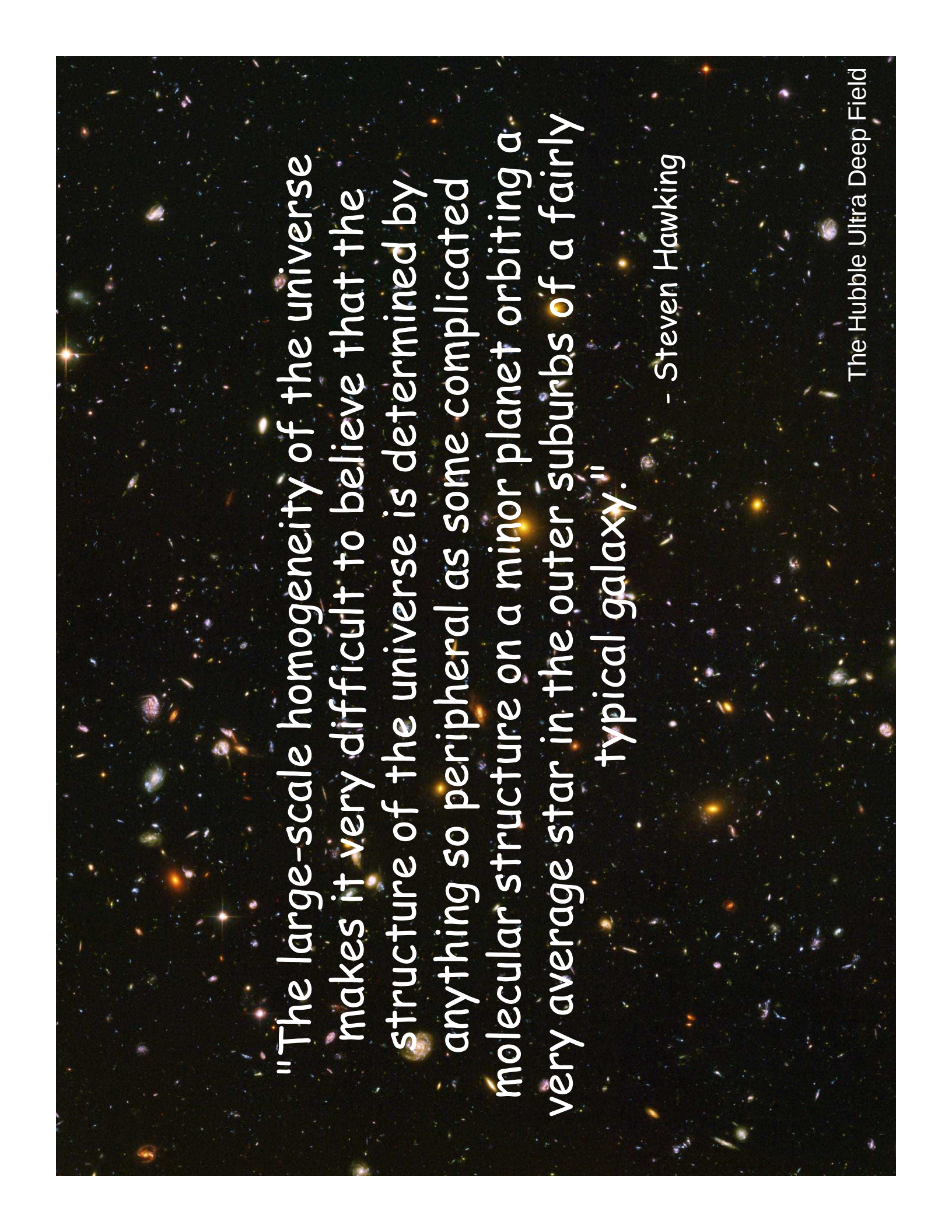


The background of the entire slide is a deep-field image from the Hubble Space Telescope, showing a vast field of galaxies and stars against a black background. The galaxies are of various shapes and sizes, some appearing as bright, irregular blobs, while others are more distinct, showing spiral or elliptical structures. The stars appear as small, bright points of light, some with visible diffraction patterns.

"The large-scale homogeneity of the universe makes it very difficult to believe that the structure of the universe is determined by anything so peripheral as some complicated molecular structure on a minor planet orbiting a very average star in the outer suburbs of a fairly typical galaxy."

- Steven Hawking

The Hubble Ultra Deep Field

What We Will Learn Today

The Size, Scale, and Age of the Universe

- What is the universe made of?
- How big is our solar system / galaxy / universe?
- How far away are the stars?
- How many stars / galaxies are there in the universe?
- How old is the universe?

Universe

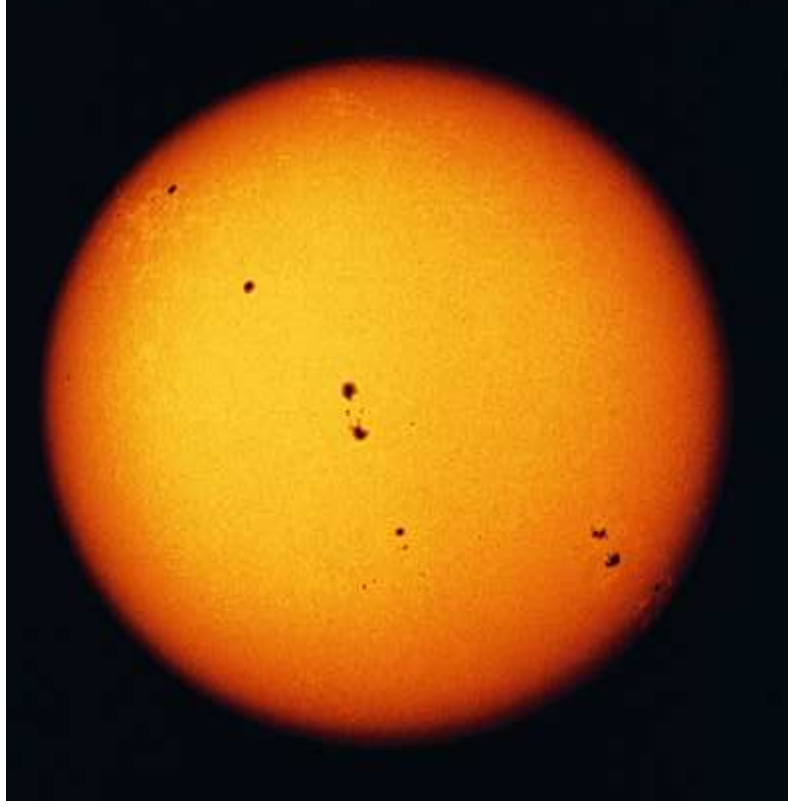
The sum total of all matter and energy

Everything within and between all galaxies

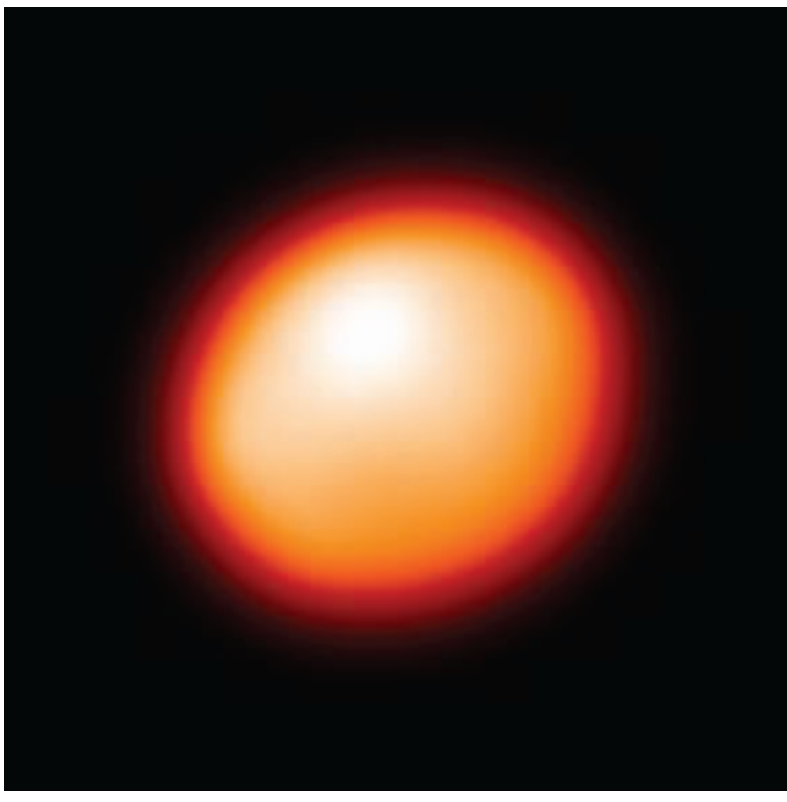
Hubble image of galaxy cluster

Star

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

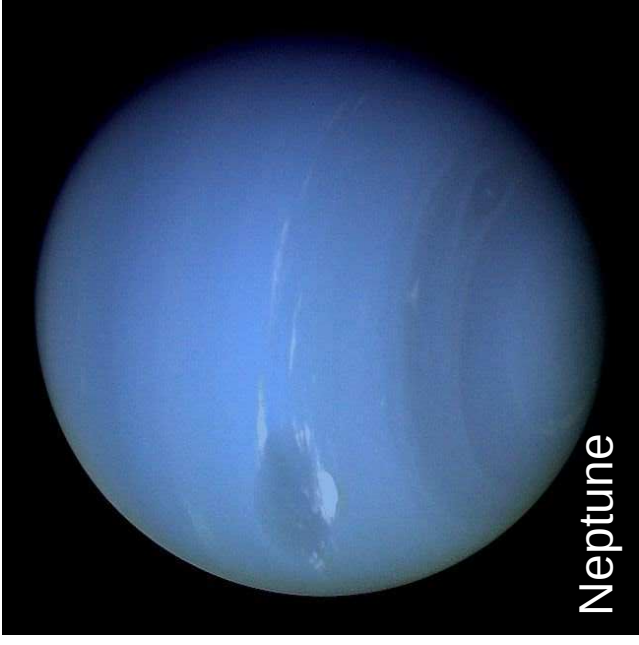


Which star is this?



And this one?

Planet



- A moderately large object that orbits a star
- Shines by reflected light
- May be rocky, icy, or gaseous

Moon (or Satellite)



Ganymede (orbits Jupiter)

An object that
orbits a planet

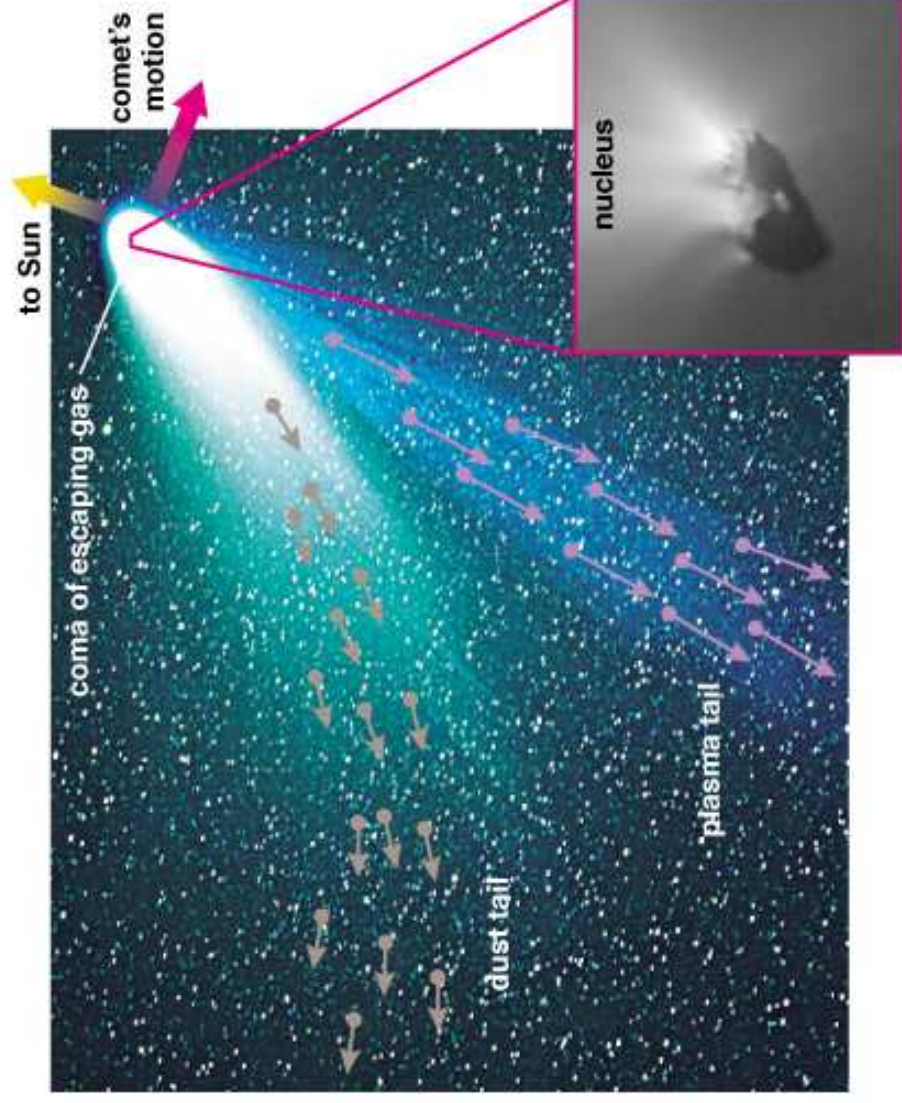
Asteroid

A relatively small
and rocky object
that orbits a star



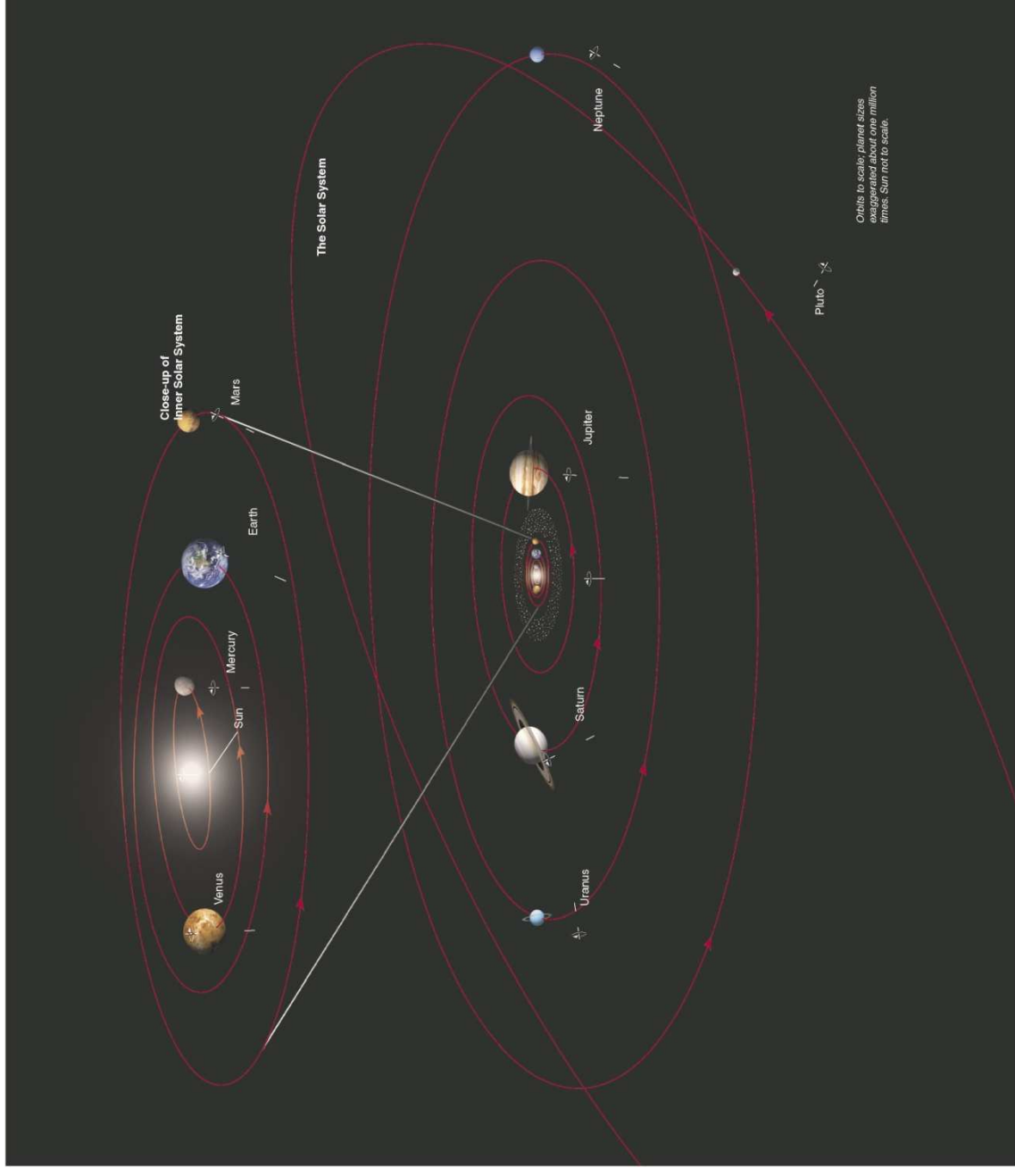
Comet

A relatively
small and
icy object
that orbits a
star



Solar (Stellar) System

A star and
all the
material
that orbits
it, including
its planets
and moons



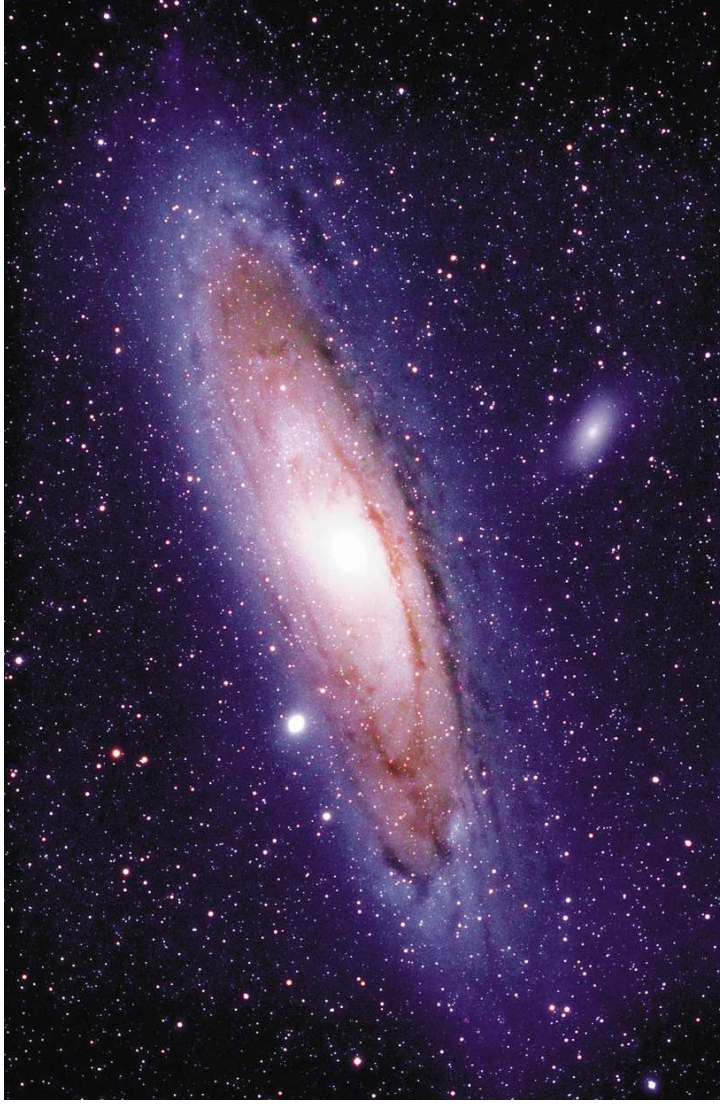
Nebula



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



Universe

The sum total of all matter and energy

Everything within and between all galaxies

Hubble image of galaxy cluster

A Note About Capitalization

Proper Names

Sun: Our sun / star

Moon: Our moon /
satellite

Earth: The planet we
live on

Solar System: Sun +
objects around it

Galaxy: Our Milky Way
galaxy

Common Names

sun: any star (e.g. Sirius)

moon: any satellite (e.g.
Saturn's moon Titan)

earth: any terrestrial
planet

solar system: any star +
objects around it

galaxy: any galaxy (e.g.
Andromeda)

A Scale Model of the Solar System



Fig 1.6

Let's make our model Solar System

What We Saw from Our Model

- Planets are tiny, compared to the Sun
- Planets fall into two groups
 - Terrestrial
 - Jovian
- The Sun is tiny, compared to the Solar System it controls
 - One grapefruit in a city!
 - The Solar System is mostly empty
- Stars are tiny, compared to distances between them
 - It's called “space” for a reason!

Astronomical Unit (AU)

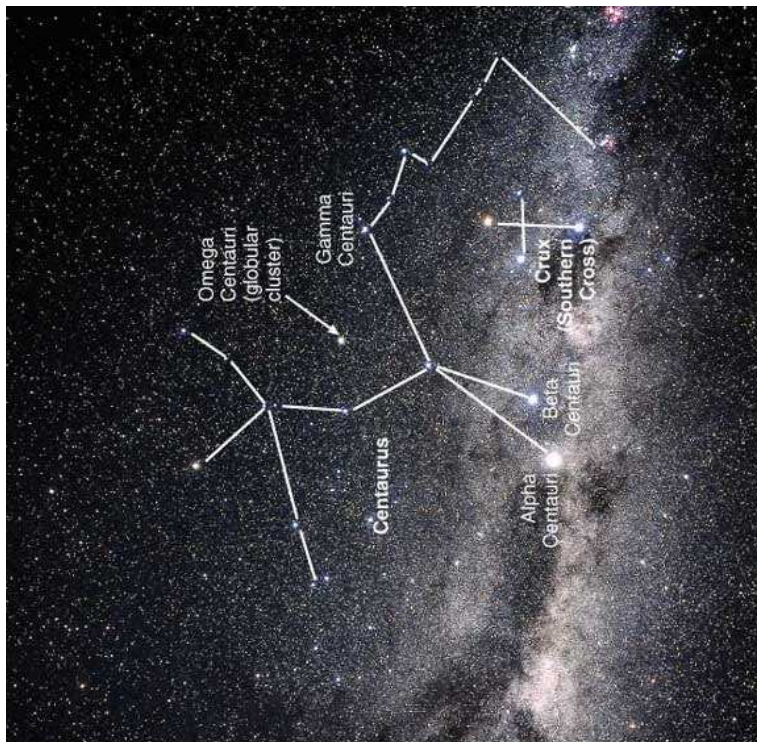
- Another unit invented for convenience
- Yardstick for measuring distances in the Solar System
- 1 AU = Average distance between Sun and Earth
- 1 AU = Approx 150 *million* km
- Remember light-year?
 - 1 light year is about 63,000 AU
 - Yardstick for interstellar distances

Interstellar Distances

- On our scale of a 5mm Sun
 - The *nearest* star (Proxima Centauri) would be at Chattanooga (actual distance ~ 4.2 ly)
 - Proxima Centauri is part of the Alpha Centauri system, visible from the Southern Hemisphere

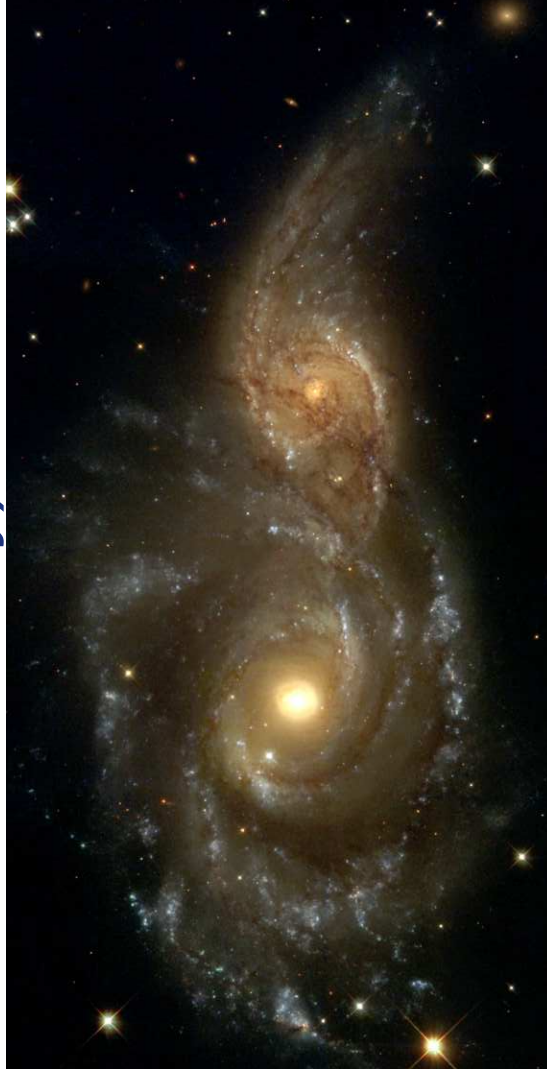
- Voyager 1
 - Launched in 1977
 - Toured Jupiter, Saturn
 - Speed 30,000 mph
 - Now ~ 100 AU away
 - Will take at least 100,000 years to get to the next star!

Fig 1.9



Galactic Scale

- On our scale of a 5 mm Sun
 - The Milky Way would be 5 times as large as the Moon's Orbit (actual size ~ 100,000 ly across)
 - The *nearest* Galaxy, Andromeda, would be beyond Mars' orbit (actual distance ~ 2.5 million ly)



The Infinite Universe

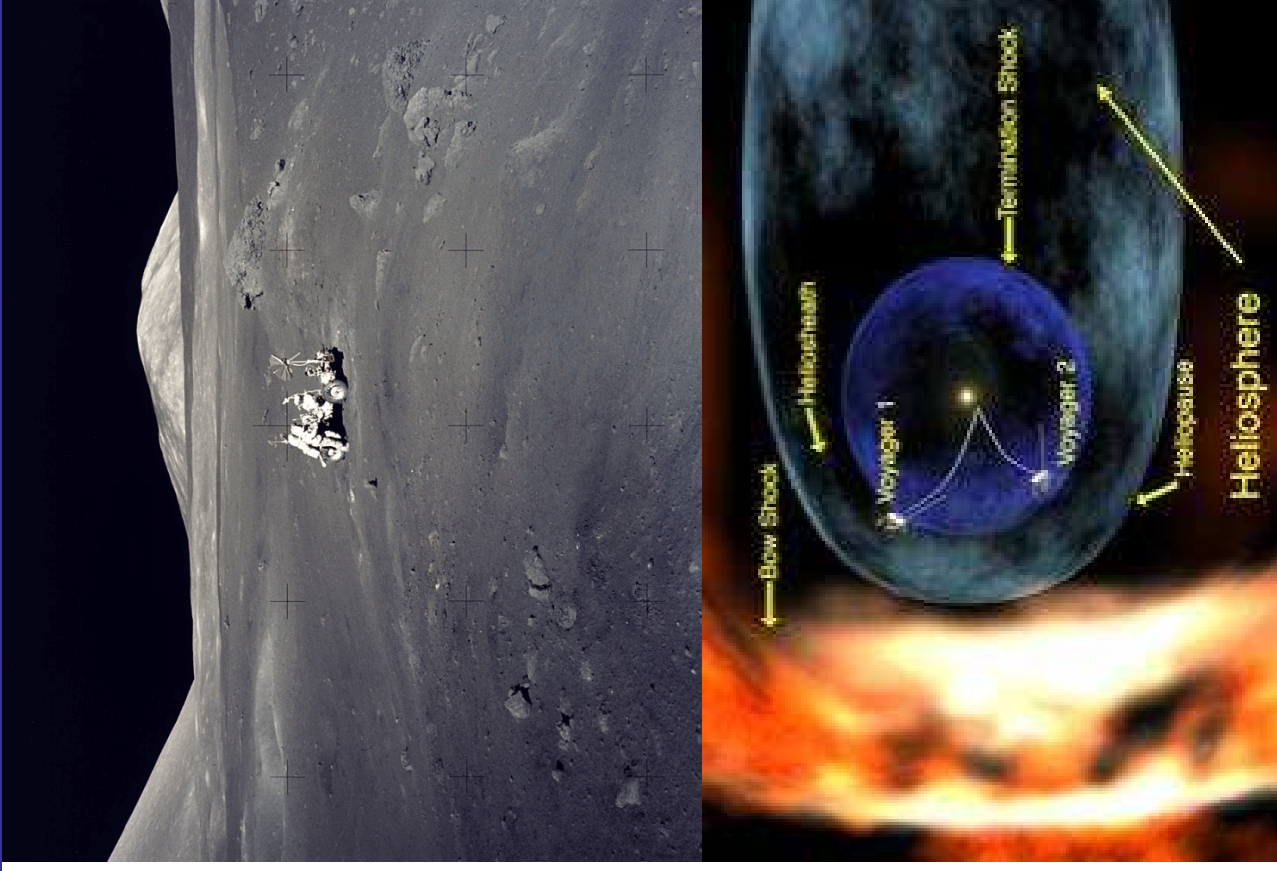
- The observable universe contains a few 100 billion galaxies
- The universe extends beyond the observable limit
 - Remember look-back time?
 - Can't “look” farther than about 14 billion light years.

Human Space Exploration

- A major achievement, but
 - We have only gone as far as the Moon
 - 1 mm on our scale model
 - Farthest spacecrafts have only gone ~ 100 AU away
 - About 50 m on our scale model, the length of an Olympic size pool

– Voyager 1

- Launched in 1977
- Speed 30,000 mph
- > 100,000 years to get to the next star!



The Universe in Numbers

- The Milky Way has over 100 billion stars
- That's 100,000,000,000 stars!
- If you counted 1 star per second
 - You would take 3,000 years to count all the stars in our galaxy!
- The Universe has over 100 billion galaxies
 - That's just the observable part!
- Number of stars in the observable universe
 - Approx $10^{11} * 10^{11} = 10^{22}$
 - Approx the number of grains of sand on Earth

The Universe in Time

- Let's shrink the age of the universe to 1 year (actual age ~ 14 billion years)

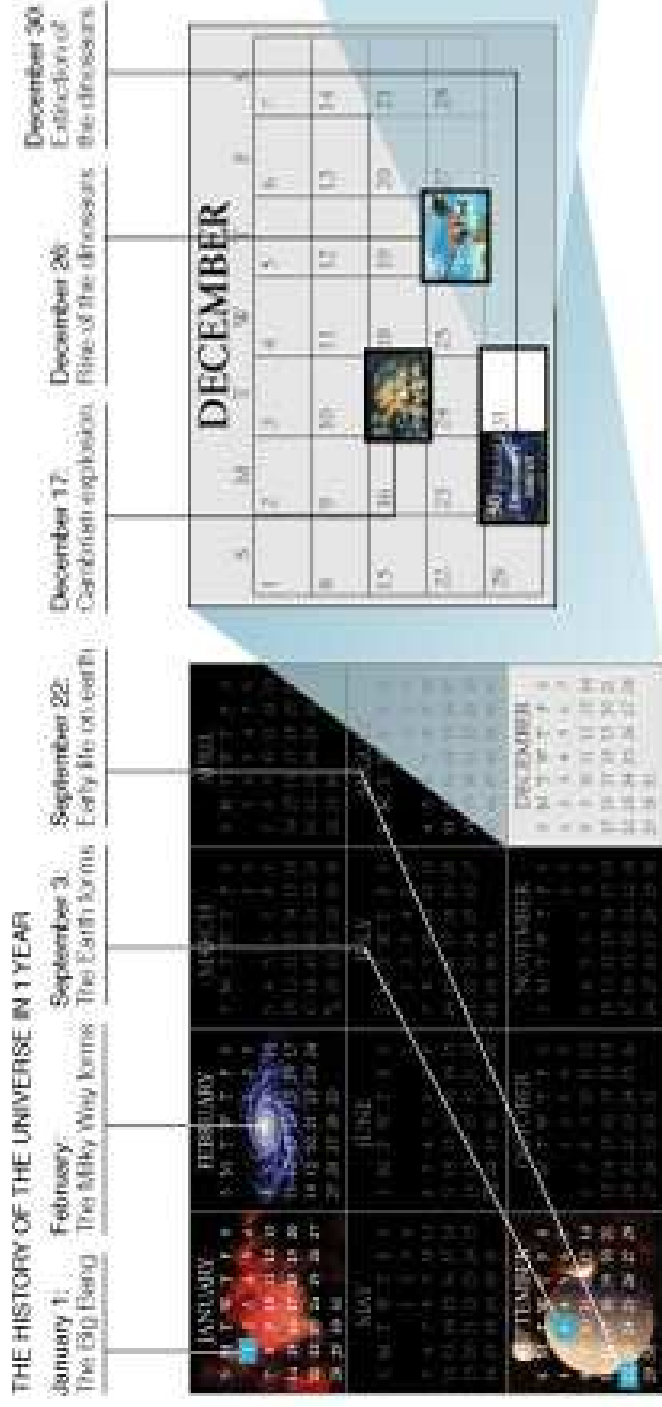
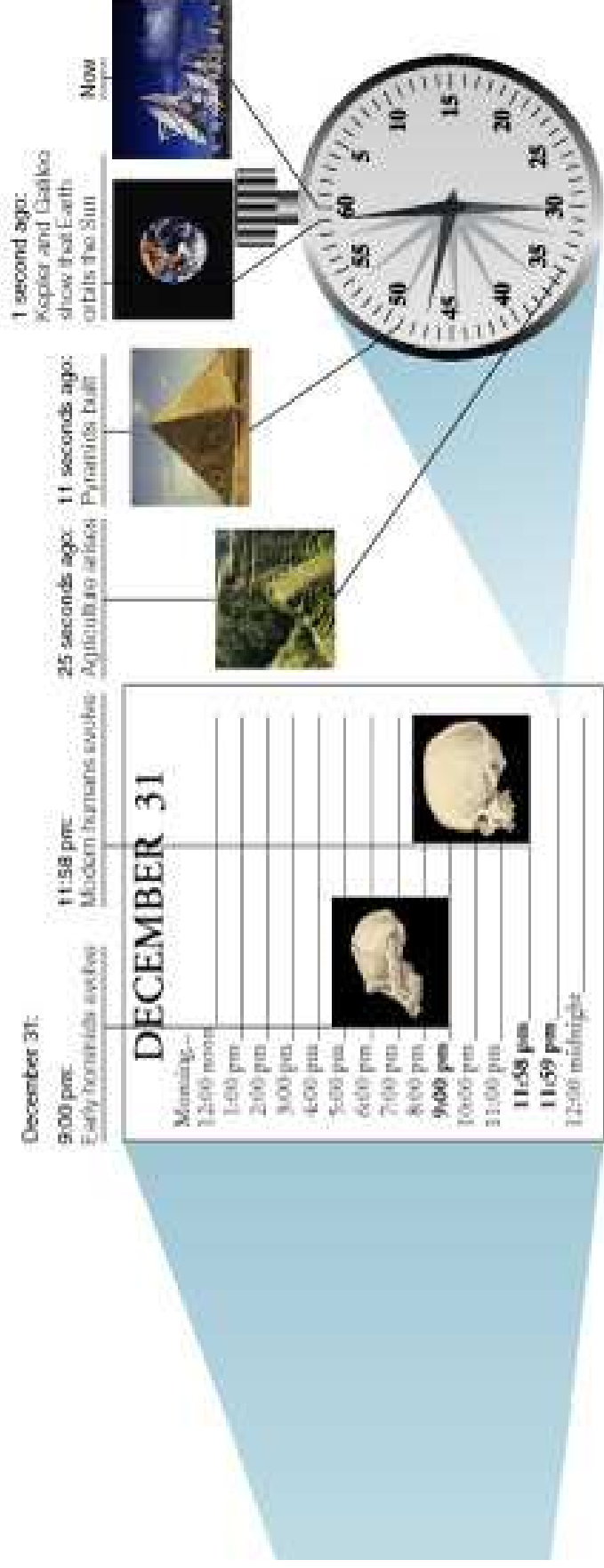


Fig 1.11

The Universe in Time

- All of recorded human history occurred in the last 30 seconds



- You were born 0.05 seconds ago!

Fig 1.11