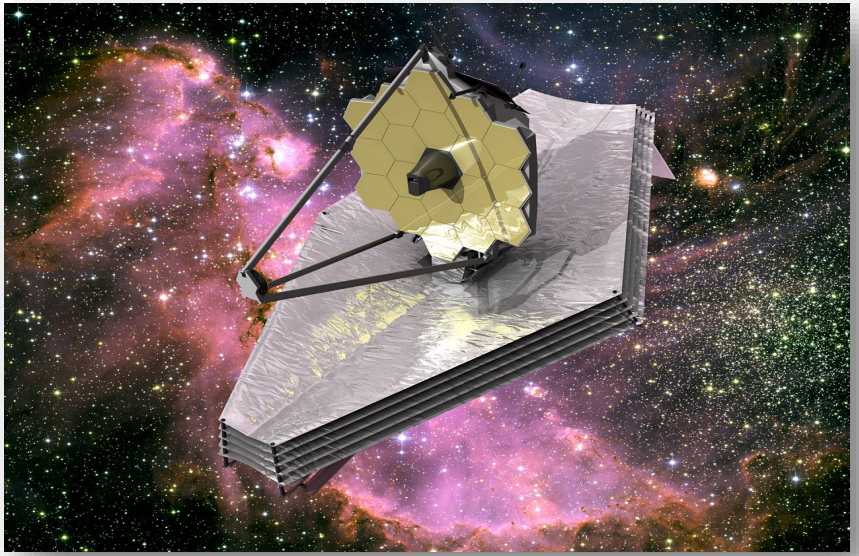
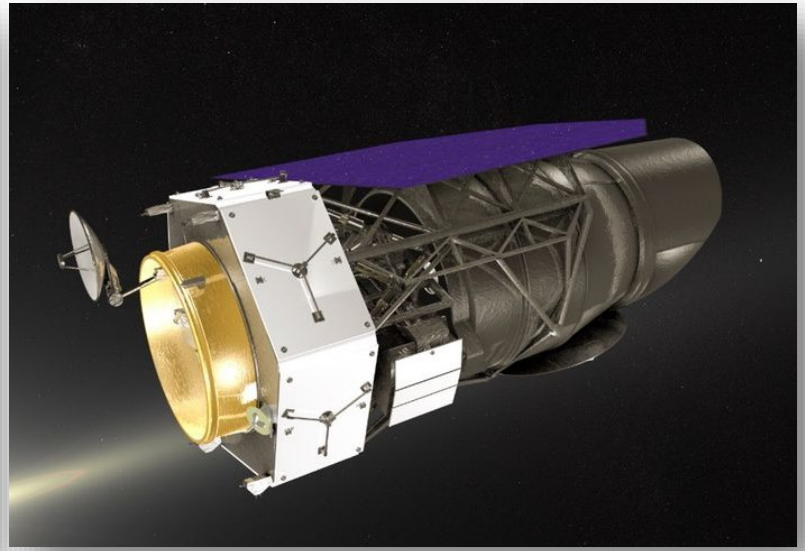
ASTR 4800 - *Space Science: Practice & Policy*

Today: Astrophysics Flagship Missions: JWST & Roman Space Telescope

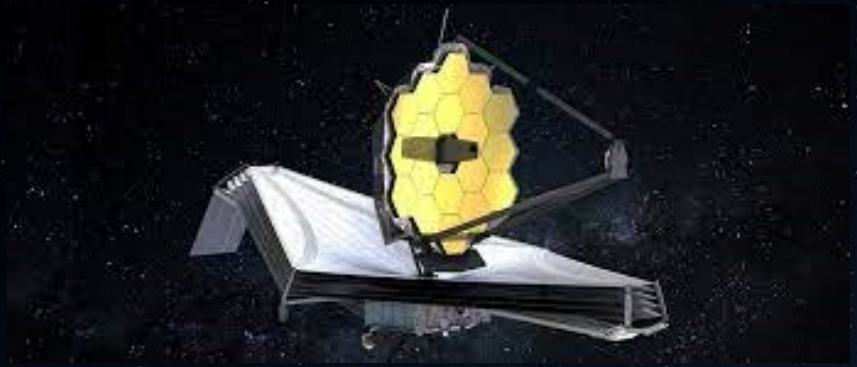
- Next Class: *Guest lecture by Dr. Eugene Tu, Director of the NASA Ames Research Center*. Read about NASA Ames via weblink on class webpage for Dec. 2.
- Any questions about final paper due next week?
- Complete FCQs.





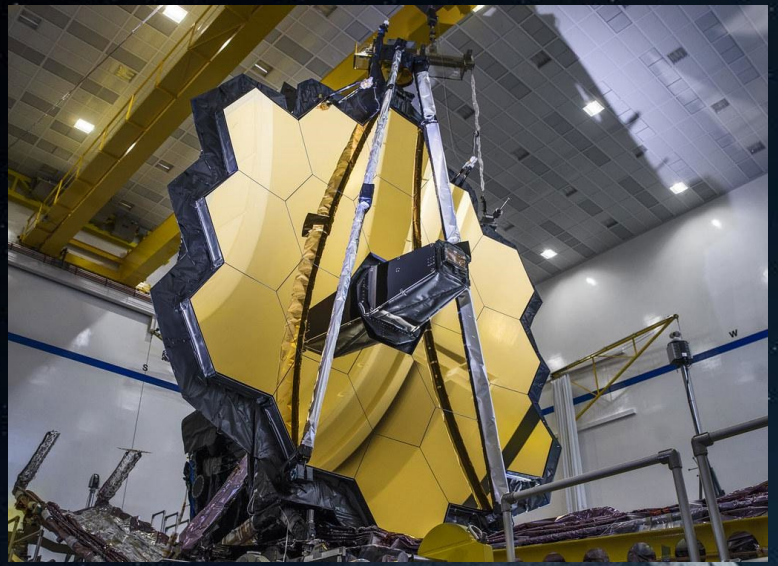
Astrophysics Flagship Telescopes - James Webb and Roman Space Telescopes

Tom Chumash & Trevor Groves



Origin of James Webb Space Telescope

- Question of what's next raised in 1989
- 1990 - Development of 8-m cooled visible & infrared telescope
- Formally known as the Next Generation Space Telescope (NGST)
- International collaboration between NASA, European Space Agency, Canadian Space Agency, Goddard Space Flight Center, Northrop Grumman, Space Telescope Science Institute



Who is James Webb?

- Administer of NASA 1961-1968
- Background in business and policy
  - Director of the Bureau of the Budget and as Undersecretary of State in the Truman administration
- Ensured U.S. possessed a scientific objective during the ‘Space Race’
  - Implications for aerospace industry and at a University level
- 1965 - urged that the Large Space Telescope would prove greatly important
- By retirement NASA had launched 75 missions
- LGBTQ pushback for James Webb as JWST name inspiration
  - 1949-1952 DOS

Going over Budget

- **$1 billion & launching in 2010**
  - Began planning in 1996
  - Construction began in 2004
  - Redesign in 2005 to scale back complexity
- **$4.5 billion & launching in 2013**
  - 2009 - NASA had difficulty inventing & building cutting-edge technologies
- **$8.8 billion & launching in 2018**
  - Lawmakers proposed bill that would cancel telescope entirely
  - Congress capped cost at $8 billion and conducted annual audits

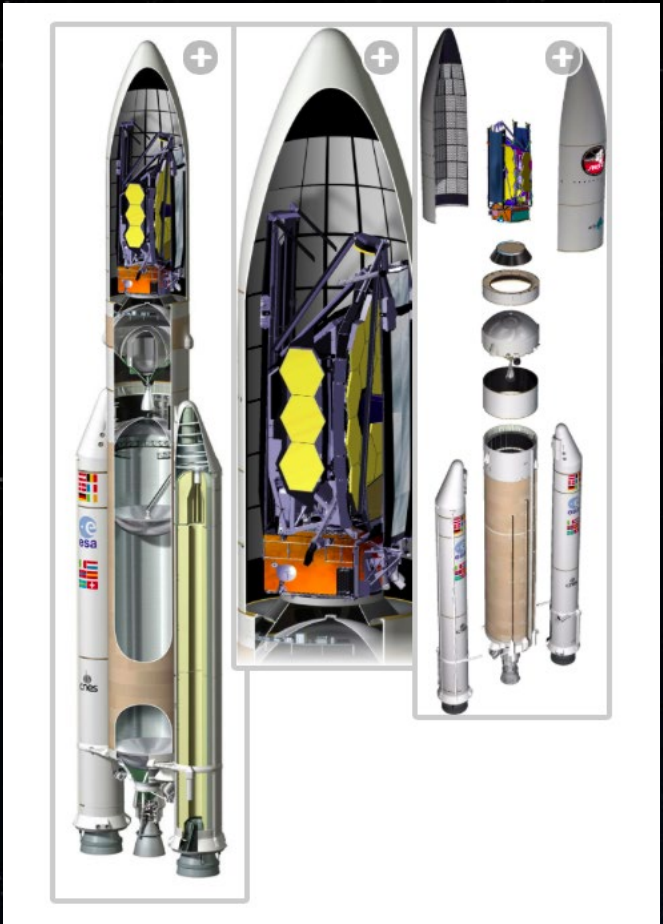
Going Over Budget

- **$9.6 billion & launching in 2021**
  - Construction completed in 2016
  - 2017: NASA announces need to launch in 2019
  - 2018 review found human errors costing program $600 million and 18 months of delays
- **Last minute jitters**
  - Coronavirus pandemic caused further delay
  - June: delayed launch further for review of Ariane 5 rocket
  - Dec 18th to Dec 22: clamp band came undone
  - Dec 22 to Dec 24: glitches with cable that allows communication

Class Exercise

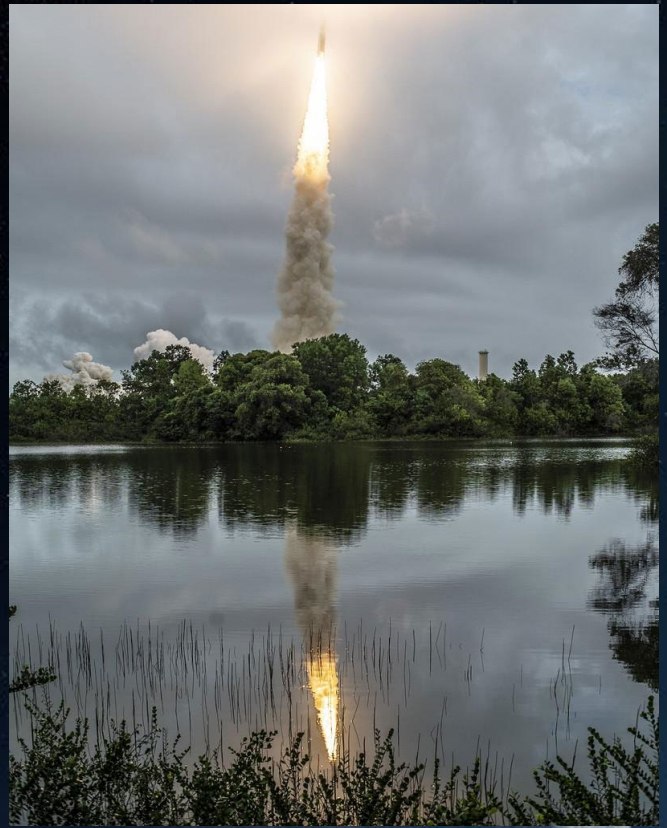
How can we avoid repeating another 1000% cost overrun with future missions?

“Cosmic Cliffs” in the Carina Nebula



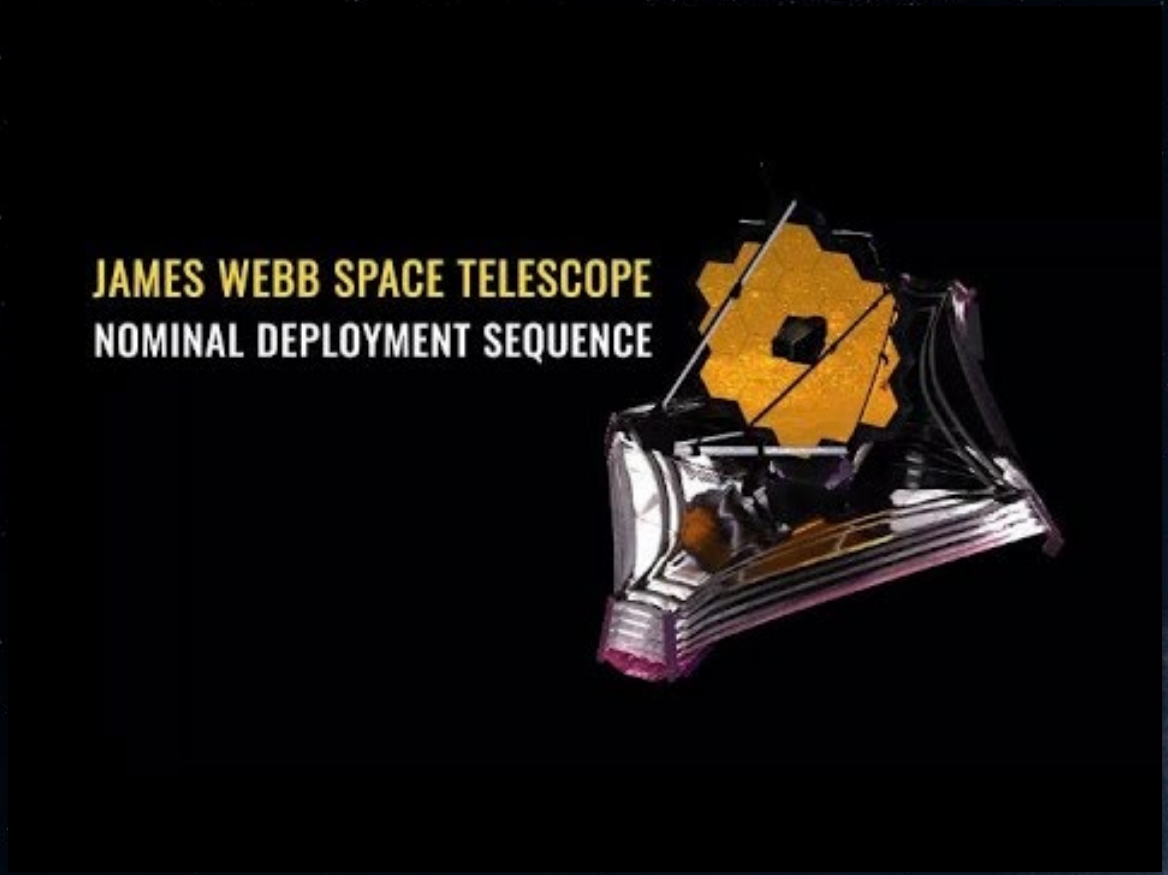
Webb’s Launch

- Ariane 5 Rocket
- Launched from European Space Agency’s Spaceport in French Guiana



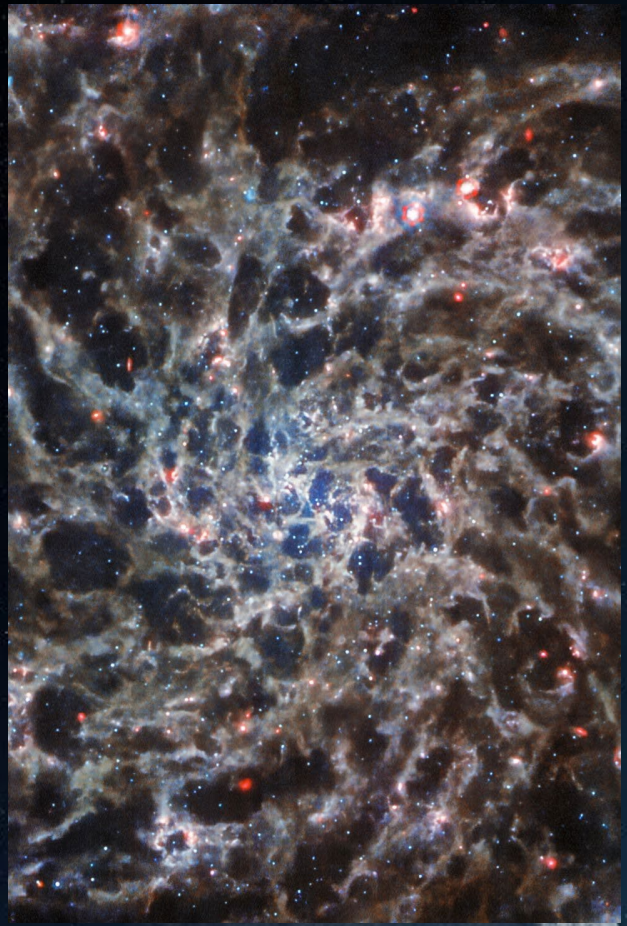
Total Payload: 6200 kg

Webb Post Launch Deployment



Mission Goals

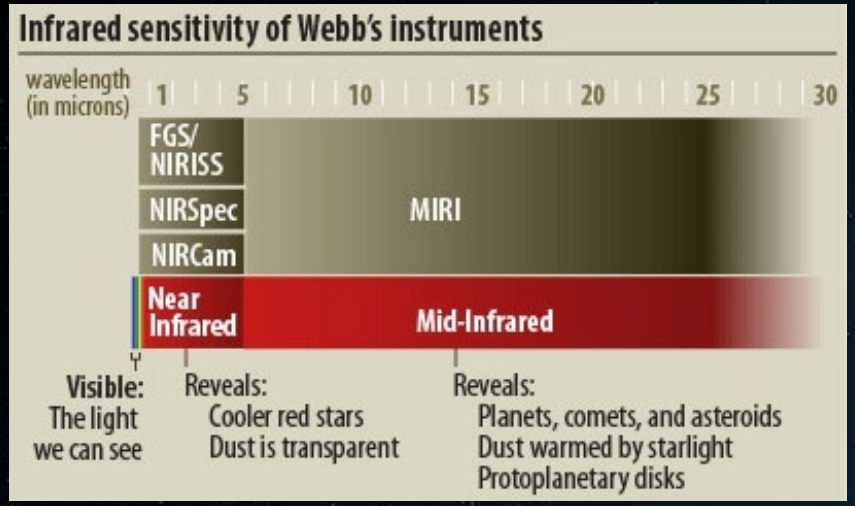
- Search for the first galaxies or luminous objects formed after the big bang
- Determine how galaxies evolved from their formation until now
- Observe the formation of stars from the first stages to the formation of planetary systems
- Measure the physical and chemical properties of planetary systems, including our own solar system, and investigate the potential for life in those systems



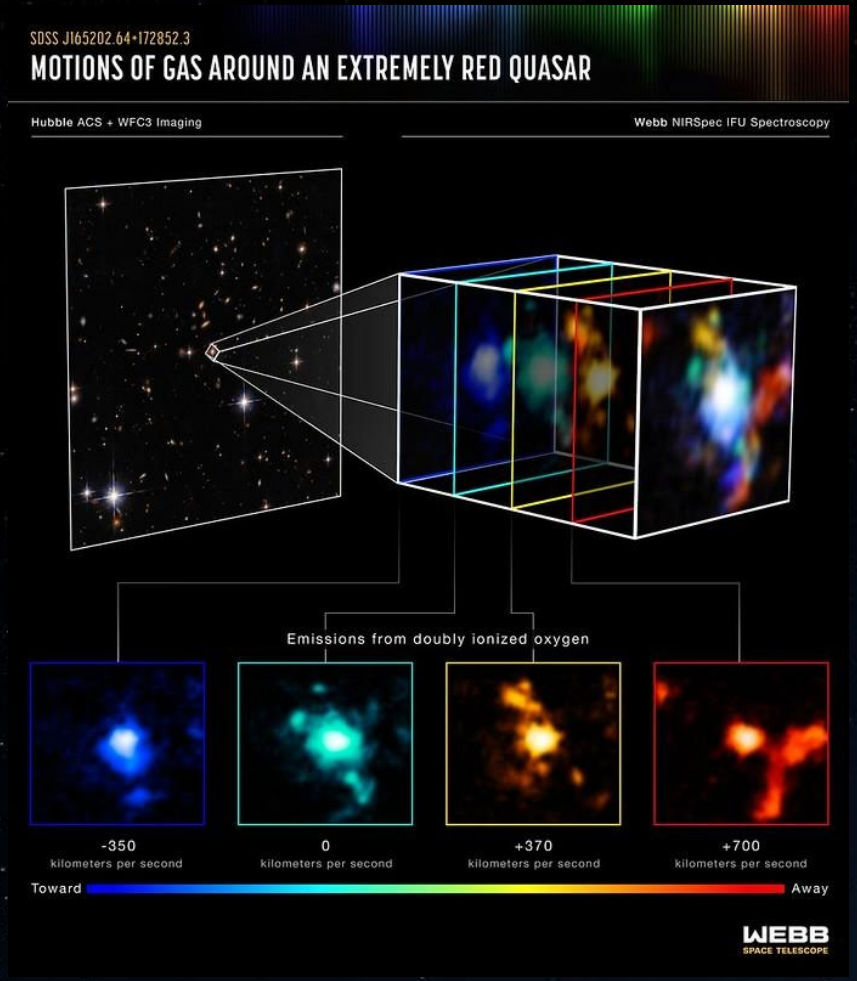
Galaxy IC 5332

Instruments

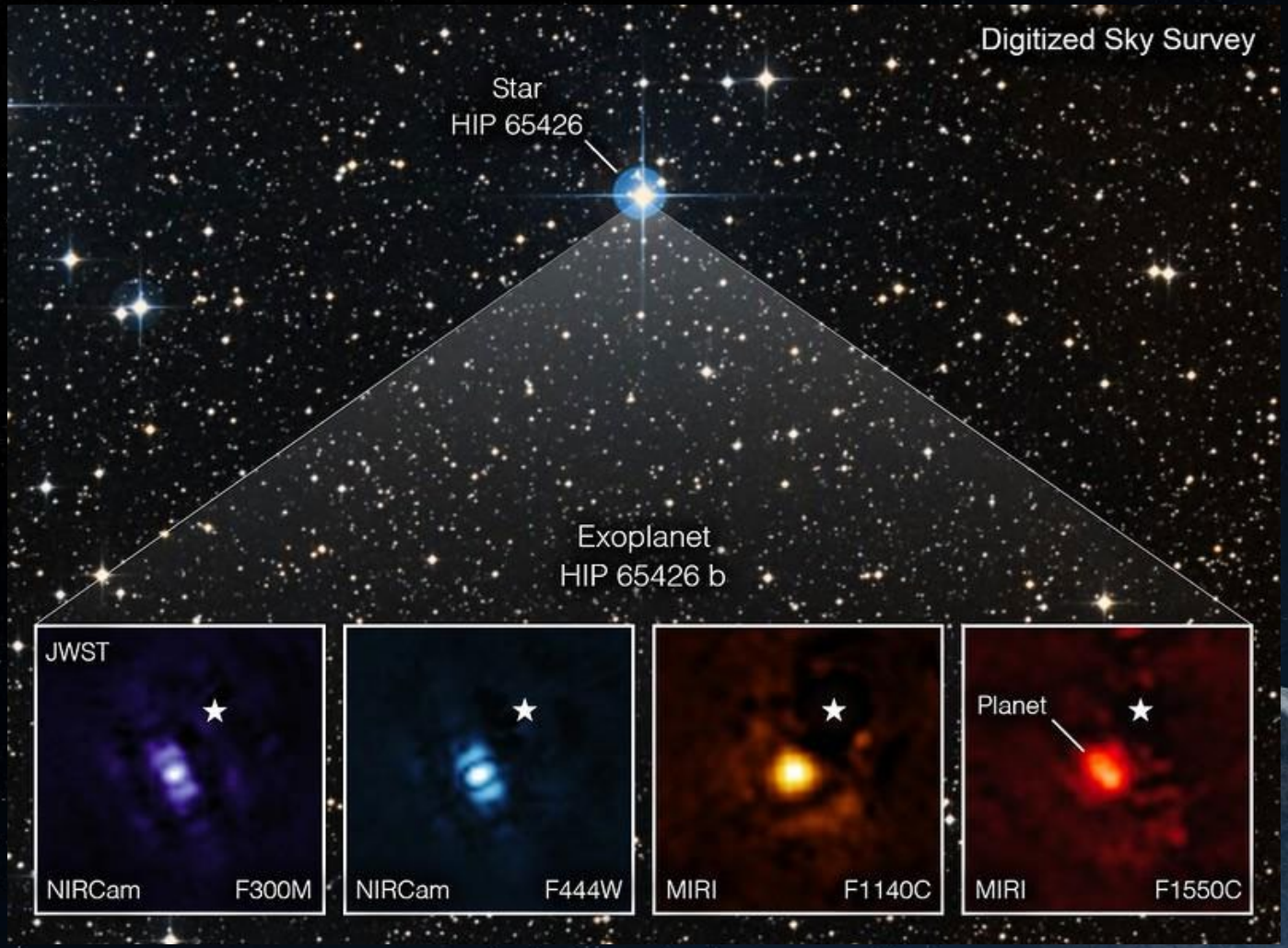
- Near Infrared Camera
  - Primary Webb viewer (transparent dust)
- Near infrared Spectrograph
  - Allows for simultaneous observation of 100 objects
- Mid Infrared Instrument
  - Redshift of distant objects
  - Camera enables wide-field broadband imaging (like Hubble)
- Fine Guidance Sensors/Near infrared imager and slitless spectrograph
  - Precision targeting with different range (0.8)



Carina Nebula

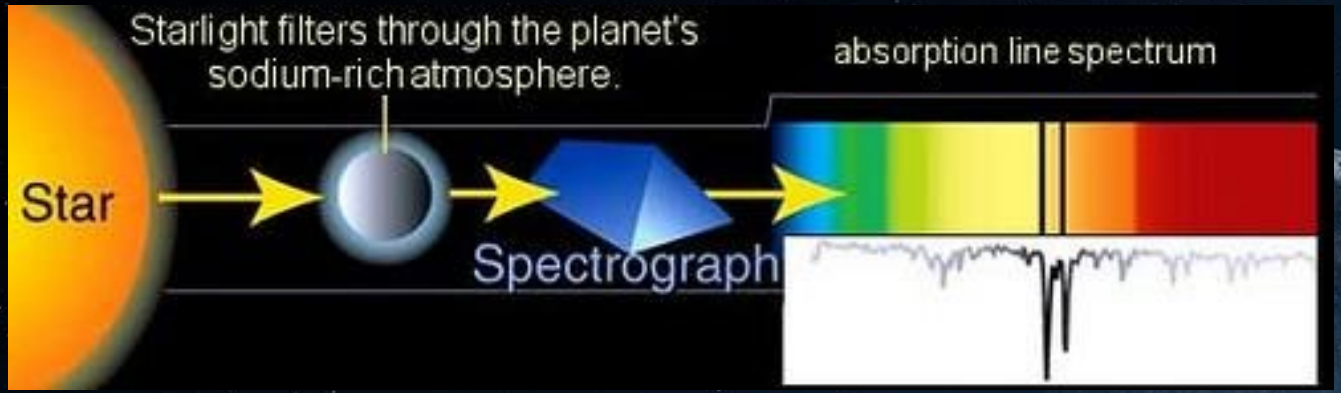


Stephan's Quintet


Digitized Sky Survey
Star
HIP 65426
Exoplanet
HIP 65426 b
JWST
NIRCam F300M
NIRCam F444W
MIRI F1140C
Planet
MIRI F1550C

Exoplanets

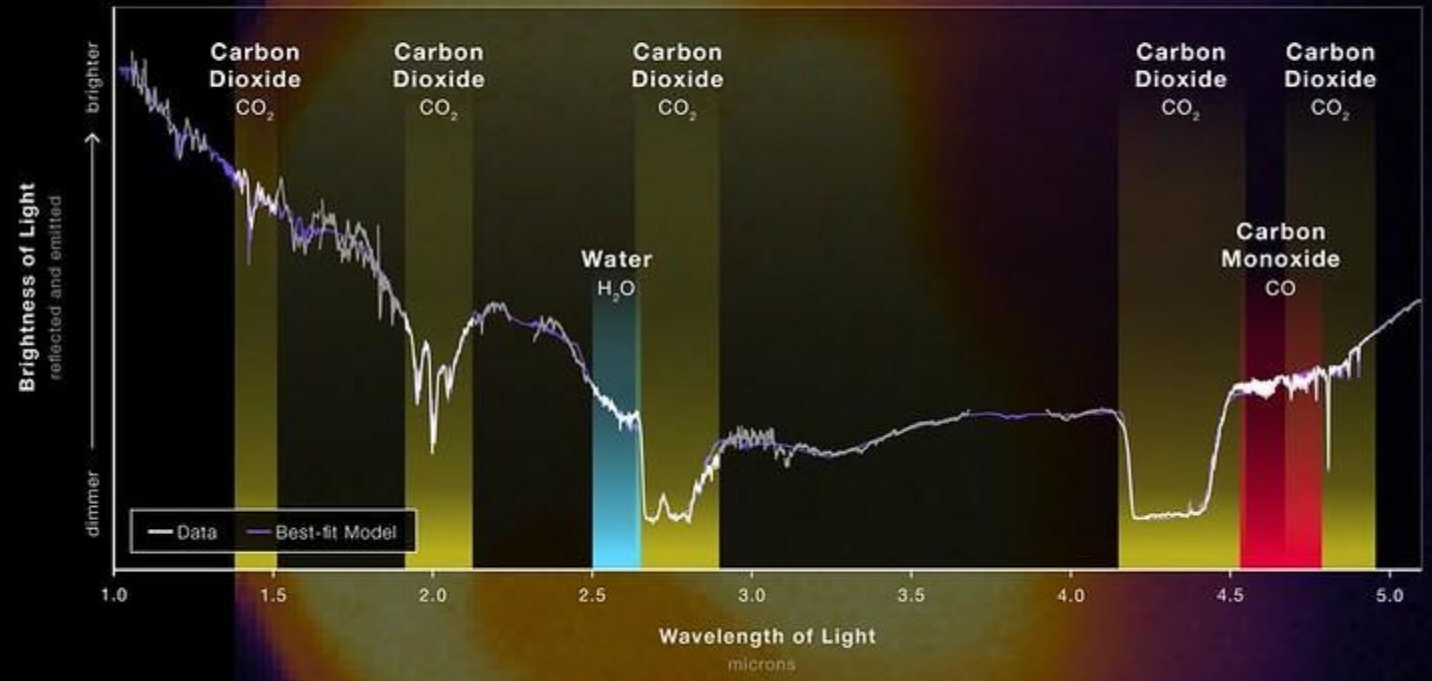
- Transit method
  - Viewing a planet while it passes between its star and Webb
  - Dimming of the starlight
  - Clear image of atmosphere for spectroscopy
- Radial velocity technique
  - Collaboration with ground based telescopes to detect ‘stellar wobble’ caused by exoplanet
  - Allows for an accurate estimate of planetary mass



MARS

ATMOSPHERE COMPOSITION

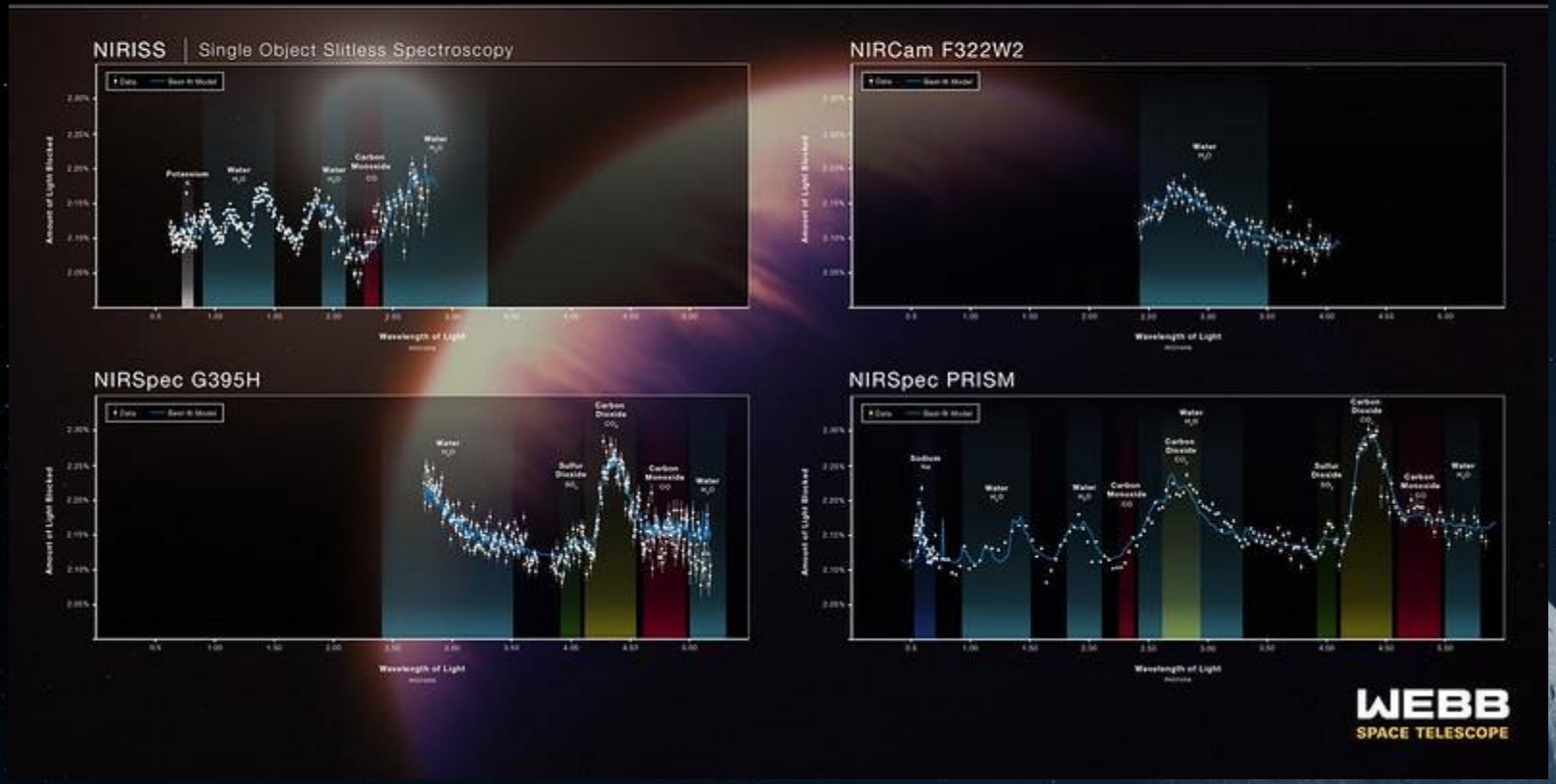
NIRSpec | Fixed Slit Spectroscopy



WEBB
SPACE TELESCOPE

HOT GAS GIANT EXOPLANET WASP-39 b

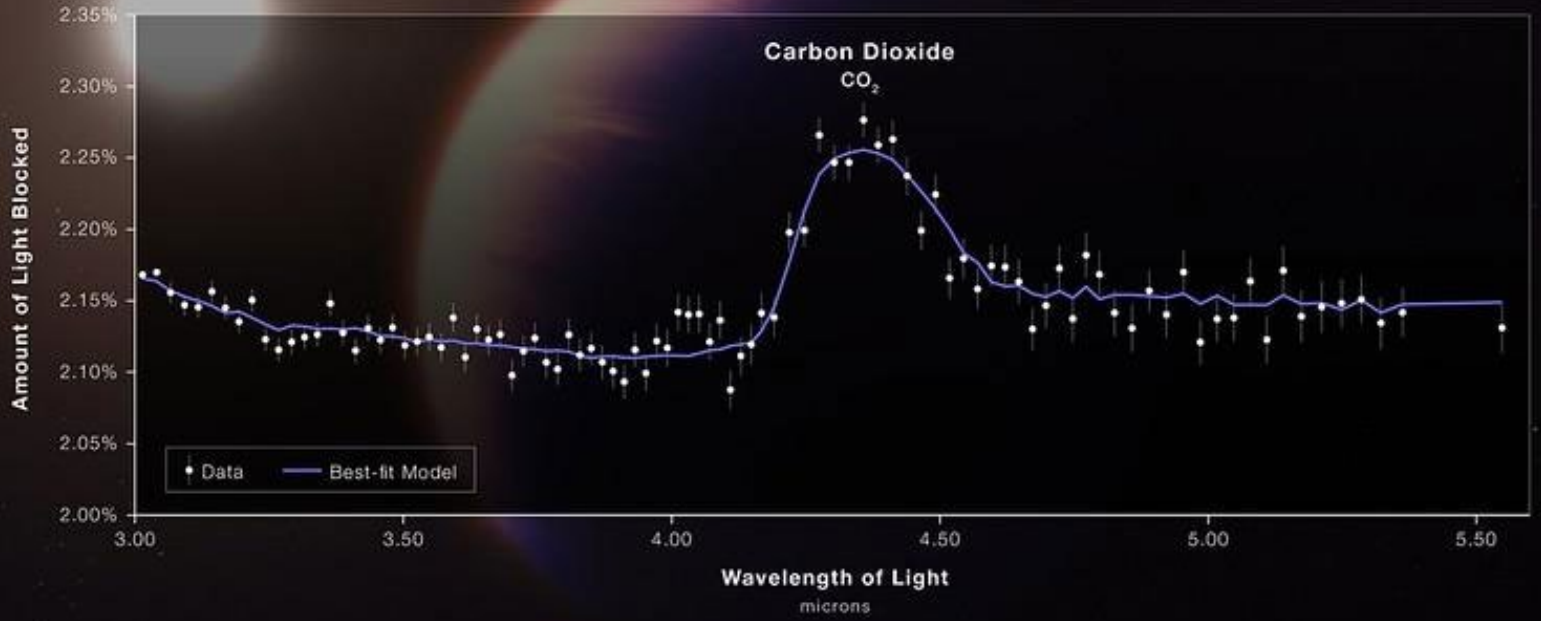
ATMOSPHERE COMPOSITION



HOT GAS GIANT EXOPLANET WASP-39 b

ATMOSPHERE COMPOSITION

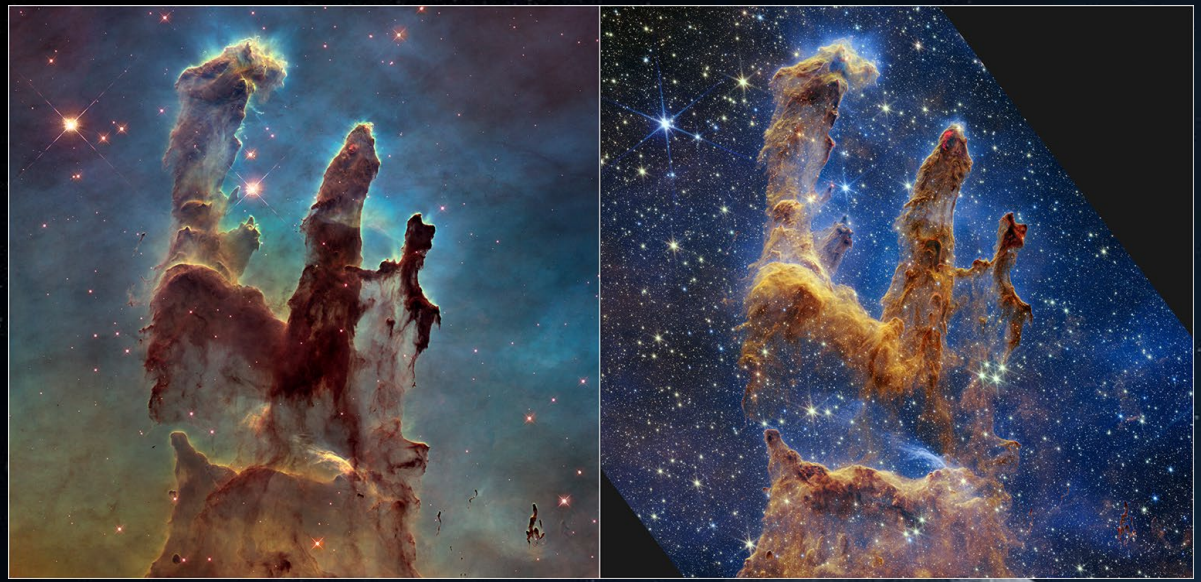
NIRSpec | Bright Object Time-Series Spectroscopy



WEBB
SPACE TELESCOPE

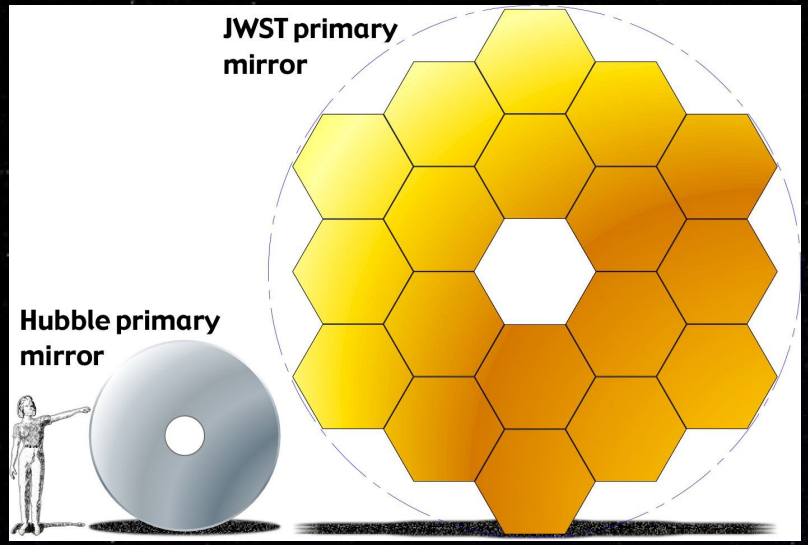
Webb vs Hubble

- Science goals of Webb motivated by results of Hubble
- Distant objects are more highly redshifted and their light is pushed from the UV and optical into the near infrared
- Webb primarily looks at universe in infrared
- Hubble studies at optical and ultraviolet wavelengths with some infrared capability



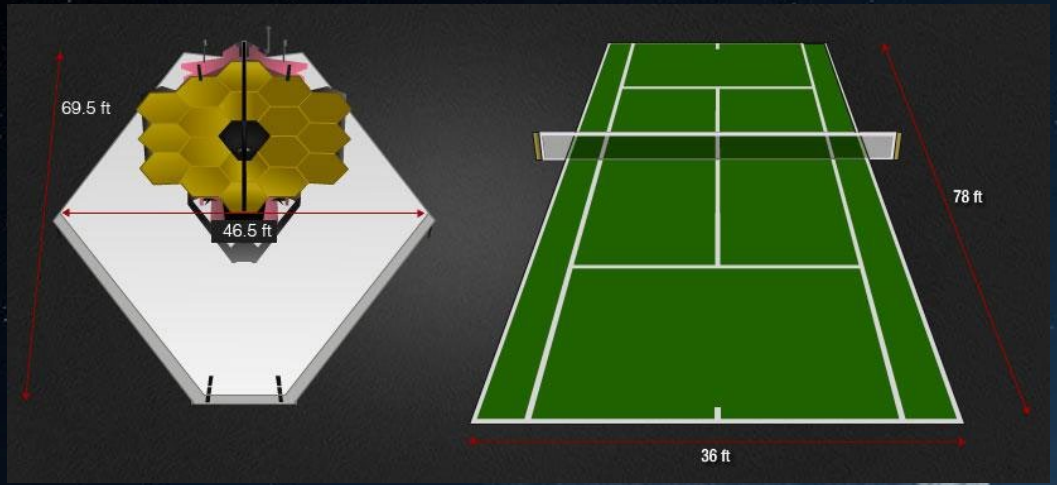

Hubble / Optical
Hubble & Webb
Webb / Infrared

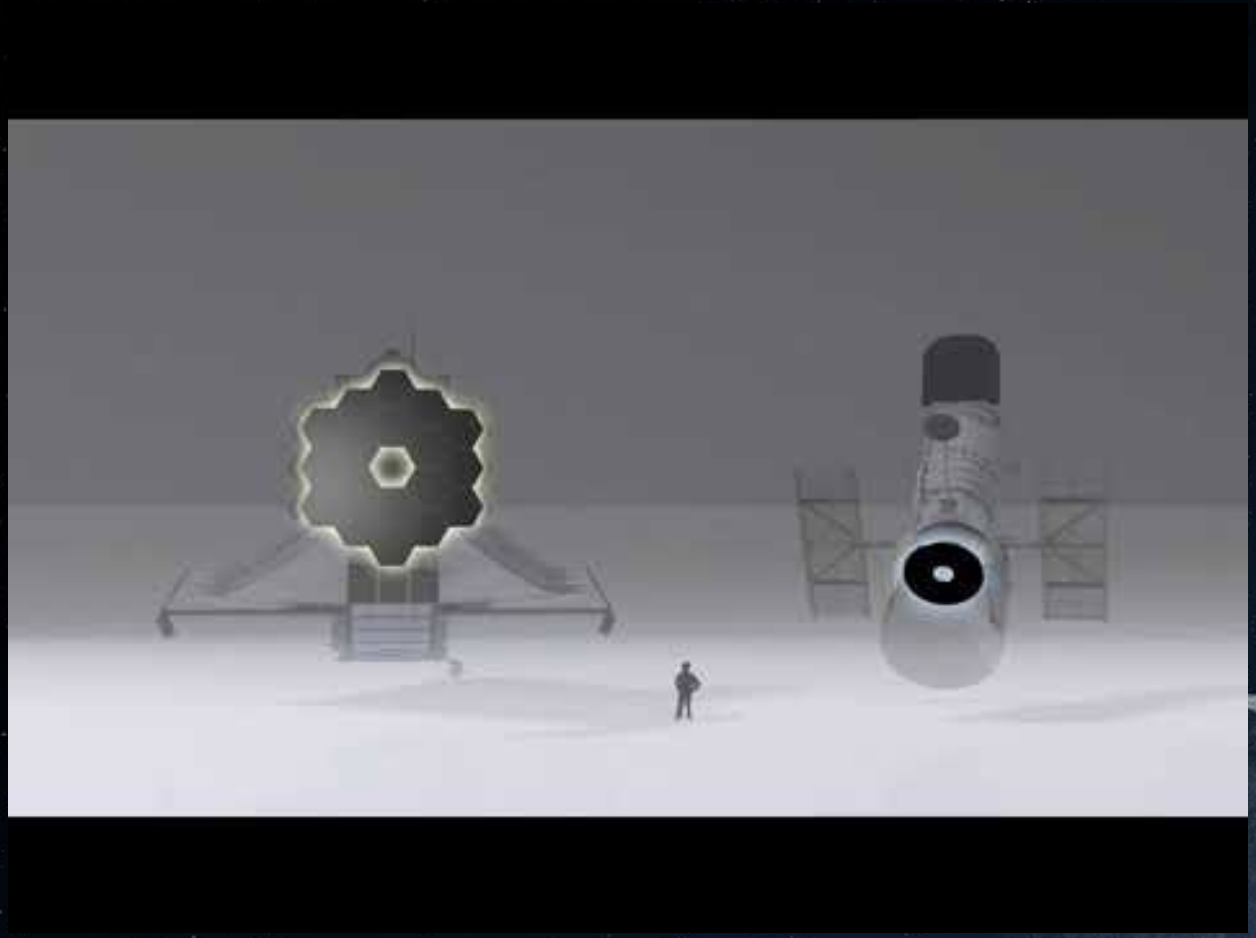
Size Comparison



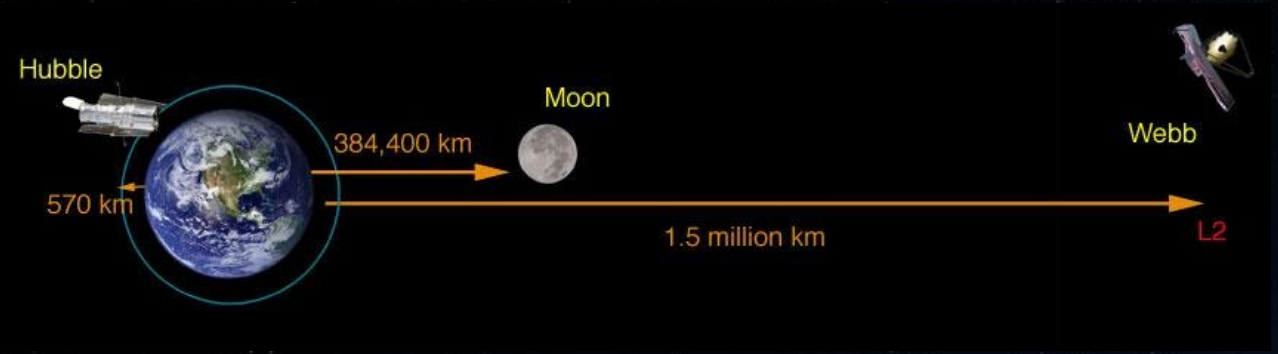
- Webb: approximately 6.5 meter diameter primary mirror
- Hubble: 2.4 meter with corresponding collecting area of 4.5 m^2
- Webb has 6.25 times more collecting area

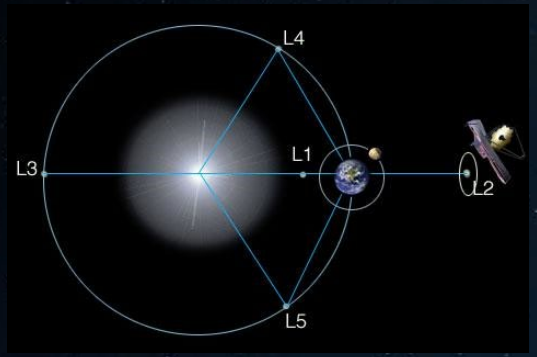
- Sunshield 69.5 ft x 46.5ft





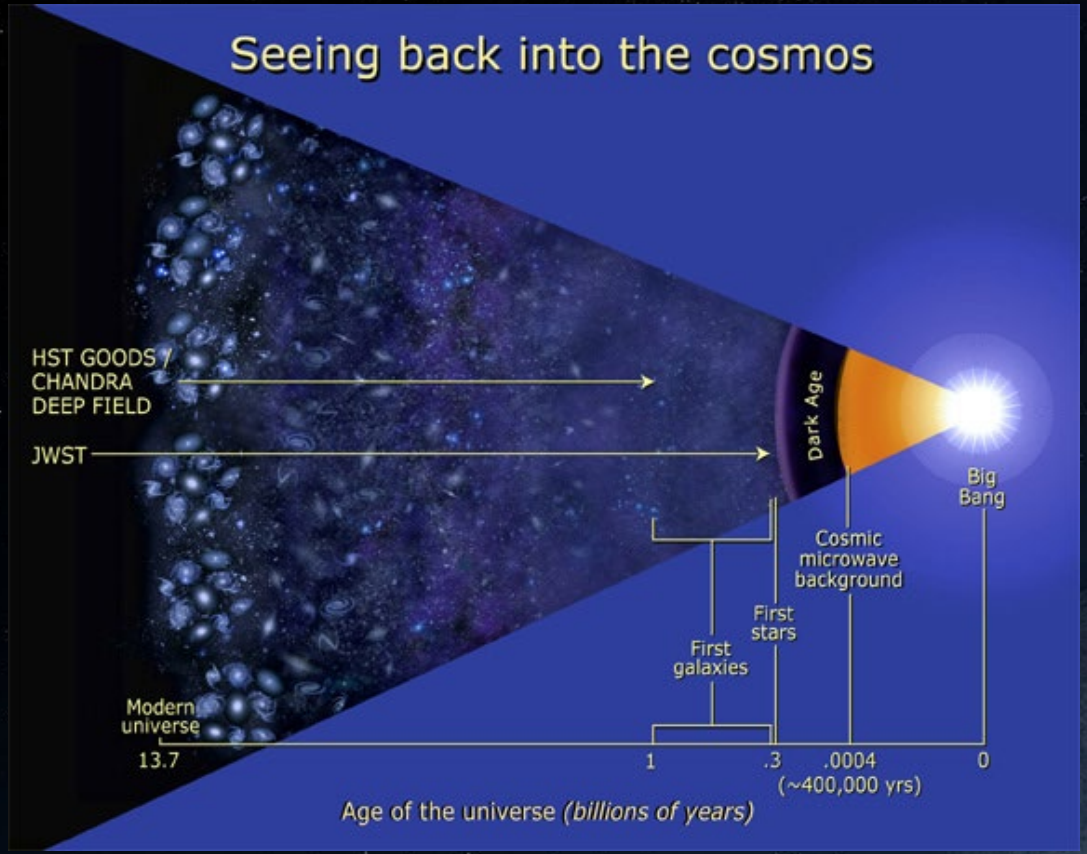
Orbit





- Orbits Sun 1.5 million miles away at Second Lagrange point
- Easy to talk to
- Not designed to be serviced
- Solar shield will block light from Sun, Earth, and Moon

How Far Will Webb See?



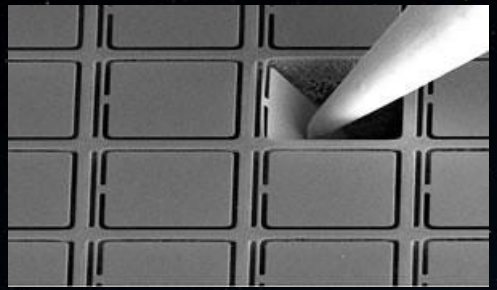
Webb Innovations

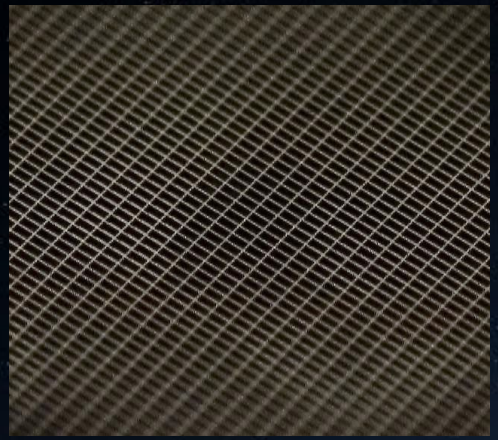
- Microshutters
- Backplane
- Sunshield Coating
- Lightweight Cryogenic Mirrors
- Wavefront Sensing and Control
- Infrared Detectors
- Cryogenic Data Acquisition Integrated Circuit
- Cryocooler

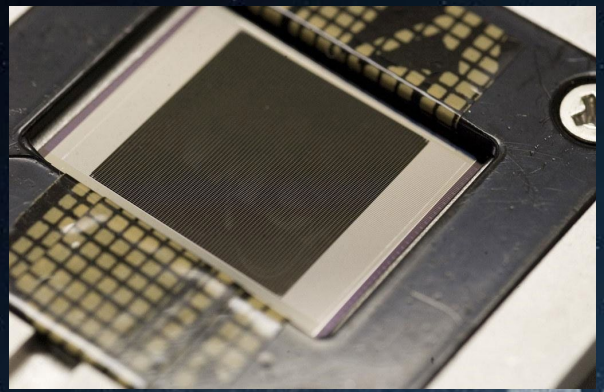
MLM Dwarf Galaxy

Microshutters

- Tiny windows with shutters
  - Each measure 100 by 200 microns, a bundle of a few human hairs
- Each quadrant has more than 62,000 individual windows,
  - Size of a postage stamp

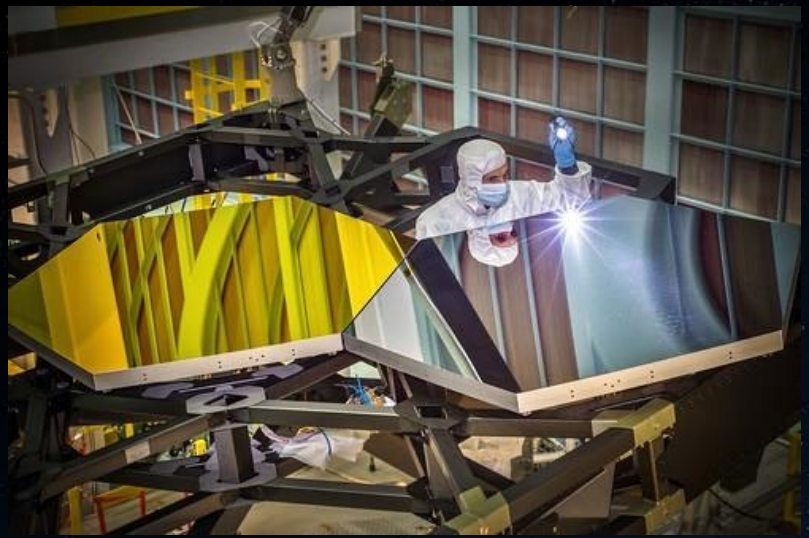


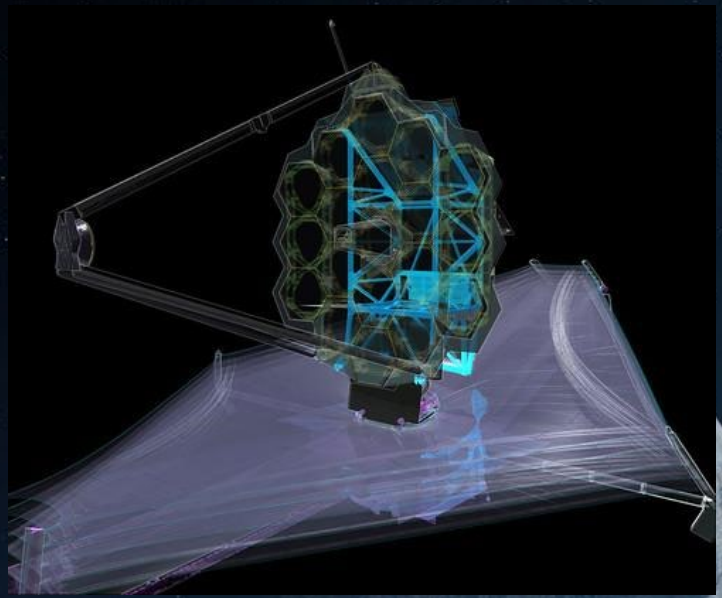




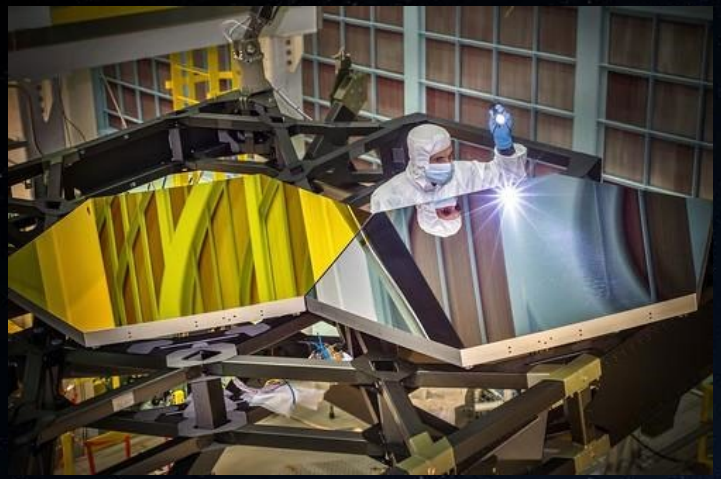
The Backplane

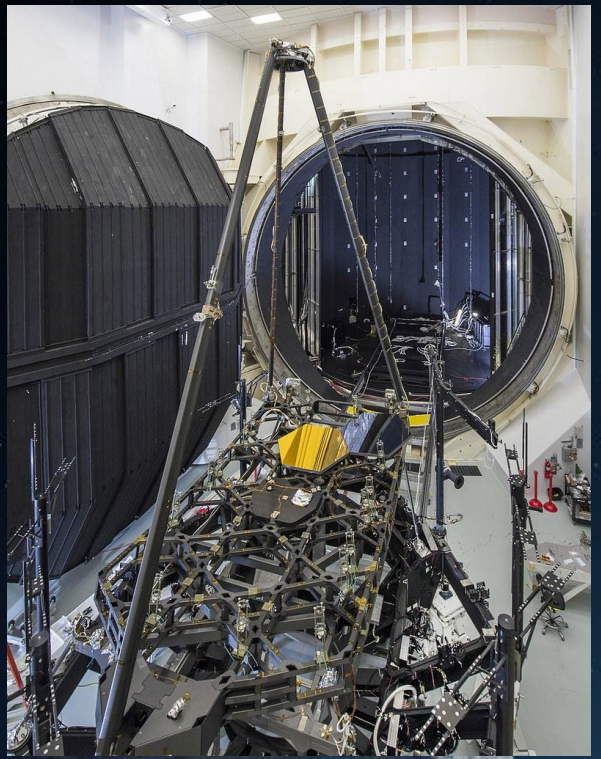
- The large structure that holds and supports many critical components
- Carries:
  - 6.5 meter primary mirror, other telescope optics, the entire module of scientific instruments
  - More than 2.5 tons of hardware






1-TON





Sunshield Coating

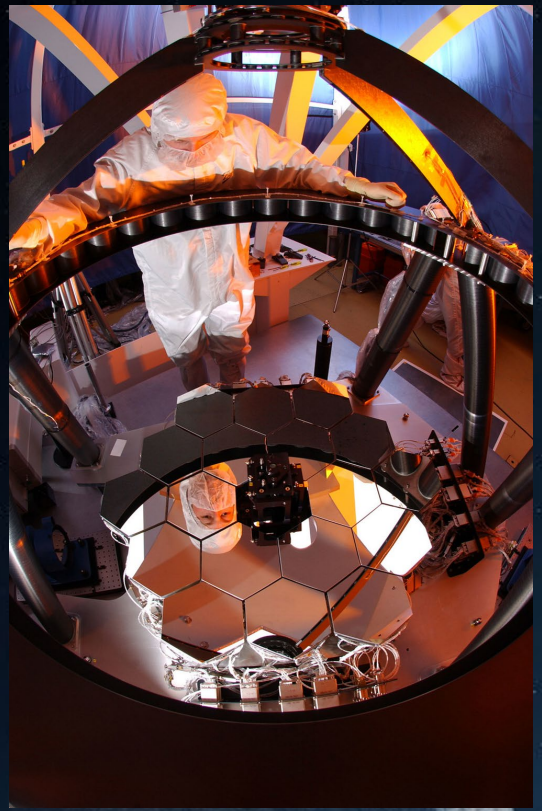
- Each layer as fine as a human hair
  - Made of Kapton: tough, high performance plastic coated with reflective aluminum and silicon
- 5 thin layers
  - Remain stable from temperatures ranging -452 to +752 degrees Fahrenheit
- Telescope must be kept extremely cold
  - Protected from sources of light & heat
  - Ensure telescope elements don't emit their own heat

Lightweight Cryogenic Mirrors

- JWST observations are to be made in the infrared wavelength
- Warm objects produce an infrared light
  - Operating temperature of -220 degrees C eliminates interference
- 18 separate for compatibility (folding maneuver)
- Ultra lightweight beryllium segments
  - Sustain extremely low temperatures in space
  - Maintains shape of each mirror barring extreme impact

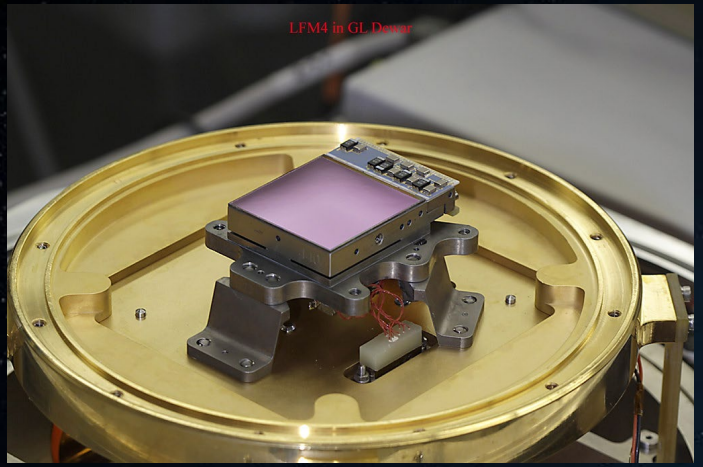
Wavefront Sensing and Control

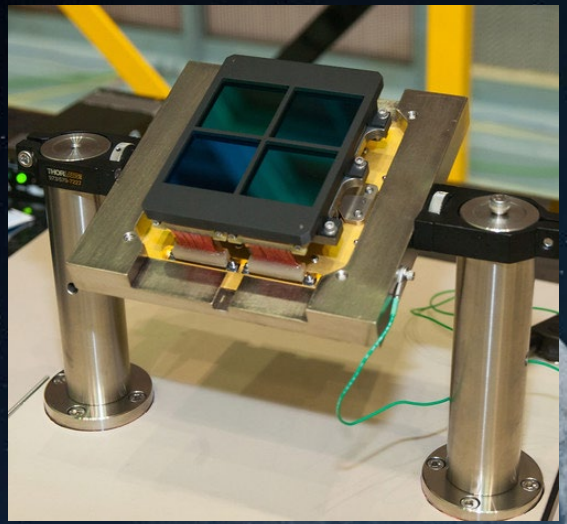
- Subsystem required to detect and correct errors in the telescopes optic system
- Critical feature to ensure 18 mirror components work together as one
- Ball Aerospace constructed and tested a scaled down model for proof of concept
- Motivated spinoff technology to improve diagnosis of eye conditions and the Lasik procedure



Infrared Detectors

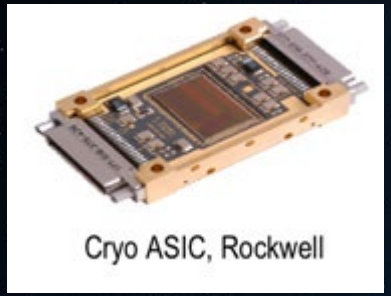
- JWST requires a large array of detectors to efficiently survey the sky
- Photons absorbed and translated into electronic signal
- Two types: ‘near-infrared’ & ‘mid-infrared’
  - Allows for variance and optimization among on-board detectors
- Resulted improvements from JWST research:
  - Lower noise, larger format, and longer lasting

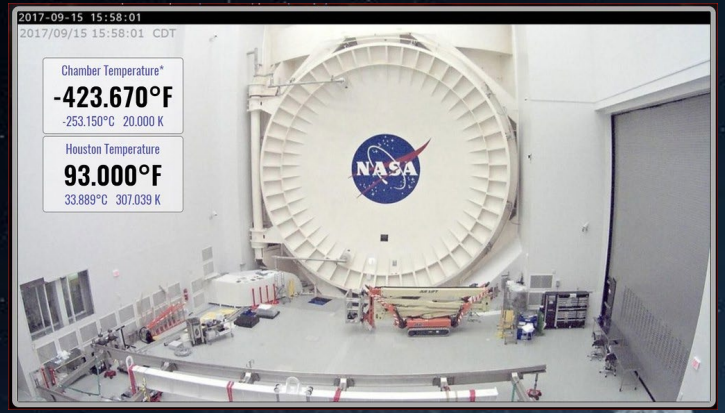




Cryogenic Data Acquisition Integrated Circuit

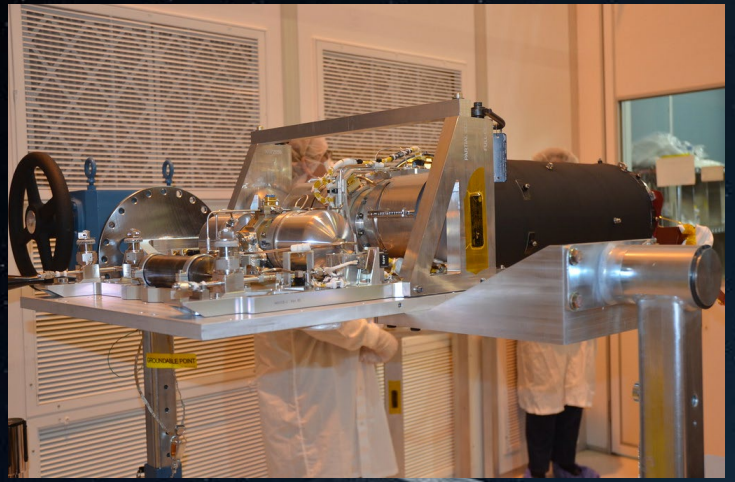
- Integrated circuit tasked with dampening noise produced by detectors and transmit the signal back to Earth
  - Translates signal from analog to digital
- Operating application specific integrated circuit (ASID) at cryogenic temperatures
- SIDECAR developed specifically for JWST
  - System Image, Digitizing, Enhancing, Controlling and Retrieving ASIC


Cryo ASIC, Rockwell

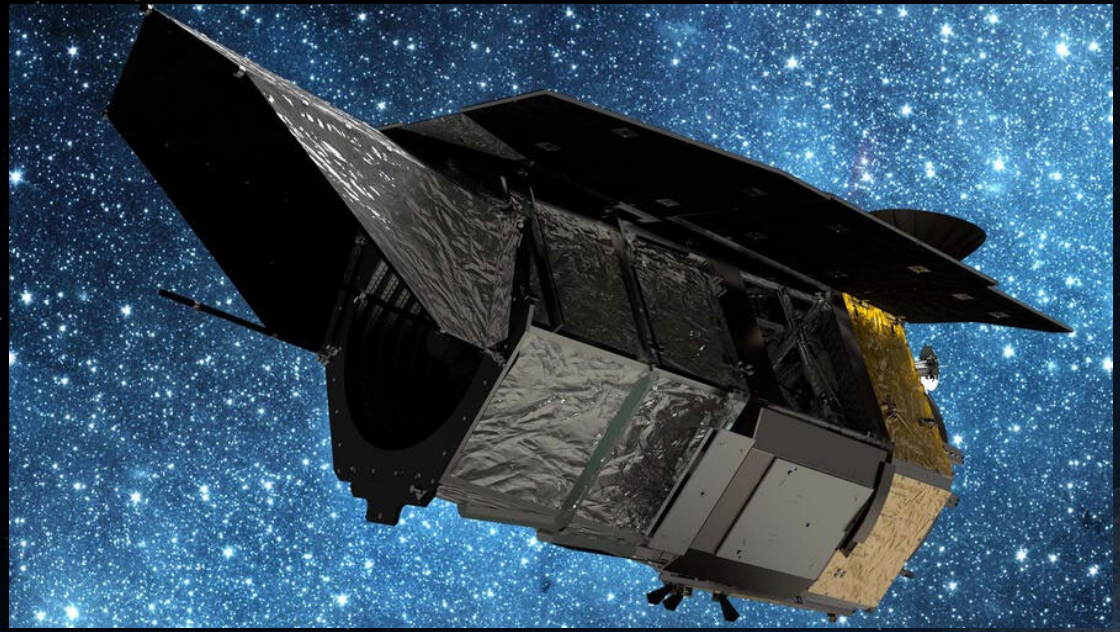


Cryocooler

- MIRI instrument requires a lower operating temperature
- Most of JWST’s subsystems are passively cooled by the sunshield
- MIRI has an active cooling system to ensure no heat builds up to alter observations made by JWST
- Operates 6.7 degrees above absolute zero
- Does not consume coolant
    - Lifetime is determined by wear of mechanical parts not fuel

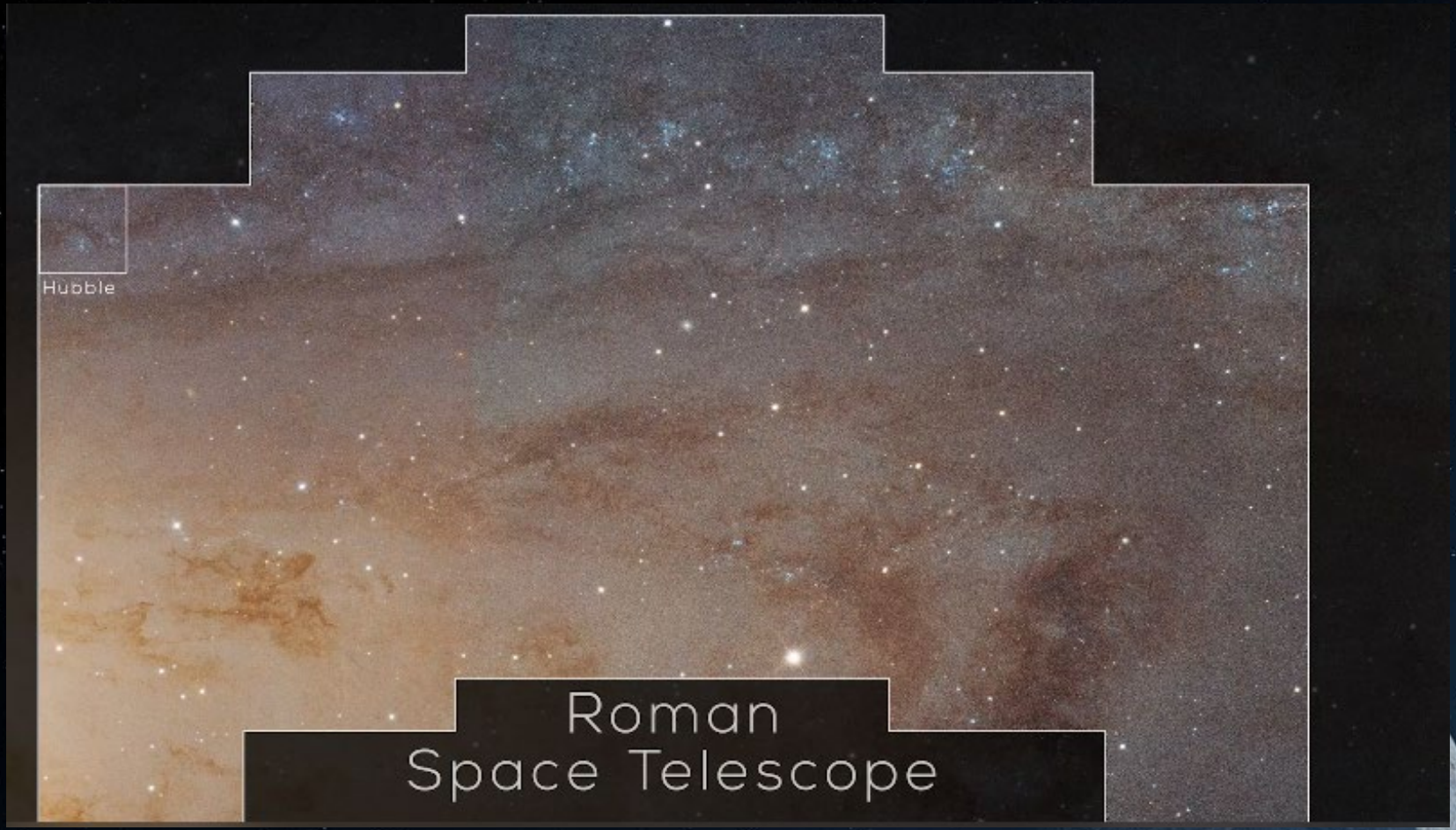


Nancy Grace Roman Space Telescope



Why is Roman Important?

- Reworked the optics so that it has a much larger field of view
  - Able to survey much faster and of higher quality than Hubble
- Complementary to Webb with wavelengths
  - Can make similar observations as Webb
- Unique location with a new perspective of the universe
- We have learned a lot about from previous space telescopes and how valuable they are
  - Roman will continue to explore but also study space telescope technology
- Further expand our observational arsenal


Hubble
Roman
Space Telescope

Who is Nancy Grace Roman?

- Known as the mother of the Hubble Space Telescope
- Born May 16, 1925, died December 25, 2018
- Became head of microwave spectroscopy at Naval Research Laboratory in 1955
- Joined NASA' Space Based Astronomy Team in 1959
- First female executive at NASA
- First Chief of Astronomy at NASA
- Biggest challenge of career was getting Hubble approved by Congress

Mission Overview: Nancy Grace Roman Telescope

- Focus on dark energy, exoplanets, and infrared astrophysics
- Primary mirror of 7.9 ft (same size as Hubble's but ¼ weight)
- 2 instruments: Wide Field Instrument & Coronagraph Instrument
- Field of view 100 times greater than Hubble
- Located at L2 point
- Will measure light from over a billion galaxies
- Perform high contrast imaging and spectroscopy
- Mission lifetime: 5 years with a potential 5 year extended mission

Budget

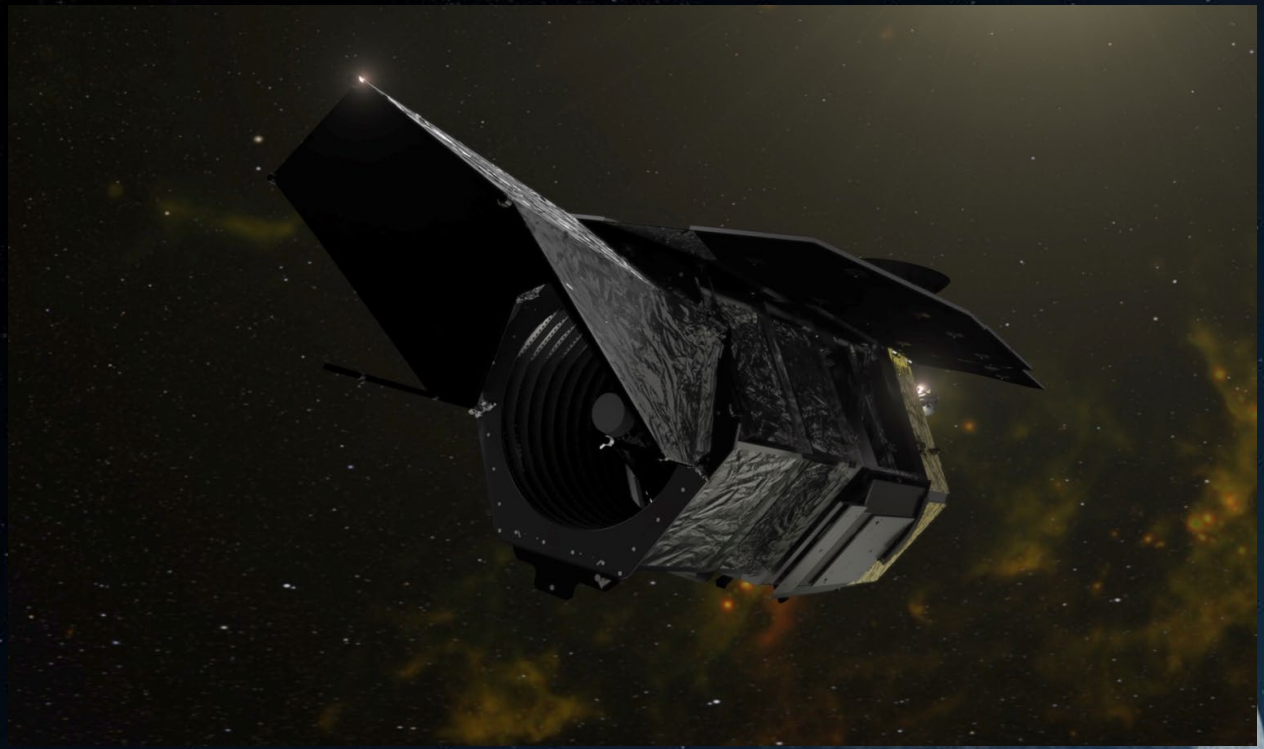
- Initially proposed under 2 billion USD
  - Now 3.2-3.9 billion USD
- Has been proposed to be cancelled several times
  - Artemis delays and expenses
- JWST: More than 10 billion
- Hubble: More than 16 billion
  - Inflation accounted for

Mission Timeline

- 2010 the mission begins
- 2013/14: satellite design initiated & instruments announced
- 2015 mission proposals initiated
- 2016 coronagraph program was held
- 2018 Ball Aerospace is awarded the contract from NASA
- 2020 officially renamed to the Nancy Grace Roman Telescope
- 2021 mirror complete and flight readiness review passed
- Head skyward between October 2026 & May 2027

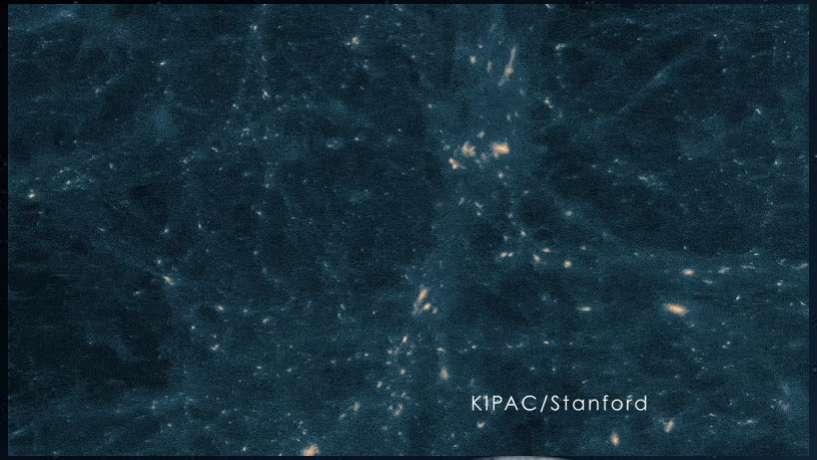
What will Roman Study?

- Dark Energy
- Dark Matter
- Exoplanets
- Large Area Near Infrared Surveys



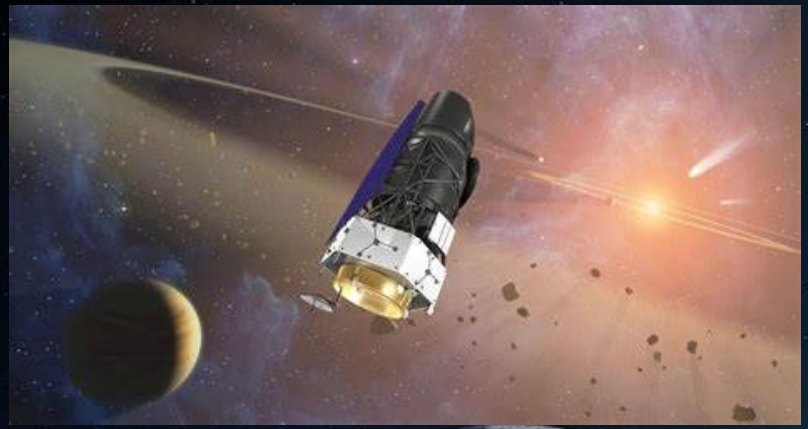
Dark Energy and Matter

- Know very little since observed 80 years ago in Coma cluster
- Roman will survey distribution of galaxies and galaxy clusters
- Use ‘weak’ gravitational lensing
  - Tracks how clumps of dark matter warps distant galaxies
  - Track history of dark matter influence



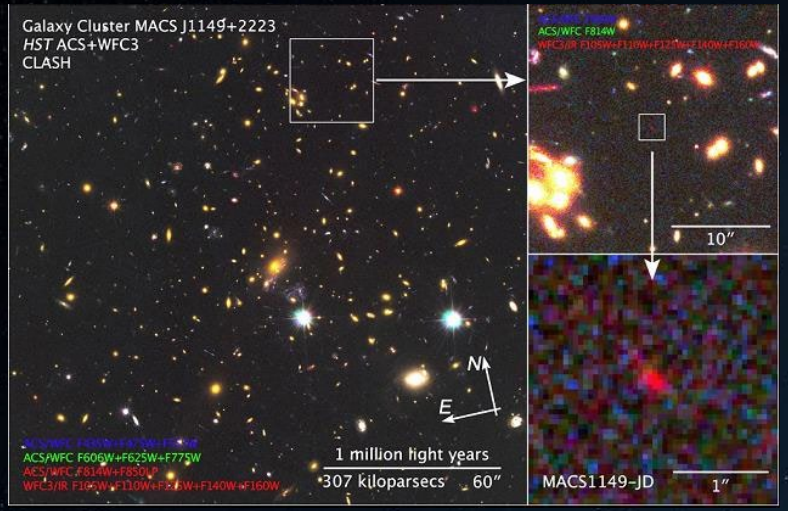
Exoplanets

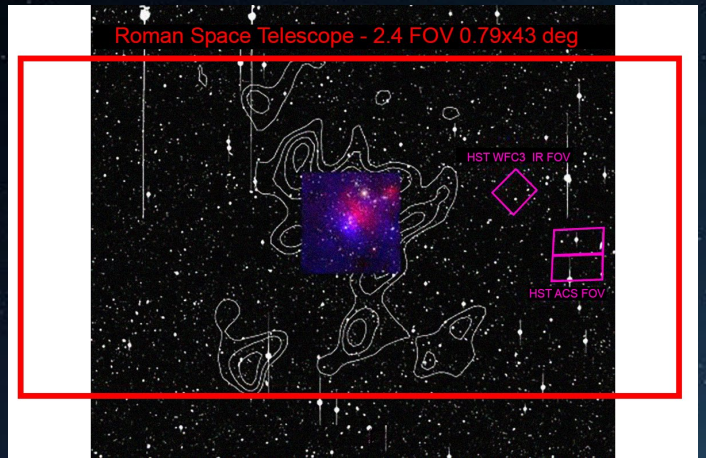
- Roman will study exoplanets very similarly as Hubble and Webb
- Use of coronagraphs to block out sunlight
  - Focused observation on desired exoplanet
- Collaboration with ground based satellites to predict mass of planet
- Roman will take advantage of solar system dust observations
  - Can allow for plotting other planets or comets trajectories
  - Specifically notes regions without dust to indicate previous movement



Large Area Near Infrared Surveys

- Making broad field of view observations will greatly improve the efficiency of stellar surveys
- Roman will be able to make a higher quantity of better quality observations
  - Allow for better mapping of distant galaxies and galaxy clusters
- Could unveil information pertaining to comparisons between galaxy clusters and their formation traits





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