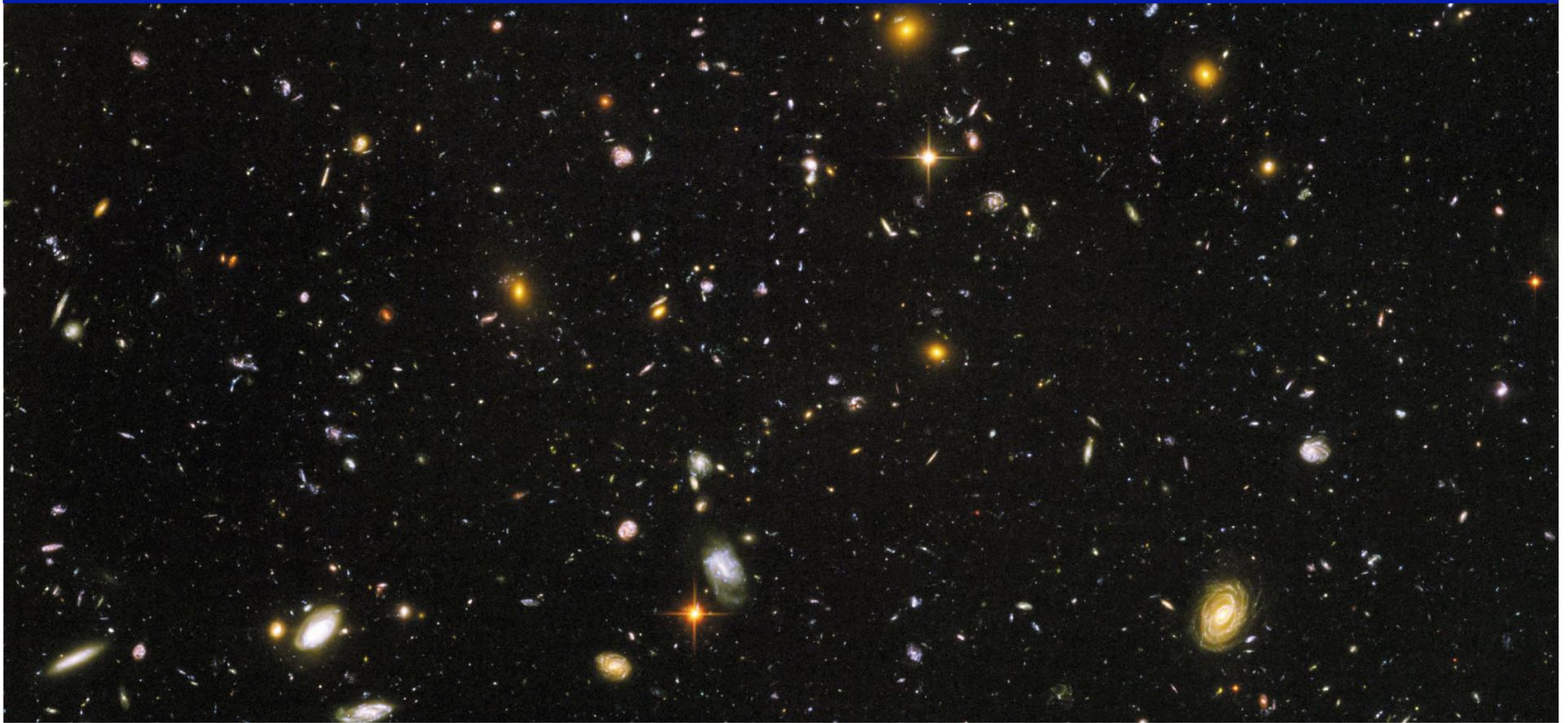


# Lecture 1: Our Place in the Universe

A trip through the Universe at the speed of light



# The Speed of Light

- Light travels at a definite, finite speed: 186,000 miles per second

$$3 \times 10^5 \text{ km/s}$$

- This speed is the Universe's "Ultimate Speed Limit" according to Einstein's *Special Theory of Relativity*

- Nothing can travel *faster than light* ... (Tachyons?)
- No body which has "rest-mass" can reach the speed of light
- As we look at distant astronomical objects we look "*back in time*"



*It's not just a good idea ...  
it's the law!*

# Say goodbye to Terra (Earth)



The Earth is 93 million miles = 8 light minutes = 1 AU (Astronomical Unit) from the Sun

# The Moon

The earth's moon is  
*1.5 light-seconds* away:

- Traveling at the speed of light it will take us 1.5 sec to reach the moon  
(250,000 mi or 400,000 km)
- We see the moon as it was 1.5s ago when sunlight bounced off (reflected from) the moon's surface

*n.b.* a *light-second*

*light-minute*

*light-year (l.y.)*

Is a distance

*1 light year = 300,000 km/s*

*x 60 sec/min*

*x 60 min/hr*

*x 24 hr/day*

*x 365 day*

*≈ 10<sup>13</sup> km or*

*6 trillion miles*

*(the distance light travels in 1 year)*

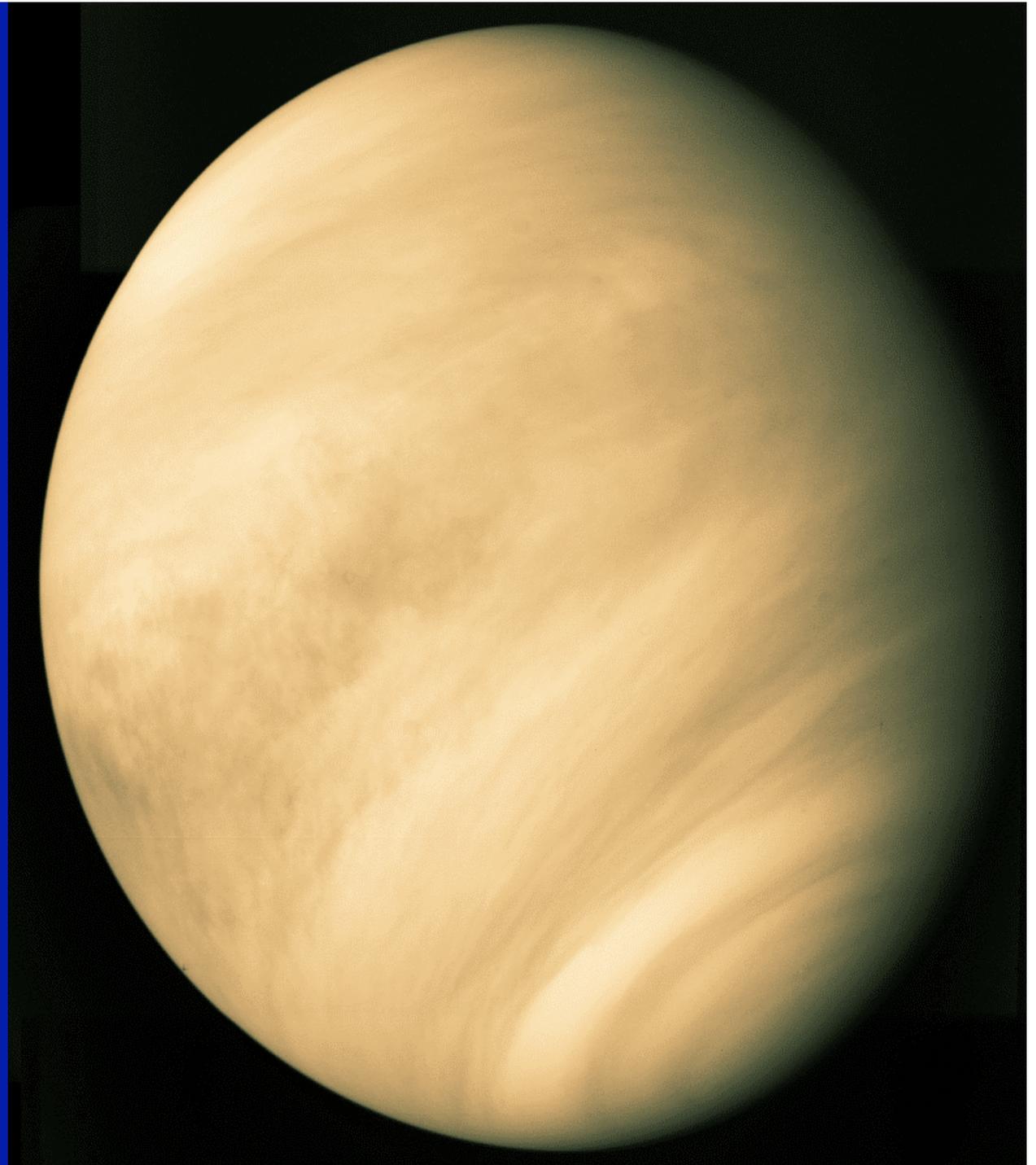


# Venus

0.6 AU from the sun

About 2 minutes away when it is closest, would take almost 15 minutes when it is on the other side of the sun.

Venus was thought originally to be our "sister planet"; visible as the "evening star" or the "morning star". We now know that Venus has a toxic atmosphere with sulfuric acid rain and a greenhouse effect that keeps the planet boiling hot.



# Mars

1.9AU = 15 light minutes  
from the sun

Mars has been an intense focus of study from space, in part because of speculation that Mars could have developed life.

Mars Spirit & Opportunity Rovers have been exploring the Martian surface since 2004.

Among the most exciting discoveries:

- a huge reservoir of ice below the south polar cap contains enough ice to blanket the planet with 30 ft of water (Express Orbiter).
- water once flowed freely on the Martian Surface (Mars Rovers)

Why is water important?

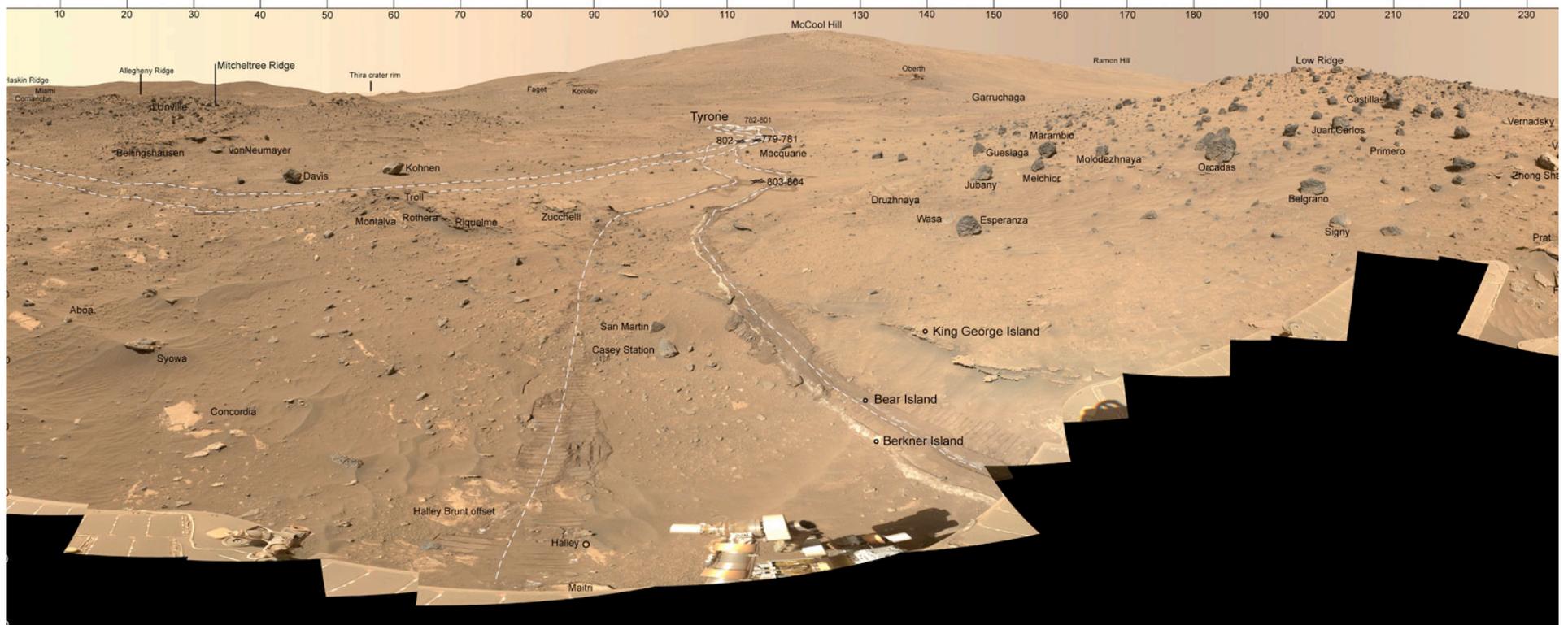


**Mars · February 1995**

**HST · WFPC2**

PR95-17 · ST ScI OPO · March 21, 1995  
P. James (U.Toledo), S. Lee (U.CO), NASA

# Mars Rover Sojourner



# Olympus Mons

is the largest volcano on [Mars](#). This [shield volcano](#), similar to volcanoes in Hawaii, measures 624 km (374 mi) in diameter by 25 km (16 mi) high (100 times larger than Mauna Loa on Earth). The [caldera](#) in the center is 80 km (50 mi) wide and contains multiple circular, overlapping collapse craters created by volcanic events. The features on the slopes of the volcano were formed by overflowing lava and debris.

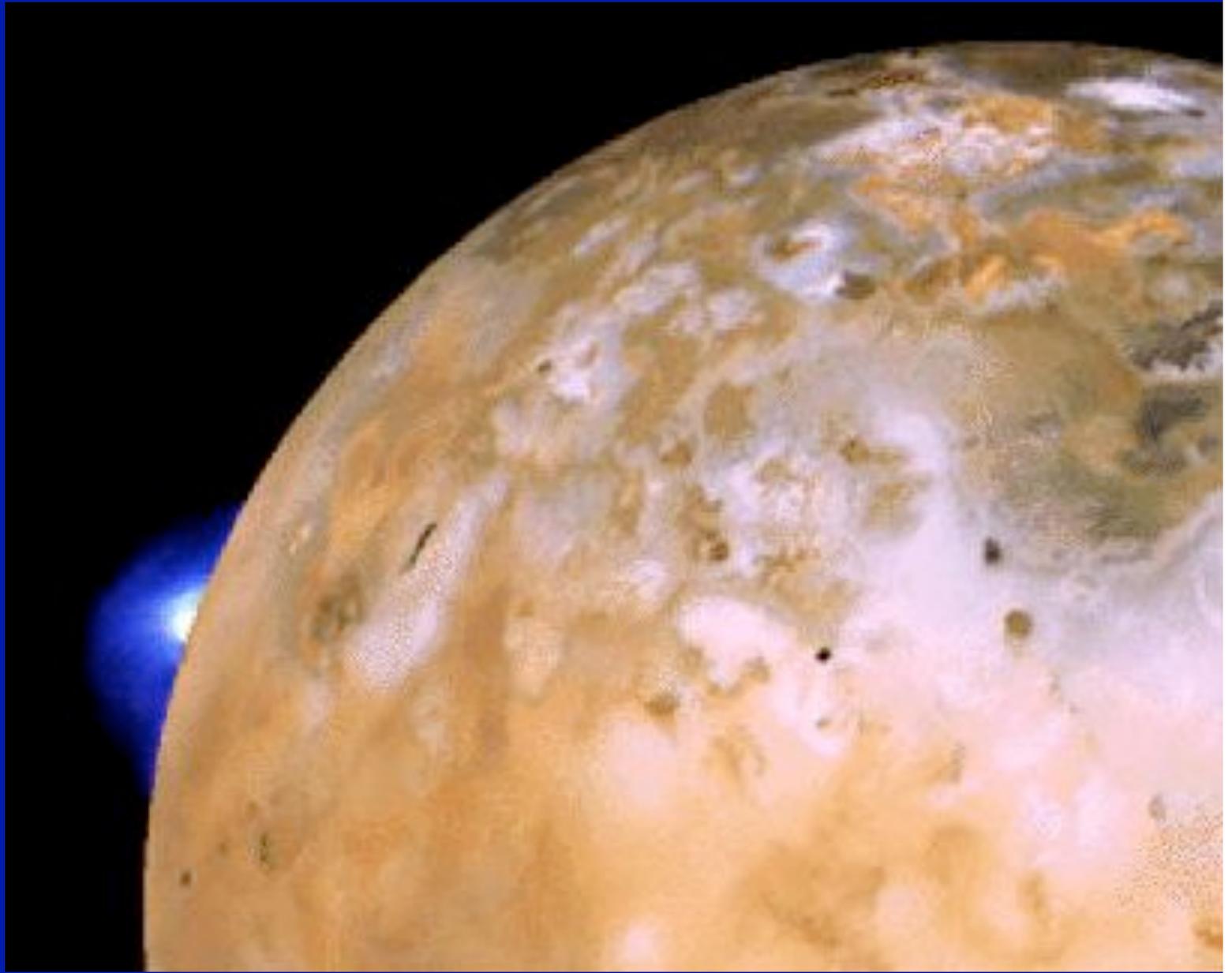


# Jupiter

5.2 AU = 40 light minutes  
from the sun



# Io - Loki Volcano

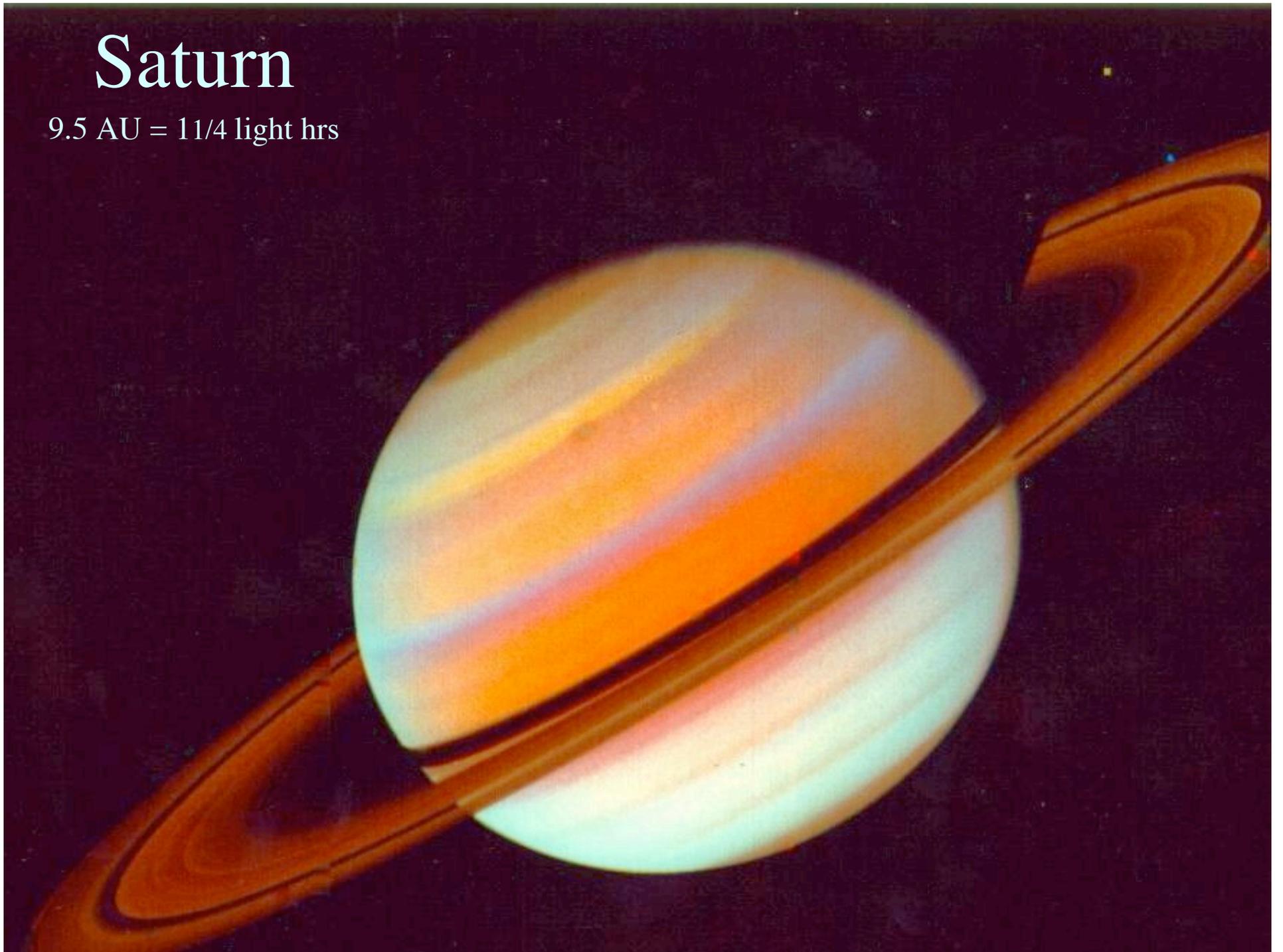


# Great Red Spot

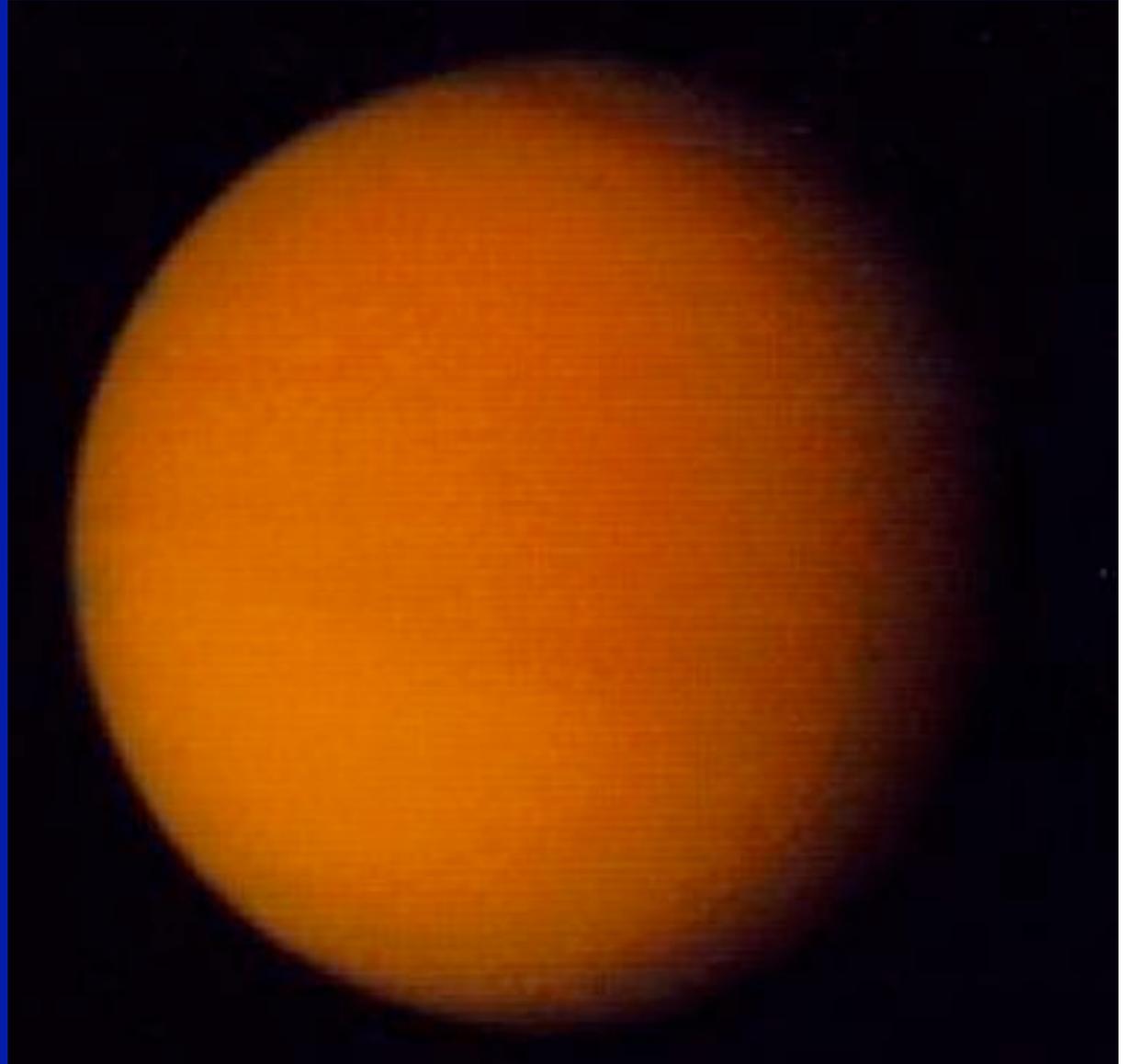


# Saturn

9.5 AU = 1 1/4 light hrs

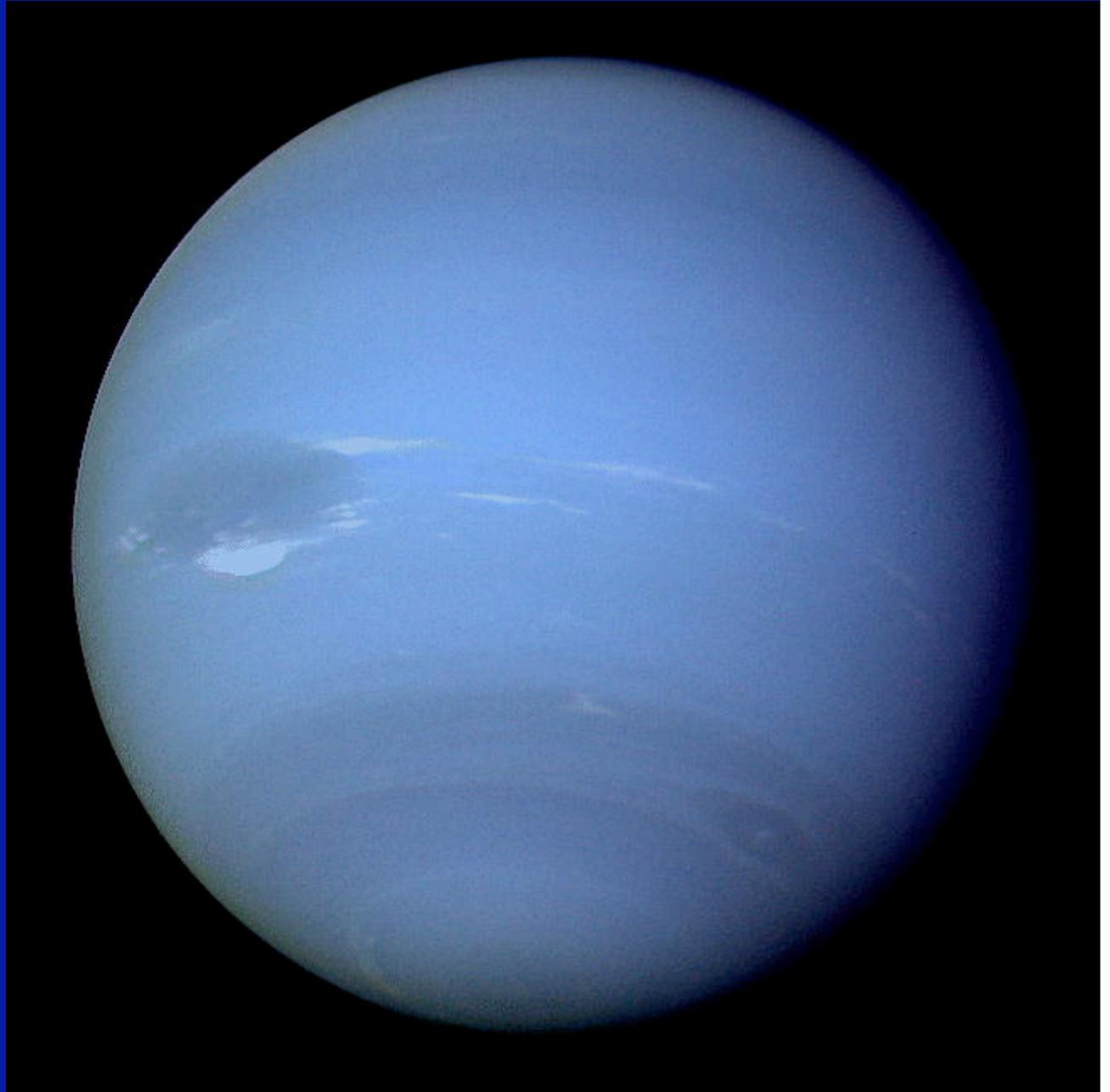


# Titan



# Neptune

30 AU = 4 light hours



# Pluto & Charon

40 AU (on average) = 5.33 light hours

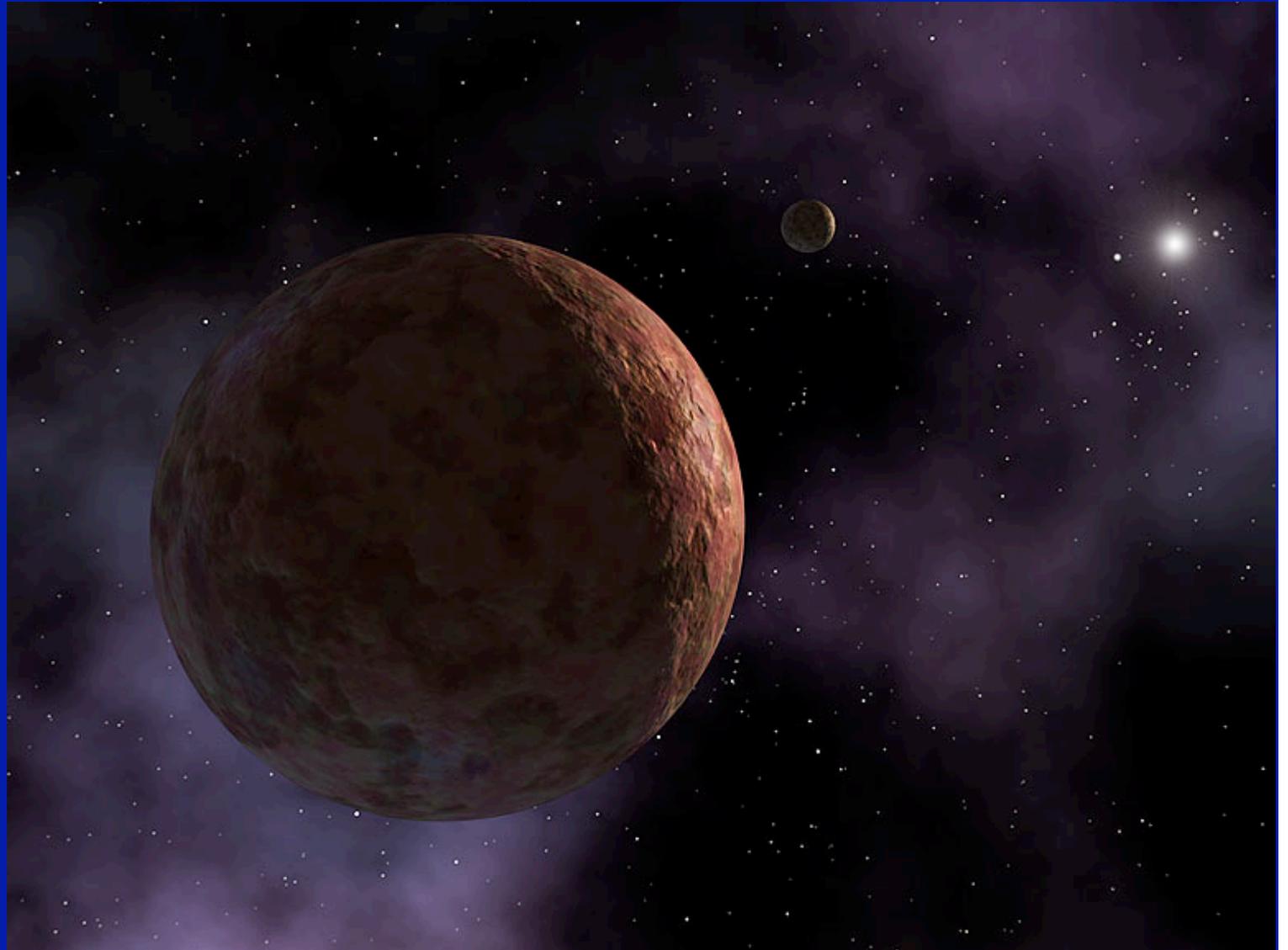
Pluto has been demoted from “Planet” status due to its small size and highly eccentric orbit. Pluto may have been captured or formed in an outer part of our solar system.



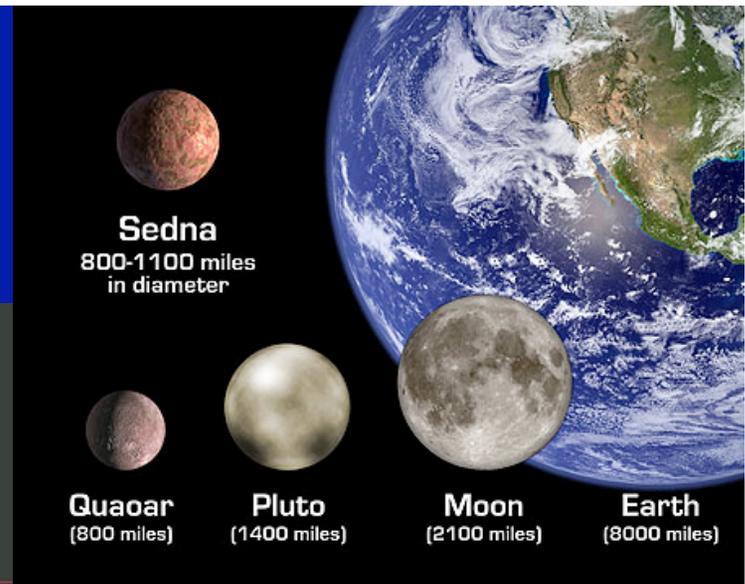
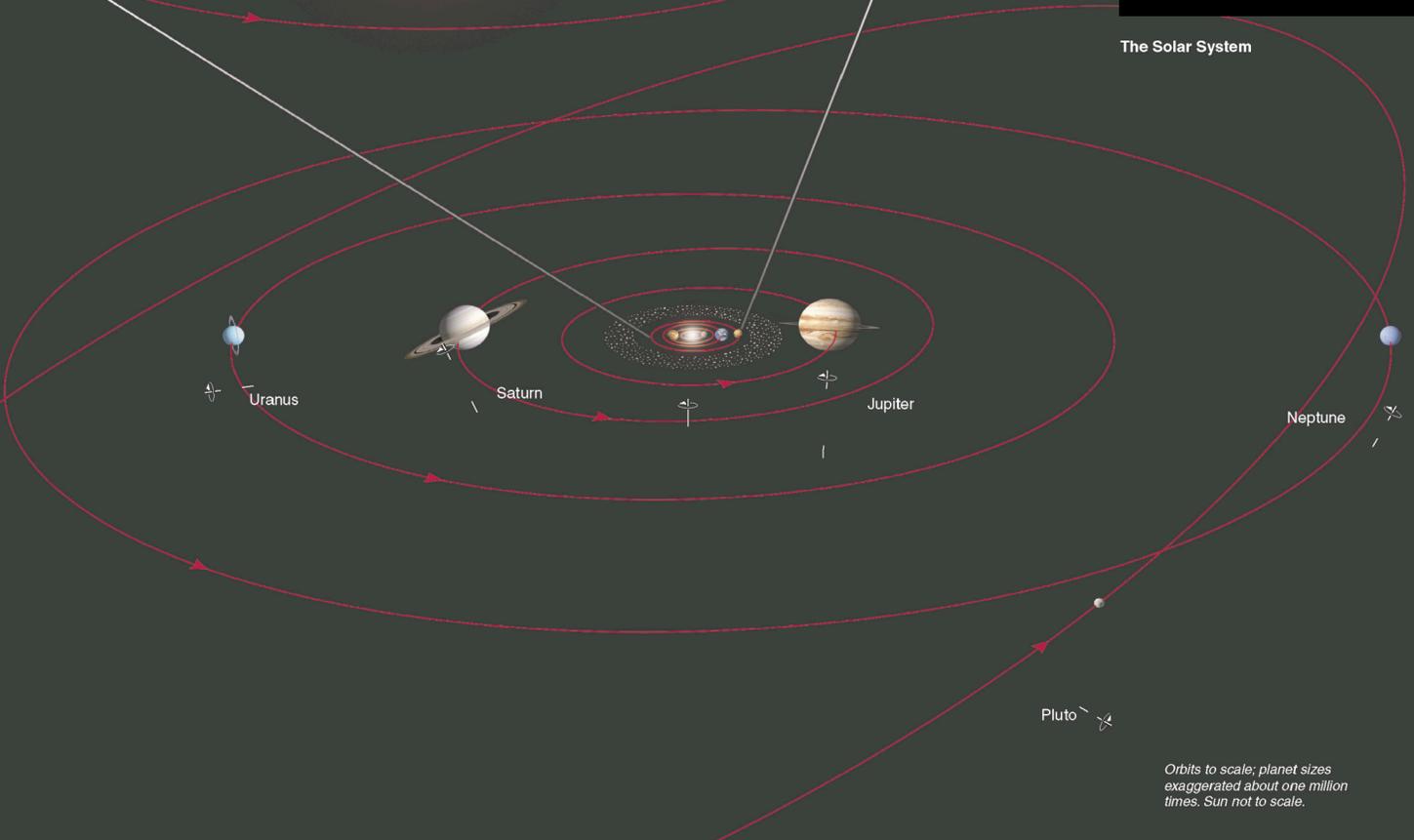
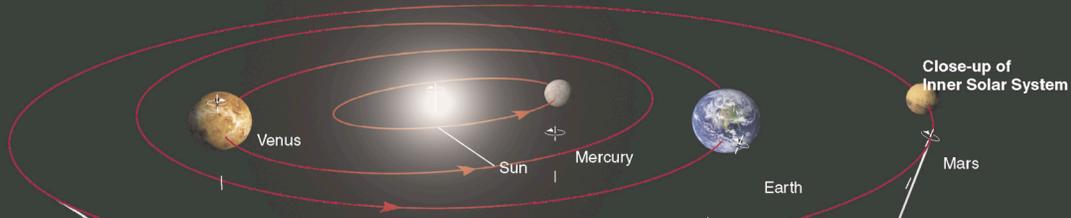
# Sedna

> 90 AU; 12 light hours

Discovered in 2004, Sedna is the most distant Solar System object known



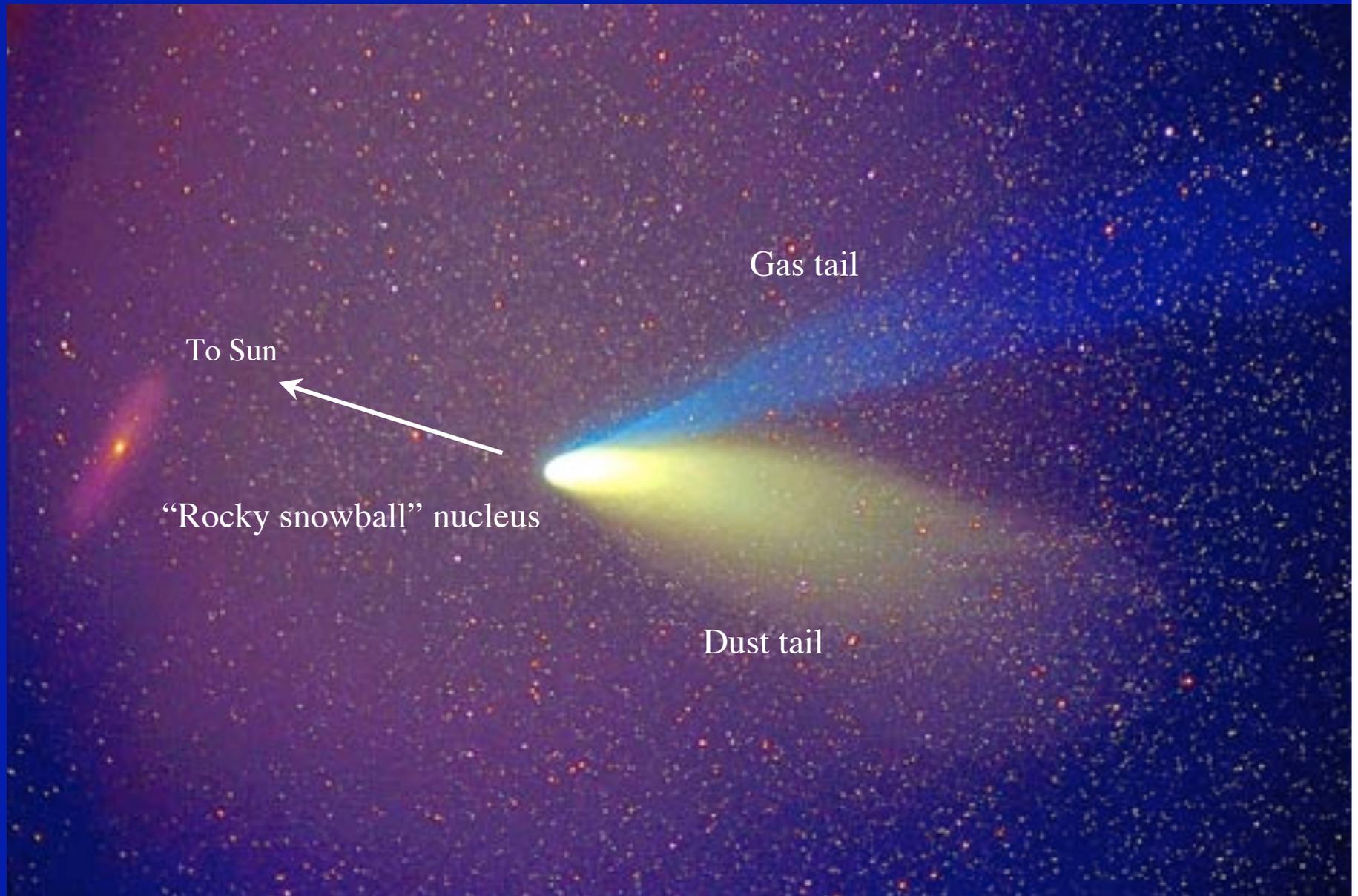
# The Inner Solar System



*Orbits to scale; planet sizes exaggerated about one million times. Sun not to scale.*

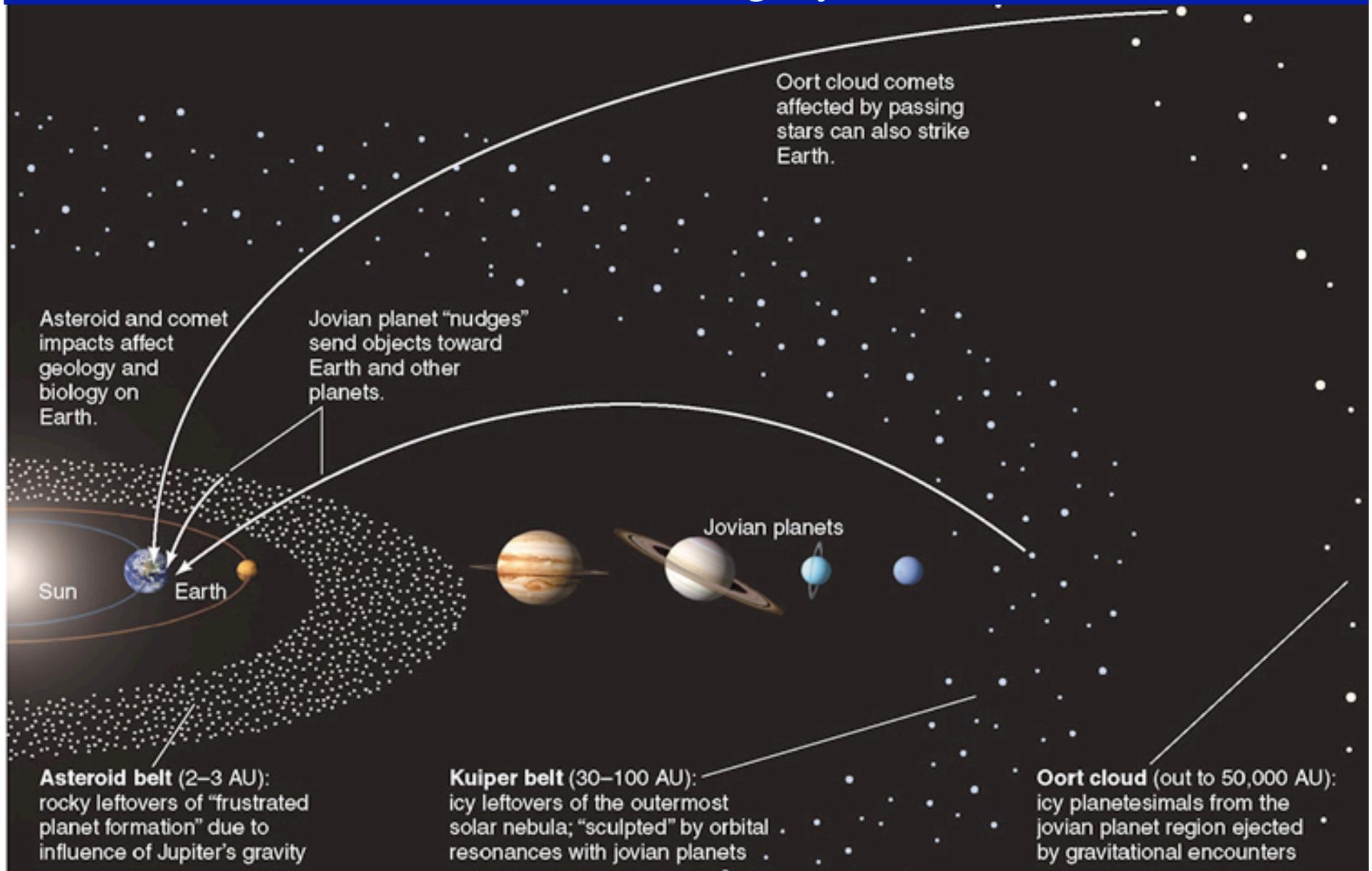
# Comet Hale-Bopp

Visited the inner Solar System in 1997



# The Outer Solar System

extends to 3/4 light year

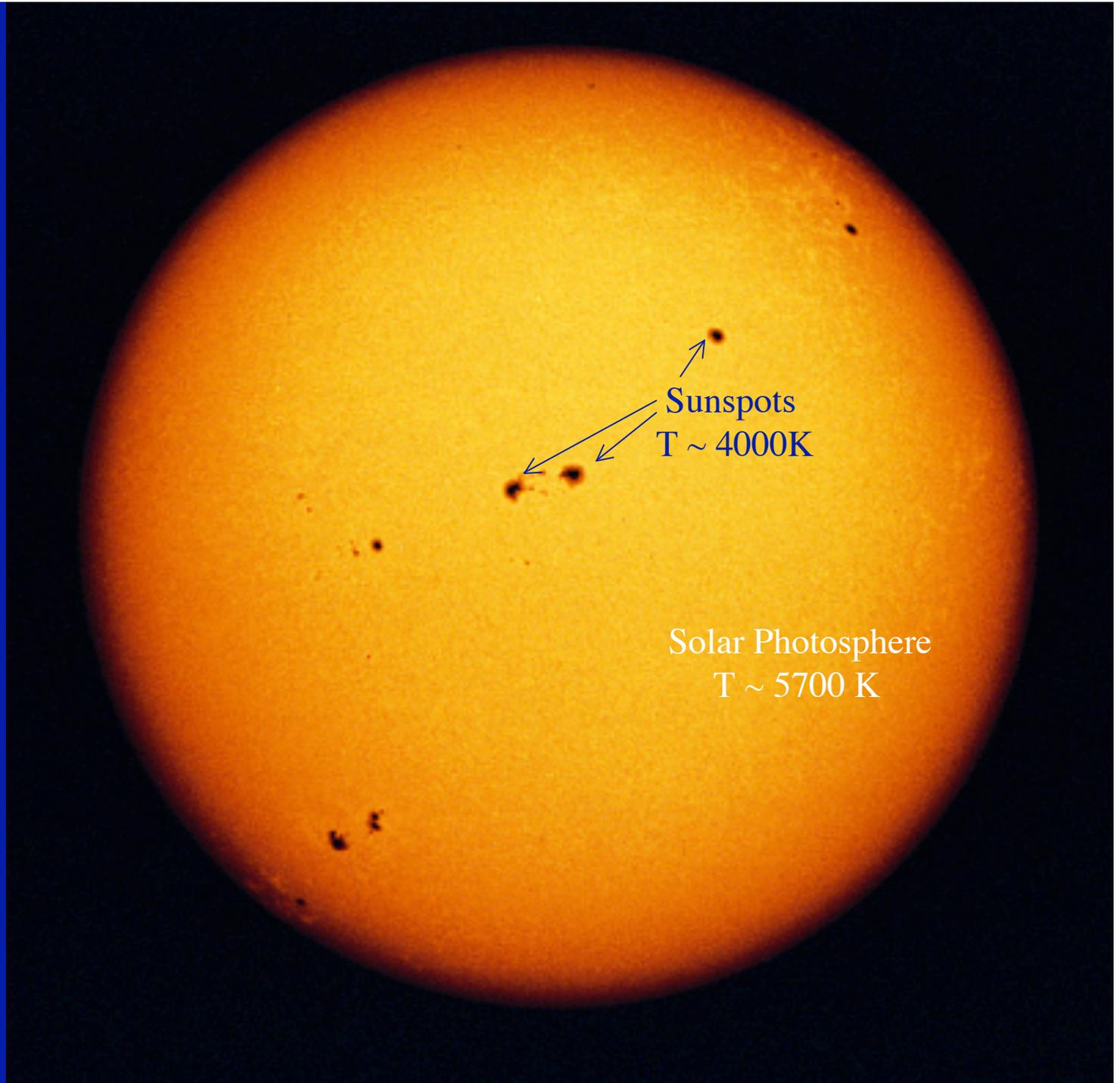


# The Sun

is a very middle  
class star

Type G2V, about  
average in all its  
properties

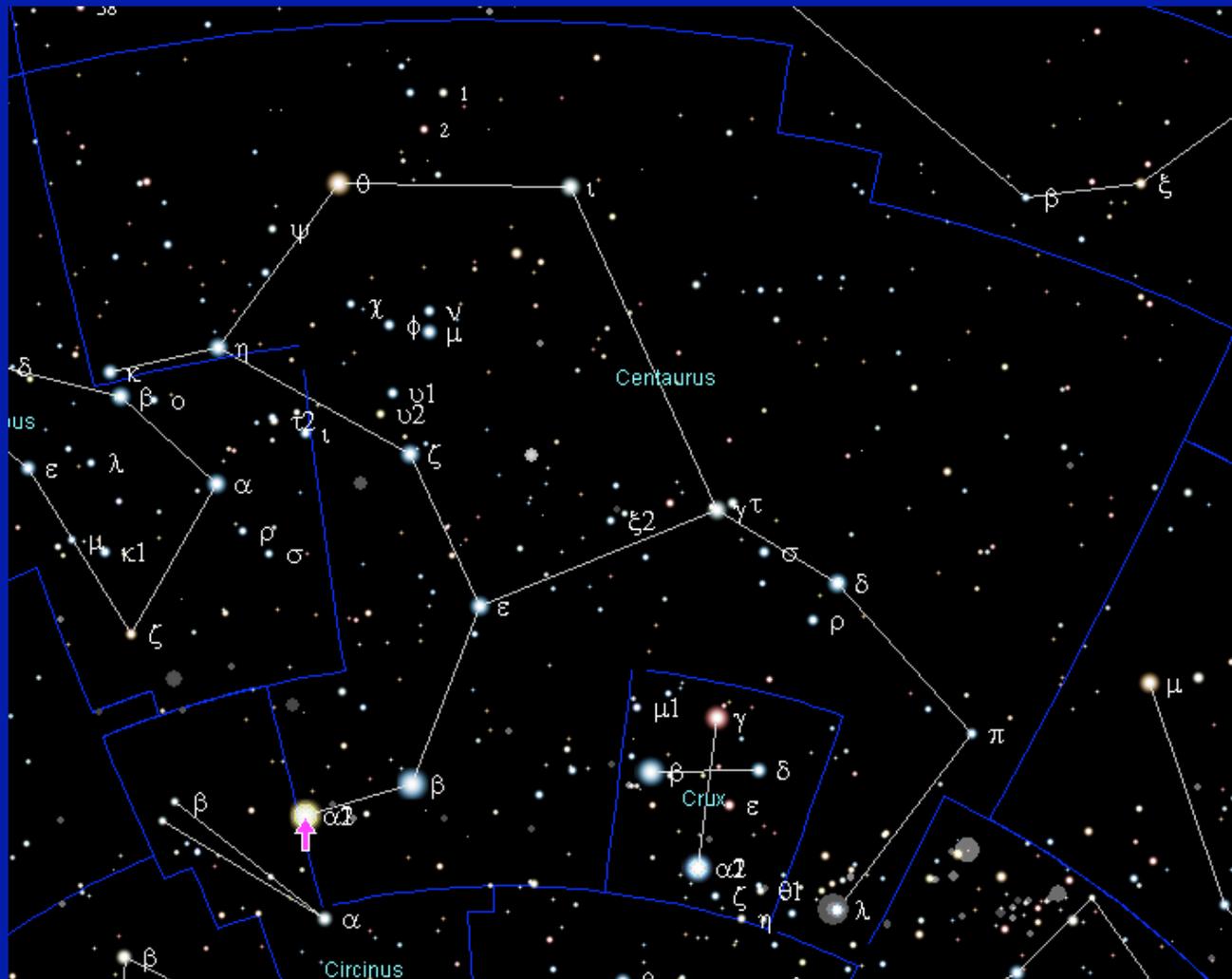
The Sun radiates heat  
energy produced in  
*nuclear fusion*  
reactions, in this case  
fusing hydrogen into  
helium



# Alpha Centauri

about 4 light years

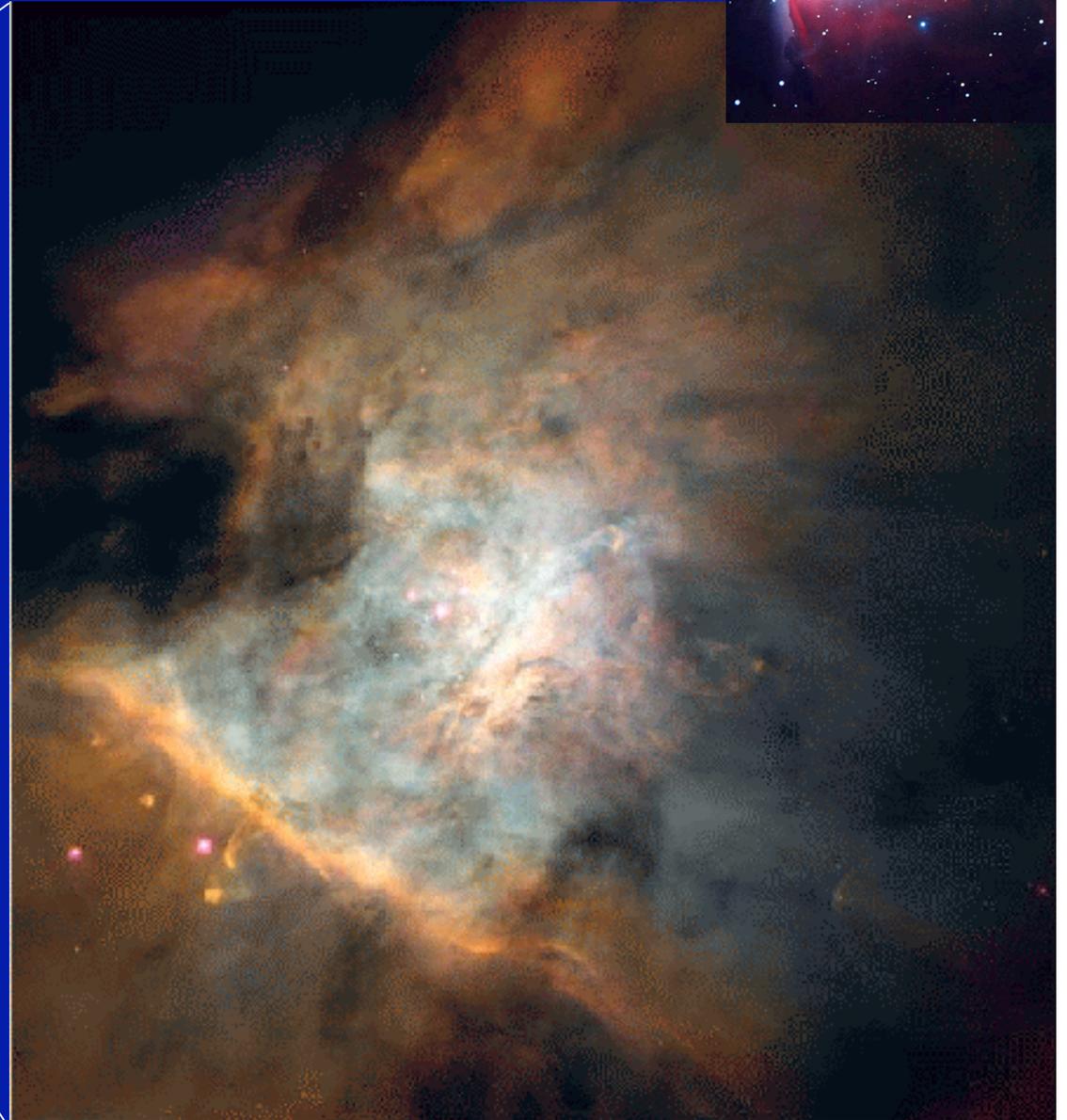
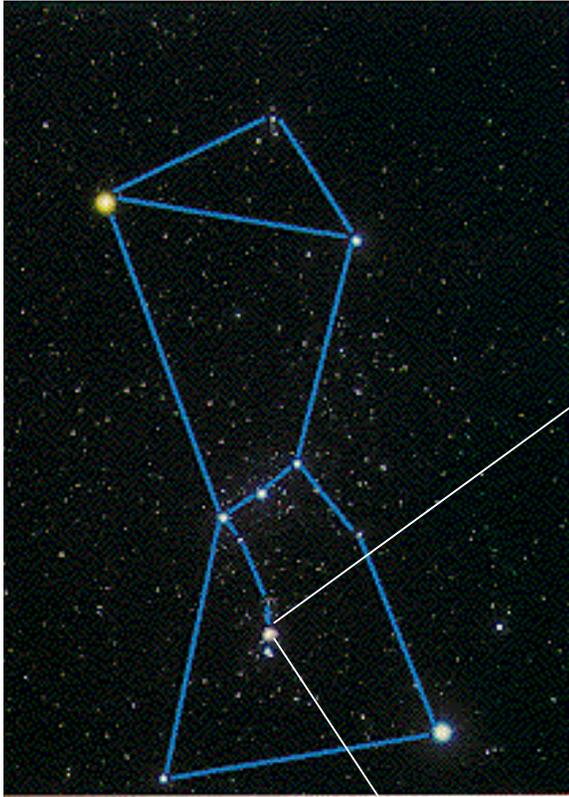
- The nearest star is a triple star system, visible in the constellation Centaurus, visible in the Southern Hemisphere



# Pleiades (aka Subaru)



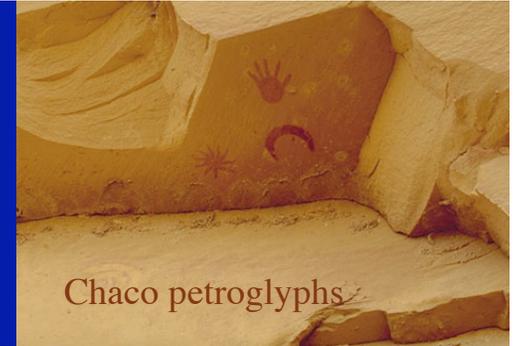
# Orion Nebula



Hot nebula of gas fluorescing from the UV light of newly formed stars at its center

# Crab Nebula

(~ 6000 ly)

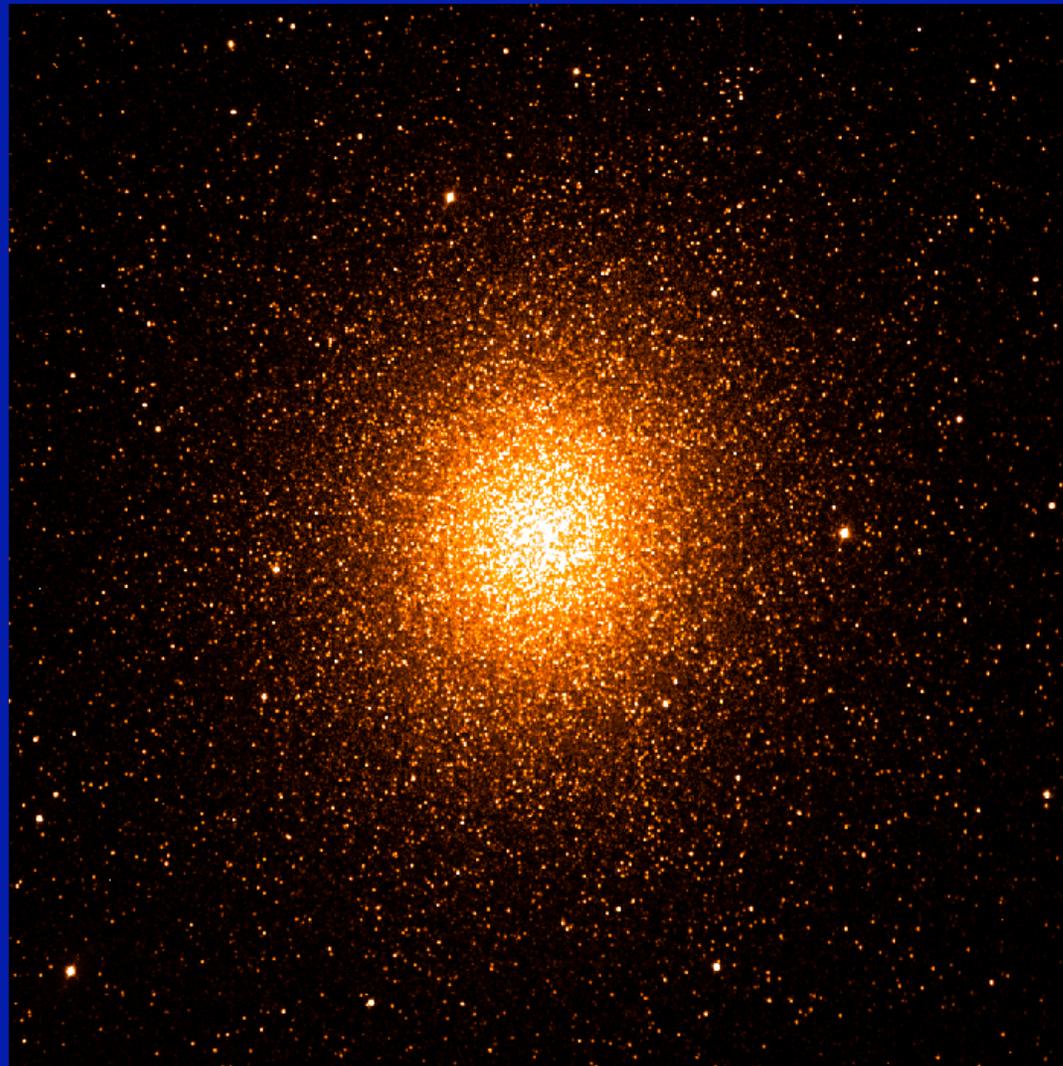


Remnant of the explosion of a massive star (supernova) which occurred in 1054 - chronicled by asians as a “guest star” and by American Indians in Chaco Canyon (see above), but curiously not mentioned in European histories.

At the center of the Crab is the remnant of the massive progenitor, a rapidly rotating, highly magnetized neutron star, a *pulsar*



# Globular Cluster in Milky Way Halo

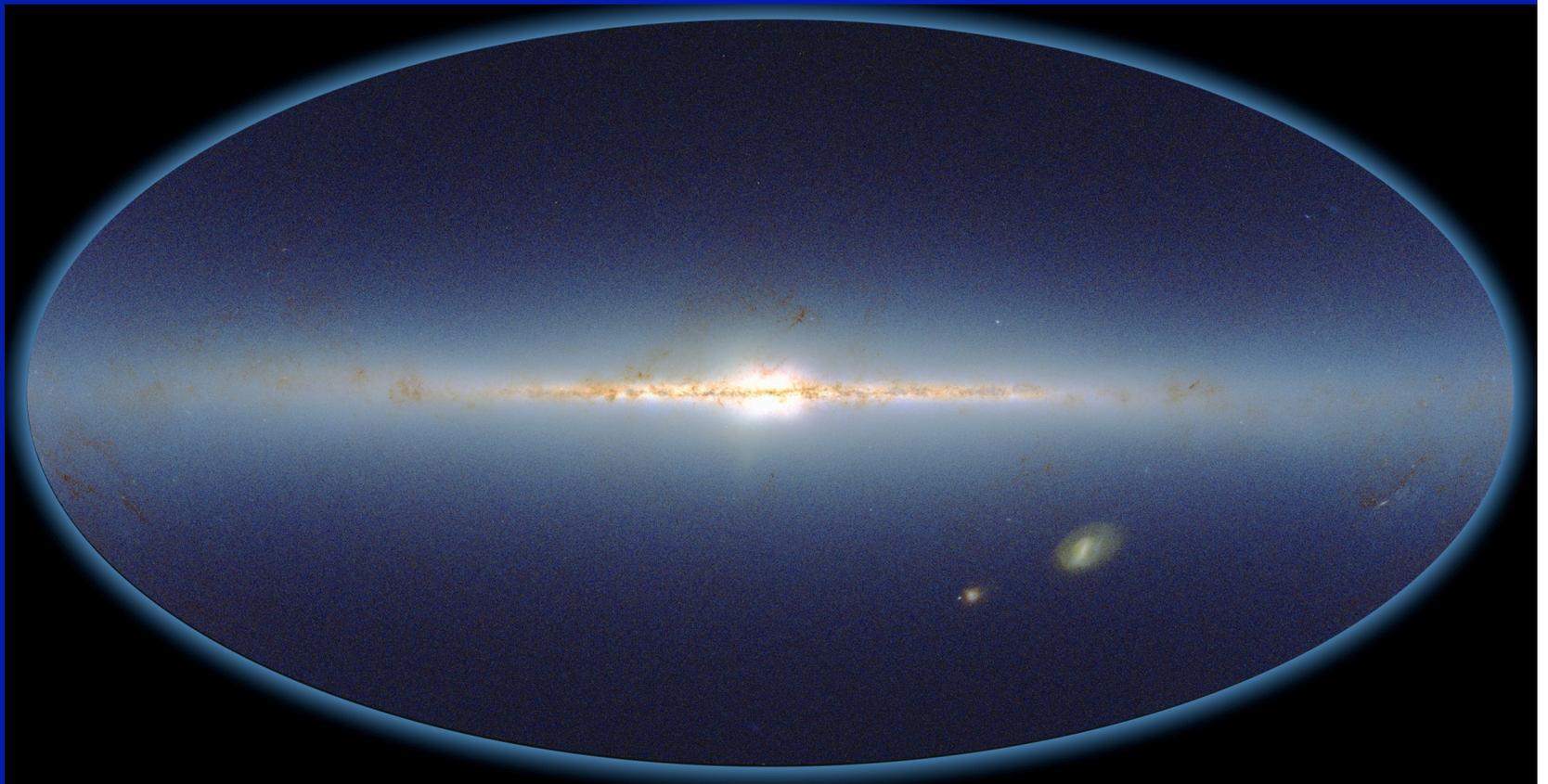


# Milky Way Galaxy



Our Sun is an average star, one of about a half a trillion stars in a galaxy of stars, dust & gas we call the Milky Way; traveling at the speed of light it would take about 100,000 yrs to cross the Galaxy.

Our Solar System lies in the plane of the Milky Way, about 25,000 ly from the Galactic Center



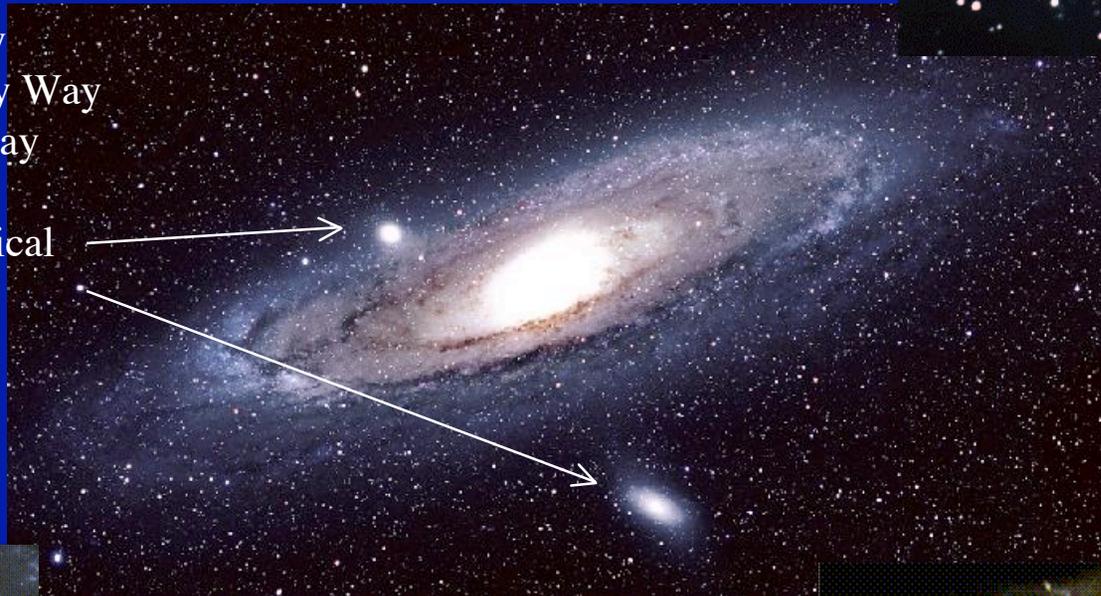
# Galaxies



Messier 33  
3 million ly

The Andromeda Galaxy  
A neighbor of the Milky Way  
is about 2 million ly away

Andromeda has 2 elliptical  
satellite galaxies

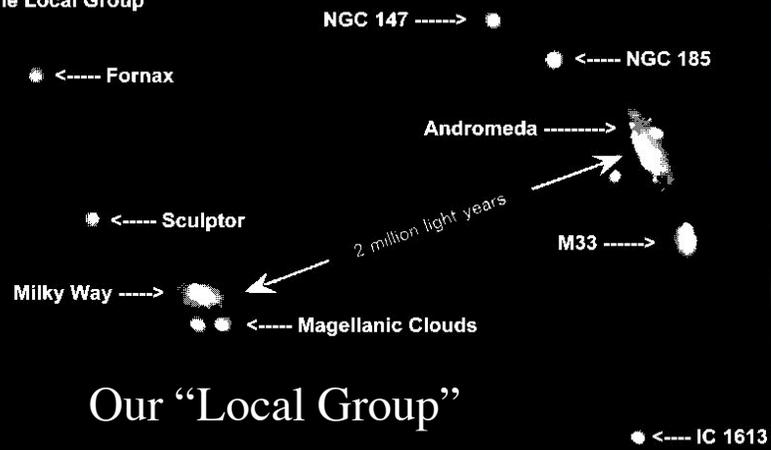


Messier 101  
27 million ly

Messier 51  
The Whirlpool  
15 million ly

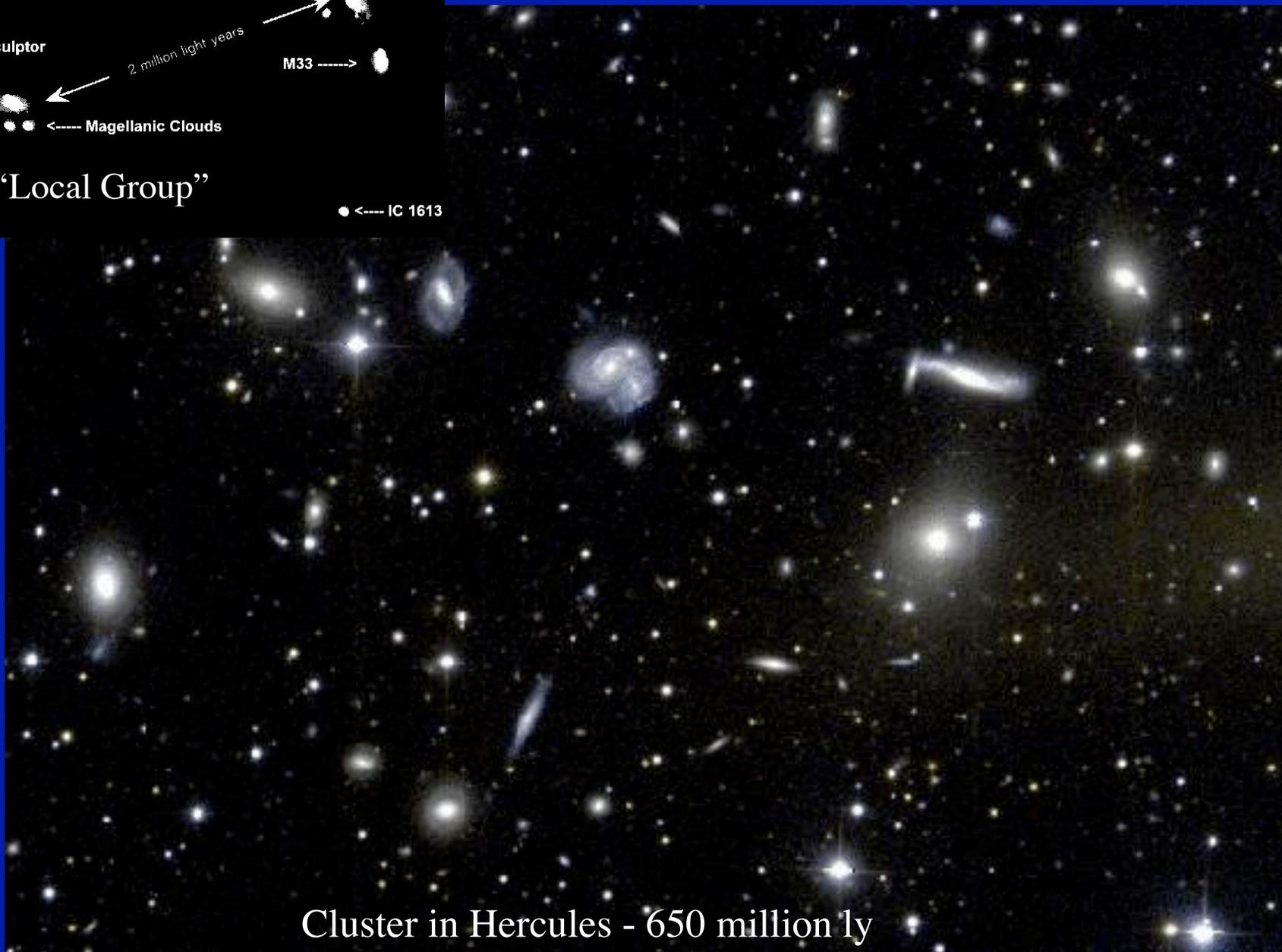


The Local Group



Our "Local Group"

# Galaxy Clusters



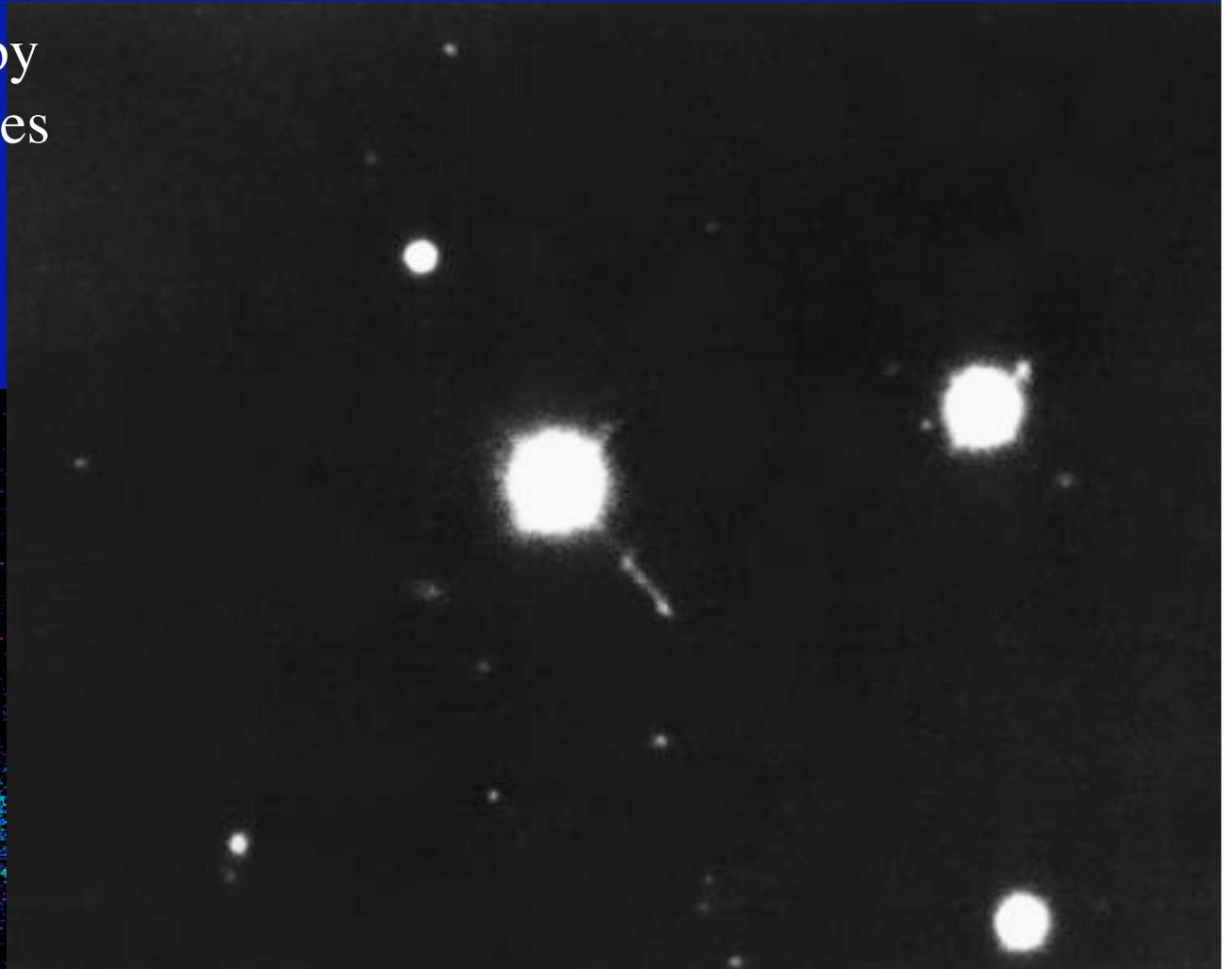
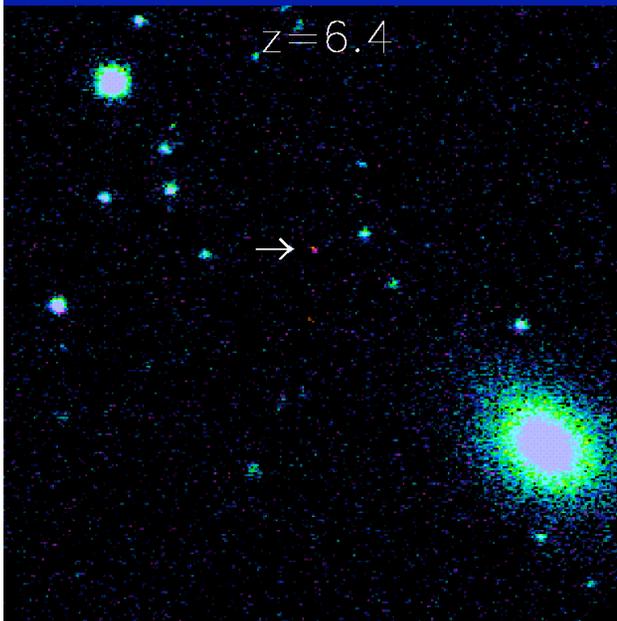
Cluster in Hercules - 650 million ly

# Quasar - 3C 273

2 billion ly

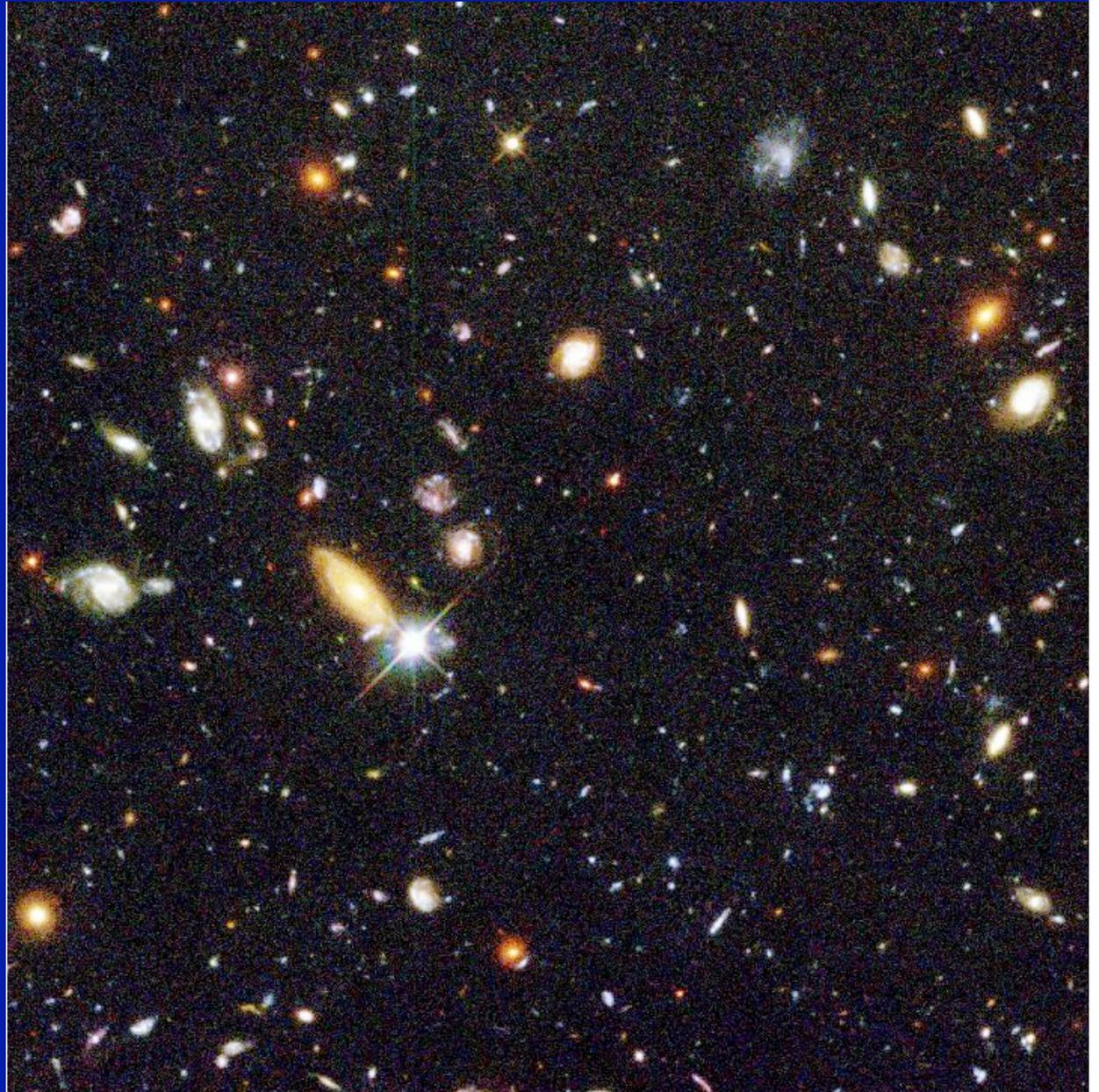
Quasars may be the most distant, powerful sources in the Universe, powered by supermassive black holes

Most distant quasar  
~ 13 billion light years



# Hubble Deep Field

The galaxies you see in  
this deep HST photo  
are billions of light  
years away



# What is our physical place in the universe?

We inhabit a small terrestrial planet, orbiting an average star, one of a half a trillion stars, in a typical galaxy, one of billions of galaxies in the visible Universe.

