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

Which star is this? And this one?
- A moderately large object that orbits a star
- Shines by reflected light
- May be rocky, icy, or gaseous
Moon (or Satellite)

An object that orbits a planet

Ganymede (orbits Jupiter)
A relatively small and rocky object that orbits a star.
Comet

A relatively small and icy object that orbits a star
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
# A Note About Capitalization

<table>
<thead>
<tr>
<th>Proper Names</th>
<th>Common Names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sun:</strong> Our sun / star</td>
<td><strong>sun:</strong> any star (e.g. Sirius)</td>
</tr>
<tr>
<td><strong>Moon:</strong> Our moon / satellite</td>
<td><strong>moon:</strong> any satellite (e.g. Saturn’s moon Titan)</td>
</tr>
<tr>
<td><strong>Earth:</strong> The planet we live on</td>
<td><strong>earth:</strong> any terrestrial planet</td>
</tr>
<tr>
<td><strong>Solar System:</strong> Sun + objects around it</td>
<td><strong>solar system:</strong> any star + objects around it</td>
</tr>
<tr>
<td><strong>Galaxy:</strong> Our Milky Way galaxy</td>
<td><strong>galaxy:</strong> any galaxy (e.g. Andromeda)</td>
</tr>
</tbody>
</table>
A Scale Model of the Solar System

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
  - One grapefruit in a city!
- 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!
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 100,000,000,000,000 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 $10^{11} \times 10^{11} = 10^{22}$
  – 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)
The Universe in Time

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

- You were born 0.05 seconds ago!