The Flamingos, “I only have eyes for you”

“Are the stars out tonight?”

https://www.youtube.com/watch?v=FvzNeh4Mq1o
The Milky Way over St Michael's Mount

https://apod.nasa.gov/apod/astropix.html
Homework for Wed’s class

• Assignment for Wed:
  – **Read** Ch. 2 of textbook
    – “Discovering the Universe for Yourself”
  – **Do** Online Exercise 01
    – includes Telescope tutorial
    – First to count for HW credit
Universe’s Phone Number
From the scale of the nucleus to the universe in 10 key steps of powers of ten

(555)-711-2555

© Stan Owocki
Hierarchy of Scale in the Universe
Scale Range of our Universe

• From humans to edge of the universe in

http://scaleofuniverse.com/
Chapter 1 overview

from the study area of your MasteringAstronomy website, click on:
  Study Area
  Media
  Prelecture Overviews
  Chapter 1: A Modern View of the Universe

Polling quiz on Ch. 1 reading
How long does it take light to travel from Sun to Earth?

A. About a second
B. About a minute
C. About 8 minutes
D. About a day
E. About a year
How long does it take light to travel from Sun to Earth?

A. About a second
B. About a minute
C. **About 8 minutes**
D. About a day
E. About a year
How long does it take light to travel from Alpha Centauri to Earth?

A. About a month
B. About a year
C. About 4 years
D. About 1,000 years
E. About 100,000 years
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How long does it take light to travel across our Galaxy

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How long does it take light to travel across our Galaxy

A. About a month
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E. About 100,000 years
Scaled Solar System Model

- For Book, at D.C. mall: Sun = size of a large grapefruit (~14 cm)

- But there is also an UD Scaled Solar System Model: Sun = size of a large beachball (D ~ 2 ft. ~ 60 cm)
a The scaled sizes (but not distances) of the Sun, the planets, and the two largest known dwarf planets.

b Locations of the major objects in the Voyage model (Washington, D.C.); the distance from the Sun to Pluto is about 600 meters (1/3 mile). Planets are lined up in the model, but in reality each planet orbits the Sun independently and a perfect alignment never occurs.
Looking back in time

- Light travels at a finite speed (300,000 km/s).

<table>
<thead>
<tr>
<th>Destination</th>
<th>Light travel time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moon</td>
<td>1 second</td>
</tr>
<tr>
<td>Sun</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Sirius</td>
<td>8 years</td>
</tr>
<tr>
<td>Andromeda Galaxy</td>
<td>2.5 million years</td>
</tr>
</tbody>
</table>

- Thus, we see objects as they were in the past:

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

This photo shows the Andromeda Galaxy as it looked about 2.5 million years ago.

Question: When will we be able to see what it looks like now?
Definition: Light-Year

- The **distance** light can travel in 1 year
- 1 year = 365x24x60x60 sec \(\approx\) 3x10^7 seconds
- speed of light \(c=300,000\) km/s = 3x10^8 m/s
- \(ly = c \times yr \approx 10^{16}\) m
• At great distances, we see objects as they were when the universe was much younger.

**Far:** We see a galaxy 7 billion light-years away as it was 7 billion years ago—when the universe was about half its current age of 14 billion years.

**Farther:** We see a galaxy 12 billion light-years away as it was 12 billion years ago—when the universe was only about 2 billion years old.

**The limit of our observable universe:** Light from nearly 14 billion light-years away shows the universe as it looked shortly after the Big Bang, before galaxies existed.

**Beyond the observable universe:** We cannot see anything farther than 14 billion light-years away, because its light has not had enough time to reach us.
Thought Question

Why can't we see a galaxy 15 billion light-years away?

A. No galaxies exist at such a great distance.

B. Galaxies may exist at that distance, but their light would be too faint for our telescopes to see.

C. Looking 15 billion light-years away means looking to a time before the universe existed.
Thought Question

Why can't we see a galaxy 15 billion light-years away?

A. No galaxies exist at such a great distance.

B. Galaxies may exist at that distance, but their light would be too faint for our telescopes to see.

C. Looking 15 billion light-years away means looking to a time before the universe existed.
How did we come to be?

1. **Birth of the Universe**: The expansion of the universe began with the hot and dense Big Bang. The cubes show how one region of the universe has expanded with time. The universe continues to expand, but on smaller scales gravity has pulled matter together to make galaxies.
How did we come to be?

**Galaxies as Cosmic Recycling Plants:** The early universe contained only two chemical elements: hydrogen and helium. All other elements were made by stars and recycled from one stellar generation to the next within galaxies like our Milky Way.
How did we come to be?

Stars are born in clouds of gas and dust; planets may form in surrounding disks.

Massive stars explode when they die, scattering the elements they’ve produced into space.

Stars shine with energy released by nuclear fusion, which ultimately manufactures all elements heavier than hydrogen and helium.

Life Cycles of Stars: Many generations of stars have lived and died in the Milky Way.
How did we come to be?

Earth and Life: By the time our solar system was born, 4½ billion years ago, about 2% of the original hydrogen and helium had been converted into heavier elements. We are therefore “star stuff,” because we and our planet are made from elements manufactured in stars that lived and died long ago.
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
What have we learned?

• How did we come to be?
  – The matter in our bodies came from the Big Bang, which produced hydrogen and helium.
  – All other elements were constructed from H and He in stars and then recycled into new star systems, including our solar system.

• How do our lifetimes compare to the age of the universe?
  – On a cosmic calendar that compresses the history of the universe into 1 year, human civilization is just a few seconds old, and a human lifetime is a fraction of a second.
Relative to the universe, how old is our solar system?

A. About 1 percent as old as the universe.
B. Between about 5 and 10 percent as old as the universe.
C. About one-third the age of the universe.
D. Nearly the same age as the universe.
Relative to the universe, how old is our solar system?

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Where is our solar system located in the Milky Way galaxy?

A. At the far edge of the galaxy’s visible disk.
B. In the halo of the galaxy.
C. Roughly halfway between the center and the edge of the visible disk of the galaxy.
D. Very near the center of the galaxy.
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How is Earth moving through space?

- Contrary to 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.
Earth orbits the Sun (revolves) once every year...

- at an average distance of 1 AU ≈ 150 million km.
- with Earth's axis tilted by 23.5° (pointing to Polaris).
- and rotates in the same direction it orbits, **counter-clockwise** as viewed from above the North Pole.
Our Sun moves randomly relative to the other stars in the local solar neighborhood…

- at typical relative speeds of more than 70,000 km/hr
- but stars are so far away that we cannot easily notice their motion
- and it orbits the galaxy every 230 million years.
More detailed study of the Milky Way's rotation reveals one of the greatest mysteries in astronomy...

Most of the galaxy's light comes from stars and gas in the galactic disk and central bulge . . .

... but measurements suggest that most of the mass lies unseen in the spherical halo that surrounds the entire disk.
How do galaxies move within the universe?

Galaxies are carried along with the expansion of the universe. But how did Hubble figure out that the universe is expanding?

From an outside perspective, the cake expands uniformly as it bakes . . .

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

- 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.
Are we ever sitting still?

**Earth rotates around its axis** once each day, carrying people in most parts of the world around the axis at more than 1000 km/hr.

**Earth orbits the Sun** once each year, moving at more than 100,000 km/hr.

**The Solar System moves relative to nearby stars**, typically at a speed of 70,000 km/hr.

**The Milky Way Galaxy rotates**, carrying our Sun around its center once every 230 million years, at a speed of about 800,000 km/hr.

**Our galaxy moves relative to others in the Local Group**, we are traveling toward the Andromeda Galaxy at about 300,000 km/hr.

**The universe expands.** The more distant an object, the faster it moves away from us; the most distant galaxies are receding from us at speeds close to the speed of light.