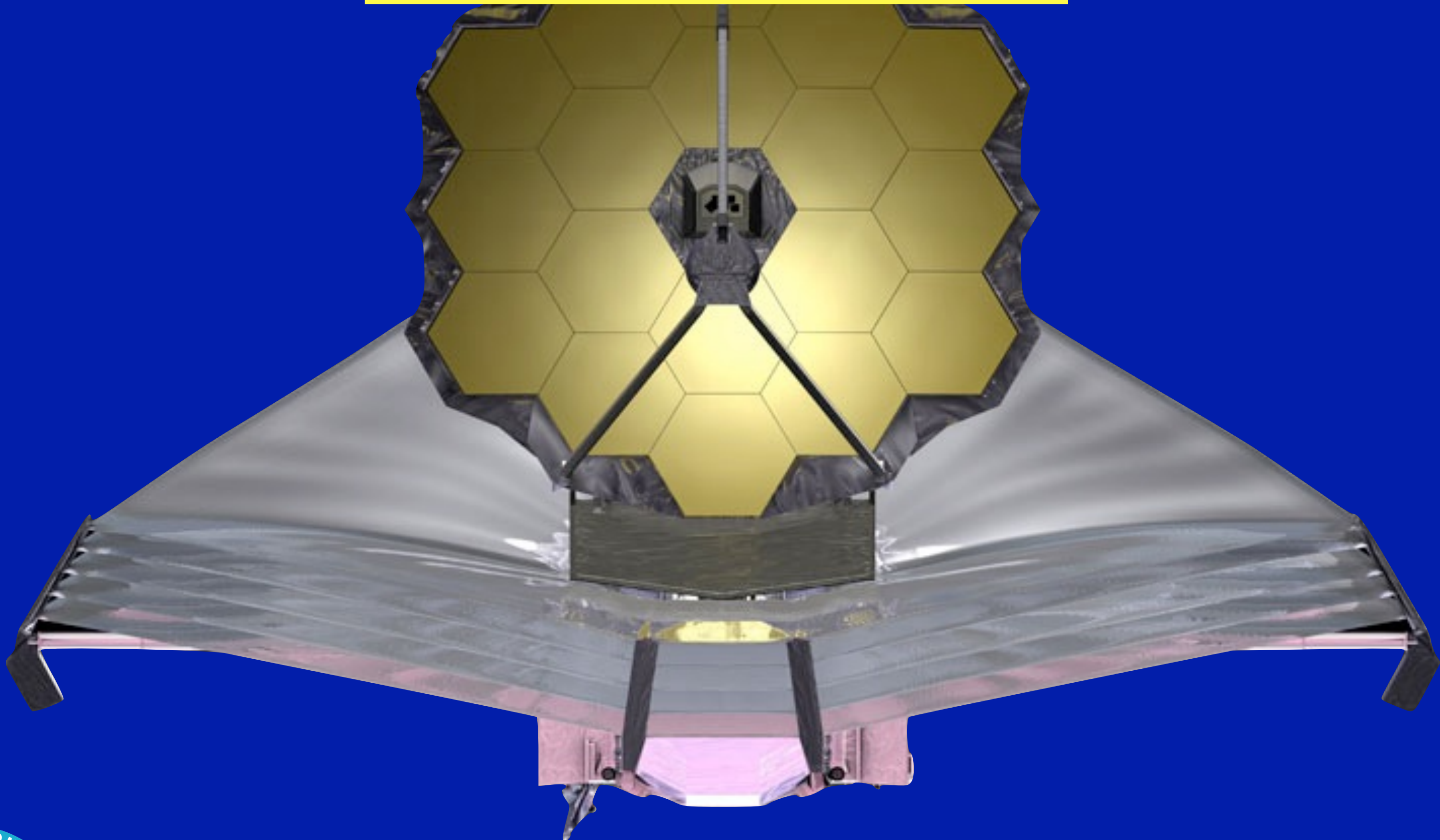
IASF-Bo 18 maggio 2016 – OABo 23 giugno 2016

JWST

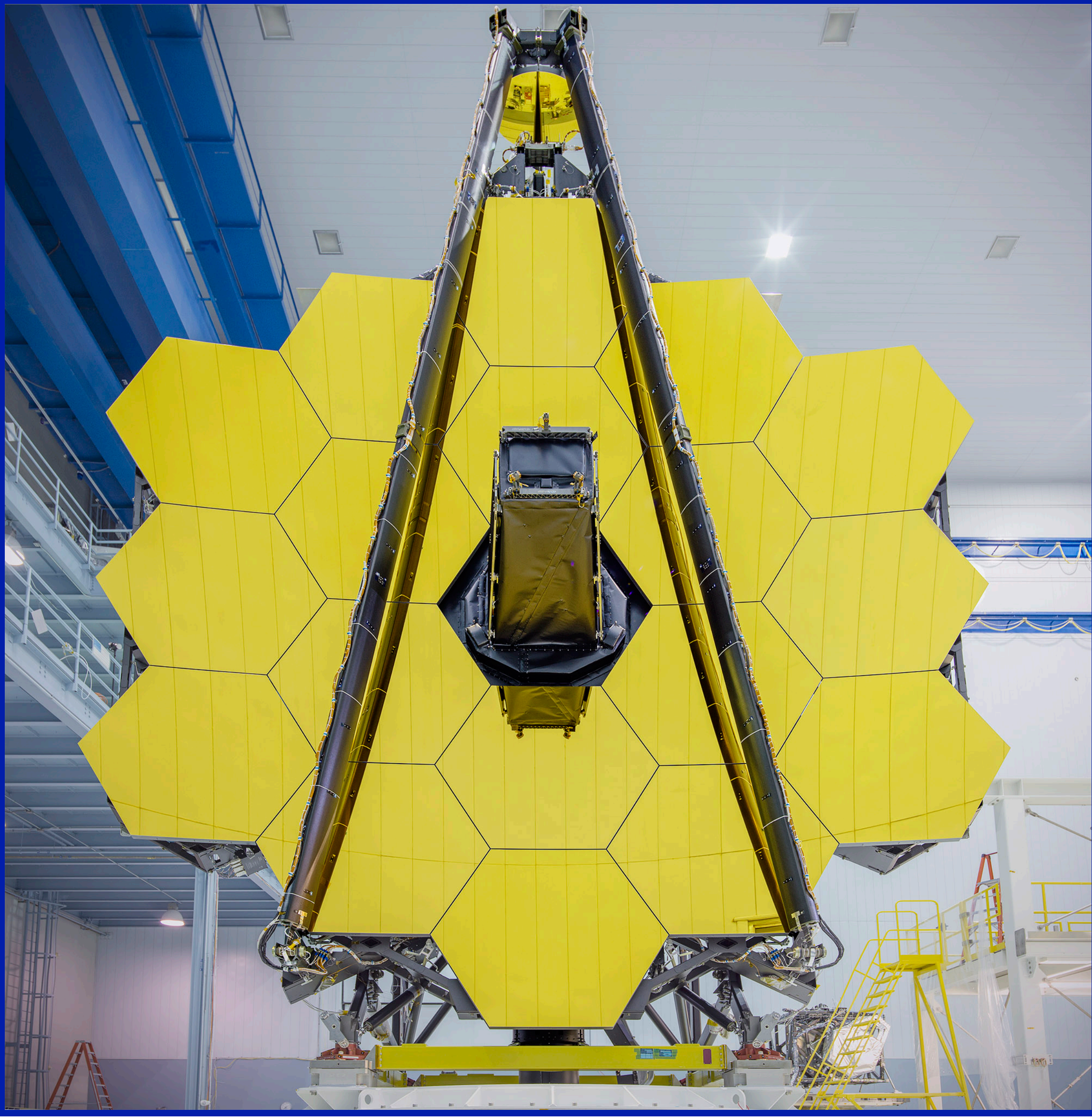


Monica Tosi

INAF-OABO e JSTAC

(JWST Science & Technology Advisory Committee)

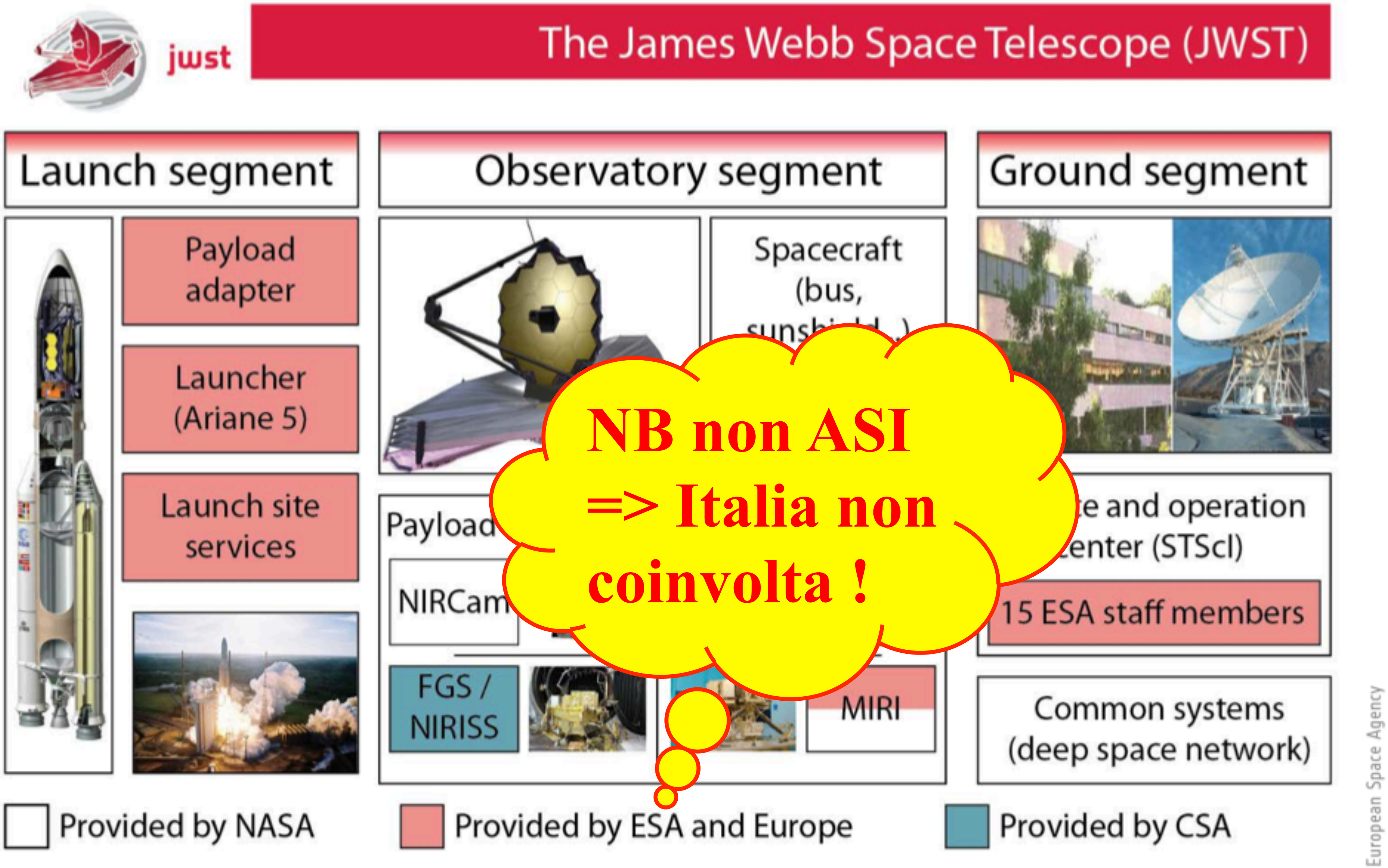
Simply Awesome!



The first segmented mirror: Horn's since 1935 in Bologna

JWST is on schedule for its Oct 2018 LAUNCH!

JWST mission in a nutshell

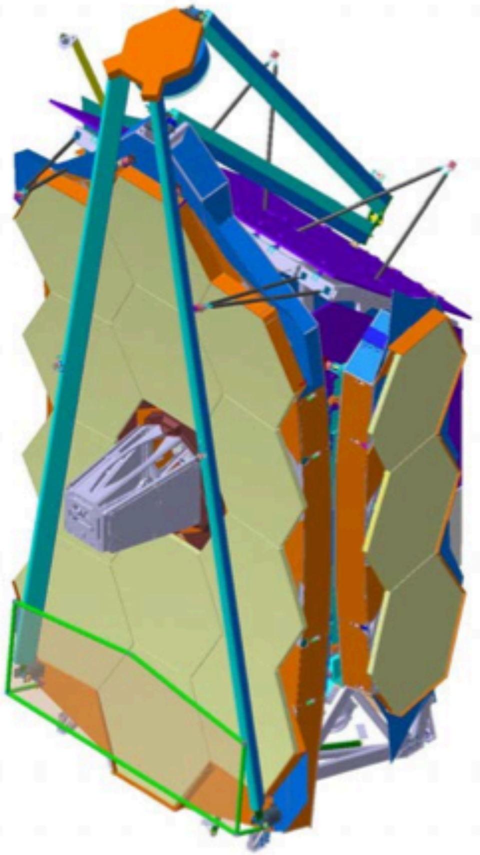


NB non ASI => Italia non coinvolta !

0.6 – 5 micron + MIRI: 5 – 28 micron

The deployment

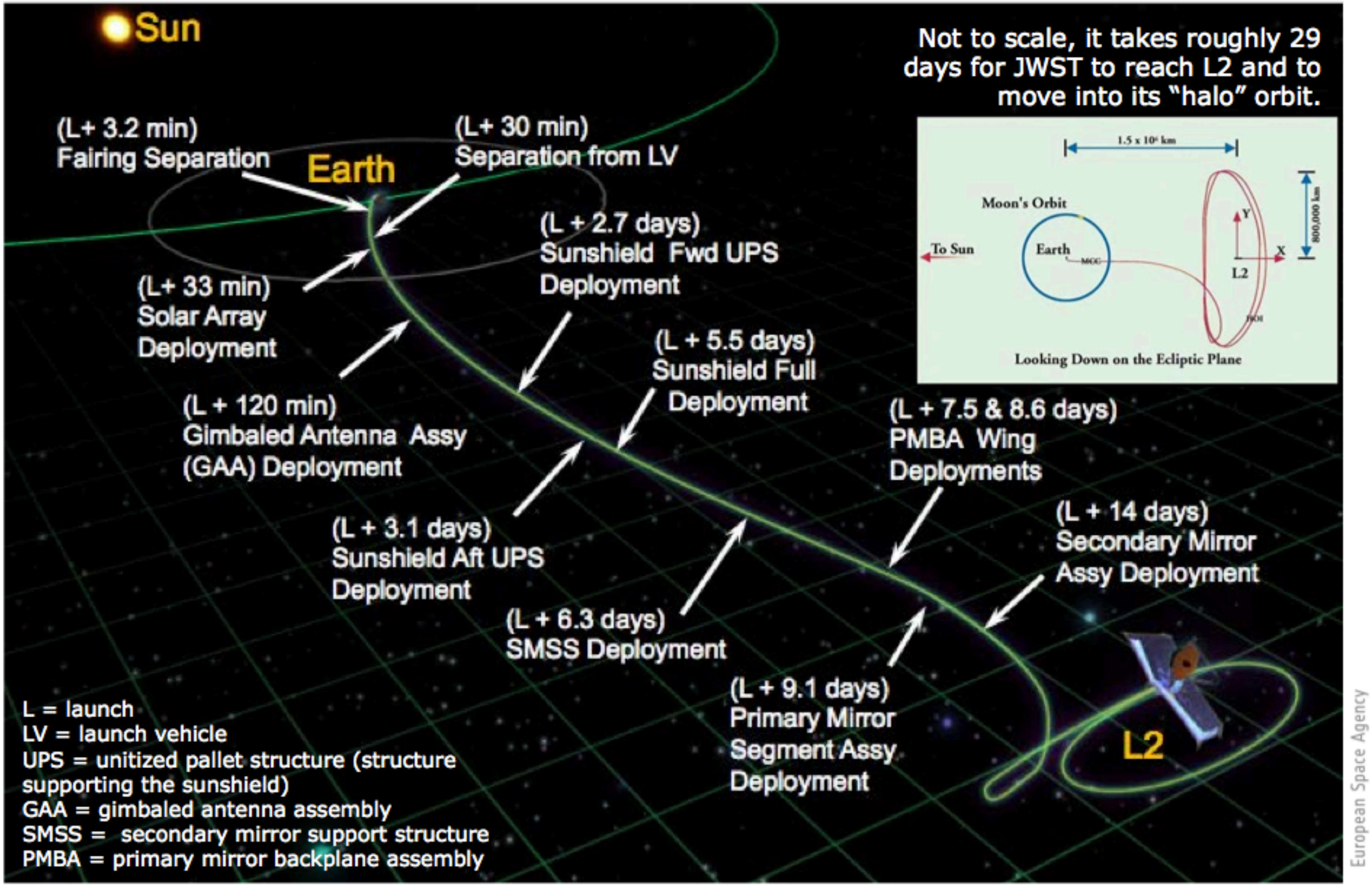
- **JWST will be launched by an Ariane 5 rocket with a 5-meter diameter fairing.**
  - JWST will be folded to fit in the Ariane 5 fairing and will deploy on in-orbit.



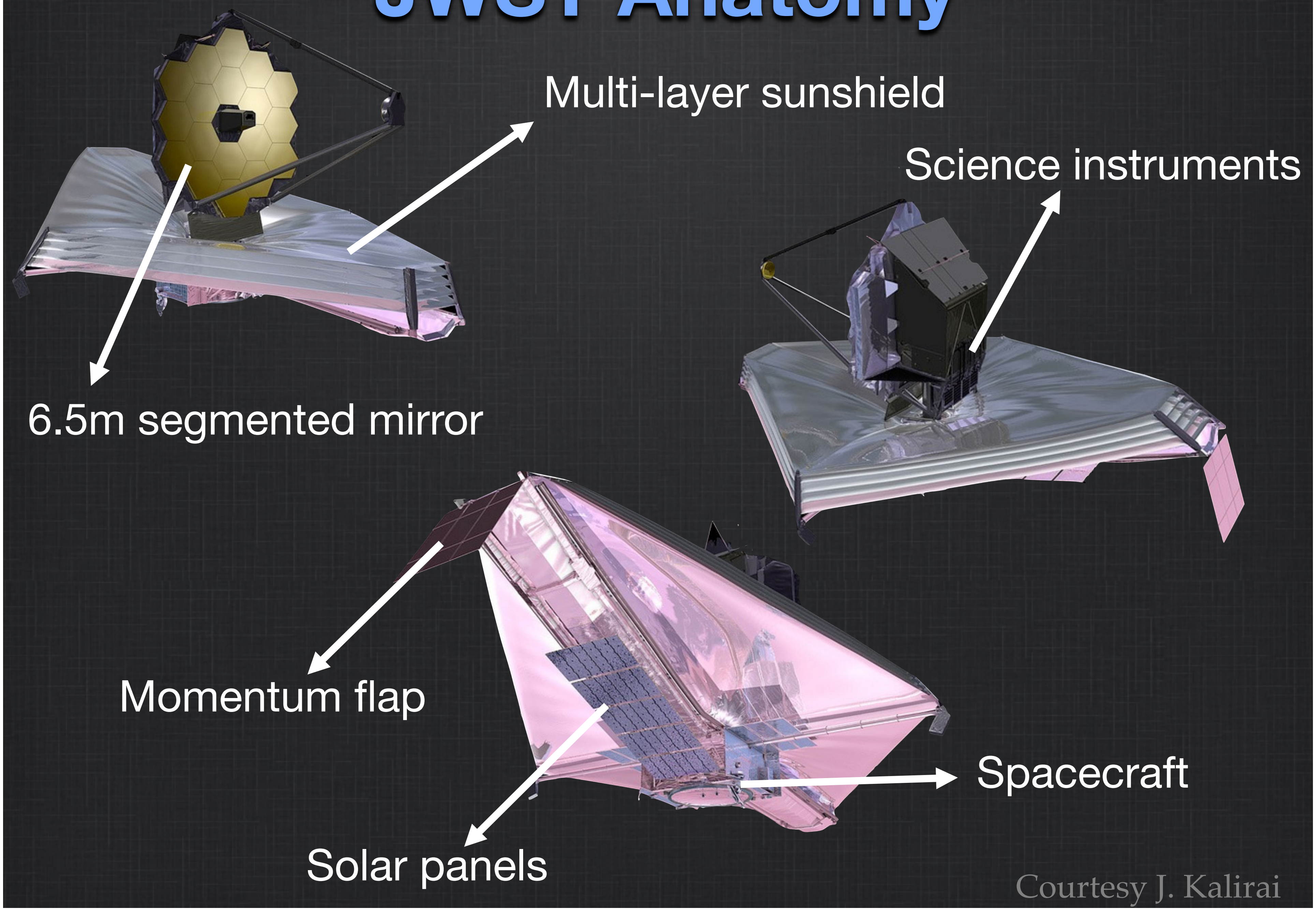
Without the sun shield

European Space Agency

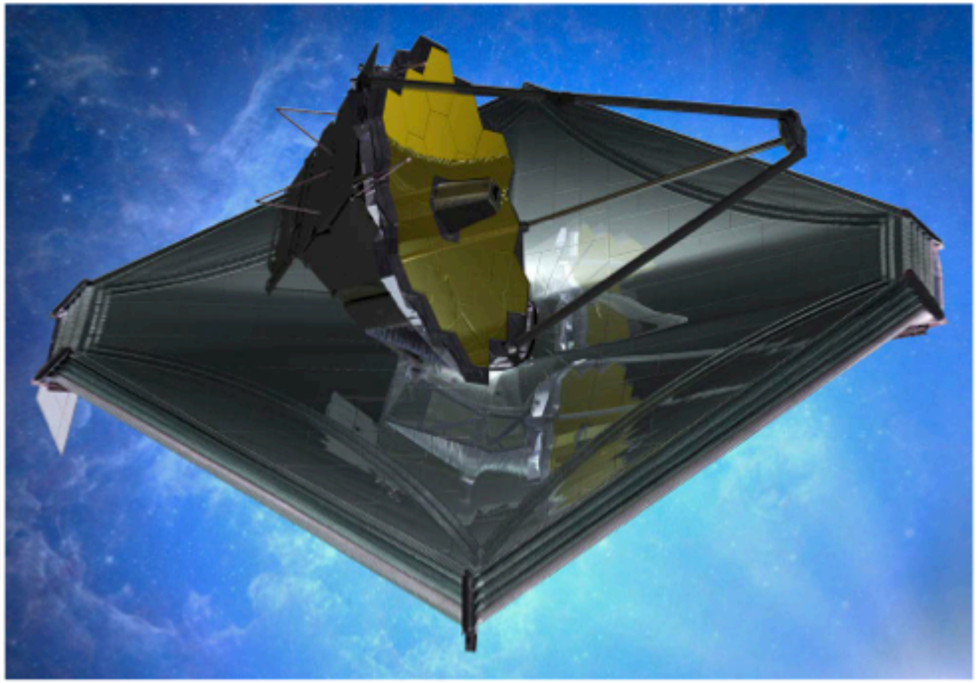
The deployment



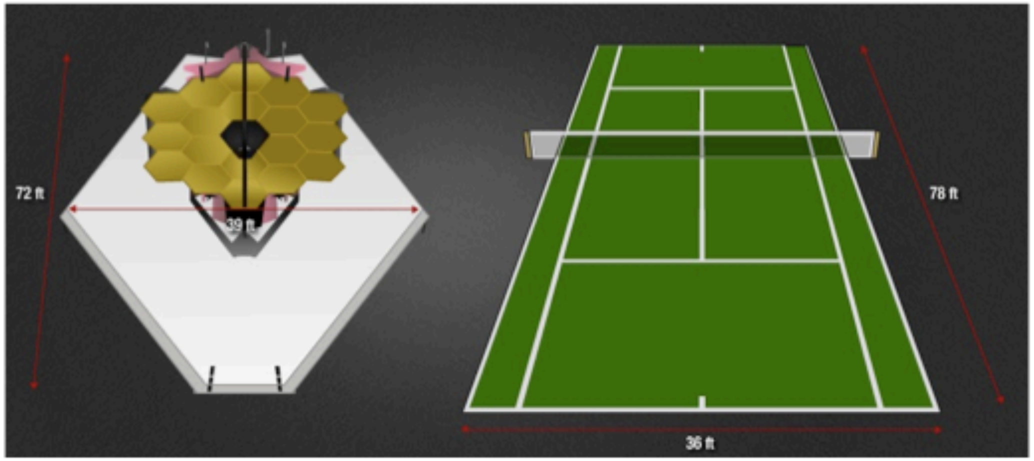
JWST Anatomy



The sunshield

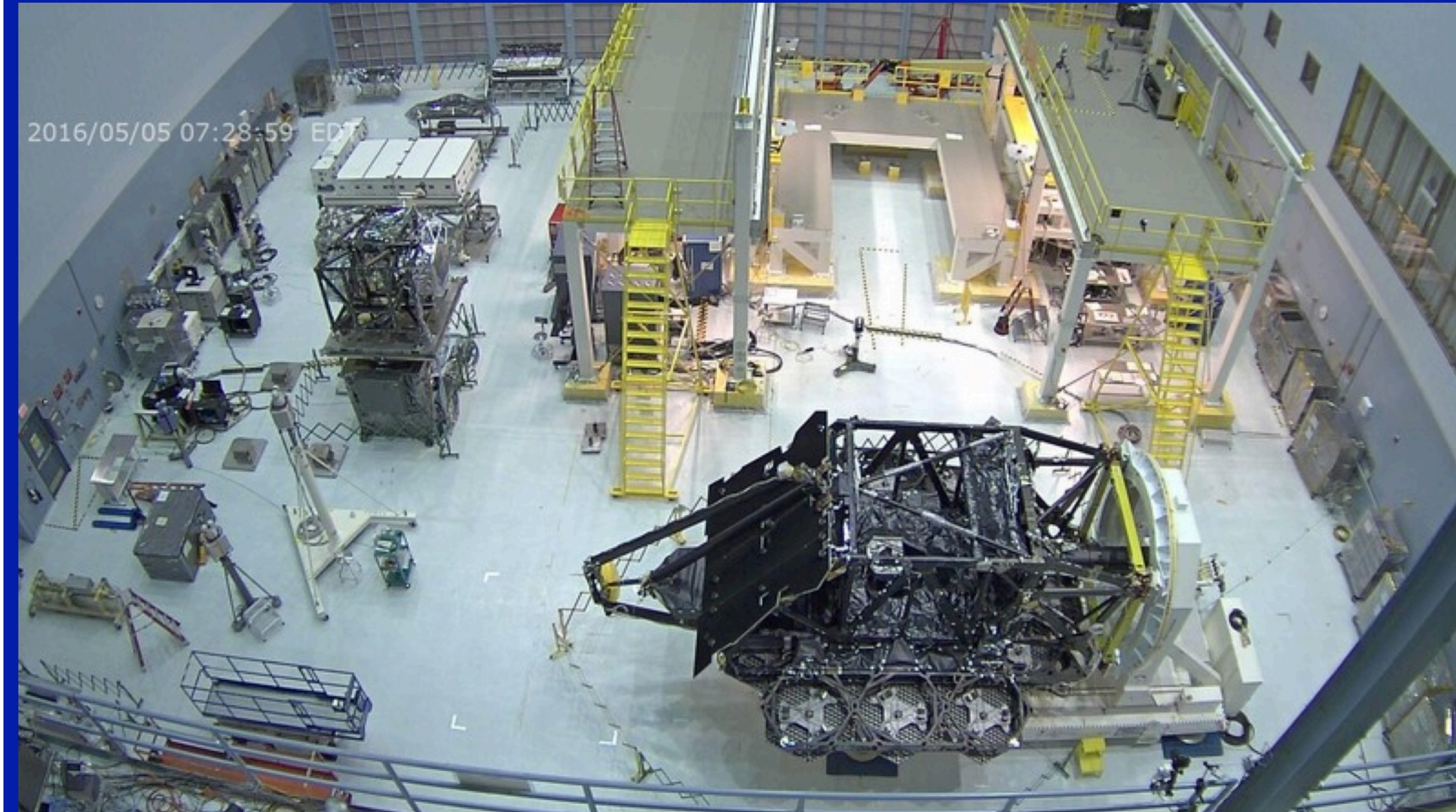


72 ft = 22 m



Pictures from beginning of May: front

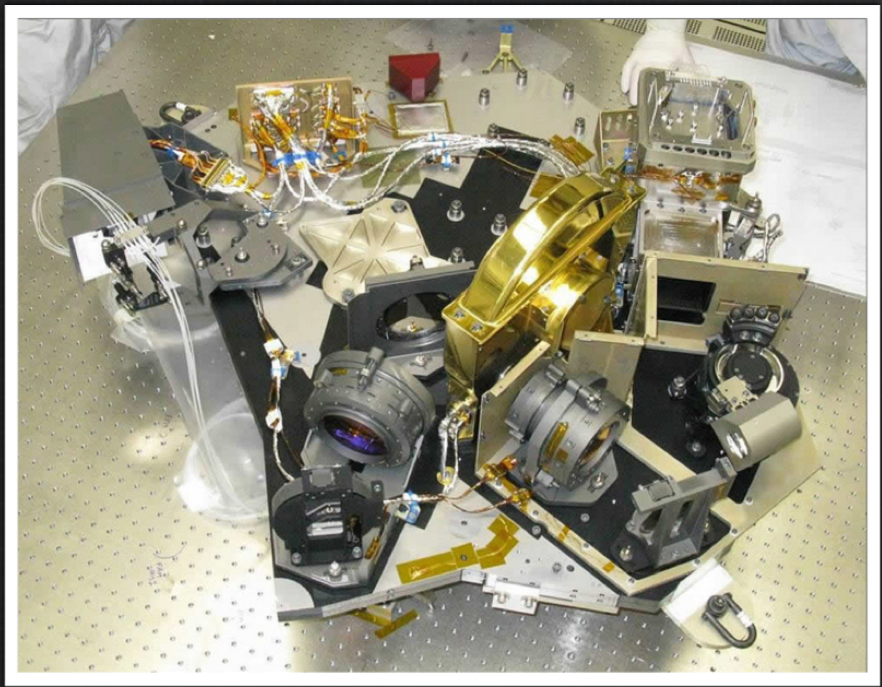
Pictures from beginning of May: side

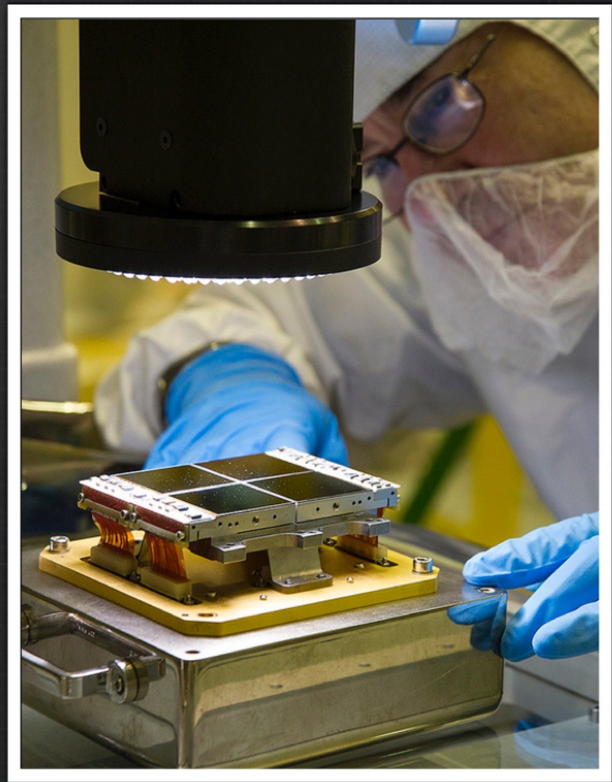


Near Infrared Camera (NIRCam)

NIRCam Capabilities

2 channel imager from λ = 0.6 to 5.0 microns, get λ < 2.5 & λ > 2.5 micron simultaneously
Nyquist sampling of diffraction limit at 2 microns (0.032”/pixel) and 4 microns (0.065”/pixel)
2.2’ x 4.4’ field of view
Short and long wavelength coronagraphy
Slitless spectroscopy for λ = 2.4 – 5.0 micron





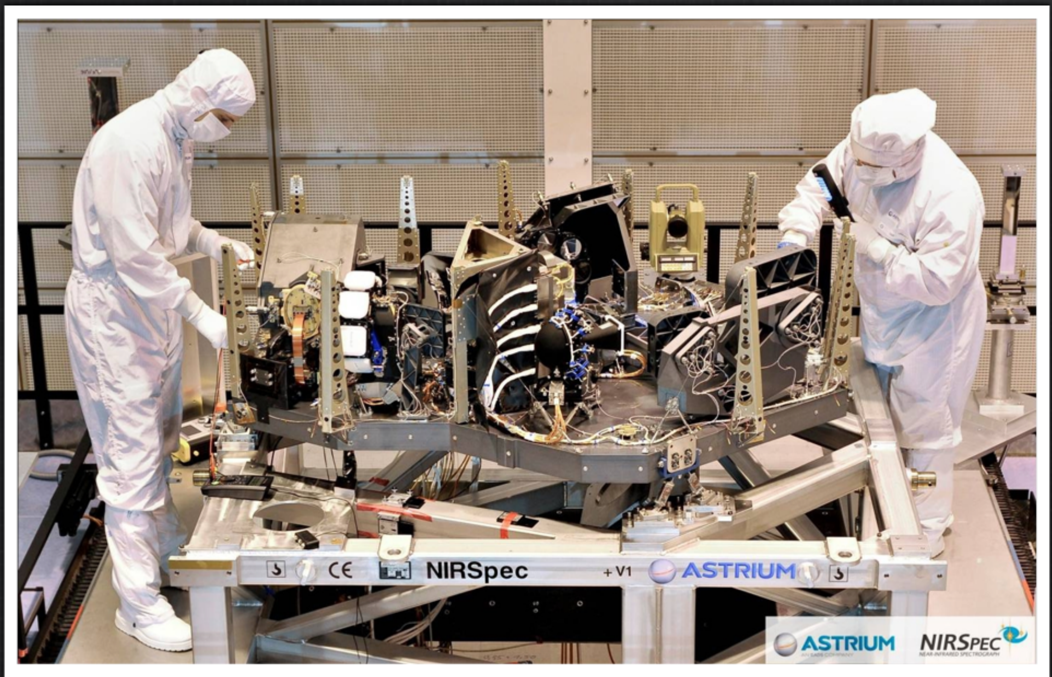
Built by Univ. of Arizona and Lockheed-Martin

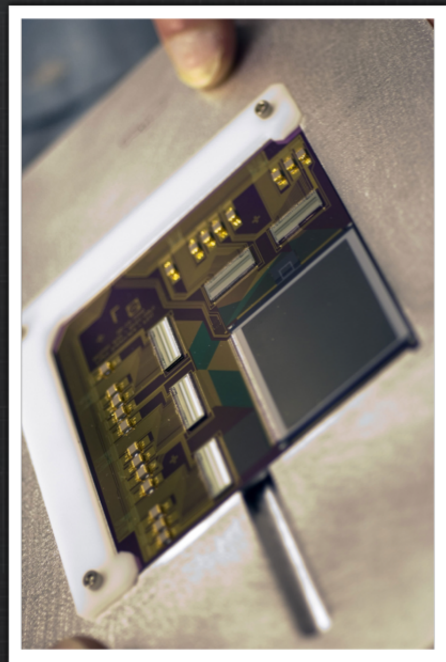
Courtesy J. Kalirai

Near Infrared Spectroscopy (NIRSpec)

NIRSpec Capabilities

Near Infrared wavelength coverage of λ = 0.6 to 5.0 microns
Three different spectral resolutions of R = 100, 1000, and 2700
Modes: Single Slit Spectroscopy (slits with 0.4” x 3.8”, 0.2” x 3.3”, 1.6” x 1.6”)
Integral Field Unit (3.0” x 3.0”)
Multi Object Spectroscopy (3.4’ x 3.4’ with 250,000 - 0.2” x 0.5” microshutters)





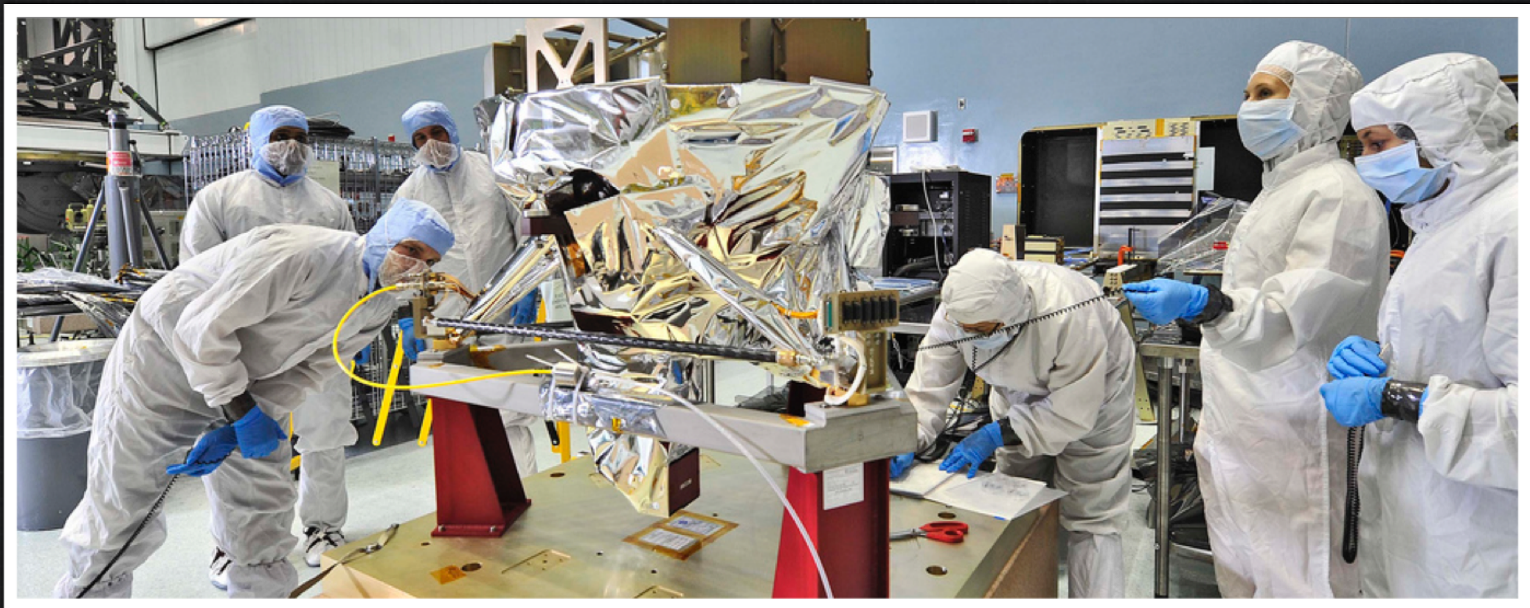
Built by ESA and Airbus

Courtesy J. Kalirai

Mid Infrared Instrument (MIRI)

MIRI Capabilities

High resolution imager with sensitivity from λ = 5 to 28 microns, 10 broad-band filters
λ = 5.0 to 28.3 microns with 0.11” pixels
1.23’ x 1.88’ field of view
Coronagraphy at 10.65, 11.4, 15.5, and 23 microns (24” to 30” field of view)
Integral Field Unit with R = 2200 to 3500, at 4 wavelengths (image slices 0.18” to 0.64”)
Single Slit Spectroscopy from 5.0 to ~14 microns in 0.6 x 5.5” slit (R ~ 100 at 7.5 microns)



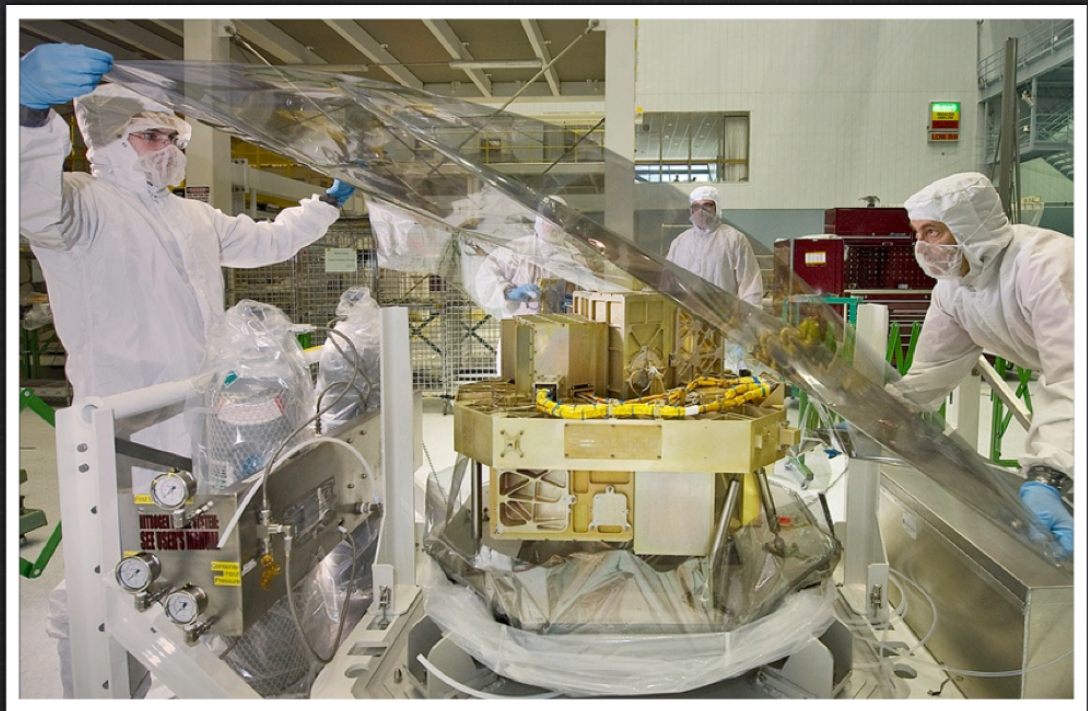
Built by ESA and JPL

Courtesy J. Kalirai

Near Infrared Imager and Slitless Spectrograph (NIRISS)

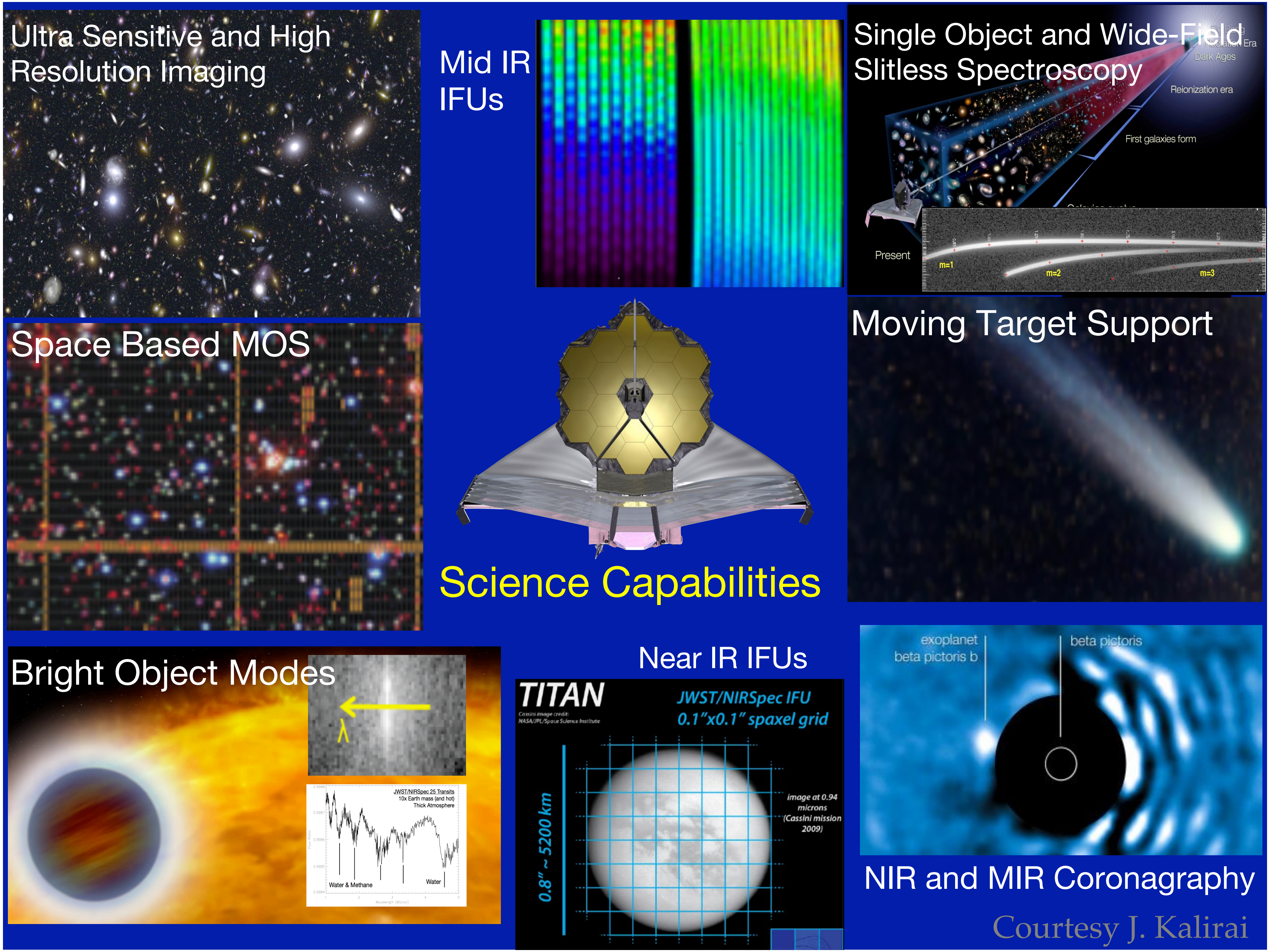
NIRISS Capabilities

Imaging - λ = 0.9 to 5.0 microns over a 2.2’ x 2.2’ field of view with 0.065” pixels
Wide Field Slitless Spectroscopy - λ = 1.0 to 2.5 microns at R ~ 150
Single Object Slitless Spectroscopy - λ = 0.6 to 2.5 microns at R ~ 700
Aperture Mask Interferometry - λ = 3.8 to 4.8 microns, enabled by non-redundant mask

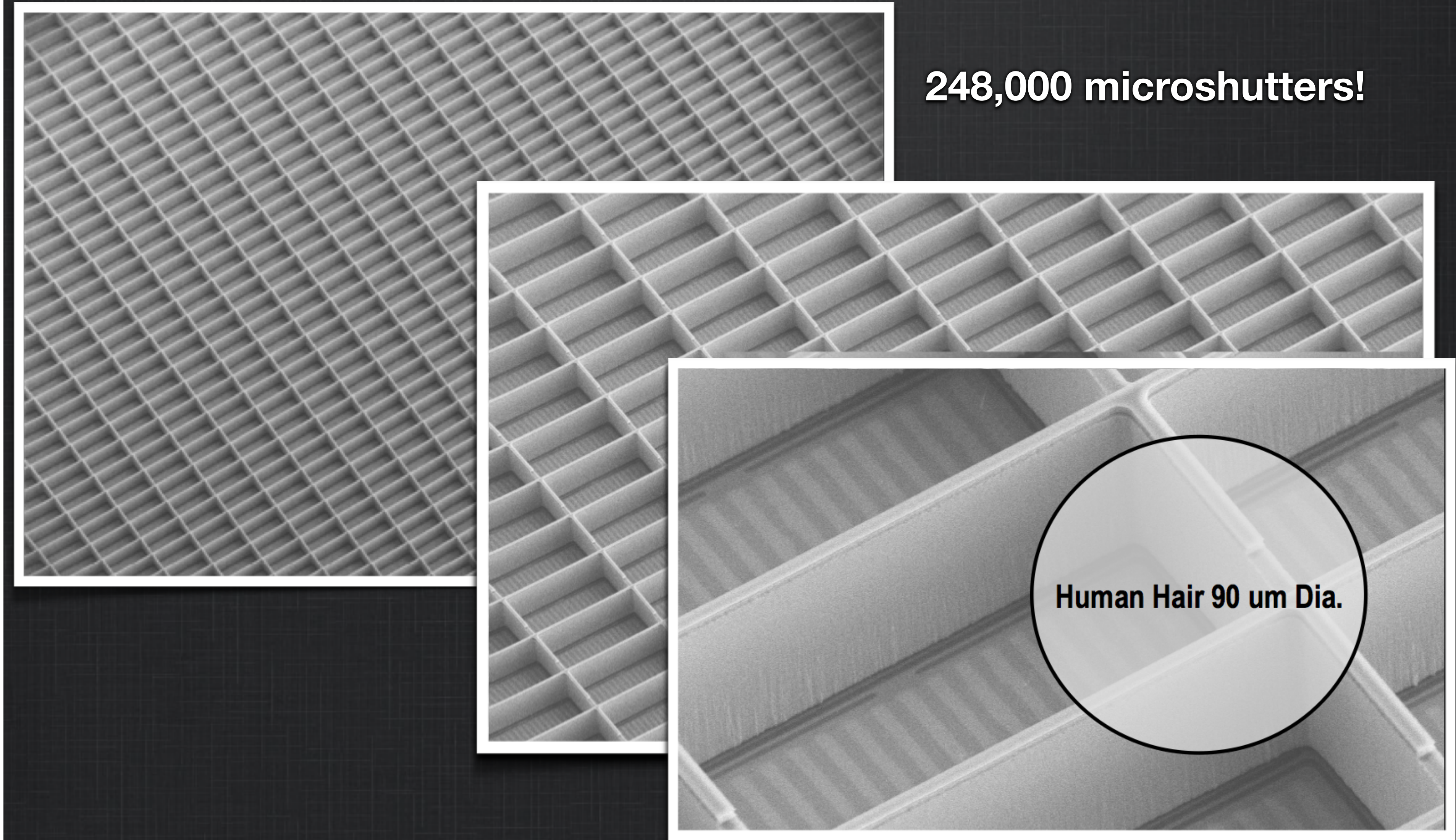


Built by CSA and COMDEV

Courtesy J. Kalirai


Ultra Sensitive and High Resolution Imaging
Mid IR IFUs
Single Object and Wide-Field Slitless Spectroscopy
Dark Ages
Reionization era
First galaxies form
Present
m=1
m=2
m=3
Space Based MOS
Moving Target Support
Science Capabilities
Bright Object Modes
λ
JWST/NIRSpec 25 Transits
10x Earth mass (and hot)
Thick Atmosphere
Water & Methane
Water
Near IR IFUs
TITAN
Cassini image credit: NASA/JPL/Space Science Institute
JWST/NIRSpec IFU
0.1"x0.1" spaxel grid
0.8" ~ 5200 km
image at 0.94 microns (Cassini mission 2009)
exoplanet beta pictoris b
beta pictoris
NIR and MIR Coronagraphy
Courtesy J. Kalirai

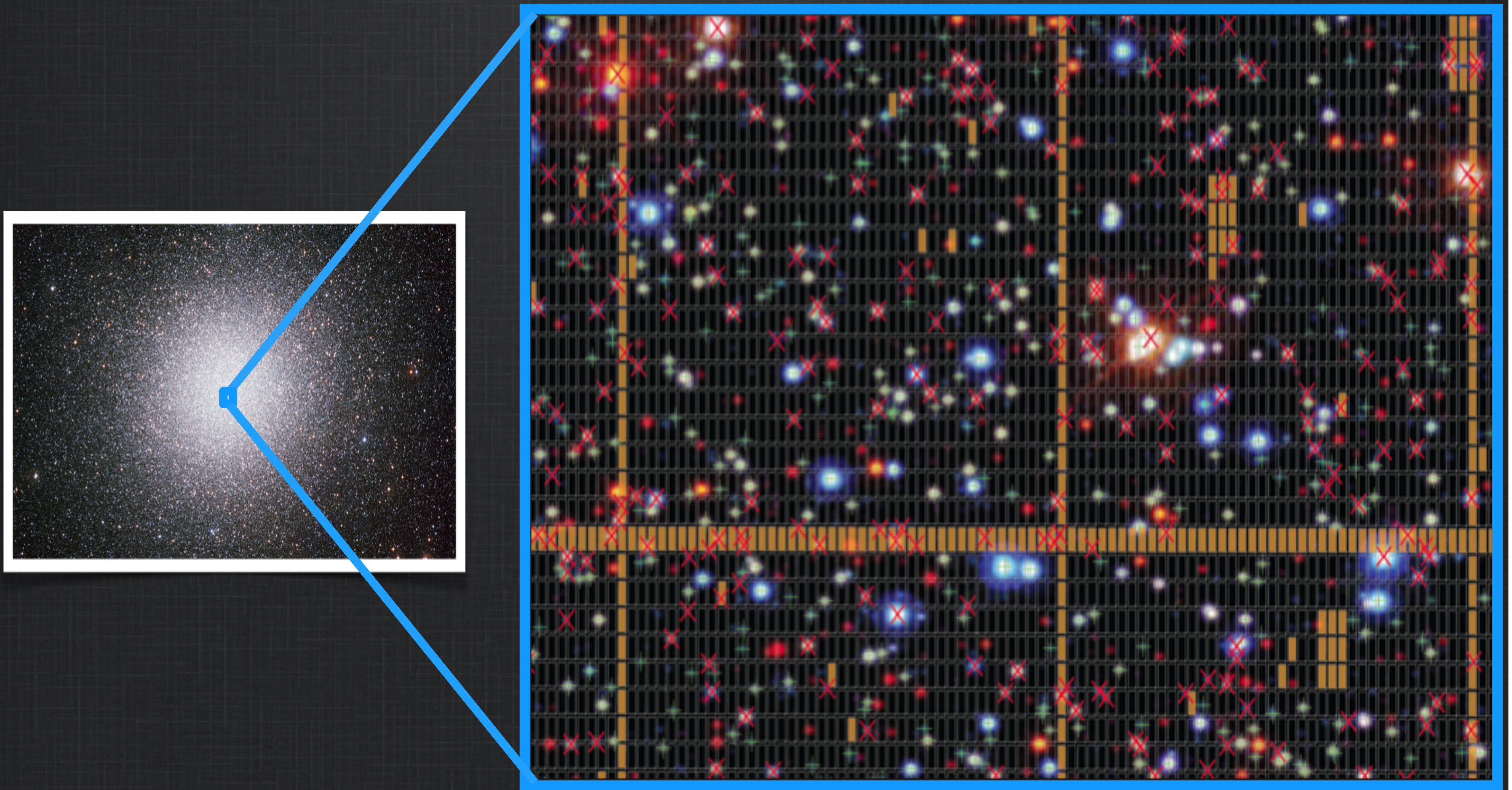
Multiplexed Spectroscopy in Crowded Environments



248,000 microshutters!

Multiplexed Spectroscopy in Crowded Environments

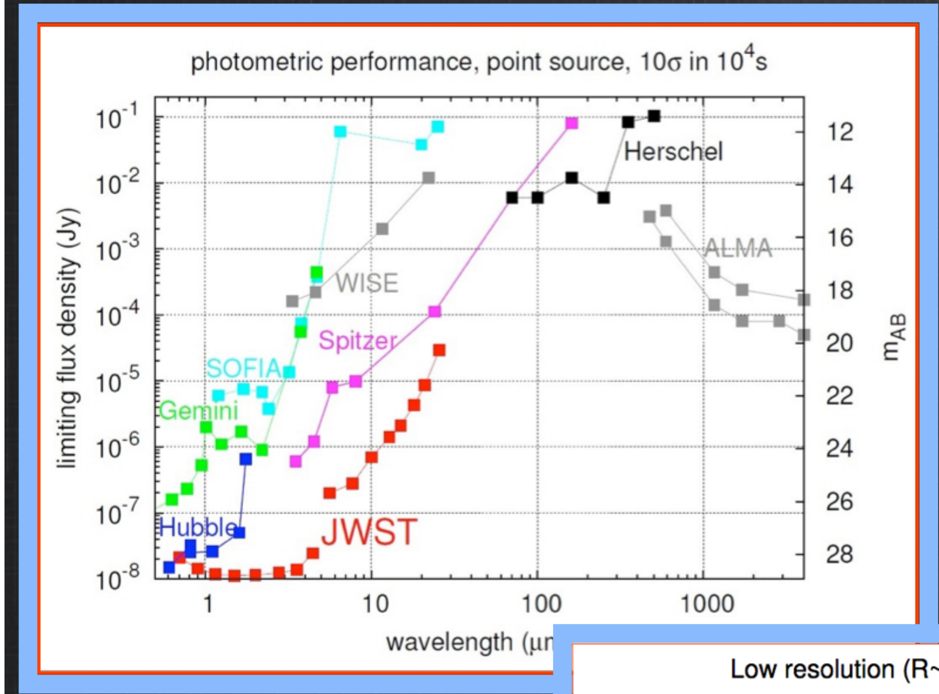
Multiplexed Spectroscopy in Crowded Environments

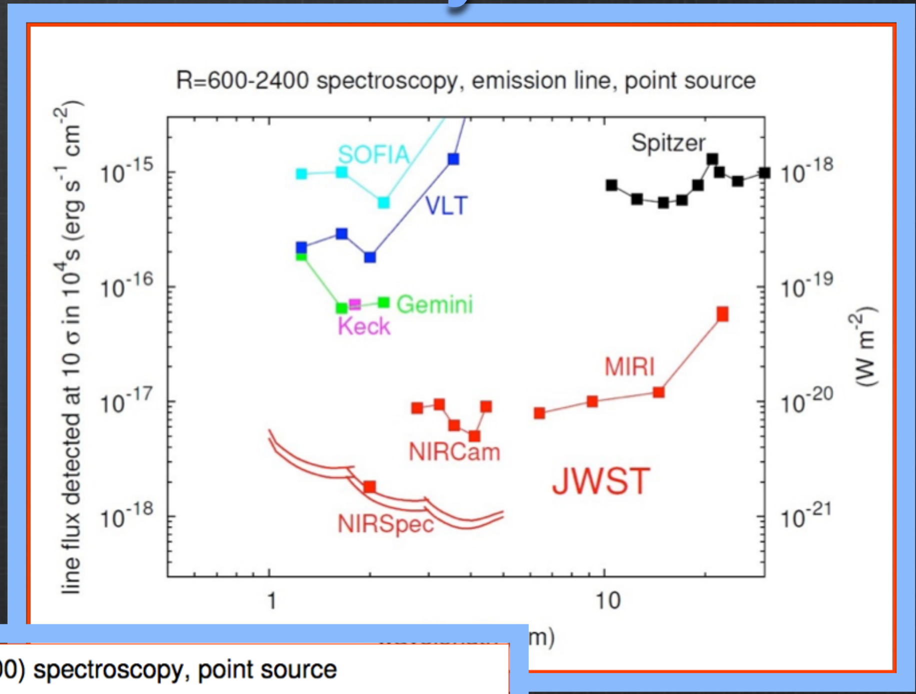


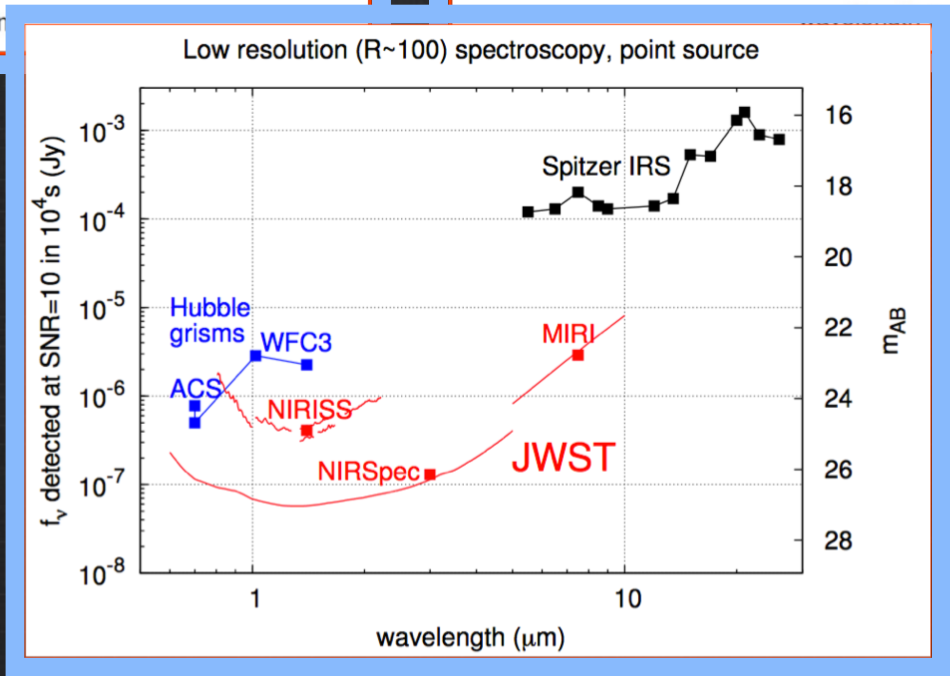
+ Targets in Operable Shutters

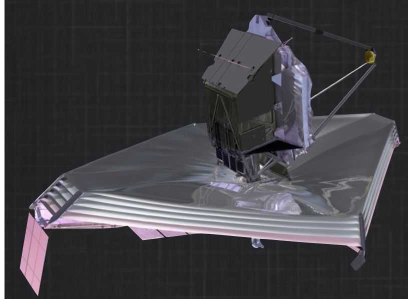
x Targets Outside Shutters

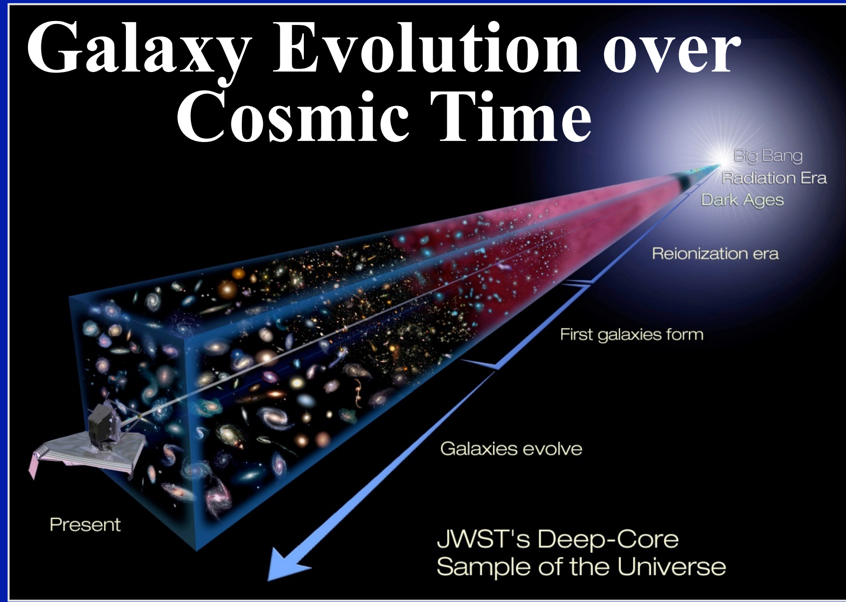
JWST Point Source Sensitivity











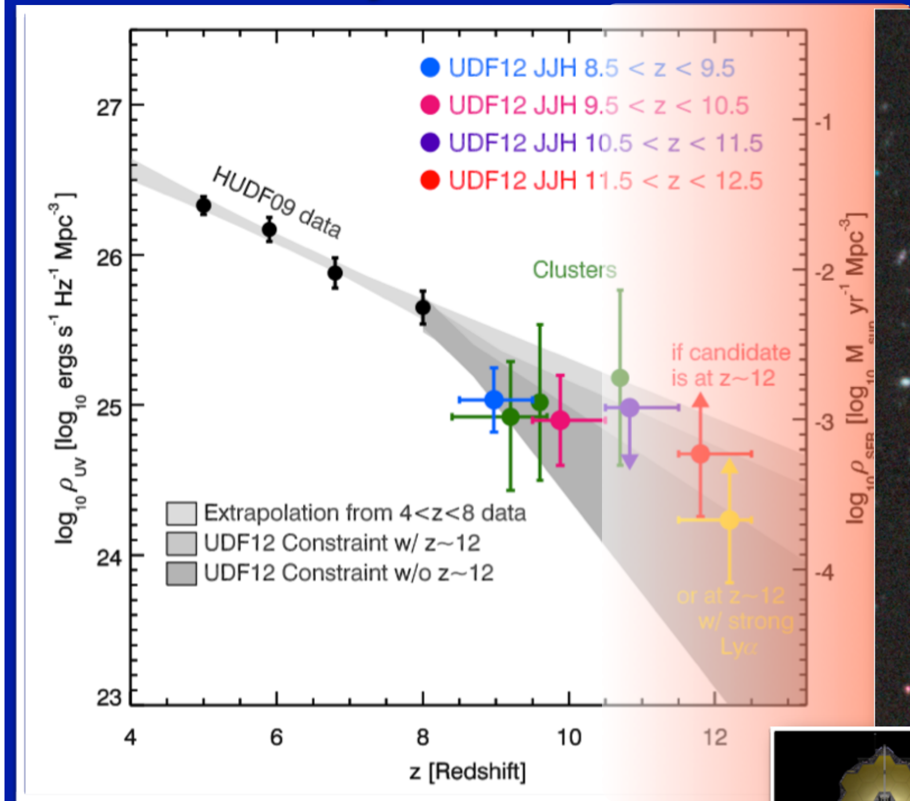
JWST Science themes

A Snapshot of the Cycle 1 JWST Science Program

"Exploring the Universe with JWST"
Conference in ESTEC
(Oct 12-16, 2015)

Finding the Universe's First Galaxies

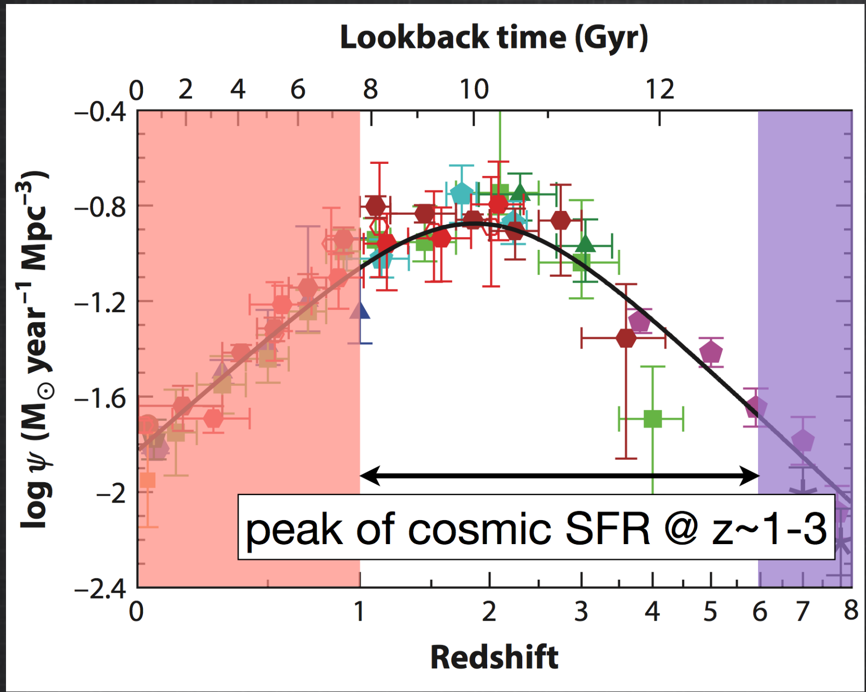
The Star Formation Rate Density vs Redshift



Oesch et al. (2012)

Courtesy J. Kalirai

A Snapshot of Cycle 1 Science



J. Lotz - Unveiling the Peak of Galaxy Assembly w/ JWST

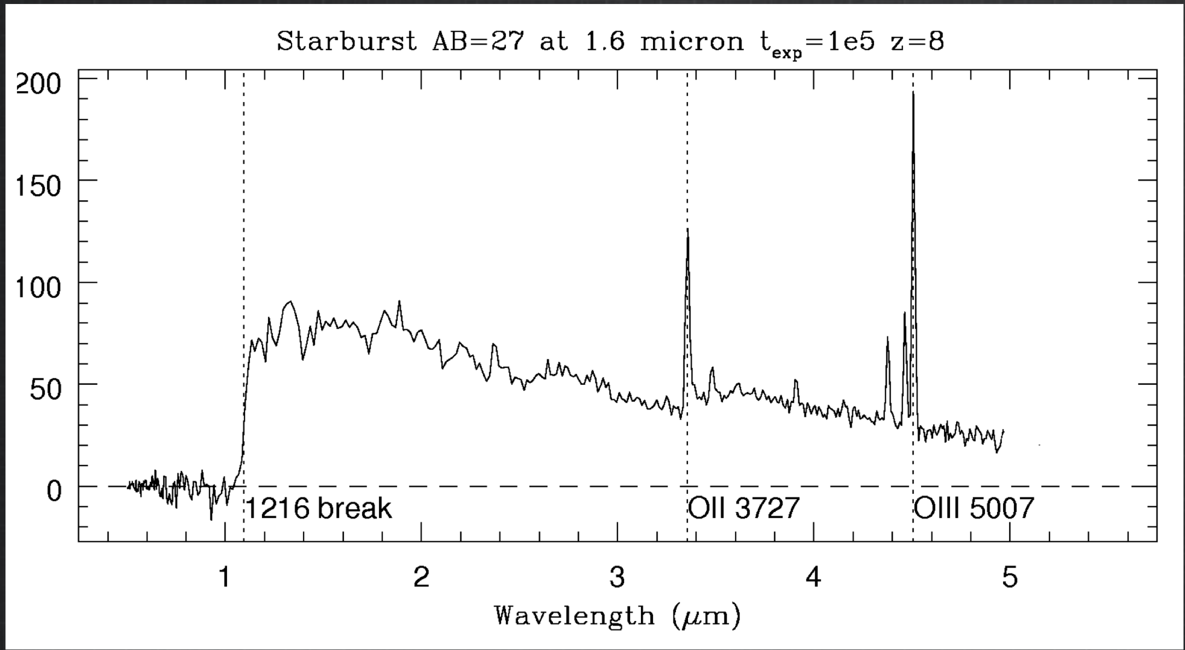
Tremendous progress in understanding $1 < z < 6$ galaxies, where 75% of the Universe's stars formed

JWST's resolution and sensitivity in the near IR will be a game changer, and answer these questions

- how much hidden star-formation at $z > 3$?
- what are we missing? red galaxies - dusty and/or old?
- galaxy structures at $z > 3$? where are the mergers? where are metals and gas outflows at high z?
- super massive black holes/AGNs at $z > 1$? what is the role of (dusty) AGN in galaxy assembly?
- what is the role of environment?

Courtesy J. Kalirai

A Snapshot of Cycle 1 Science



R. Ellis - z = 8 galaxy **spectra** w/ JWST

Hubble deep field imaging has contributed to demographics of early galaxies (#s, LFs, colors)

JWST spectroscopy will address detailed astrophysics

- nature of star formation: regular or burst-like (feedback)
- ionizing spectrum (stellar pops, role of AGN)
- escape fraction of Lyman limit photons
- chemical composition: O/H, C/O ratios (early nucleosynthesis)
- is there dust?

Courtesy J. Kalirai

Resolved stellar populations anchor our knowledge of the Universe

JWST Characteristics

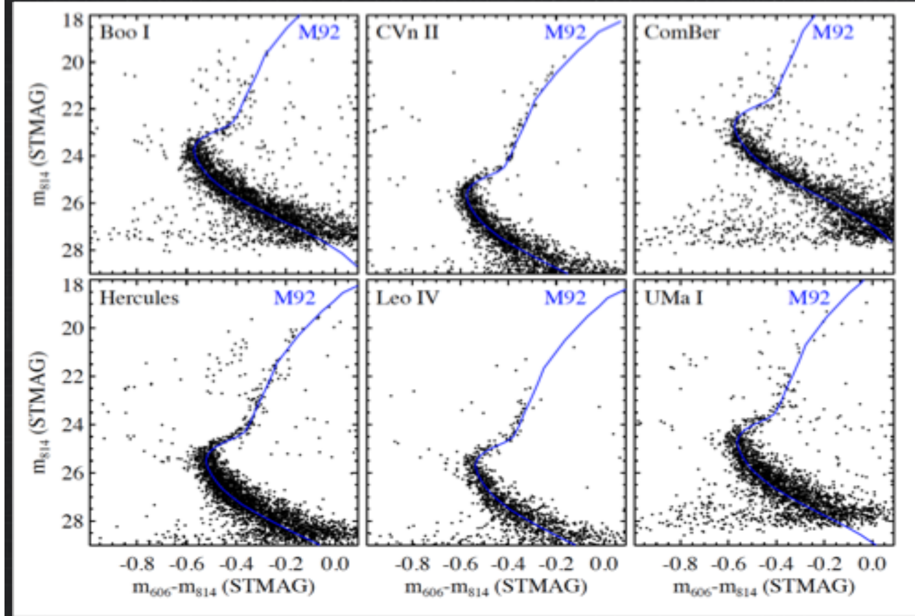
1.) Superb sensitivity at near-infrared wavelengths.
2.) Multiple imaging and spectroscopic modes with fine sampling.
3.) High spatial resolution.
4.) Relatively large fields of view.

Synergy with other facilities

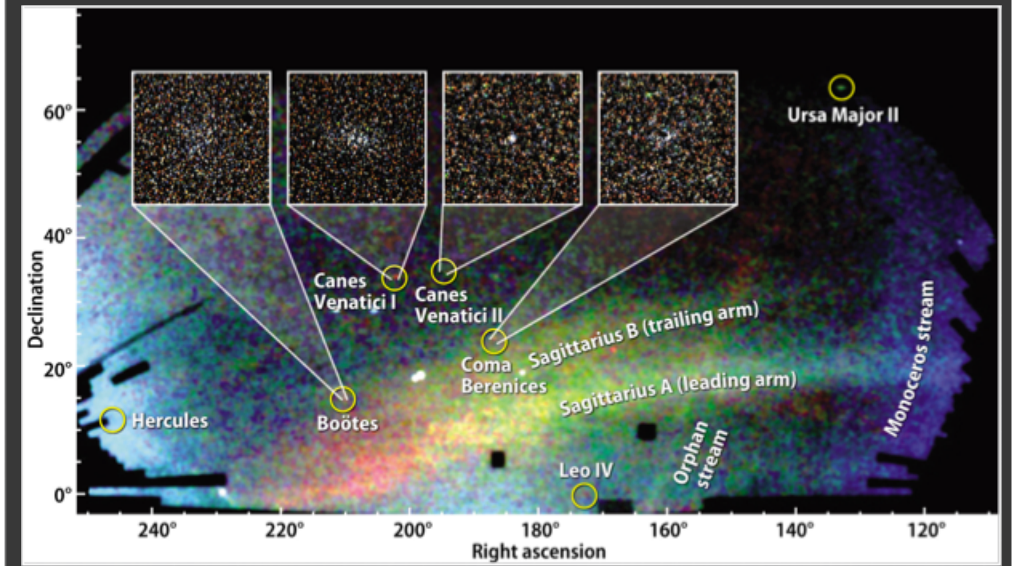
1.) Extremely large telescopes (E-ELT, TMT, GMT)
2.) Upcoming large surveys (EUCLID, LSST)
3.) HST will hopefully still be around.

adapted slide from Jason Kalirai (Project Scientist - James Webb Space Telescope)

Halo Formation – Dwarf Galaxies and Globular Clusters



Brown et al. (2014)



Belokurov et al.

Many Outstanding Problems

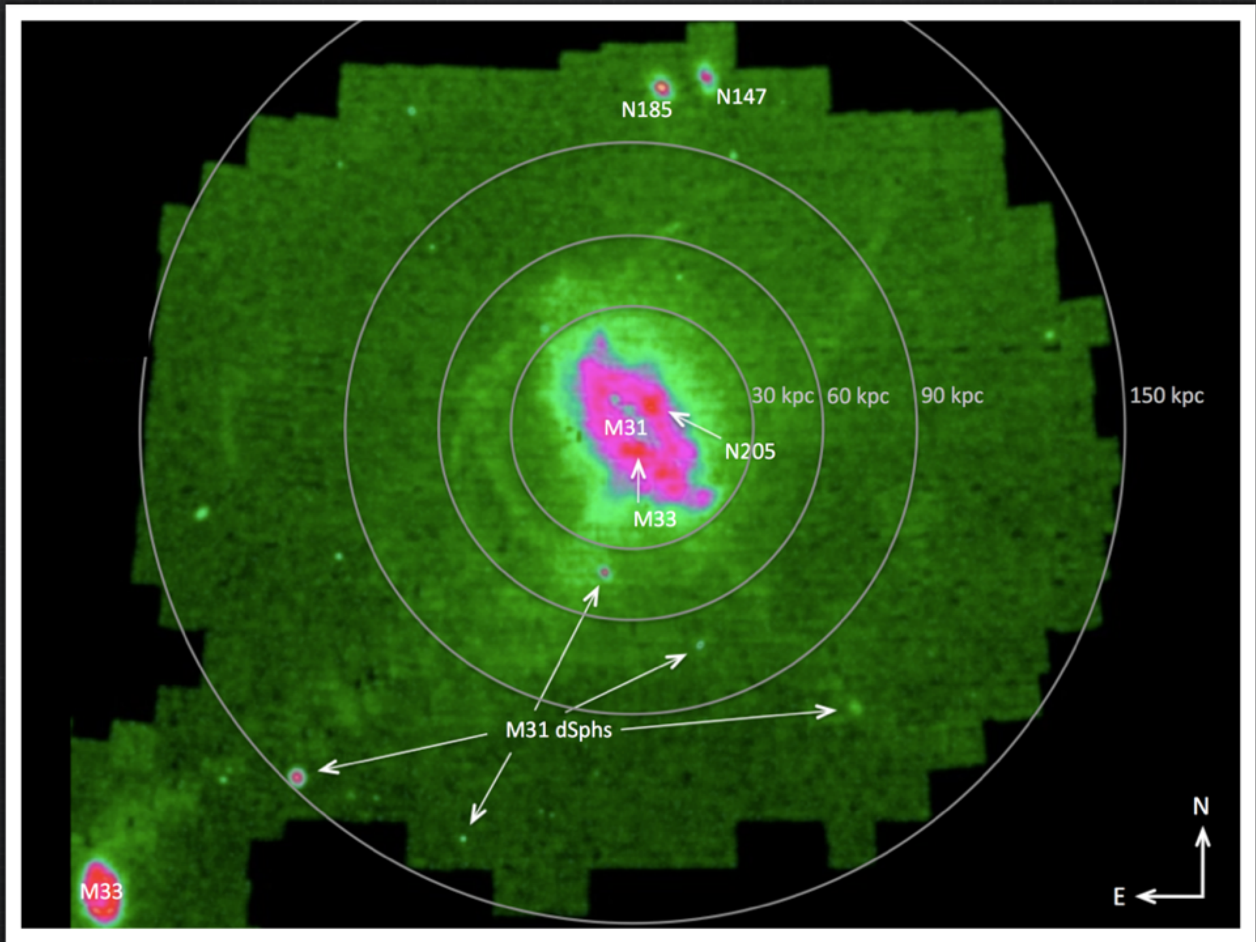
1) Is the census of small satellites consistent with CDM predictions on galactic scales?
2) Is there a low luminosity threshold for galaxy formation?
3) Is the spatial distribution of dSphs (planar vs spherical) consistent with CDM?
4) Can we test different DM models with 3D resolved velocities?
5) Do sub-Gyr age measurements reveal any cosmologically-driven synchronization in the SFHs?

...

Courtesy J. Kalirai

Current situation

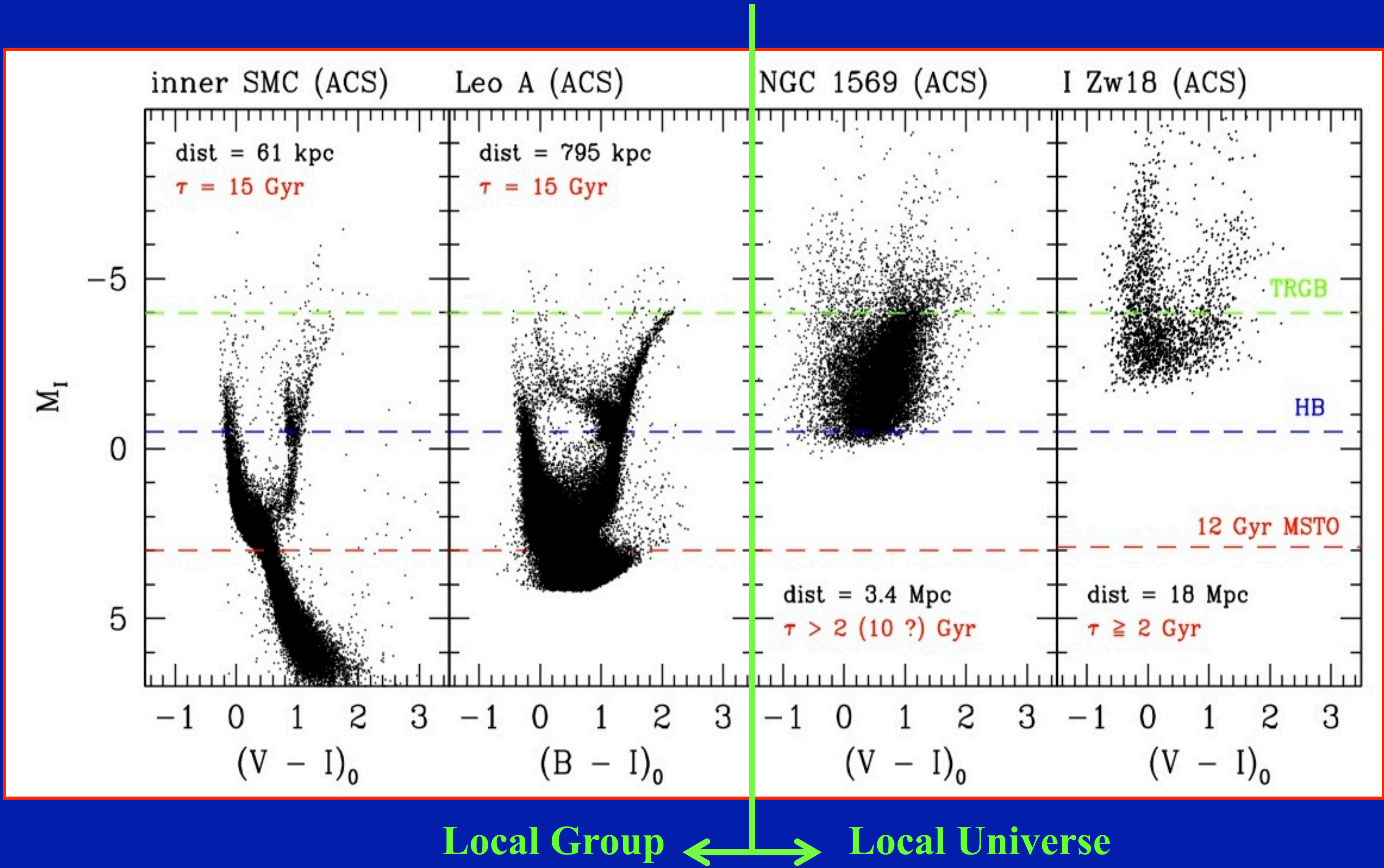
CFHT, SDSS, DECam, Pan-STARRS



McConnachie et al. (2009)

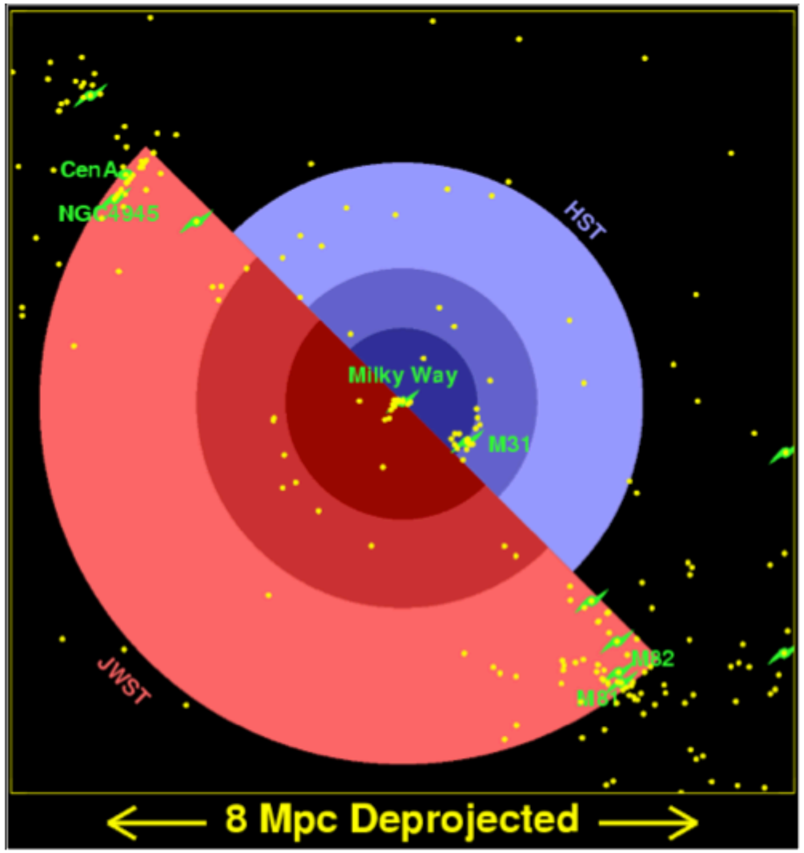
Courtesy J. Kalirai

Effect of distance on star resolution
→ on reachable lookback times / stellar ages: the case with HST-ACS



Resolved stellar populations

Increasing Survey Area with JWST



from Brown et al. 2008 White Paper on Studying Resolved Stellar Populations with JWST

The volume of space that can be surveyed in 10, 100, and 1000 hrs reaching 0.5 mag below the Main Sequence turnoff in a 12 Gyr old population.

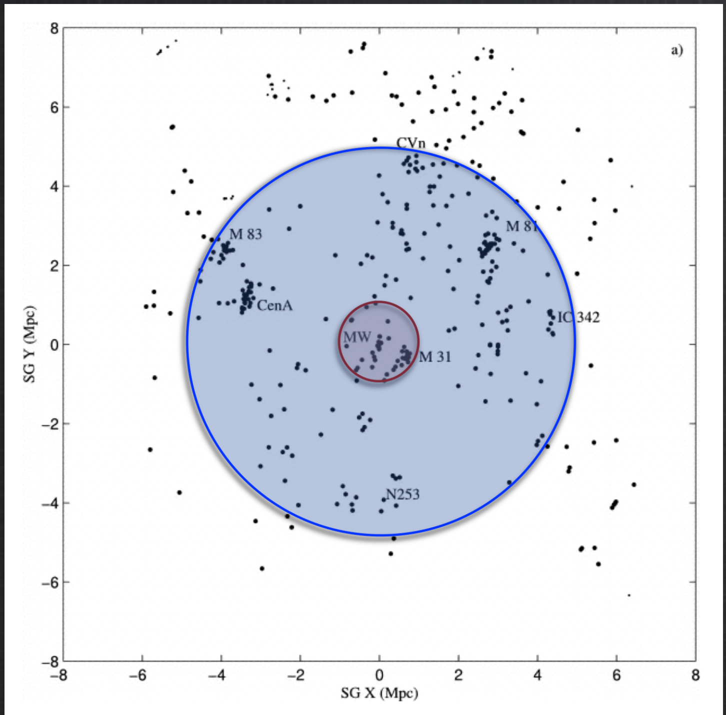
1 Mpc, m-M=25 oMSTO~29; HB~24.7

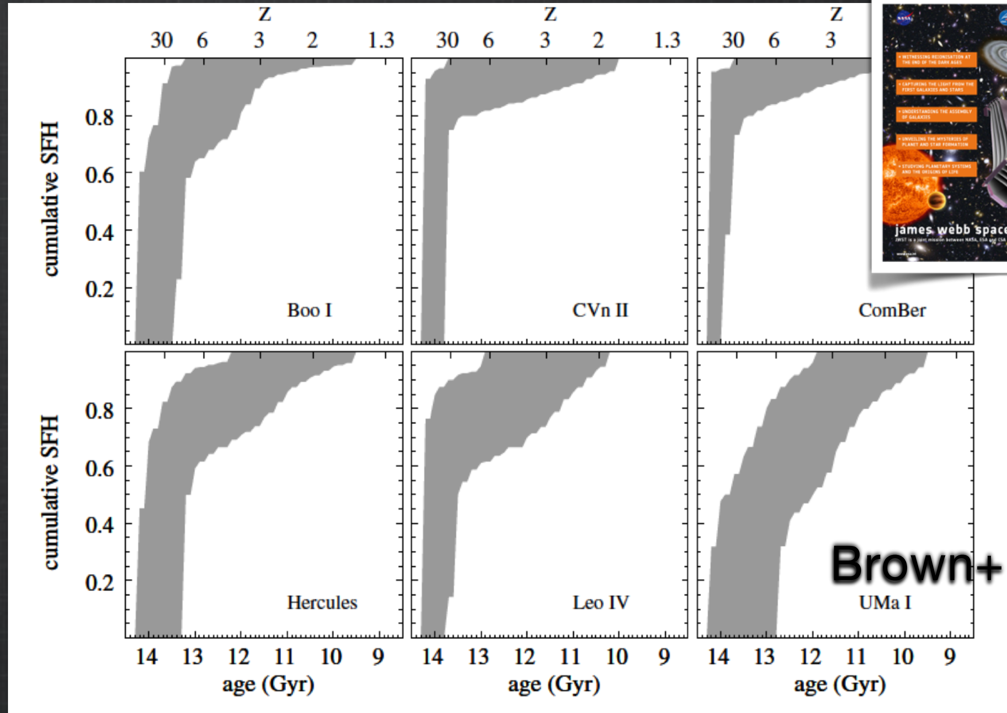
1.7 Mpc, m-M=26.1 oMSTO~30.1; HB~25.8

4 Mpc, m-M=28 oMSTO~32; HB~27.7

Object	$(m-M)_0$	θ(1 pc)
LMC	18.5	4"
M31	24.3	0.3"
Sculptor Group	26.5	0.1"
M81/82	27.8	0.06"
Cen A	28.5	0.04"
Leo Group	30.0	0.02"
Virgo Cluster	31.2	12 mas
Fornax cluster	32.0	11 mas
50Mpc	33.5	4 mas
Arp220	34.5	2 mas
Perseus Cluster	34.5	2 mas
Stephan's Quintet	35.0	2 mas
Coma Cluster	35.0	2 mas
Redshift z~0.1	38.5	0.5mas
Redshift z~0.3	41	0.2mas

A Snapshot of Cycle 1 Science





Brown+ (2014)

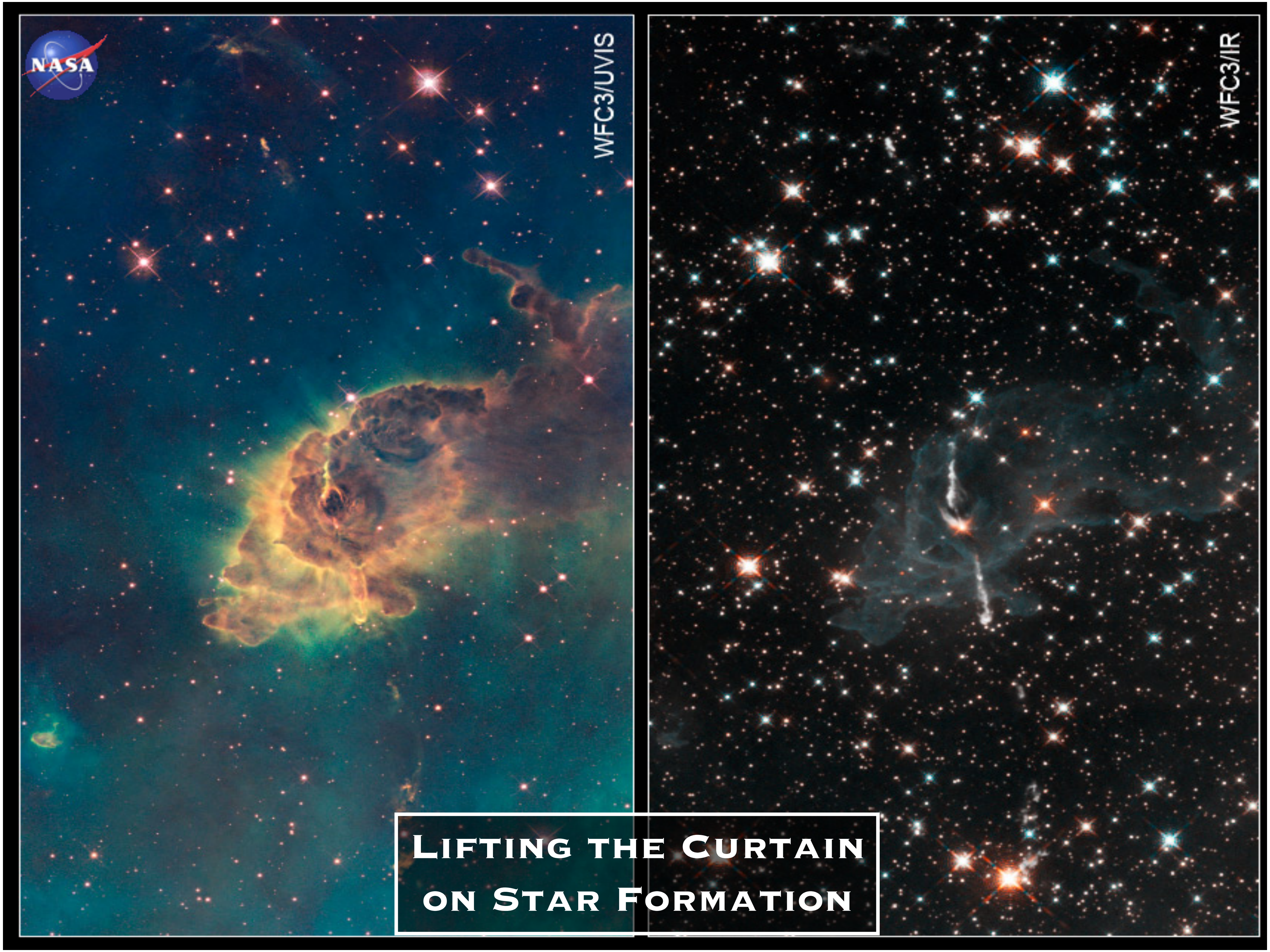
A. Ferguson - Resolving Populations in the Local Volume w/ JWST

HST has been limited to direct measurements of the oldest stellar generations in the Local Group

JWST will measure the fossil record of different galaxy types in detail

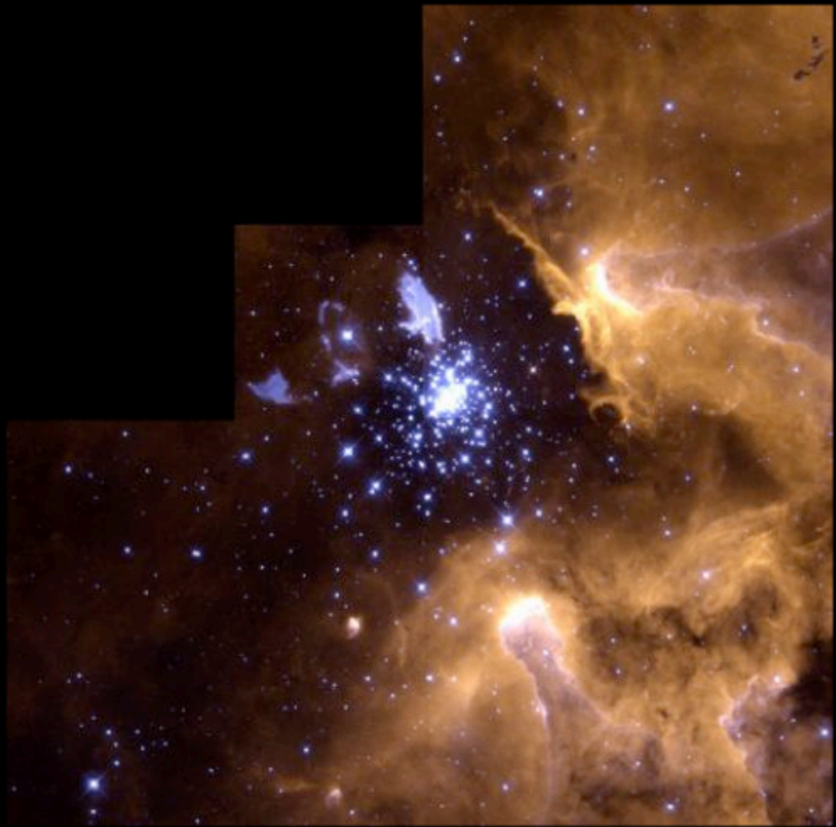
- wonderful opportunity to connect near-field and far-field approaches that study galaxy assembly
- infrared baseline provides high precision ages of dark matter dominated UFDs (suppression by reionization)
- diverse history of dwarfs and their cosmological significance
- spatially resolved star formation histories for different galaxy types in the Local Volume

Courtesy J. Kalirai


NASA
WFC3/UVIS
WFC3/IR
LIFTING THE CURTAIN
ON STAR FORMATION

Formation of stars and IMF

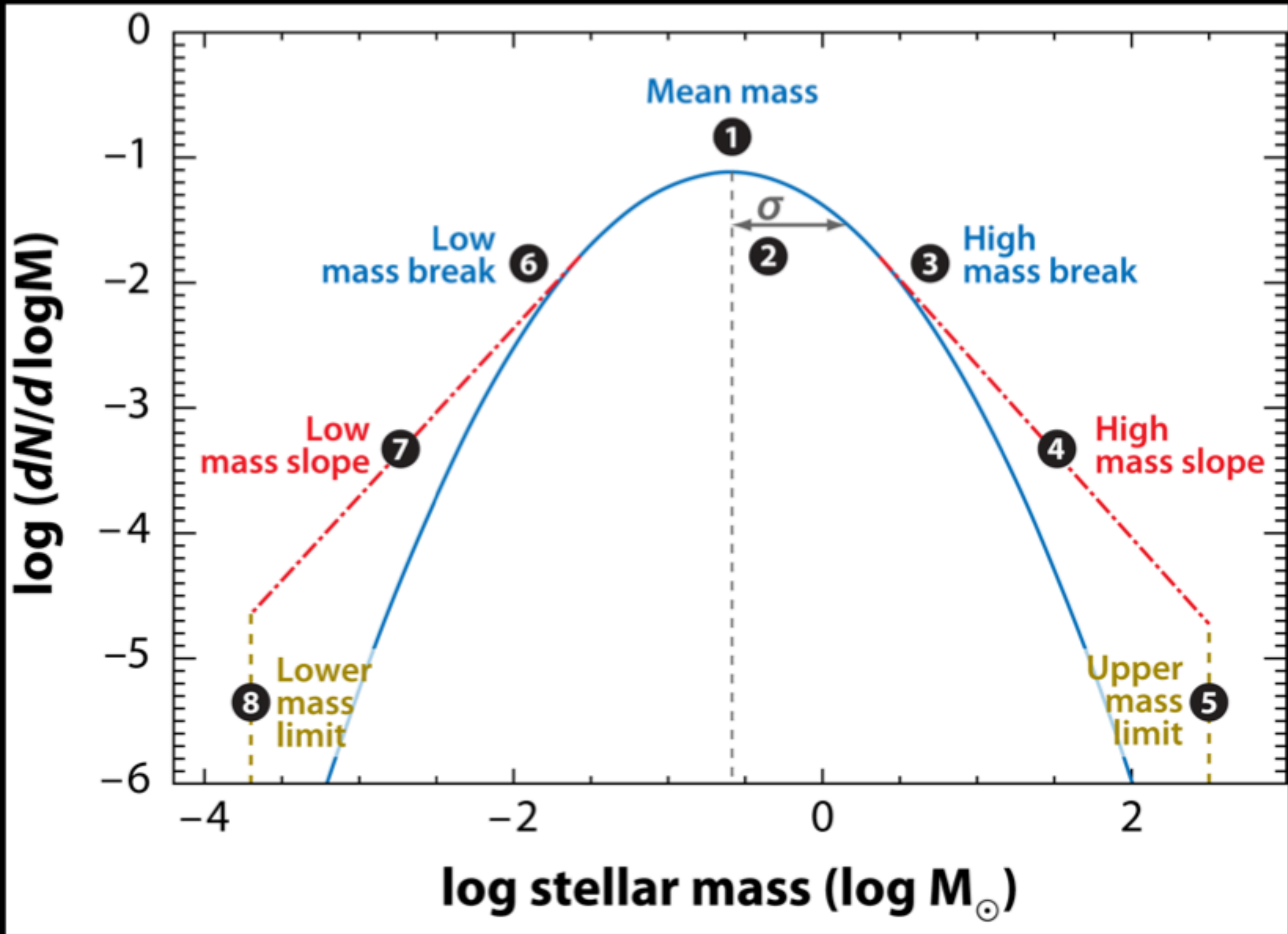
NIRCam/NIRSPEC Observations of Young Clusters



"Extreme" clusters within Local Group:
Below hydrogen burning limit.

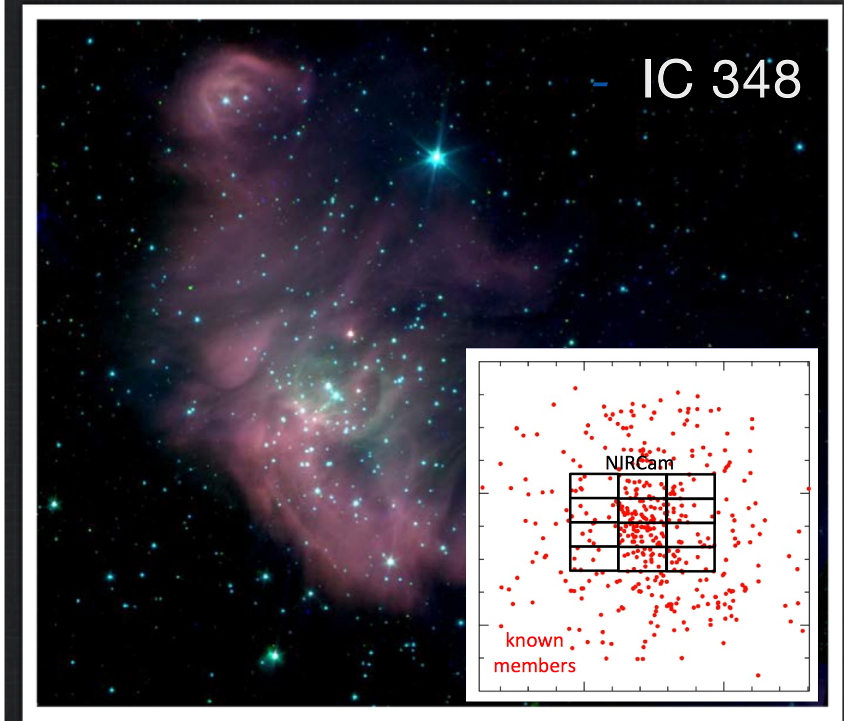
Nearest embedded clusters to go deep:
<1 Jupiter mass

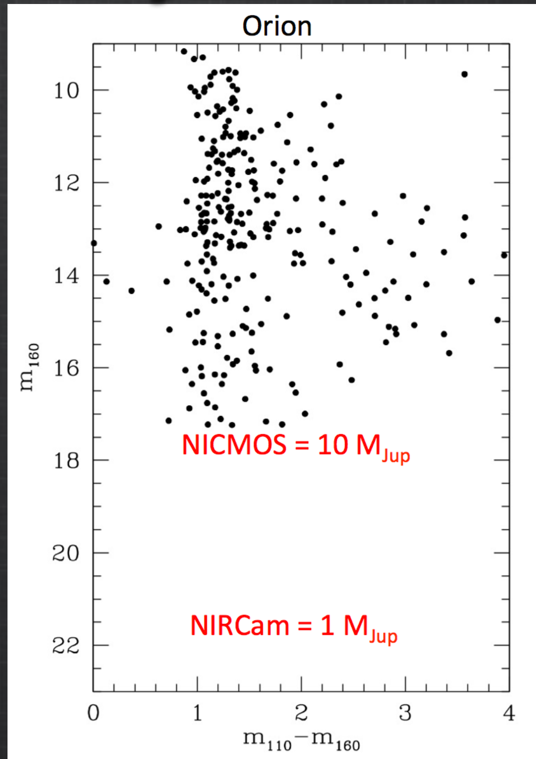
Formation of stars and IMF

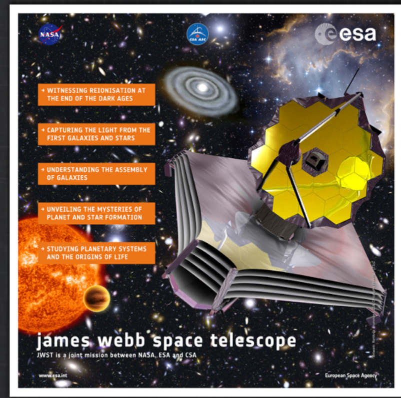


Bastian, Nate, et al. 2010;
Annu. Rev. Astronomy & Astrophysics vol. 48

A Snapshot of Cycle 1 Science







K. Luhman - Pre Main Sequence Stars and the IMF w/ JWST

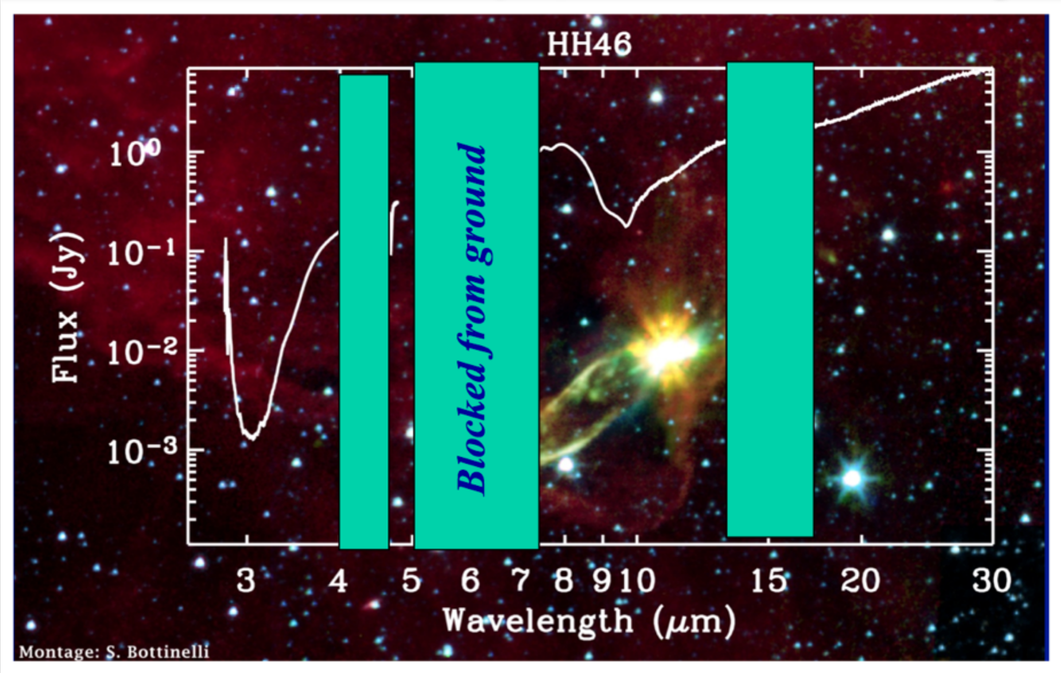
Space based IR observations have uncovered the substellar regime

JWST NIR and MIR imaging will measure complete stellar-planetary census in star forming regions

- JWST will see free floating Jupiter mass objects in Orion
- thousands of circumstellar disks in a variety of environments and evolutionary states
- unbiassed IMF over a complete mass distribution, and its variation with environment (e.g. spatial)
- spectra of 1-10 M_{JUP} objects in clusters to help interpret spectra of young planets

Courtesy J. Kalirai

A Snapshot of Cycle 1 Science



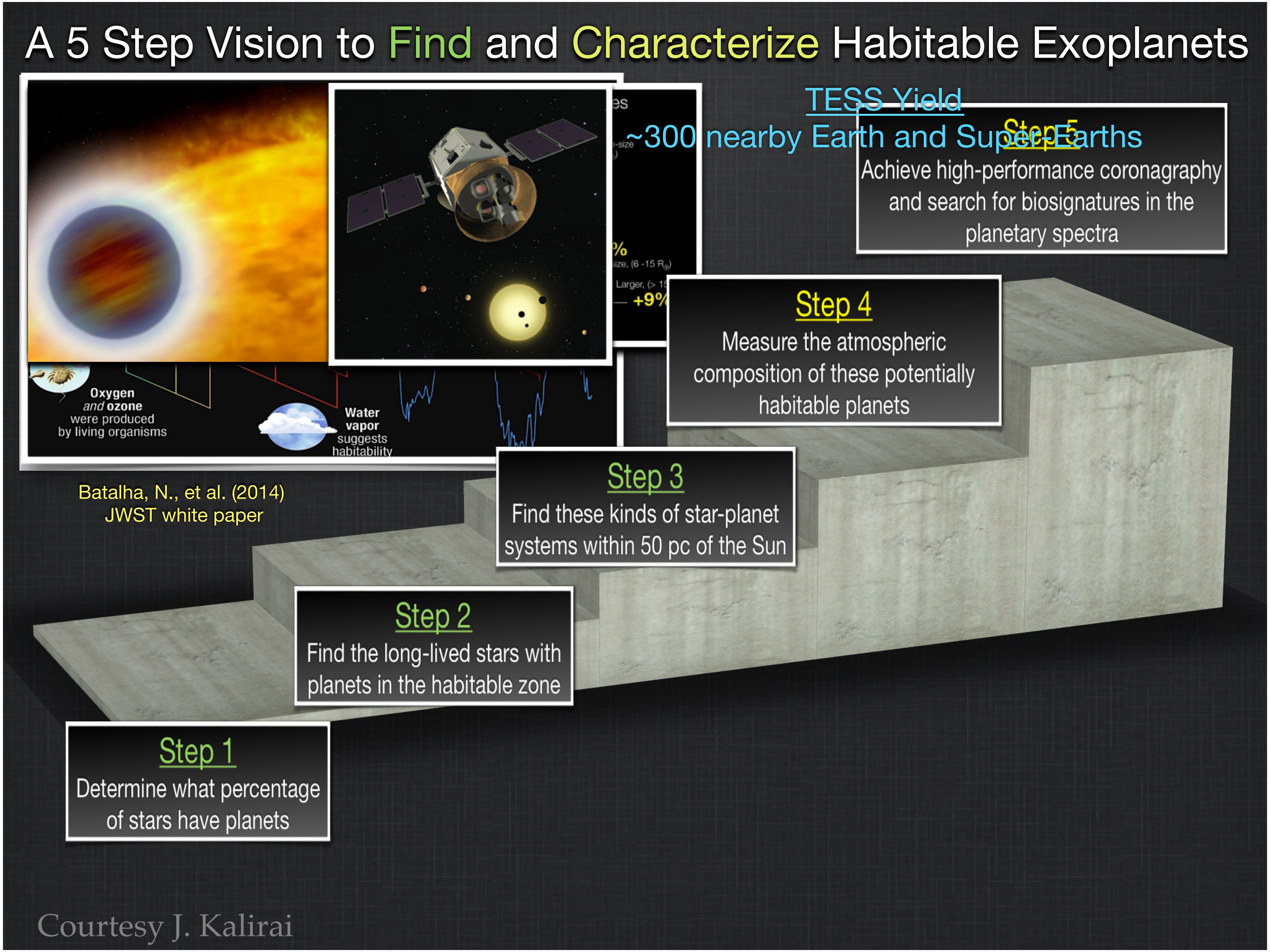
E. van Dischoeck - Embedded Phase of Star Formation w/ JWST

Spitzer, Herschel, WISE, and ground submm have built complete inventories of protostars out to a few kpc

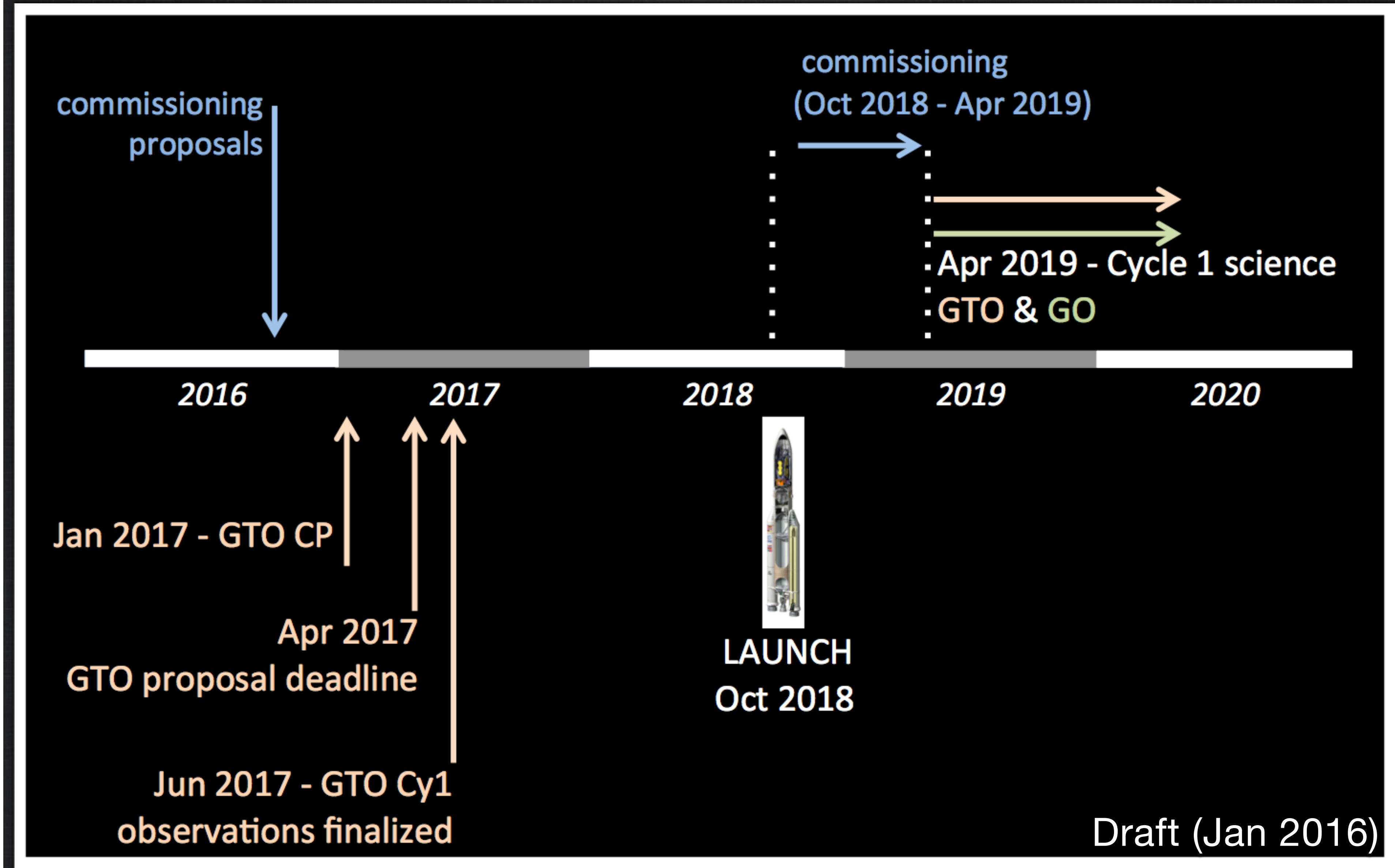
JWST IFU spectroscopy will now characterize physics and chemistry on 10 - 1000 AU scales

- lots of IR diagnostics to use, giving insights on the disk, accretion, shock, UV, high energy, etc.
- need modeling tools and lab data!
- JWST spatial resolution will resolve disks and envelopes
- Physical structure of warm dust, geometry, earliest stages of massive star formation, variability, where does matter enter disk, fragmentation, resolve accretion from outflow shocks, water transport from clouds.

Courtesy J. Kalirai


A 5 Step Vision to Find and Characterize Habitable Exoplanets
TESS Yield
~300 nearby Earth and Super-Earths
Step 5
Achieve high-performance coronagraphy and search for biosignatures in the planetary spectra
Step 4
Measure the atmospheric composition of these potentially habitable planets
Step 3
Find these kinds of star-planet systems within 50 pc of the Sun
Step 2
Find the long-lived stars with planets in the habitable zone
Step 1
Determine what percentage of stars have planets
Oxygen and ozone were produced by living organisms
Water vapor suggests habitability
Batalha, N., et al. (2014) JWST white paper
Courtesy J. Kalirai

JWST Science Planning Timeline



Courtesy J. Kalirai

JWST Commissioning Phase (6 months)

Phase III - Commissioning the Science (60 days)

Each instrument is independently focused, calibrated, and characterized

Science instruments participate in observatory level tests (thermal slew, stray light, mechanism disturbance, moving target)

Begin ERO, ERS, Cycle 1 science and calibration programs asap

Phase I - Commission the Spacecraft (30 days)

Launch and mid-course corrections

Deployment of solar arrays, sunshield, mirrors

Subsystem check outs

NIR instrument cooldown modifications

Oct 2018 — April 2019

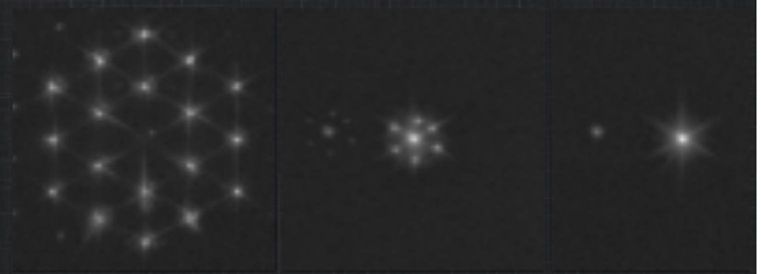
Phase II - Commissioning the Telescope (90 days)

Fine phasing of Optical Telescope Element (OTE) with NIRCam & FGS

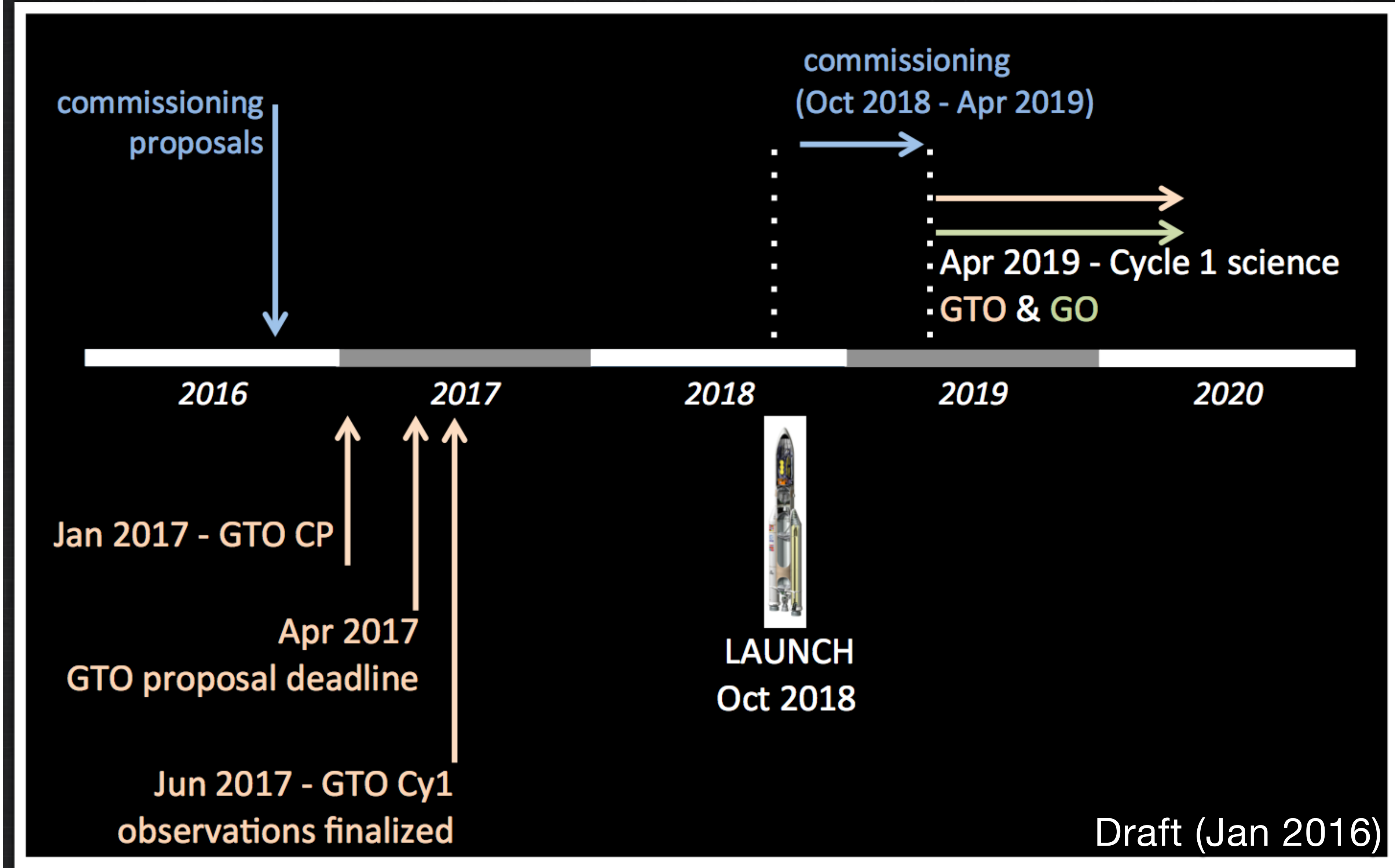
NIR instruments are activated and checked out

MIRI cooldown via the cryocooler

All science instruments used to align and optimize OTE

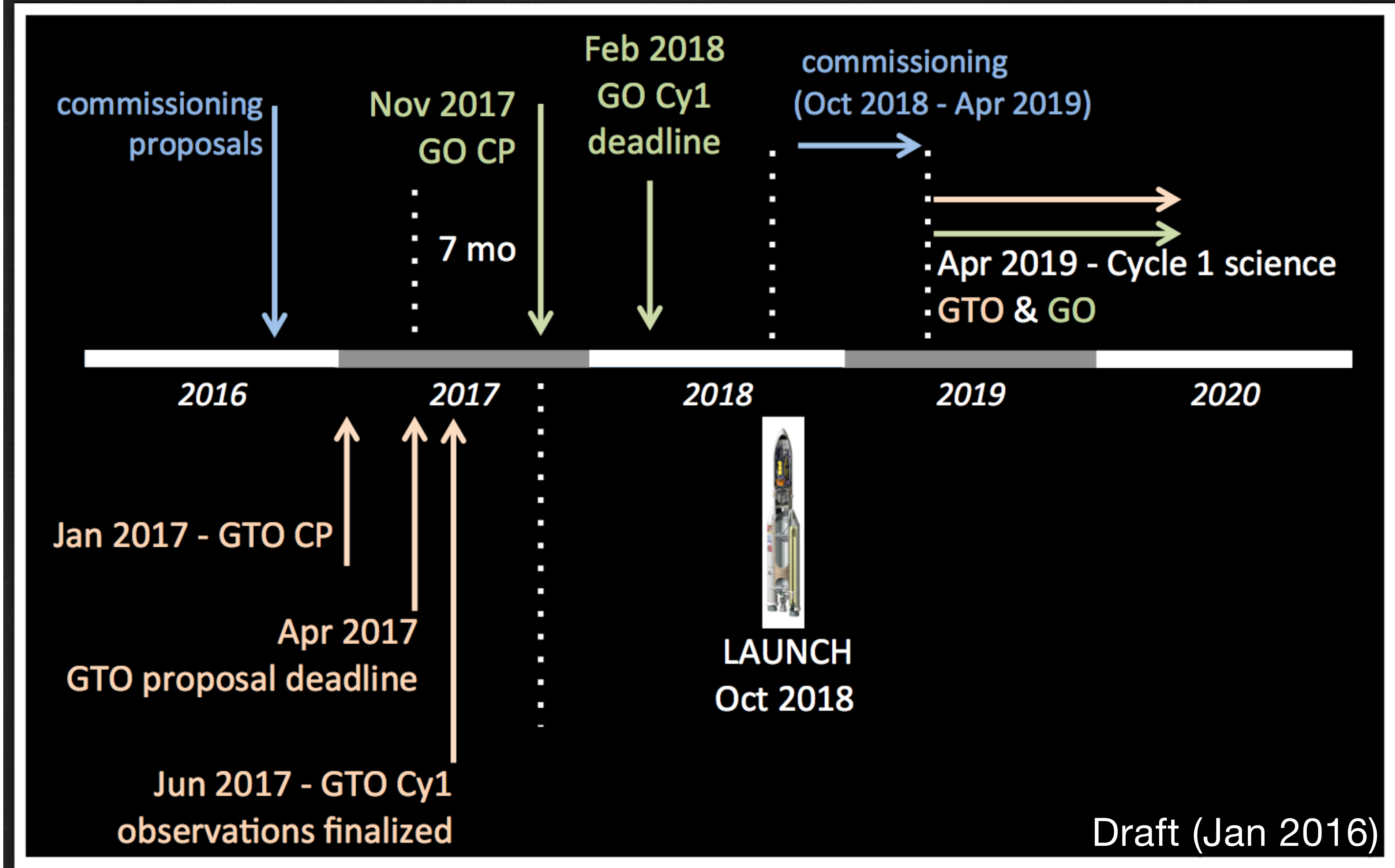


JWST Science Planning Timeline



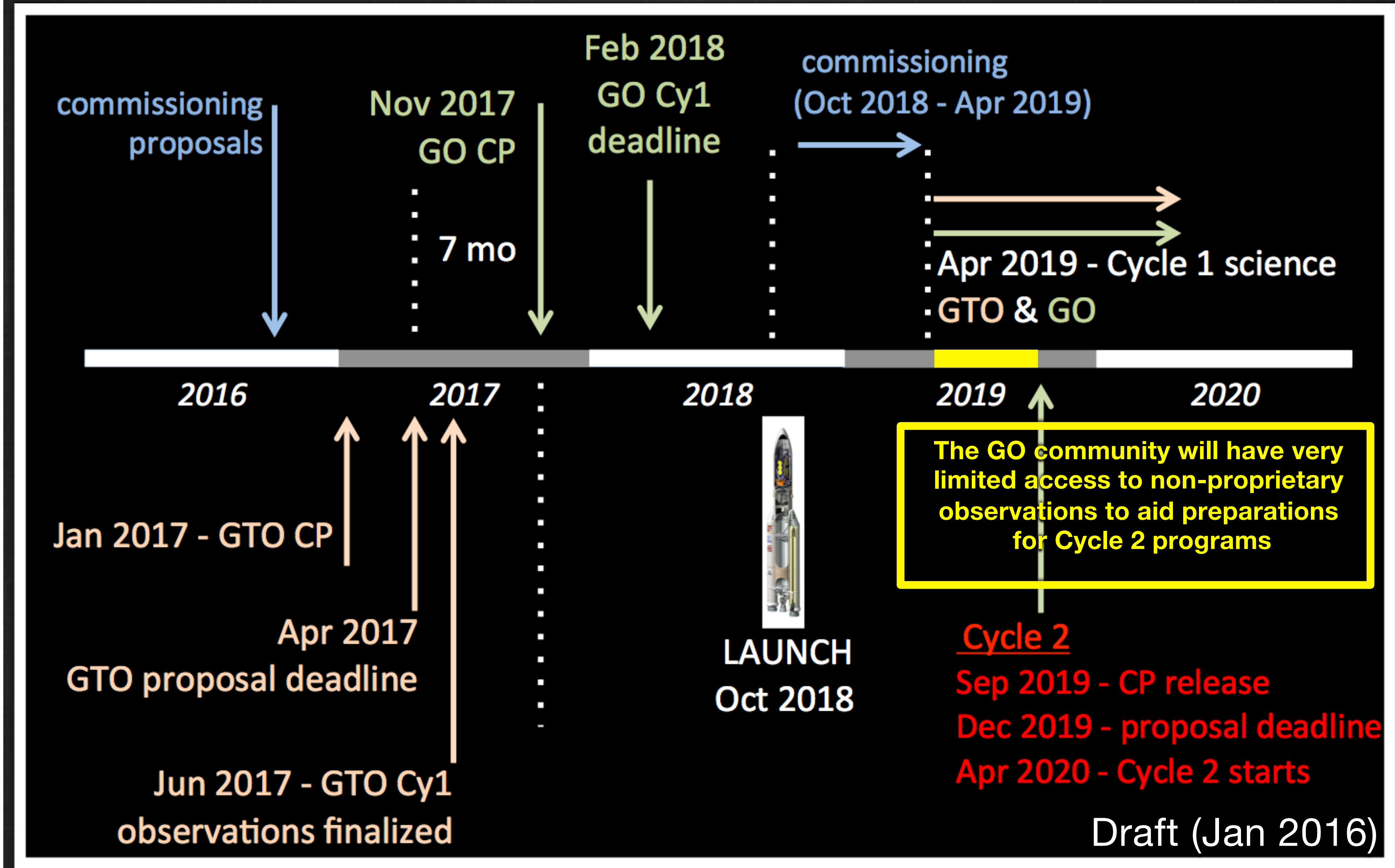
Courtesy J. Kalirai

JWST Science Planning Timeline



Courtesy J. Kalirai

JWST Science Planning Timeline



Courtesy J. Kalirai

JWST Science & Technology Advisory Committee

The JSTAC advises the STScI Director on STScI's readiness to support science operations, implementation of NASA policies, and other matters related to the GO science community

Represents the Scientific Community and Advises the STScI Director

Roberto Abraham (Toronto)
Neta Bahcall (Princeton)
Natalie Batalha (NASA Ames)
Stefi Baum (Manitoba)
Roger Brissenden (Chandra/SAO)
Hashima Hasan (NASA-HQ, ex-officio)
Tim Heckman (Johns Hopkins)
Garth Illingworth (Santa Cruz, Chair)
Malcolm Longair (Cavendish)
John Mather (NASA-GSFC, ex-officio)
Mark McCaughrean (ESA, ex-officio)
Chris McKee (Berkeley)
Brad Peterson (Ohio State)
Alain Ouellet (CSA, ex-officio)
Joseph Rothenberg (JHR Consulting)
Eric Smith (NASA-HQ, ex-officio)
Lisa Storrie-Lombardi (Spitzer/Caltech)
Monica Tosi (Bologna)

http://www.stsci.edu/jwst/advisory-committee

The Early Release Science Program (ERS)

The JSTAC has recommended an Early Release Science Program for JWST

June 2010

"..to obtain images and spectra that would be used to demonstrate key modes of the JWST instruments. The goal of this program is to enable the community to understand the performance of JWST prior to the submission of the first post-launch Cycle 2 proposals that will be submitted just months after the end of commissioning."

"The JSTAC recommends that the First-Look data be released both in raw form and with any initial calibrations as soon as possible; the key aspect is speed."

Program Implementation

- ⋆ STScI had an open dialogue about ERS concepts at recent meetings (e.g., Jan 2016 AAS meeting)
- ⋆ Program will be supported by Director's Discretionary time (assume ~15 modes x 20-25 hrs)
- ⋆ Program will be shaped with significant involvement of the astronomical community
- ⋆ Program will be selected to span key JWST observing modes, data analysis challenges, science areas
- ⋆ Program will execute early in Cycle 1 and have no proprietary time
- ⋆ ERS teams will be responsible for rapid delivery of science enabling products to MAST

The ERS program is a fantastic opportunity to become an expert on JWST

http://www.stsci.edu/jwst/science/ers

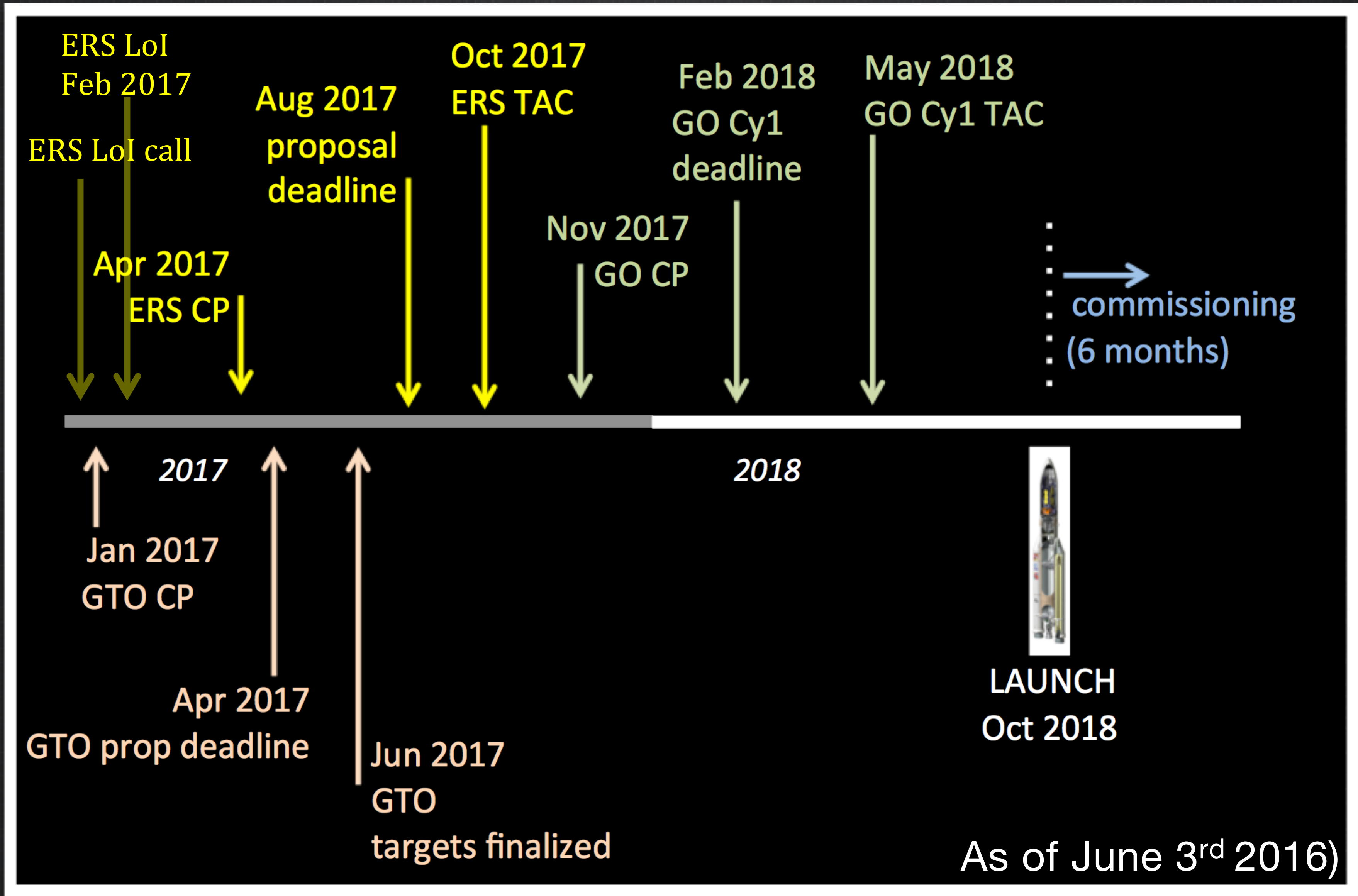
N. Reid's ERS Presentation from the Jan 2016 AAS Meeting:
http://www.stsci.edu/jwst/doc-archive/presentations

Review ERS-DD boundary conditions iterated with JSTAC:

1. Designed, executed by community investigators; selected by peer-review.
2. Director's discretionary program, totaling ~500 hours.
3. Spans key JWST observing modes, data analysis challenges, science areas. (JWST has 14 distinct imaging, coronagraphic, and spectroscopic observing modes.) *10-15 medium sized (30-70 hr) programs; multi-mode proposals encouraged*
4. Substantive, science-driven programs, with potential to enable community archival research in Cy1, and/or be building blocks for community to use to design more challenging JWST future program.
5. Data will have no proprietary period.
6. Among first obs to execute after commissioning in Cy1. *Must be schedulable early Cy1; CVZ targets preferred.*
7. ERS teams responsible for delivery of science enabling products to community in coordination with MAST. Delivery timescale to support community preparation of Cycle 2 proposals.
8. Reviewed, selected, publicized prior to the release of GO Cy1 Call for Proposals. ERS proposal deadline in 2017Aug.

Courtesy J. Lee

JWST Cycle 1 Early Release Science (ERS)



The ERS program http://www.stsci.edu/jwst/science/ers

For further info:

https://jwst.stsci.edu/

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

http://sci.esa.int/jwst/

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

http://www.inaf.it/it/sedi/sede-centrale-nuova/direzione-scientifica/ufficio-spazio/workshops-meetings

Thank you