Astronomy 100

Chapter 1 Overview

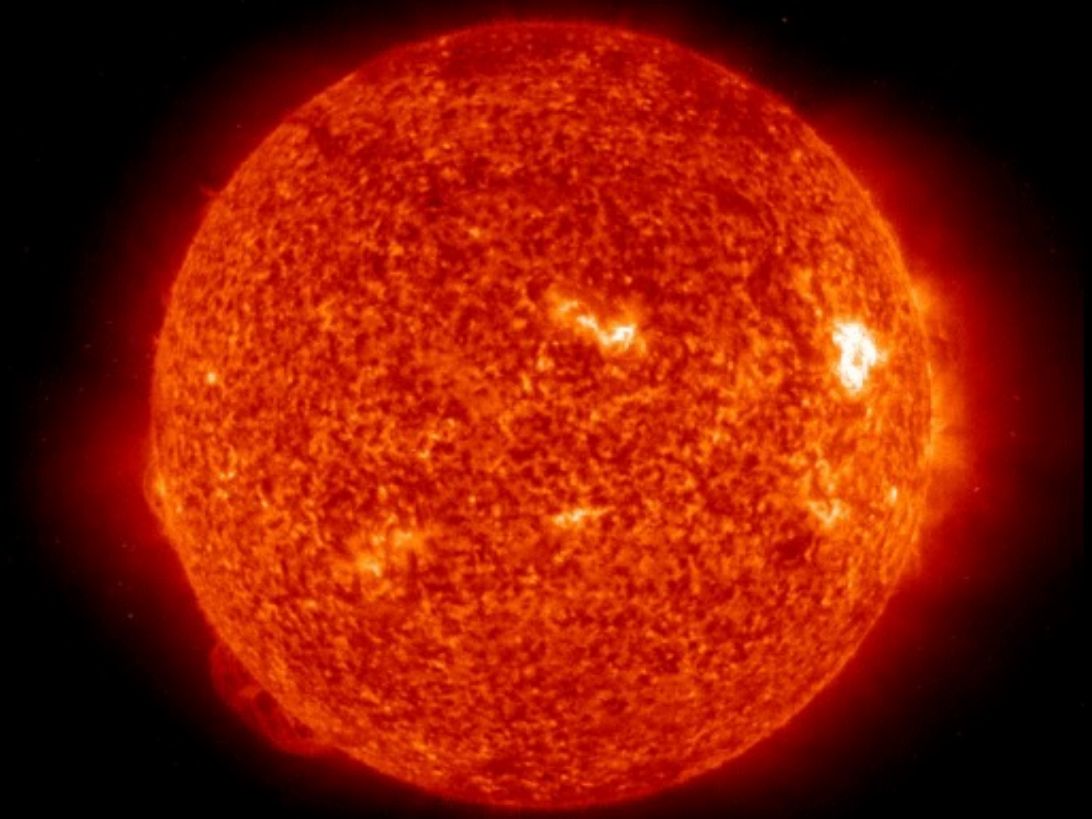
Vera Gluscevic

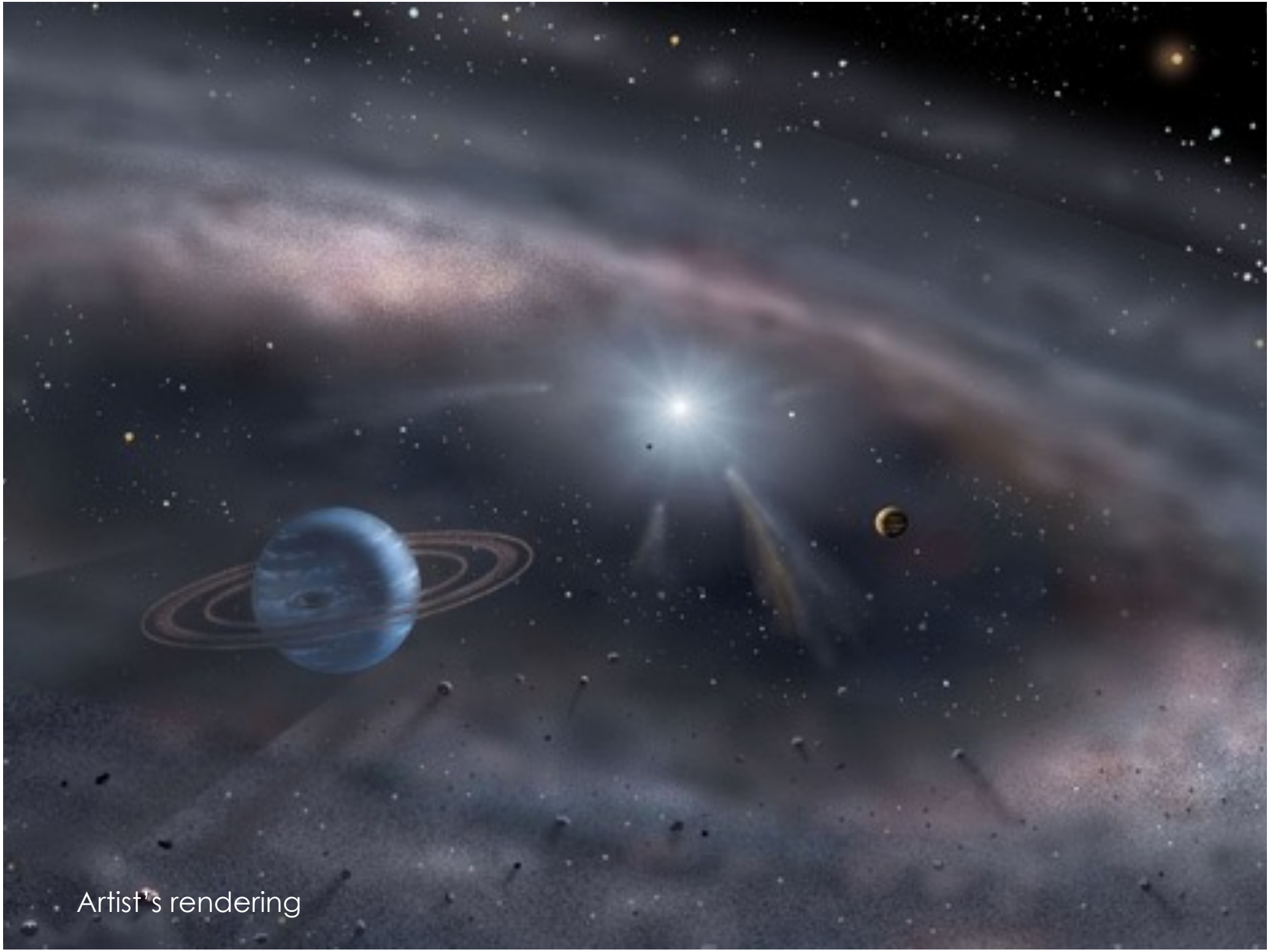
Image: Vahe Peroomian

Cosmic inventory

Star

A large, glowing ball of gas that generates heat and light through nuclear fusion

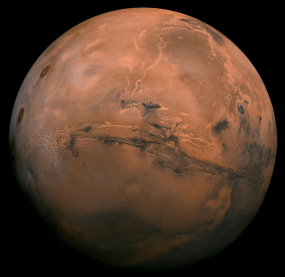




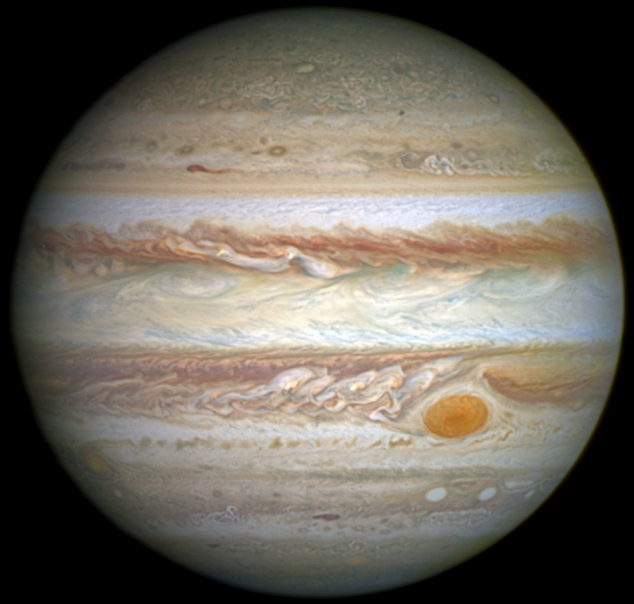
Artist's rendering

Planet

A moderately large object that orbits a star; it shines by reflected light. Planets may be rocky, icy, or gaseous in composition.



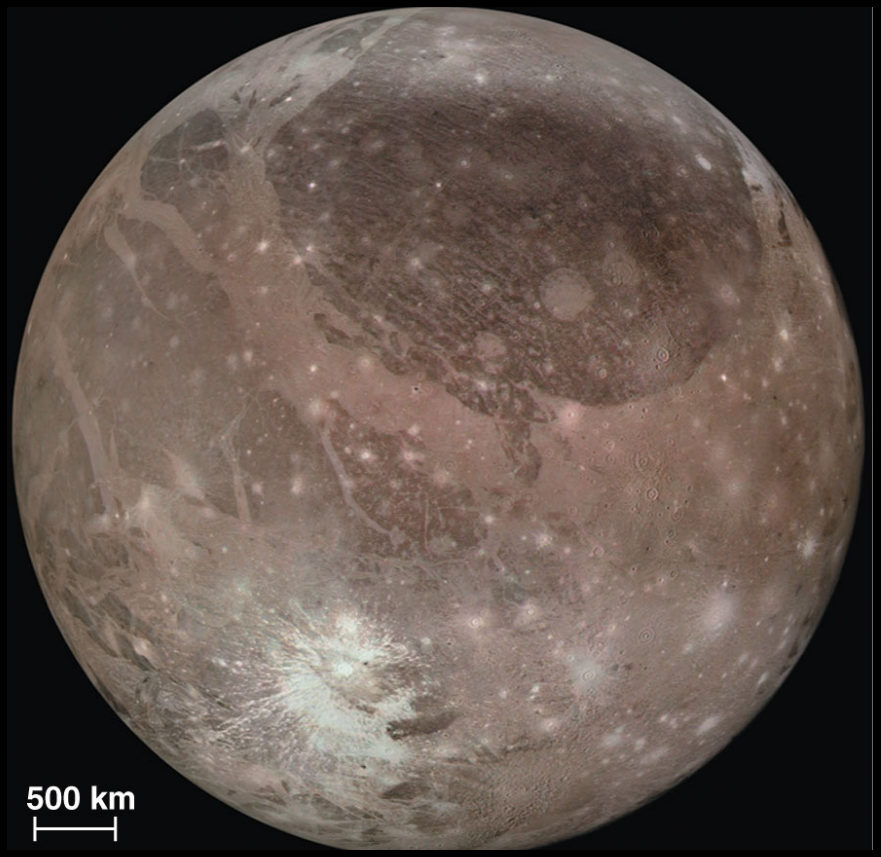
Mars



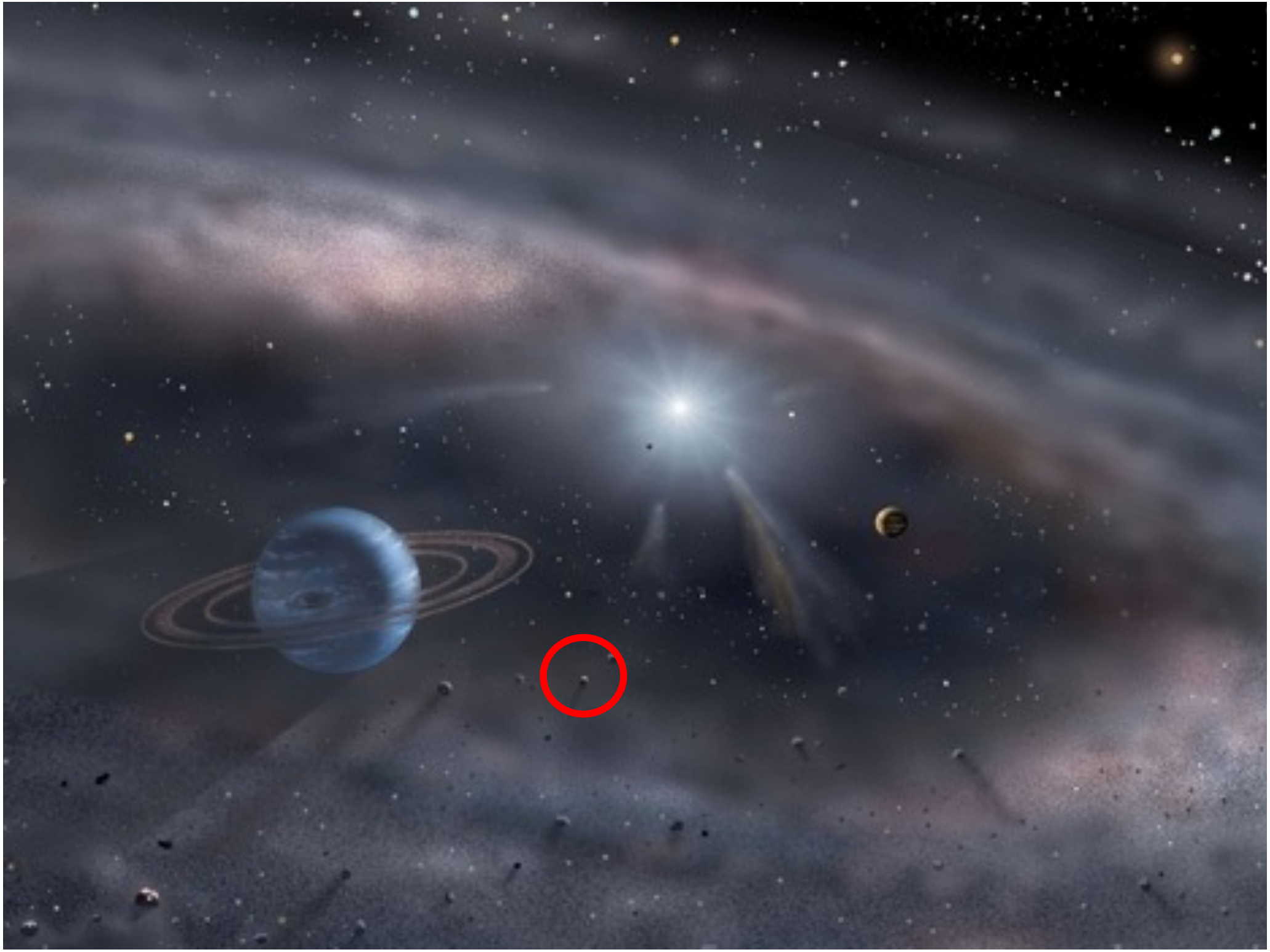
Jupiter

Moon (or Satellite)

An object that orbits a planet.



Ganymede (largest moon of Jupiter)



Asteroid

A relatively small and rocky object that orbits a star.

Mathilde

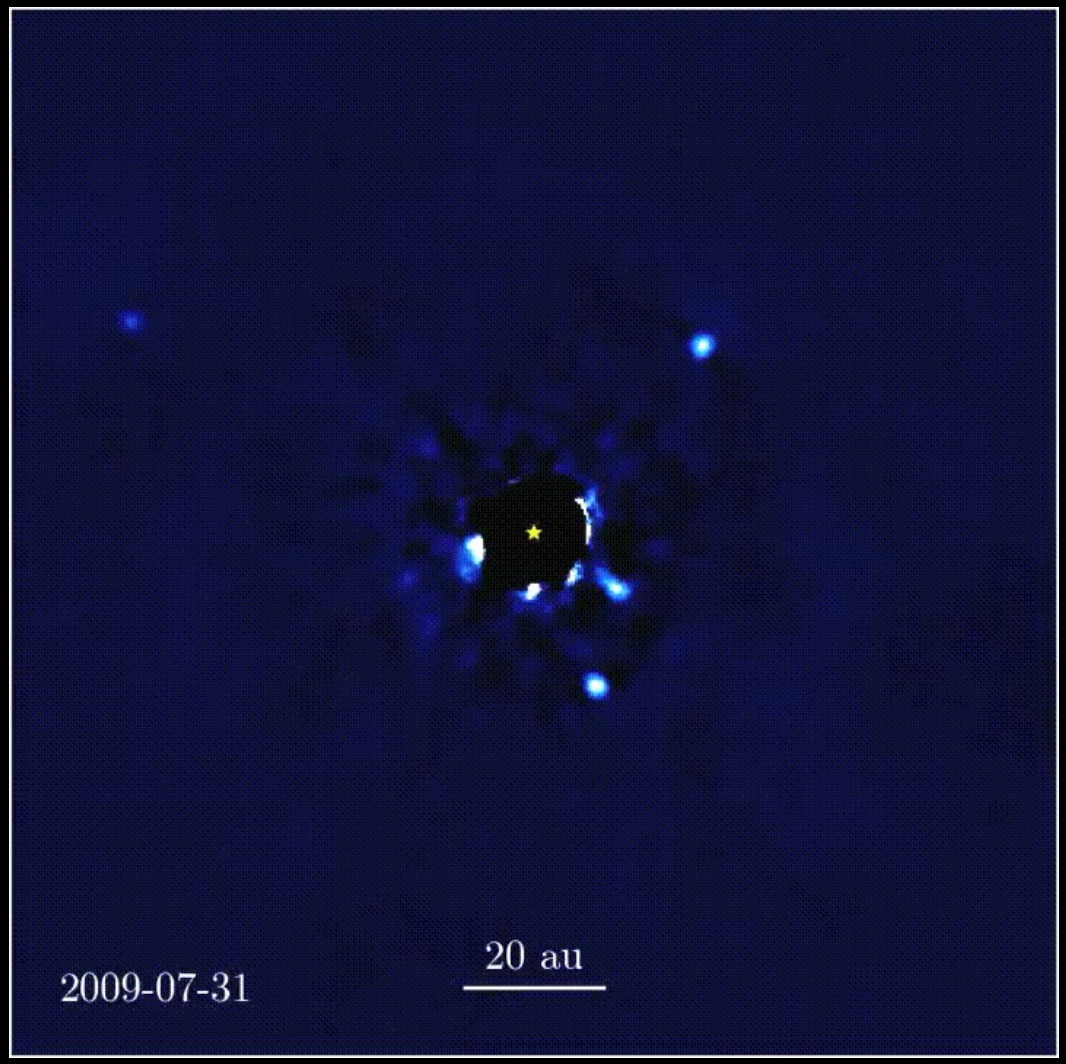
Comet

A relatively small and *icy* object that orbits a star.

NEOWISE Comet

Solar System

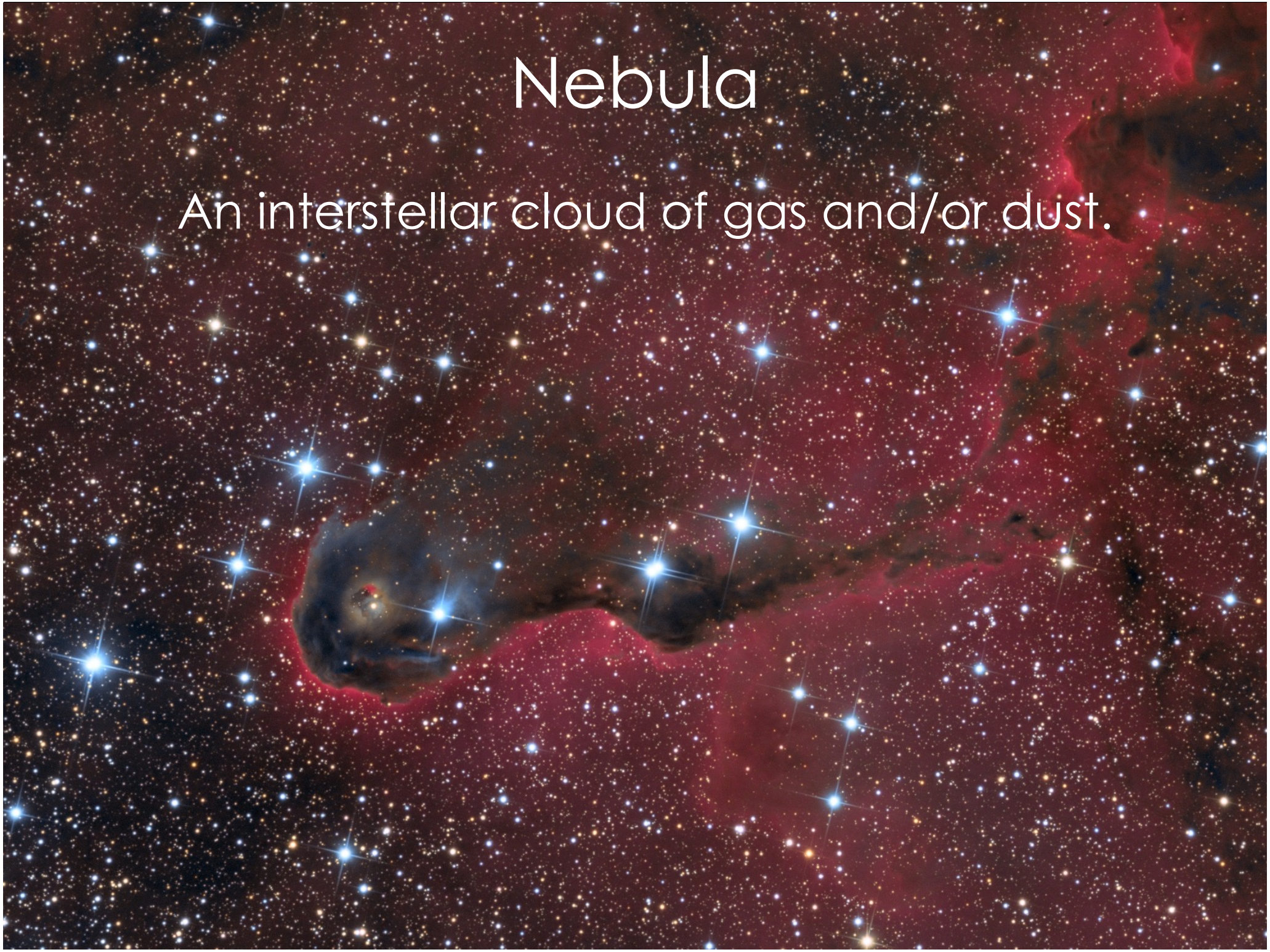
A star and all the material that orbits it, including its planets, moons, asteroids, comets, etc.



HR 8799 Star System
Images taken with the Keck Telescope
Source: Wikipaedia

Nebula

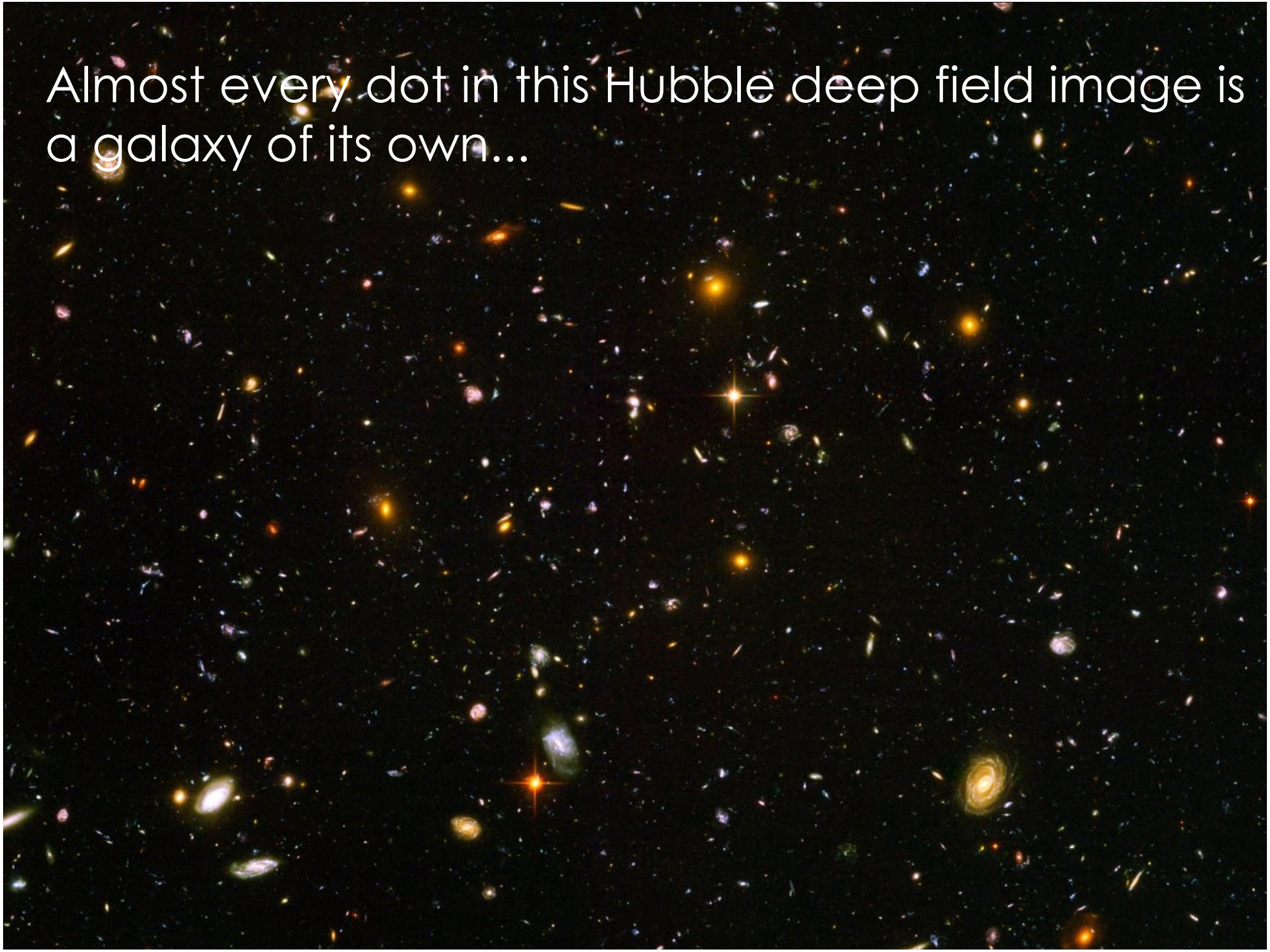
An interstellar cloud of gas and/or dust.



Galaxy

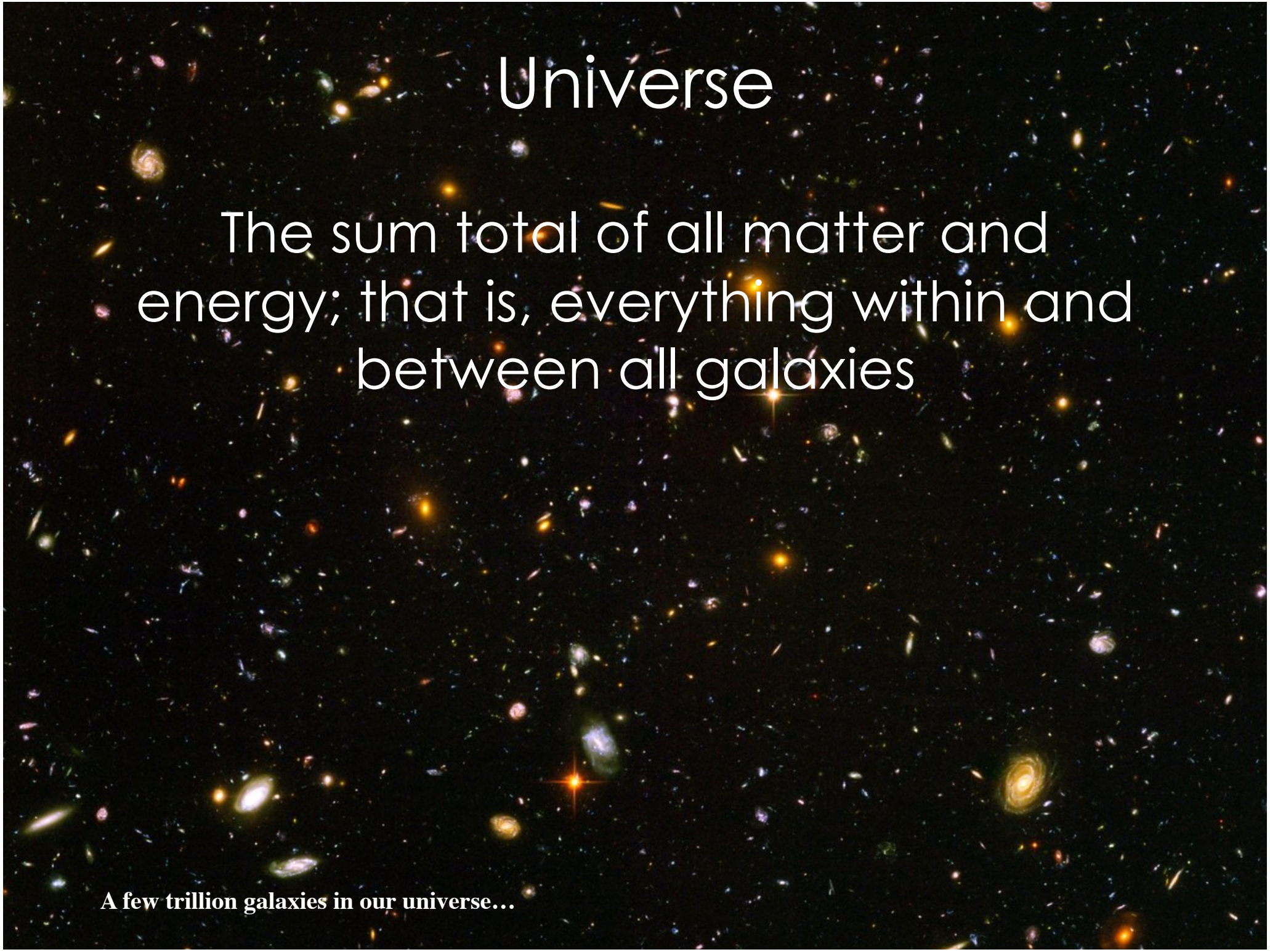
A great "island" of stars in space, all held together by gravity and orbiting a common center.

M31, the great galaxy in Andromeda


Almost every dot in this Hubble deep field image is a galaxy of its own...

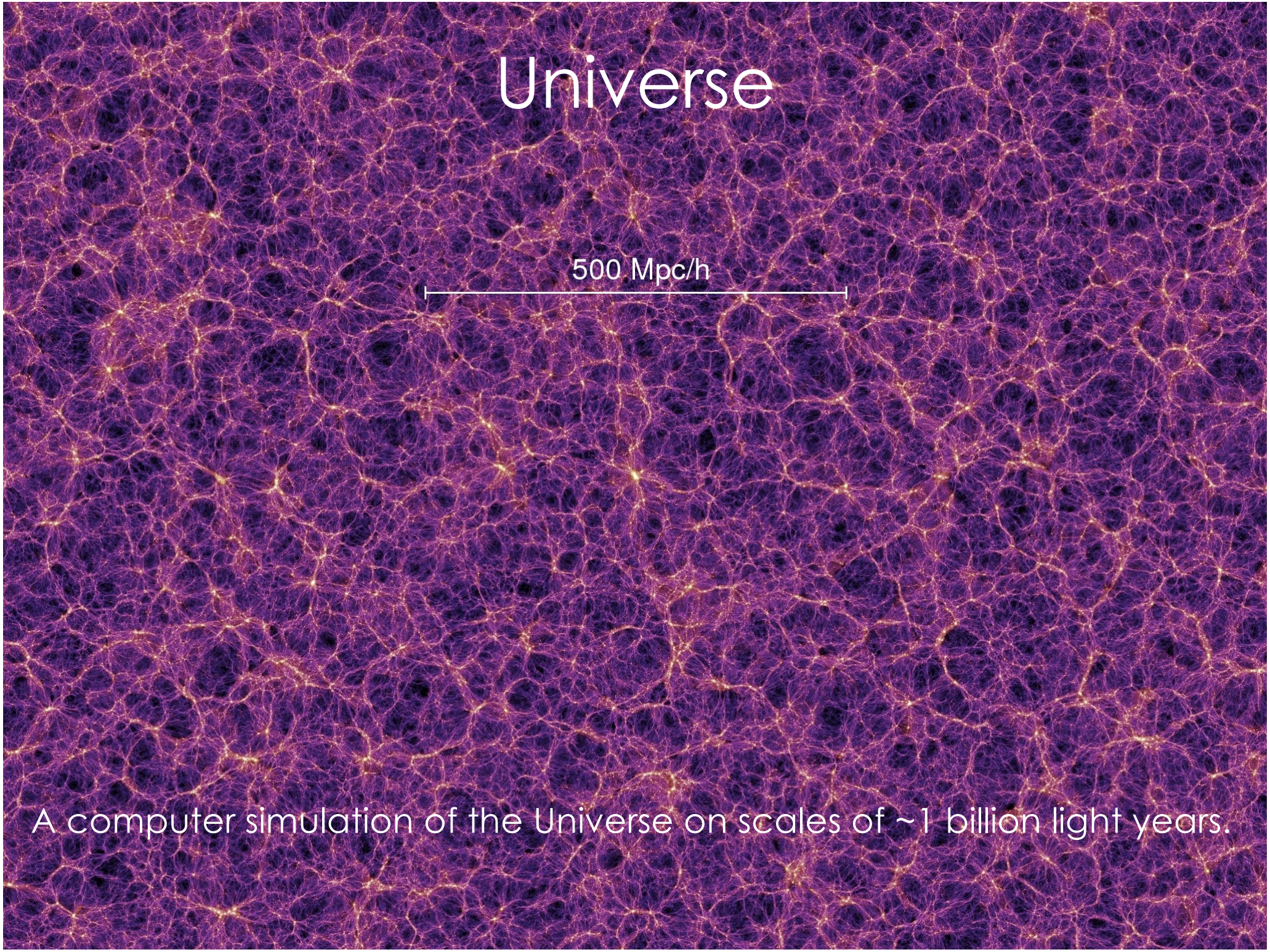
Universe

The sum total of all matter and energy; that is, everything within and between all galaxies



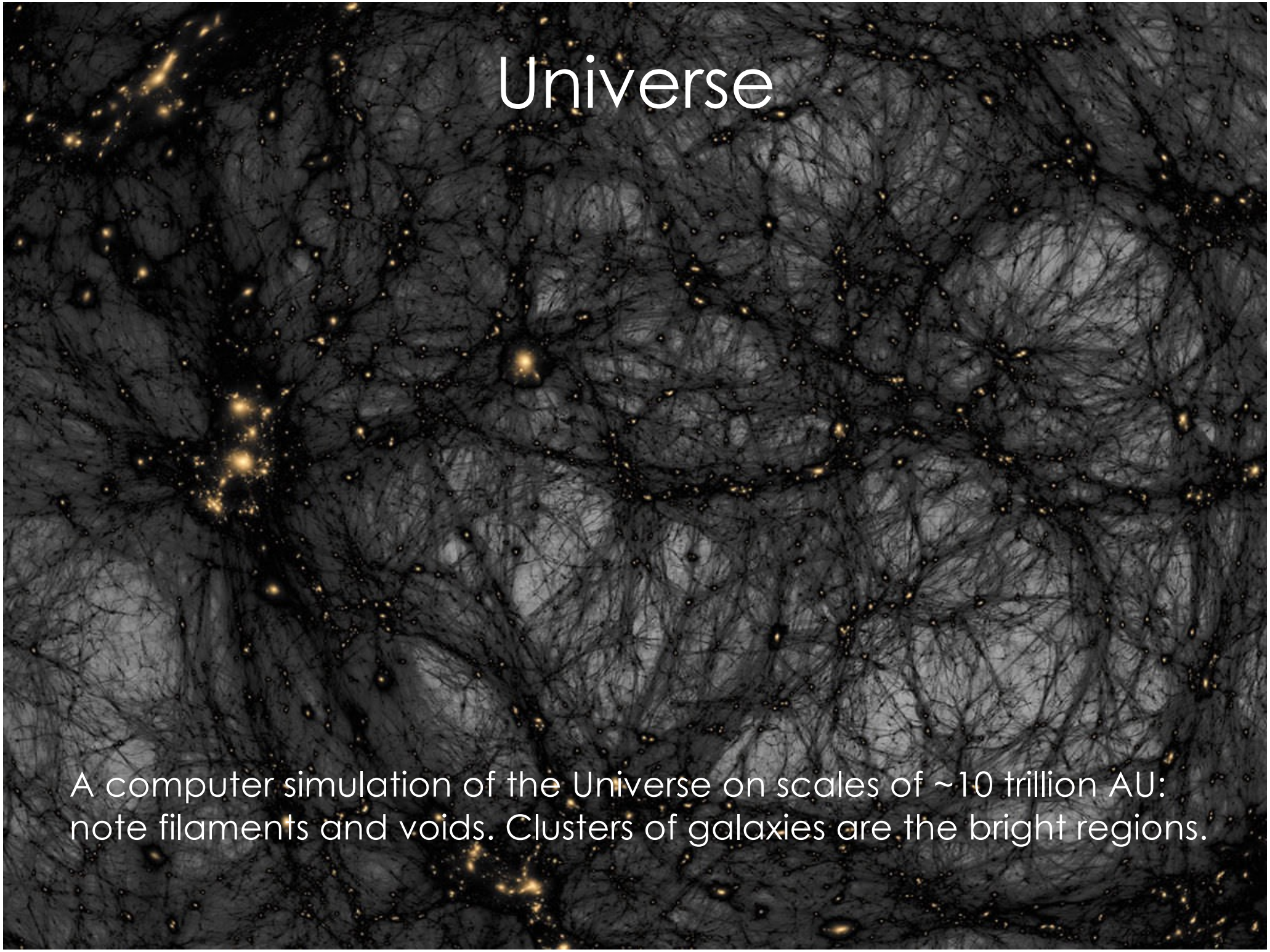
A few trillion galaxies in our universe…

Universe



A computer simulation of the Universe on scales of ~1 billion light years.

Universe

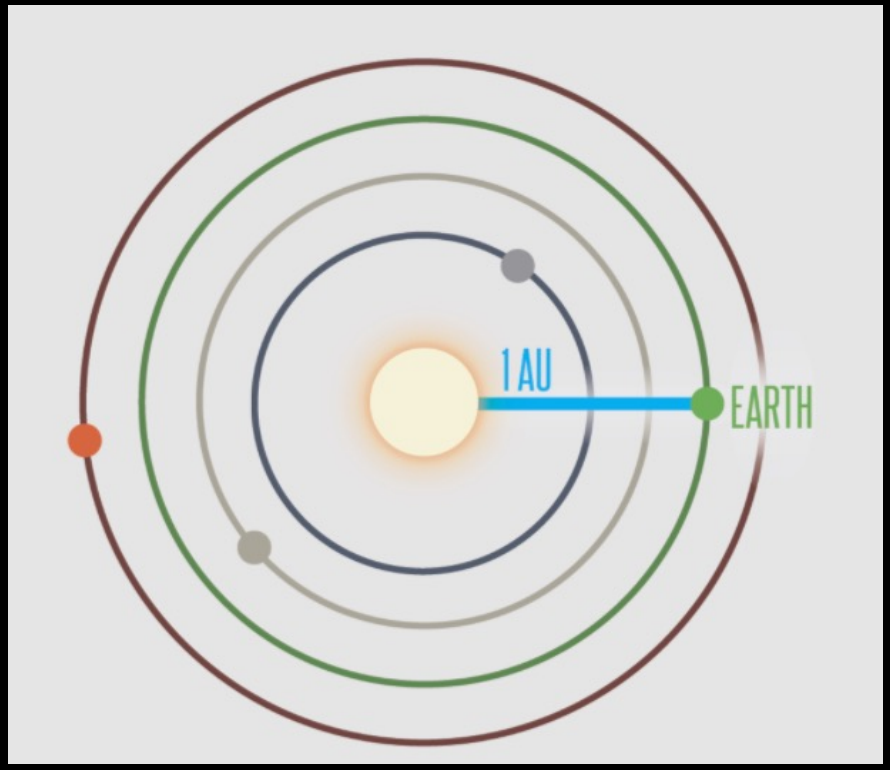


A computer simulation of the Universe on scales of ~10 trillion AU: note filaments and voids. Clusters of galaxies are the bright regions.

Astronomical Unit (AU)

= a unit of distance equal to the average distance from the Earth to the Sun (about 93 million miles or 150 million kilometers).

E.g. Mars is 1.5 AU from the Sun, Jupiter is 5.2 AU from the Sun.



A light year

= the distance light travels in 1 year.

- Light travels at a speed of 300,000,000 meters per second.
- 1 year is 365 days = 31,536,000 seconds.
- 1 light year = 9.46×10^{15} meters (63,000 AU, or 5,879,000,000,000 miles)

https://www.youtube.com/watch?v=GoW8Tf7hTGA&t=395s

Plan for this lesson:

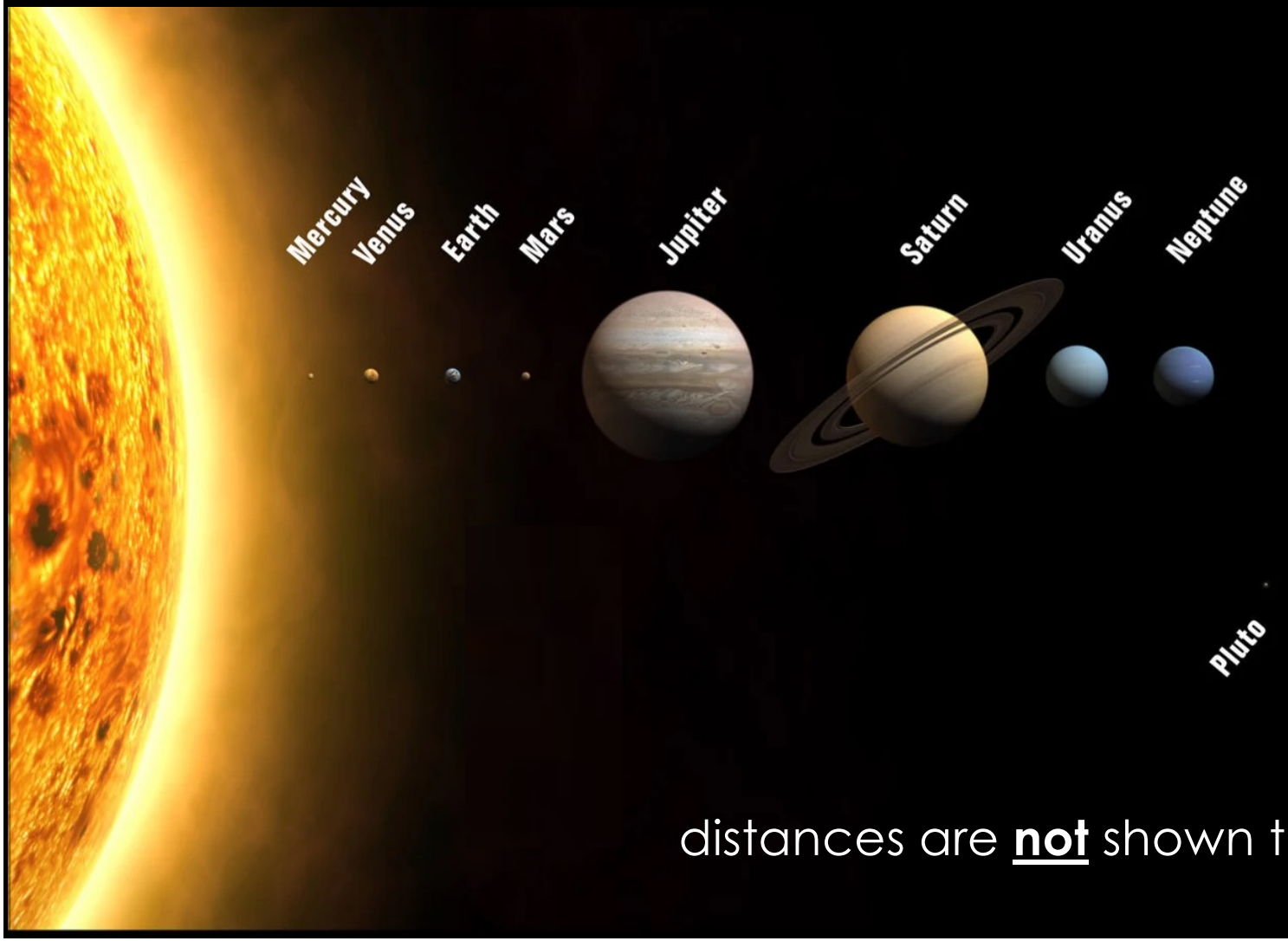
Our cosmic address
Speed of light
Cosmic motions
Size and age of the Universe

What is our cosmic address?

What is our cosmic address?

The Solar System

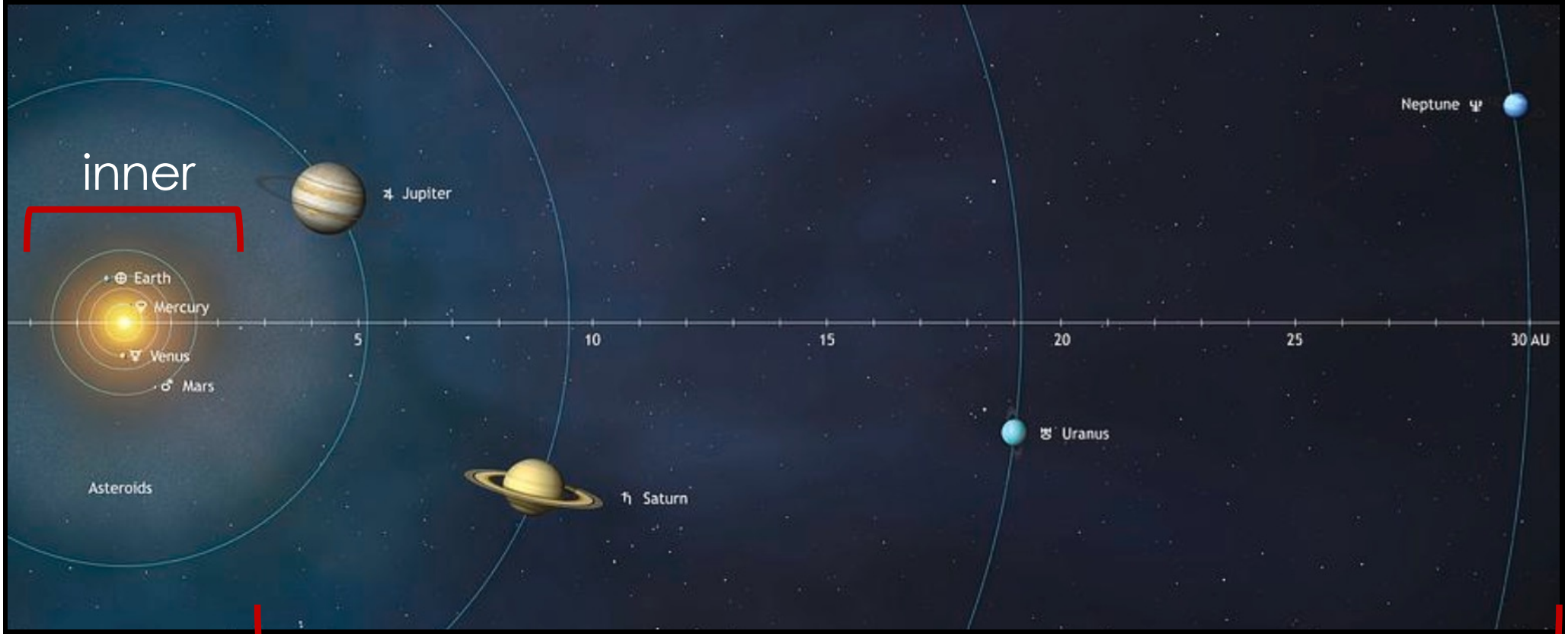
1 star + 8 planets + several dwarf planets + moons + asteroids + comets (all orbiting the Sun)



distances are **not** shown to scale!

The Solar System

distances <u>are</u> now shown to scale.



outer

Our stellar neighborhood

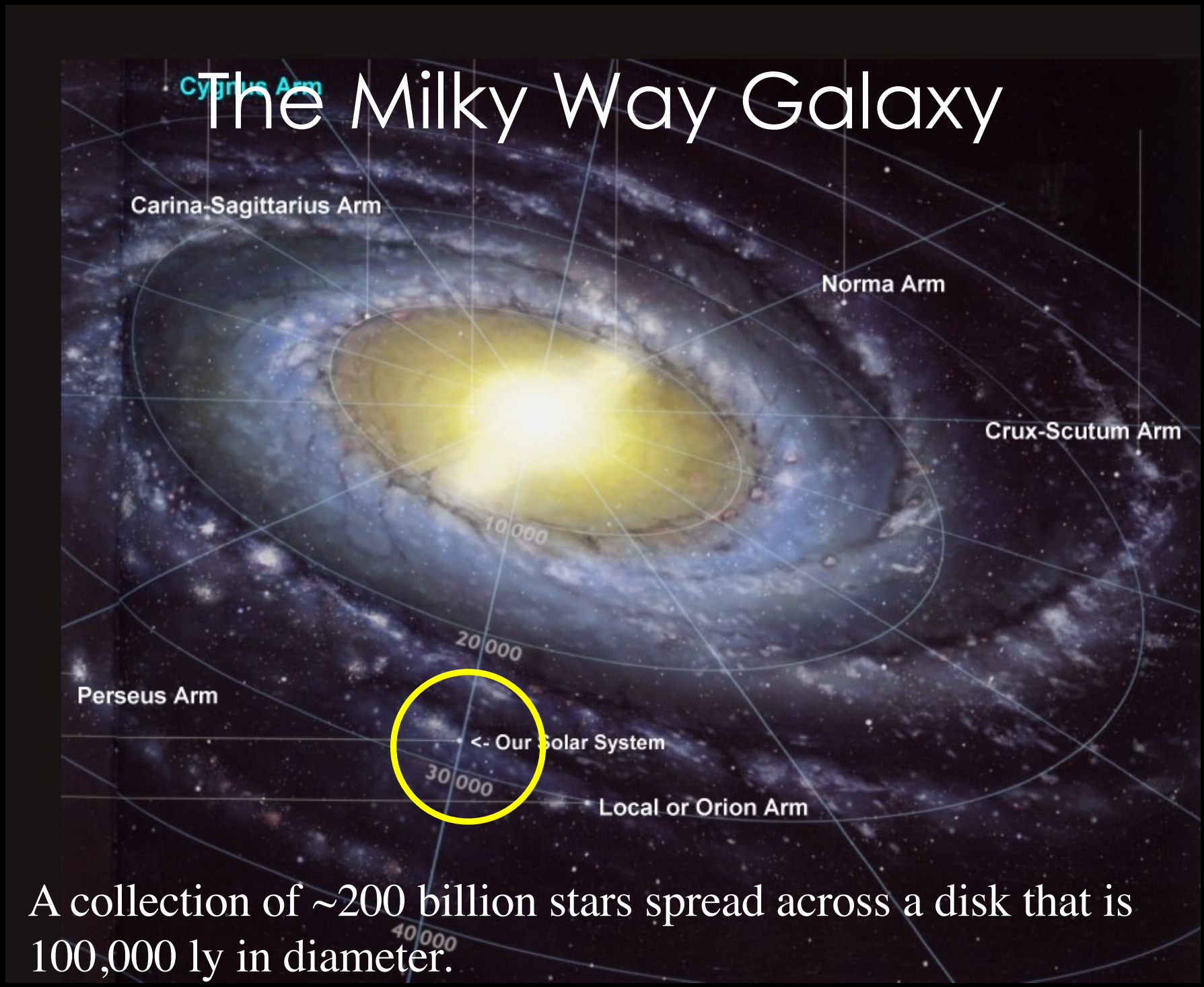
Nearest star to the Sun is **Proxima Centauri** (4.4 light years away).
Only 12 stars within 10 light years of the Sun.

http://stars.chromeexperiments.com

The Milky Way

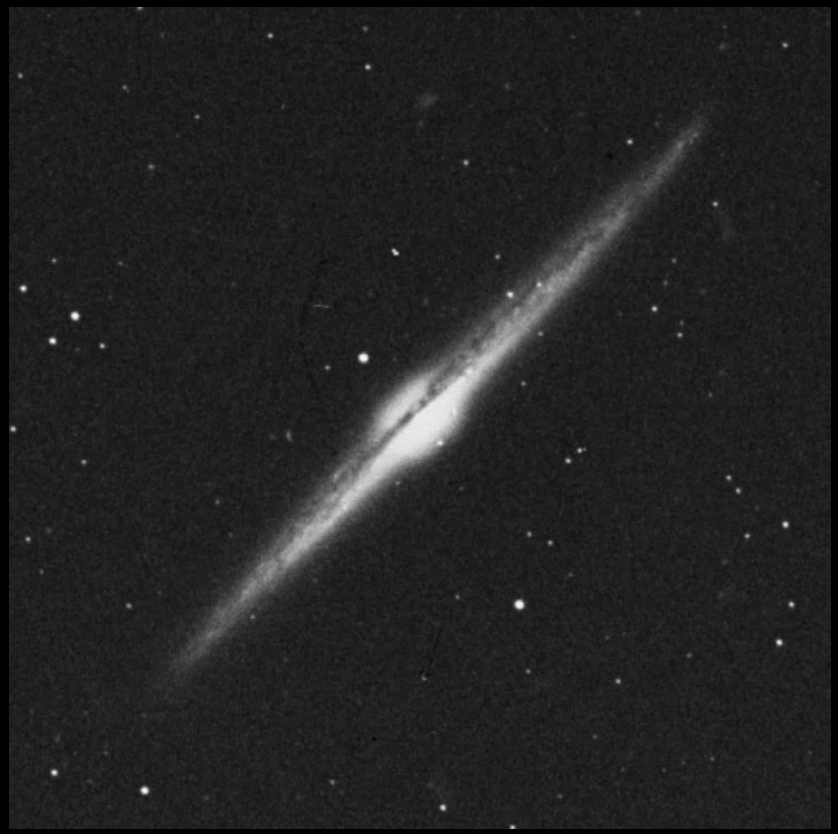
Image: Vahe Peroomian

The Milky Way Galaxy



A collection of ~200 billion stars spread across a disk that is 100,000 ly in diameter.

The Milky Way Galaxy

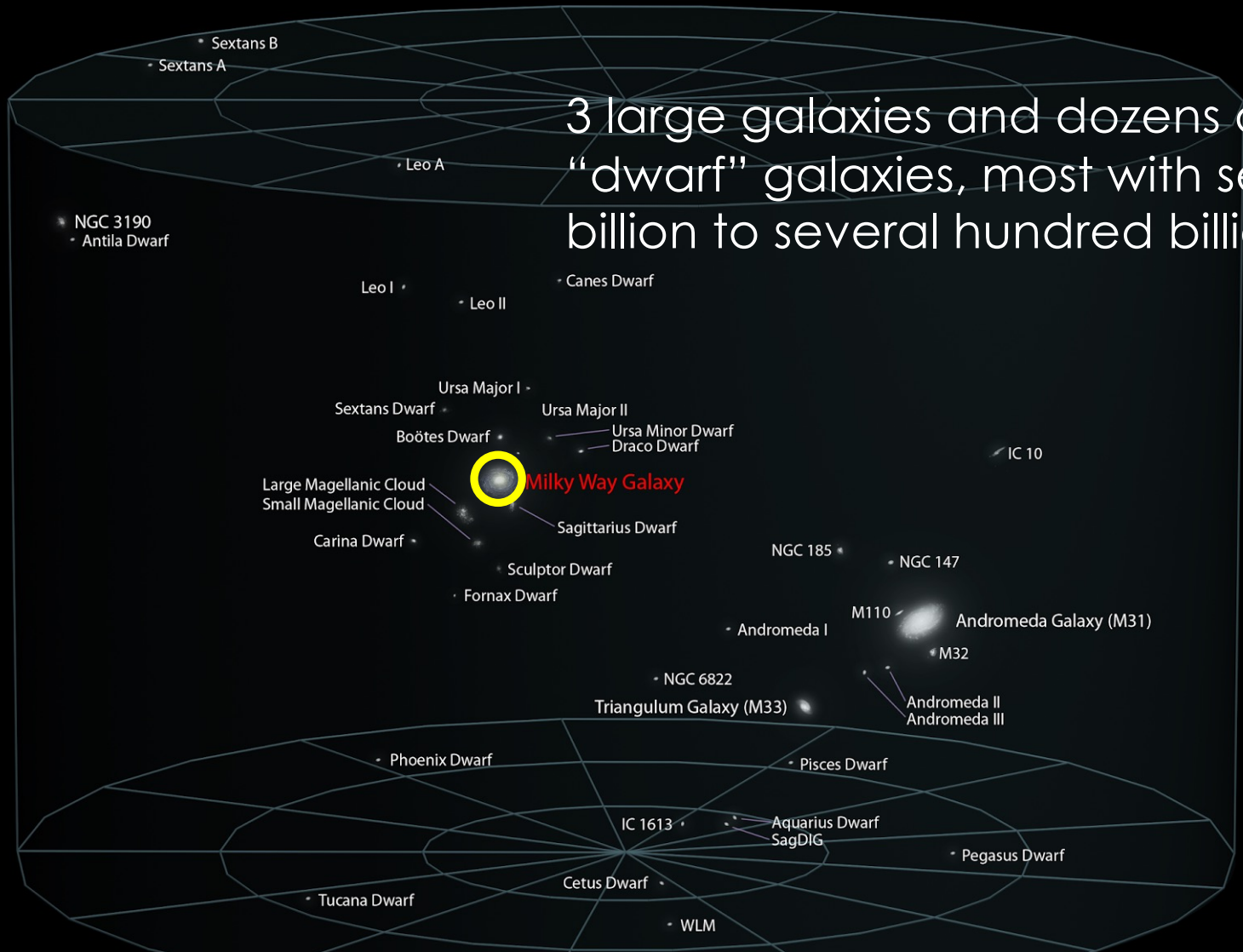


The Milky Way is a **Spiral Galaxy** like those pictured above.

The Andromeda Galaxy

2.5 million ly from Earth

The Local Group of Galaxies…



3 large galaxies and dozens of smaller "dwarf" galaxies, most with several billion to several hundred billion stars

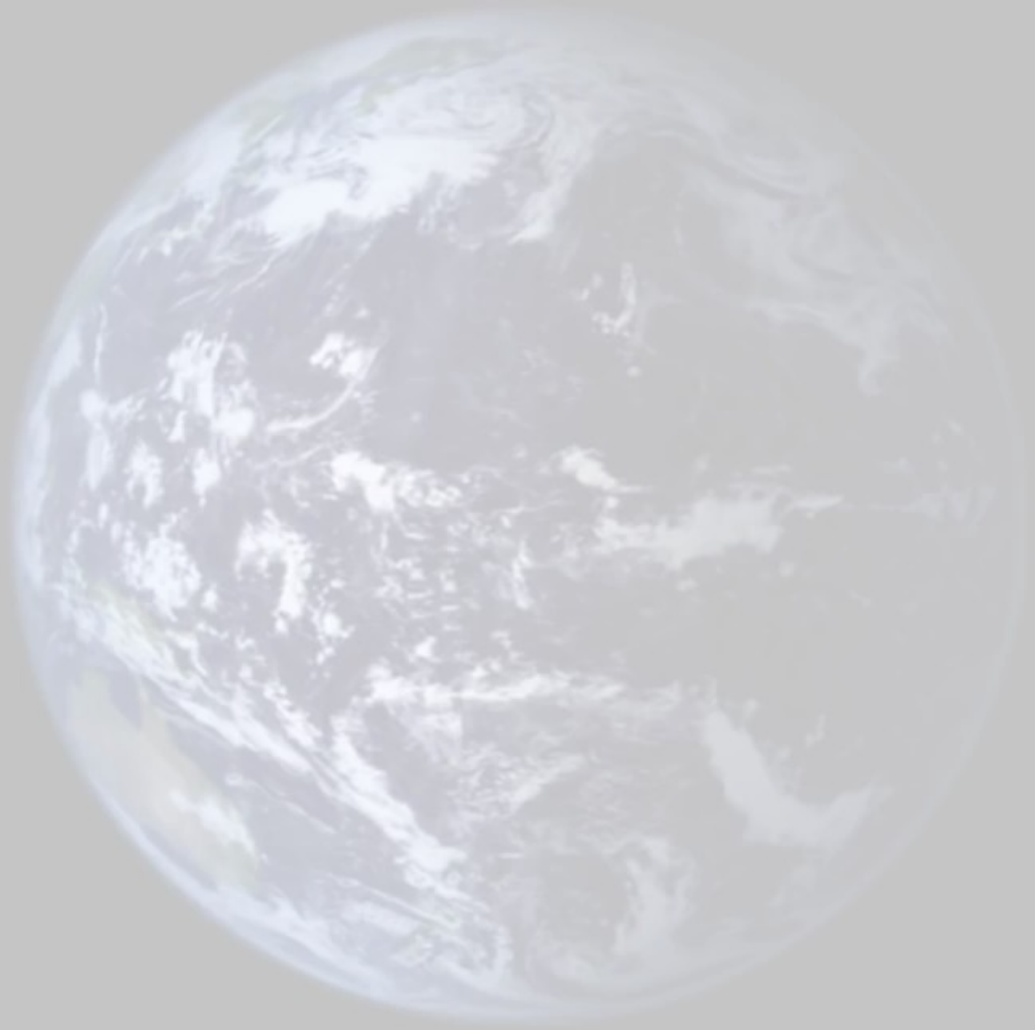
The cylinder in the diagram is about 6 million ly across!

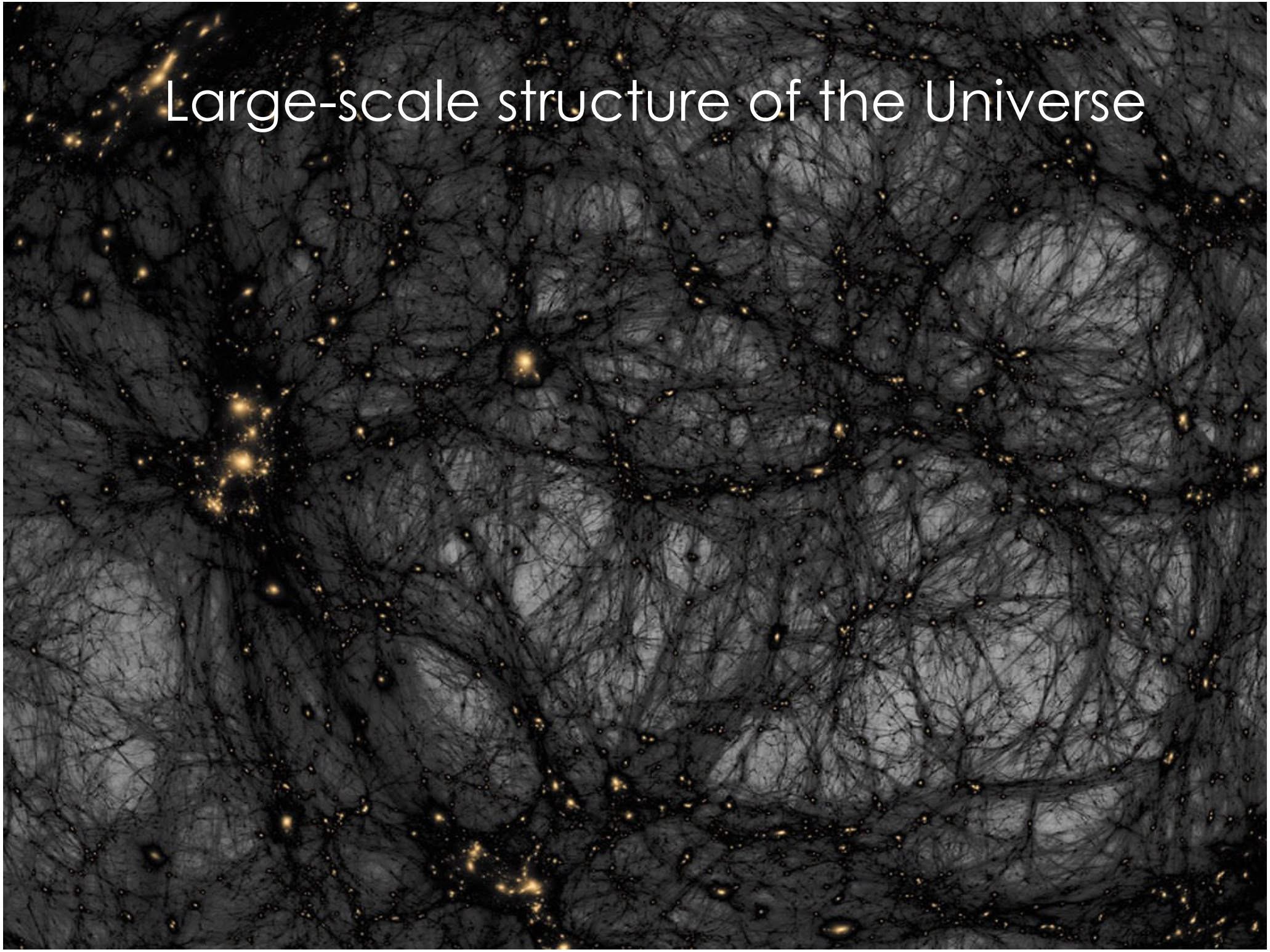
Virgo Cluster

Virgo cluster of about 1000 galaxies.


Trillion galaxies in the visible universe

The Laniakea Supercluster (The Local Supercluster)




Large-scale structure of the Universe

Scientific Notation

- As we measure larger and larger distances (or small ones, actually), we're going to have too many zeros to deal with!
- Count the number of zeros, and write the number in scientific notation:

  1 million = 1,000,000 (6 zeros) = 1×10^{6}

  1 billion = 1,000,000,000 (9 zeros) = 1×10^{9}

  1 trillion = 1,000,000,000,000 (12 zeros) = 1×10^{12}

  1 millionth = 1 / 1,000,000 = 0.000001
  (5 zeros and a 1 after decimal) = 1×10^{-6}

How many stars and galaxies are out there?

- The Milky Way is one of about a trillion galaxies.
- 10^{11} stars/galaxy $\times$ 10^{12} galaxies = 10^{23} stars

The Universe has as many stars as grains of (dry) sand on *all* Earth's beaches.

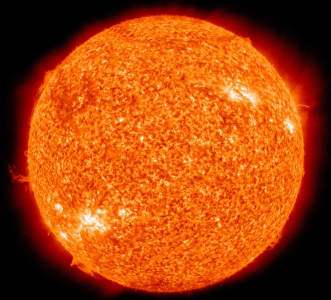
question for you

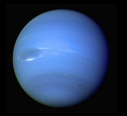
How do we know all this?

The speed of light

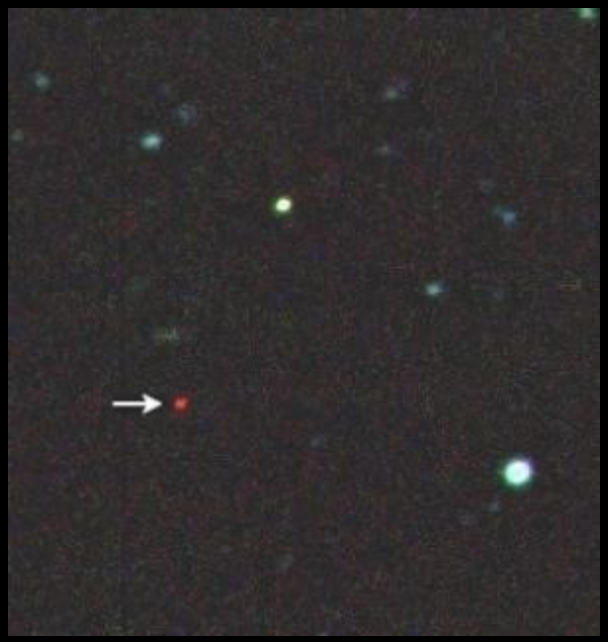
No particles or radiation can travel faster than the speed of light through the universe (300,000 km/sec).

It takes sunlight 8 minutes 20 seconds to travel from the Sun to the Earth and 4 hours to reach Neptune.





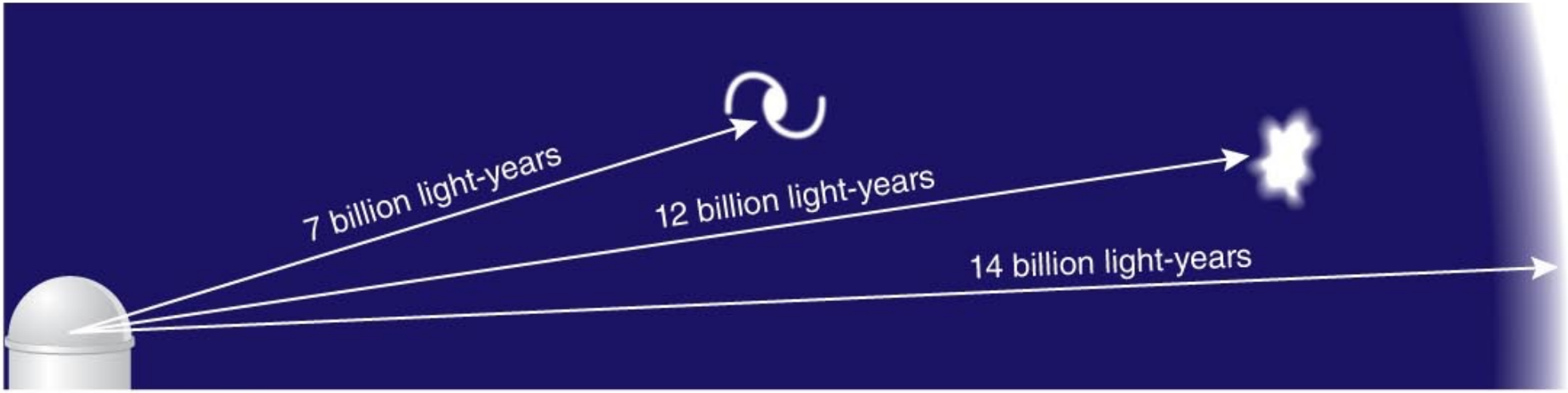
We see the Andromeda as it was 2.5 million years ago. In a classroom, you'd be roughly 10 billionths of a light second away from me...



Because the speed of light is finite, the further away we look, the **farther back in time** we're looking.

Lookback time

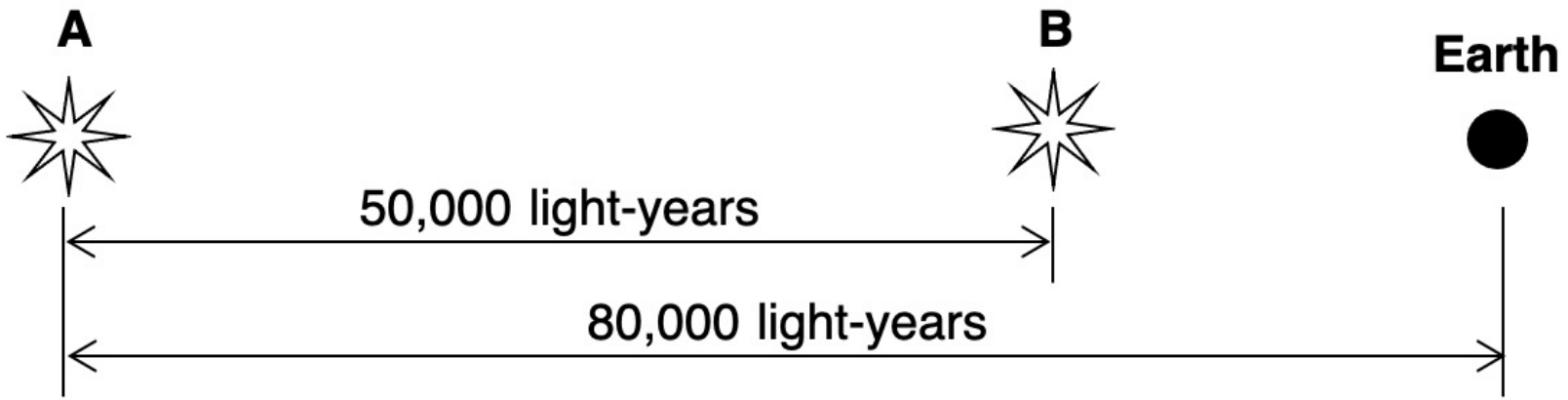
= time the light took to travel to us.



In astrophysics, we look farther back in time
when we look farther away...

question for you

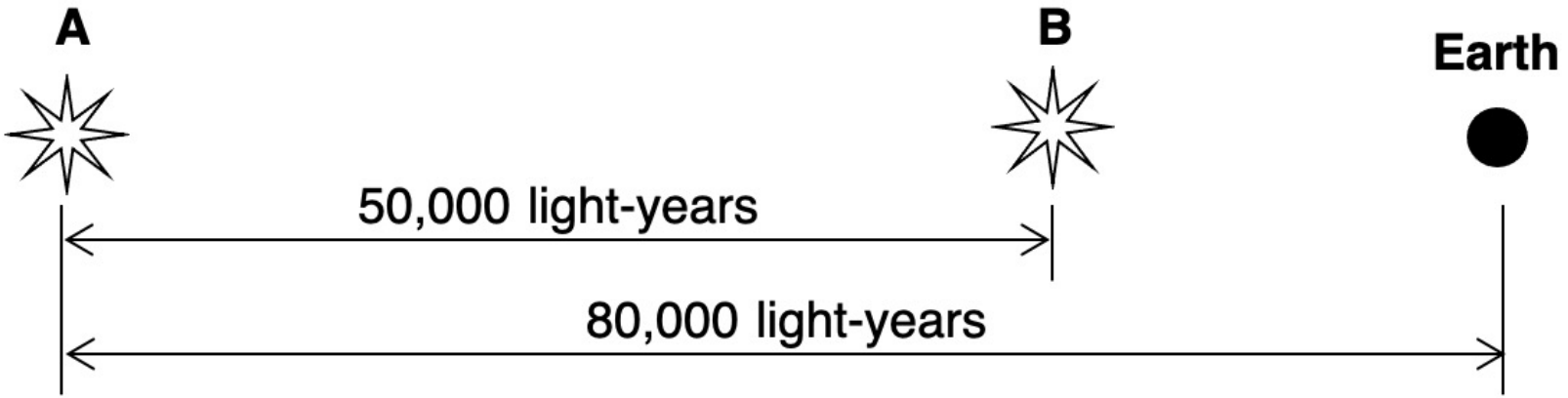
Star A is born 80,000 light years away from the Earth. How old does the star appear when we first see it on Earth, and how old is it at that moment actually?



A. it appears to be 0 years old, and it is actually 80,000 years old
B. it appears to be 80,000 years old, and it is actually 0 years old
C. it appears to be 80,000 years old, and it is actually 160,000 years old
D. it appears to be 50,000 years old, and it is actually 80,000 years old
E. I have no idea.

question for you

When an observer on Earth can first see Star A, how old would Star A appear to an observer orbiting Star B?

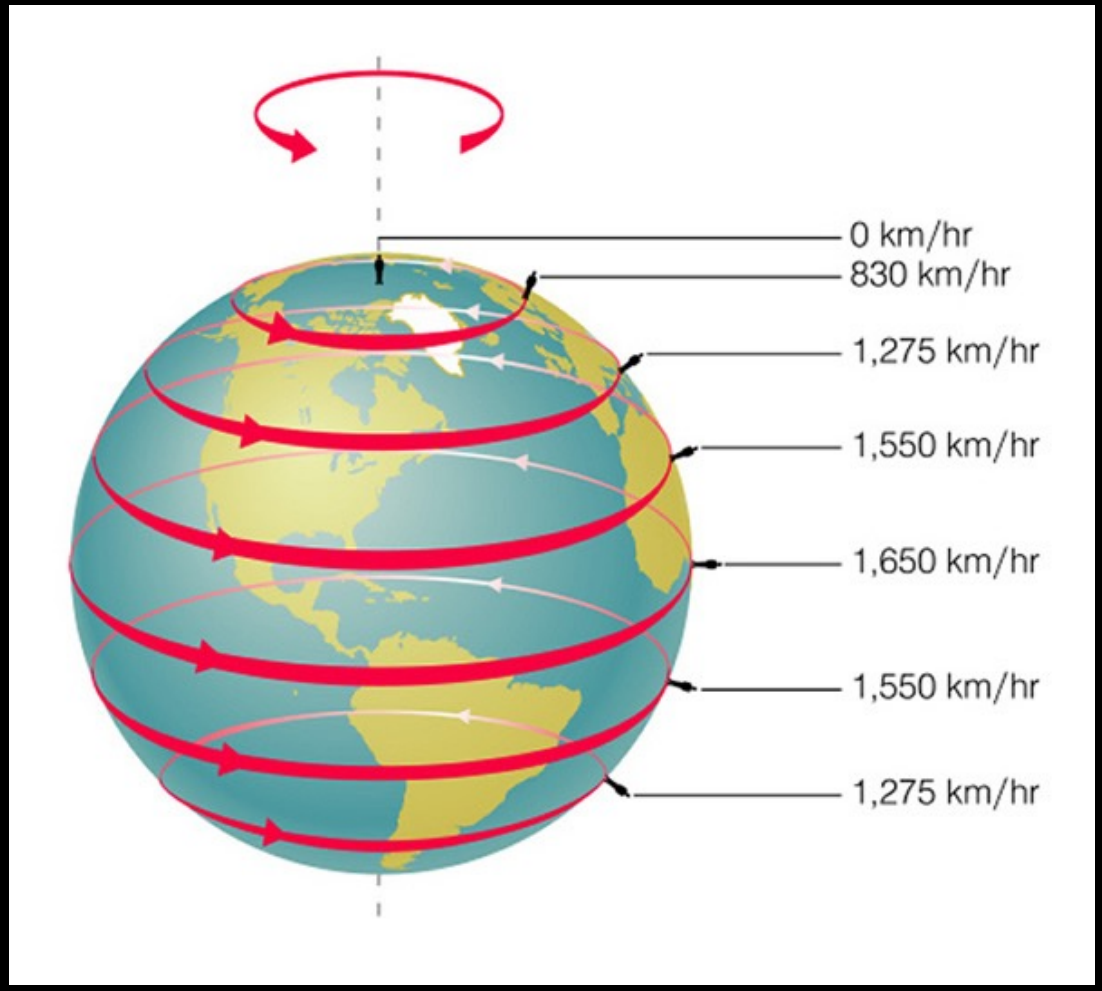


A. 30,000 years old
B. 50,000 years old
C. 80,000 years old
D. 130,000 years old

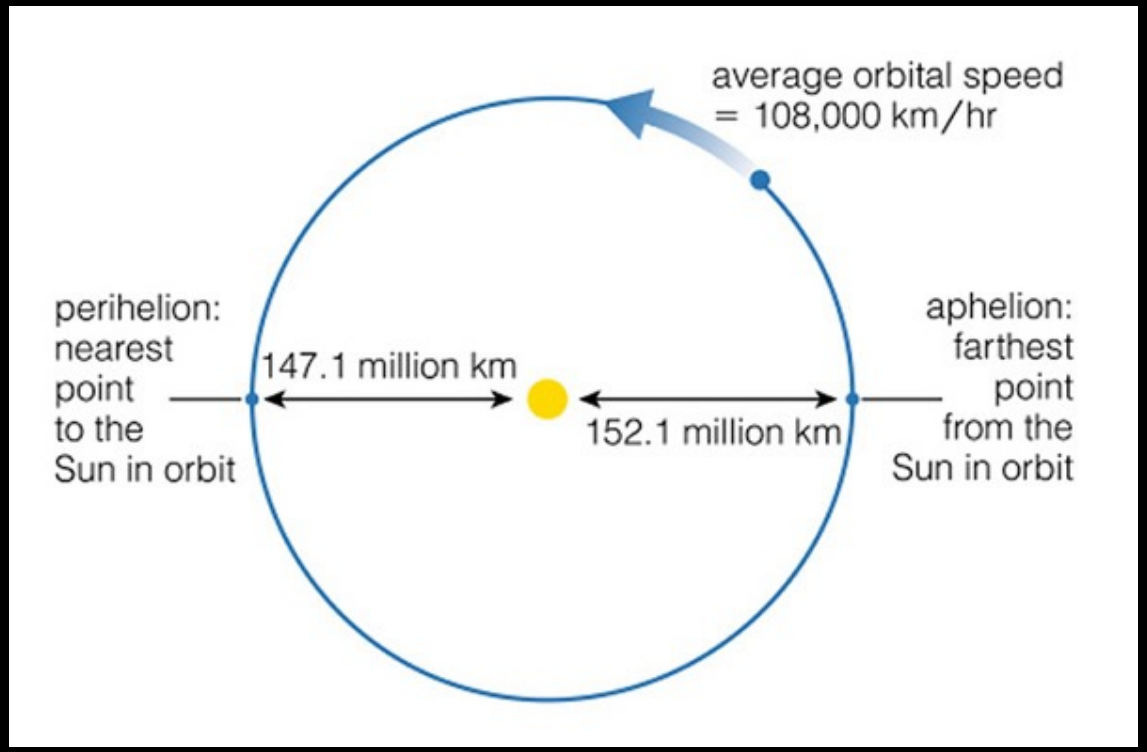
Motions

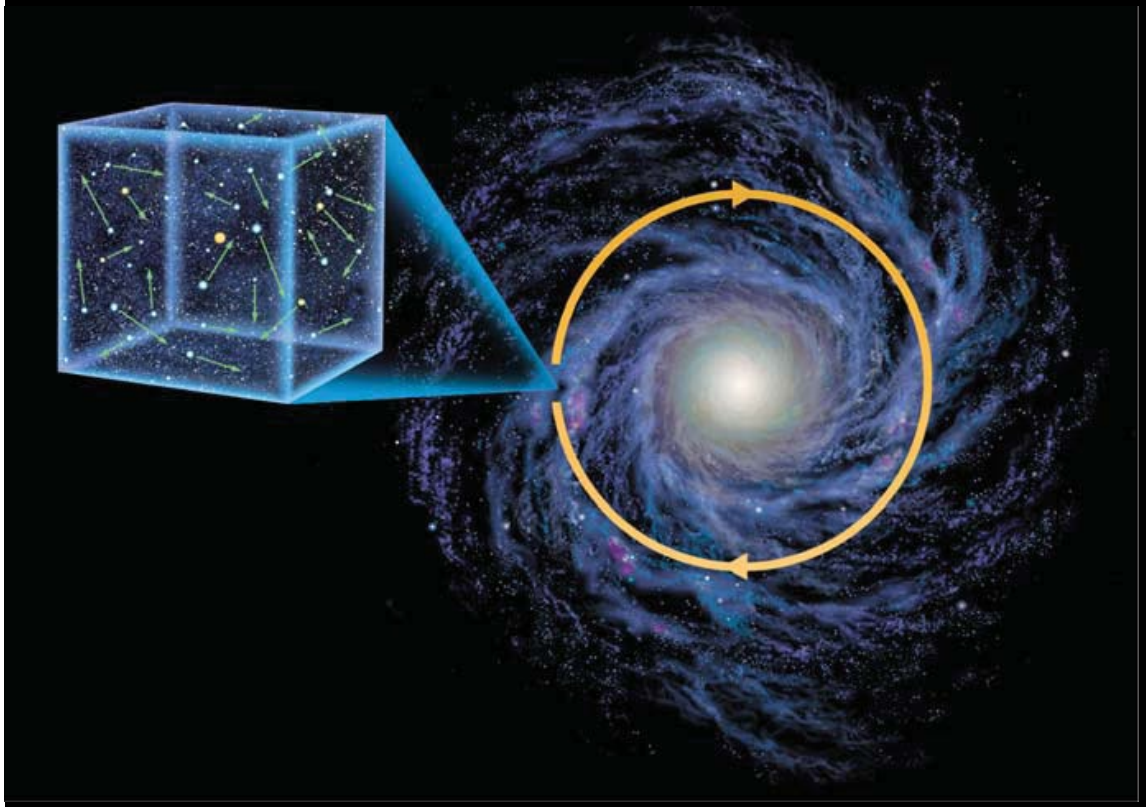

The sky appears mostly still…

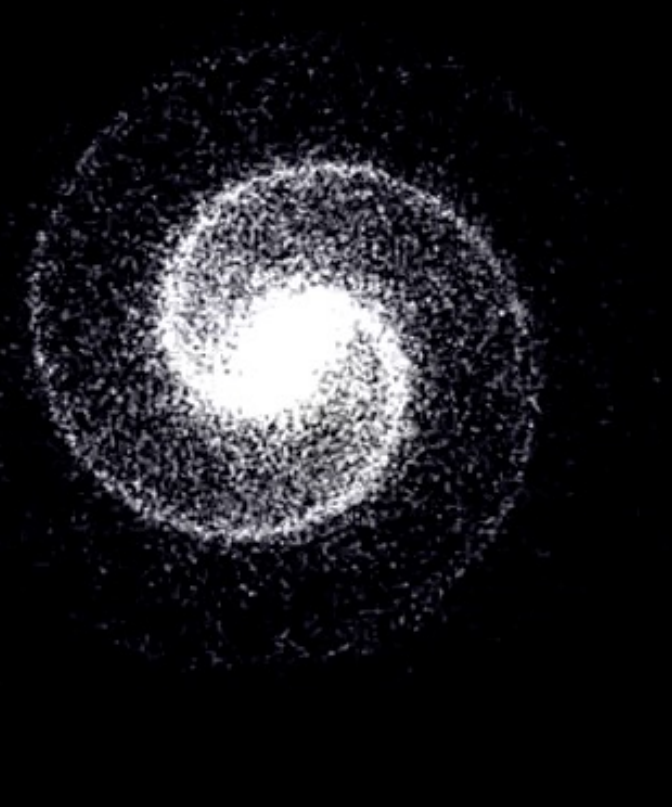
The Earth **rotates** on its axis (passing through the north and south poles) from west to east once a day.



The Earth **revolves** around the Sun on an elliptical orbit once a year.







Stars drift around in random directions, plus all go around the Galactic center.

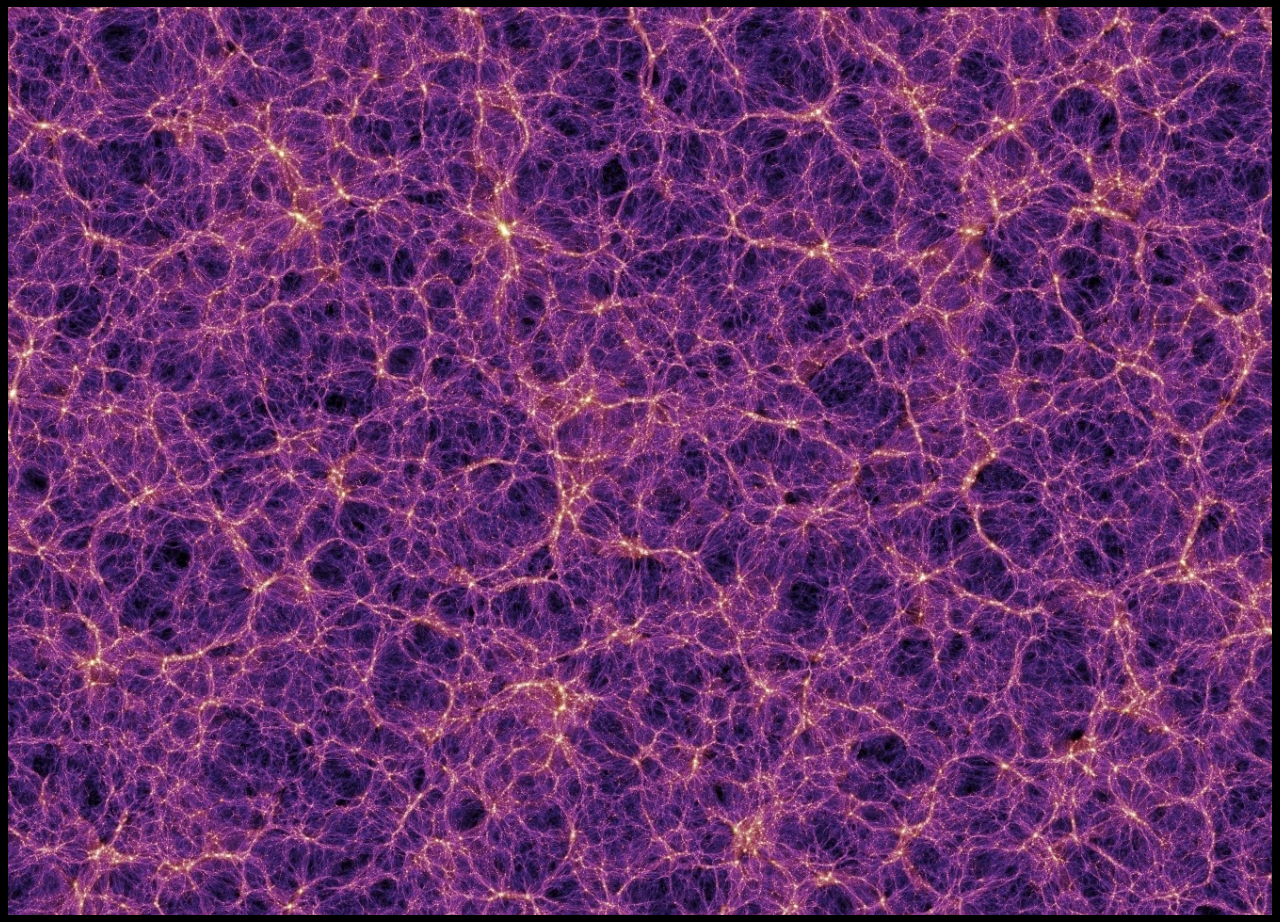
The Sun completes one revolution about the Galactic center every 240 million years.

We're constantly moving!

- Earth daily rotation: ~ 1500 km/hr
- Earth's revolution: ~ 108,000 km/hr
- Sun's revolution about galactic center: ~ 740,000 km/hr

Expansion of the Universe

Distances between galaxies far away from each other are expanding. There is no "center" to the expansion, it is happening in all directions, like stretching of a balloon.



question for you

If the lookback time to a distant object is 13 billion years, how far is this object from us right now?

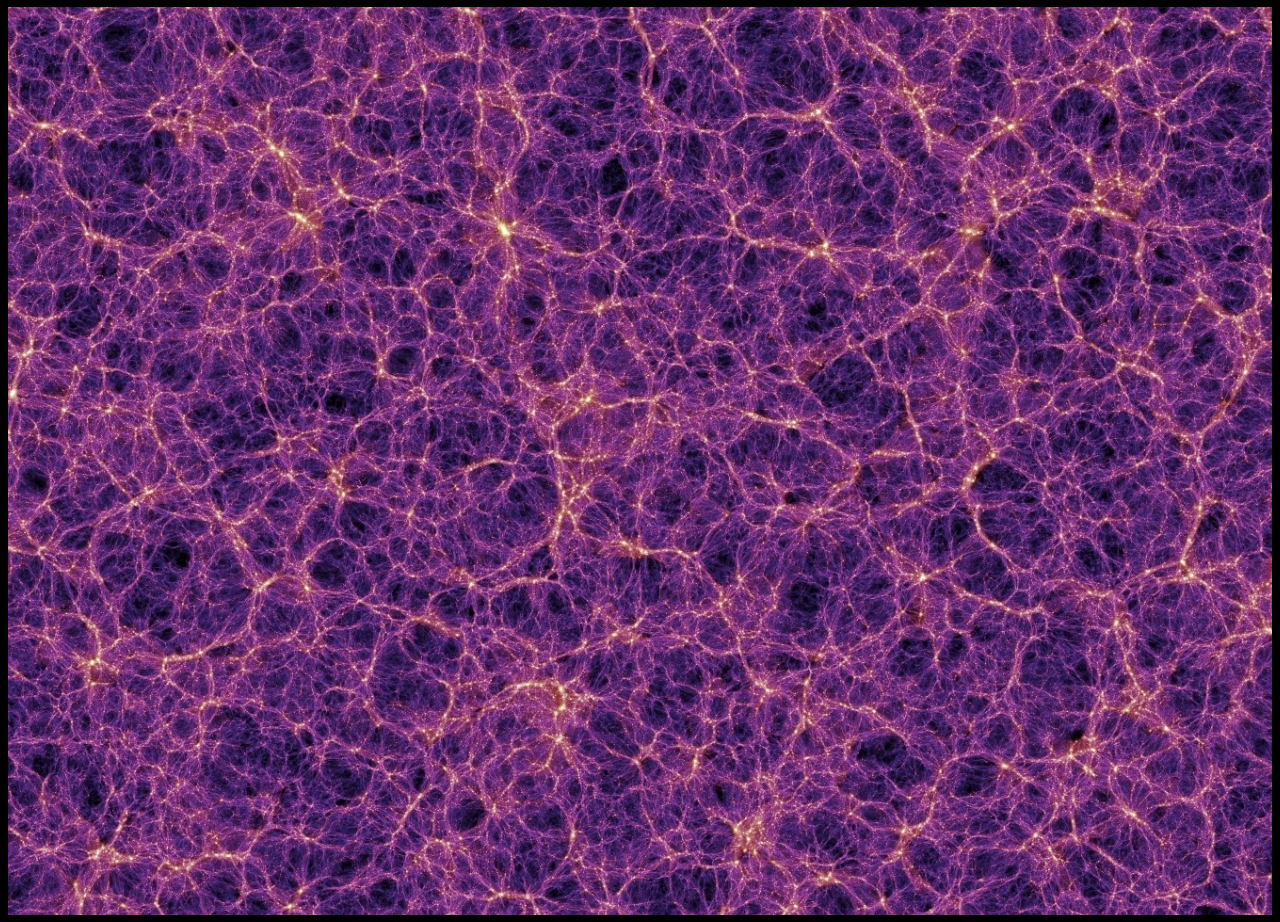
A. exactly 13 billion light years
B. >13 billion light years
C. < 13 billion light years
D. I have no idea

question for you

Does this mean that our calculations with stars A and B were wrong, because they did not account for the expansion of the Universe?

Expansion of the Universe only happens on large scales!

(distances between very far objects are stretching, but invividual galaxies are not themselves stretching)



Size and age of the Universe

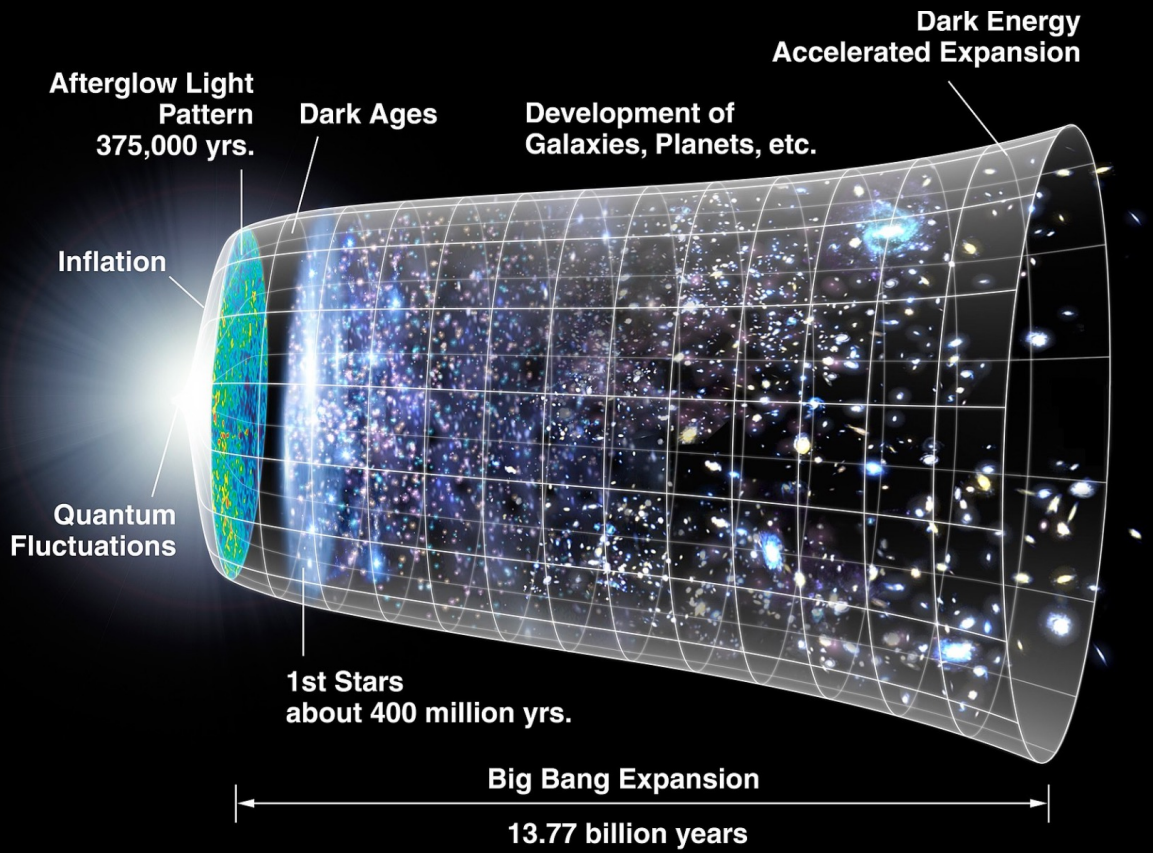
Age of the Universe

- The Universe was born in the **Big Bang13.7 billion years** ago, and has been expanding ever since.

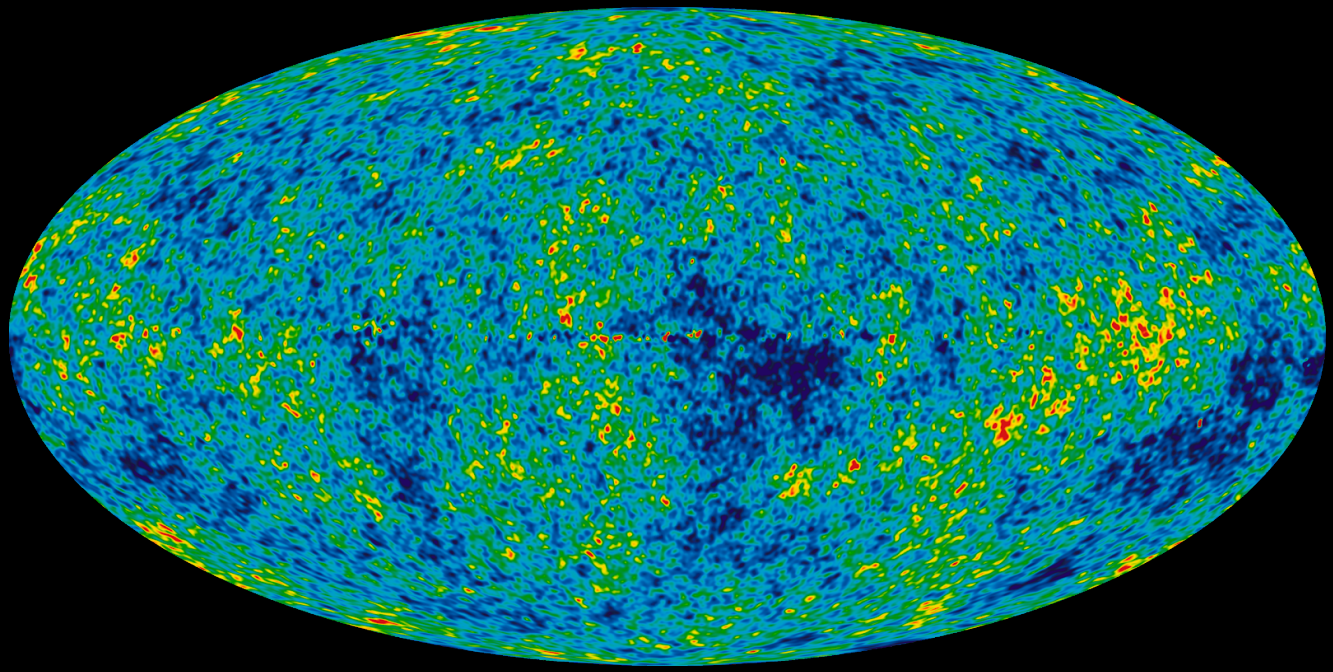
- Milky Way formed 1-2 billion years after the Big Bang.
- The Solar System formed 9 billion years after the Big Bang.

Size of the Universe

- Everything we see today was once within a microscopic volume.
- **Observable Universe** = the portion of the Universe that we can in principle see, given the age of the Universe.
- Because of the expansion of the Universe, the Observable Universe is a sphere with a radius of about 45 billion light years.



Cosmic microwave backgroun radiation = farthest we can see into the past



The Cosmic Calendar

https://www.dailymotion.com/video/x256gon

What did we learn in Chapter 1?

- Our solar system is very small part of the Universe.
- Distances are measured in astronomical units (AU) within the solar system.
- Light years are the units used for distances beyond the solar system.
- Our home galaxy is the Milky Way, which is within the Laniakea supercluster of galaxies.
- The Universe is 13.7 billion years old.
- The farther away we look, the further back in time we're seeing.
- The Observable Universe is the portion of the Universe that we can in principle see, given its age.
- There are up to 2 trillion galaxies in the Observable Universe.
- The Milky Way galaxy formed about 1 – 2 billion years after the Universe began with the Big Bang.
- The solar system formed about 9 billion years after the Big Bang.
- All of human history occupies an incredibly tiny fraction of the age of the Universe.