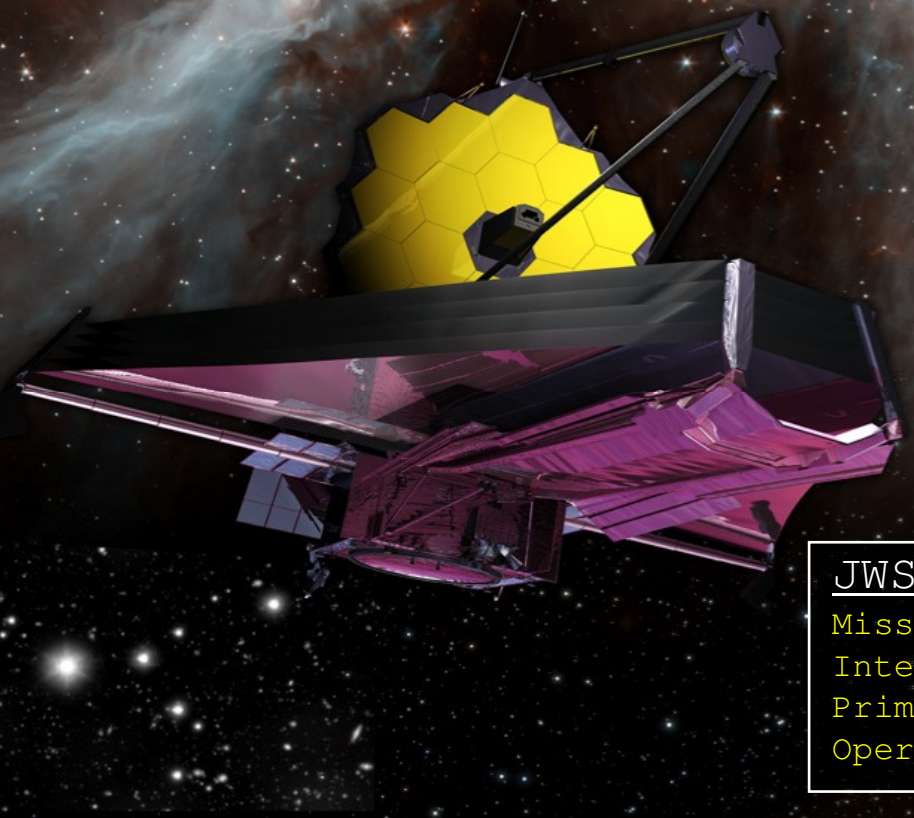

Astronomy
and the
James Webb
Space Telescope
John Mather, Senior Project
Scientist, NASA GSFC

The James Webb Space Telescope



JWST Instruments

Near Infrared Camera (NIRCam) - Univ. of Arizona
Near Infrared Spectrograph (NIRSpec) - ESA
Mid-Infrared Instrument (MIRI) - JPL/ESA
Tunable Filter Imager (TFI) - CSA

JWST Organization

Mission Lead: NASA's Goddard Space Flight Center
International Collaborators: ESA and CSA
Prime Contractor: Northrop Grumman Aerospace Systems
Operations Center: Space Telescope Science Institute

JWST Description

Deployable IR telescope with 6.5 meter segmented adjustable primary mirror
Cryogenic temperature telescope and instruments for IR performance
Launch on an ESA Ariane 5 rocket to Sun-Earth L2 point (1 million miles)
5-year science mission requirement (10-year goal)

The James Webb Space Telescope

James E. Webb (1906 – 1992)

- Second Administrator of NASA (1961 – 1968)
- Oversaw first & Second manned spaceflight programs (Mercury, Gemini)
- Oversaw Mariner and Pioneer planetary exploration programs
- Oversaw Apollo program: On time, On budget!
- Supported space science at NASA and universities

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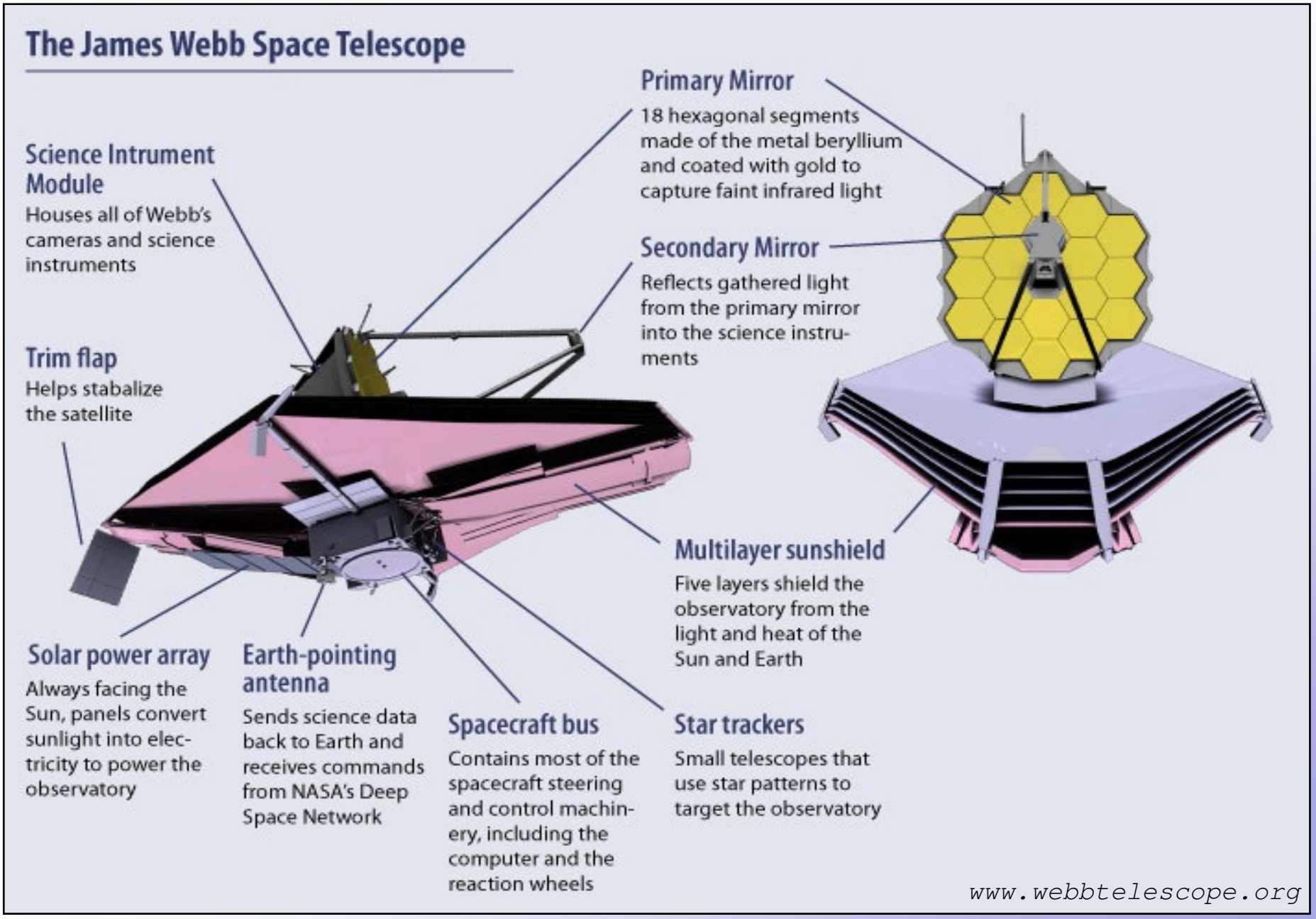
JWST Design



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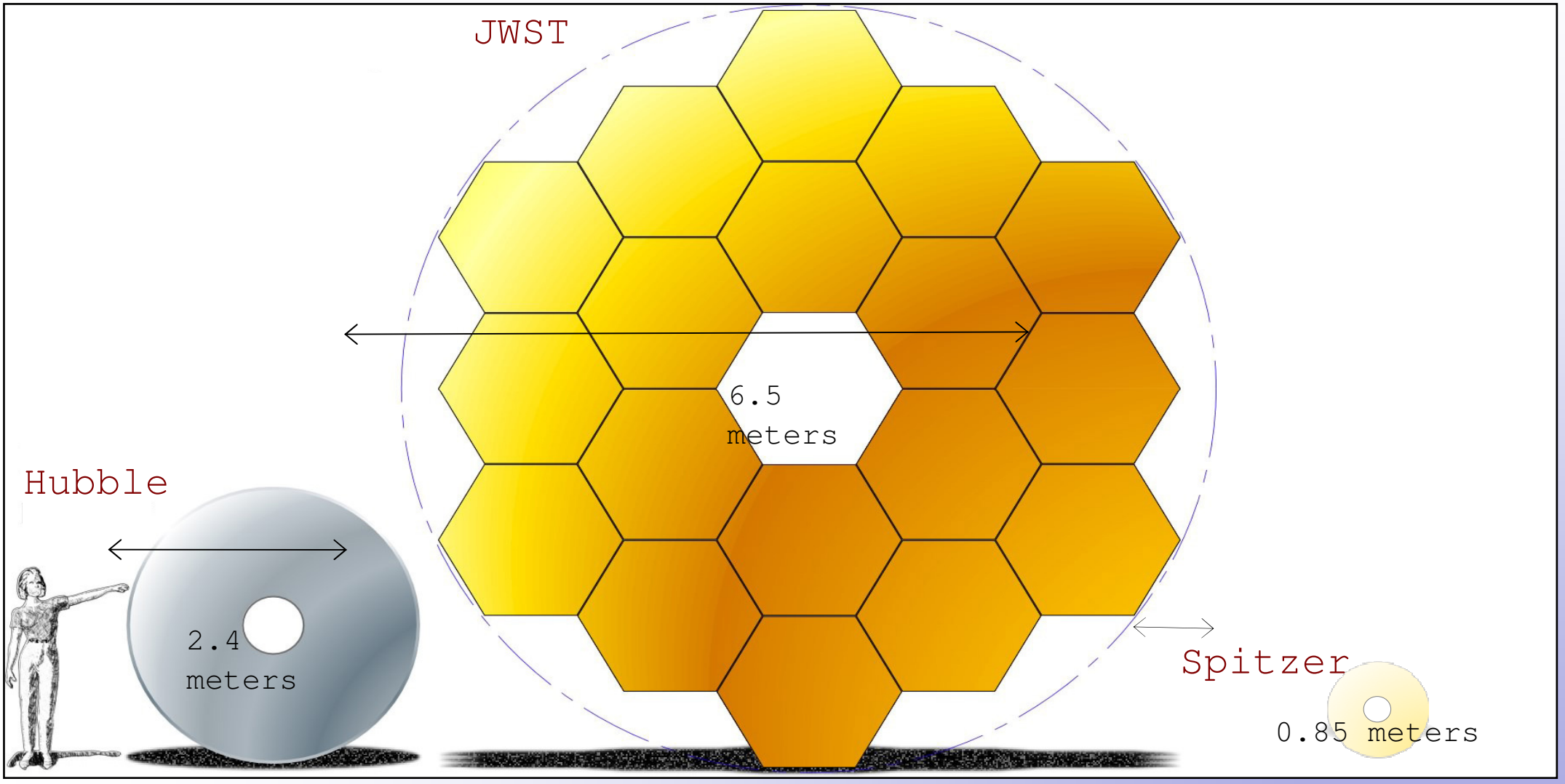

Light Gathering Power

JWST = 25 m^2 ; Hubble = 4.5 m^2 ; Spitzer = 0.6 m^2 ; Herschel 9.6 m^2

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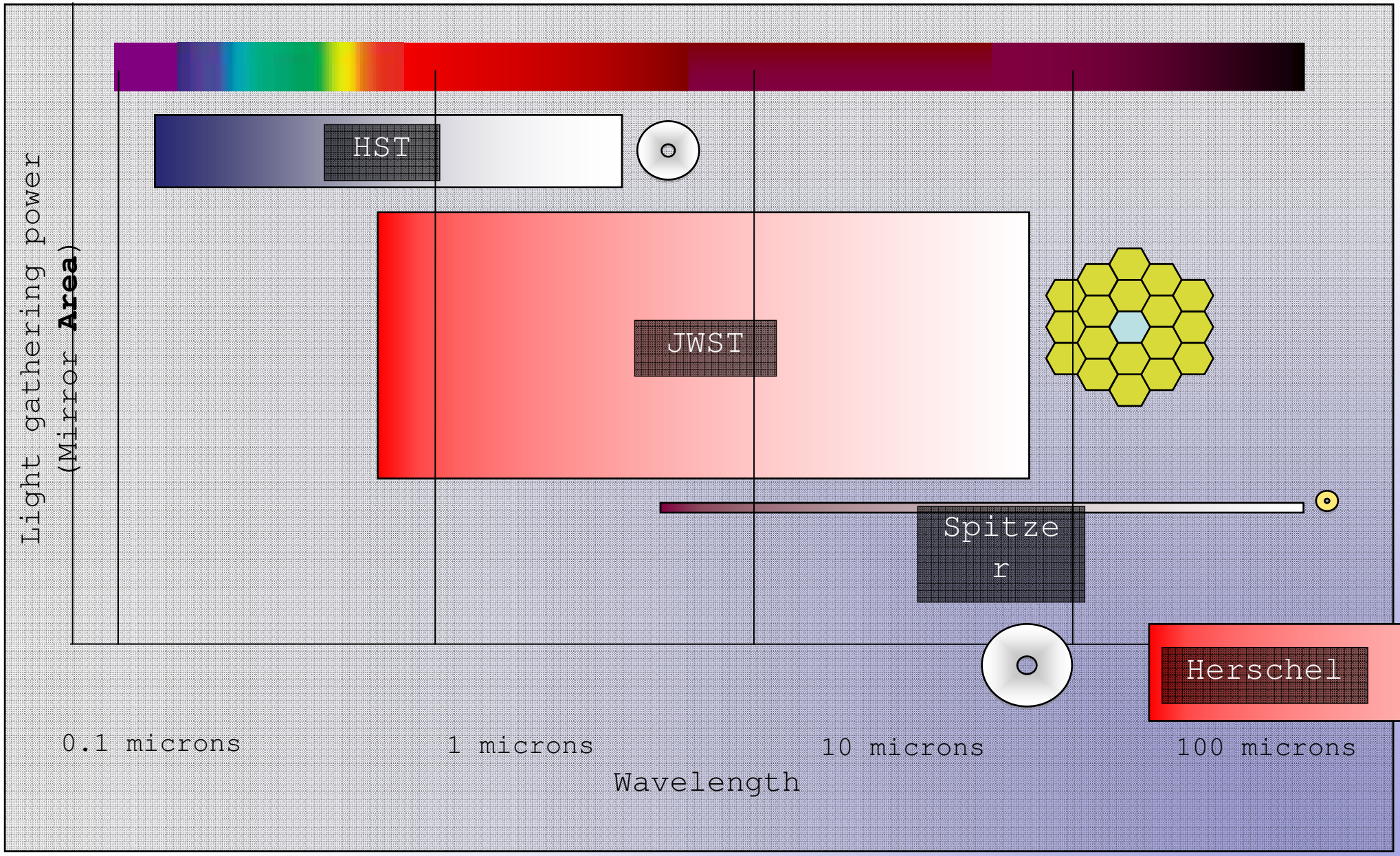

Light Gathering Power

JWST = 25 m^2 ; Hubble = 4.5 m^2 ; Spitzer = 0.6 m^2 : Herschel = 9.6 m^2

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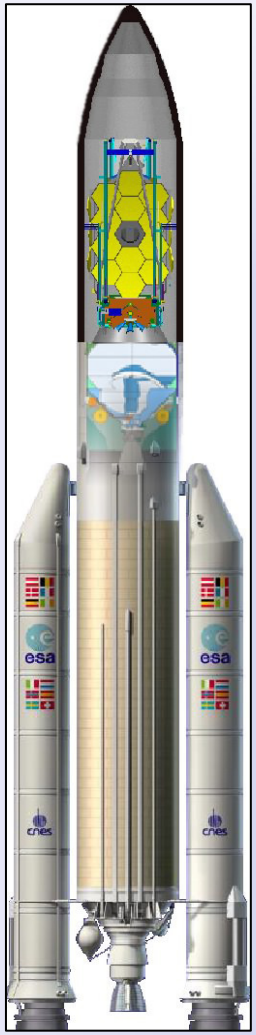
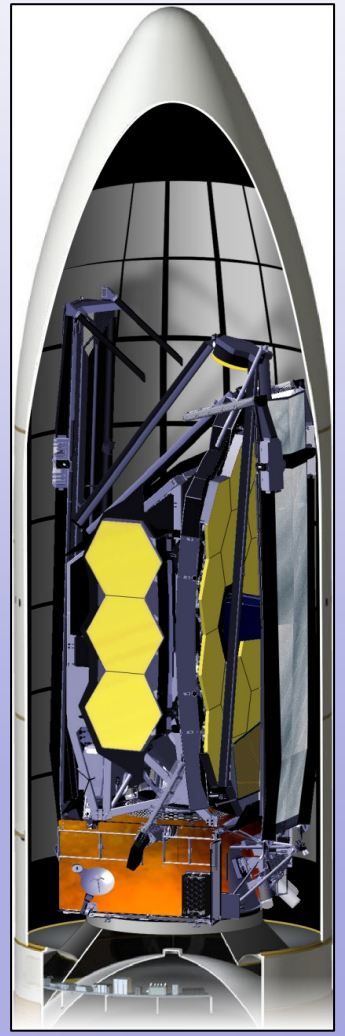
JWST Launch

- Launch vehicle is an Ariane 5 rocket, supplied by ESA
- Site will be the Arianespace's ELA-3 launch complex near Kourou, French Guiana





Arianespace – ESA – NASA

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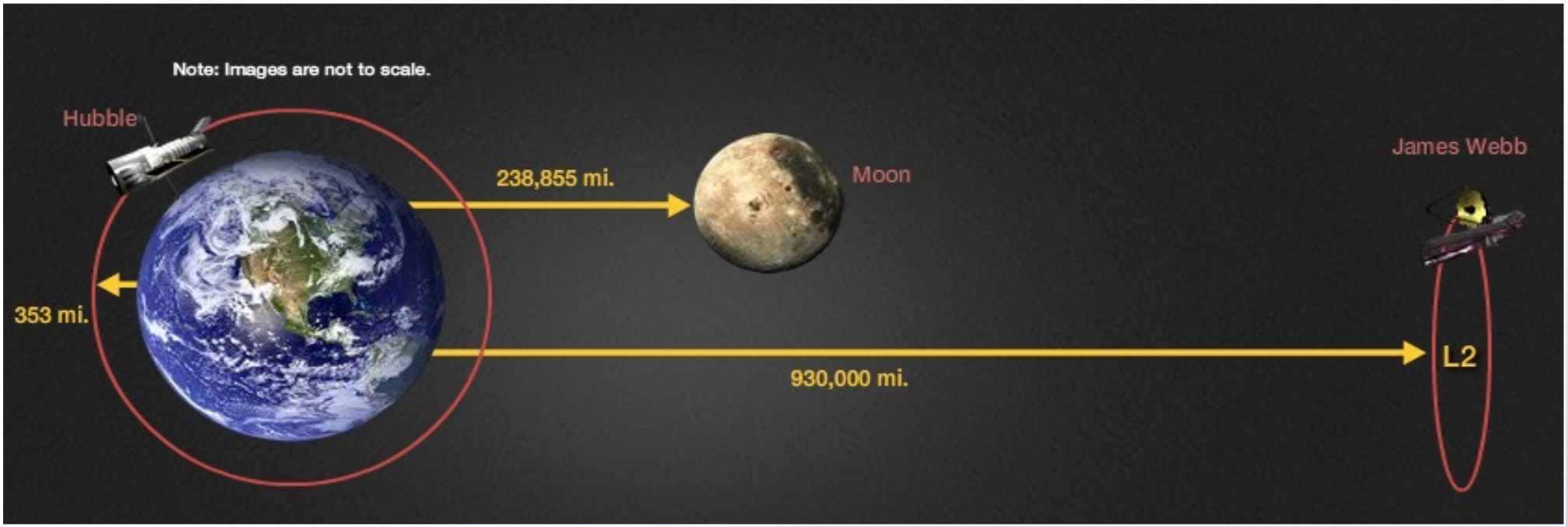
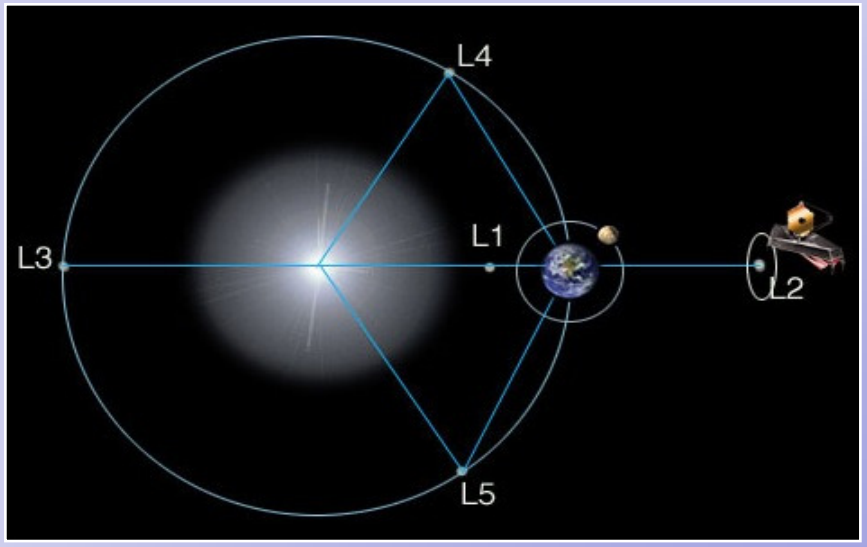


JWST Orbit

- JWST will orbit Sun-Earth L2 Lagrange point, 1.5 million km from Earth



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JWST Instruments

The Near Infrared Camera (NIRCam) – U AZ/ LM

- Visible and near infrared camera (0.6 – 5 micron)
- 2.2 x 4.4 arcmin field of view, diffraction limited
- Coronagraphs

The Near Infrared Spectrograph (NIRSpec) – ESA

- Multi-object dispersive spectrograph (1 – 5 micron)
- 3.4 x 3.4 arcmin field of view with 0.1 arcsec pixels
- R = 1000 and 2700 gratings and R = 100 prism
- IFU over 3 x 3 arcsecond region

The Mid Infrared Instrument (MIRI) – Europe/JPL

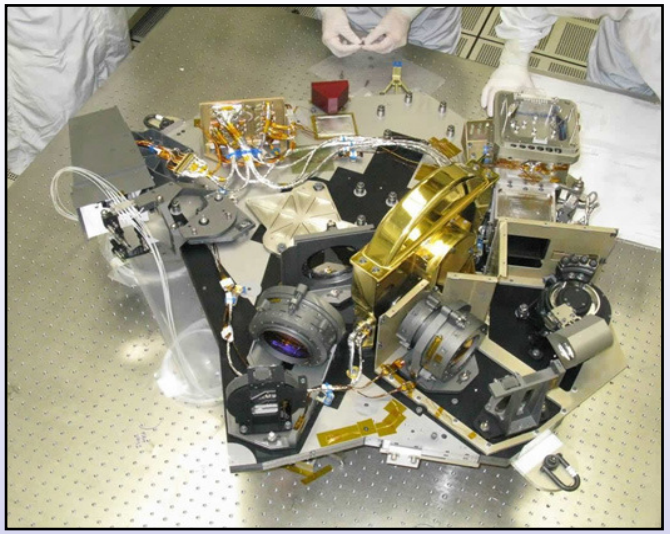
- Mid-infrared camera and slit spectrograph (5 – 28 microns)
- 1.9 x 1.4 arcmin imaging field of view with 0.11 arcsec pixels
- R = 100 slit spectrograph (5 – 10 micron) and IFU (R = 3000)
- Coronagraphs

Near IR Imager Slitless Spectrograph (NIRISS) – CSA

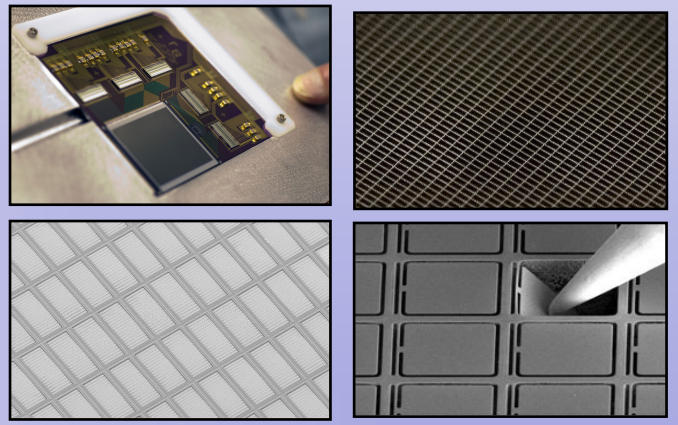
-2.2 x 2.2 arcmin field of view, Slitless (grism)
-R ~ 150, 0.8 – 2.25 microns optimized for Ly alpha galaxy surveys
-R ~ 700, 0.7 – 2.5 microns optimized for exoplanet transits

The Fine Guidance Sensor (FGS) – CSA

- 2.4 x 2.4 arcmin imager for target acquisition
- Rapid readout of subarray for ACS control
- Ensures 95% probability of finding a guide star anywhere in sky



NIRCam



NIRSpec

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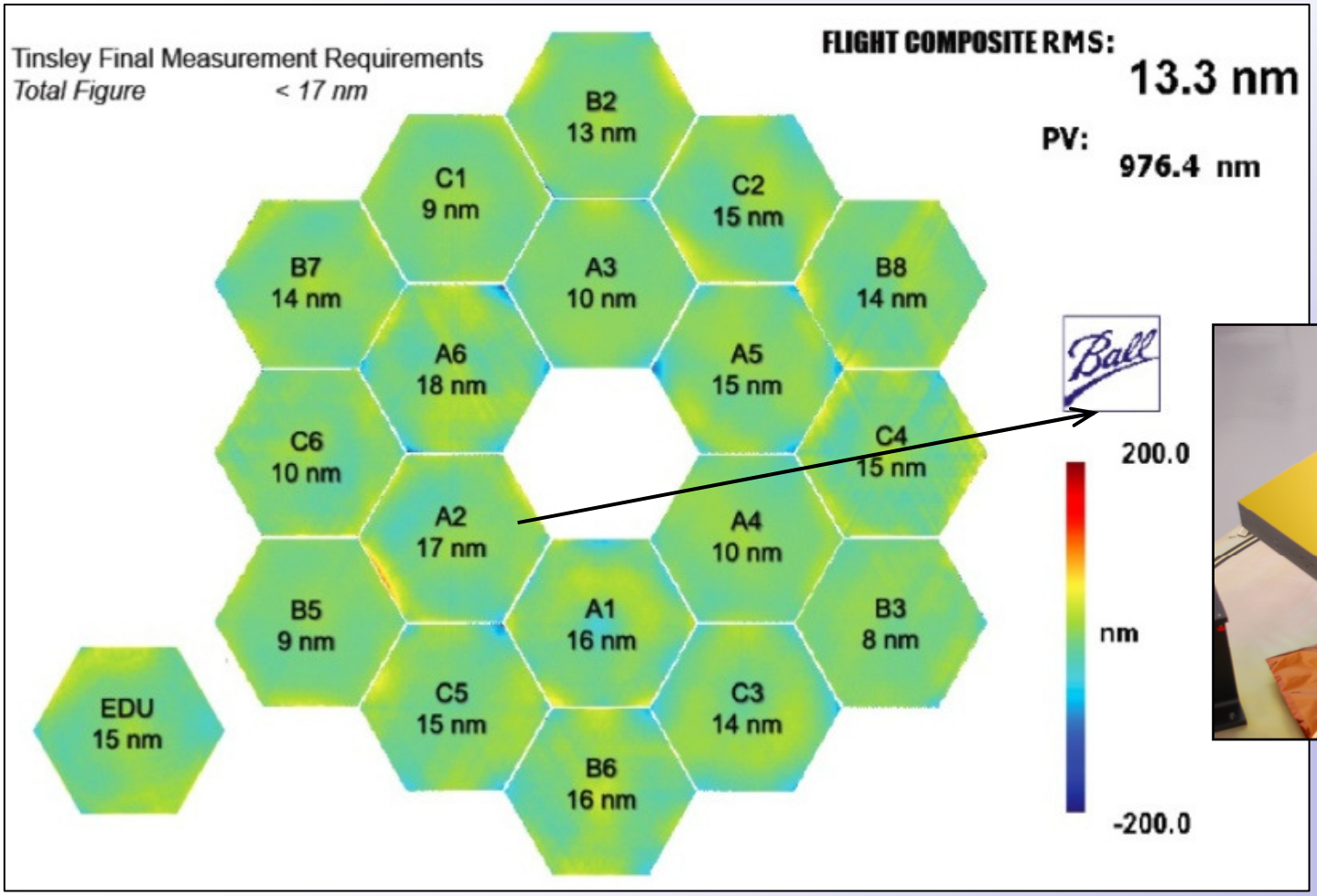
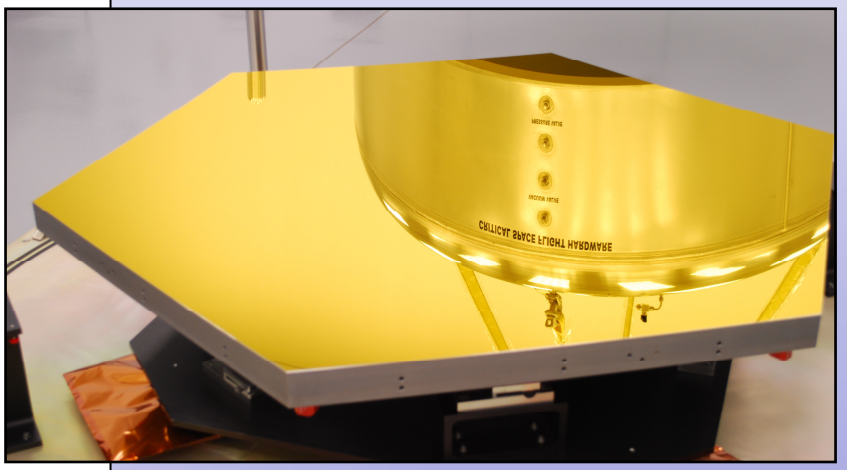
JWST Mirrors

Status as of Feb 2012

- All 18 PMs + Tertiary + FSM Polished, coated, tested cold





Courtesy of M. Clampin (GSFC)

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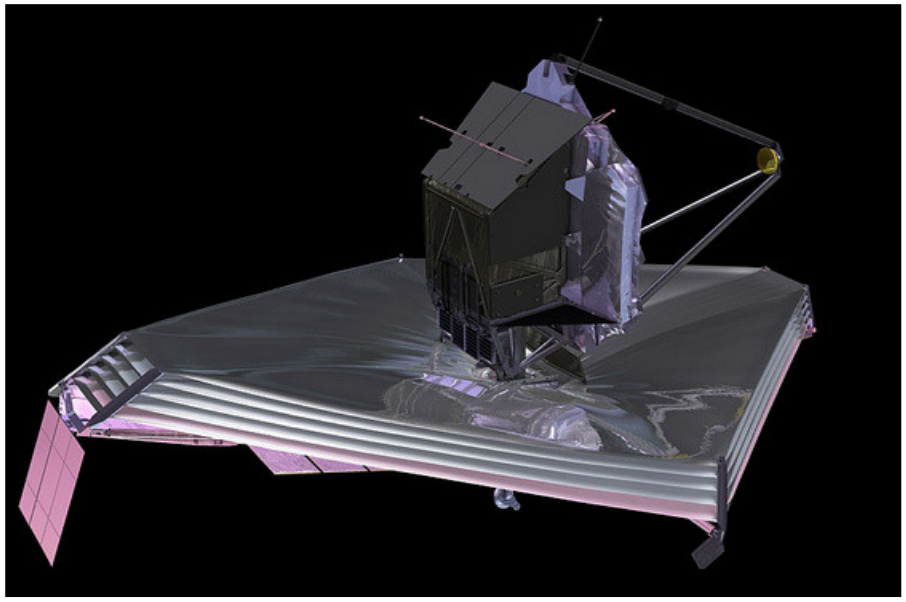
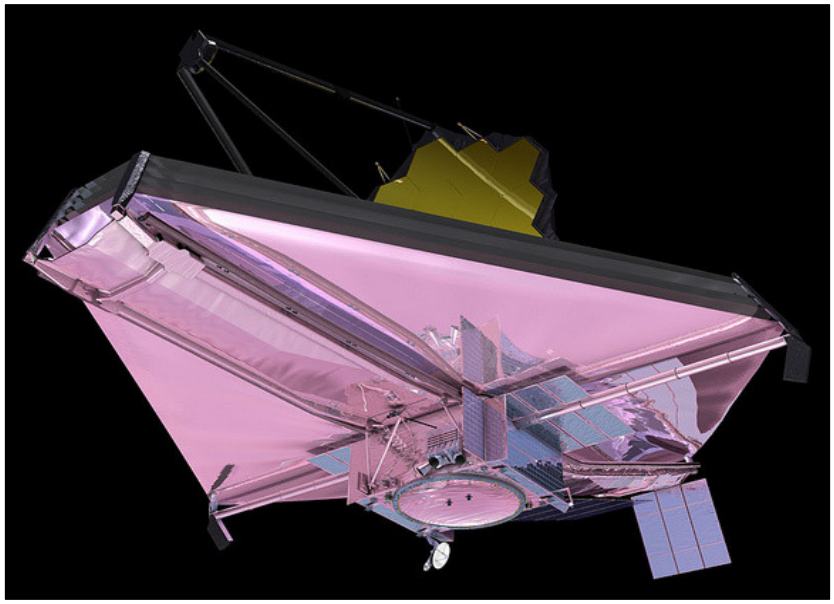
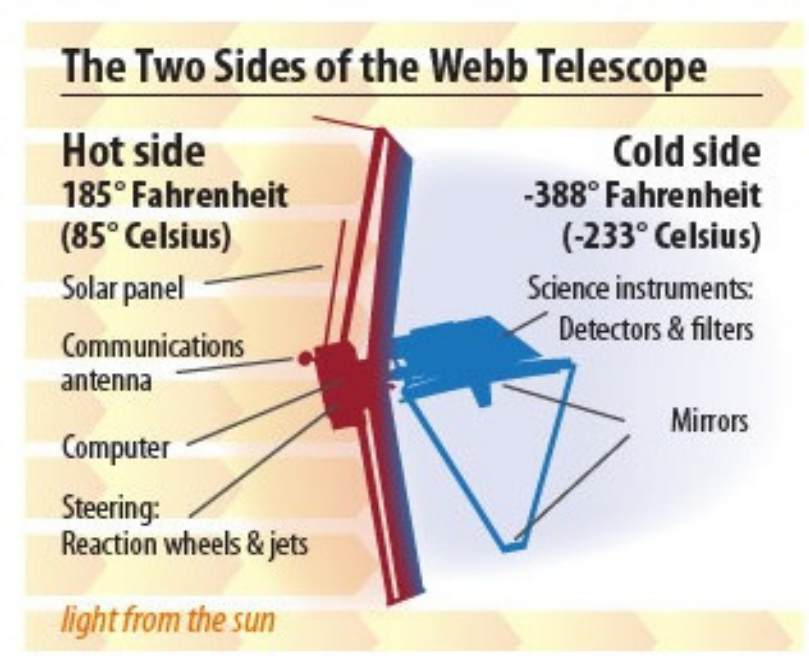
JWST Sunshield





Sunshield Facts

- Measures 73 x 40 feet and has 5 layers
- Contains 400 temperature sensors
- Made of heat-resistant kapton
- Coated with silicon on sun side
- Sun side reaches 358 K (85° C)
- Dark side stays at 40 K (-233° C)



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The JWST sunshield

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JWST Science Themes – The Quest for Origins

1.) The End of the Dark Ages
- Discover the first stars, protogalaxies, supernovae, and black holes
- Follow the Universe's ionization history across cosmic time

2.) The Assembly and Evolution of Galaxies
- Track the merger of protogalaxies
- Study the effects of black holes on their surroundings
- Map the evolution of dark matter, stars, and metals through galaxy growth

3.) The Birth of Stars and Planetary Systems
- Unveil newborn stars and planets in dusty clouds
- Reveal the dependency of star formation to environment
- Measure how chemical elements are produced and recirculated
- Complete the stellar and substellar inventory
- Measure the IMF to below the H-burning limit, in different environments

4.) The Origins of Life
- Study the formation of planets
- Measure the composition of atmospheres, probe for liquid water
- Complete the census of the outer solar system

JWST Science summarized in 15 JWST Science White Papers
http://www.stsci.edu/jwst/science/whitepapers

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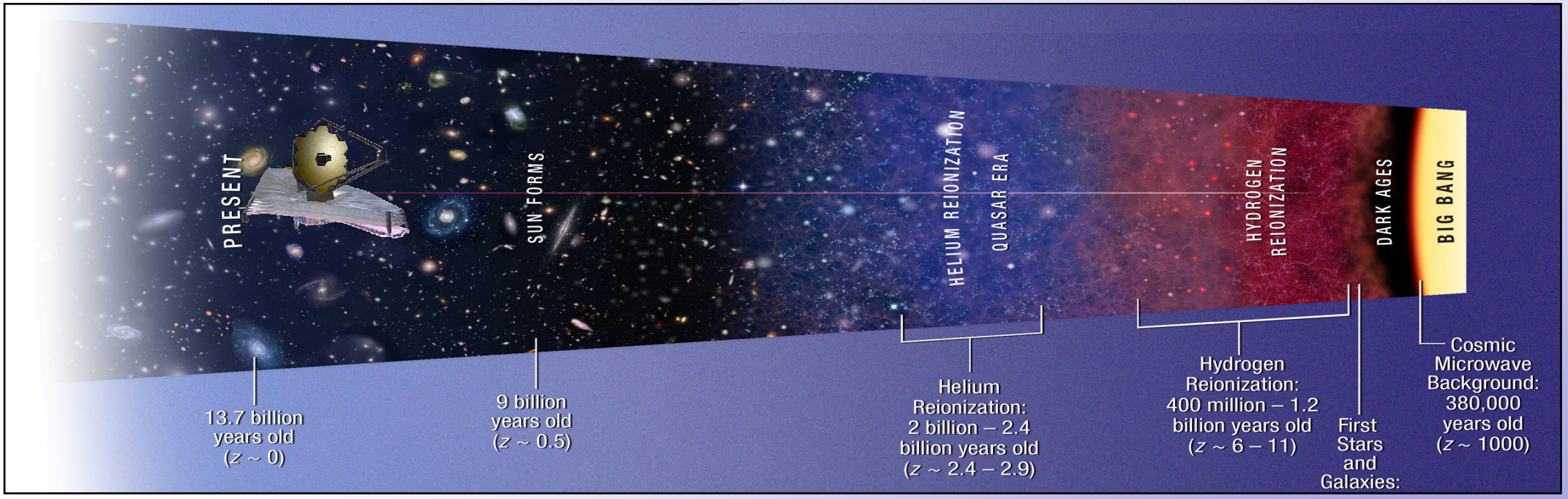
JWST Science Themes – The End of the Dark Ages

JWST Questions

1.) What are the first galaxies?
2.) When did reionization occur?
3.) What is the Universe's reionization history?
4.) What sources caused reionization?



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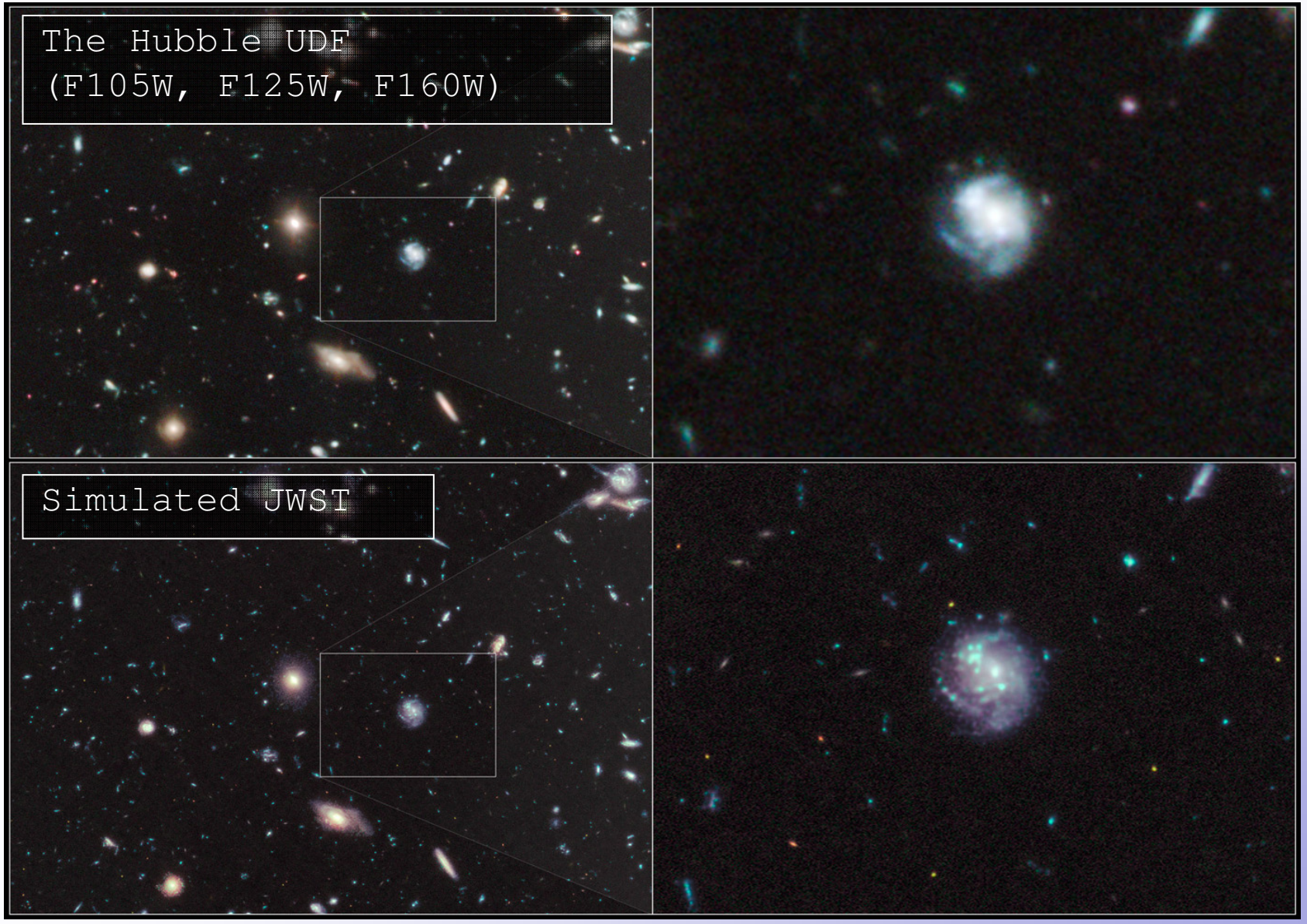
JWST Science Themes – The End of the Dark Ages



JWST will have higher angular resolution than Hubble for deep fields

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JWST Science Themes – The Assembly and Evolution of Galaxies

31.25 Mpc/h

JWST Questions

1.) Where and when did the hubble sequence form?
2.) Do hierarchical formation models and global scaling relations explain diverse galaxy morphologies and their cosmic evolution?
3.) How did the heavy elements form?
4.) What role do ULIRGs and AGN play in galaxy evolution?

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JWST Science Themes – The Birth of Stars and Planetary Systems

The power of high-res ir imaging
(Hints from WFC3)

The Carina Nebula

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JWST Science Themes – The Birth of Stars and Planetary Systems

– Lifting the Curtain on Star Formation (optical)

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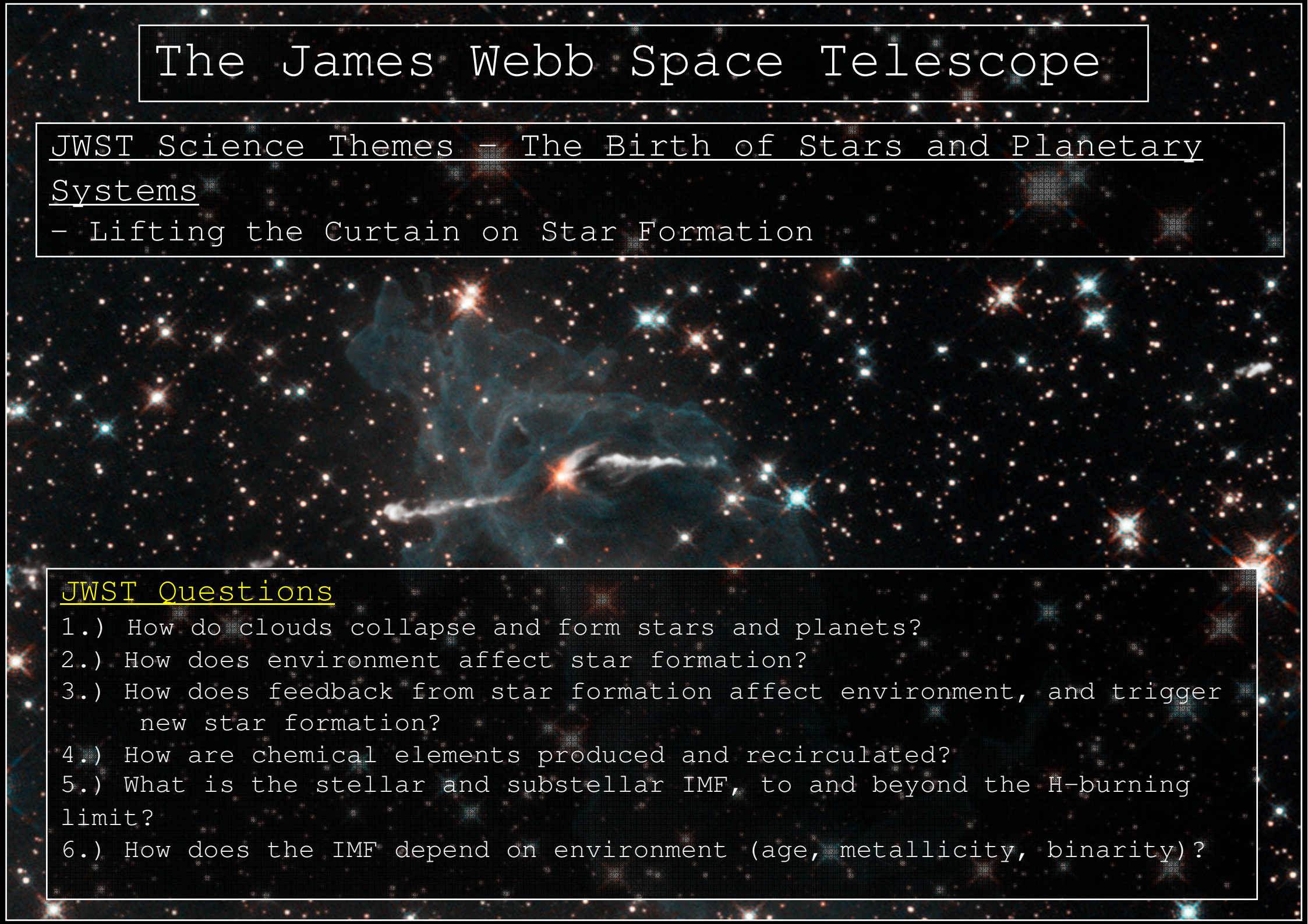
JWST Science Themes – The Birth of Stars and Planetary Systems

– Lifting the Curtain on Star Formation



JWST Questions

1.) How do clouds collapse and form stars and planets?
2.) How does environment affect star formation?
3.) How does feedback from star formation affect environment, and trigger new star formation?
4.) How are chemical elements produced and recirculated?
5.) What is the stellar and substellar IMF, to and beyond the H-burning limit?
6.) How does the IMF depend on environment (age, metallicity, binarity)?

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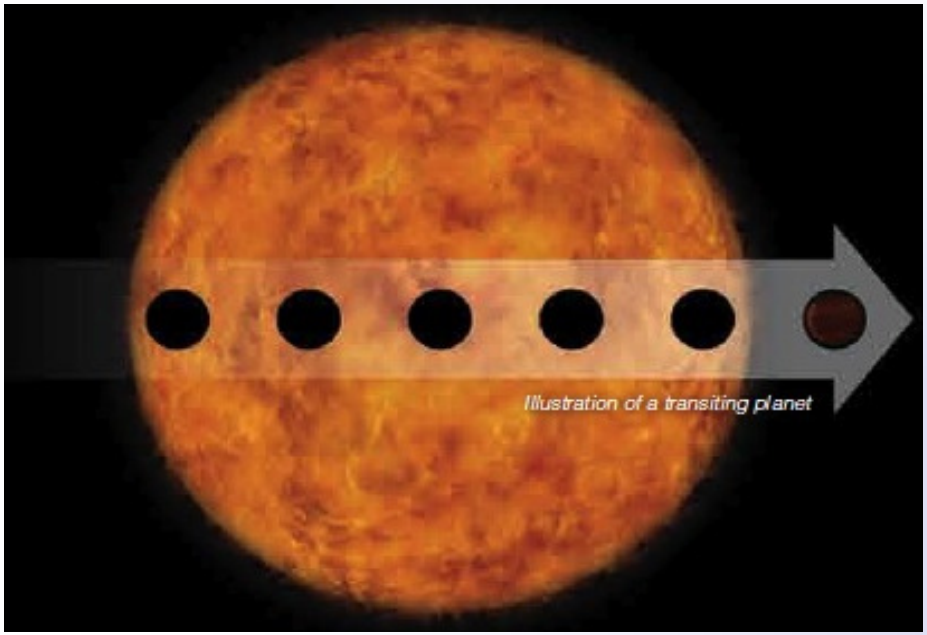
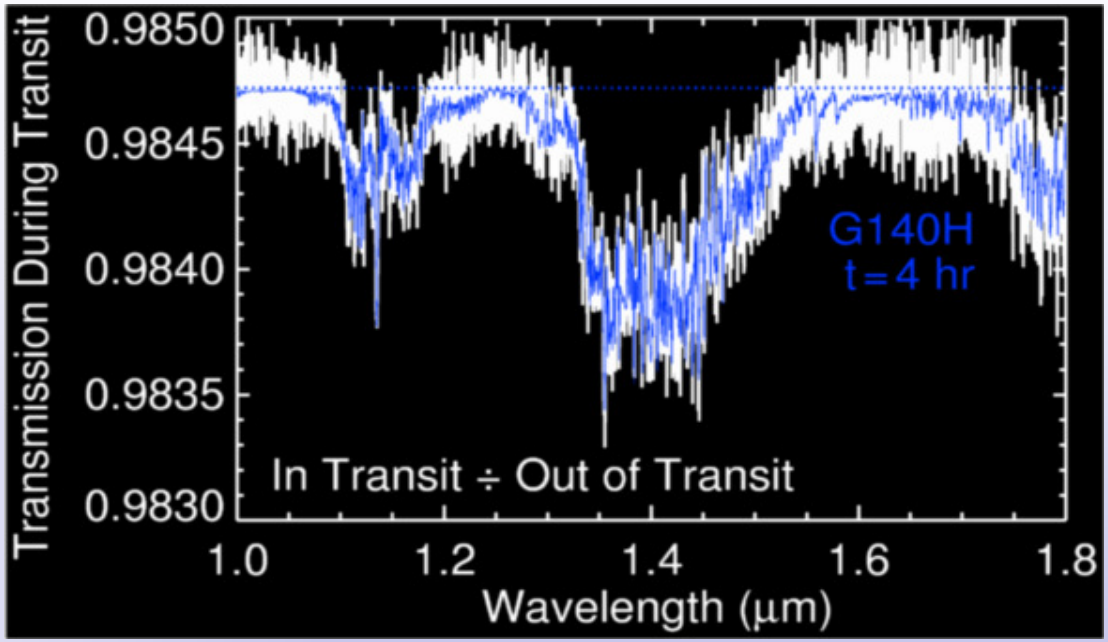
JWST Science Themes – The Origins of Life





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

JWST Questions

1.) How do planets Form?
2.) What are the properties of circumstellar disks like our solar system?
3.) What criteria should be used to establish habitable zones?
4.) Is there evidence for liquid water on exoplanets?

JWST will detect water in habitable zone super Earths

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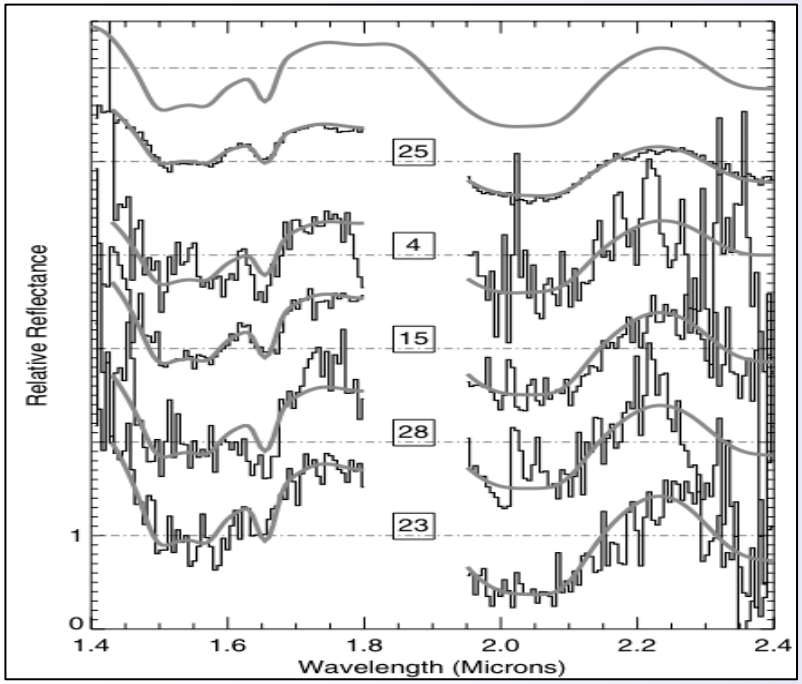
Artist's impression of a binary KBO

The Outer Solar System

1.) NIRSpec will measure IR spectra for all known Kuiper Belt Objects (KBOs).

2.) Spectral features from water ice will be mapped at redder wavelengths than currently possible, revealing surface mineralogy.

3.) The Chemical compositions of these objects will provide clues to the nature of the solar nebula.
This in turn provides insights on the early formation and evolution of the solar system.



NIRC spectra of water ice features in Haumea collision family objects

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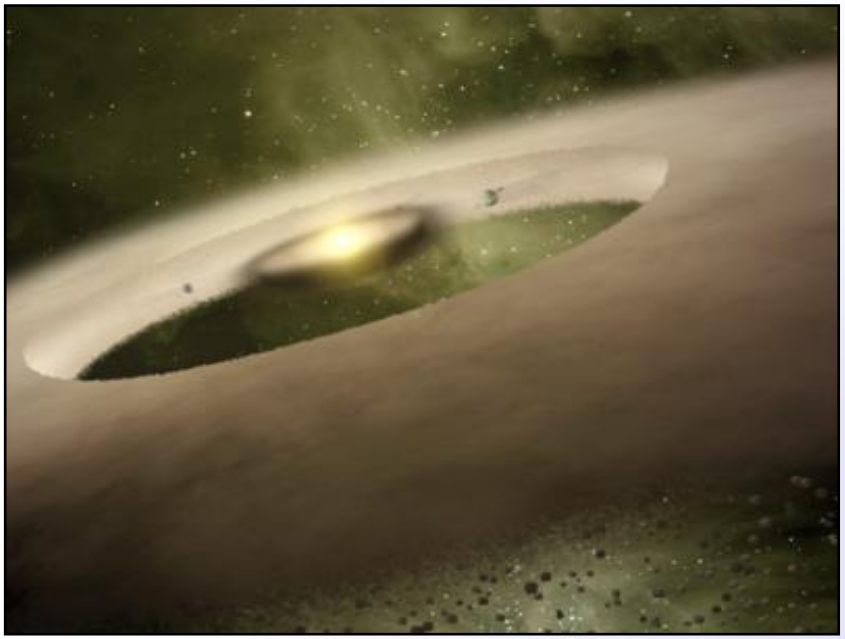
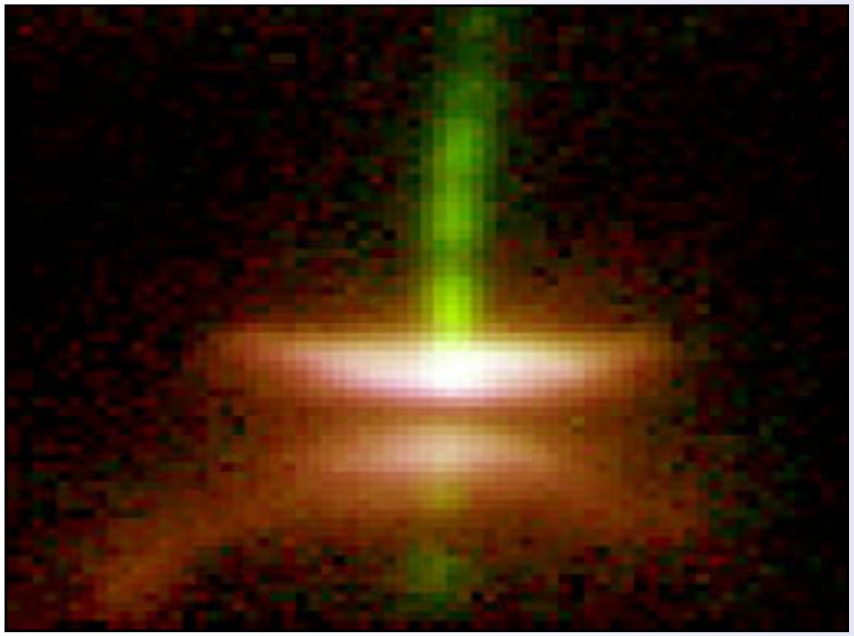


Protoplanetary Disks

1.) Resolve structure in the nearest disks at >30 AU scales with TFI and MIRI Coronography

2.) Measure dust settling characteristics as a part of planetesimal build up

3.) Trace gaps and asymmetries produced by embedded protoplanets



HH 30 edge-on disk with NIRSpec/MIRI IFU FOV

4.) Delineate gas content and parent populations

5.) Measure radial dependency of gas chemistry

6.) Probe mass inflow and outflow

7.) Measure statistics of disk properties vs stellar mass and environment

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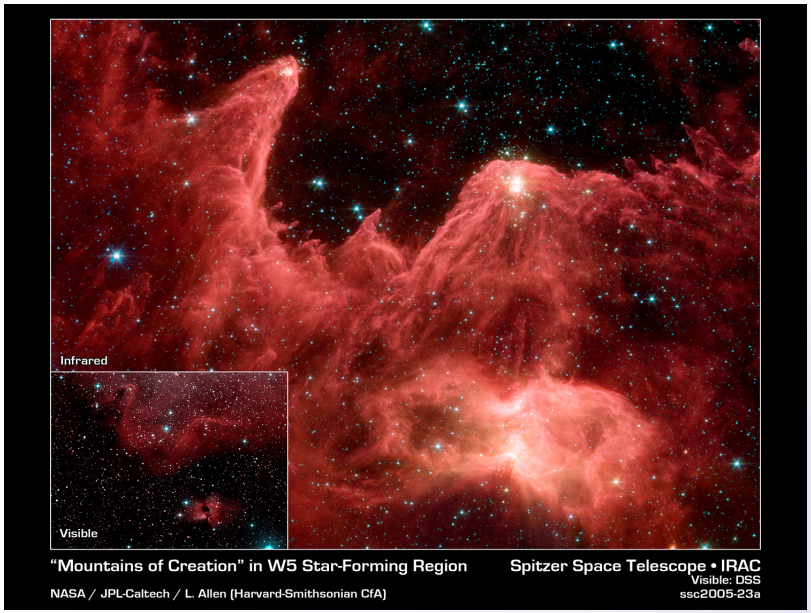


Bow shock around the Galactic O-type runaway star ζ Ophiuchi

Massive Stars: Formation

1.) How do hot, massive stars emerge from their dust-obscured natal cocoons?

2.) How does their presence affect the formation of other stars?

Massive Stars: Feedback

3.) How does the evolution of massive stars shape their galactic environments?

4.) How does metallicity effect massive star evolution?

Massive Stars: Circumstellar Structure

5.) What causes circumstellar nebulae to form around LBV and WR stars?

6.) How is mass lost from these stars?

7.) How are their outflows structured?

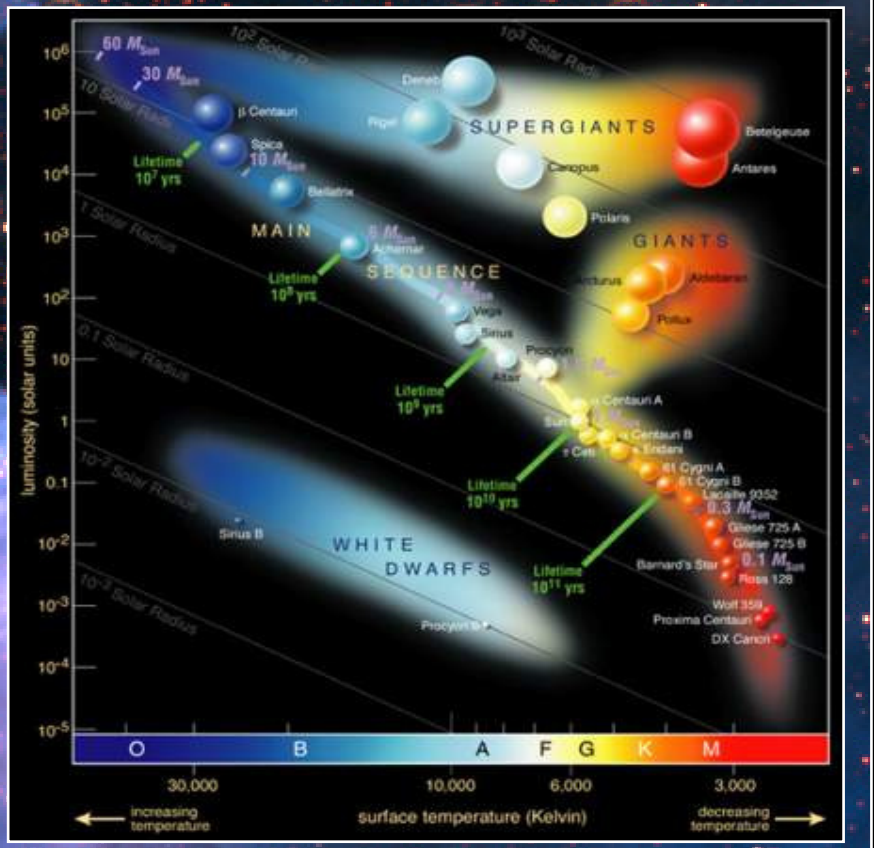
The James Webb Space Telescope

Resolved Stellar Populations – Local Group

1.) NIRCam and TFI Imaging plus NIRSpec MOS spectroscopy of star forming regions and Milky Way components will provide age and abundances distributions, testing formation and assembly models.

2.) Use near-IR imaging to complete a stellar inventory of nearby populations, by measuring stars from the brightest giant phases to low mass dwarfs.

3.) MIRI imaging and spectroscopy will penetrate extincted regions to discover and characterize T_{eff}, log(g), and mass for stars down the hydrogen burning limit, and into sub-stellar regimes.



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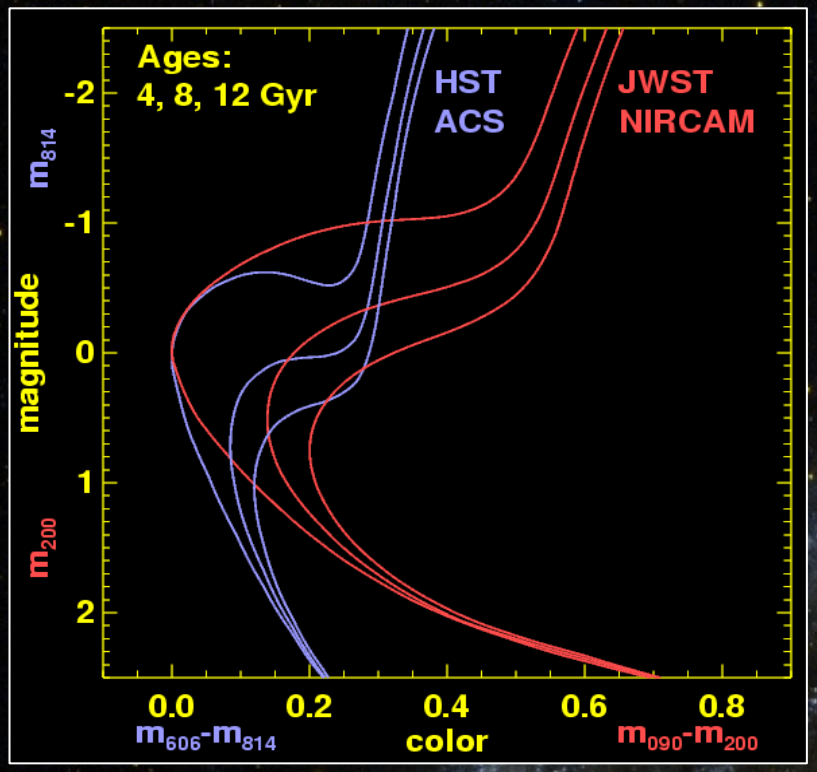


Resolved Stellar Populations - Local Volume

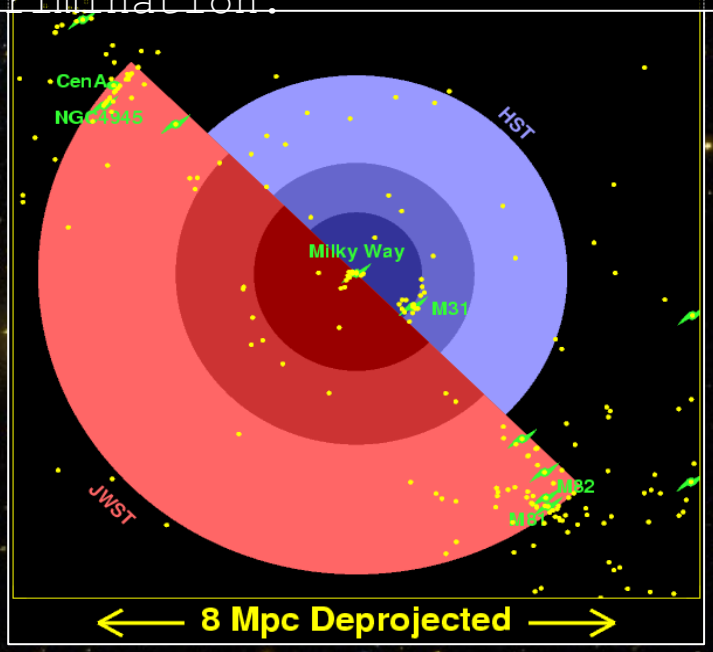
1.) Photometry will reach faint main sequence stars like our Sun in galaxies outside the local group. Extended star formation periods will be efficiently measured with filters well-separated in wavelength.

2.) Relative to HST Imaging, JWST/NIRCAM will have superb sensitivity over a broad wavelength range, be diffraction limited, and have a larger field of view. This will yield deep near-IR CMDs with excellent age discrimination.

3.) A view of the nearby universe, with galaxies at their true distances. Concentric circles correspond to hypothetical observing programs of 10, 100, and 1000 hours.

4.) At a given distance, JWST will be nearly six times faster than HST for this type of work.

5.) For a given exposure time, JWST can explore galaxies about 50% further away than those available to HST.



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Transient Objects

1.) Explore the nature of exotic transients through increased sensitivity and resolution (GRBs, Sne, tidal disruption events, unknown objects, …).

2.) Measure the nature of Dark Energy through IR light curves of SNe.

3.) Measure the SNe rate at high-z and probe its connection with the star formation rate and galaxy morphology.

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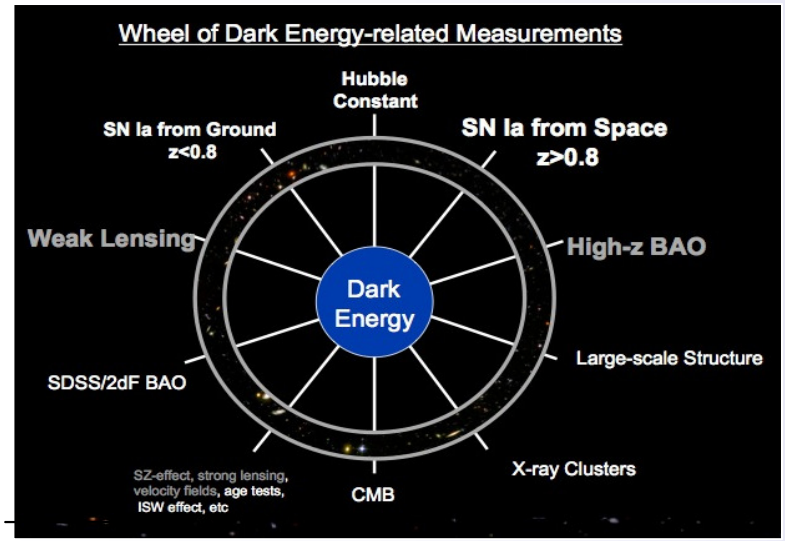
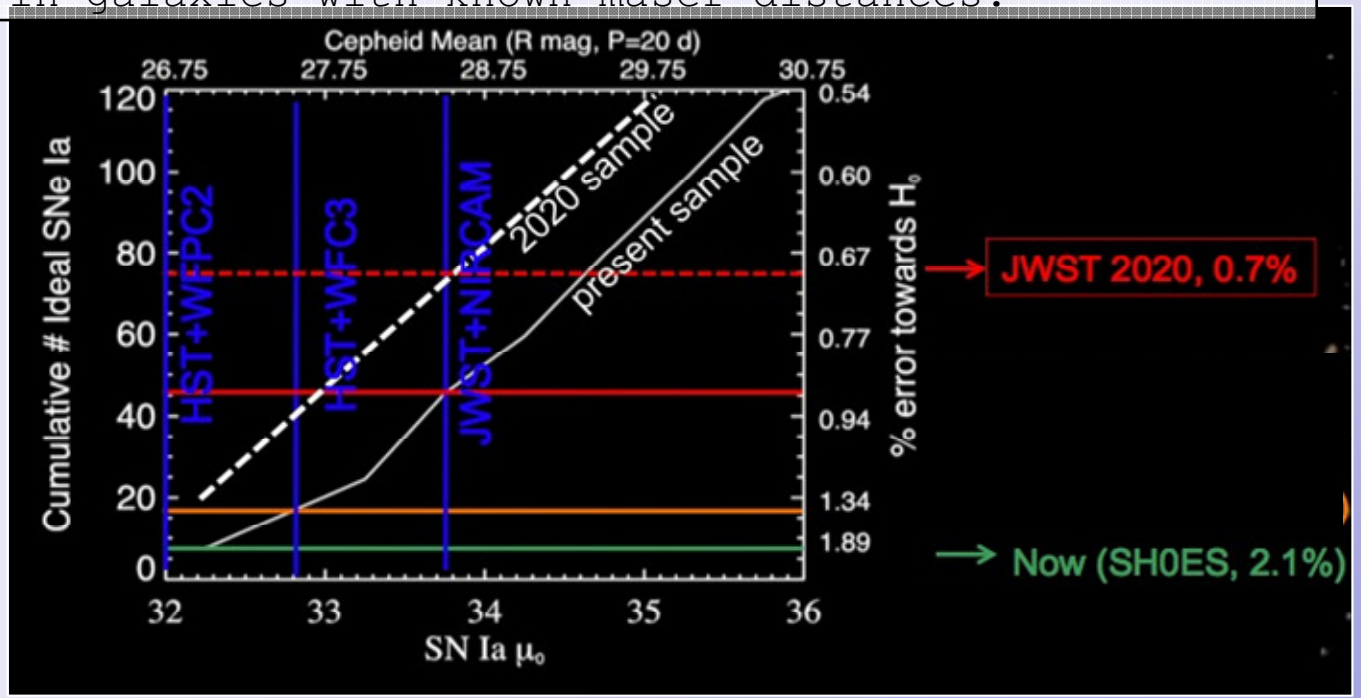
Dark Energy and Dark Matter: The acceleration parameter of the Universe

1.) Leverage multiple techniques to minimize systematic errors.
2.) wide field surveys will find targets.
3.) Measure very distant supernovae (standard candles?)
4.) SNe rest frame IR light curves – may be better standard candles?
5.) directly measure effects of dark matter from distorted geometry of distant objects, masses of galaxies and clusters to high-z, rotation curves, etc…
6.) Map cosmic archeology at high-z (prior to acceleration, formation of clusters).
7.) Measure Cepheid variables in galaxies with known maser distances.





JWST will constrain Dark Energy through exquisite measurements of H_0

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Visit JWST at:

- The Space Telescope Science Institute (STScI): http://www.stsci.edu/jwst/
- NASA Goddard Space Flight Center (GSFC): http://www.jwst.nasa.gov/
- European Space Agency (ESA): http://sci.esa.int/science-e/www/area/index.cfm?fareaid=29
- Canadian Space Agency (CSA): http://www.asc-csa.gc.ca/eng/satellites/jwst/default.asp
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- Twitter: @NASAWebbTelescp
- Youtube: http://www.youtube.com/user/NASAWebbTelescope

- Newsletter at STScI: https://blogs.stsci.edu/newsletter/
- Newsletter at GSFC: http://www.jwst.nasa.gov/newsletters.html