

Grade 12 Earth and Space Science

SES4U

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Chapter 1

Unit 1: Astronomy

1.1 Episode 1: Standing up in the Milky Way

1. What is responsible for creating wind and keeping everything in the solar system in its clutches?
 - Gravity
2. What lies between Mars and Jupiter?
 - The asteroid belt
3. What had to be invented before we could discover Saturn and Neptune
 - The telescope
4. What is the name of the spacecraft that has travelled the farthest away from Earth?
 - Voyager 1
5. What is the Oort Cloud?
 - A cloud of billions of ice planetesimals surrounding the sun
6. What is the "address" of Earth in the cosmos?
 - Earth, Solar System, Orion Arm, Milky Way, Local Group, Virgo Supercluster, Laniakea Supercluster, Universe
7. Who was able to prove Giordano Bruno right 10 years after his death?
 - Galileo

1.2 Episode 4: A Spacetime Odyssey

1. Why do we see the Sun rise before it is over the horizon?
 - Because Earth's atmosphere refracts the Sun's image
2. How far away is Neptune from Earth (in light hours)?

- 4.17 light hours
3. Using the idea of how fast light travels, how do scientists know our universe is older than 6500 years?
 - We know that there are objects farther than 6500 light year away from Earth.
 4. Why does no one know what happened before the Big Bang?
 - No evidence survived
 5. How long after the Big Bang did it take for stars to form?
 - Millions of years
 6. What did Einstein call the “rules” that must be obeyed when traveling at high speeds?
 - Principle of relativity

1.3 Measuring the Universe

1.3.1 Some important constants

The speed of light c :

$$c = 3.00 * 10^8 \frac{m}{s} (3SD)$$

The distance of a light year:

$$\text{A light year} = 9.4608 * 10^{15} m (3SD)$$

The distance between **Earth** and **Sun** refers to the *Astronomical Unit (AU)*

$$AU = 1.4958 * 10^{11} m (3SD)$$

One Parsec is **3.26** light years

$$\text{Parsec} = 3.0824 * 10^{16} m (3SD)$$

1.3.2 Unit Conversion

Example. If 1 inch = 2.54 cm, then 4.5 inches is equivalent to how many cm?

$$4.5 \text{ inch} * \frac{2.54 \text{ cm}}{1 \text{ inch}} = 11.43 \text{ cm}$$

$$\therefore 1 \text{ inch} = 2.54 \text{ cm}$$

1.3.3 Radar

This method is very accurate, it can measure the distance to the moon with an **3 cm** precision!

Using radar in Astronomy has some limitations:

- Electromagnetic waves tend to *spread out with distance* causing weaker signals
- The furthest we can measure with this technique is *with a few AUs*

1.3.4 Parallax

Parallax refers to how closer objects appear to move compared to farther away objects. This is commonly used in video games to give the illusion of depth.

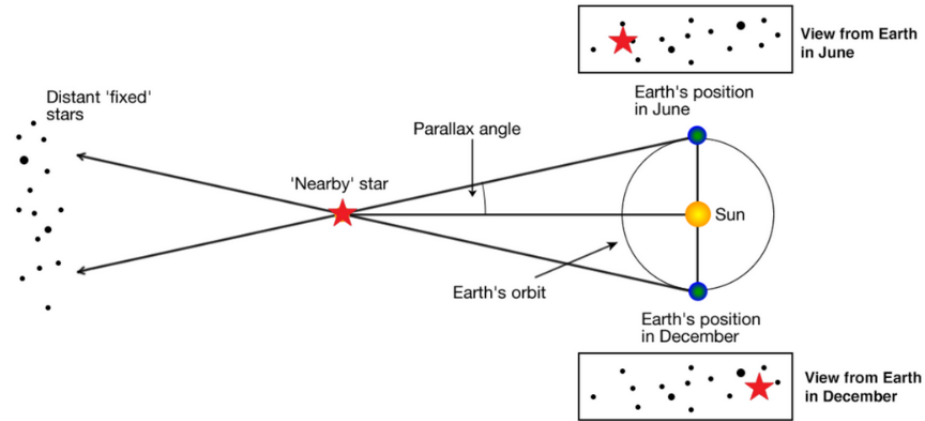


Figure 1.1: Parallax

If we measure the angles that a star shifts using arcseconds, we arrive at how the **parsec** is defined

$$d = \frac{1}{p} \quad (1.1)$$

d = distance in Parsec
 p = parallax angle in arcseconds

*Remainder: The distance that can accurately be measured from the Earth using parallax is **100** parsecs.*

1.4 Cepheid Variable Stars, Redshift and Hubble's Law

1.4.1 Apparent Magnitude and Absolute Magnitude

In this chapter, I will directly define few terms:

Definition 1.4.1. *Apparent magnitude = How bright an object appears from Earth's surface*

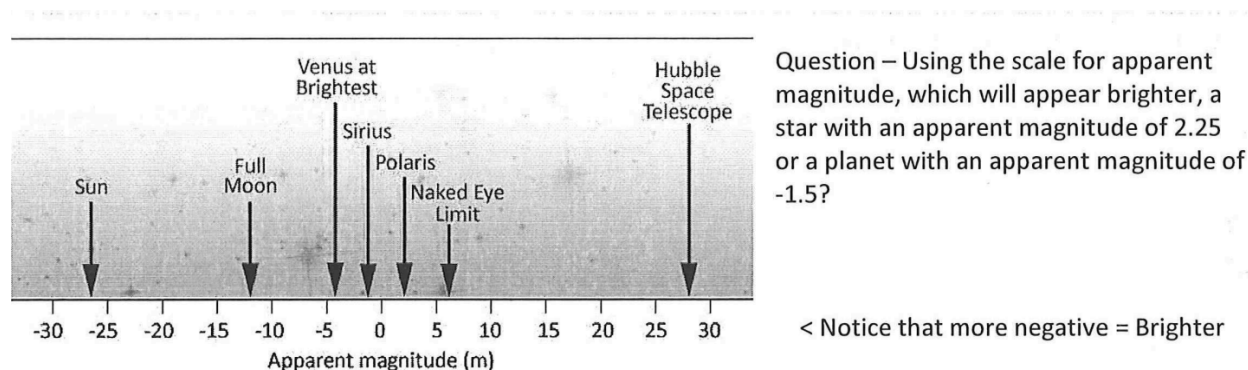


Figure 1.2: Apparent magnitude (m)

Definition 1.4.2. *Absolute Magnitude: How bright an object would appear if it was exactly 10 parsecs away*

1.4.2 Cepheid Variable stars

Definition 1.4.3. *Cepheids: Special stars that change how luminous they are at regular time intervals*

Cepheids "pulsate" with periods ranging from 1 to 100 days

1.4.3 Determining absolute magnitudes using Cepheid Variables

Absolute magnitudes of stars can be determined using cepheids. It was discovered that period of pulsation is directly related to the star's luminosity

Definition 1.4.4. *luminosity: The amount of energy emitted by a star each second.*

longer periods have higher luminosities

Cepheid Variables are also called "standard candles". Using this method, we can determine distances from 1000 parsecs up to 50 million parsecs

1.4.4 Hubble's Law

Hubble's Law states that:

The **further** away an object is, the **faster** moving away from us.

Hubble's law:

$$v = Hd$$

v = velocity of object in km/h
 d = distance in megaparsecs (Mpc)
 (1 Mpc = 1 million pc)
 H = Hubble's constant

If the velocity of an object is known, we can then calculate their distance.

1.4.5 Redshift

Luckily, people can determine the the velocity of fast-moving objects with **Redshift**. Remember, Doppler Effect causes red shifts

1.4.6 Overall summary of this section

In this subsection, I will briefly summary what we learn for measuring the distance

To start off, we have **radar**:

Able to measure the distance to the moon with an 3 cm precision. **Distance:** few AUs

After Radar, we have **parallax**:

Using this formula:

$$d = \frac{1}{p}$$

p = parallax angle in parsec
 d = distance in Parsec

We can measure objects **100** parsecs from our Earth

Then, we get **Cepheid Variables**:

We can use Cepheid's period of changes to determine luminosity. Use period to determine the **Absolute Magnitude**, and use formula "Standard Candles" to determine distances.

This method can measure objects from **1000 parsecs** to **50 million** parsecs

Finally, we can use **Redshift** and **Doppler Effect** to determine the velocity of object:

Then use Hubble's Law:

$$v = Hd$$

v = the velocity of the object in km/h
 H = Hubble constant

d = the distance of the object from our earth in Mpc

To determine further away distance of object

1.5 Cosmology

1.5.1 Some stupid theories

People used to think the sky was a giant **dome** and all the stars were spots on it

Study of Cosmology: *the study of the largest scale we know of: billions and billions of galaxies*

1.5.2 Is our Universe finite?

Olber's paradox: *If the universe is infinite, we would see light from every point in the sky. Then why is the sky dark at night?*

The fact that the sky is dark at night is a clue that the universe is **not infinite**

1.6 Developments in Cosmology

Theory of General relativity by Einstein in 1916

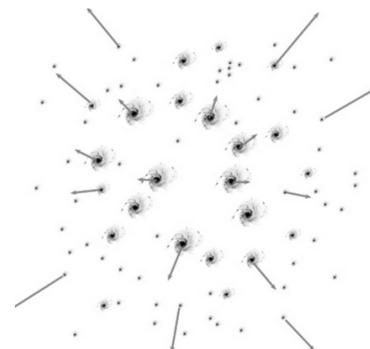
1. Describe how **space** is curved by **matters** and **energy**
2. Predicted that the universe should **expanded or contract**, he added an extra term "Cosmological Constant", to make sure his equations were static
3. Later he said it was "the biggest blunder" of his life



Hubble discovers other galaxies and Hubble's Law in 1922 and 1929

He discovered:

- ! All galaxies were moving **away** from us
- ! All galaxies are **Redshift**
- ! Back to the past, the galaxies would all be **closer** together. There must be a time when all the galaxies **overlap**. This time happened 11.8 billions years ago. This is considered the age of the universe.



Alpher and Gamow calculate cosmic abundances in 1948

Alpher and Gamow assumed that the early universe was very **hot** and calculate the **abundance of certain elements** (other than hydrogen) during the early stages of the universe.

Helium - 25%
Deuterium - 0.001%
Lithium - 0.00000001%

This predictions were confirmed by observational evidences

The theory: *became known as **Big Bang Nuclear Synthesis***

Cosmic microwave background (CMB) was discovered in 1964

While trying building a telescope, Penzias and Wilson, accidentally discovered that there was a signal came from every direction in the sky. The signal has the same frequency as **microwave** and a temperature about **2.7 degrees kelvin**.

The signal was latter interpreted to be the **light** from the **early stages of universe**. It's the first light ever emitted from the Big Bang.

Singularity Theorems in 1968

Roger Penrose and **Stephen Hawking** proved mathematically that the universe must have started with a **singularity**

The means there was a **beginning to the time itself**