Hubble & James Webb Space Telescopes

Optical Engineering

Prof. Elias N. Glytsis

School of Electrical & Computer Engineering
National Technical University of Athens

Hubble Telescope

General Information

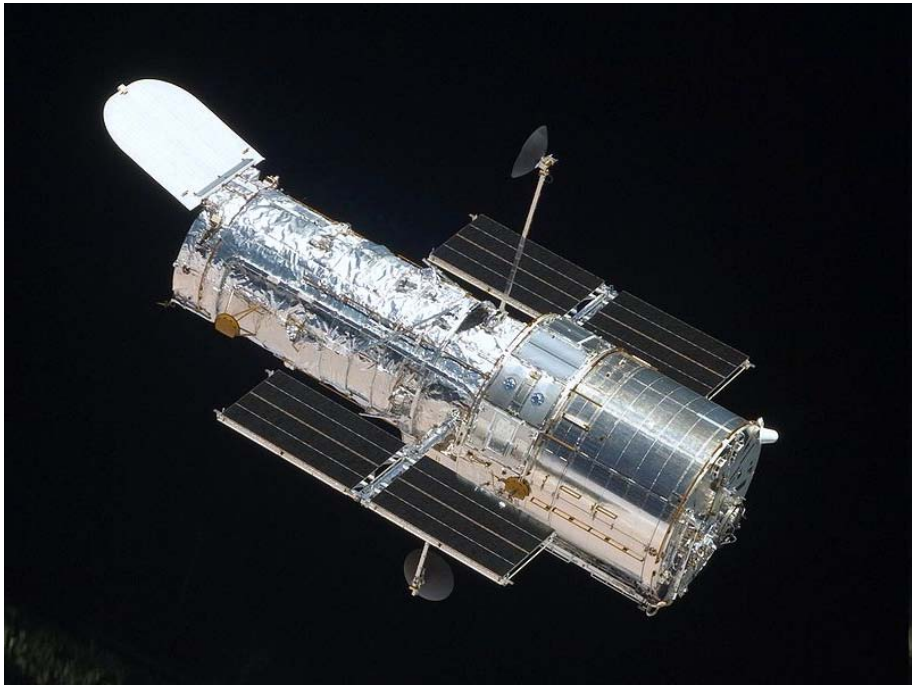
Launch: April 24, 1990, from space shuttle Discovery (STS-31)
Deployment: April 25, 1990
First Image: May 20, 1990: Star Cluster NGC 3532
Servicing Mission 1: December 1993
Servicing Mission 2: February 1997
Servicing Mission 3A: December 1999
Servicing Mission 3B: February 2002
Servicing Mission 4: May 2009

Size

Length: 43.5 ft (13.2 m)
Weight: At Launch: ~24,500 lb (11,110 kg)
Post SM4: ~27,000 lb (~12,247 kg)
Maximum Diameter: 14 ft (4.2 m)

Hubble's Mirrors

Primary Mirror Diameter: 94.5 in (2.4 m)
Primary Mirror Weight: 1,825 lb (828 kg)
Secondary Mirror Diameter: 12 in (0.3 m)
Secondary Mirror Weight: 27.4 lb (12.3 kg)

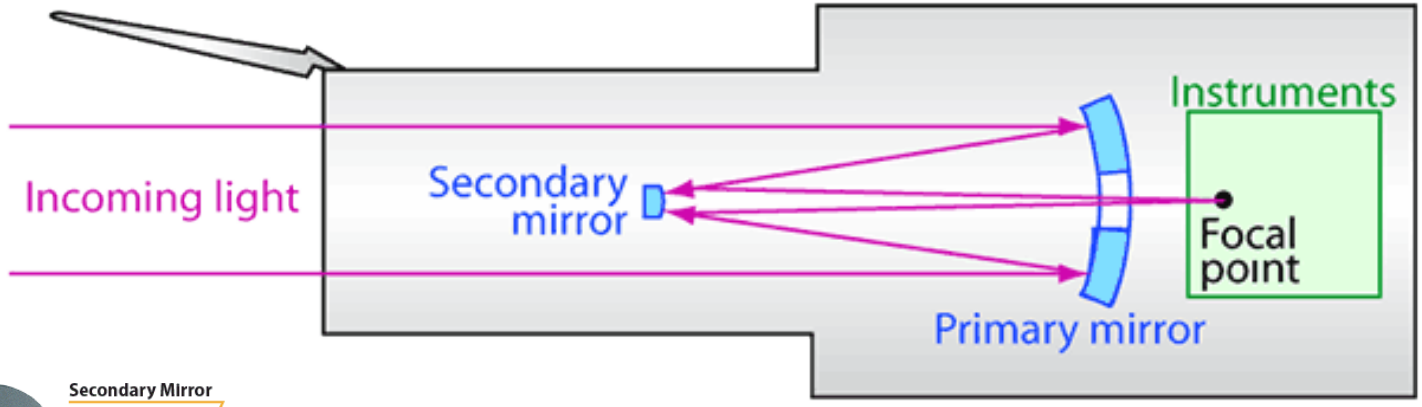


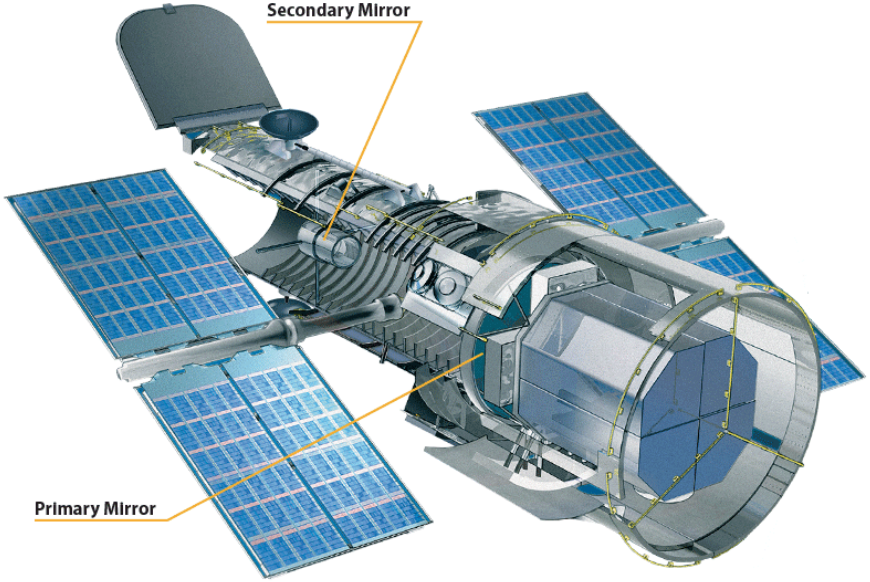
http://en.wikipedia.org/wiki/Hubble_Space_Telescope

http://hubblesite.org/the_telescope/hubble_essentials/

Hubble Telescope

Cassegrain Configuration

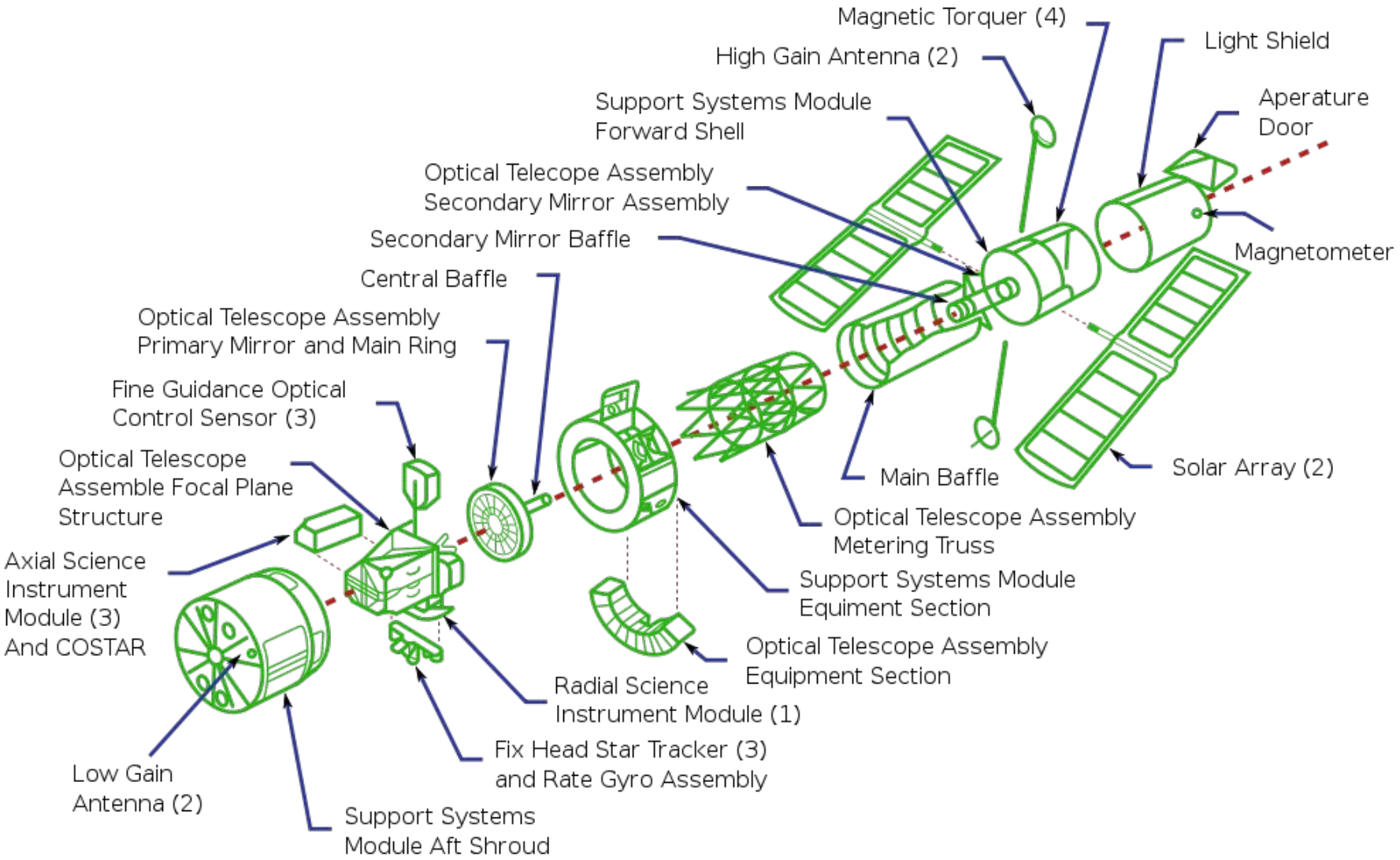




https://www.nasa.gov/content/goddard/hubble-space-telescope-optics-system

http://hubblesite.org/the_telescope/hubble_essentials/image.php?image=light-path

Hubble Telescope Main Parts



http://en.wikipedia.org/wiki/Hubble_Space_Telescope

The Spherical Aberration Problem

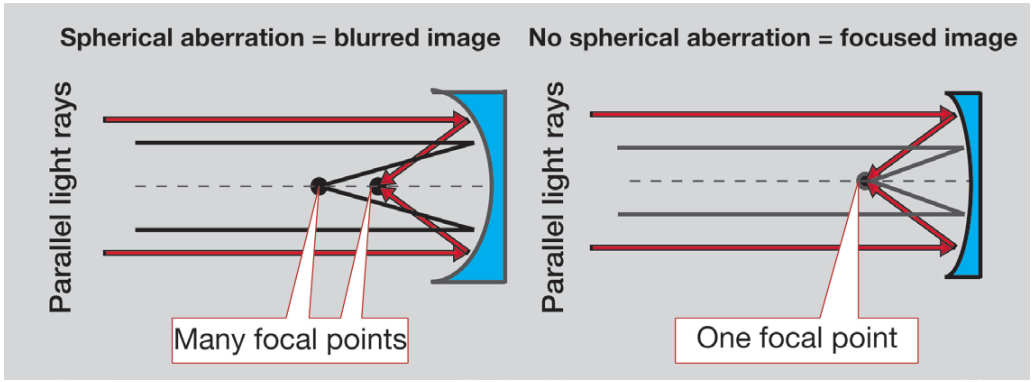
Shortly after the Hubble Space Telescope's launch in 1990, operators discovered that the observatory's primary mirror had an aberration that affected the clarity of the telescope's early images.

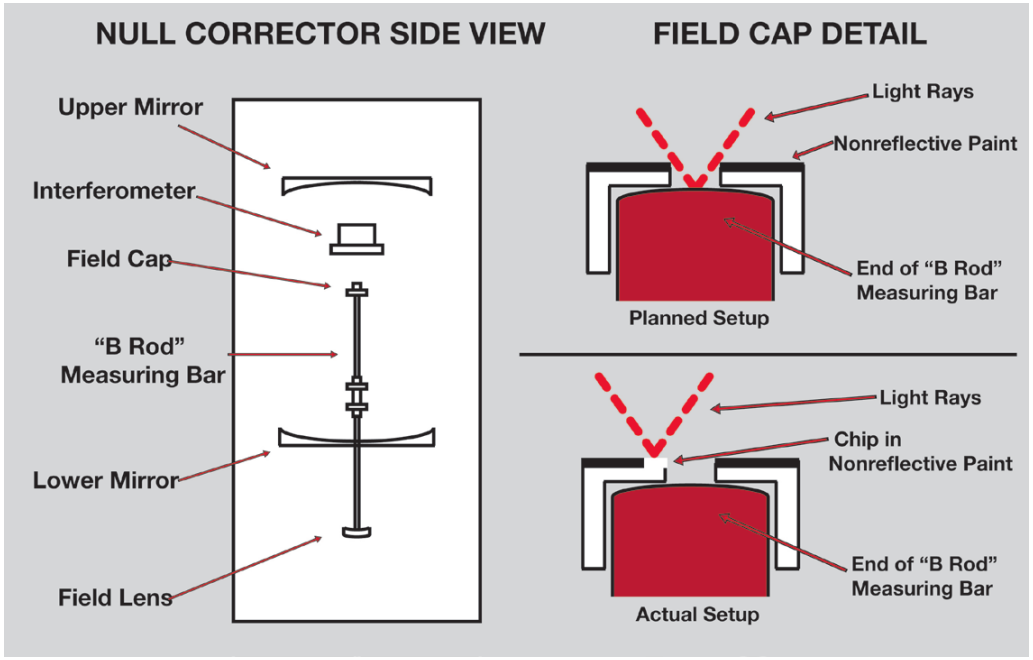
The corrective optics and new instruments were built and installed on Hubble by spacewalking astronauts during a shuttle mission in 1993. The Corrective Optics Space Telescope Axial Replacement (COSTAR) instrument, about the size of a telephone booth, placed into Hubble five pairs of corrective mirrors that countered the effects of the flaw.

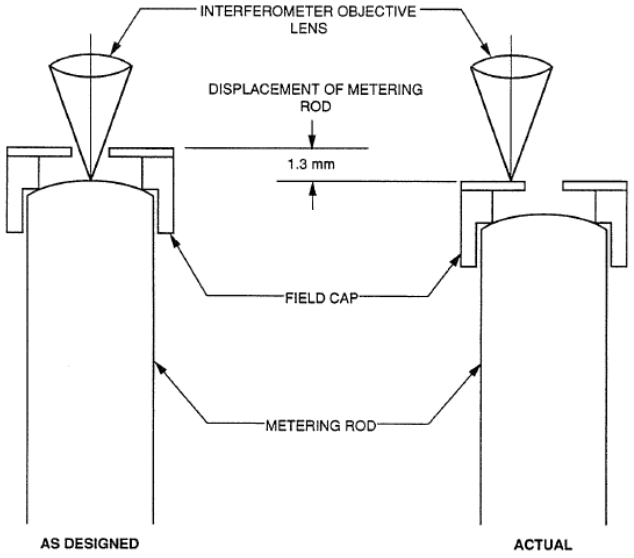
This photograph shows the Hubble Space Telescope's primary mirror being ground at the *Perkin-Elmer Corporation's* large optics fabrication facility in 1979, more than a decade before its very small but very significant flaw was discovered.

https://www.nasa.gov/content/hubbles-mirror-flaw

The Spherical Aberration Problem







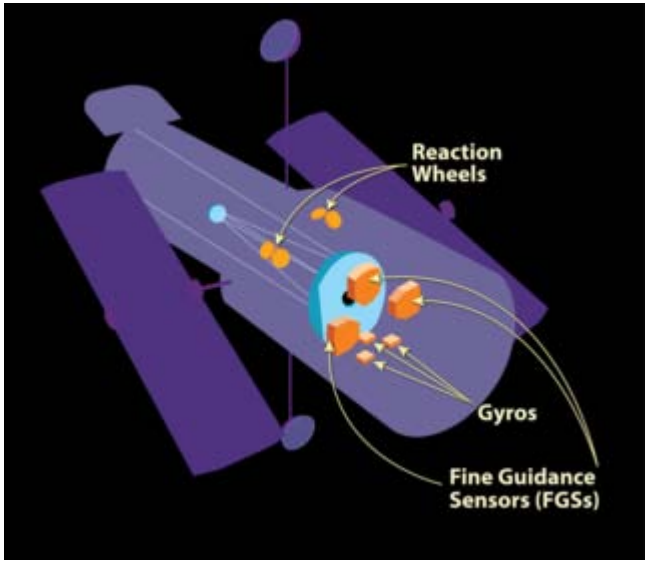
System Failure Case Studies, NASA, vol. 5, issue 7 July 2011

The Spherical Aberration Problem

Galaxy M100 taken with WFPC (Wide Field Planetary Camera)1 (left) and WFPC2 (right) shows the greatly improved image quality after the telescope's spherical aberration was corrected.

http://www.spacetelescope.org/about/history/aberration_problem/

Hubble's Guiding System



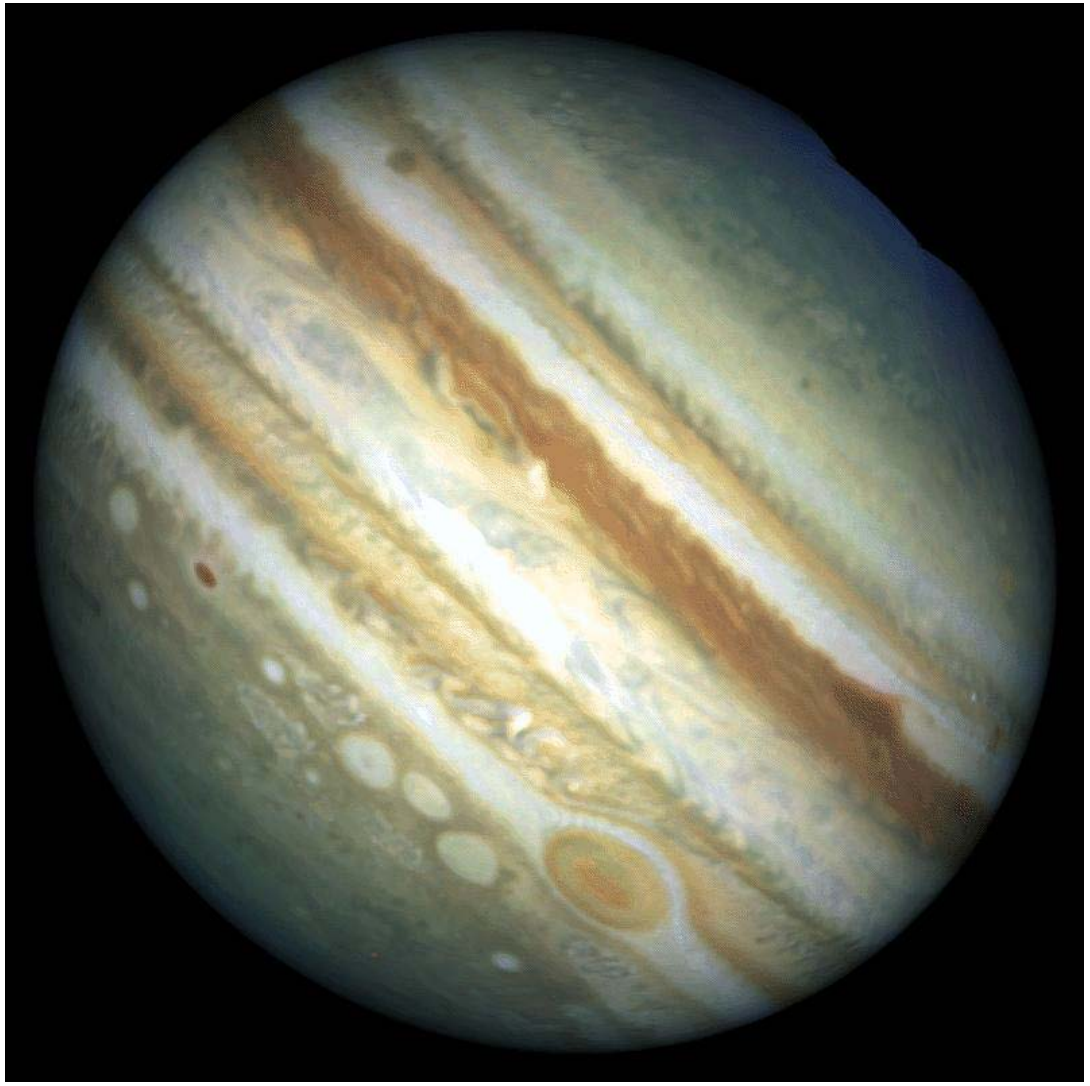
The three Fine Guidance Sensors are part of Hubble's Pointing Control System, which also includes gyroscopes (gyros) and reaction wheels.

Fine Guidance Sensors measure the position of guide stars and thereby detect and correct unwanted drifts of the telescope from its desired pointing.

https://www.nasa.gov/content/hubble-space-telescope-fine-guidance-sensors

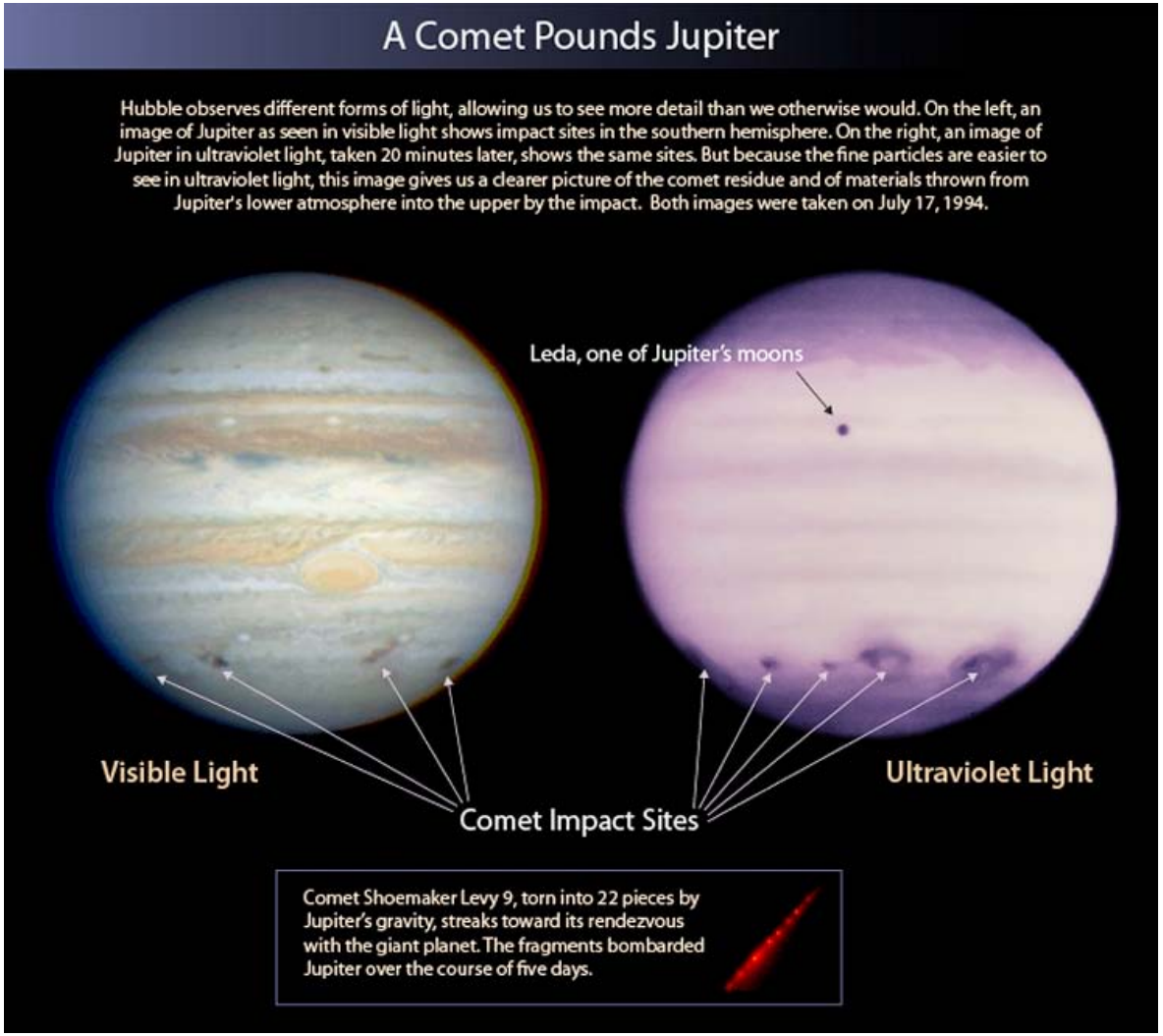
Hubble Telescope Sample Images

Jupiter



Hubble Telescope Sample Images

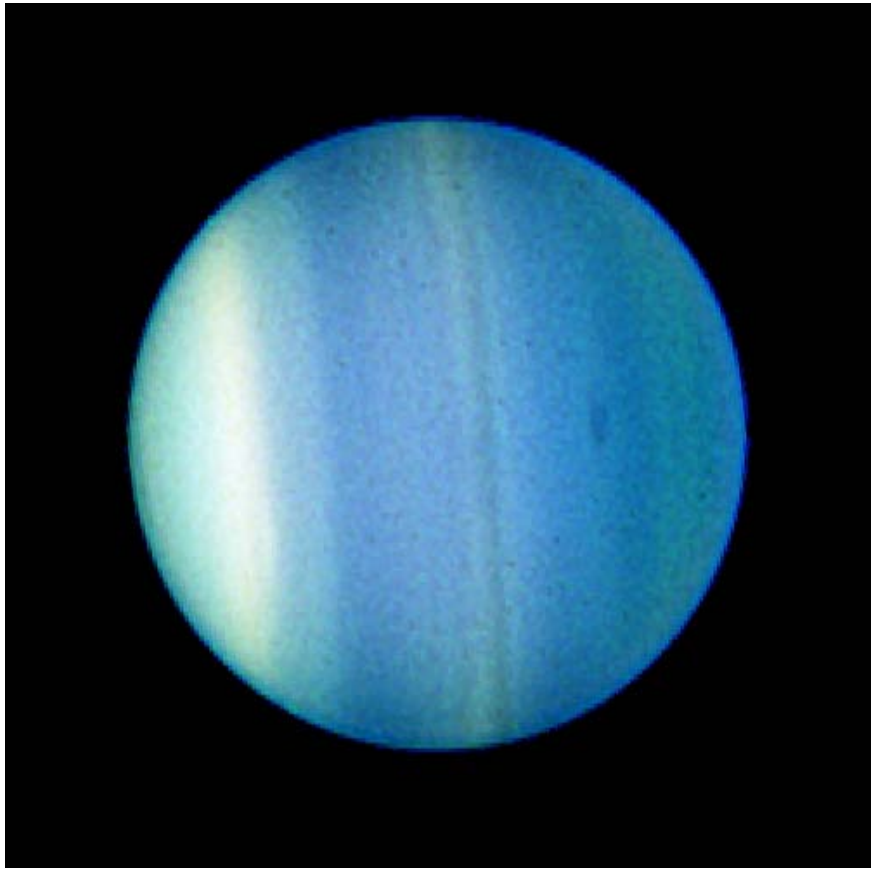
Jupiter



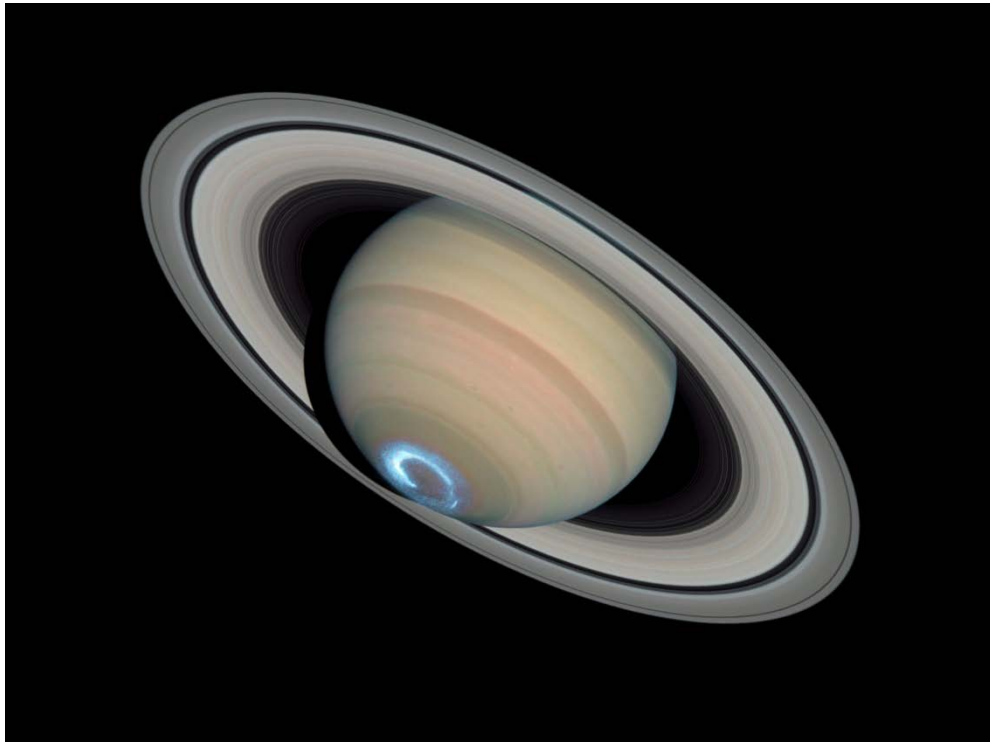
http://hubblesite.org/hubble_discoveries/breakthroughs/planetary

Hubble Telescope Sample Images

Uranus



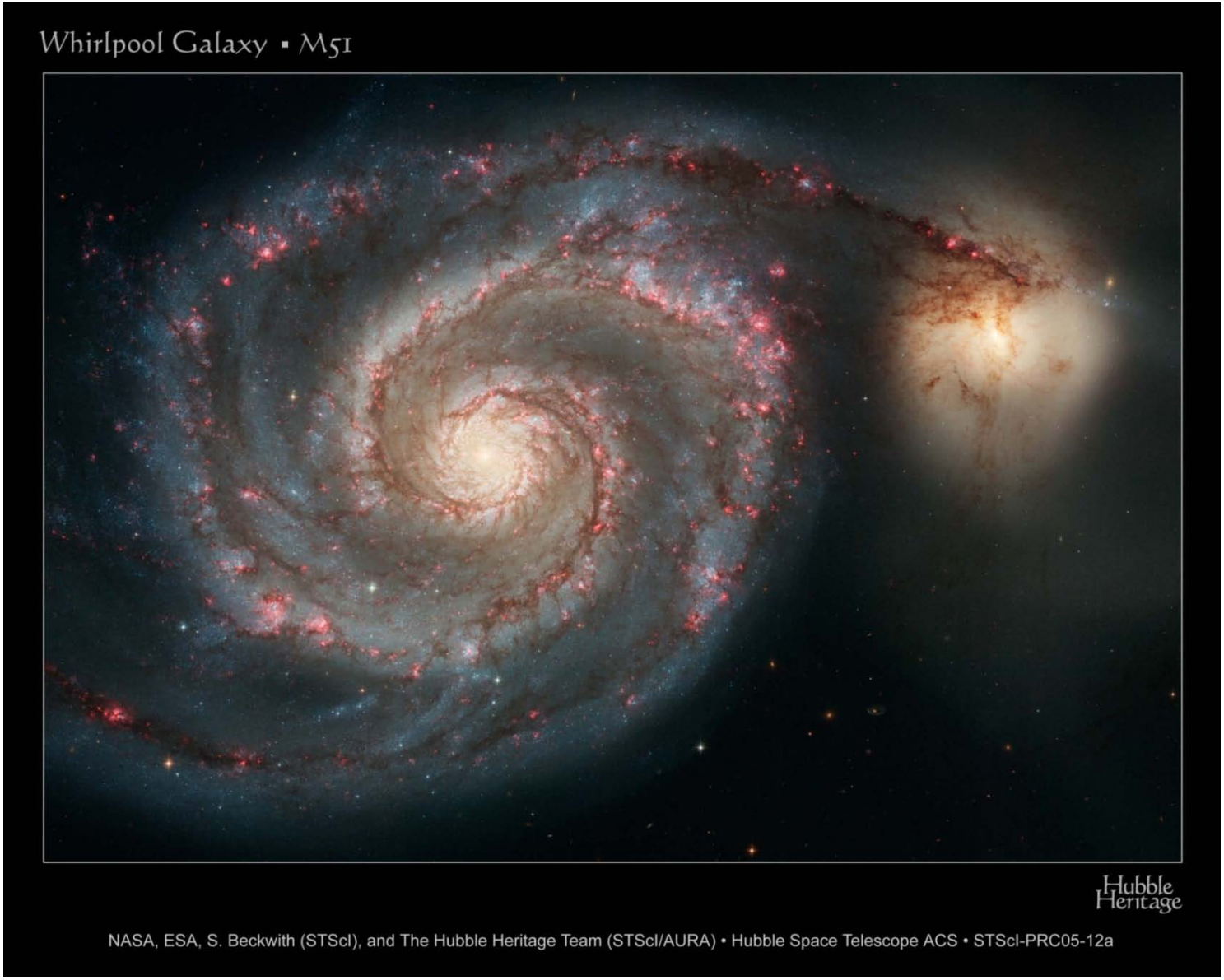
Saturn



Hubble Telescope Sample Images

Spiral Galaxy NGC 3370, Home to Supernova Seen in 1994

Hubble Telescope Sample Images



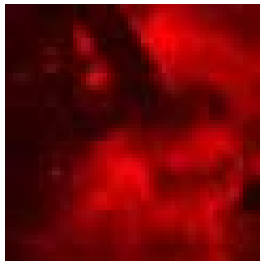
Hubble Telescope Sample Images

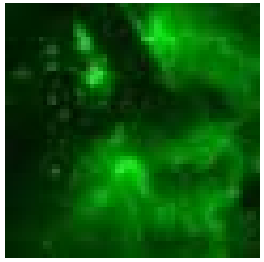
Hubble Telescope Sample Images

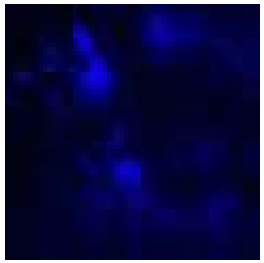
Supernova 1994D in Galaxy NGC 4526

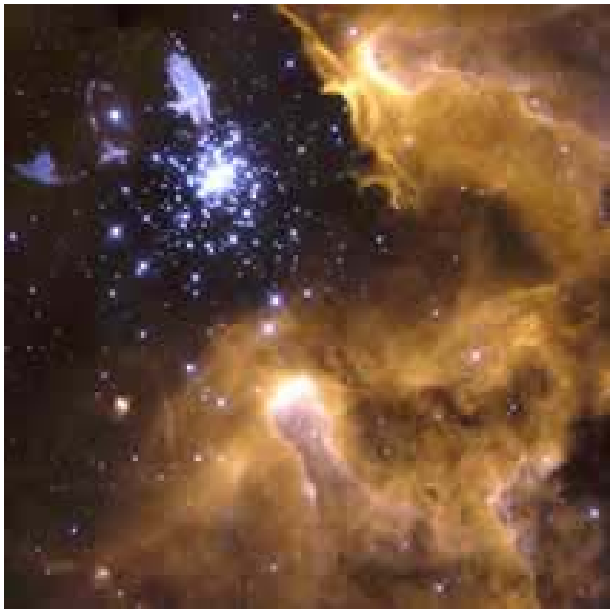
Hubble Telescope Image Formation Details

A typical Hubble image is made from a combination of black-and-white images representing different colors of light.









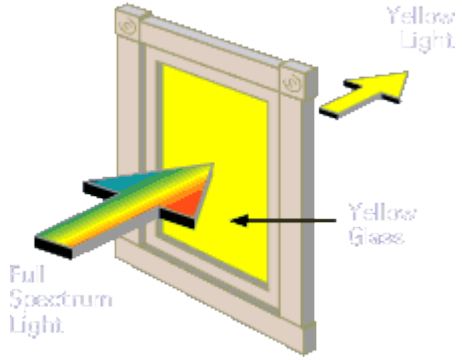
Because of the way our eyes work, almost any color can be simulated by combining red, green, and blue light. All the colors combined make white light.

http://hubblesite.org/gallery/behind_the_pictures/meaning_of_color/

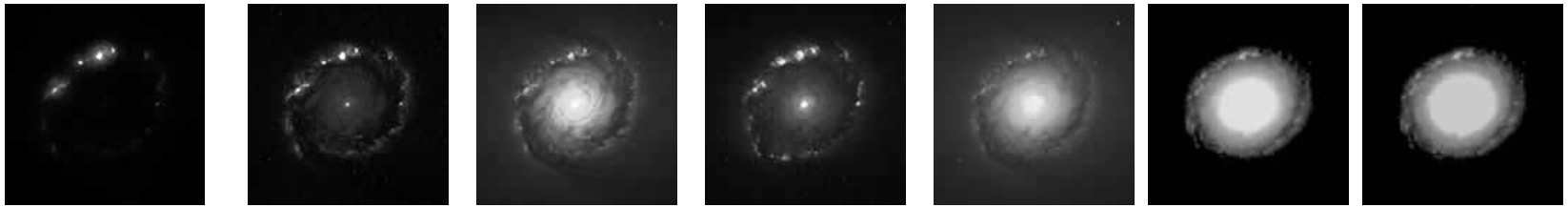
Hubble Telescope Image Formation Details

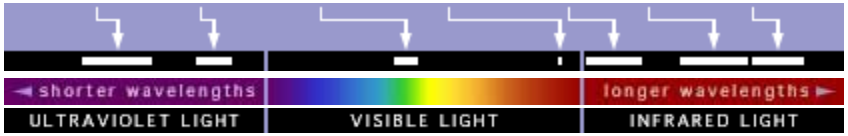
Color Filter

Light from distant
Object (star, galaxy, etc.)

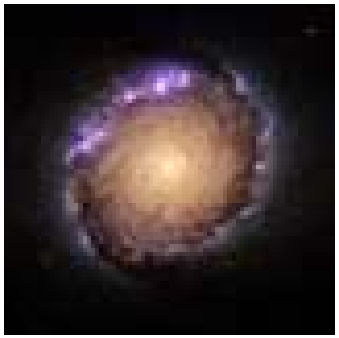


Filtered grey image



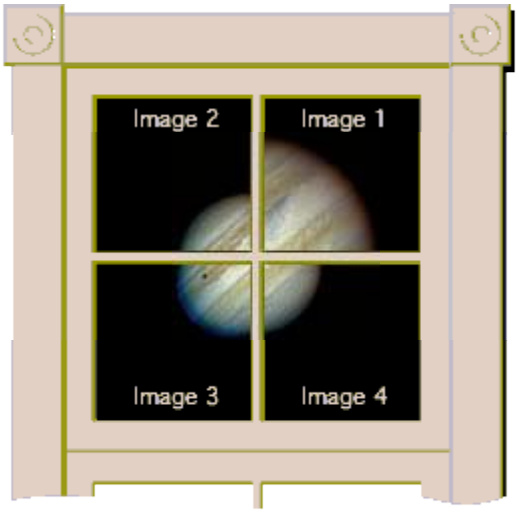


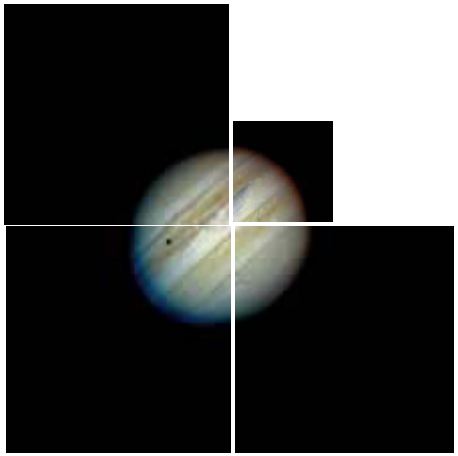
Combined filtered images
give color perception



http://hubblesite.org/gallery/behind_the_pictures/meaning_of_color/filters.php

Hubble Telescope Image Formation Details

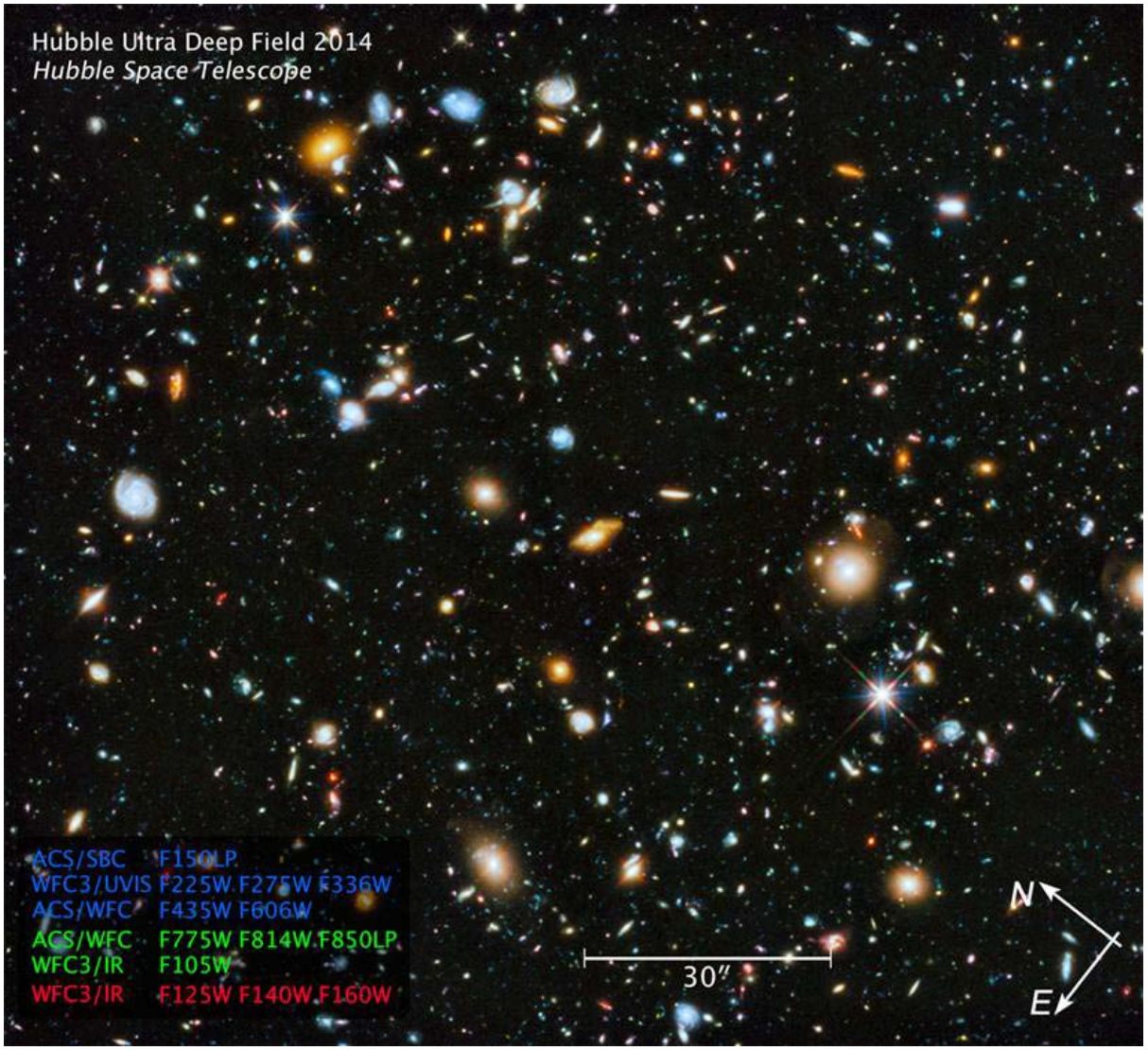




Many Hubble images have a curious stair-step shape. These images come from a scientific instrument called the Wide Field and Planetary Camera 2, or WFPC2 — which was removed from the telescope in mid-2009. It is WFPC2's unique design that underlies the oddly-shaped images in Hubble's portfolio. But WFPC2 has a unique feature. One of its cameras records a magnified view of the section it's observing, which allows us to see finer detail in that section.

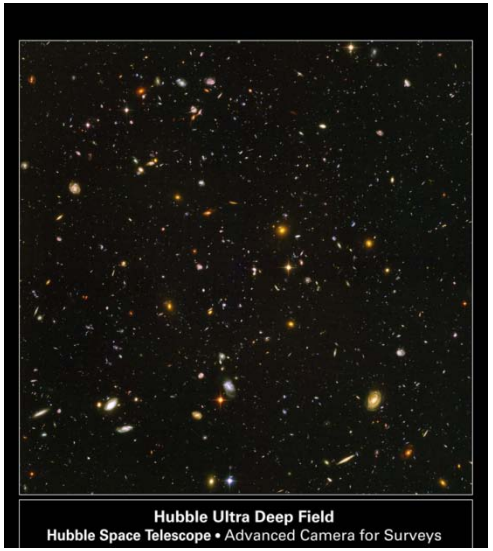
http://hubblesite.org/gallery/behind_the_pictures/wacky_shape/constructing.php

Hubble Team Unveils Most Colorful View of Universe Captured by Space Telescope

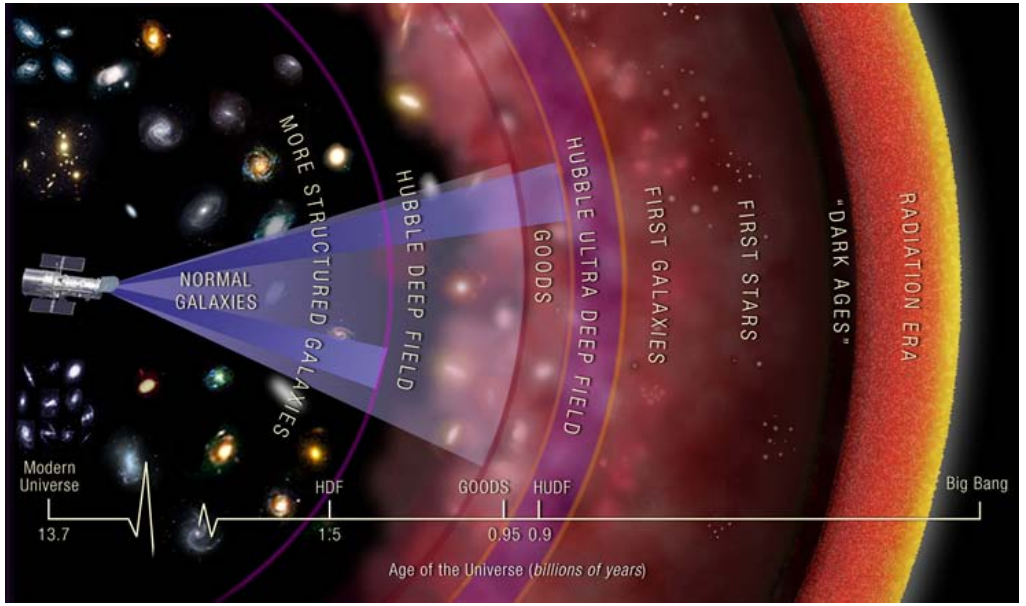


http://www.nasa.gov/press/2014/june/hubble-team-unveils-most-colorful-view-of-universe-captured-by-space-telescope/

Taking the Universe's Baby Pictures

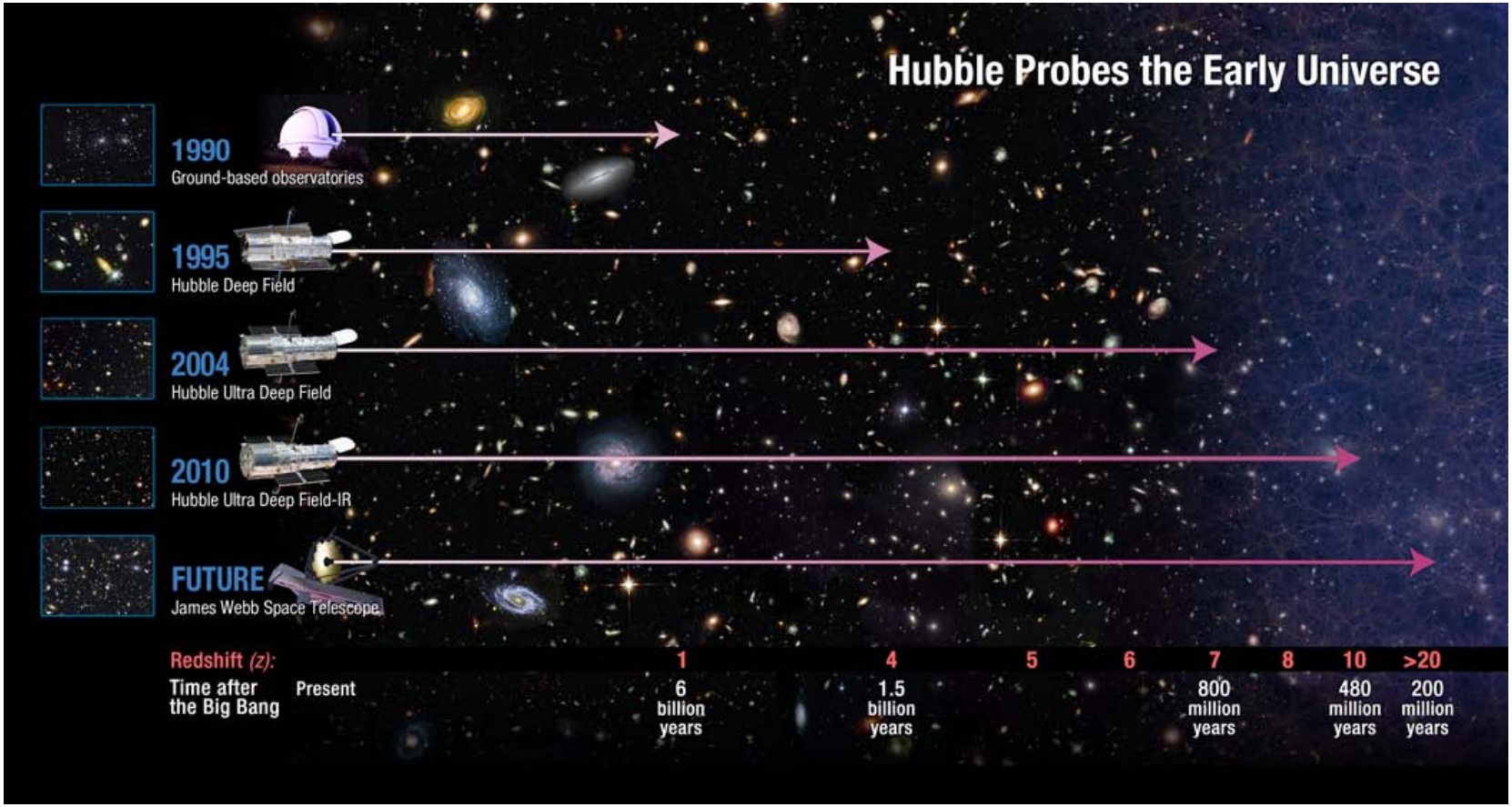


Hubble's Deepest Views Of The Universe
Hubble Deep Field
Hubble Ultra Deep Field
Great Observatories Origins Deep Survey (GOODS)
A tiny section of the Hubble Ultra Deep Field captures a sprinkling of the estimated 10,000 galaxies visible in the image.



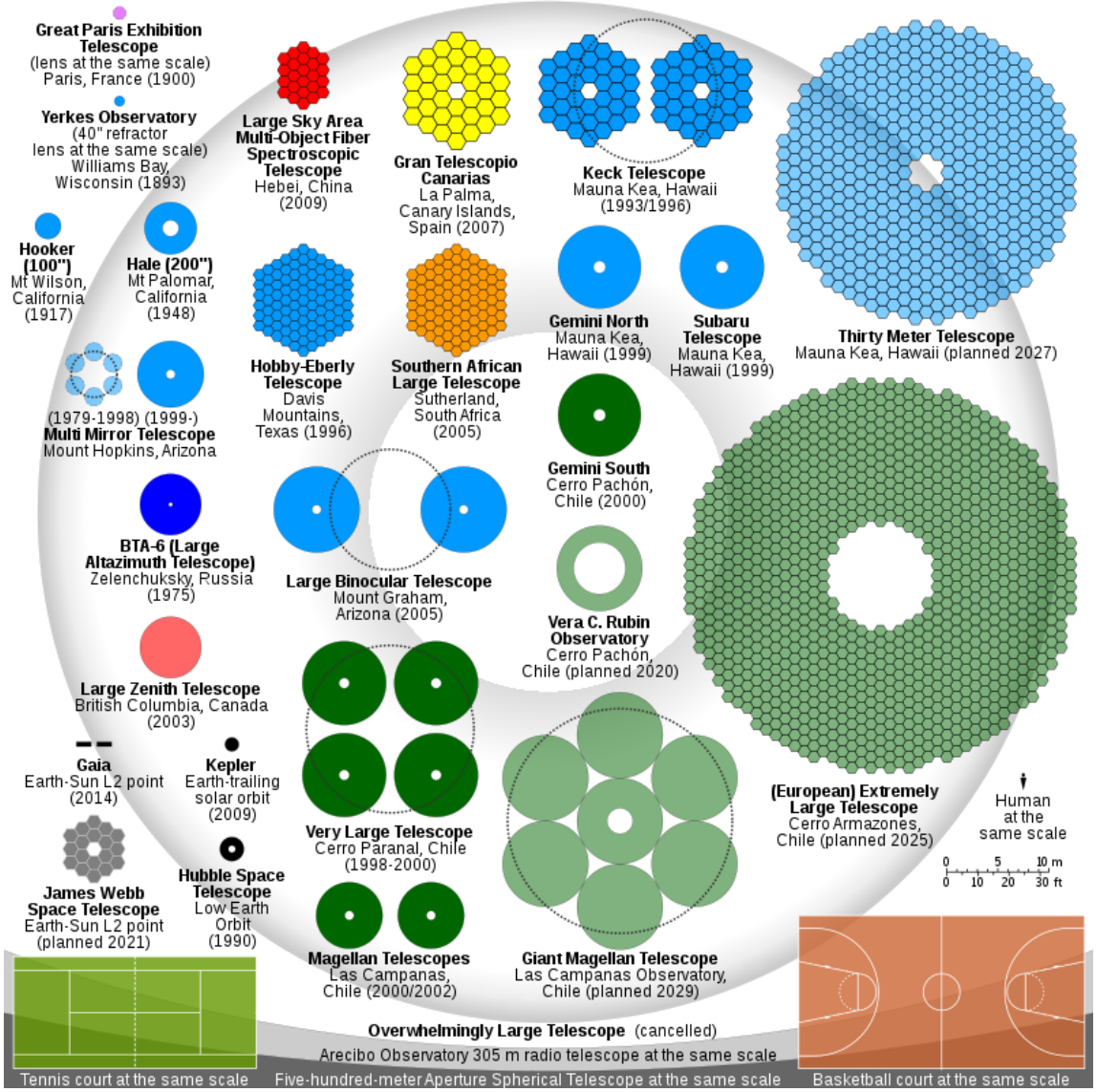
http://hubblesite.org/hubble_discoveries/breakthroughs/cosmology

Taking the Universe's Baby Pictures



https://upload.wikimedia.org/wikipedia/commons/d/dc/Hubble_Probes_the_Early_Universe.jpg

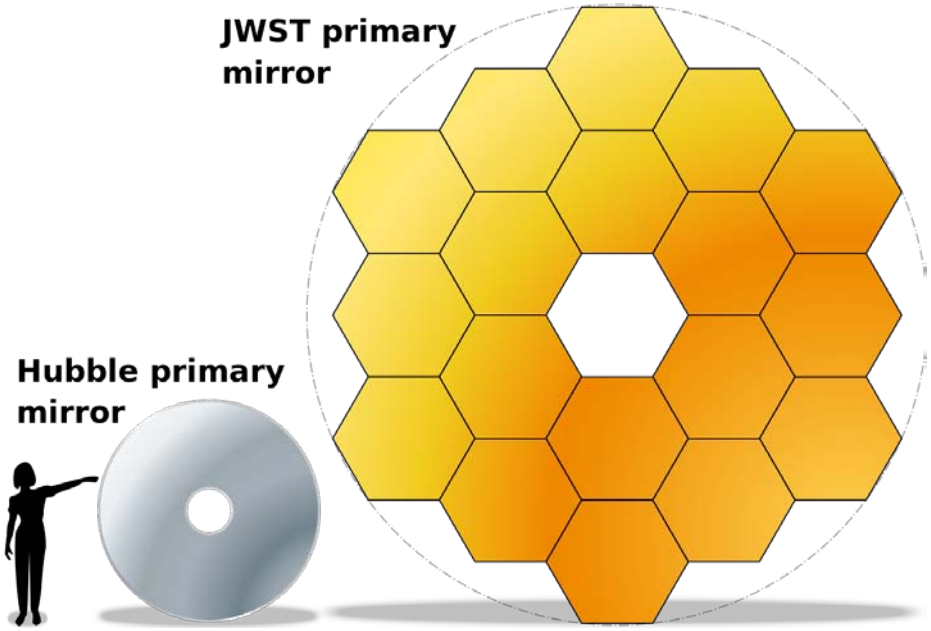
Primary Mirrors of Various Telescopes



https://en.wikipedia.org/wiki/List_of_largest_optical_reflecting_telescopes

James Webb Space Telescope

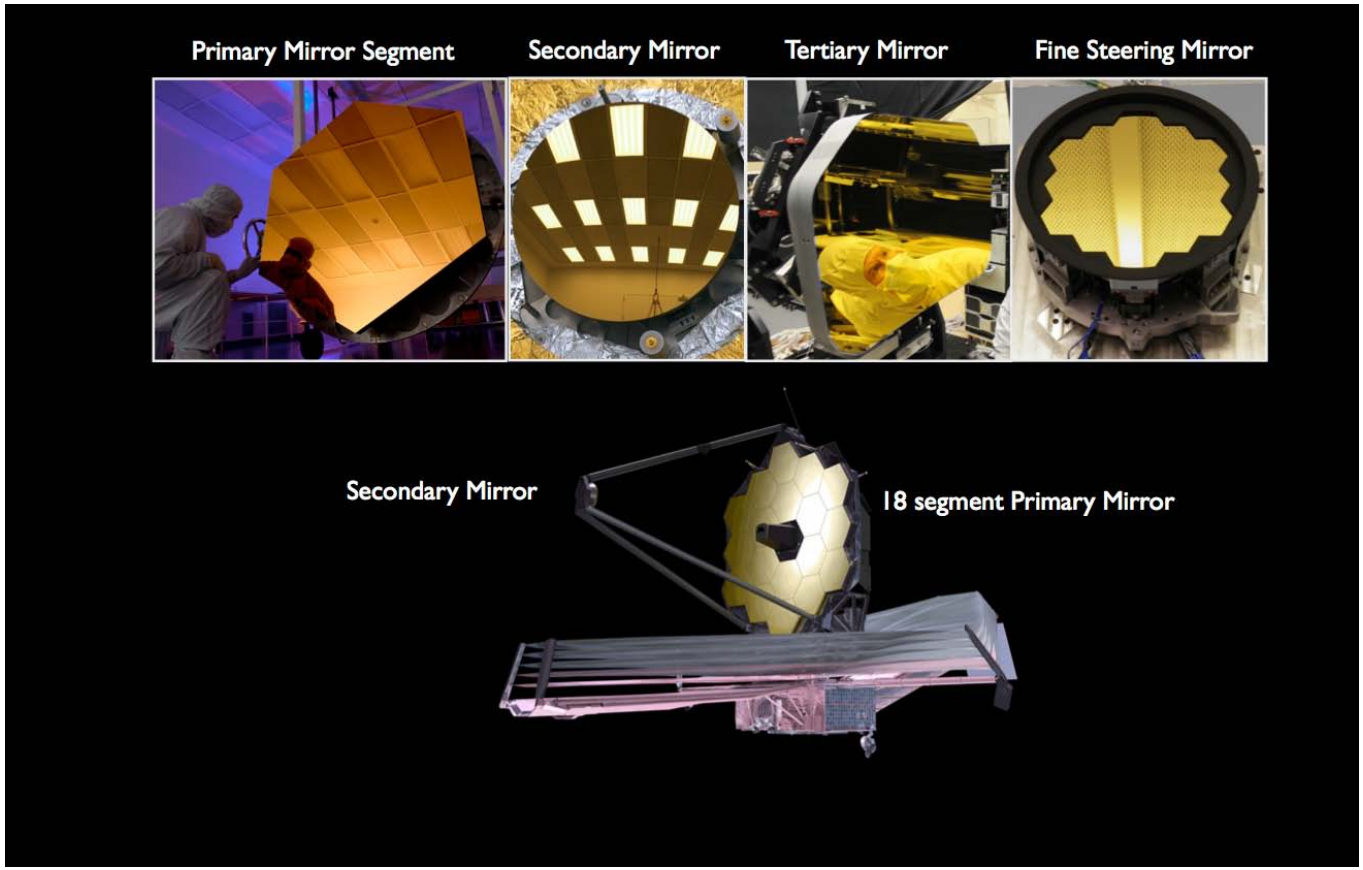
(NASA, launched in December 25, 2021)



Type	Korsch-type Telescope
Diameter	6.5 m (21 ft)
Focal length	131.4 m (431 ft)
Collecting area	25 m^2 (270 sq ft)
Wavelengths	from 0.6 μm (orange) to 28.5 μm (mid-infrared)

James Webb Space Telescope

(NASA launched in December 31, 2021)



https://www.flickr.com/photos/nasawebbtelescope/sets/72157658888594928/

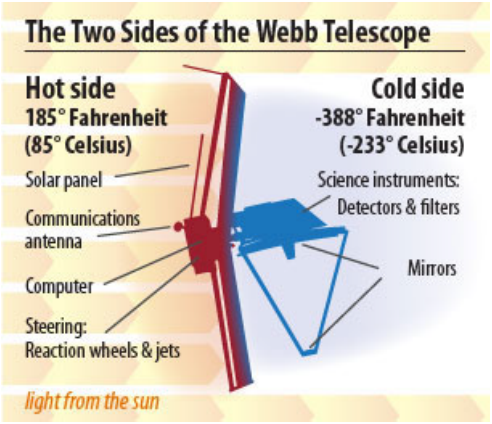
James Webb Space Telescope

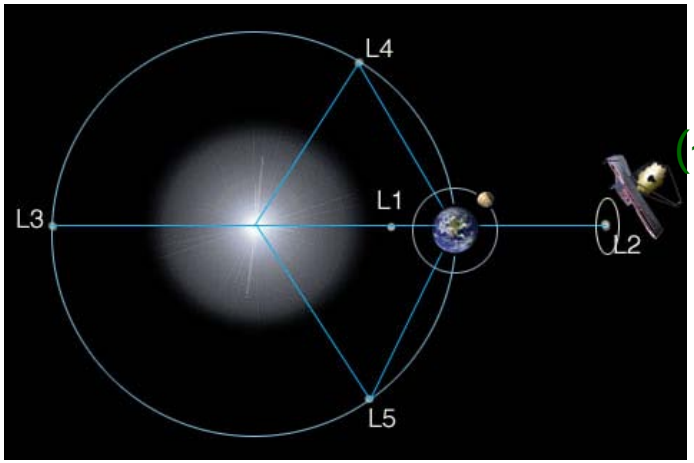
https://farm5.staticflickr.com/4755/39858029851_f01519d853_b.jpg

Launch configuration of the JWST in an [Arianne 5]

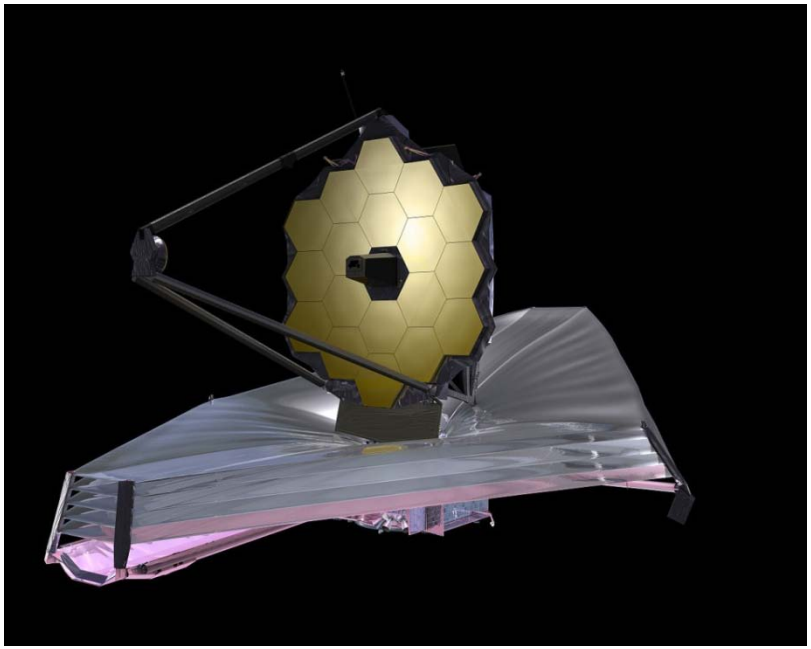
https://www.jwst.nasa.gov/content/about/launch.html

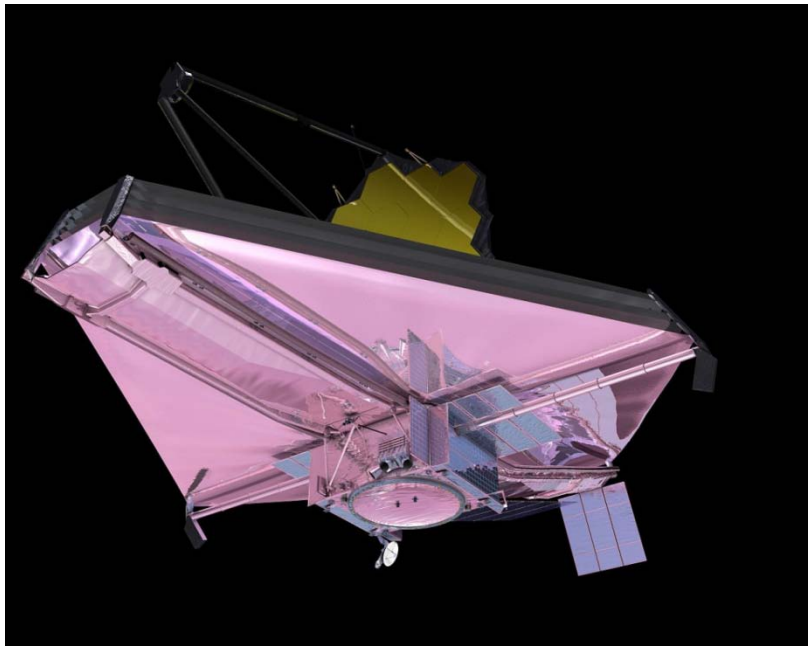
James Webb Space Telescope





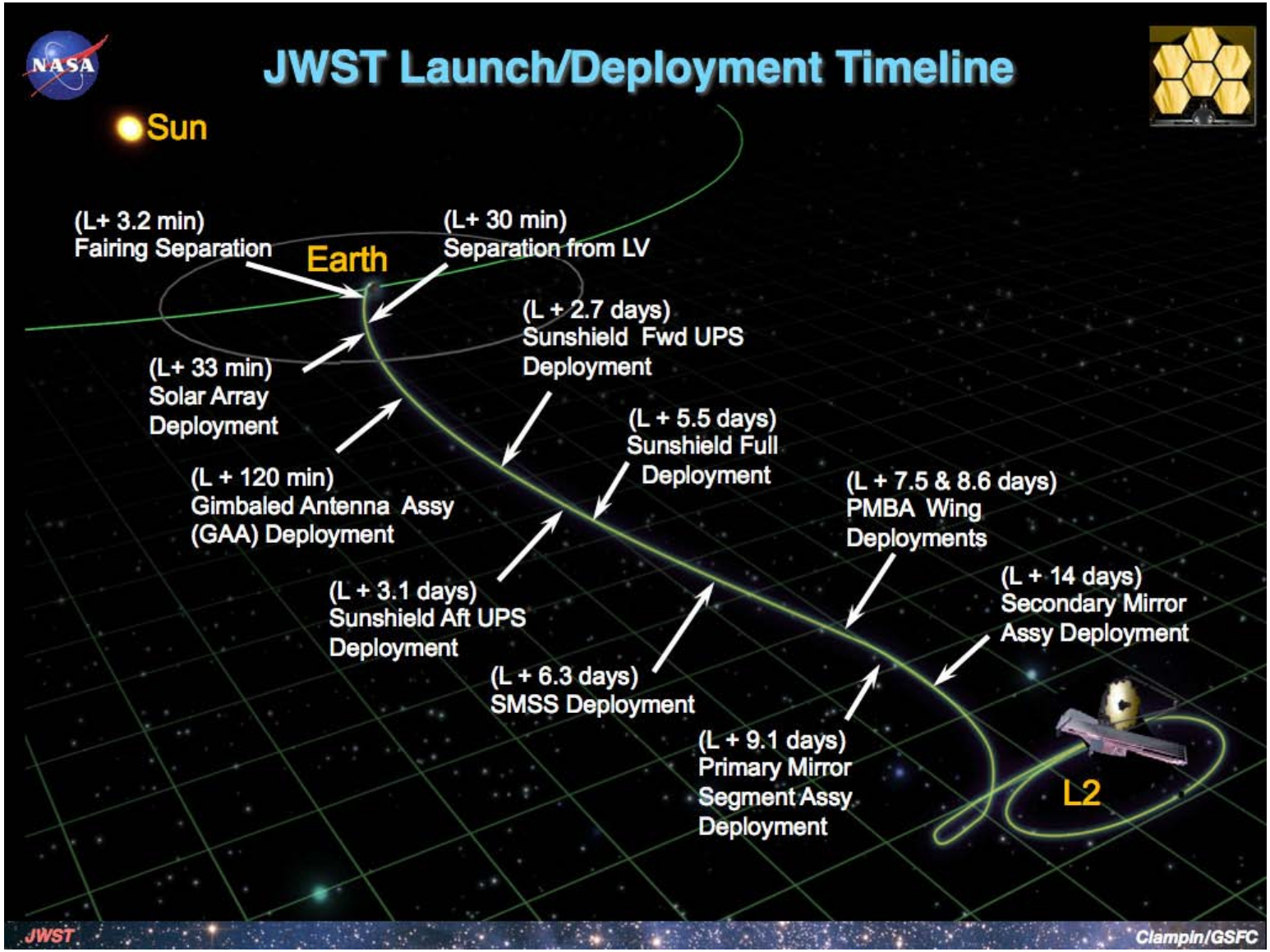
Around L2 point
(~1.5 million km from earth)





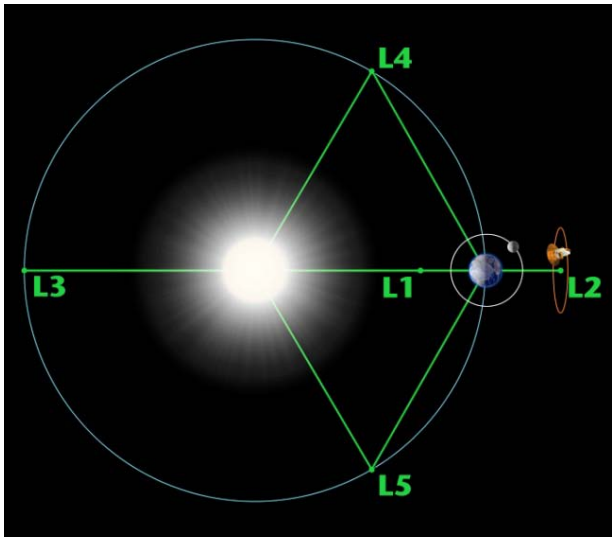
http://en.wikipedia.org/wiki/James_Webb_Space_Telescope

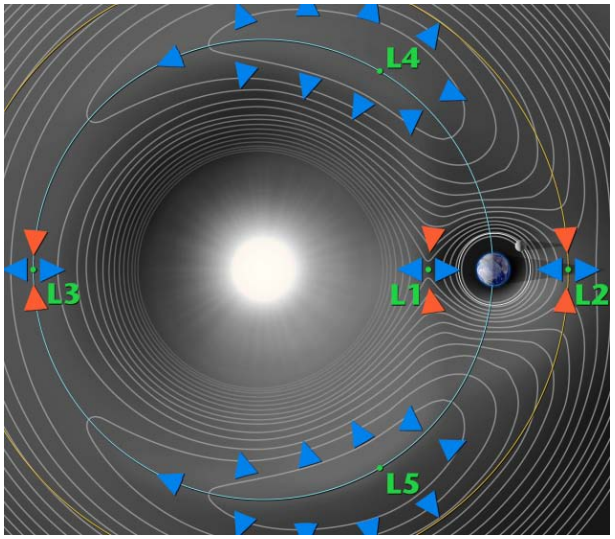
James Webb Space Telescope



https://upload.wikimedia.org/wikipedia/commons/6/6a/JWSTDeployment.jpg

Lagrangian Points





L4 and L5 correspond to hilltops and L1, L2 and L3 correspond to saddles (i.e. points where the potential is curving up in one direction and down in the other). This suggests that satellites placed at the Lagrange points will have a tendency to wander off (try sitting a marble on top of a watermelon or on top of a real saddle and you get the idea). But when a satellite parked at L4 or L5 starts to roll off the hill it picks up speed. At this point the Coriolis force comes into play - the same force that causes hurricanes to spin up on the earth - and sends the satellite into a stable orbit around the Lagrange point. https://solarsystem.nasa.gov/resources/754/what-is-a-lagrange-point/

The **L1** point position is useful for solar observations since it is near Earth but in constant sunlight. It could also be useful for collecting solar power. Conversely, the **L2 point** is perpetually in the shadow of Earth, and as such offers a prime location for observing the outer planets or deep space.

First Images from James Webb Space Telescope

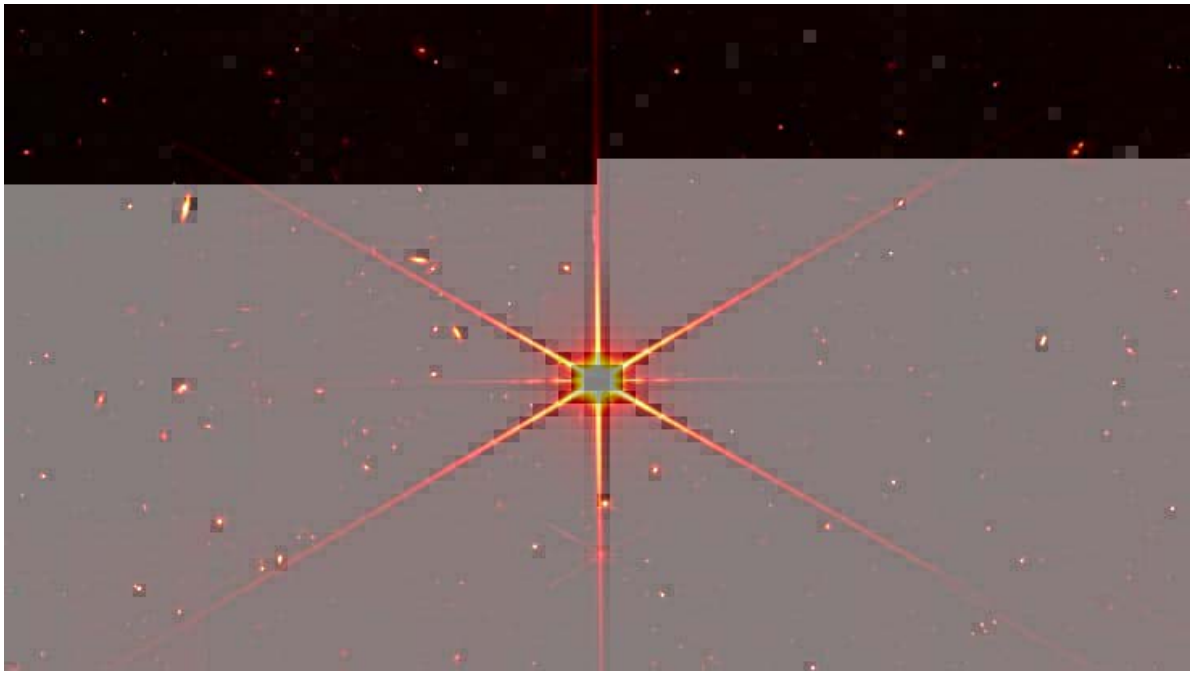
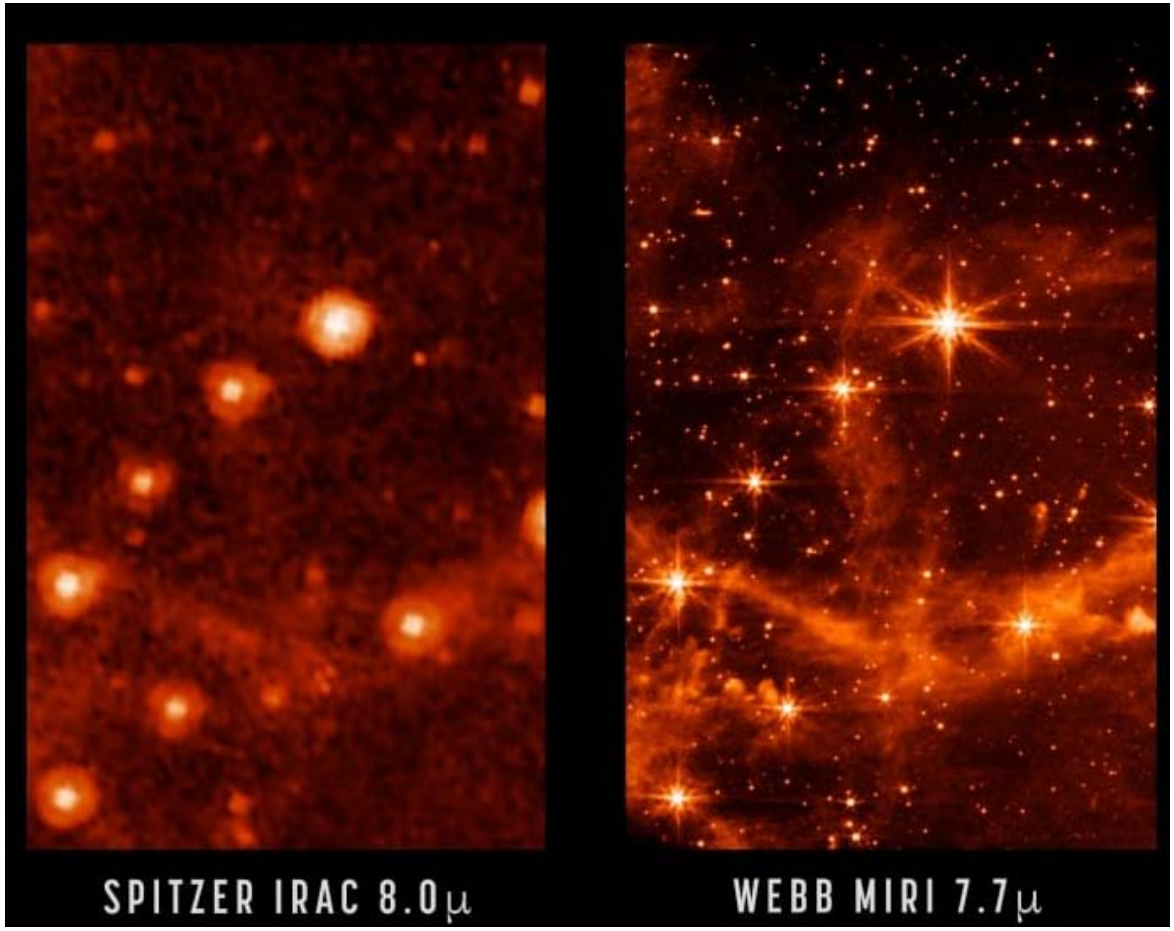


Image of star HD84406 in Ursa Major (about 242 light years away) . This star is 100 times fainter than what can be seen with the human eye but very bright for the stars that JWST will study.

https://cosmosmagazine.com/space/james-webb-telescope-first-images/

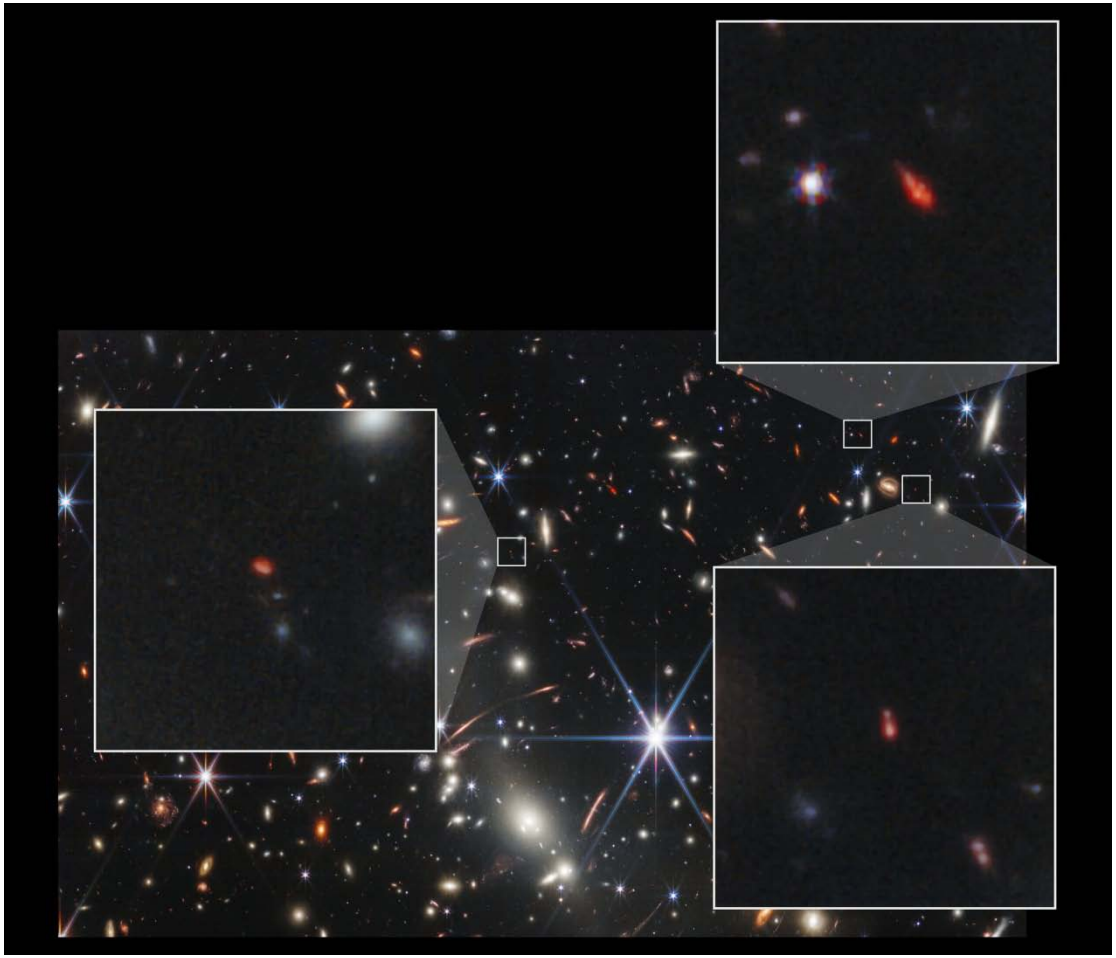
First Images from James Webb Space Telescope



This combination of images provided by NASA on Monday shows part of the Large Magellanic Cloud, a small satellite galaxy of the Milky Way, seen by the retired Spitzer Space Telescope, left, and the new James Webb Space Telescope. The new telescope is in the home stretch of testing, with science observations expected to begin in July 2022.

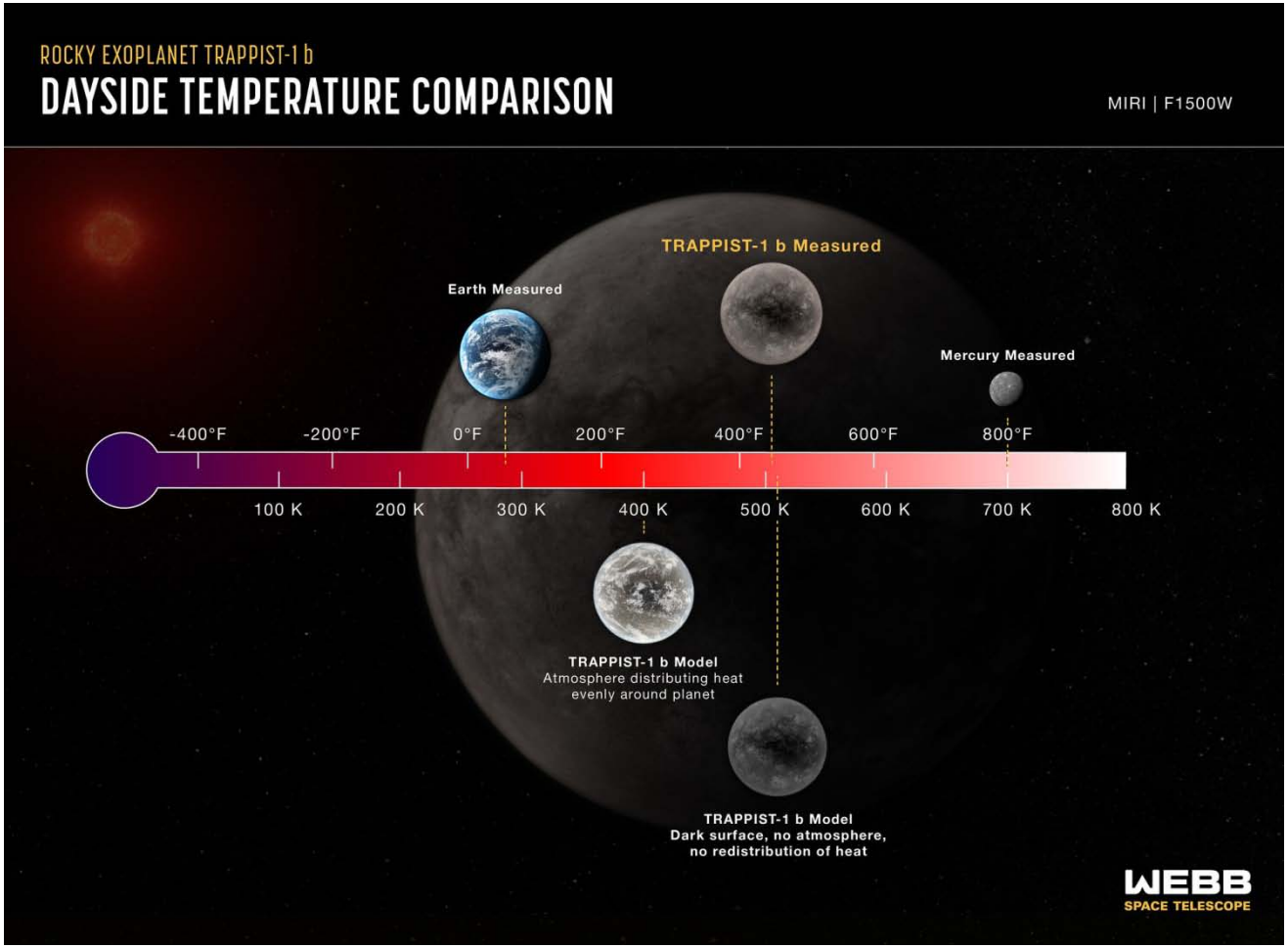
https://www.cbc.ca/news/science/james-webb-telescope-images-1.6447622

Young Distant Galaxies Images from James Webb Space Telescope



https://www.flickr.com/photos/nasawebbtelescope/52619016131/in/album-72177720305127361/

James Webb Space Telescope – Rocky Exoplanet Temperature



https://www.flickr.com/photos/nasawebbtelescope/52775182434/in/album-72177720305127361/