

Lecture Outline

Chapter 1: A Modern View of the Universe

The Essential Cosmic Perspective
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Seventh Edition

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1.1 The Scale of the Universe

Our goals for learning:

- What is our place in the universe?
- How big is our universe?

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➤ What is our place in the universe?

- ☐ Planet
 - We live on planet Earth
- ☐ Solar (Star) System
 - Our solar system's star is the Sun
- ☐ Galaxy
 - Our galaxy the Milky Way contains over 100 billion stars

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- ☐ Galaxy Cluster (Group)
 - Local Group contains 40 galaxies
- ☐ Super Cluster
 - Clusters of galaxy clusters arranged in chains with huge voids between them
- ☐ Universe
 - Contains billions of galaxies

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Astronomical objects and the metric system

Earth is about 8000 miles across

- 1mi = 1.6 km
- 1km = 1000m
- 1m = 1 large step

d = 13000 km or 13×10^3 km
c = 40000 km or 4×10^4 km

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Planet

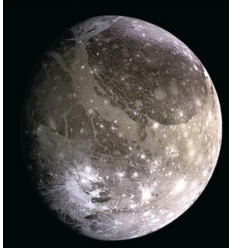
Neptune 50,000 km across

- ☐ 3 conditions (2006)
 - Orbits a star
 - Large enough for it's own gravity to make it round
 - Cleared most objects from orbital path
- ☐ A moderately large object that orbits a star

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Moon (or Satellite)

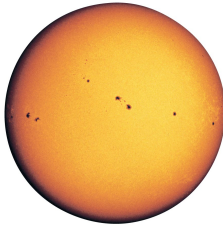
- An object that orbits a planet
 - Ganymede is 5300 km across
 - Our moon is 3500 km across



Ganymede (orbits Jupiter)

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Star




- Our sun is a star
 - 1 million km across
- Betelgeuse is a super giant star 1.6 billion km across
 - 1.6×10^9 km
- A large, glowing ball of gas that generates heat and light

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Asteroid

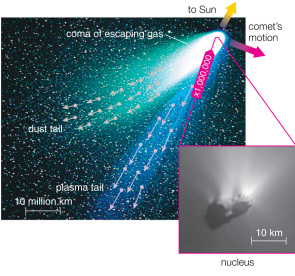
- A relatively small and rocky object that orbits a star



Eros: 33 km across **Ceres: 940 km across**

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Comet

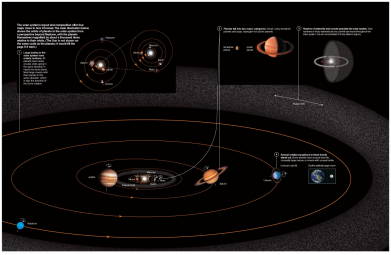


- A relatively small and icy object that orbits a star

Average comet nucleus is less than 10km across

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Solar (Star) System

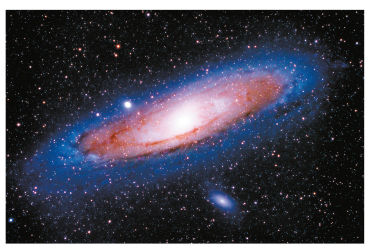


- A star and all the material that orbits it.
 - 285 billion km wide $\sim 285 \times 10^9$ km

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Galaxy

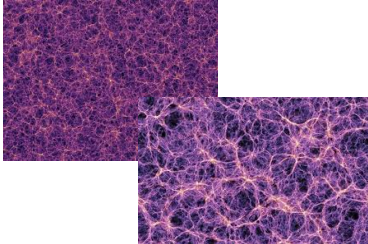
- A great island of stars in space, orbiting a common center
- Galaxies contain a million to a trillion stars
- Our galaxy the Milky Way contains over 100 billion stars
- 9.5×10^{17} km wide



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Universe

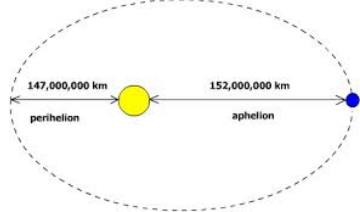
- The sum total of all matter and energy



Astronomical Distance Measurements

AU

- The Earth is 1 AU (Astronomical Unit) from the sun
 - 150 million km or 93 million miles



Light-year

- The distance light can travel in 1 year

1 light-year = (speed of light) × (1 year)

$$= \left(300,000 \frac{\text{km}}{\text{s}} \right) \times \left(\frac{365 \text{ days}}{1 \text{ yr}} \times \frac{24 \text{ hr}}{1 \text{ day}} \times \frac{60 \text{ min}}{1 \text{ hr}} \times \frac{60 \text{ s}}{1 \text{ min}} \right)$$

- About 10 trillion kilometers (6 trillion miles)

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Looking back in time


- Light travels at a finite speed
 - 300,000 km/s (or 187,000 miles per second)

This is "fast" you could circle the Earth 8 times in one second.

Destination	Light travel time
Moon	1 second
Sun	8 minutes
Alpha Centauri (closest star system)	4 years
Andromeda Galaxy (closest galaxy)	2.5 million years

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- Light takes time to travel the vast distances in space. When we look deep into space, we see objects as they were when the light source left them:



The farther away we look in distance, the further back we look in time.

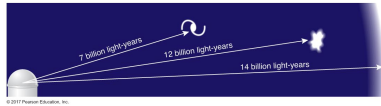
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- Our closest neighbor the Andromeda Galaxy as it looked about 2½ million years ago.
- Question: When will we be able to see what it looks like now?**

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The Observable Universe



- ☐ The universe is 14 billion years old ← Time
- ☐ We cannot observe light further than 14 billion light-years ← Distance

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How big is the universe?



How big is Earth compared to our solar system?

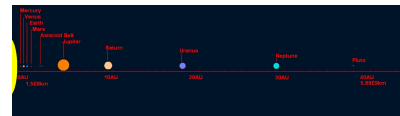
Let's reduce the size of the solar system by a factor of 10 billion; the Sun is now the size of a large grapefruit (14 cm diameter).

How big is Earth on this scale?

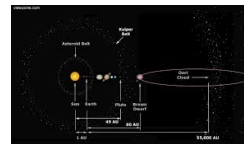
- A. a tip of a ballpoint pen
- B. a marble
- C. a golf ball

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Earth on a 1-to-10 billion scale



- ☐ The sun is 1 AU (Astronomical Unit) from the Sun
 - 150 million km or 93 million miles



- If the Sun was the size of a grapefruit the Earth would be the size of the point on your pen 15 meters (50 ft) away

The scale of the solar system

- ☐ On a 1-to-10 billion scale:

- Sun is the size of a large grapefruit (14 cm or 5.5 in).
- The size of the solar system would be about the size of your campus at LBCC.



How far away are the stars?


On our 1-to-10 billion scale, How far would you have to walk to reach Alpha Centauri?

- A. 1 mile
- B. 10 miles
- C. 100 miles
- D. the distance across the United States (2500 miles)

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Alpha Centauri

- Our closest neighboring star.
- It is a triple star system
- 4.4 light years away



How big is the Milky Way Galaxy?

- 100 billion stars
- 100,000 light years across



Thought Question

Suppose you tried to count the more than 100 billion stars in our galaxy, at a rate of one per second...

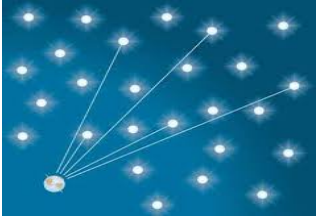

How long would it take you?

- A. a few weeks
- B. a few months
- C. a few years
- D. a few thousand years

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Are there an infinite number of stars in the universe?

- Olbens' Paradox
 - If so why isn't the night sky bright

- The Milky Way is one of about 100 billion galaxies.
- There are about 100 billion stars in each galaxy

$10^{11} \text{ stars} \times 10^{11} \text{ galaxies} = 10^{22}$
 10 000 000 000 000 000 000 000

There are as many stars as grains of (dry) sand on all Earth's beaches

What have we learned?

- What is our place in the universe?**
 - Earth is part of a star system, which is in the Milky Way Galaxy consisting of 100 billion stars, which is a member of the Local Group of galaxies in the Local Super cluster, which reside in the Universe containing 100 billion other galaxies.

Some people think that our tiny physical size in the vast universe makes us insignificant.

Others think our ability to learn about the wonders of the universe gives us significance despite our small size.

What do you think?

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1.2 The History of the Universe

Our goals for learning:

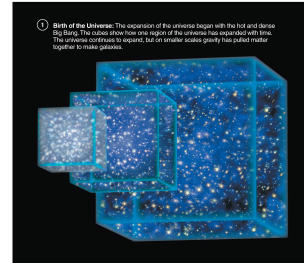
- How did we come to be?
- How do our lifetimes compare to the age of the universe?

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➤ How did we come to be?

The Big Bang

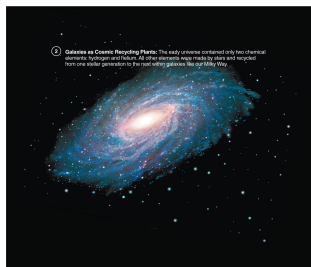
- ❑ Rate of expansion suggest the universe was born 14 billion years ago.



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Stellar Lives and Galactic Recycling

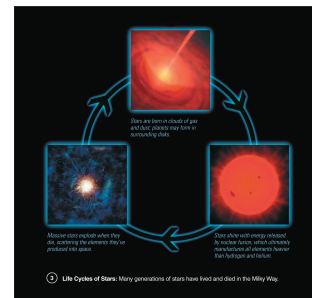
- ❑ Although the universe expands on a small scale gravity has drawn matter together



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Life Cycle of stars

- ❑ Star is born when matter becomes so dense and hot it generates nuclear fusion.
- ❑ Primary elements were Hydrogen and Helium



"We are made of star stuff"

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Nebula

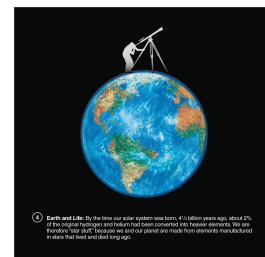
- ❑ An interstellar cloud of gas and/or dust



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Earth and Life

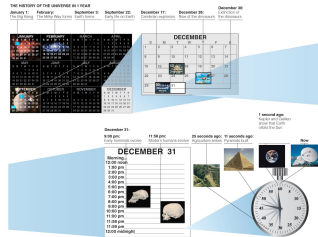
- ❑ Took generations of stars to produce heavier elements
- ❑ At creation of solar system 4 ½ billion years ago there was 2% heavier elements



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➤ How do our lifetimes compare to the age of the universe?

- ❑ The cosmic calendar: A scale on which we compress the history of the universe into 1 year



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Cosmic calendar

Date	Event
Jan 1	The Big Bang
Feb	Milky Way forms
Sept 3	Earth forms
Dec 26	Rise of the dinosaurs
Dec 31(9pm)	Early hominids
Dec 31(11:58pm)	Modern humans evolve
11 seconds ago	Pyramids built
.05 second ago	You were born

1.3 Spaceship Earth

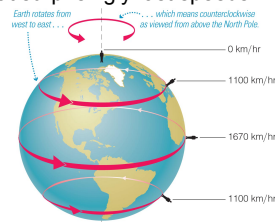
Our goals for learning:

- How is Earth moving in through space?
- How do galaxies move within the universe?

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➤ How is Earth moving through space?

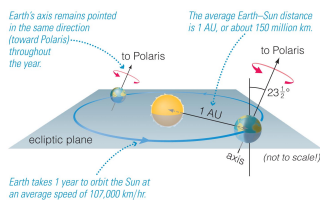
- ❑ Contrary to our perception, we are not "sitting still."
- ❑ We are moving with the Earth in several ways, and at surprisingly fast speeds.



Earth rotates around its axis once every day.

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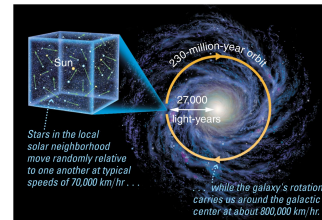
- ❑ Earth orbits the Sun once every year
- ❑ Rotates (*spin*) in the same direction it revolves (*orbits*), counter-clockwise as viewed from above the North Pole.



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Motion Within the Milky Way

- ❑ Our solar system moves random within our local solar neighborhood
 - 70,000 km/hr
- ❑ Our solar system orbits the galactic center
 - 27,000 light years from center
 - 230 million years



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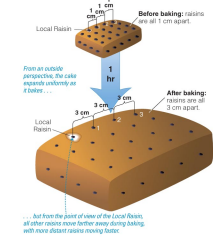
More detailed study of the Milky Way's rotation reveals one of the greatest mysteries in astronomy...



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How do galaxies move within the universe?

Galaxies are carried along with the expansion of the universe.



... And from the point of view of the Local Raisin, all other raisins move farther away during baking, with more distant raisins moving faster.

Raisin Number	Distance Before Baking	Distance After Baking (1 hour later)	Speed
1	1 cm	2 cm	2 cm/hr
2	2 cm	4 cm	4 cm/hr
3	3 cm	6 cm	6 cm/hr
...

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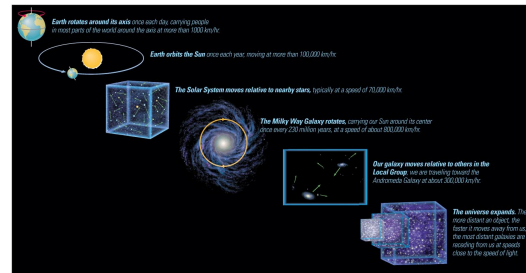
How did Hubble discover that the universe is expanding?

- all galaxies outside our Local Group are moving away from us.
- the more distant the galaxy, the faster it is racing away.

Conclusion: We live in an expanding universe.

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Are we ever sitting still?



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Motion Summary

- We rotate on the Earth at 1000 km/hr
- The Earth revolves around the Sun at 100,000 km/hr
- The Sun moves randomly in our local solar neighborhood at 70,000 km/hr
- The local neighborhood orbits the Milky Way at 800,000 km/hr
- The Milky Way moves away from other galaxies at increasing speeds