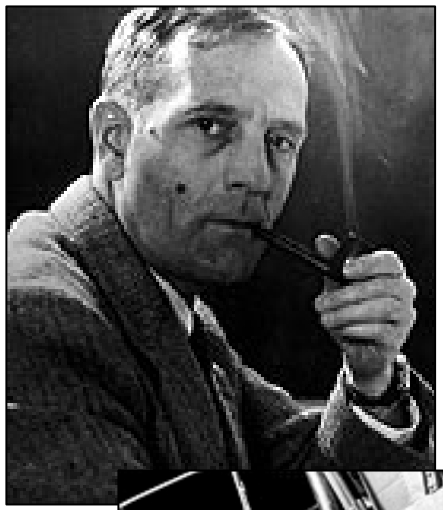
NASA's Hubble Space Telescope and Ball Aerospace

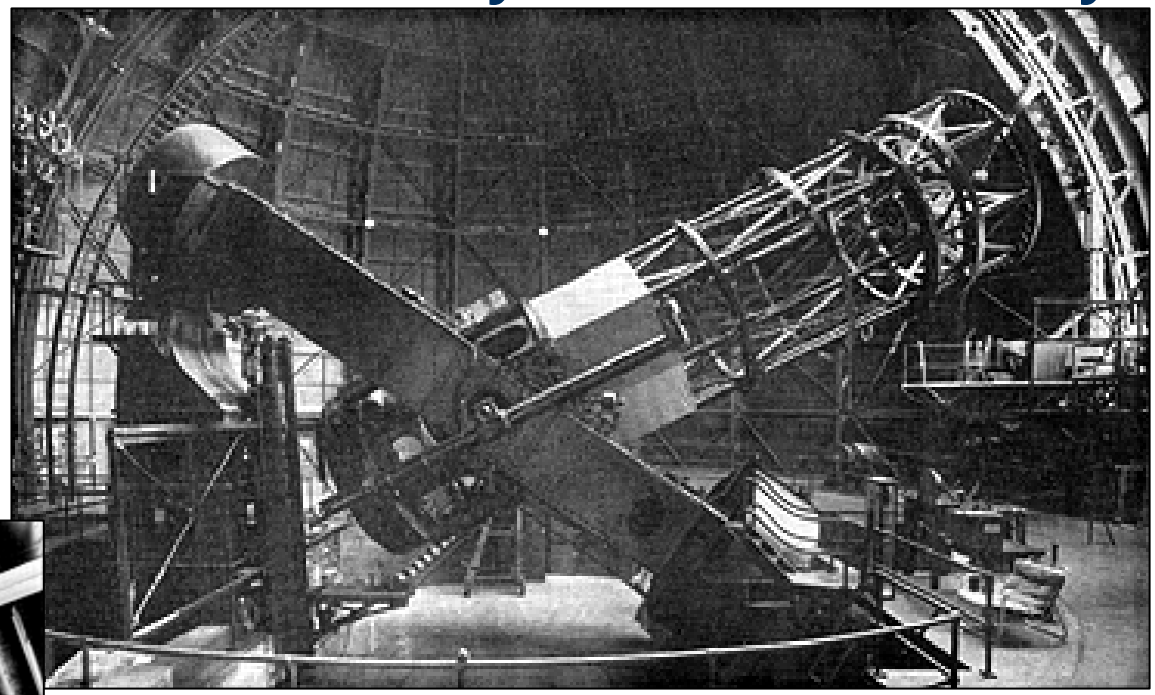
Dennis Ebbets

With Space Shuttle Discovery, February, 1997

Eat. Drink. Imagine.

Edwin Hubble Was An American Astronomer In The Early 20th Century

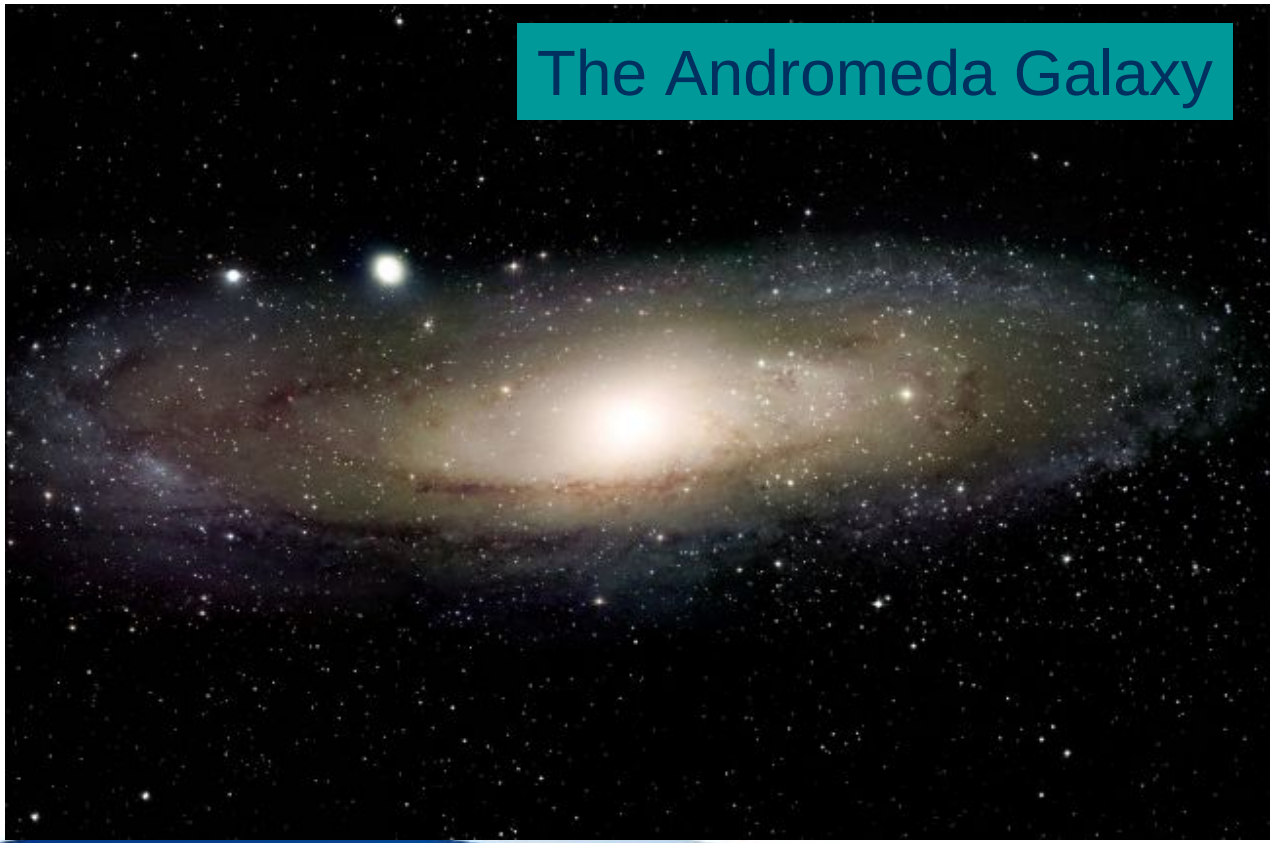




The 100 inch Hooker Telescope at Mt. Wilson Observatory was the most powerful in the world in the early 1900s.

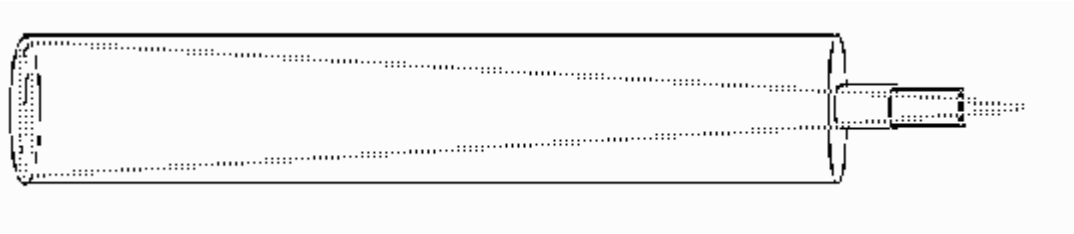
Hubble's Discoveries Revolutionized Our Understanding Of The Universe

The "spiral nebulae" are "island universes" similar to our Milky Way.
The universe is expanding.

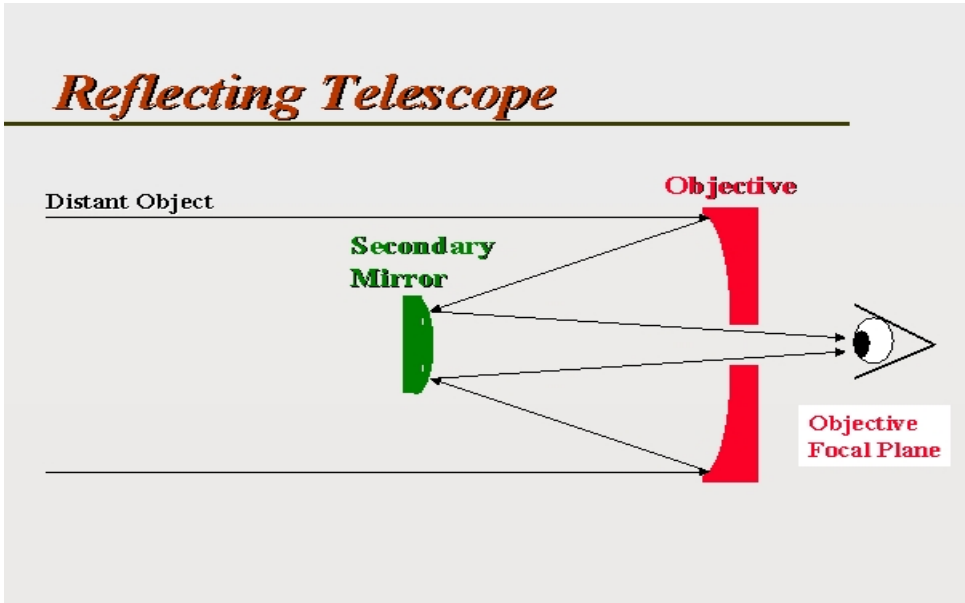


Billions of stars outside our galaxy more than 1 million light years away

There Are Two Basic Designs For Astronomical Telescopes



Refracting telescopes use lenses to collect and focus light.

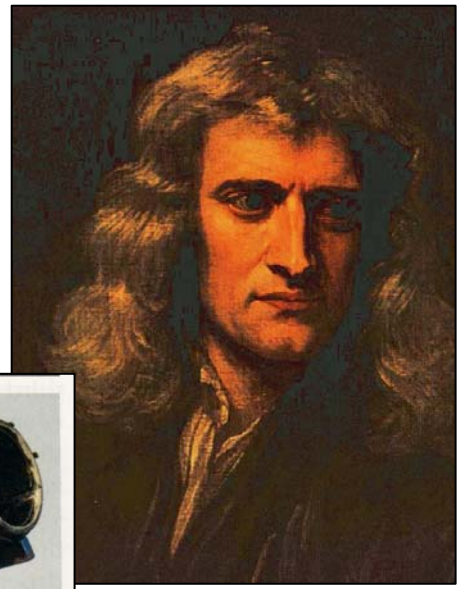


Reflecting telescopes use mirrors.

The HST is a reflecting telescope.

These Telescopes Were Invented In The 17th Century

Galileo demonstrated the refractor in 1611



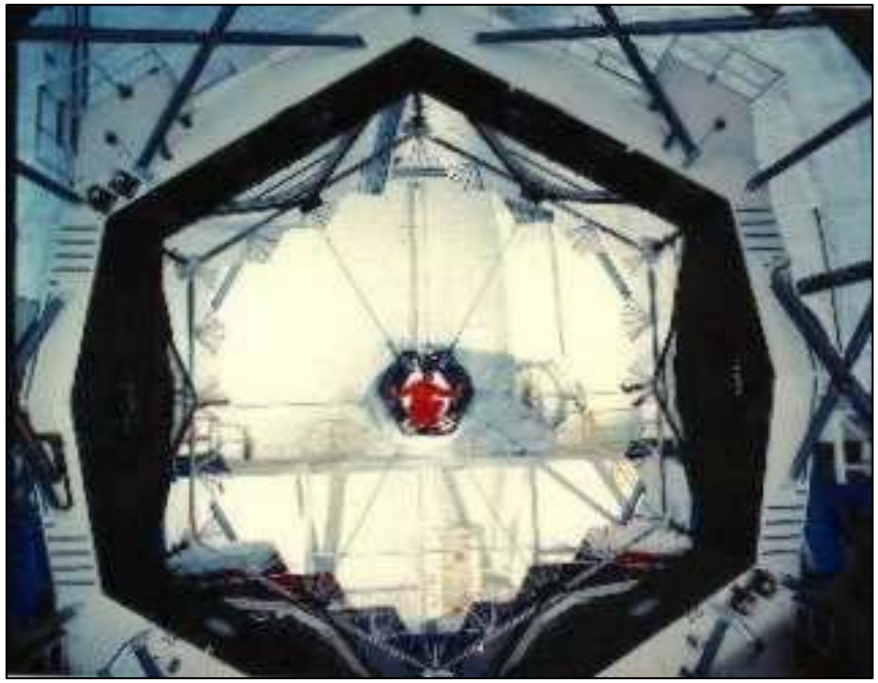
Isaac Newton developed the reflector in 1668

Refractors Are Quality Telescopes For Amateurs And Professionals

Watching Comet Halley 1986

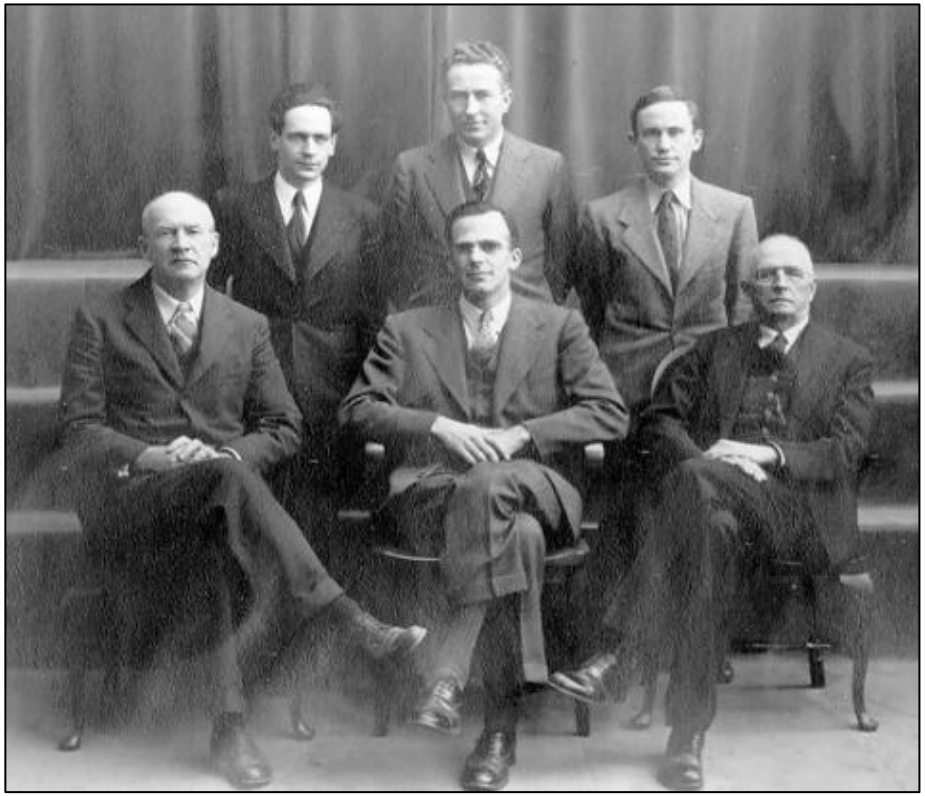
Yerkes 40 inch is world's largest. Hubble PhD

The World's Largest Telescopes Are All Reflectors These Days

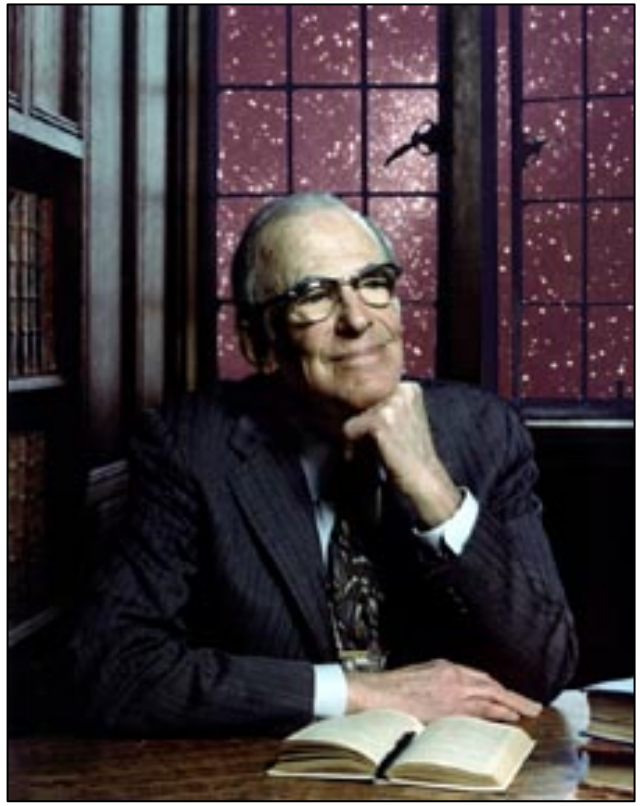


Keck observatory, 10m diameter
36 hexagonal segments
Gemini observatory, 8m diameter
circular monolith

A Space Telescope Was First Proposed In 1946



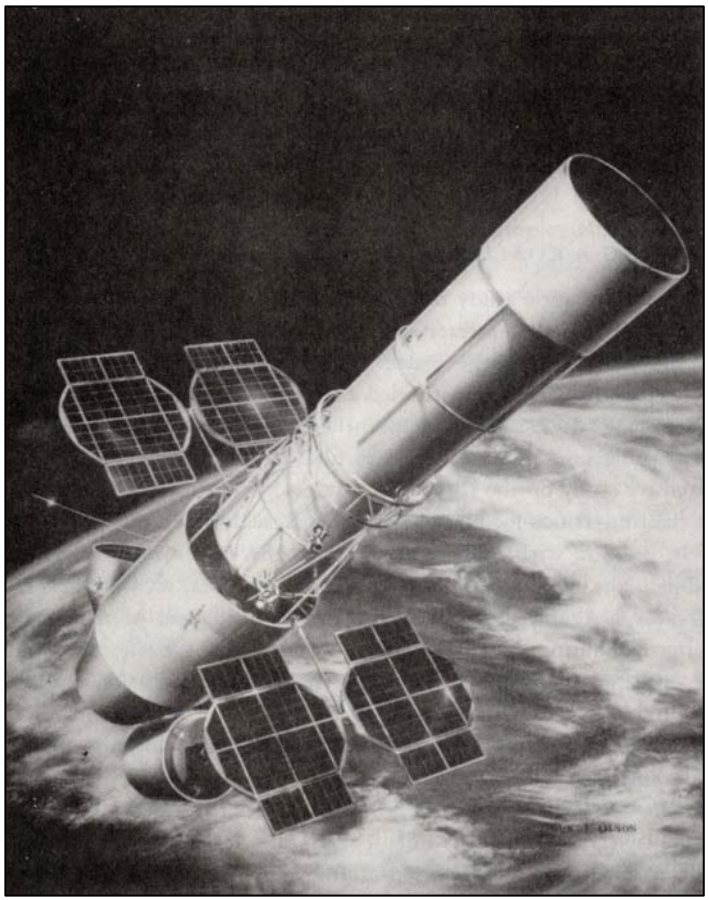
Princeton University
Astronomy Faculty 1949



Lyman Spitzer
1914 - 1997

Eat. Drink. Imagine.

NASA Studied How A Large Space Telescope Could Be Built



The Apollo program developed the capabilities to consider large projects.

Advantages of a telescope in space:

- **Sharper images**
- **All wavelengths**
- **Fainter objects**

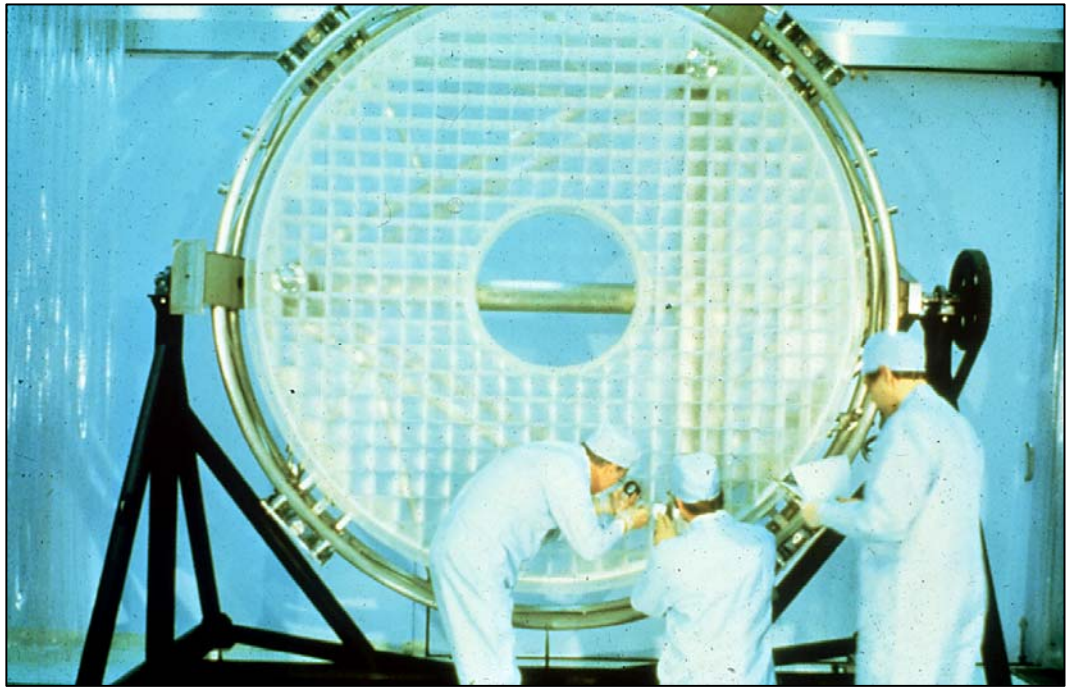
A 1965 design by Boeing included a 3 m telescope in a space station with astronauts and astronomers.

By The Mid 1970s The Basic Design Issues Had Been Settled

Robotic observatory
Reflecting telescope
Shuttle launched
Low earth orbit
15 year mission
Periodic servicing
Largest space telescope

Named in honor of Edwin Hubble

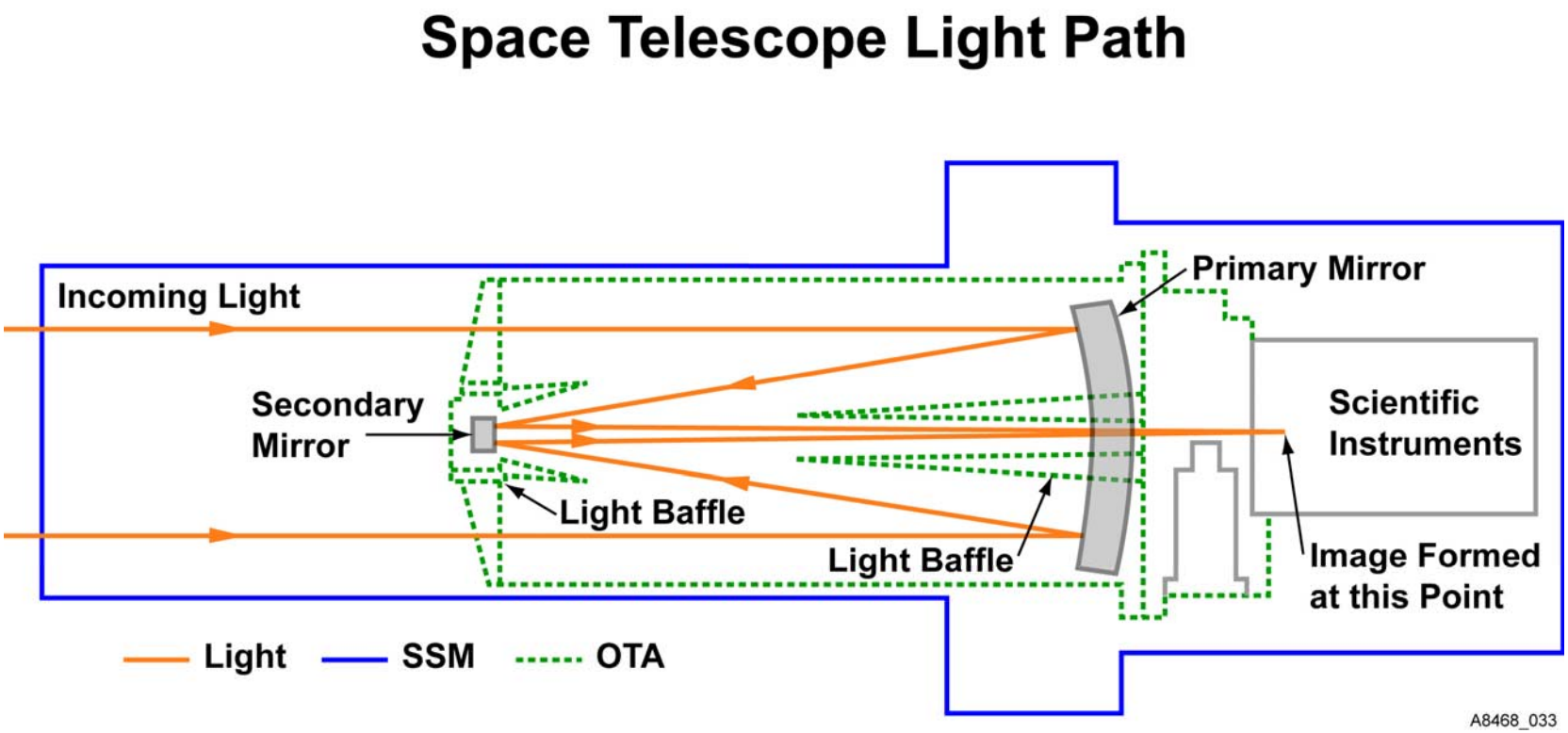
The Primary Mirror Is 2.4 Meters In Diameter



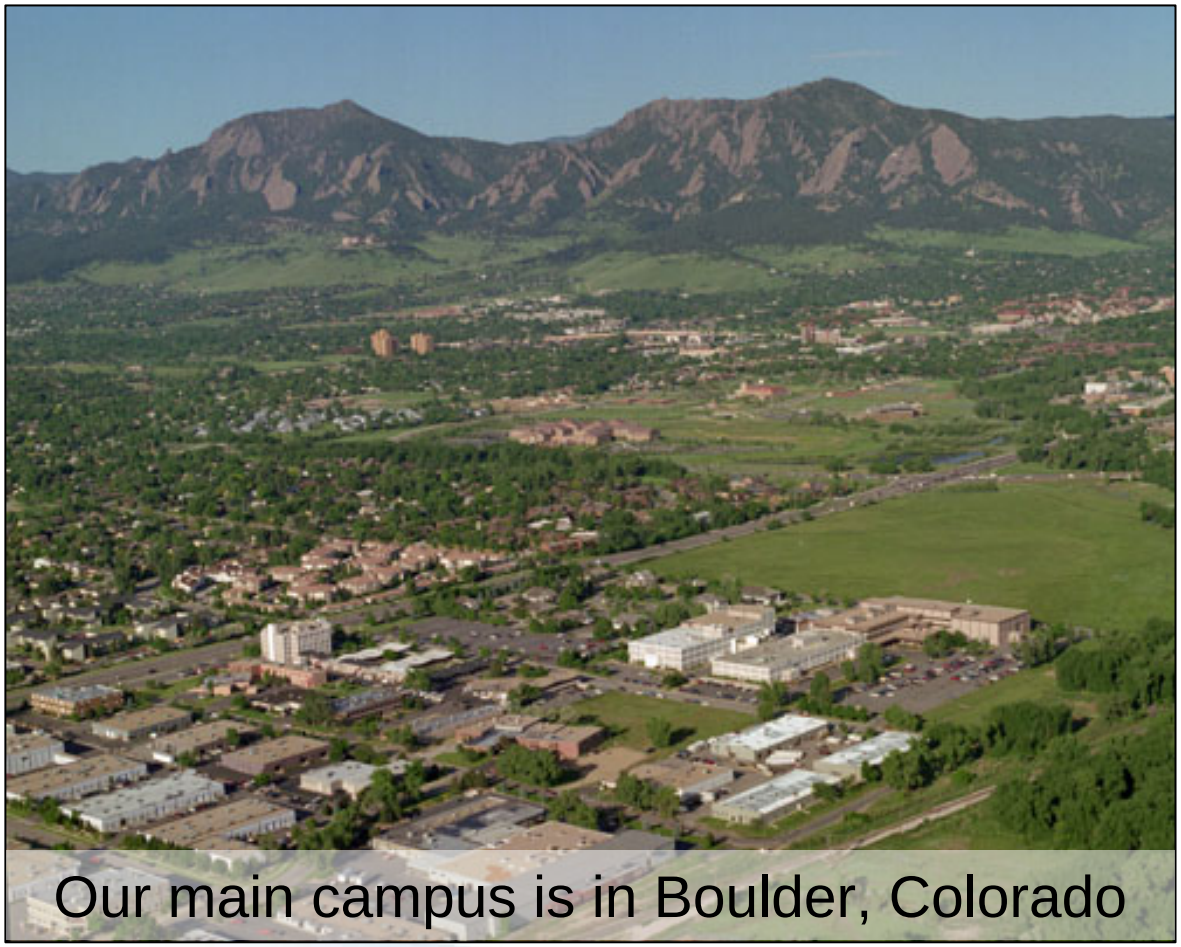
It was built by Perkin-Elmer corporation in Danbury, CT in the early 1980s

Architecture is monolith
Rigid with no figure control

The Optical Concept Is Similar To All Reflecting Telescopes



Ball Aerospace Builds Scientific Instruments For Space Astronomy



Our main campus is in Boulder, Colorado

Eat. Drink. Imagine.

We Built One Of The First Generation Instruments For HST

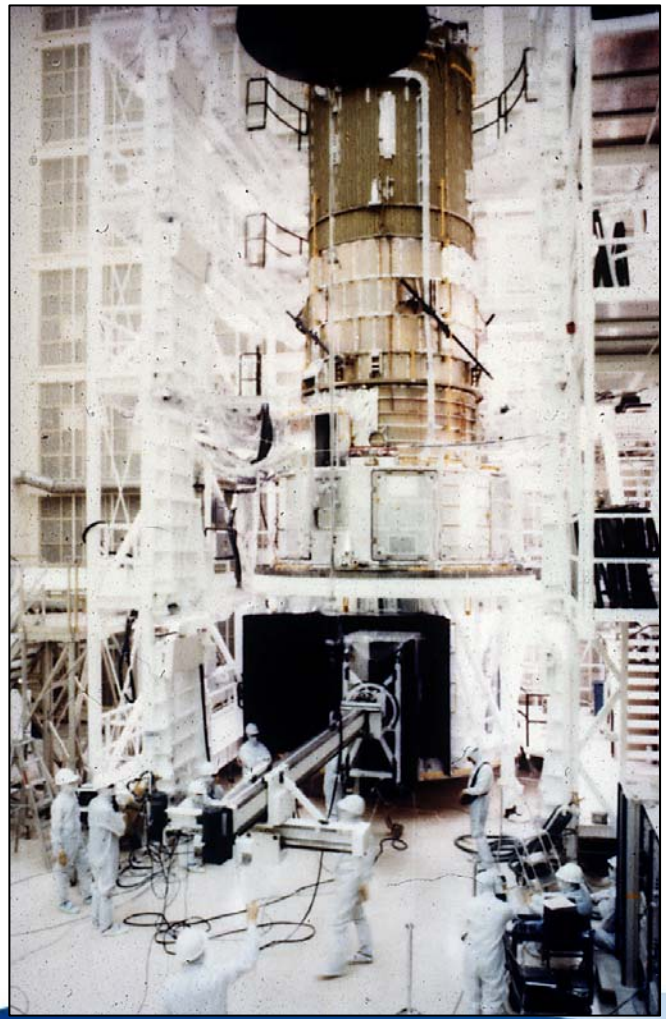
1m x 1m x 2m
800 lbs on earth
5 years to build

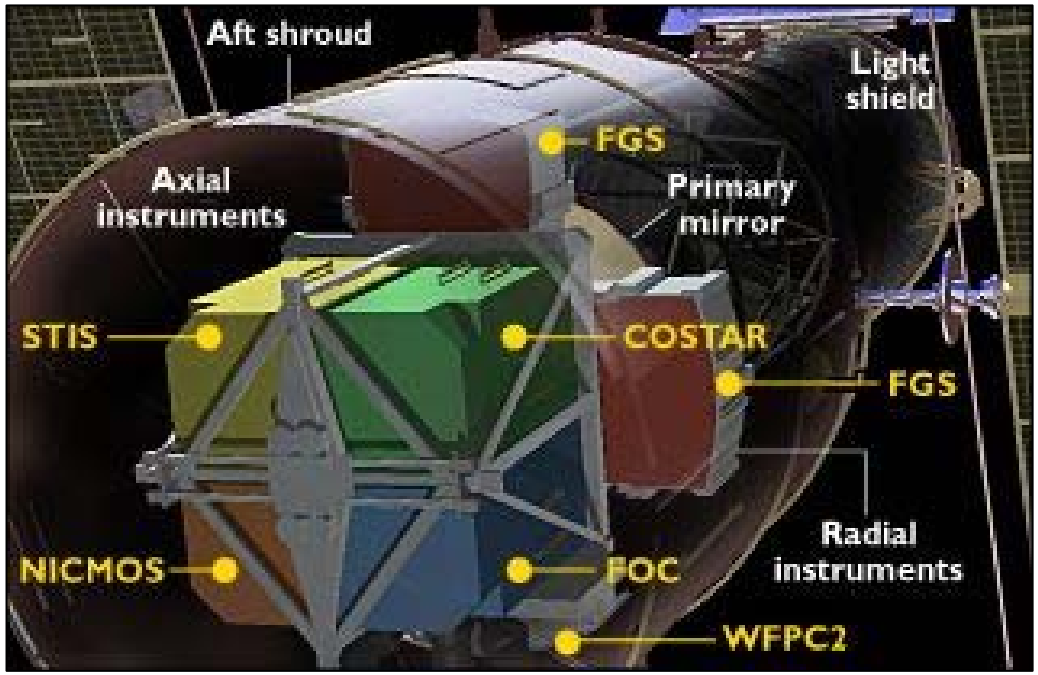
Ultraviolet spectra
high precision data
physical properties
of stars, galaxies &
matter in between

1990 - 1997

Goddard High Resolution Spectrograph

The Instruments Were Integrated Into The Telescope

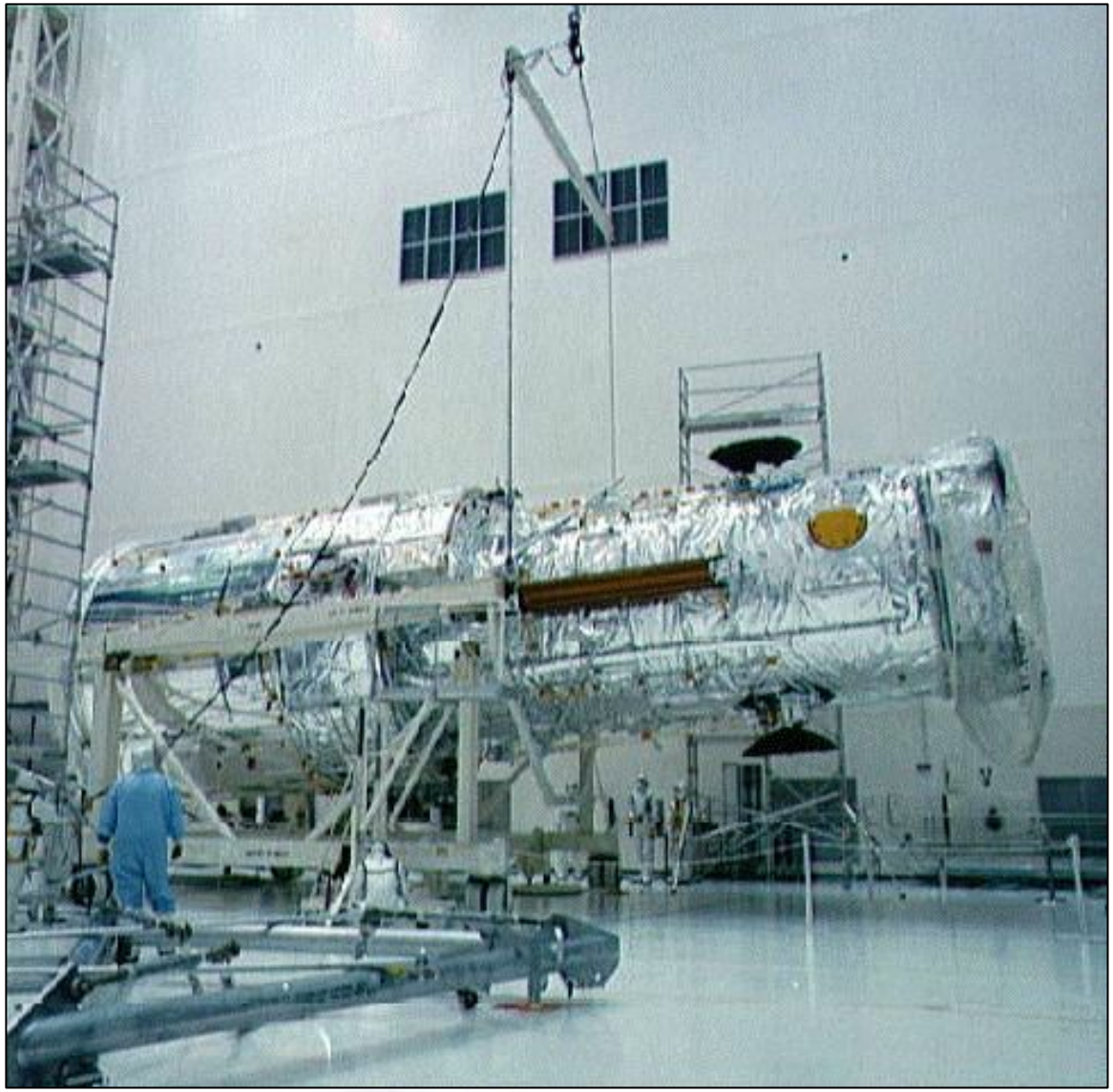




Ball's STIS, NICMOS and COSTAR were installed by astronauts in orbit.

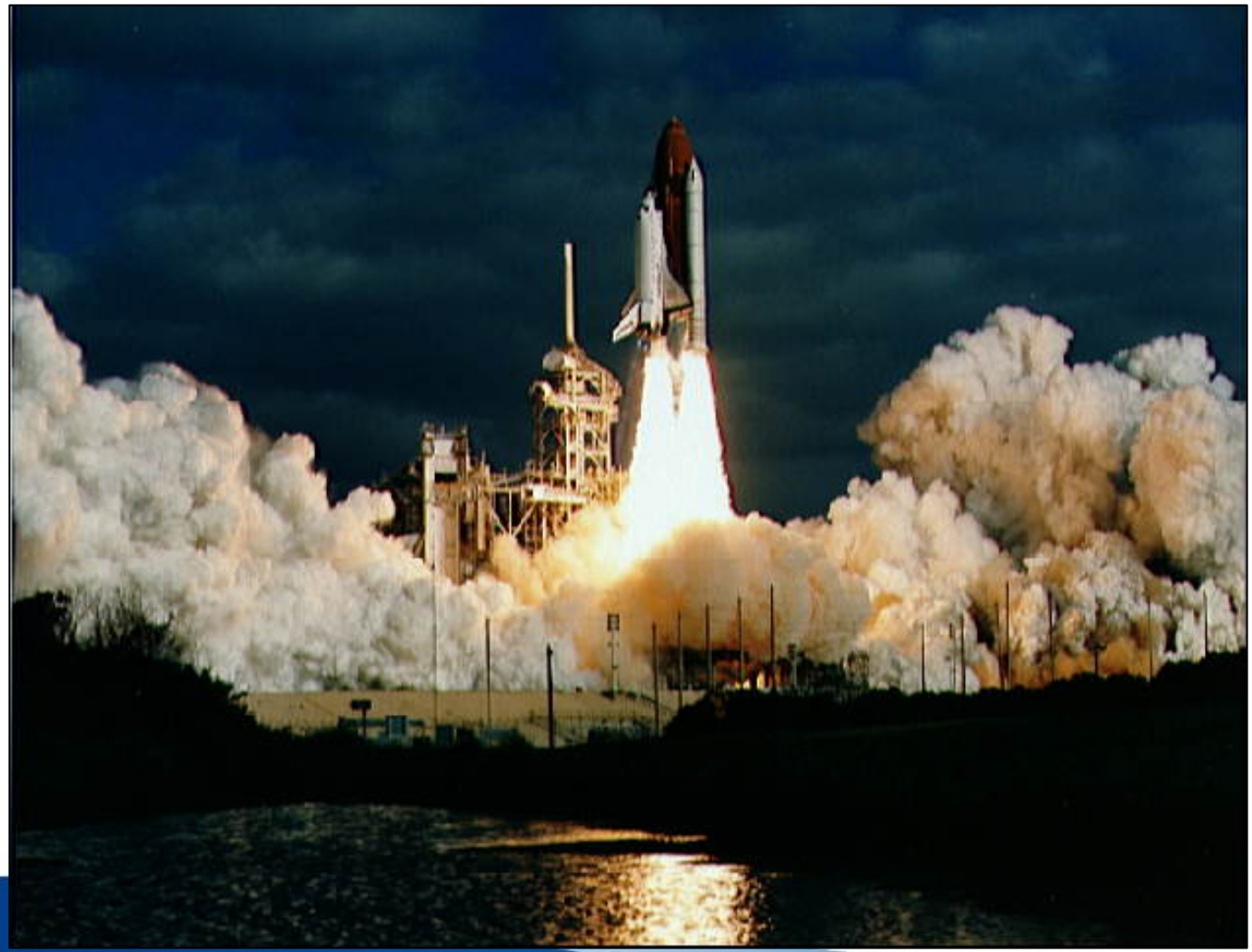
Ball's Goddard High Resolution Spectrograph was installed before launch.

Eat. Drink. Imagine.



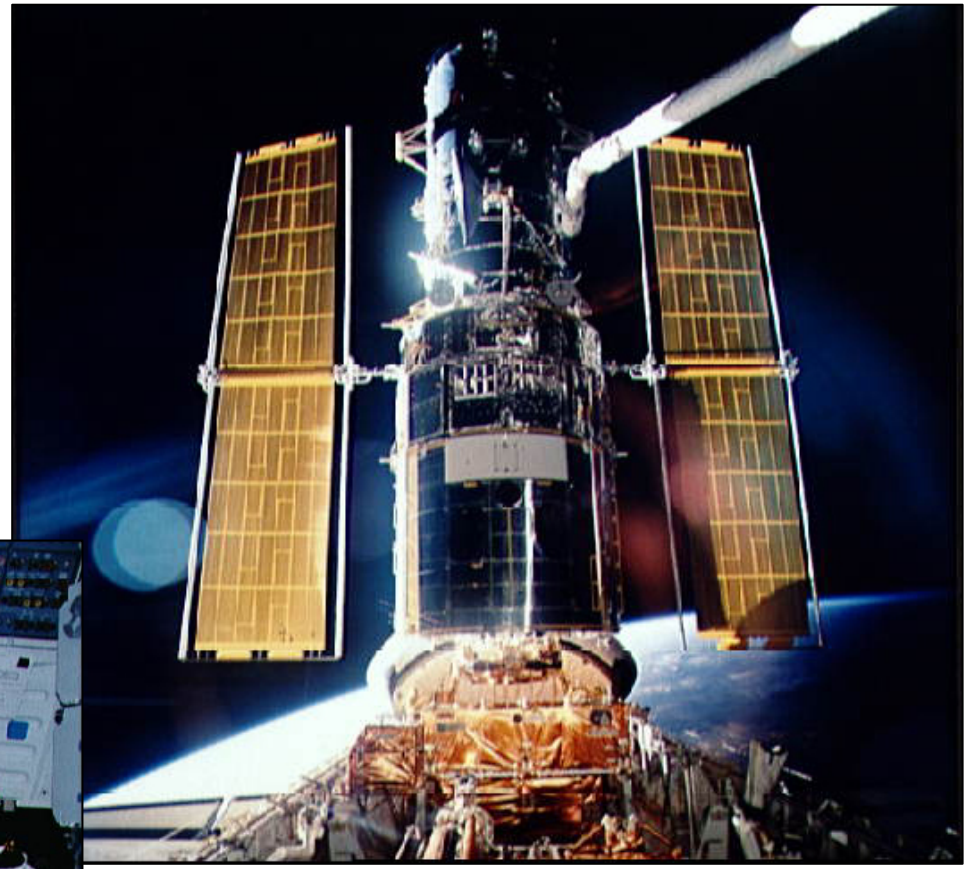
HST was flown to Florida and prepared for launch at Kennedy Space Center

HST Was Launched by Space Shuttle Discovery in April, 1990



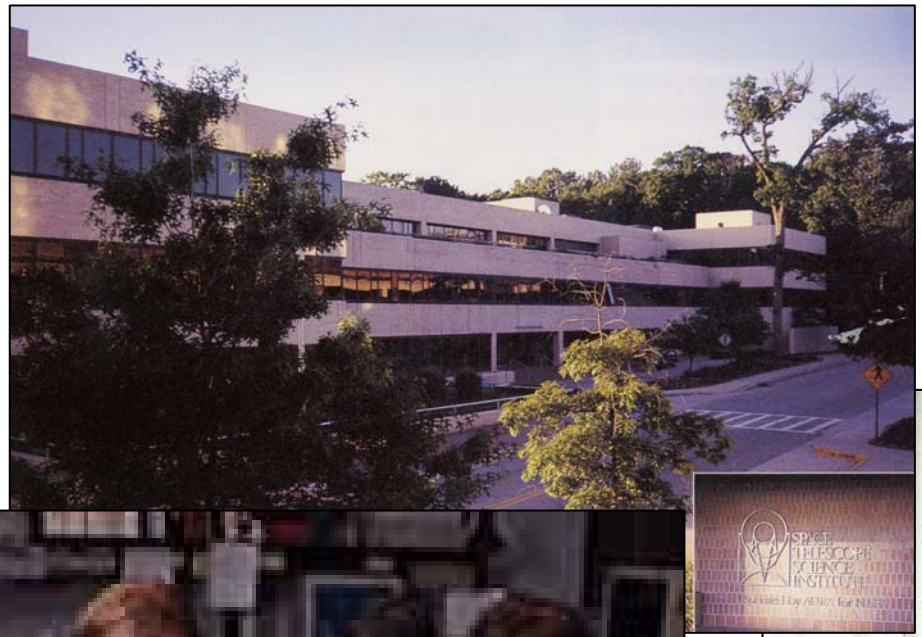
Eat. Drink. Imagine.

It was placed into orbit by Shuttle astronauts



Launched from Cape Canaveral
Altitude about 600 km
Circular orbit
96 minute period
Traveling nearly 18000 mph

HST is Operated From The Space Telescope Science Institute



Observations are planned, scheduled and monitored.
Data are processed and archived.
Guest observers.
EPO activities

Eat. Drink. Imagine.

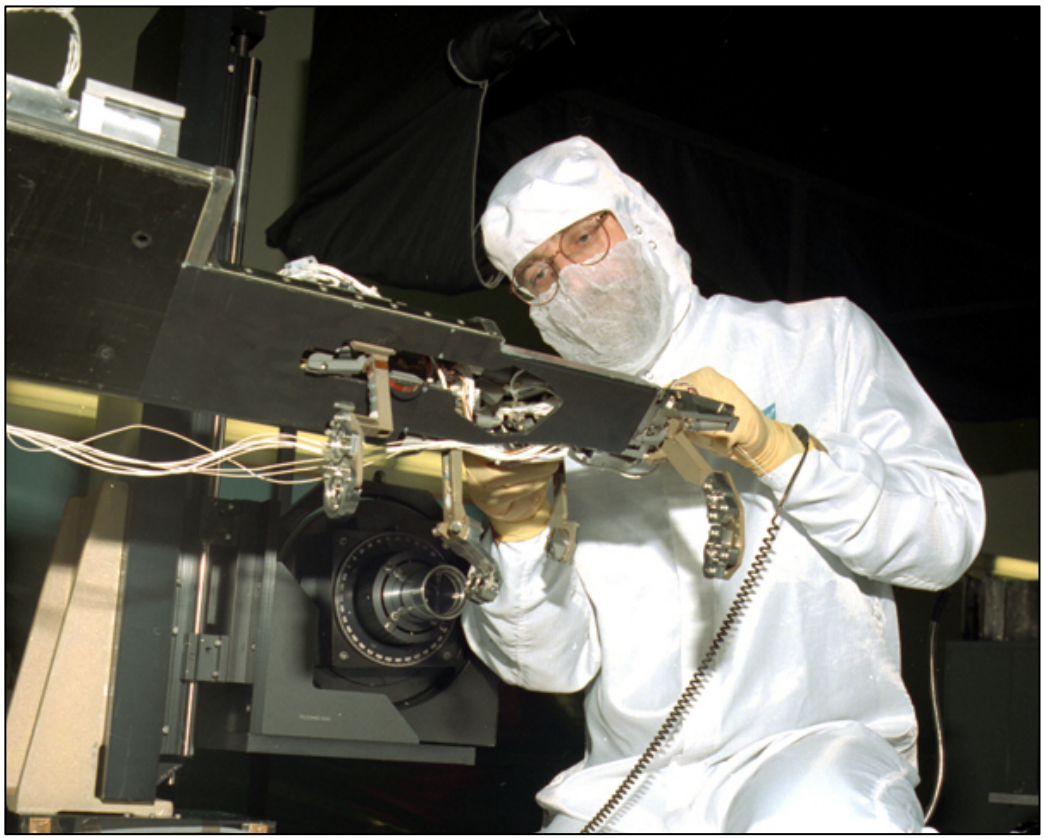
Servicing Missions Will Ensure A Productive 20 Year Lifetime

Replace limited-lifetime items
Repair malfunctions
Update with new technology
Reboost orbit

December 1993
February 1997
December 1999
February 2002

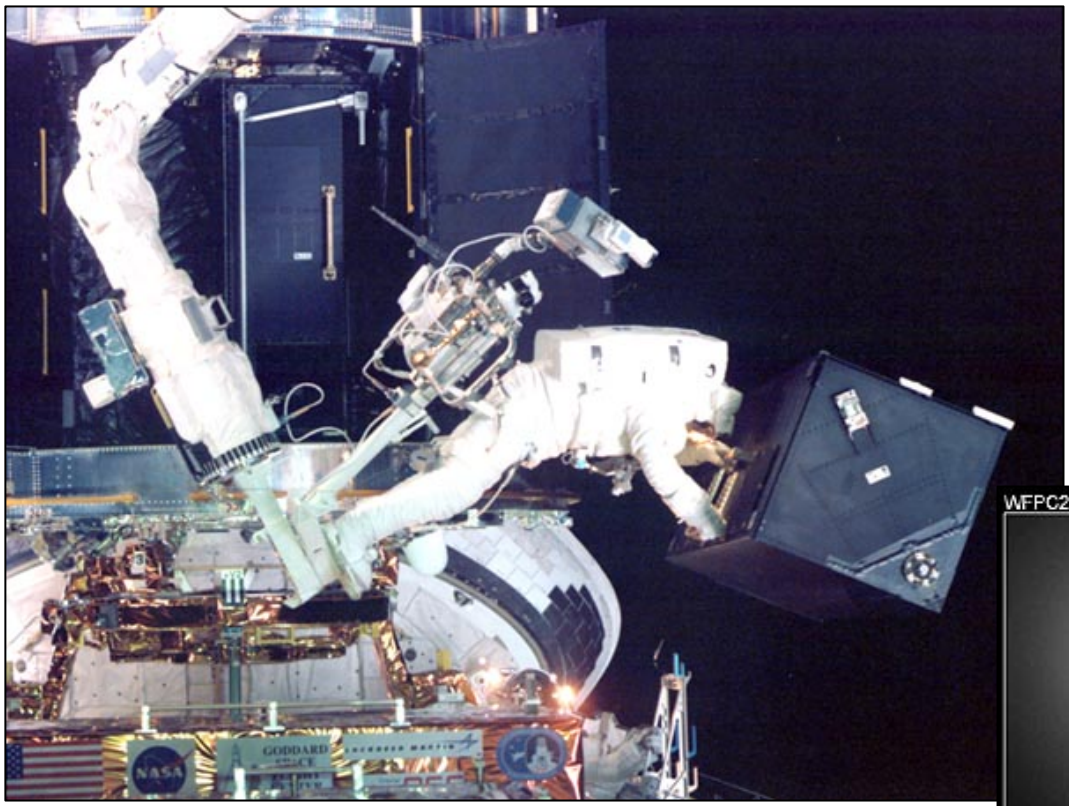
Fall 2008

COSTAR Was The First Replacement Instrument

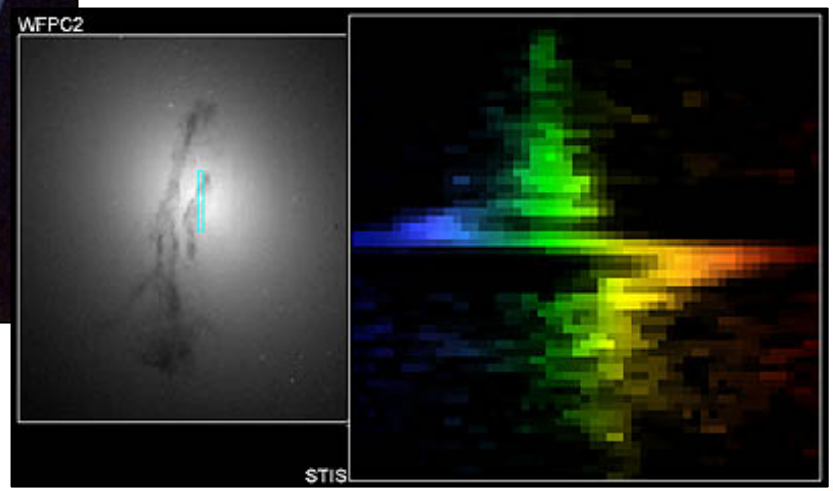


- **C**orrective **O**ptics **S**pace **T**elescope **A**xial **R**eplacement
- Designed quickly to repair optical aberration
- Installed on first service mission in 1993

STIS Was An Advanced Spectrograph That Replaced GHRS



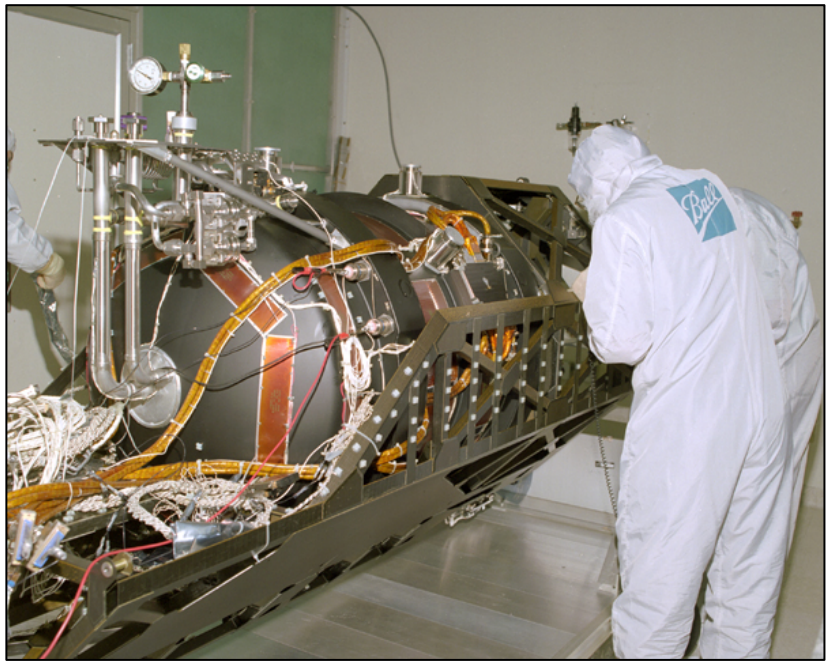
It’s data provided the best proof of the existence of black holes in the centers of galaxies.



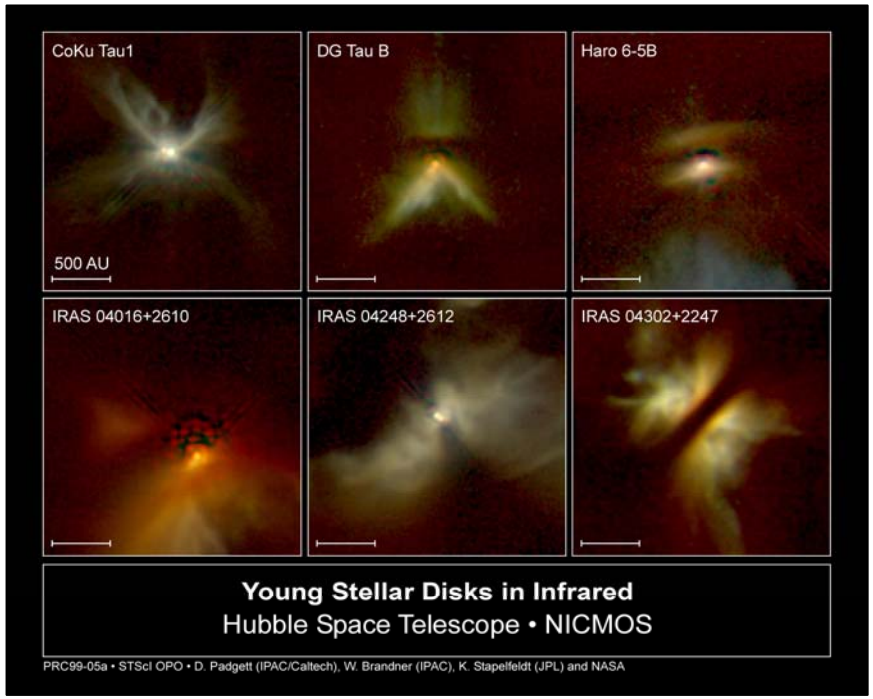
Eat. Drink. Imagine.

NICMOS Was The First Cryogenic Infrared Instrument On HST

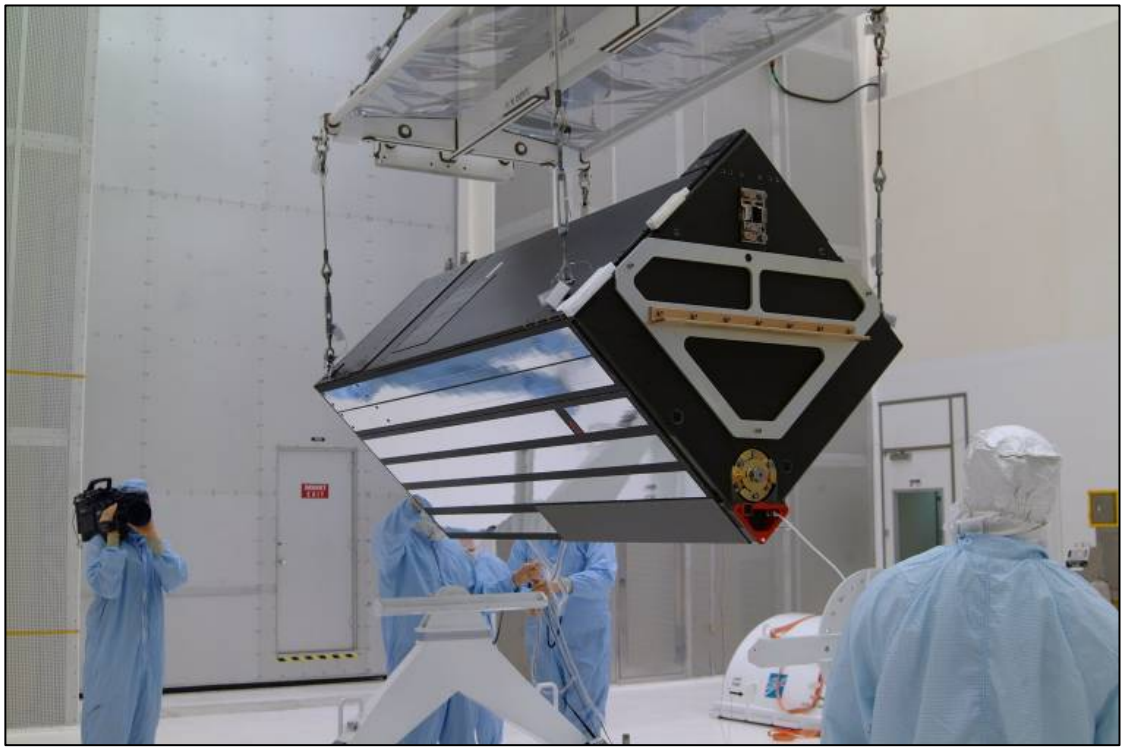
(It's Still Active)

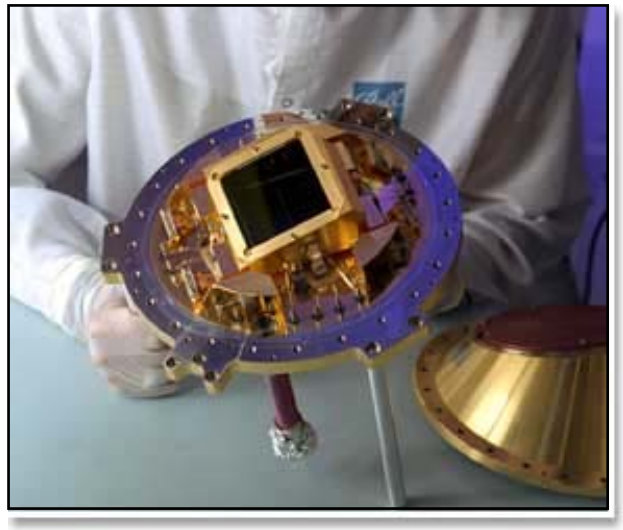


Much of its work involves the formation of stars and planets.



The Advanced Camera For Surveys Was Built At Ball As The Third Generation Imaging Instrument





Eat. Drink. Imagine.

ACS Has Taken Some Of Hubble's Most Spectacular Images

WFC3 Will Be The Primary Imaging Instrument After 2008

- It provides both visible and near infrared access
- It uses the most modern detectors available to astronomers
- Collaboration between Ball and NASA GSFC

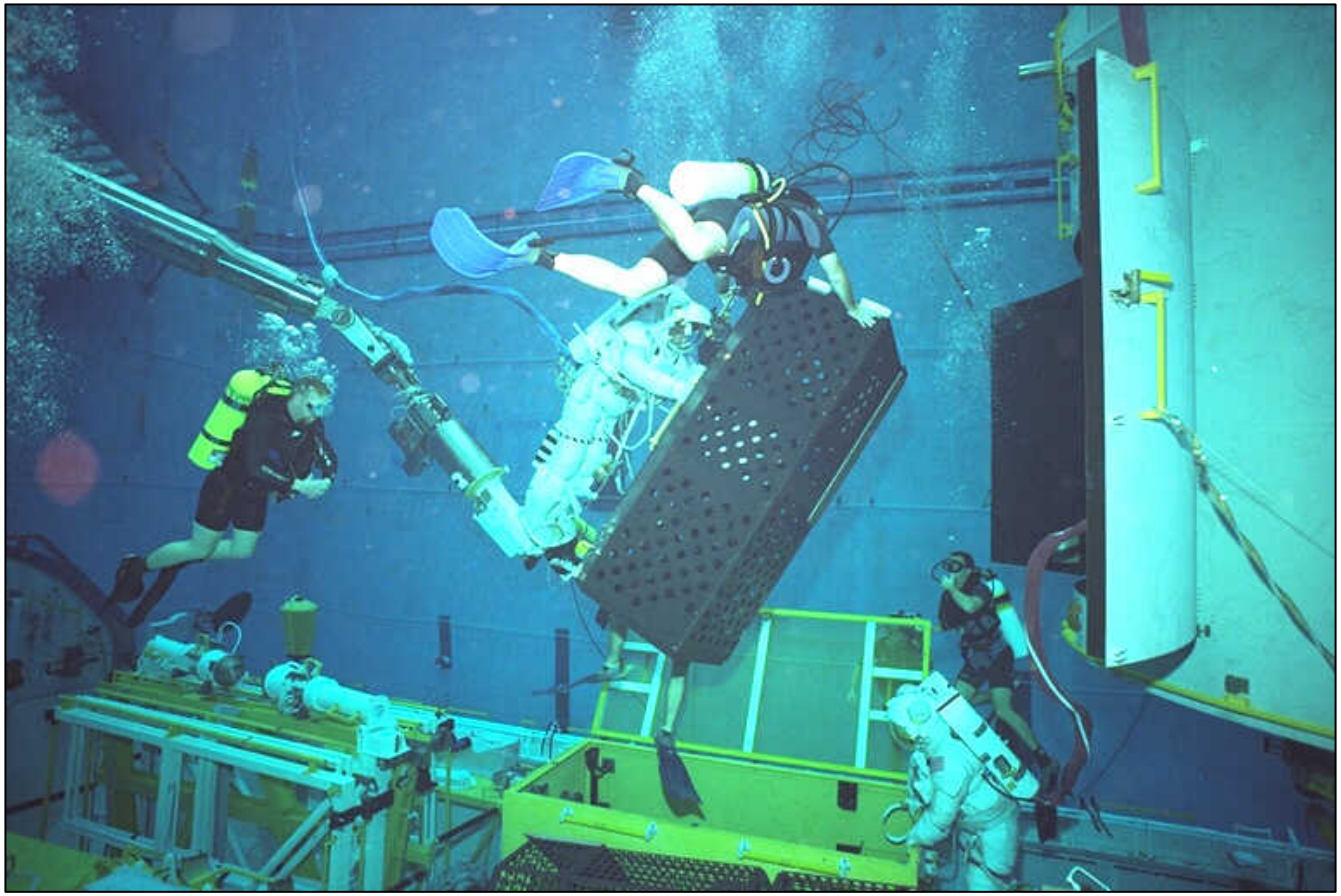
COS Will Be The Most Sensitive UV Spectrograph Ever Flown

- It will replace COSTAR
- It will record spectra of faint quasars, and study the intergalactic medium along the line of sight

We Deliver Fully Qualified Hardware to NASA

Eat. Drink. Imagine.

Astronauts Train Underwater To Simulate Weightlessness



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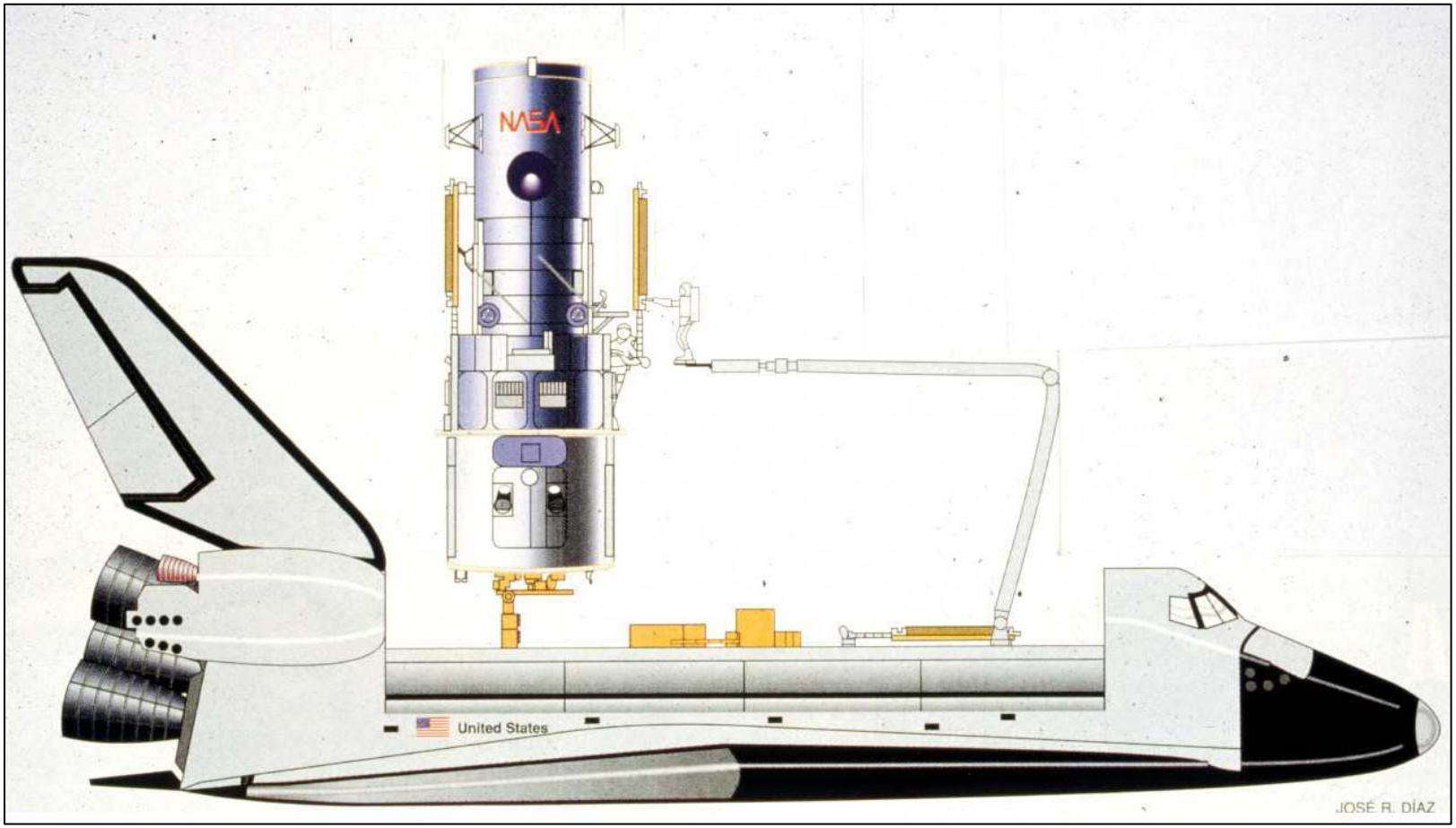
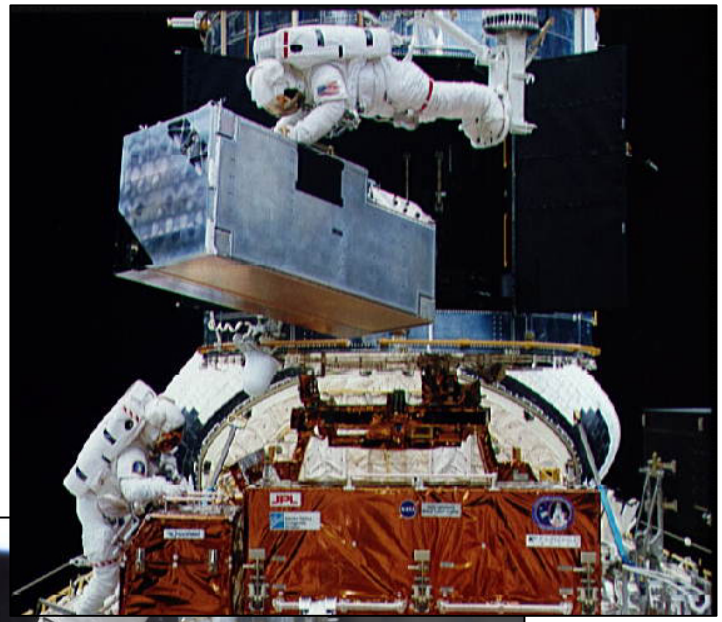
Astronauts Work In Pairs To Carry Out The Servicing Tasks



Eat. Drink. Imagine.

EVA Astronauts Install New Equipment



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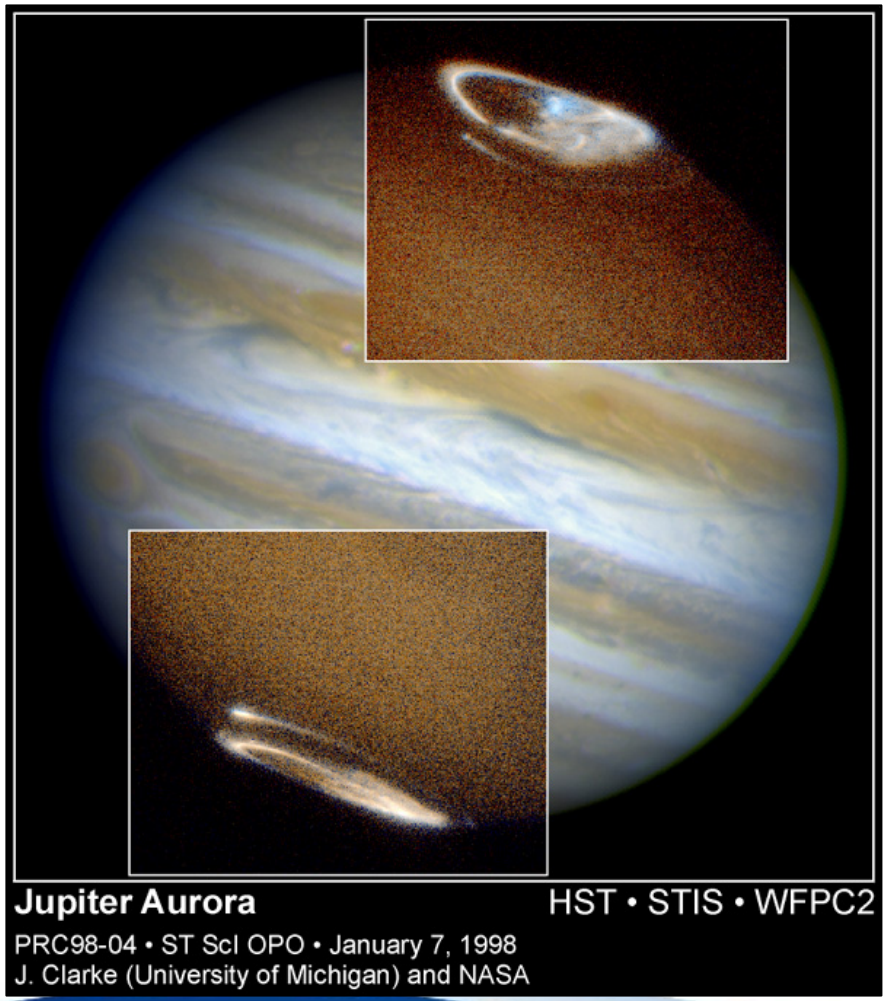
HST's Scientific Mission Includes All Areas Of Astronomical Research

Mars

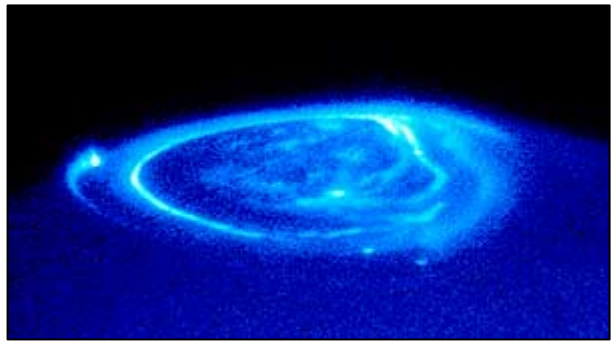
June 26, 2001
43 million miles

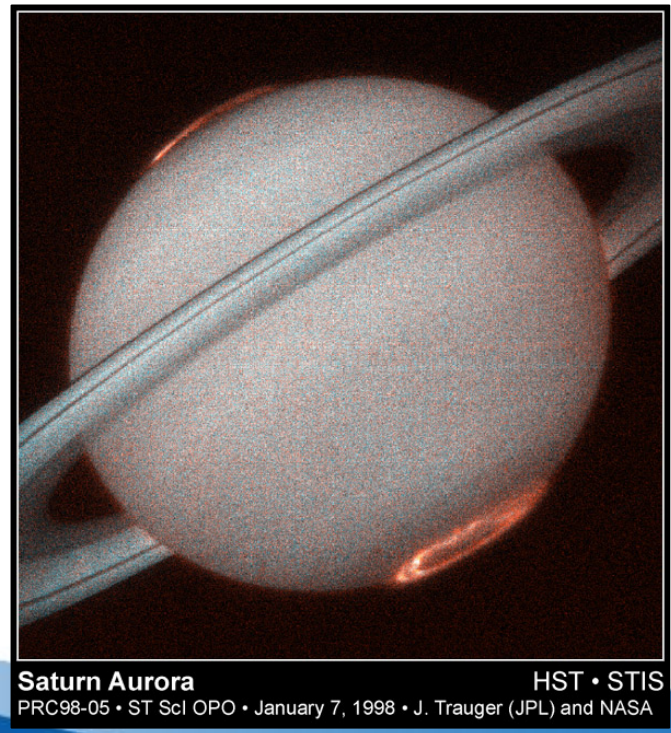
The Aurorae of Jupiter and Saturn



Jupiter Aurora HST • STIS • WFPC2

PRC98-04 • ST ScI OPO • January 7, 1998
J. Clarke (University of Michigan) and NASA



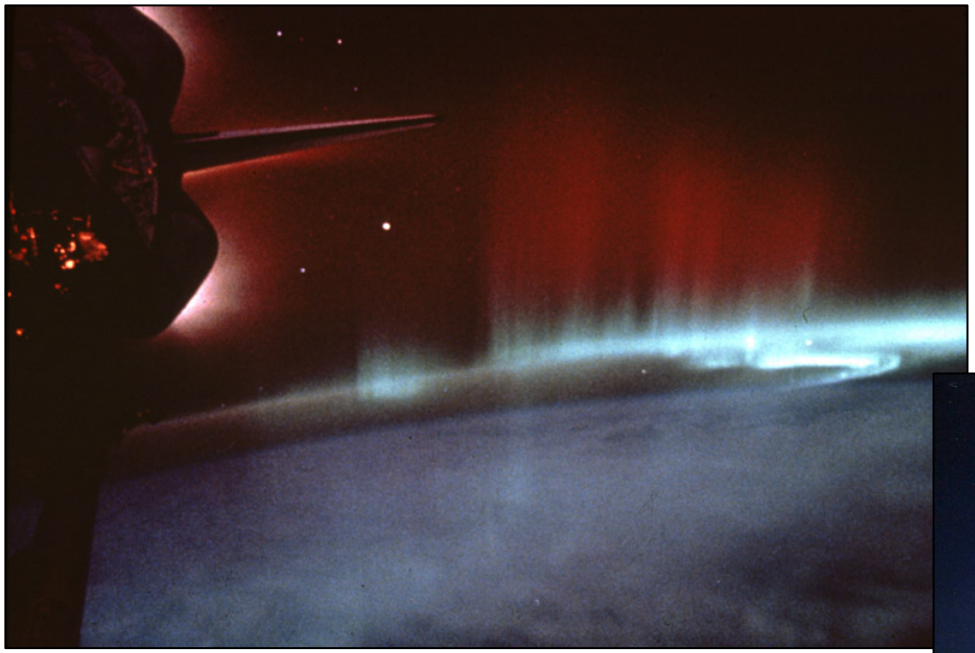


Saturn Aurora HST • STIS

PRC98-05 • ST ScI OPO • January 7, 1998 • J. Trauger (JPL) and NASA

The Earth's aurora

(not Hubble pictures)

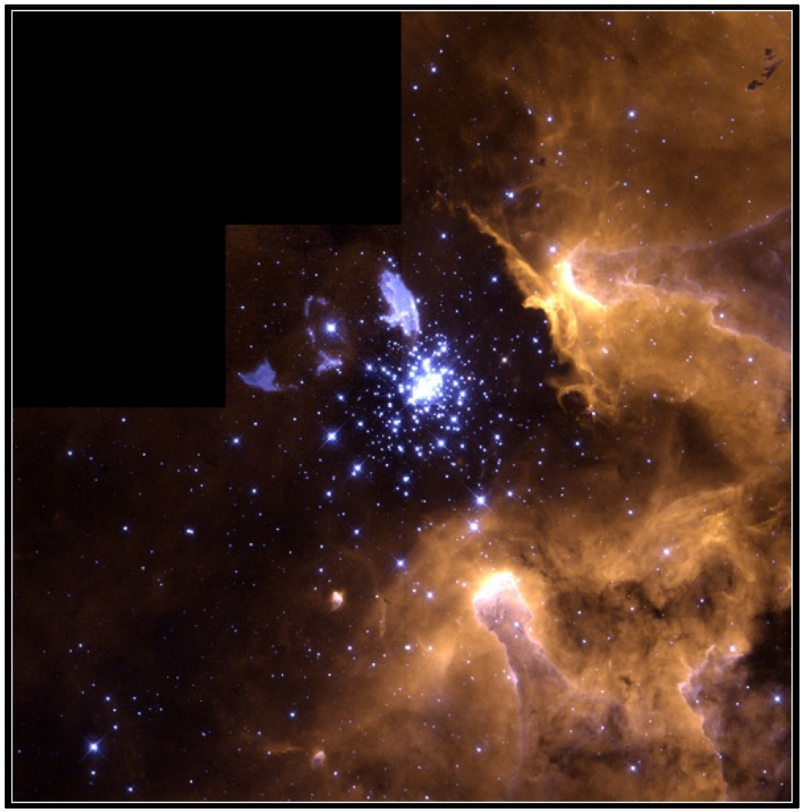


As seen from the shuttle.

As seen from Fairbanks AK.

We can now study several examples of the interaction of a planet with its star.

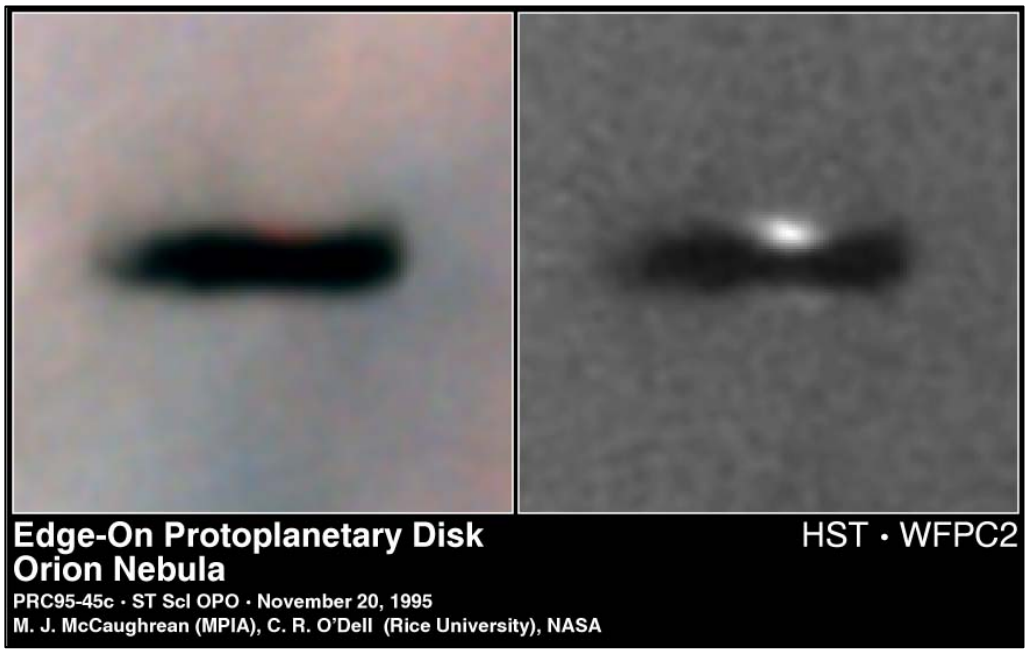
Star Formation Is An Important Field Of Study

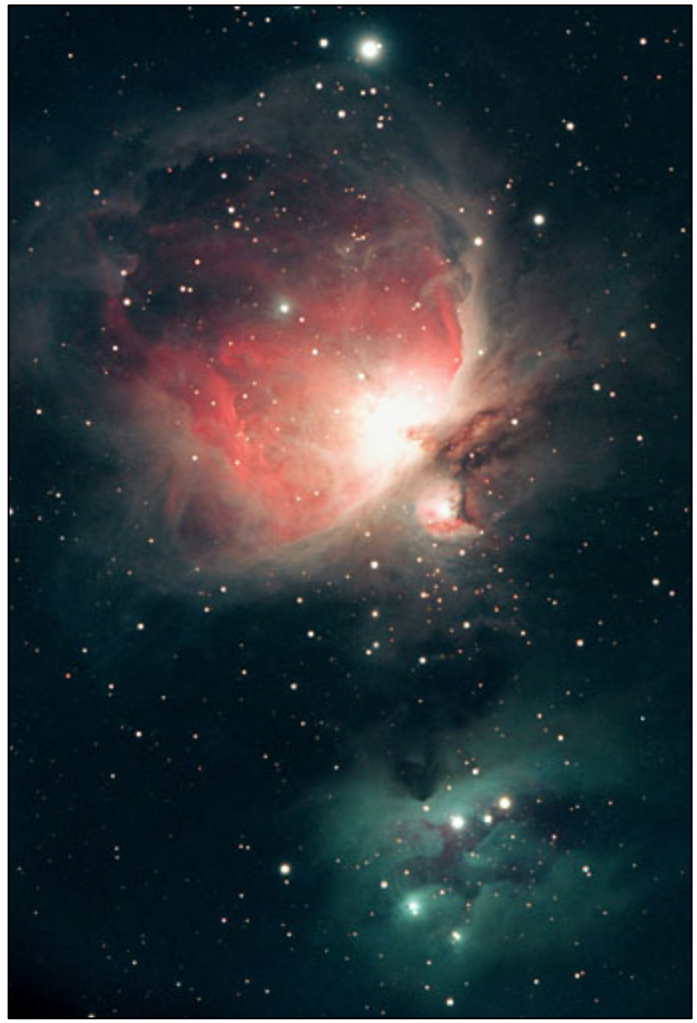


Our sun probably formed 4.5 billion years ago in a cluster that has since dispersed.

The Orion Nebula Is A Nearby Region Where New Stars Are Forming

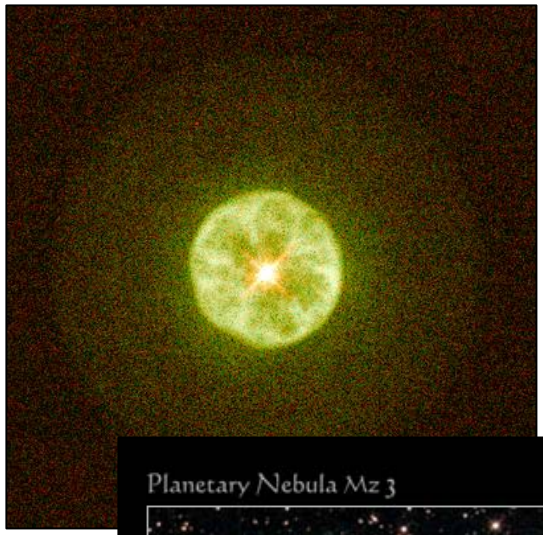
Hubble has discovered the raw material from which planetary systems may form around more than 150 young stars.

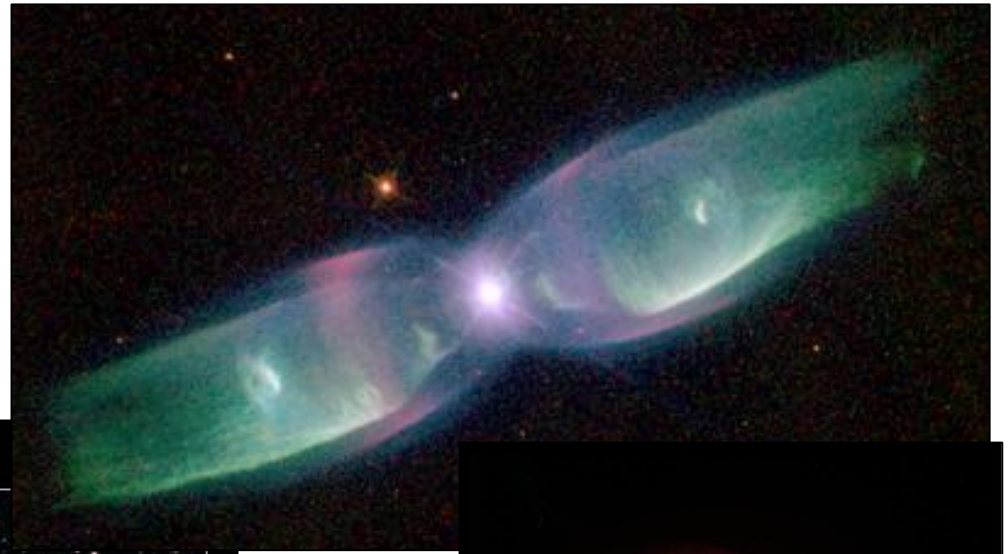


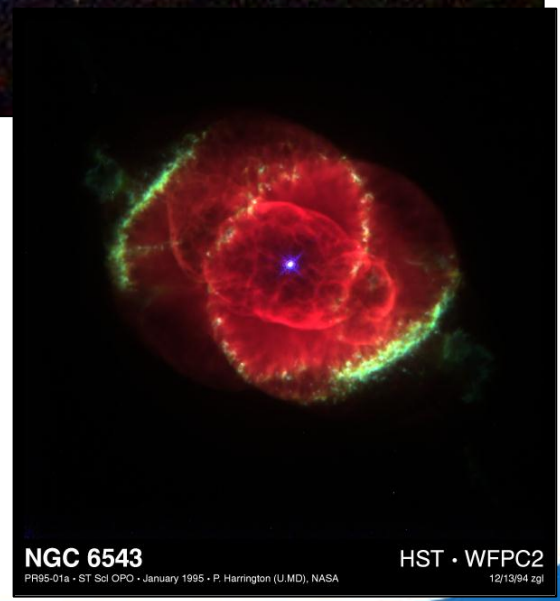


Eat. Drink. Imagine.

Many Stars Eject Matter Into Space In Their Old Age







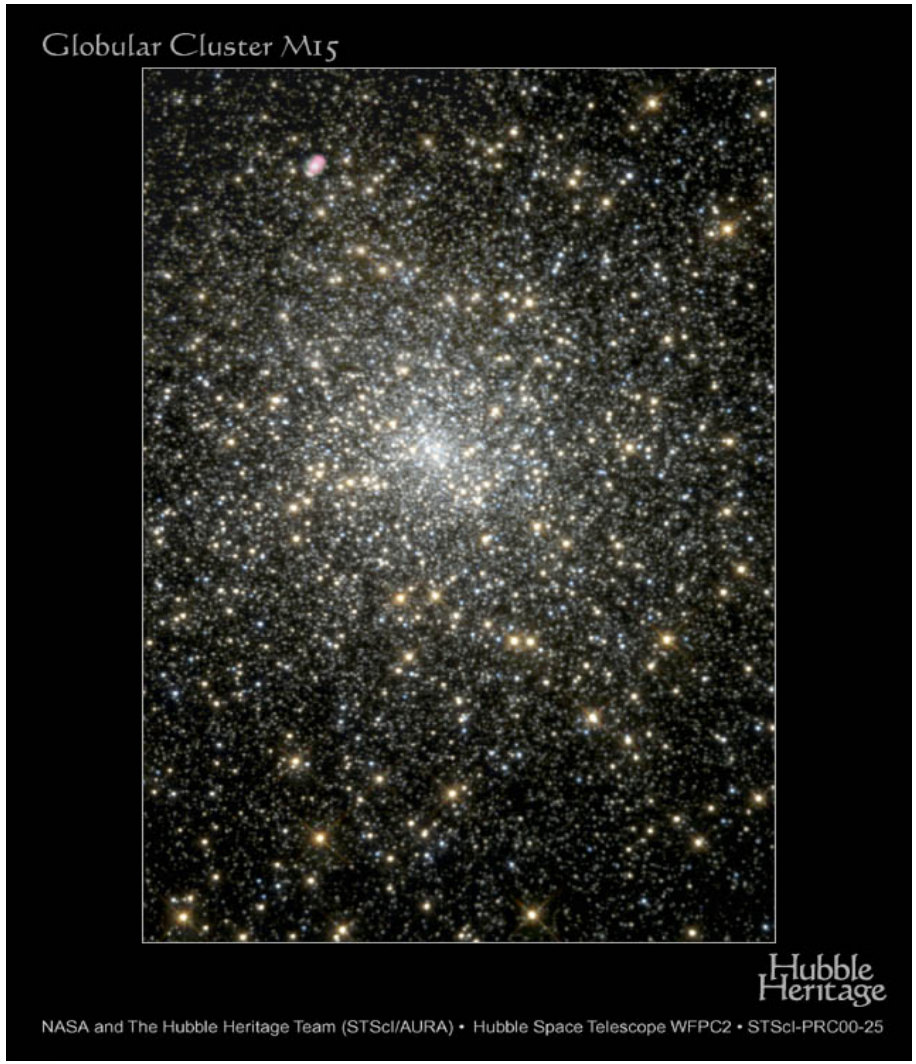
Globular Clusters Contain Some Of The Oldest Stars

May have been first objects to form as the universe cooled after the Big Bang

They appear to be about 13 billion years old

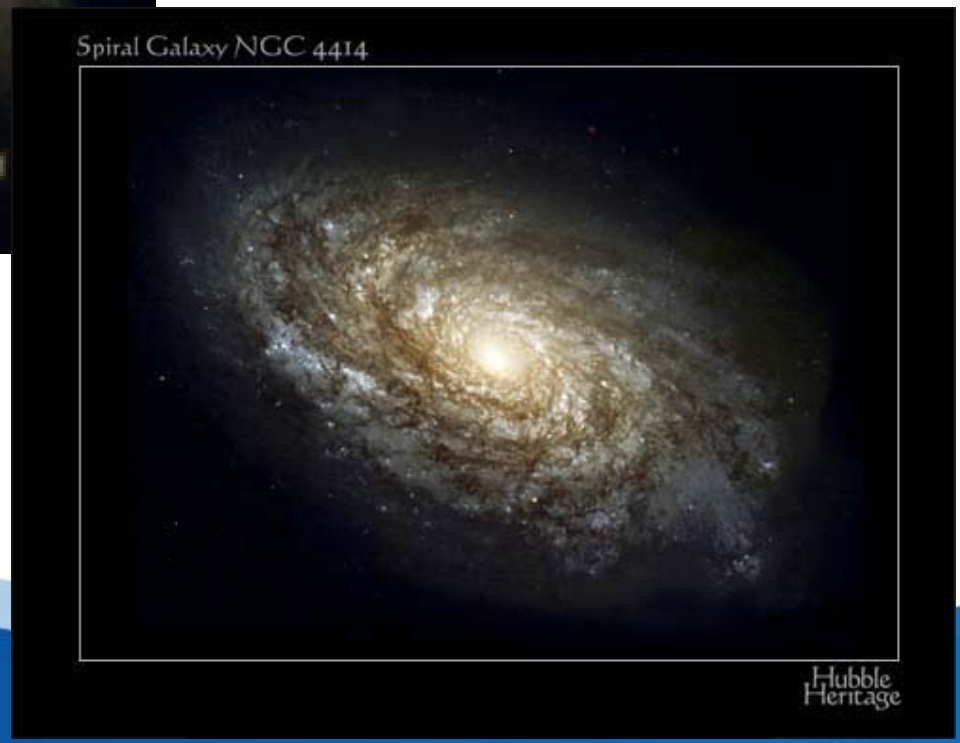
About 100000 stars

Several hundred near our Milky Way galaxy



Galaxies May Contain 100 Billion Stars

We are part of the Milky Way galaxy. We are about 2/3 of the way out from the center, near the inner edge of a spiral arm. One ‘lap’ takes about 250 million years!



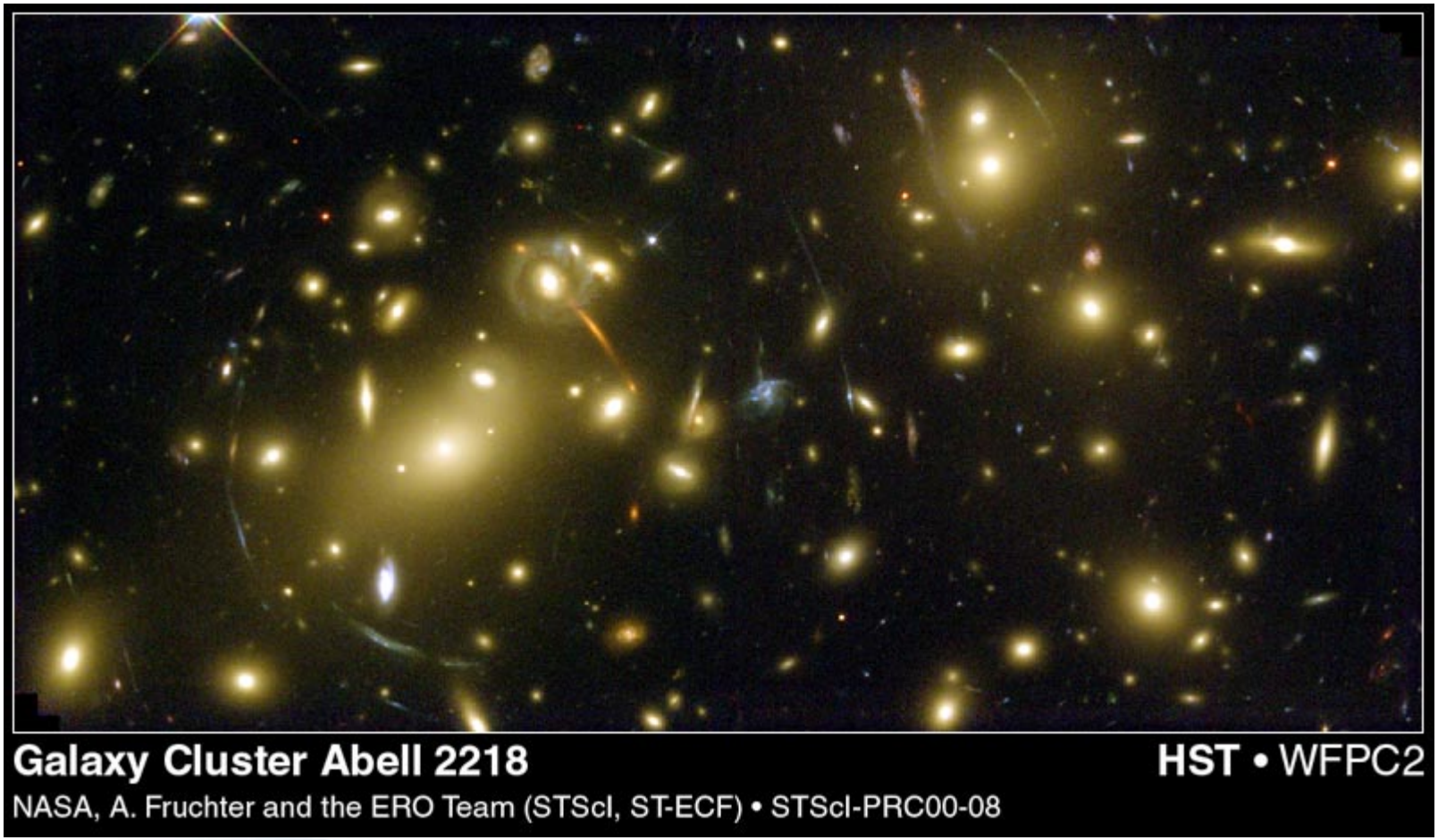
Galaxies Interacted With Each Other When The Universe Was Younger And Smaller

The Mice • Interacting Galaxies NGC 4676 **HST • ACS**

NASA, H. Ford (JHU), G. Illingworth (UCSC/LO), M. Clampin (STScI), G. Hartig (STScI) and the ACS Science Team
STScI-PRC02-11d

Eat. Drink. Imagine.

There Are Billions Of Galaxies In The Universe



Galaxy Cluster Abell 2218 **HST • WFPC2**

NASA, A. Fruchter and the ERO Team (STScI, ST-ECF) • STScI-PRC00-08

Eat. Drink. Imagine.

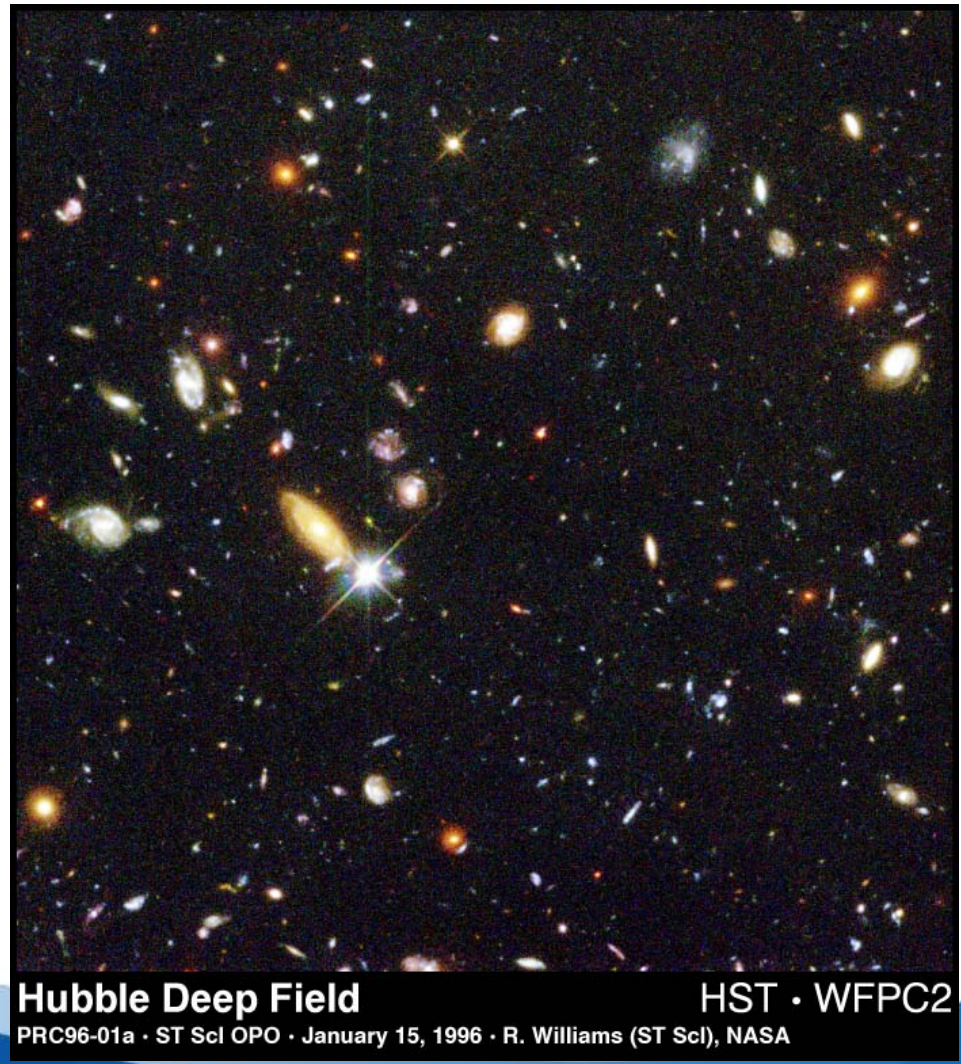
The Hubble Deep Field Discovered Very Distant Galaxies

2 weeks of exposure time

galaxies are several billion light years away from us

light left them several billion years ago

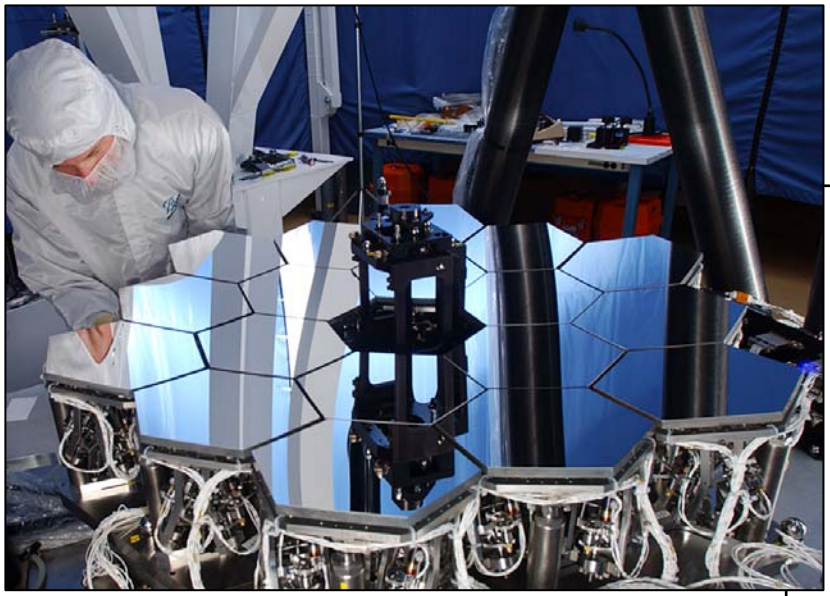
young star-forming regions in the early universe



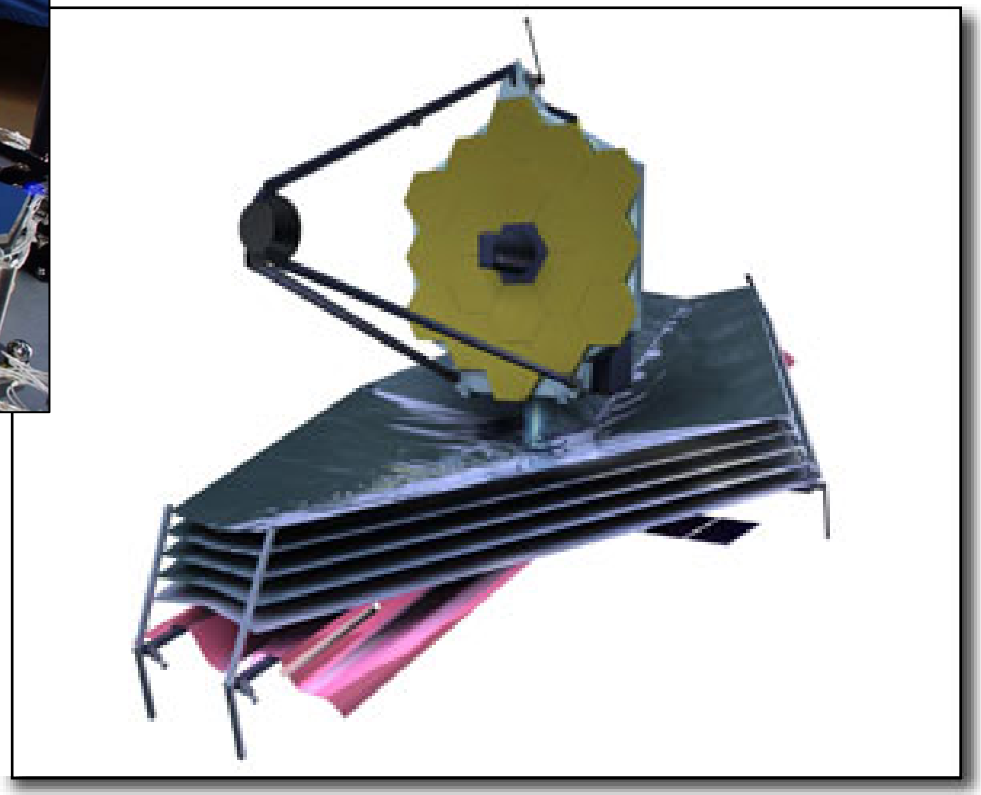
HST Will Continue Past 2010

Eat. Drink. Imagine.

JWST Will Be The Scientific Successor To HST When Launched In 2013



1/10 scale model testbed



Ball is developing the telescope optical system as a subcontractor to Northrop-Grumman