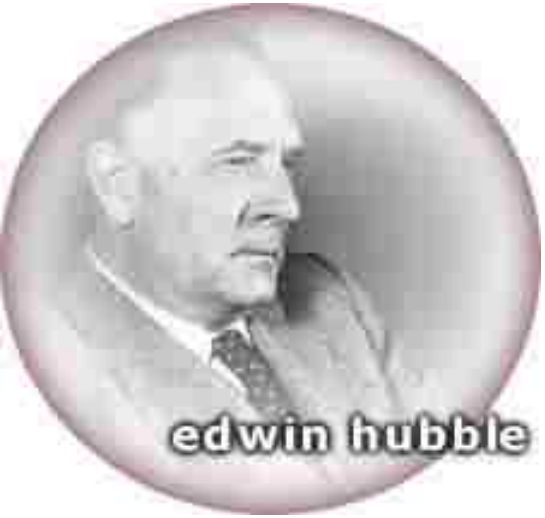
Hubble Space Telescope

HUBBLE ABOVE EARTH

Hubble's Name



NASA named the world's first space-based optical telescope after American astronomer Edwin P. Hubble (1889–1953). Dr. Hubble confirmed an "expanding" universe, which provided the foundation for the Big Bang theory.

Scientists believe our universe began with a "big bang" some 13.7 billion years ago. If all the events in the history of the universe until now were squeezed into 24 hours, Earth wouldn't form until late afternoon and humans would have existed for only **2 seconds**.

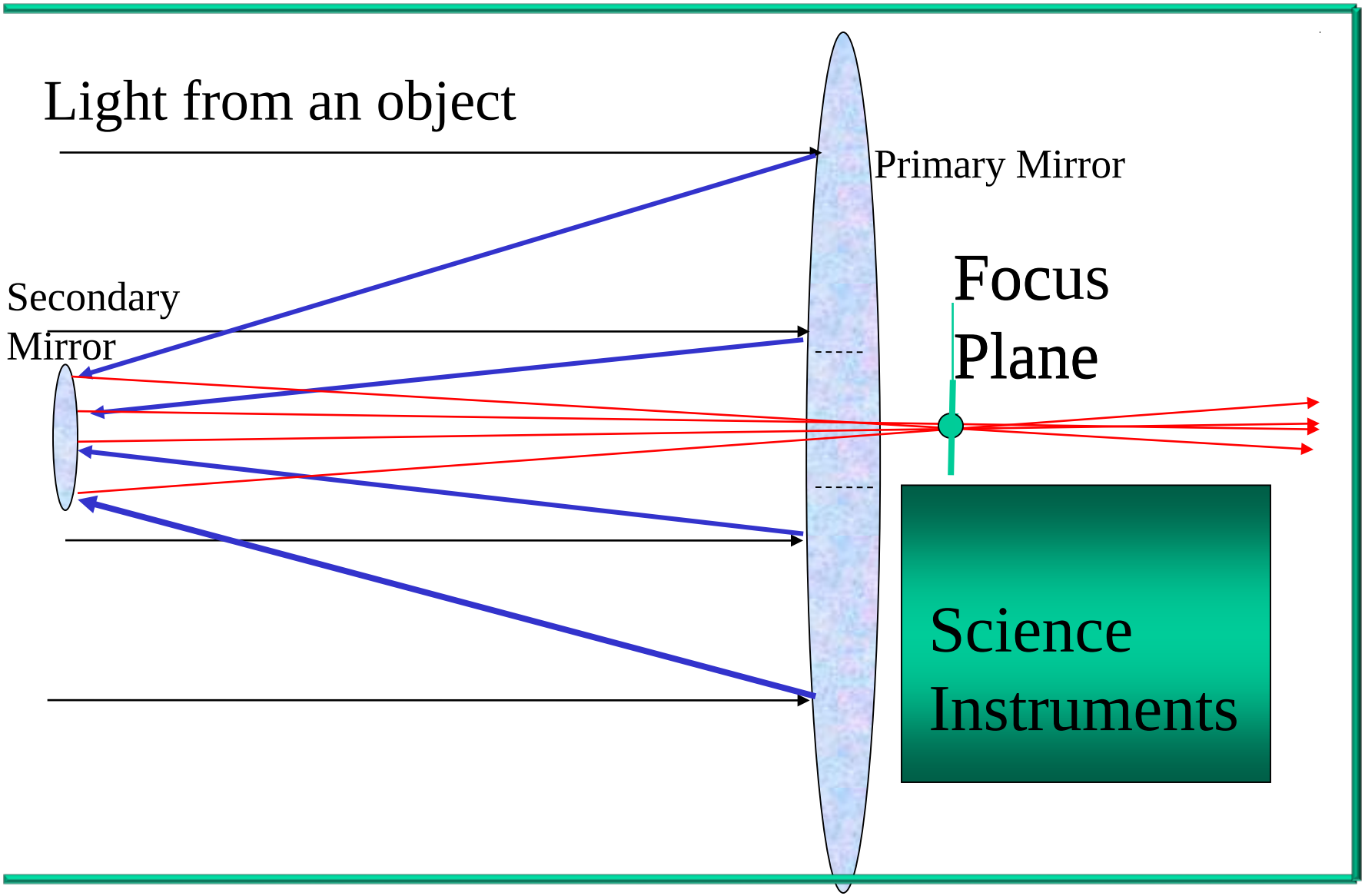
Hubble Mirrors

Primary Mirror
Diameter: 94.5 inches (2.4 m)
Weight: 1,825 lb. (828 kg.)

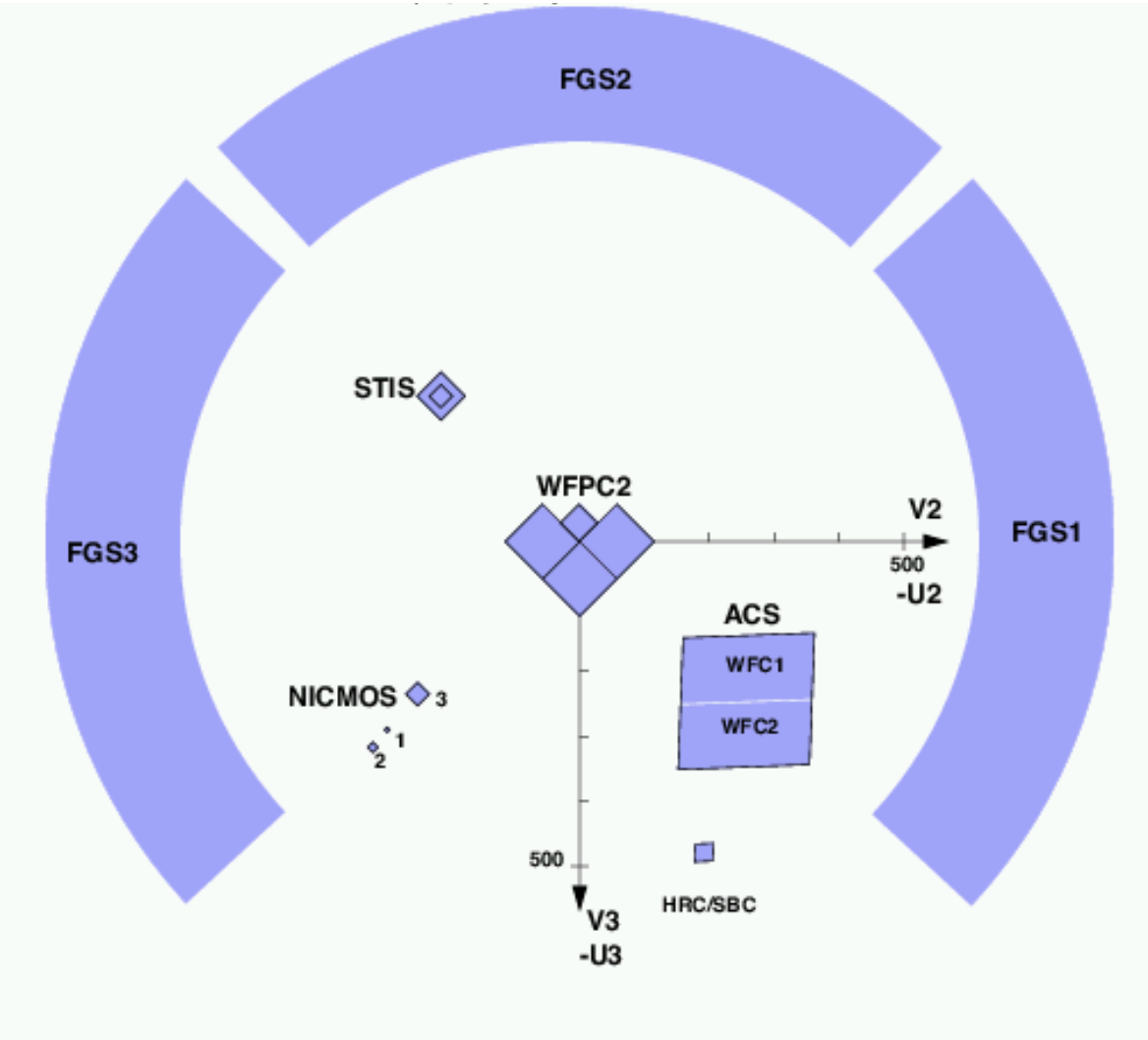
Secondary Mirror
Diameter: 12 in (0.3 m)
Weight: 27.4 lb (12.3 kg)

Hubble's two mirrors were ground so that they do not deviate from a perfect curve by more than 1/800,000ths of an inch. If Hubble's primary mirror were scaled up to the diameter of the Earth, the biggest bump would be only six inches tall.

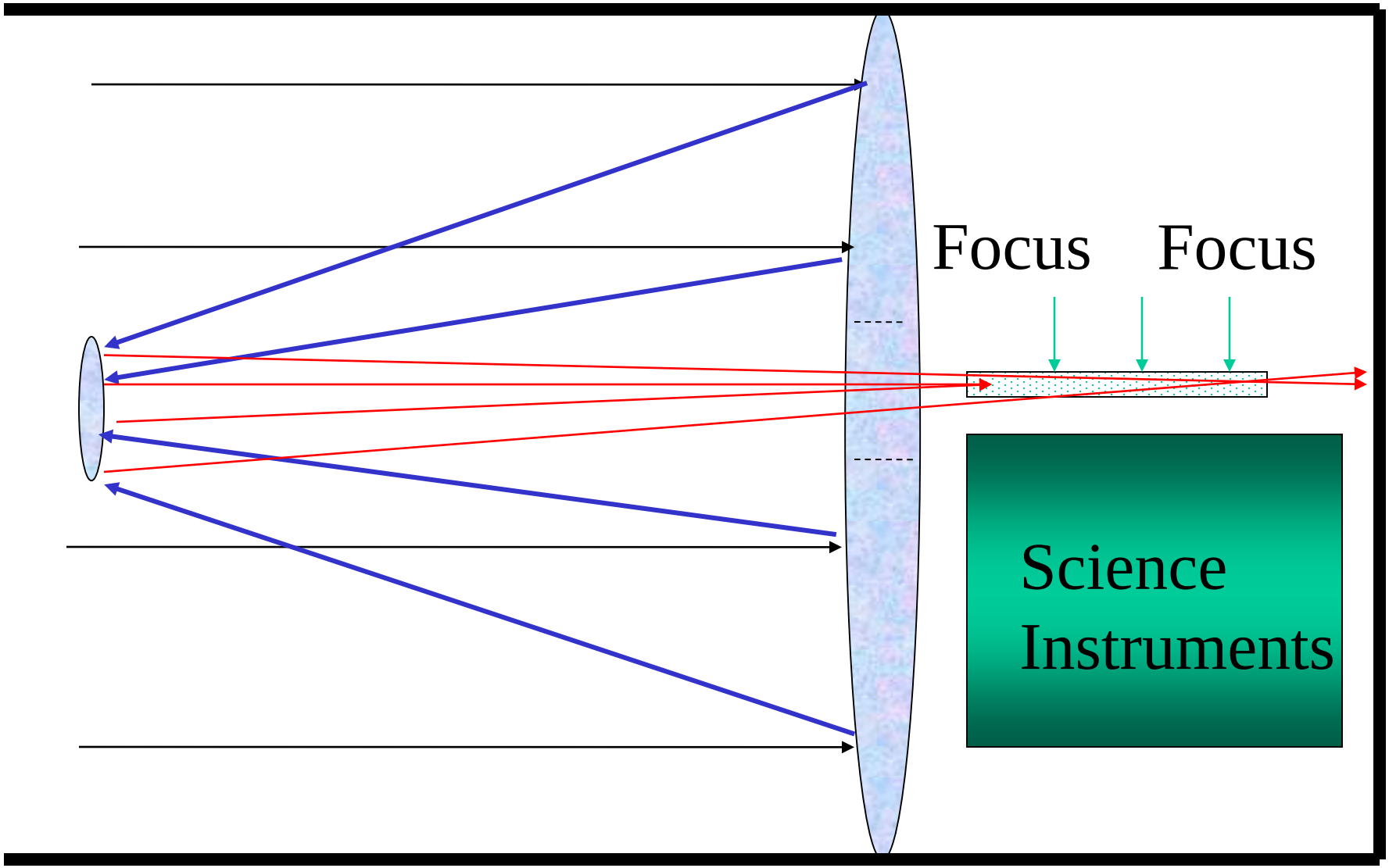
How Hubble Should Have Worked



Hubble's Focal Plane



Hubble's Problem - Spherical Aberration



The Mirror Problem

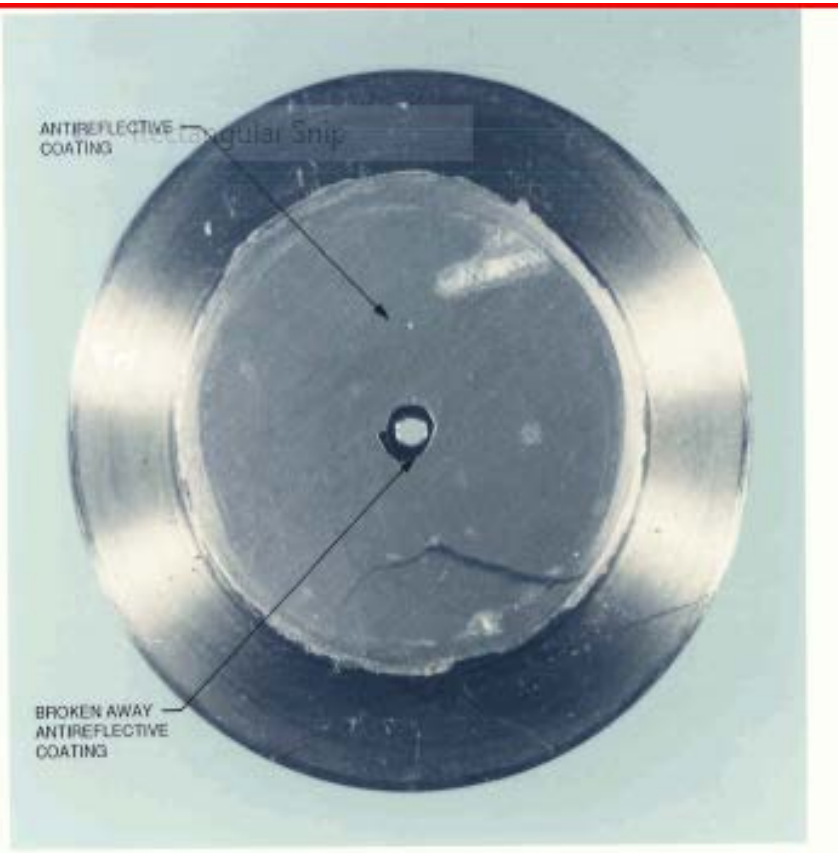
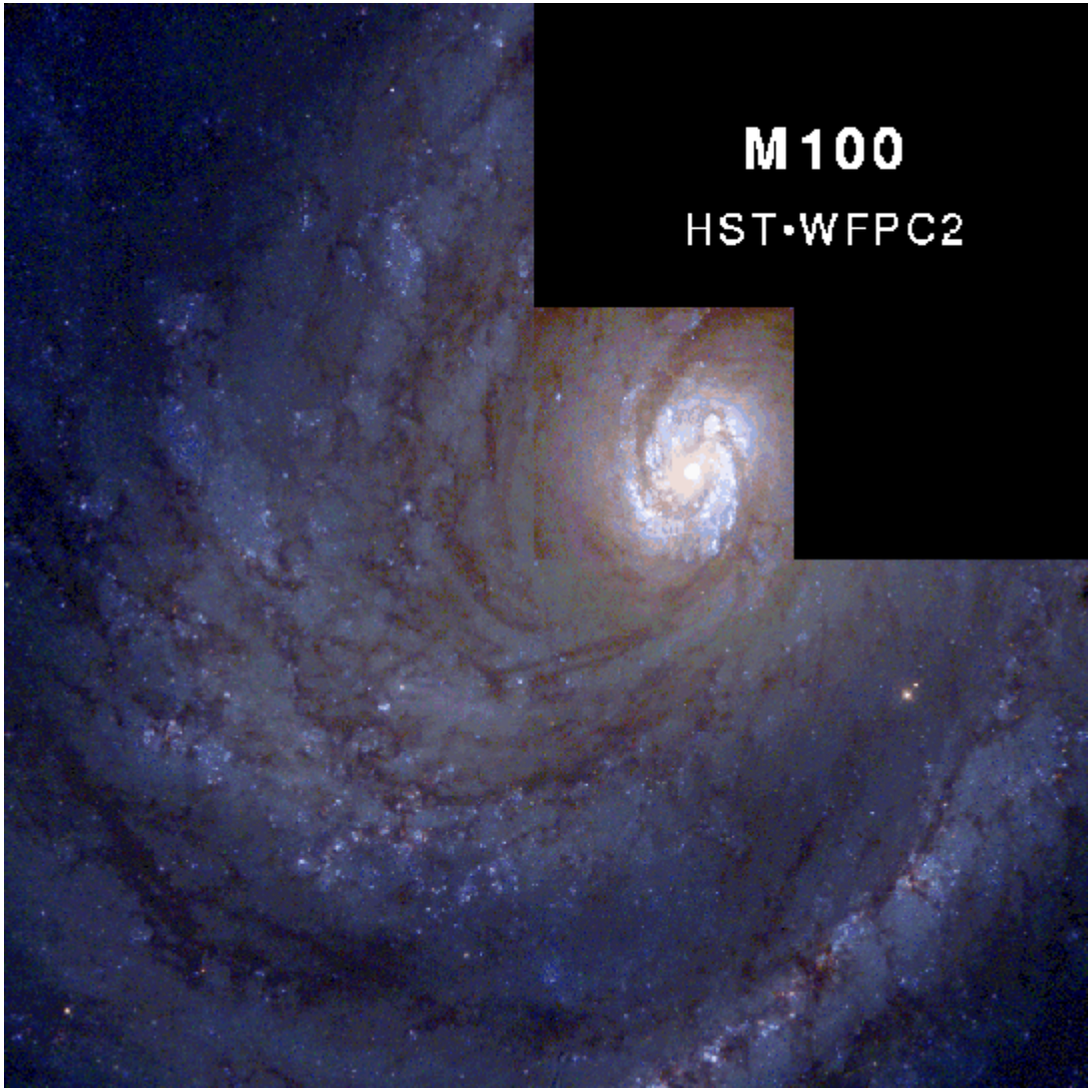


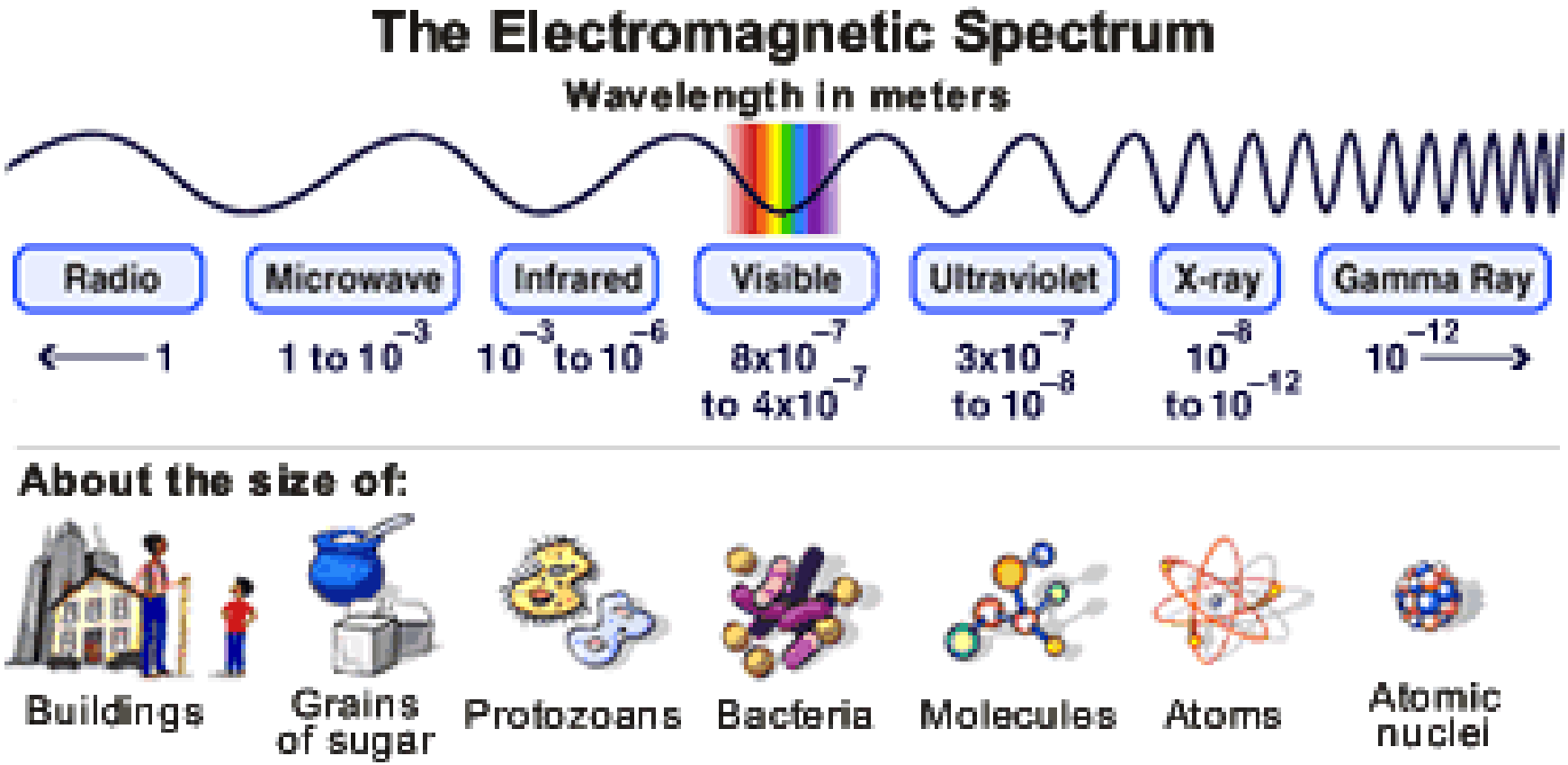
Figure 7-5. Top view of the field cap, showing the aperture and the area where the antireflective coating had broken away.

M100

Wide Field Planetary Camera 1

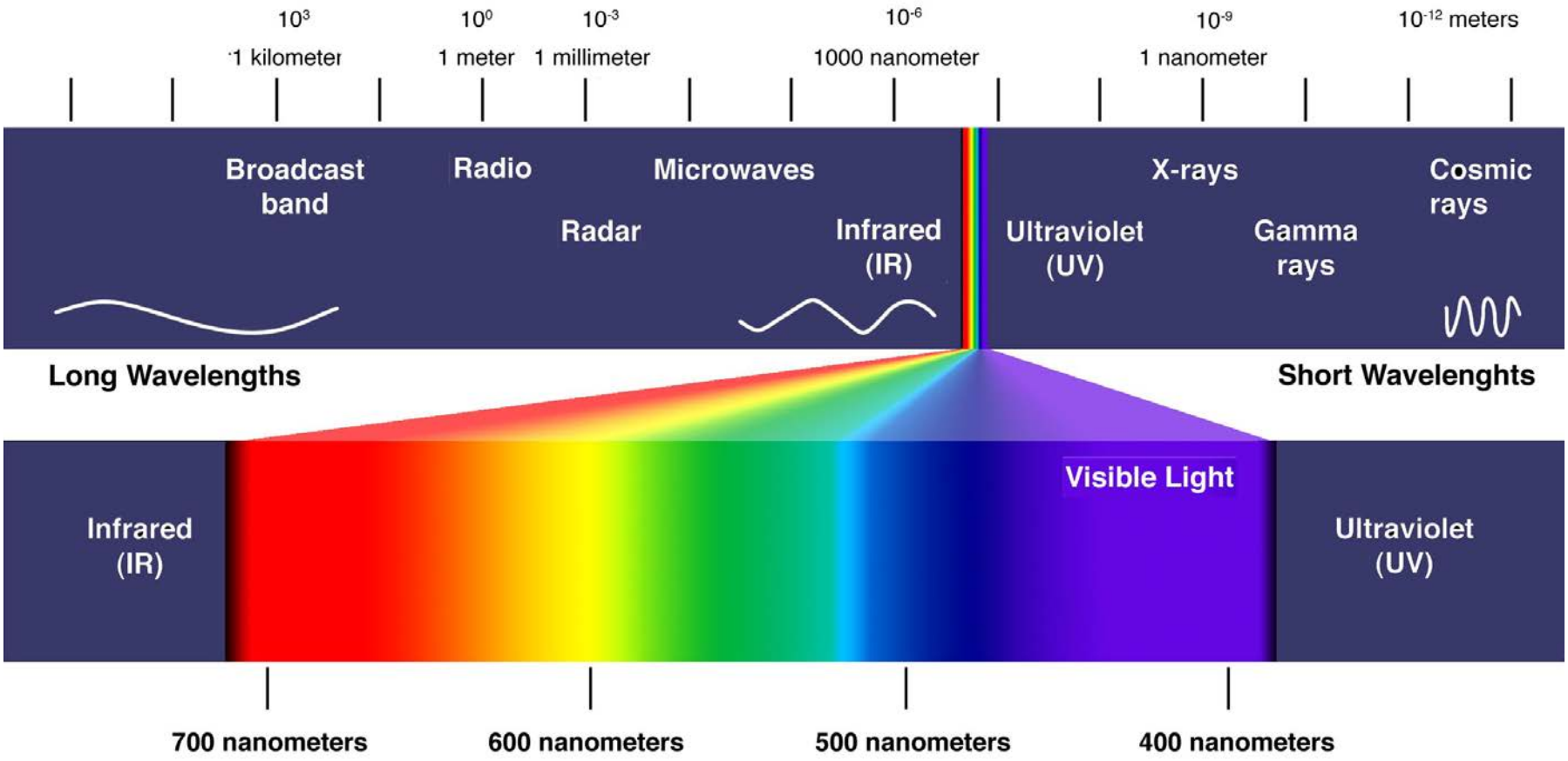
Wide Field Planetary Camera 2


M100
HST•WFPC2

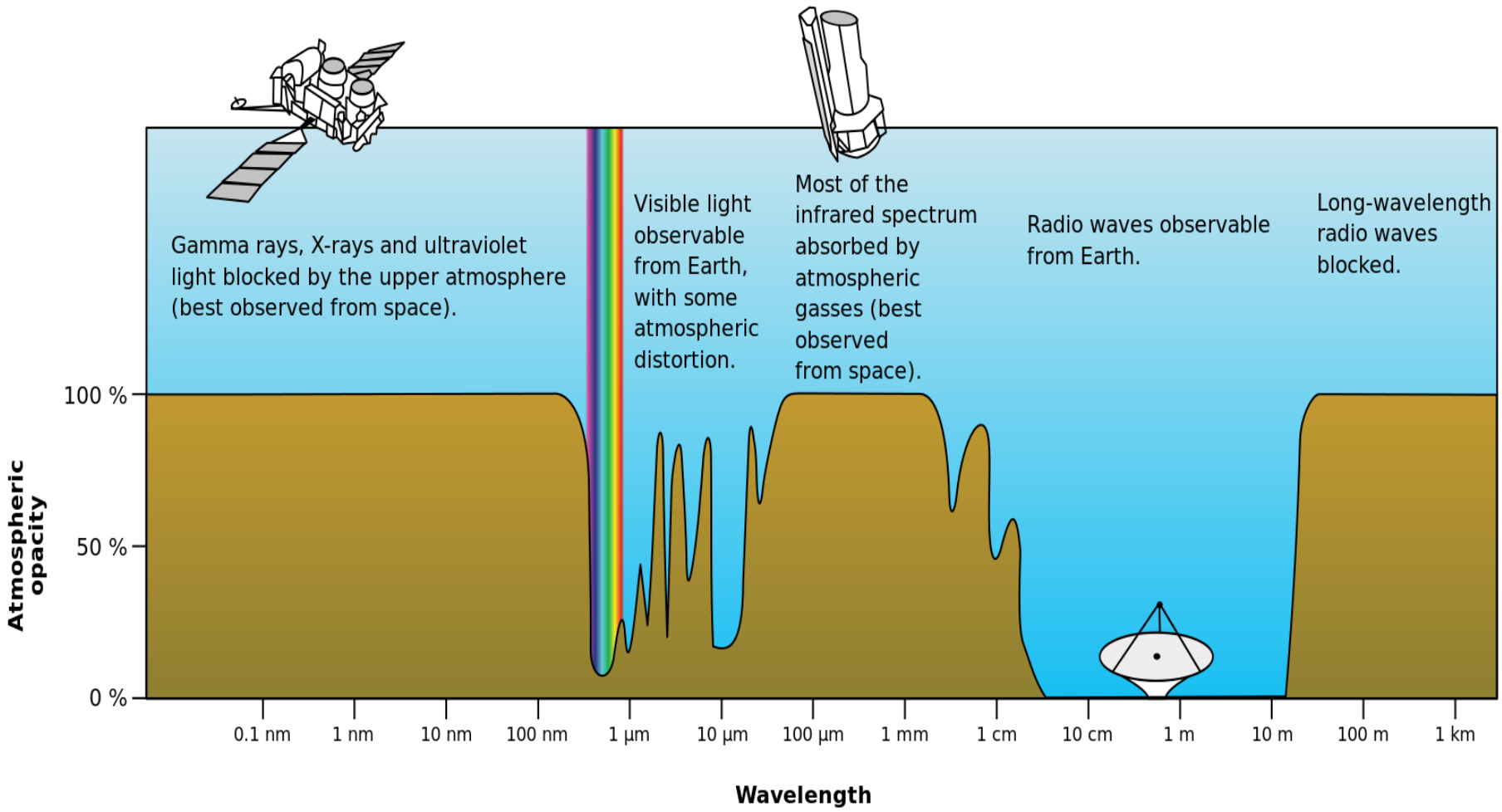


Wavelength x Frequency = Speed of Light

Electromagnetic Spectrum

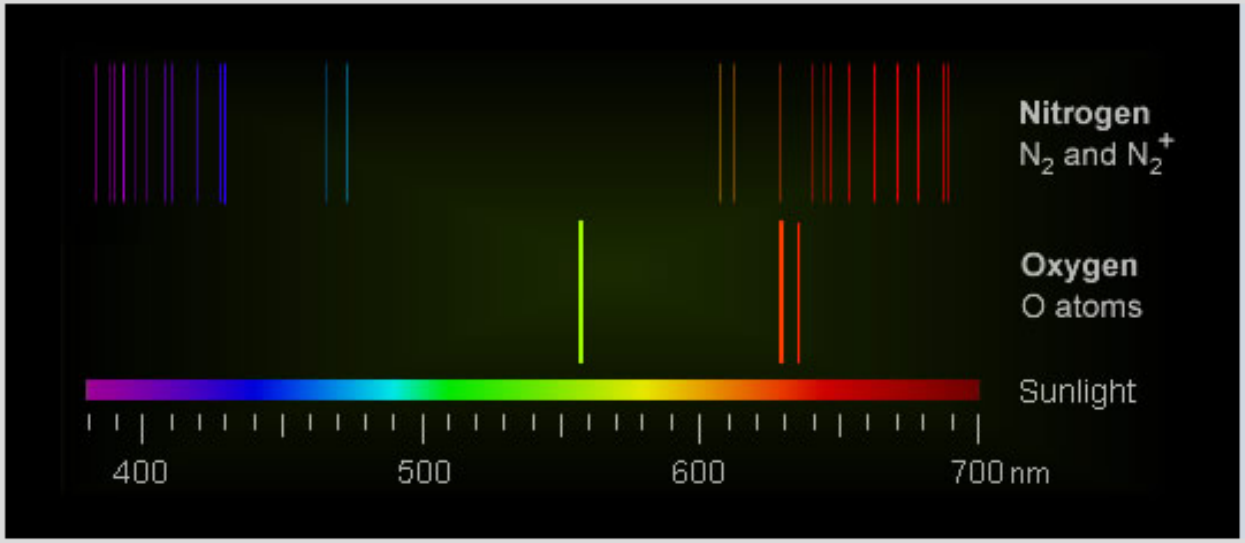


Why Telescopes are in Space



Spectra – Oxygen and Nitrogen

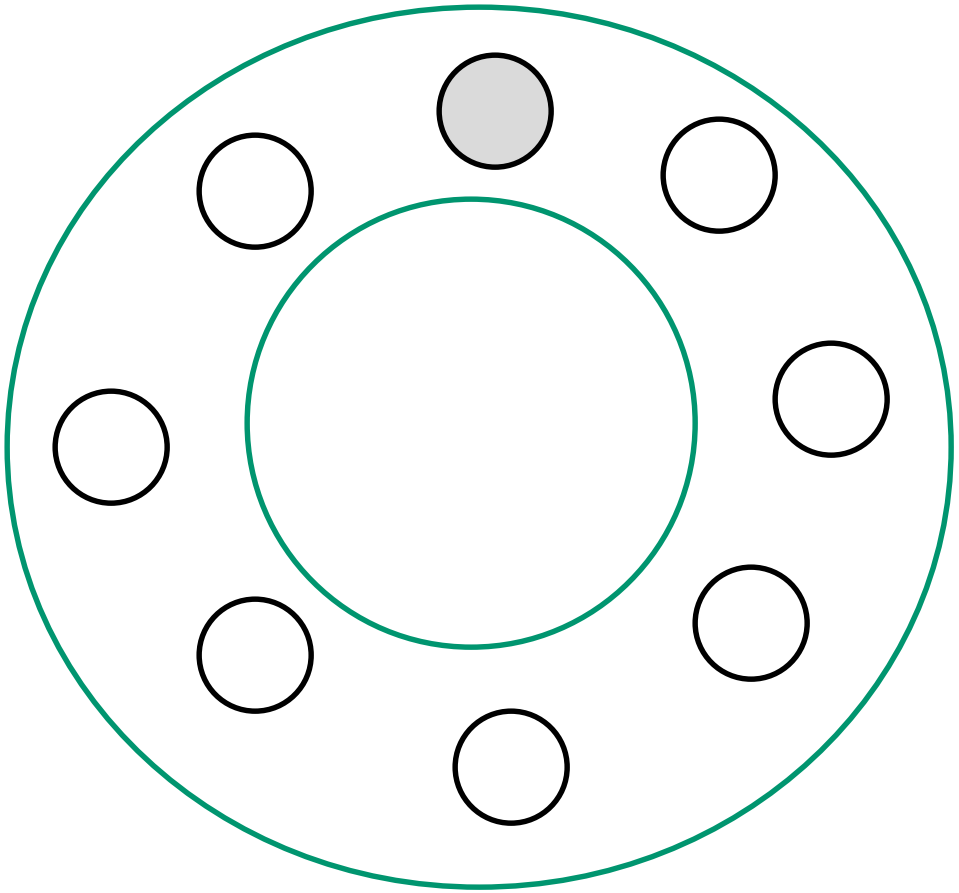
Glowing Gases - Aurorae



Auroral light is mostly from electronically excited oxygen atoms. Green radiation prevails at low altitudes and red at higher.

Excited nitrogen molecules and nitrogen molecular ions produce pink and red at low altitudes.

Camera Filter Wheels



x 3

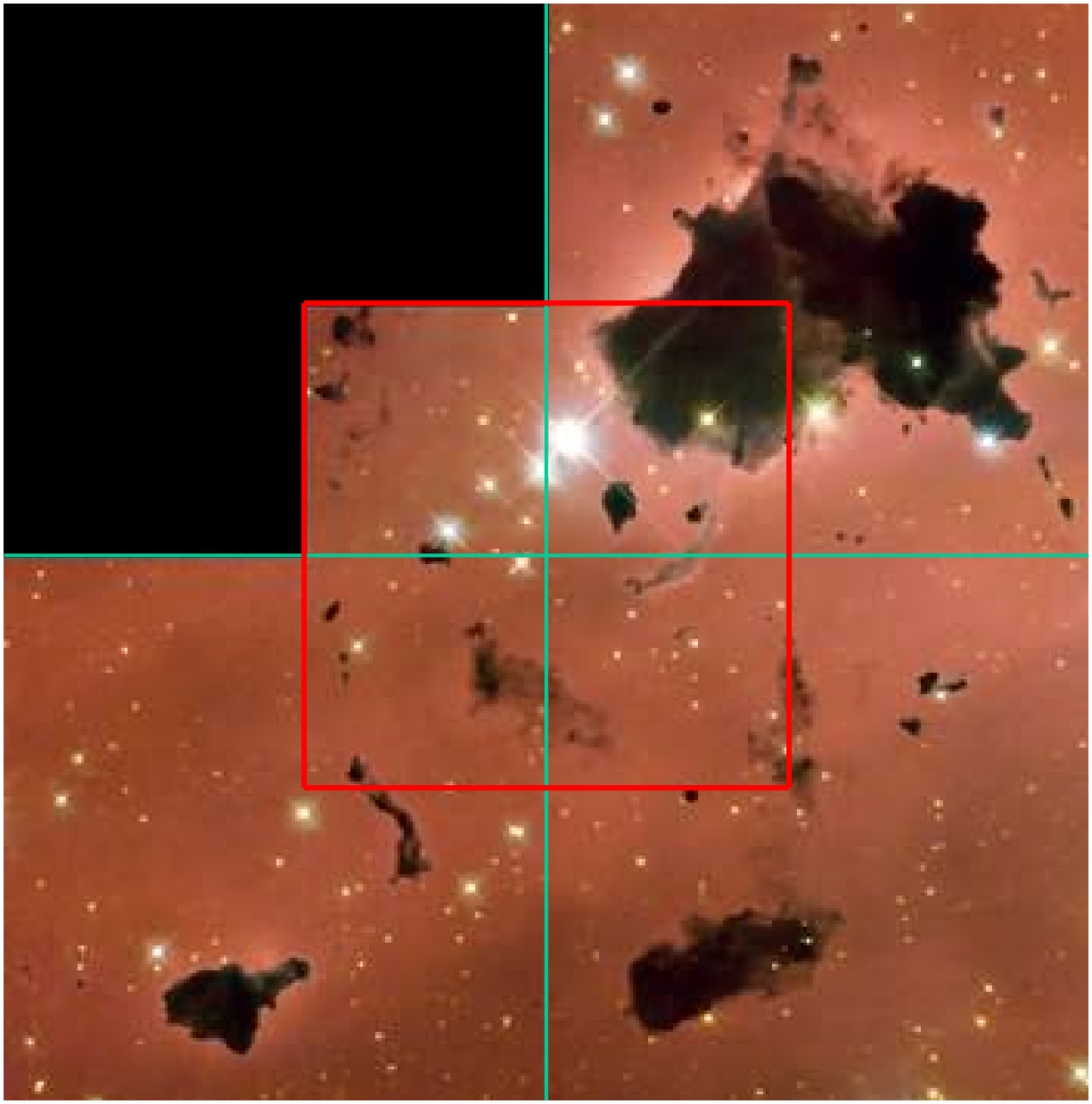
Camera Evolution

- Launch – Dec. 1993 Wide Field & Planetary Camera (WF&PC I)
  - Internal Field of View .043 arcsec
  - 8 - 800 x 800 pixel arrays – Charged Coupled Device (CCD's)

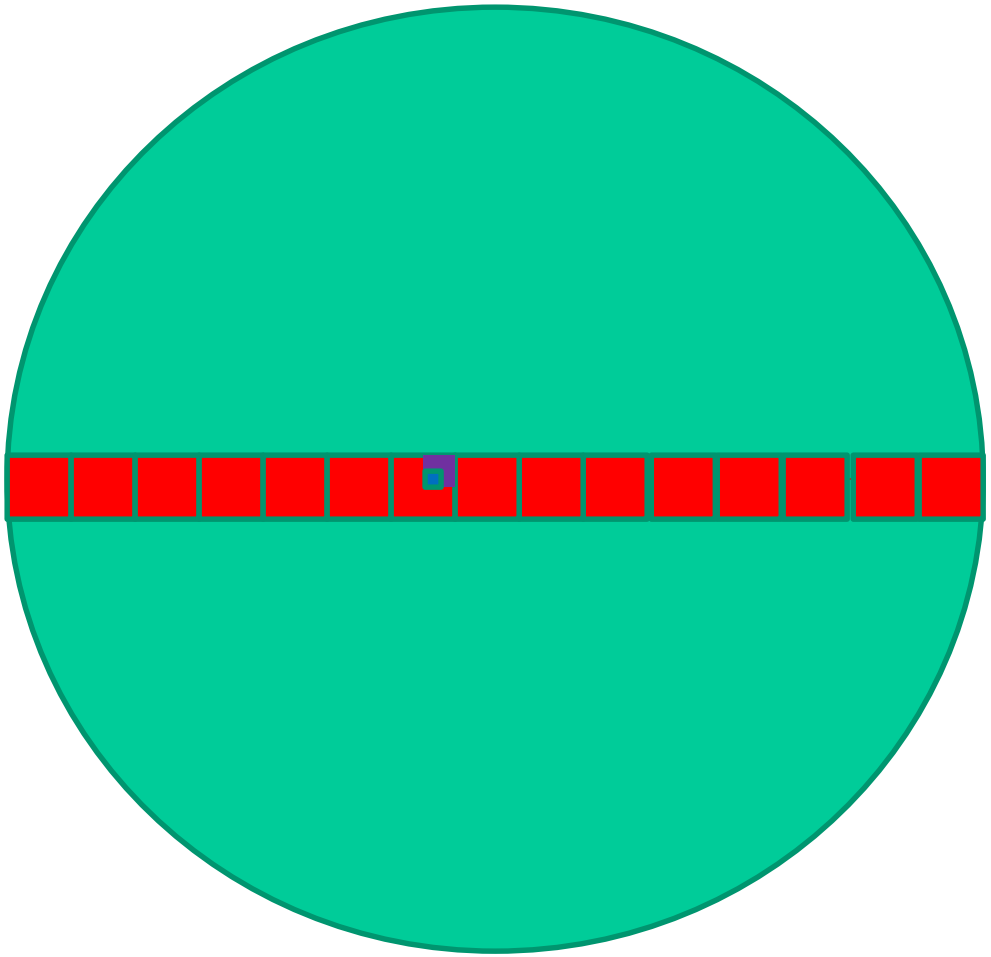
- Dec. 1993 – May 2009 WF&PC II
  - Internal Field of View .043 arcsec
  - 4 - 800 x 800 pixel arrays – CCD's

- May 2009 – Present WFC III
  - Max. Resolution .04 arcsec
  - 2 - 2048×4096 pixel array
  - 1 – 1 meg x 1 meg IR array

Wide Field and Planetary Camera II



Imaging the Moon

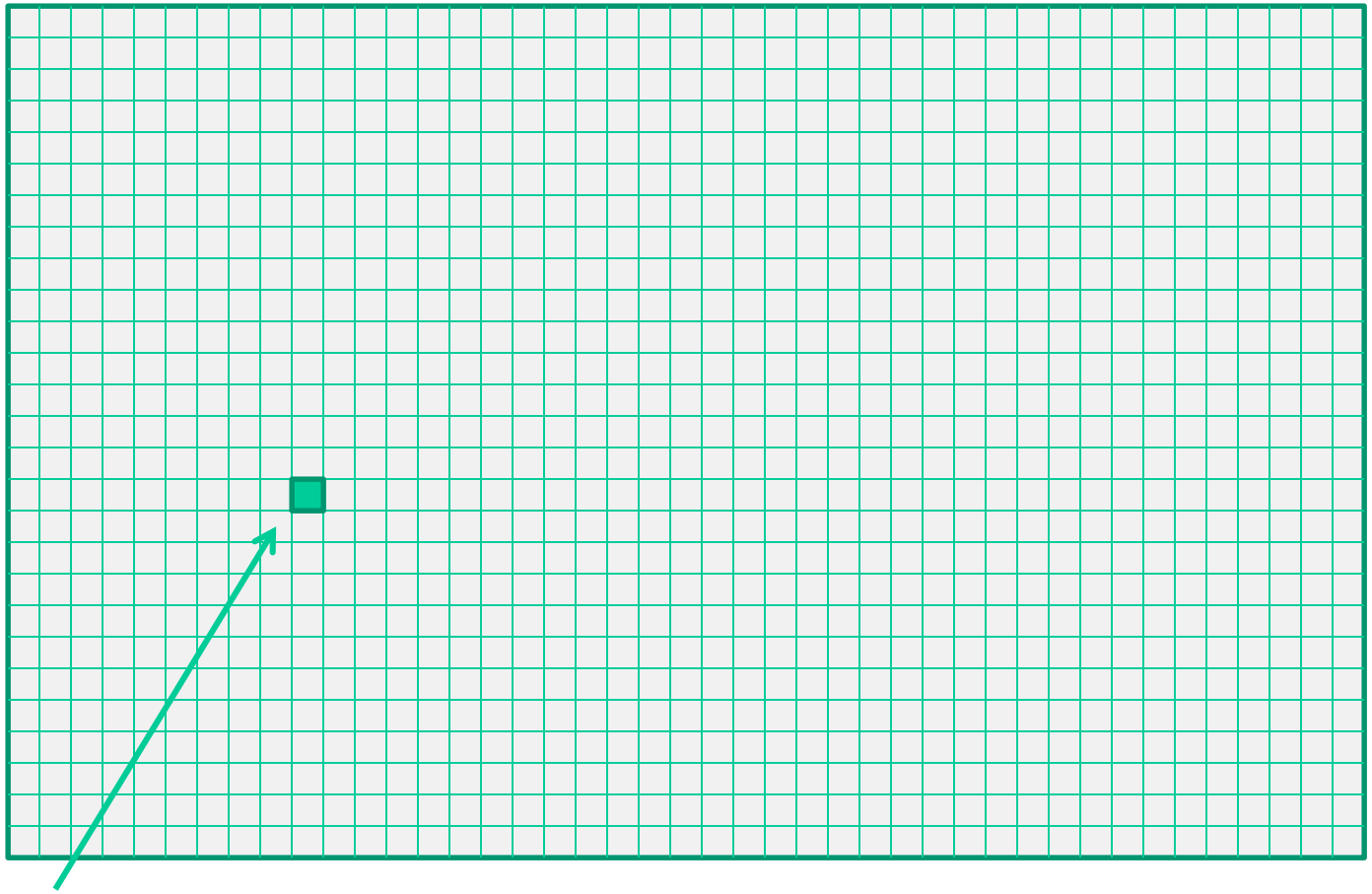


Pointing Hubble

In order to take images of distant, faint objects, Hubble must be extremely steady and accurate. The telescope is able to lock onto a target without deviating more than 7/1000th of an arcsecond or 7 milliarcseconds.

- Circle = 360 degrees, therefore 1^{o} = 1/360 of a circle
- An arcminute = 1/60 of a degree
- An arcsecond = 1/60 of an arcminute = 1/3,600 of a degree
- 7/1,000 of an arcsecond = 7/3,600,000 of a degree or about **$1/500{,}000^{o}$**

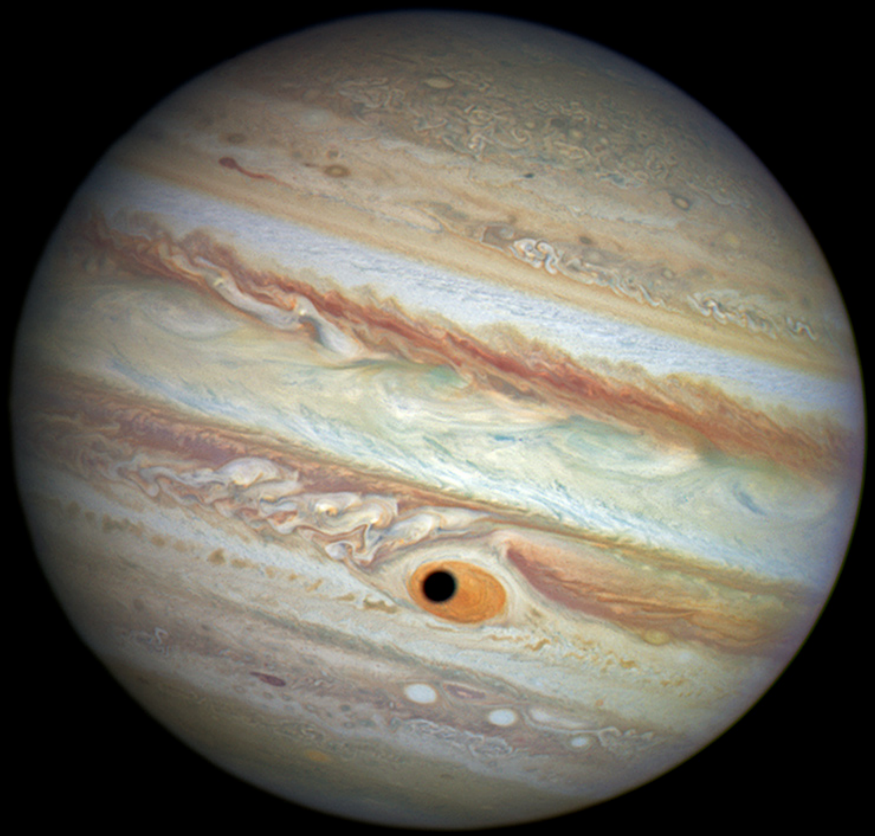
Charge-Coupled Device (CCD) for the Planetary Camera



1 pixel has a .043 x .043” FOV

MARS

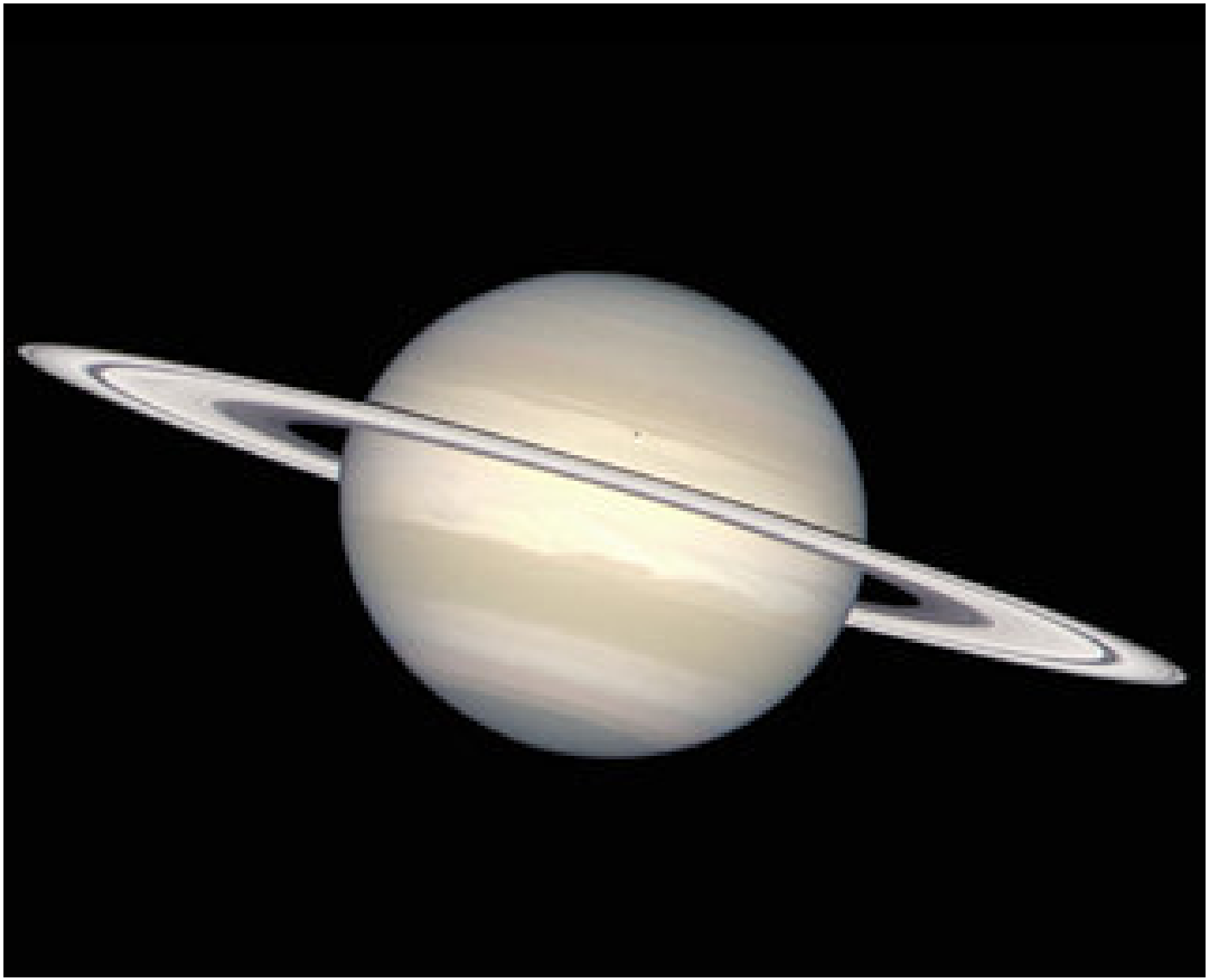
Jupiter's Great Red Spot and Ganymede's Shadow



Hubble Heritage

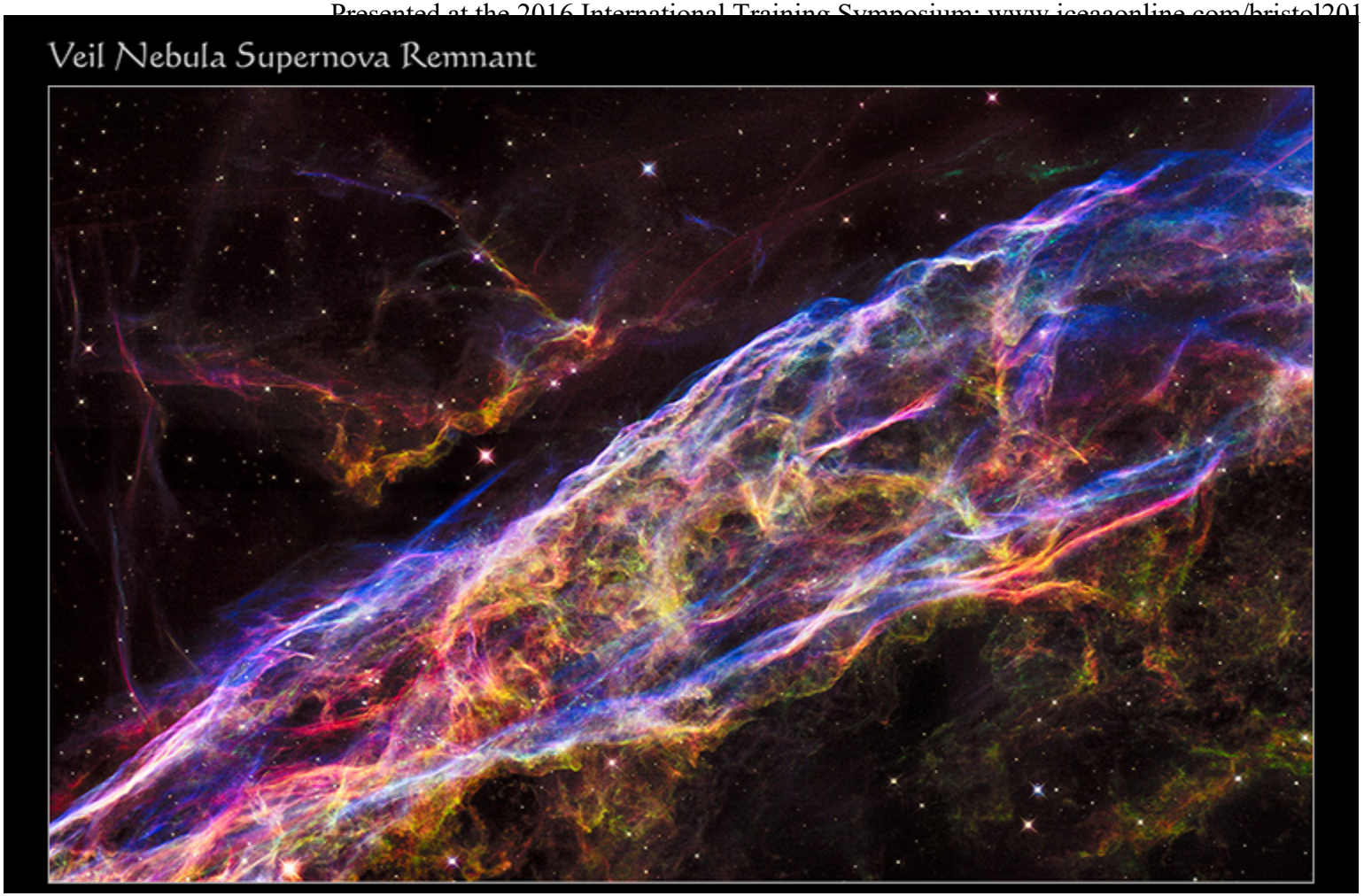
NASA and ESA • *Hubble Space Telescope* • WFC3/UVIS • STScI-PRC14-31b

SATURN



Hubble used WFC filters tuned to the specific colors of fluorescing sulfur, hydrogen, and oxygen atoms.

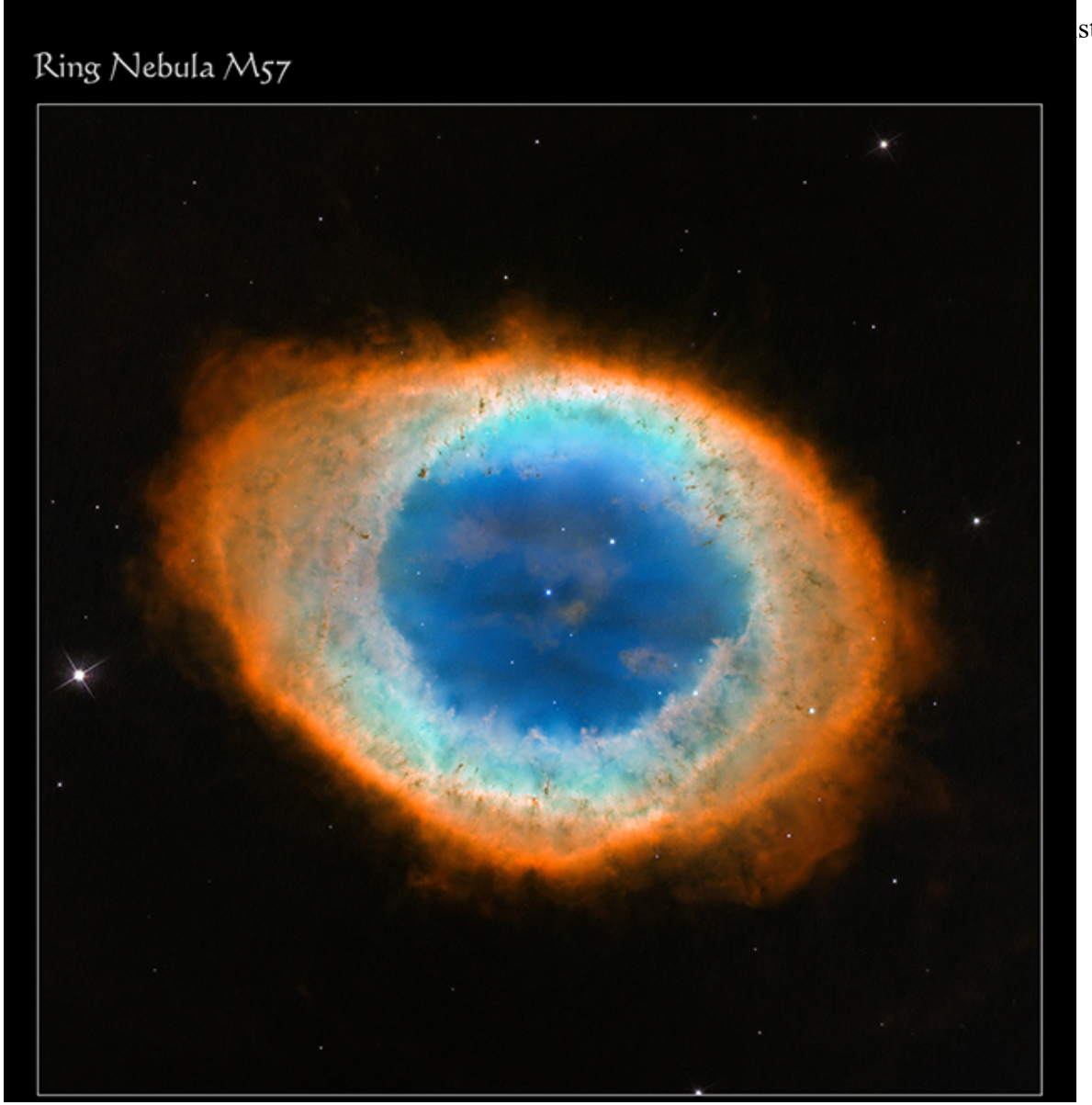
F502N (O III)
F657N (H-alpha)
F673N [S II]
F606W (*V*)
F814W (*I*)



This close-up look unveils wisps of gas, which are all that remain of what was once a star 20 times more massive than our sun. The fast-moving blast wave from the ancient explosion is plowing into a wall of cool, denser interstellar gas, emitting light. In this image, red corresponds to the glow of hydrogen, green from sulfur, and blue from oxygen.

Eagle Nebula -- Pillars of Creation

This image is a composite of separate exposures acquired by the WFC3 instrument on the Hubble Space Telescope. Several filters were used to sample and narrow wavelength ranges. The color results from assigning different hues (colors) to each monochromatic (grayscale) image associated with an individual filter. In this case, assigned colors are:
F502N ([O III])blue
F657N (Hα + [NII])green
F673N ([S II])red



In the image, the deep blue color in the nebula's center is emitted from atoms of helium. The inner ring's sea-green glow is produced by hydrogen and oxygen, while the red of the outer ring traces nitrogen. The darker orange comes from sulfur.

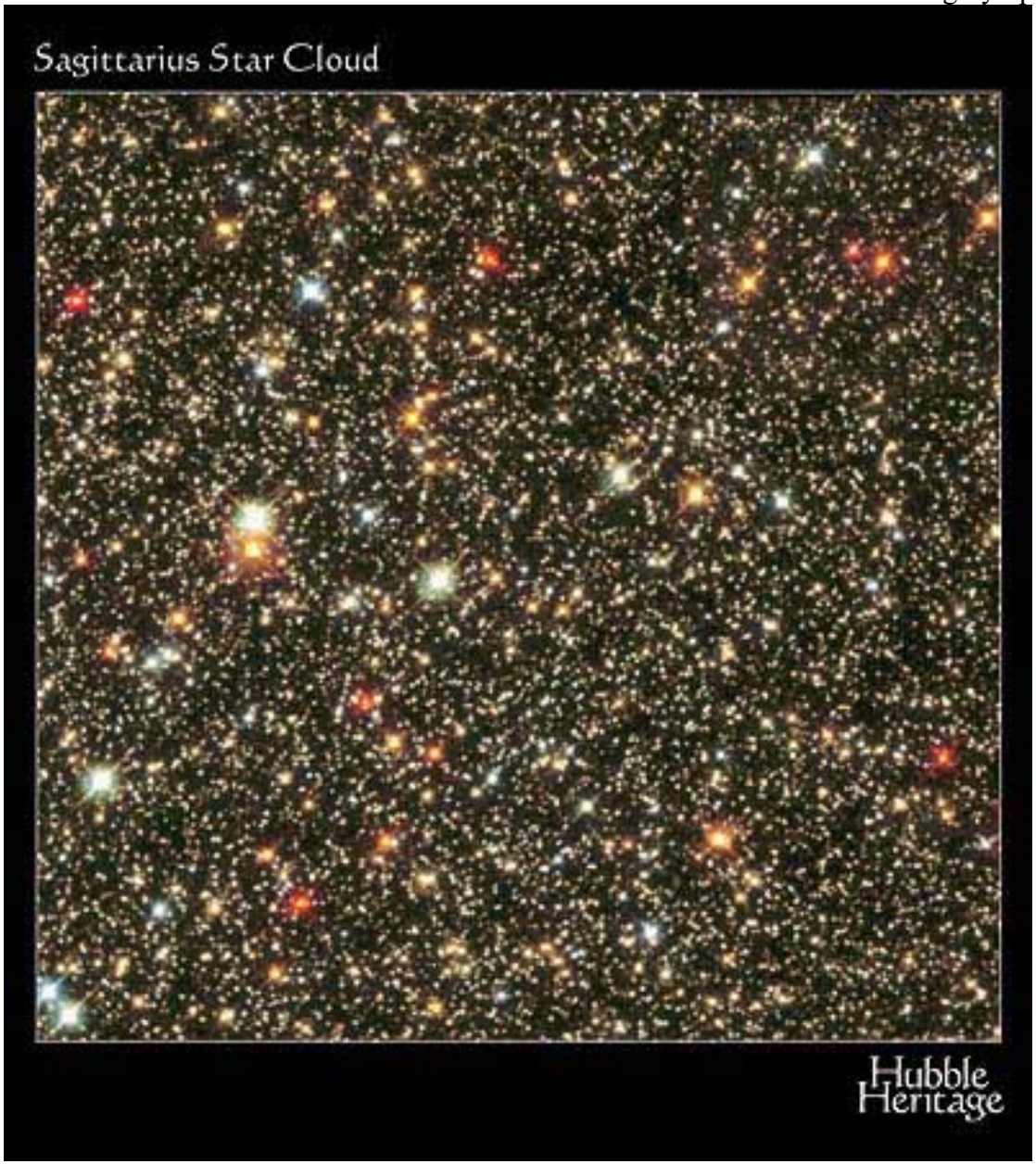
Spirograph Nebula

Nebula lies about 2,000 light-years from Earth.

A false-color representation, through filters that isolate light from various chemical elements. Red shows emission from ionized nitrogen (the coolest gas in the nebula, located furthest from the hot nucleus), green shows emission from hydrogen, and blue traces the emission from ionized oxygen (the hottest gas, closest to the central star).

Milky Way -- Center

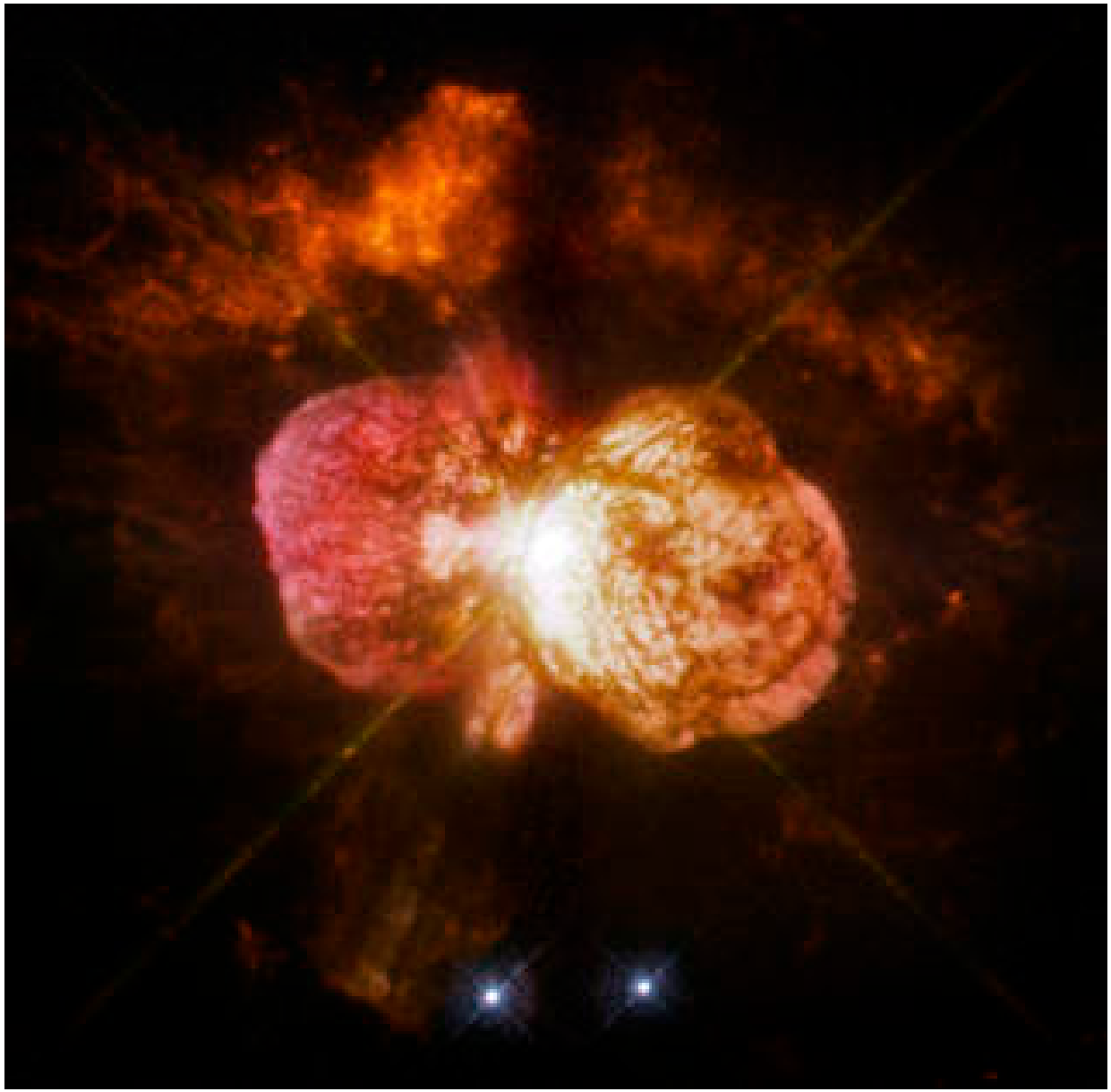
Yellow represents the near-infrared observations of Hubble. Red represents the infrared observations of Spitzer. Blue and violet represent the X-ray observations of Chandra. In this image, violet represents lower energy X-rays and blue indicates higher energy.

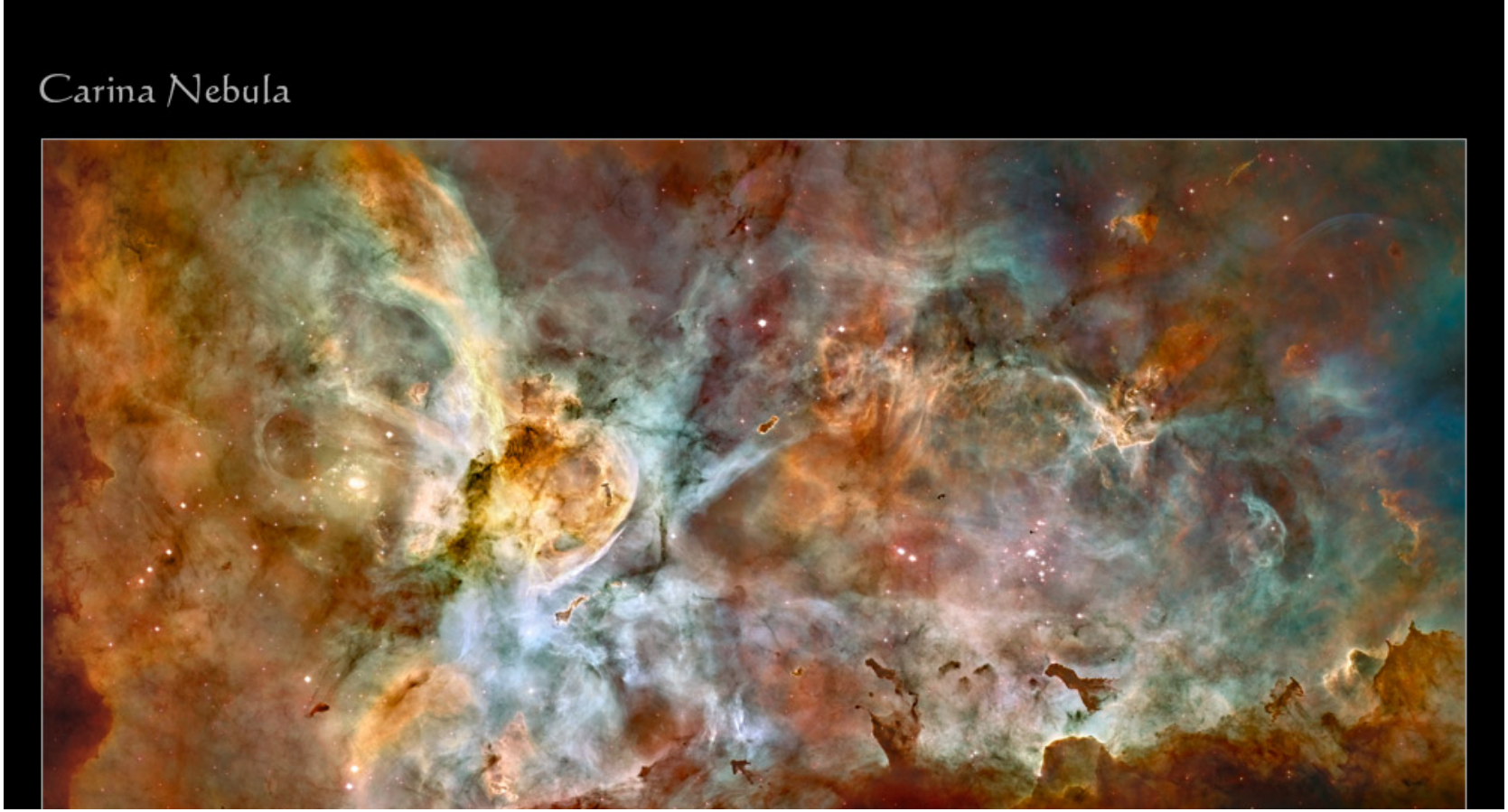


A keyhole view towards the heart of our Milky Way Galaxy, where a dazzling array of stars reside. Most of the view of our galaxy is obscured by dust. Hubble peered into the Sagittarius Star Cloud, a narrow, dust-free region, providing this spectacular glimpse of a treasure chest full of stars.

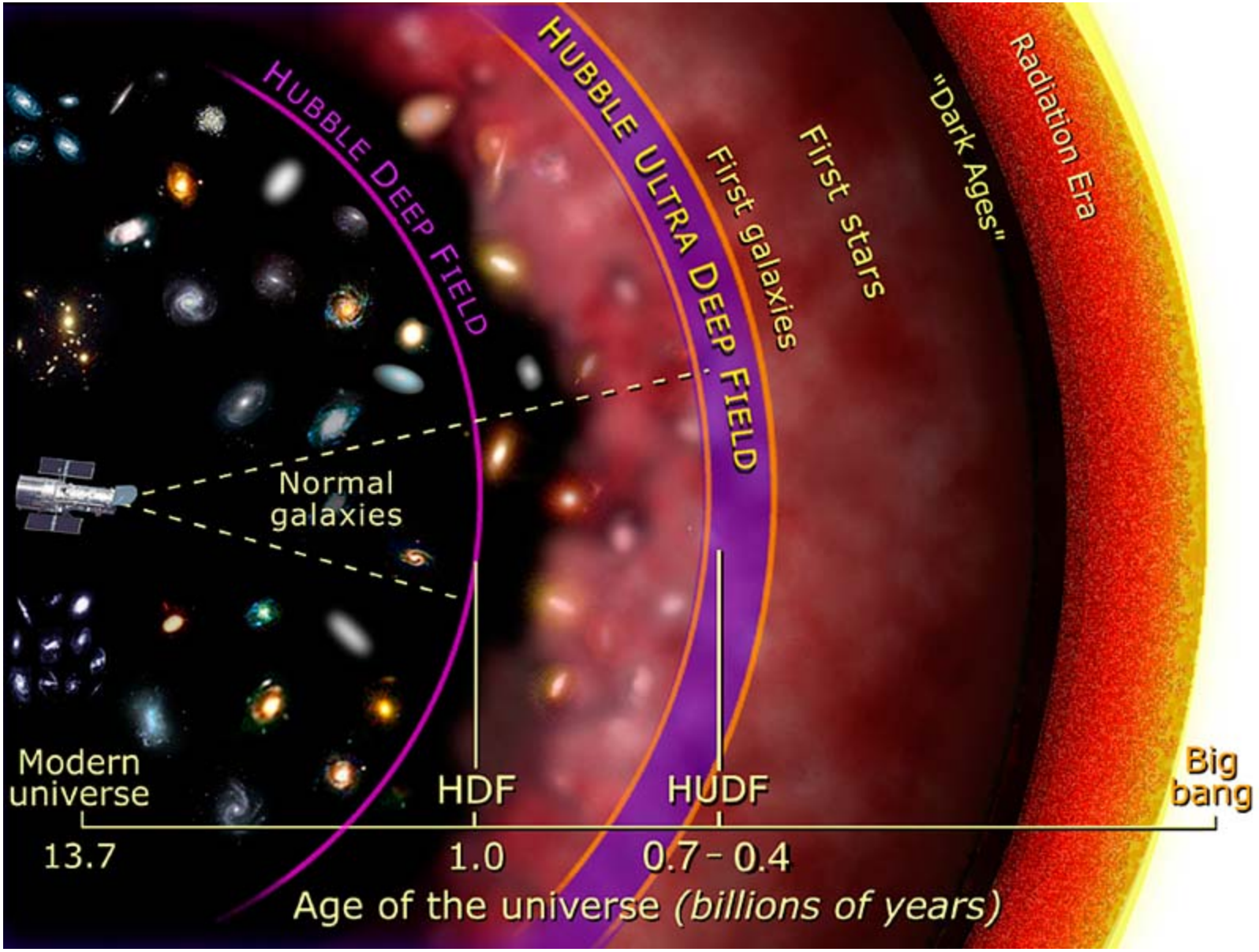
This is a true-color image. It is 13.3 light-years across or 3 times the distances from the sun to our nearest star.

Eta Carinae

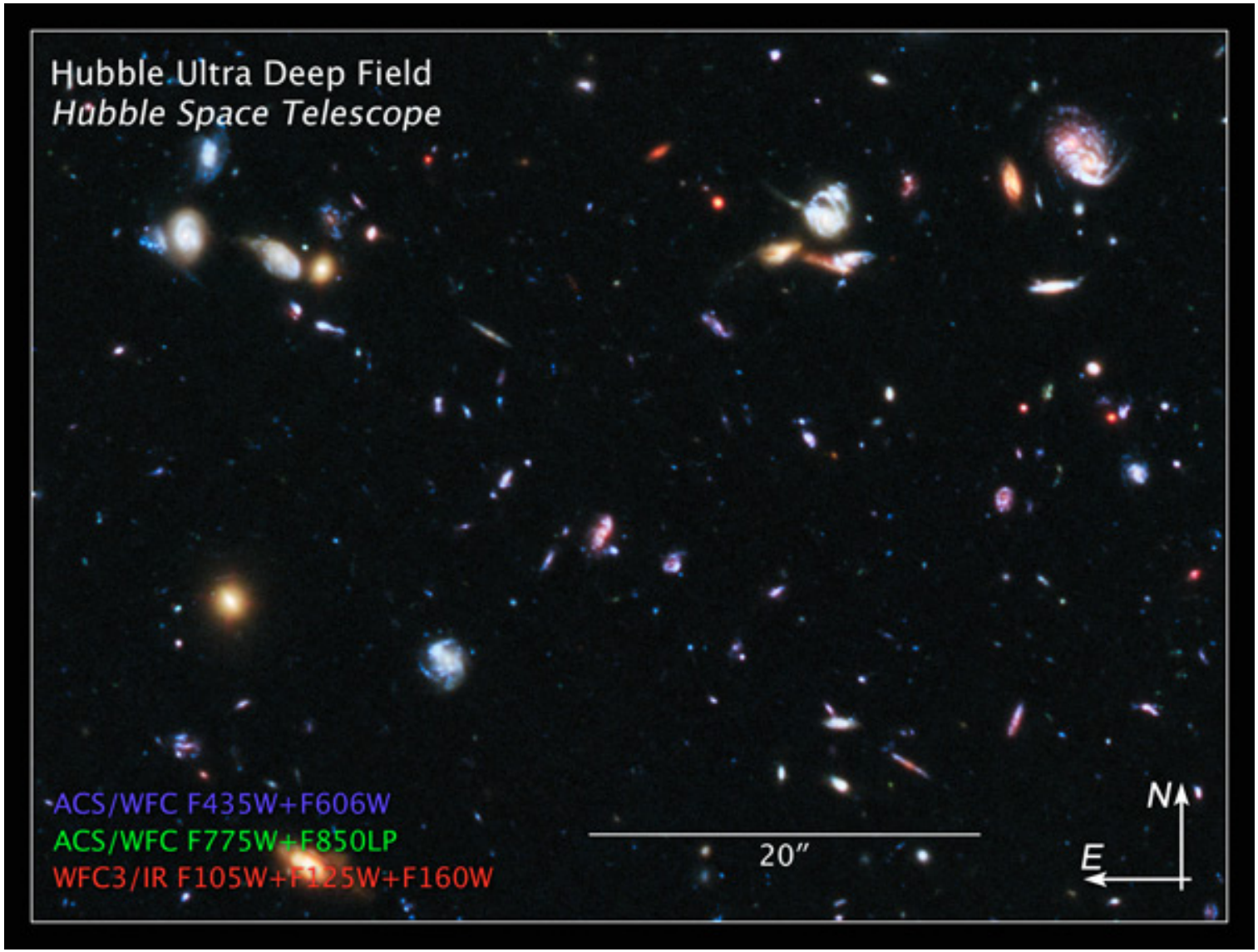




Hubble's view of the nebula shows star birth in a new level of detail. The fantasy-like landscape of the nebula is sculpted by the action of outflowing winds and scorching ultraviolet radiation from the monster stars that inhabit this inferno. The immense nebula **contains at least a dozen brilliant stars that are roughly estimated to be at least 50 to 100 times the mass of our Sun**. The most unique and opulent inhabitant is the star Eta Carinae, at far left. Eta Carinae is in the final stages of its brief and eruptive lifespan, as evidenced by two billowing lobes of gas and dust that presage its upcoming explosion as a titanic supernova.


Hubble Deep Field
Hubble Ultra Deep Field
First galaxies
First stars
"Dark Ages"
Radiation Era
Normal galaxies
Modern universe
HDF
HUDF
Big bang
13.7
1.0
0.7 - 0.4
Age of the universe (billions of years)

About 3,000 distinct galaxies could be identified in the images,[11] with both irregular and spiral galaxies clearly visible, although some galaxies in the field are only a few pixels across. In all, the HDF is thought to contain fewer than twenty galactic foreground stars; by far the majority of objects in the field are distant galaxies.[



This image is a composite of many separate exposures made by the ACS and WFC3 instruments on the Hubble Space Telescope using ten different filters. The color results from assigning different hues (colors) to each monochromatic image.