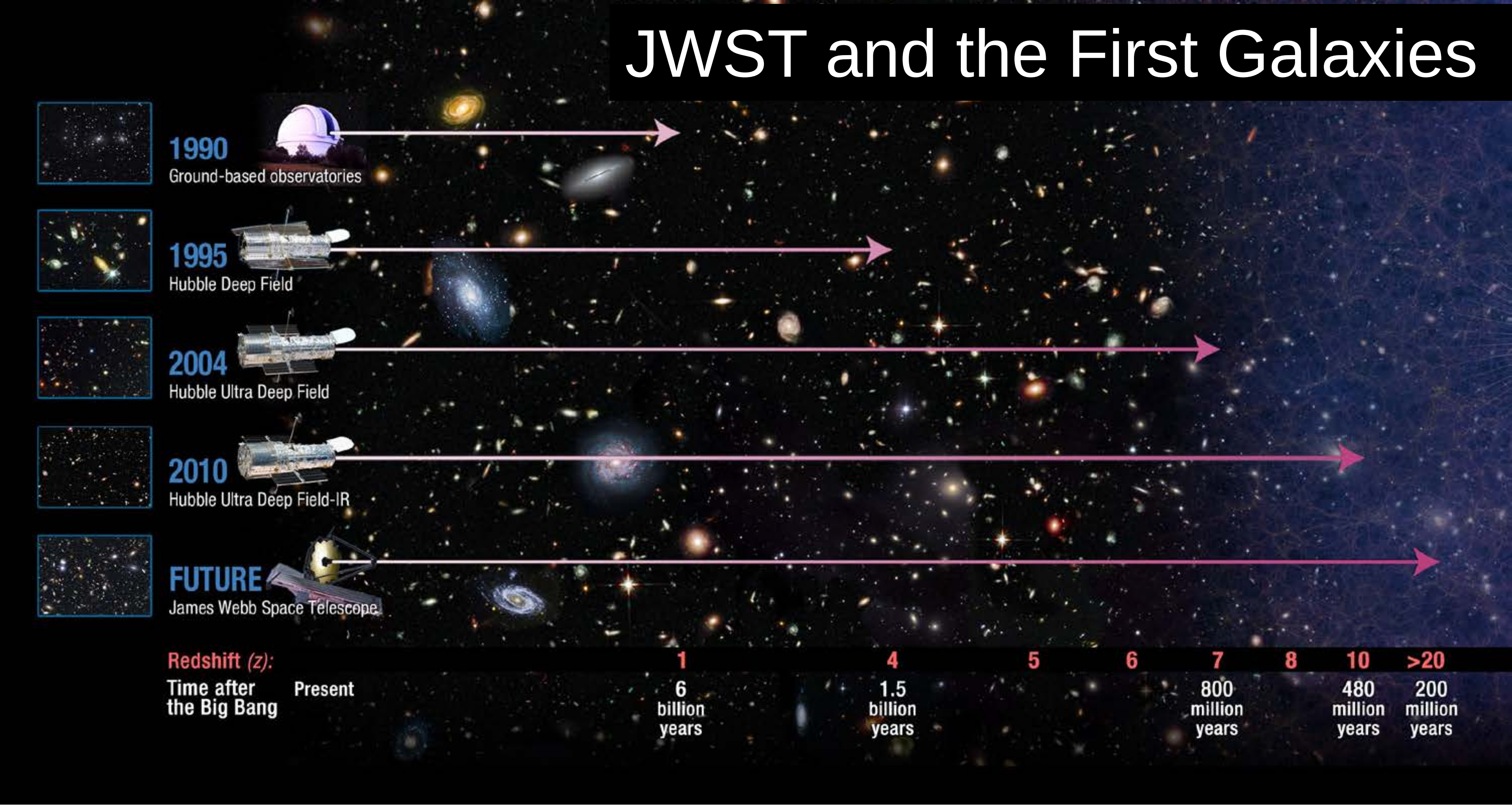
JWST will yield the first **direct ages in galaxies** outside the Local Group **in 10 hours**

concentric circles indicate 10, 100, and 1000 hours



T. Brown et al. (2008), JWST White Paper, *"Studying Resolved Stellar Populations with JWST"*

JWST and the First Galaxies



Why measure galaxies in the Universe's first billion years?

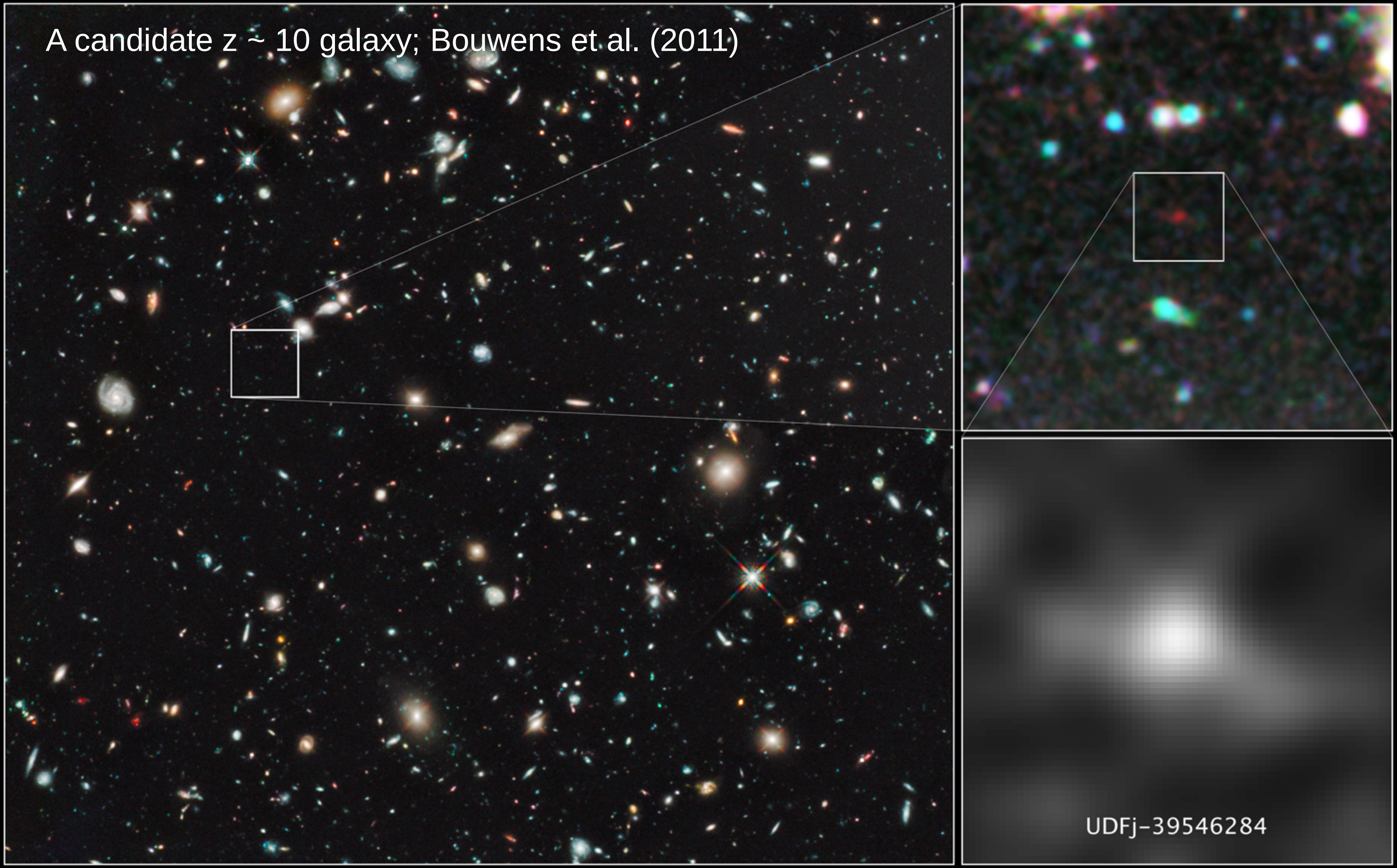
Seeds of today's galaxies started growing

Dark matter halos of massive galaxies first formed

Significant metals first formed

When the Universe was reionized

JWST will resolve ambiguities in fitting SEDs from Hubble and Spitzer by spectroscopically characterizing early systems at $z = 9$, and characterizing stellar contributions to $z > 10$.

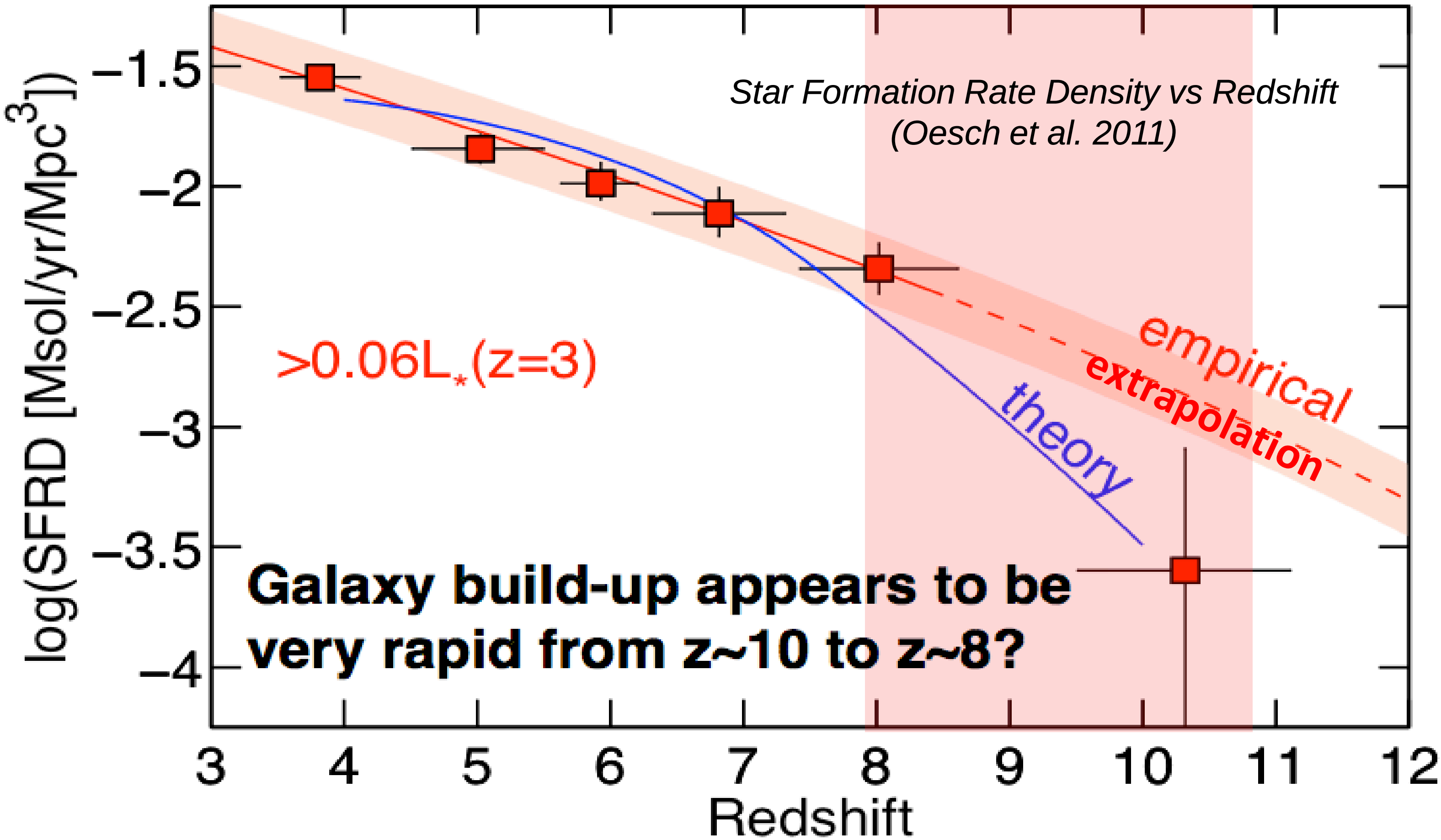


Hubble Ultra Deep Field 2009-2010
Hubble Space Telescope • WFC3/IR

NASA, ESA, G. Illingworth (University of California, Santa Cruz),
R. Bouwens (University of California, Santa Cruz and Leiden University), and the HUDF09 Team

STScI-PRC11-05

JWST and First Galaxies



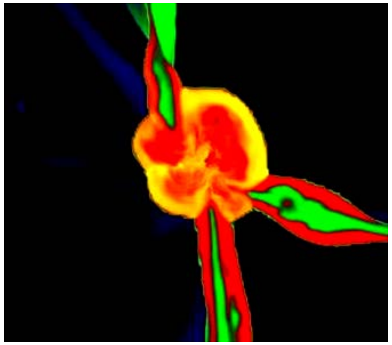
Hints from Hubble that a big change is occurring 400 – 600 Myr after the Big Bang.

JWST will provide a robust picture of the number of galaxies and their properties.

May need help from gravitational lensing (do homework now).

How do we know if we've found the *first* galaxies? See R. Ellis' talk at the *"Frontier Science Opportunities with JWST"* meeting.

JWST and First Supernovae



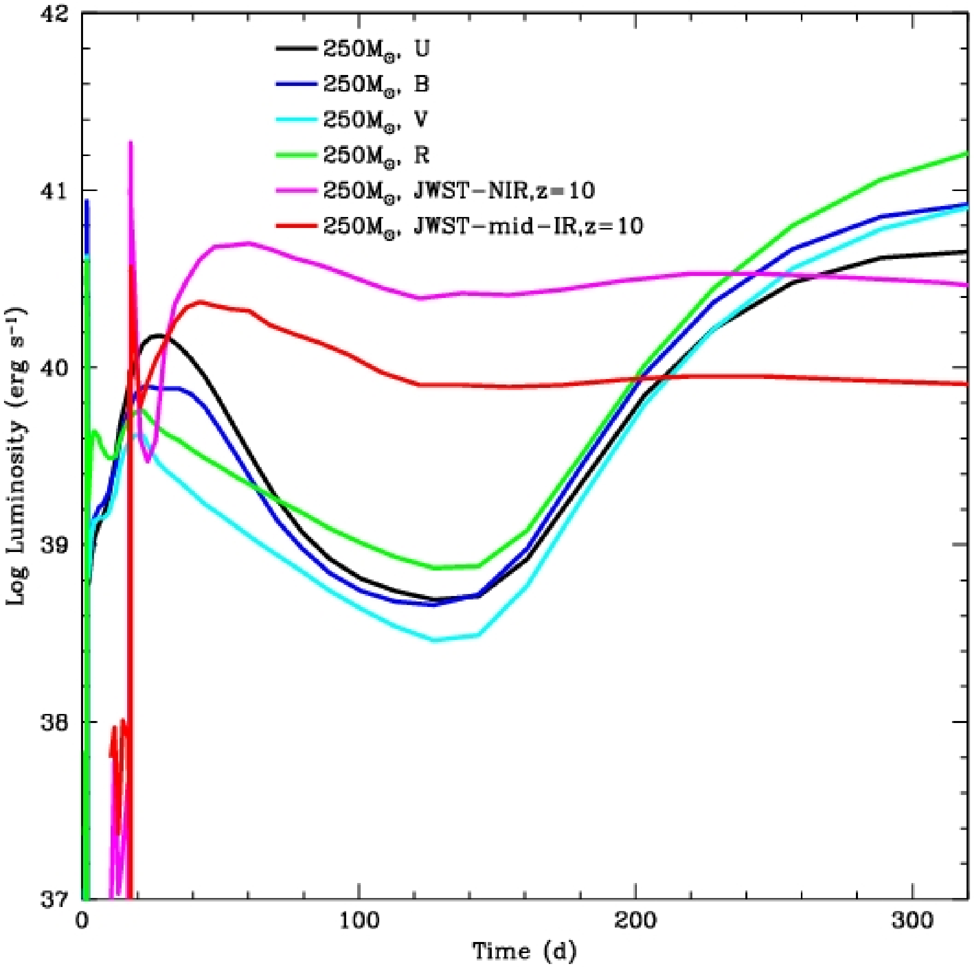
D. Whalen's talk at the "Frontier Science Opportunities with JWST" meeting

New simulated light curves show late time rise over > 100 days

Infrared energy diffuses out through dense ejecta of PI SNe…

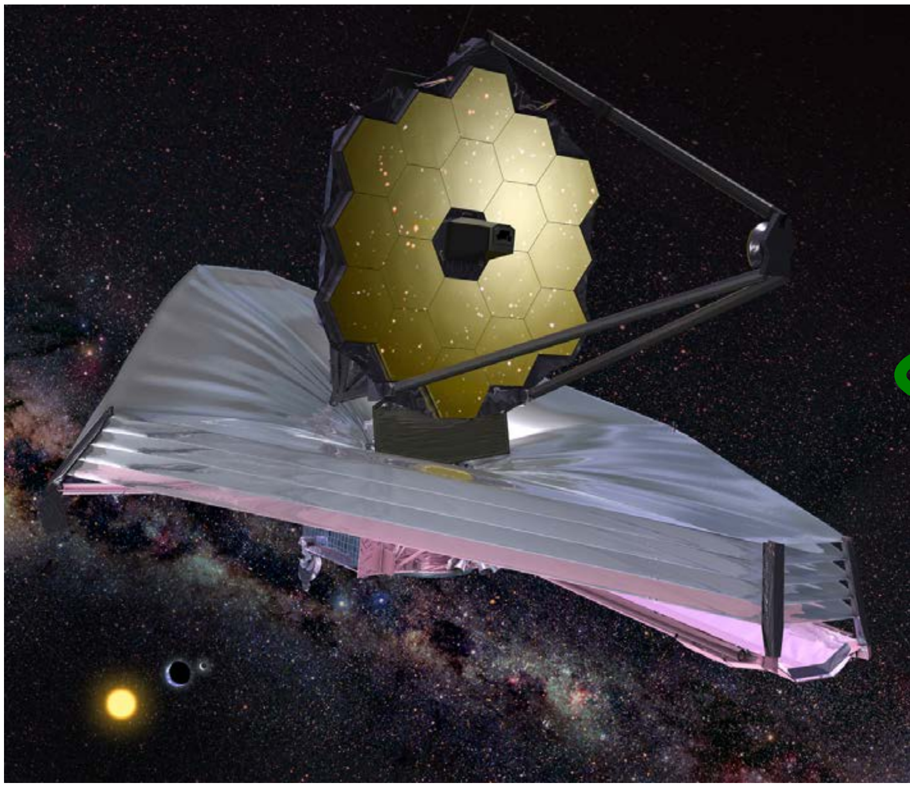
Can be measured with JWST to z > 10 and maybe 15 with strong lensing in this model

Ground-based follow up with 30-m telescopes will help distinguish progenitors



JWST status update

reminder: there is an “one miracle per major mission” rule, so for JWST we addressed some needed “miracles” *before we even formally started*….



Technological Firsts for this mission

Segmented Beryllium Primary Mirror

Composite Backplane Structure

Mirror Phasing and Control Software

Application Specific Integrated Circuit

Micro-Shutters

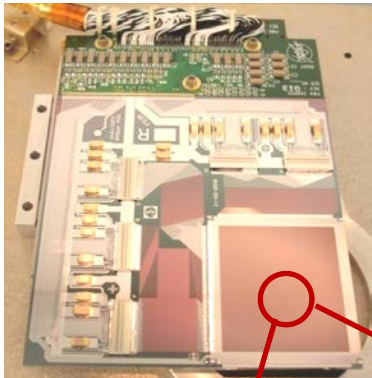
Sunshield Membranes

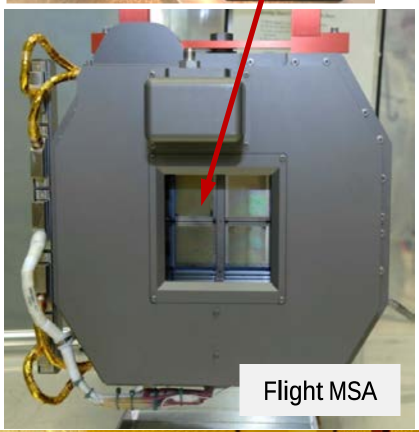
Mid-Infrared Detectors

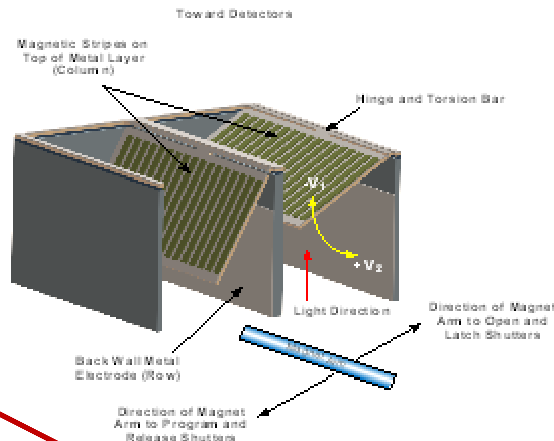
Cryo-cooler for Mid-Infrared Instrument

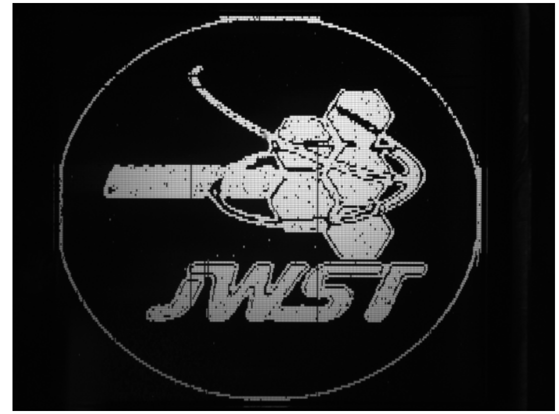
Other “inventions” (e.g., Tinsley’s Shack-Hartmann technique for mirror surface measurement, SSHS)

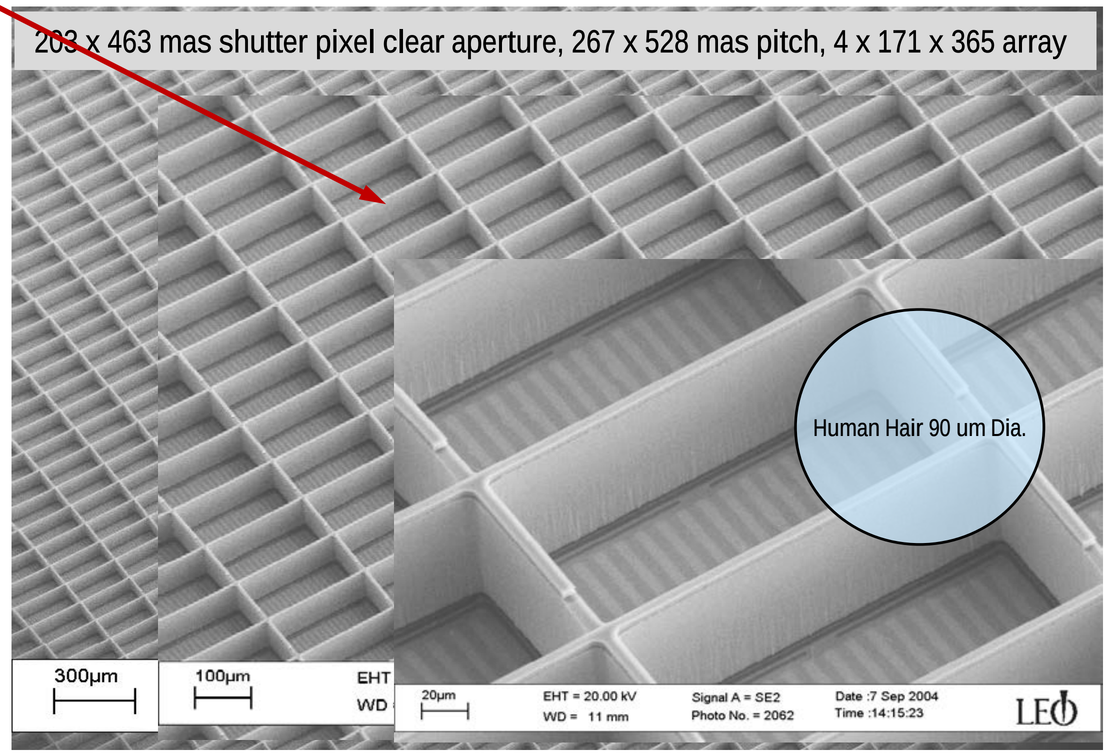
NIRSpec Microshutter Array

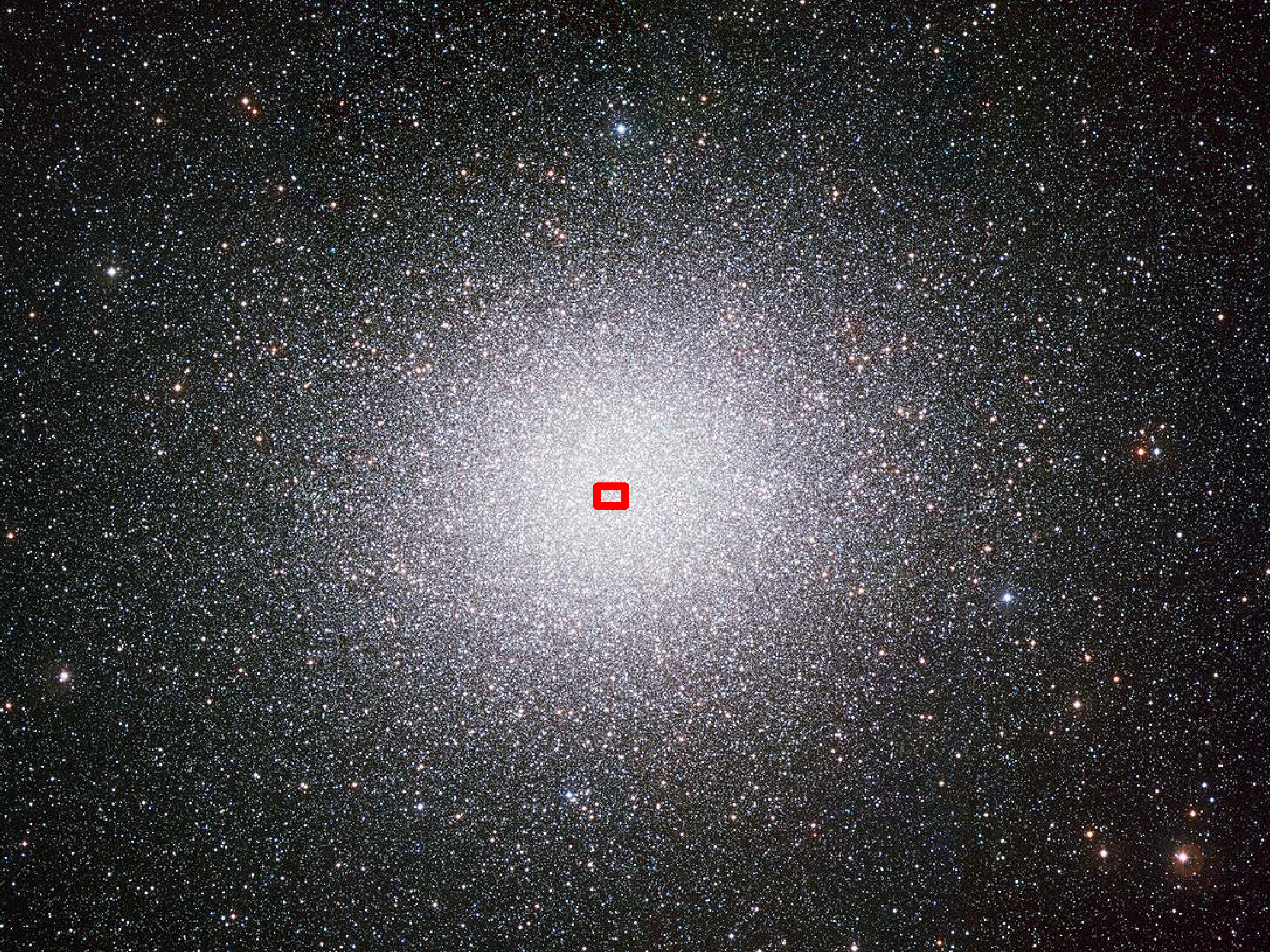




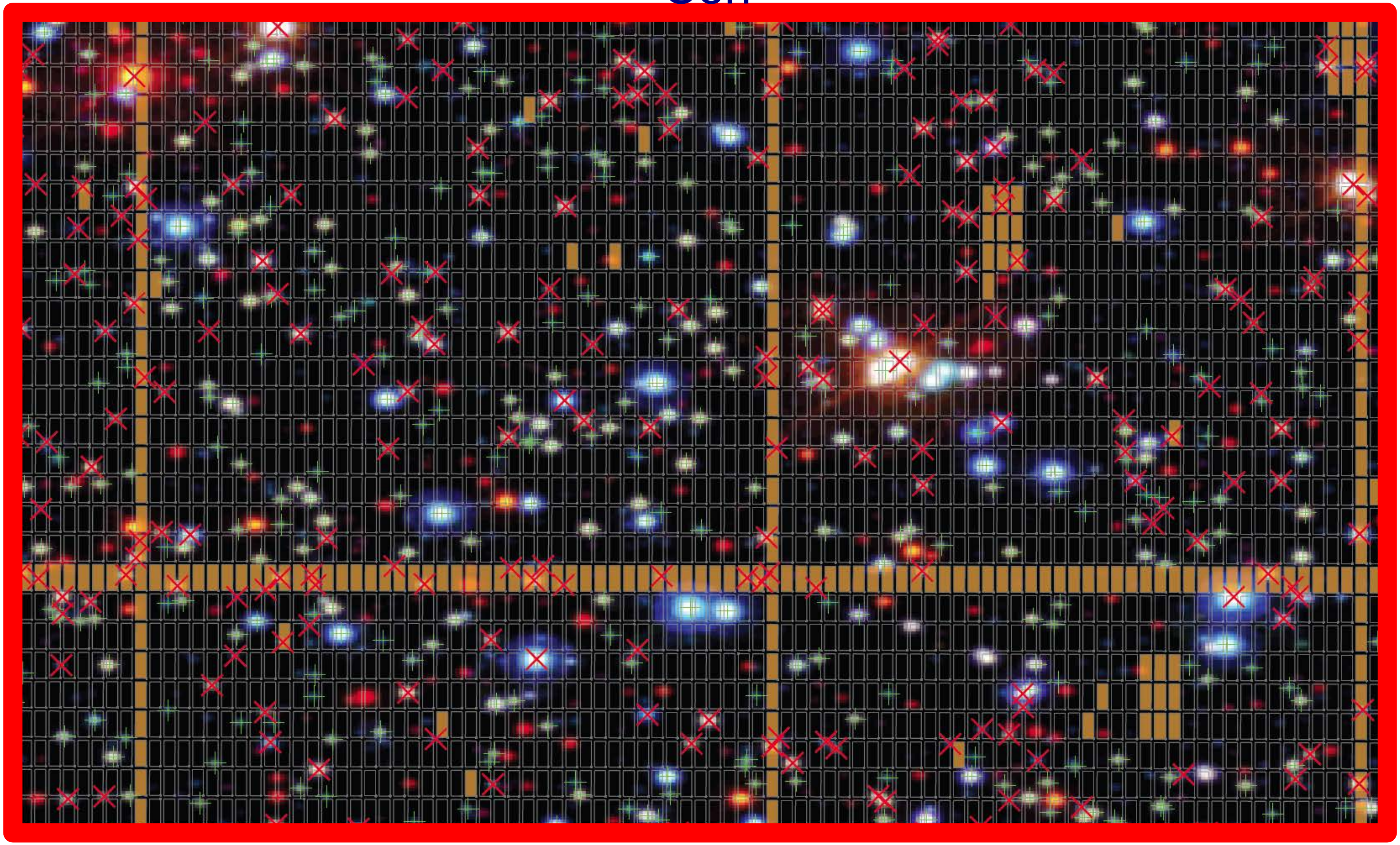








NIRSpec Microshutter Array superimposed on center of Omega Cen



+ Targets in operable shutter   x Targets outside shutters

JWST– 6.5 segmented mirror in space

JWST– Ambient Optical Assembly Stand

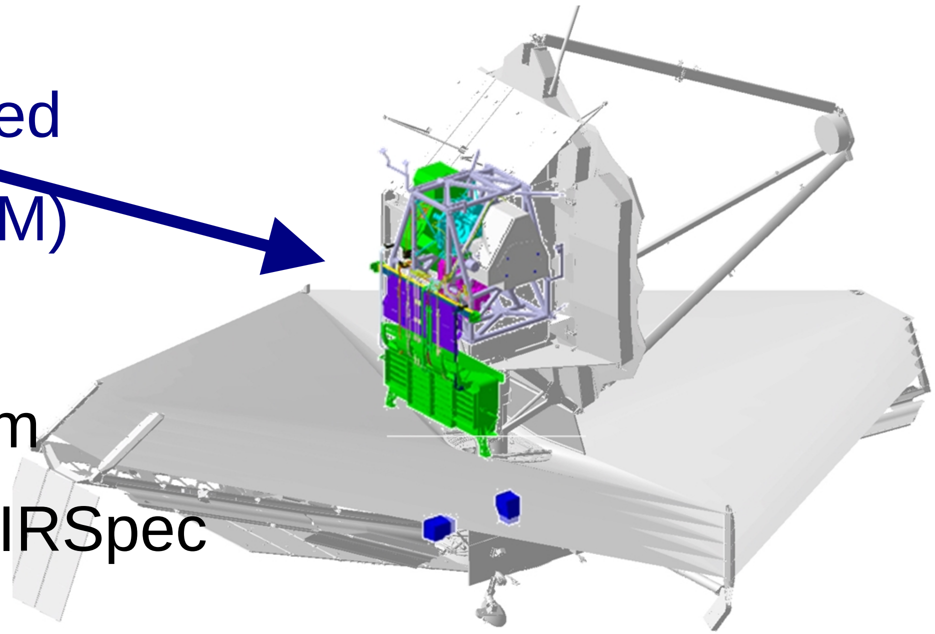
http://www.jwst.nasa.gov/webcam.html

AOAS built in the GSFC High Bay earlier this year

Time-lapse video at: http://www.nasa.gov/topics/technology/features/webb-assembly-stand.html

JWST technology – complex suite of instruments

Four instruments in the Integrated Science Instrument Module (ISIM)



Near Infrared Camera – NIRCam

Near Infrared Spectrograph – NIRSpec

Mid Infrared Instrument – MIRI

Near Infrared Imager and Slitless Spectrograph – NIRISS

Not your Typical Telescope

- >40 imaging filters with fields of view larger than Hubble
- 8 different types of spectroscopic modes (wide field grism, single object, IFU, multiobject, etc.)
- 7 coronographs including non-redundant aperture masks for high-resolution imaging

NIRCam

NIRSpec


NIRSpec
+V1
ASTRIUM
ASTRIUM
NIRSpec
NEAR-INFRARED SPECTROGRAPH

MIRI

MIRI Unloaded At GSFC

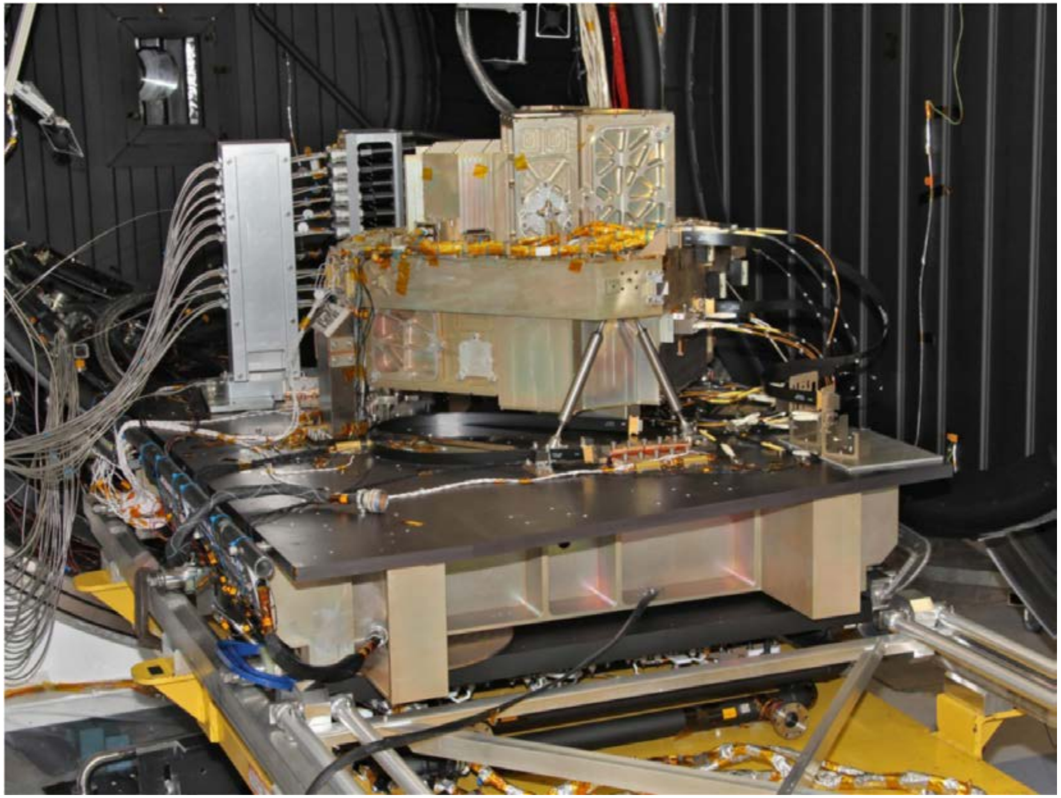
MIRI box delivered to Building 29

MIRI in SSDIF

MIRI in High Bay in Building 29

NIRISS

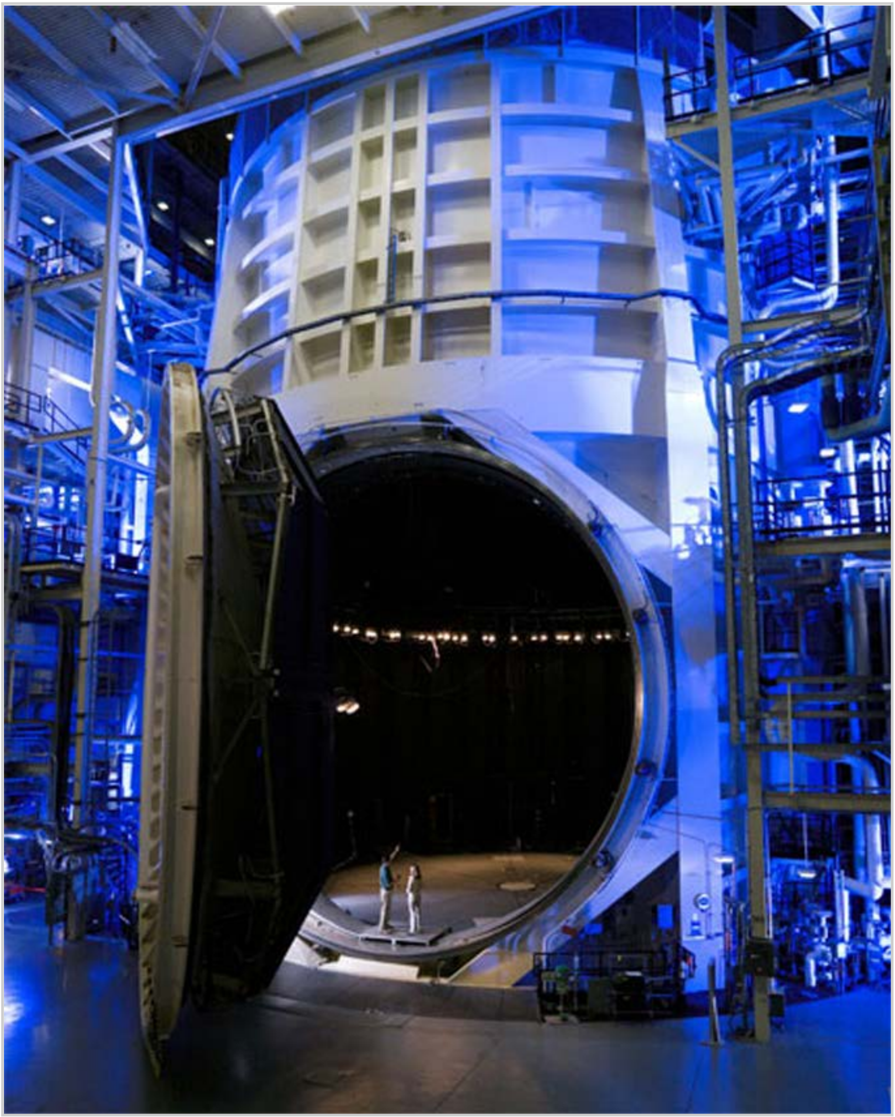
CSA's Near InfraRed Imager and Slitless Spectrograph

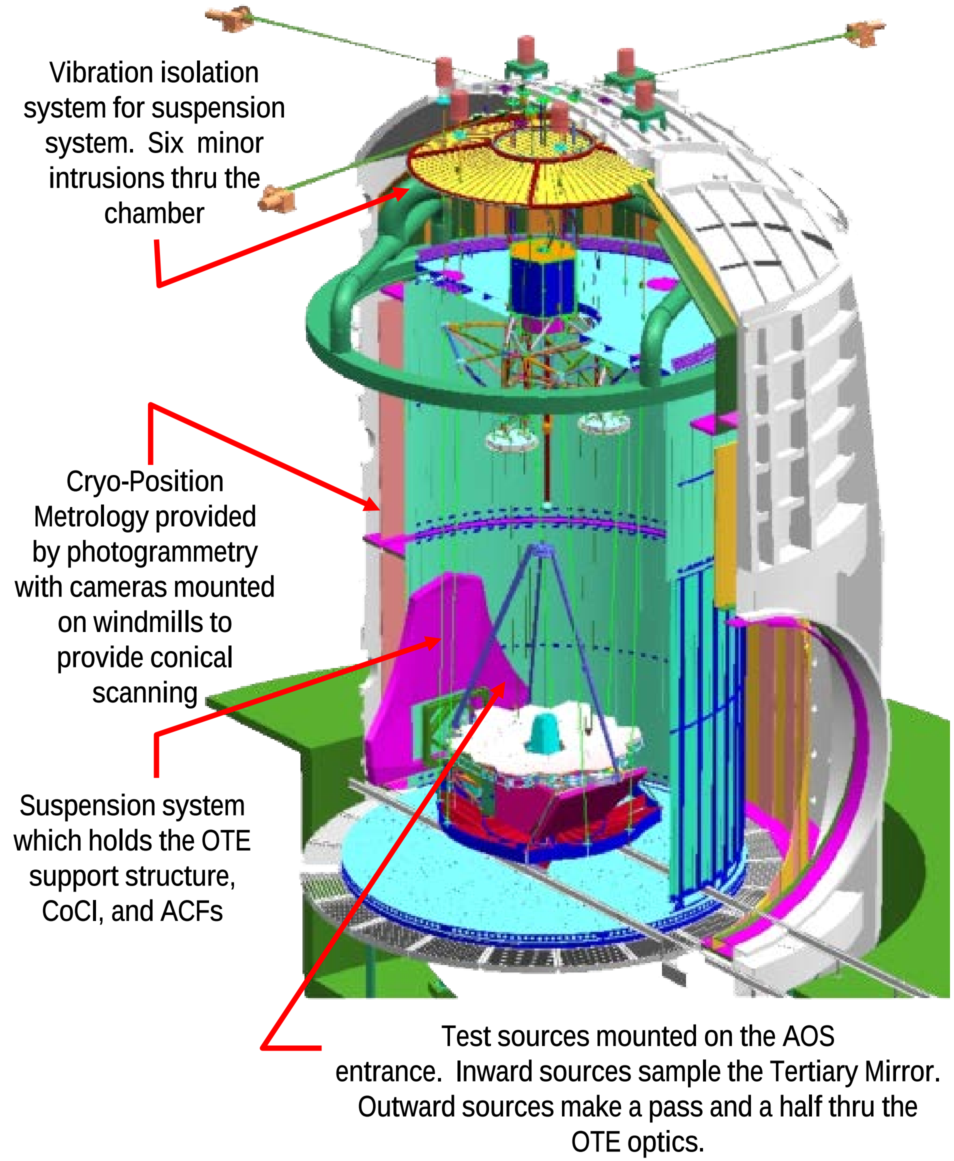


85-day CVAC campaign successfully completed
100's of Gbytes of data acquired and in analysis
Outgassing test successfully passed
Guider performance was checked successfully
Hardware performance is as modelled

JWST technology – tennis-court sized 5-layer sunshield

JWST Technology – Integration and Testing





NEXT SLIDE

JWST Technical Milestones

FY2012 to date

Month	Milestone	Comments
Oct '11	Begin construction of 140,000-lb robotic facility to build segmented main mirror at GSFC	Assembly began 10/4
Nov '11	Complete electronics simulator model for Integrated Science Instrument Module ("ISIM") Deliver tools for software development environment and verification	Completed 11/15 Completed 10/27
Dec '11	Install Helium shroud floor at Johnson Space Center thermal vacuum chamber ("JSC TVC") Determine root cause of NIRSpec optical bench flaw	Completed 10/26 Completed 12/15
Jan '12	Conduct Critical Design Review for Spacecraft-to-Optical Telescope Element vibration isolation system Finish building Center of Curvature Optical Assembly ("COCOA") for testing primary mirror in JSC TVC Review preliminary requirements for ground structure for spacecraft equipment panels Complete Aft Optic System integration and alignment Update Program Plan and Program Commitment Agreement to reflect replan	Completed 12/15 Completed 1/13 Completed 12/1 Completed 12/2 Completed 1/28
Feb '12	Complete assembly and initial testing of main mirrors at Marshall Space Flight Center Install Helium shroud walls at JSC TVC	Completed 12/19 Completed all panels 2/2
Mar '12	Complete assessment of System Engineering Team thermal margins Deliver ISIM computer #2 to ISIM integration and testing Complete analysis of JSC TVC telescope testing equipment plans	Completed 3/1 SDRAM part failure in T/V. Completed 5/16 Completed 3/19
Apr '12	Receive Flight Mid-infrared Instrument (MIRI) from Europe, first of the telescope's four science instruments Complete Critical Design Review for Sunshield Support Structure Complete all composite parts for mechanism that lifts telescope away from spacecraft after launch (Deployable Tower Assembly)	Received 5/29 Completed 3/21 Completed 2/28
May'12	Finish testing the COCOA Measure Sunshield template layer 5 shape to confirm its accuracy Conduct budgetary and schedule review of initial program and project performance since completing the 2011 replan	Completed 3/9 Completed 4/23 Completed 5/30

JWST public resources

JWST **Recent Accomplishments** http://www.jwst.nasa.gov/recentaccomplish.html

JWST **Exposure Time Calculator** http://jwstetc.stsci.edu/etc/

JWST **Email Contact** For Community Input jwst_input@stsci.edu

JWST **PSF** Tool http://www.stsci.edu/jwst/software/webbpsf.html

JWST **Facebook Page** For Astronomers “JWST Observer”

JWST **Webb-cam** http://www.jwst.nasa.gov/webcam.html

JWST **Science Talks** from the “Frontiers Meeting”
https://webcast.stsci.edu/webcast/searchresults.xhtml?searchtype=20&eventid=147&sortmode=2

JWST **Twitter** @auraJWST

JWST **Websites** http://www.stsci.edu/jwst and http://www.jwst.nasa.gov

James Webb Space Telescope at this SPIE meeting: 1 of 6

Optical transmission for the James Webb Space Telescope, Paul A. Lightsey, Benjamin B. Gallagher, Neal Nickles, Ball Aerospace & Technologies Corp. (USA) [8442-119]

James Webb Space Telescope stray light performance status update, Paul A. Lightsey, Zongying Wei, Ball Aerospace & Technologies Corp. (USA) [8442-120]

Multi-field alignment of the James Webb Space Telescope, D. Scott Acton, J. Scott Knight, Ball Aerospace & Technologies Corp. (USA). [8442-121]

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