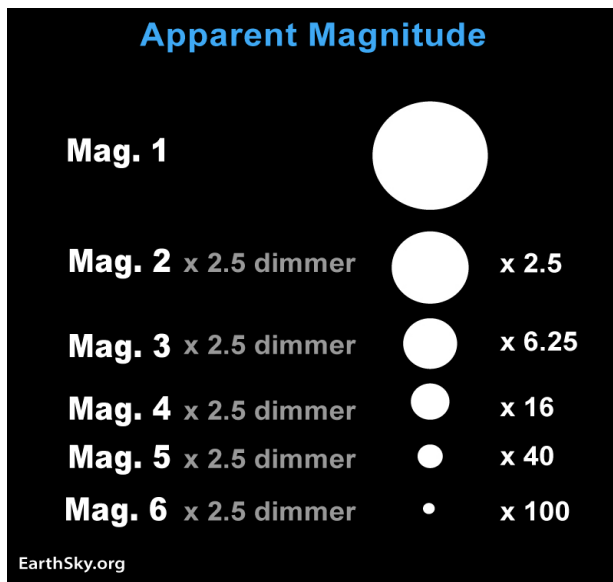


## Topic 13: Exploring Starlight



### 13.1 Apparent Magnitude and Brightness

- The **magnitude scale** measures the brightness of stars as seen from Earth.
- A lower magnitude means a brighter star (e.g., Sirius: -1.46, Vega: 0, Faintest visible: +6).
- A few stars, planets and of course our own Sun have been recategorised so they appear brighter than 1. Sirius appears at -1, Venus at -4, a full Moon at -9 and the Sun at -29.
- In calculations apparent magnitude is represented by **m**.
- Apparent magnitude **does not** consider distance.



Difference in Magnitude	Brightness Ratio
1	2.5
2	6.25
3	16
4	40
5	100

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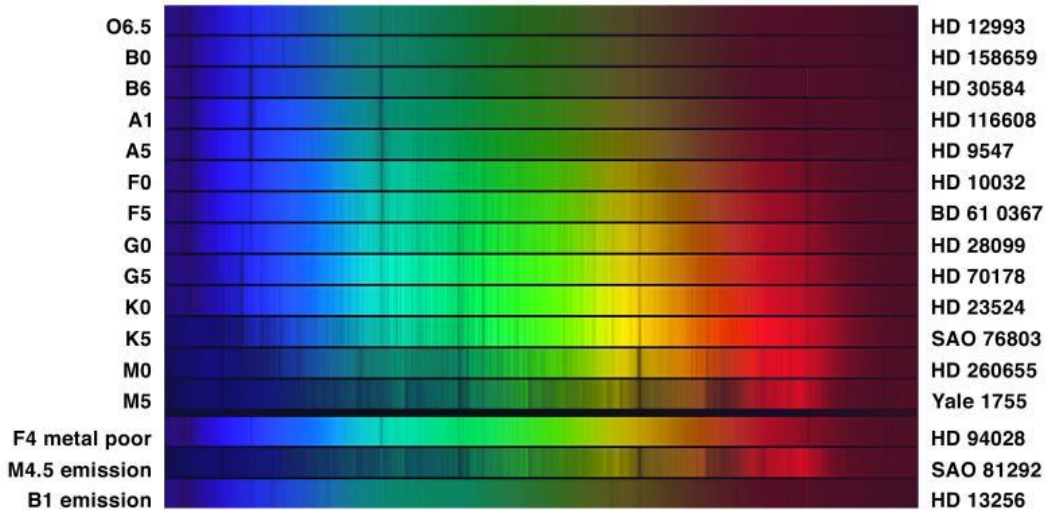
### 13.2 Absolute Magnitude

- The **absolute magnitude (M)** is how bright a star would appear if placed **10 parsecs away** from Earth.
- Helps compare intrinsic brightness of stars.

$$M = m + 5 - 5 \log d$$

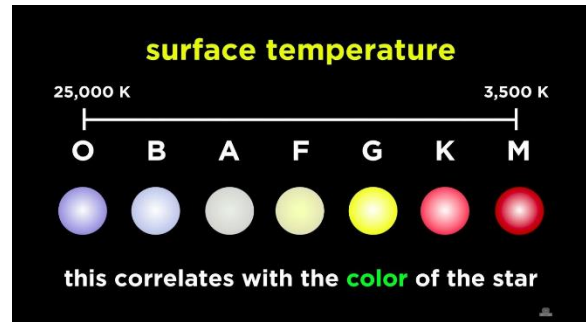
where d is the distance in parsecs.

## 13.4 Stellar Spectra and Classification



- Isaac Newton used a prism to split white light into different colours. Astronomers use a spectrometer which uses the same principle to study a star's chemical composition, temperature and even its velocity away from or to Earth.
- A **stellar spectrum** tells us:
  - **Composition** (absorption and emission lines)
    - We can tell what atoms are present in the star by different coloured lines in the spectrum. These are called spectral lines. Some lines are dark and called absorption lines. These show what atoms are absorbing the light. Some lines are bright and called emissions lines. These show what atoms are emitting light.
    - If there are darker lines that show Hydrogen and bright lines that show Helium we can say that the star has finished burning its Hydrogen and started burning Helium. A red giant would fit this evidence.
  - **Temperature** (hotter stars = bluer, cooler stars = redder).
    - We can estimate the star's surface temperature. By measuring its temperature distribution over a long period, we can even estimate its sunspot or starspot cycle. From the stellar spectrum we can also determine the revolution of a star in the same way we can use a spectrometer to measure the differential rotation of our own Sun.
  - **Radial velocity** (redshift = moving away, blueshift = moving closer).
    - We can measure the radial velocity of stars. By measuring the distance between certain spectral lines, we can measure its wavelength and be able to tell if and by how much it shows redshift (longer wavelengths show it is moving away from us) or blueshift (shorter wavelengths show it is moving towards us).
- When we look at the spectrum of a binary it can present problems for us as we will see the combined spectrum for both stars.

- Stars are classified into **spectral types**: **O B A F G K M** (hottest → coolest).
- Each star is different and there are many different types of stars. Astronomers categorise these by temperature and their chemical composition that they obtain from a star's stellar spectrum.
- Stars are divided into 7 main categories and then given a number between 0 to 9 within each to denote temperature within the category. Distinguishing letters after that you might see such as 'III', 'V', 'VII' etc tell us if the star is a regular giant, main sequence or white dwarf etc.
- So you can have an 'M' class star of under 3,000° K and depending on the information after it, this could then be a red dwarf or super red giant
- The Sun is classed as a **G2 star (5800K)** .

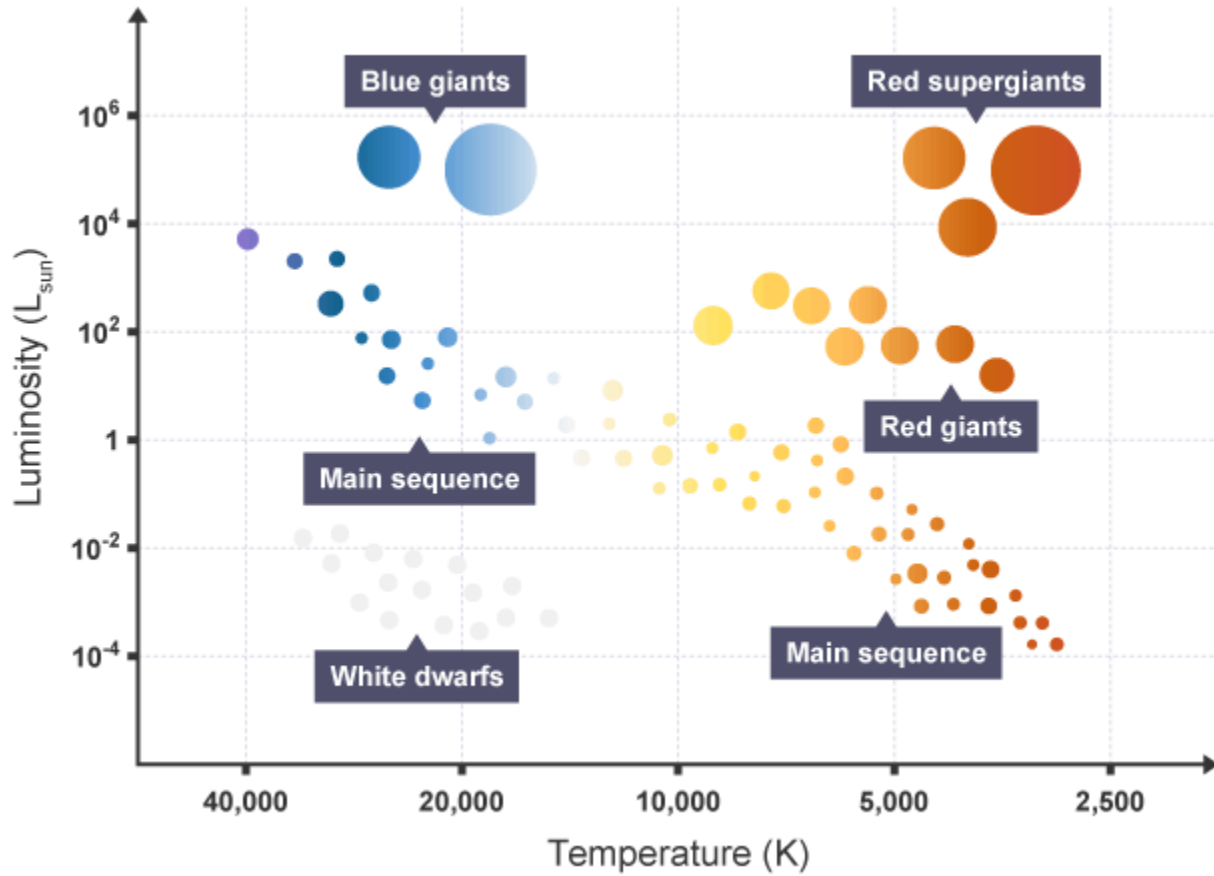


Type	Colour	Temperature	Spectral lines
O	Violet -white	30,000° K+	Helium with Hydrogen
B	Blue-white	12,000 - 30,000° K	Hydrogen with Helium
A	White	8,000 - 12,000° K	Hydrogen Rich
F	Yellow-White	6,000 - 8,000° K	Calcium
G	Yellow	5,000 - 6,000° K	Some Iron lines
K	Orange	3,000 - 5,000 ° K	Many Metallic lines
M	Red	<3,000 ° K	Metallic and Carbon lines

(Remember the order using a mnemonic: "**Oh Be A Fine Girl/Guy, Kiss Me**")

### 13.7 The Hertzsprung-Russell (H-R) Diagram

- The **H-R diagram** plots stars based on **luminosity (brightness) vs. temperature (color)**.
- Key regions:
  - **Main Sequence** (normal hydrogen-burning stars, e.g., Sun) [prominent diagonal band]
  - **Red Giants & Supergiants** (large, bright but cool). [top right]
  - **White Dwarfs** (small, hot but dim).



### 13.9 Inverse Square Law of Brightness

- This is the same principle as when we discussed gravitation.
- The brightness of a star decreases with distance:

$$\text{Intensity} \propto \frac{1}{\text{distance}^2}$$

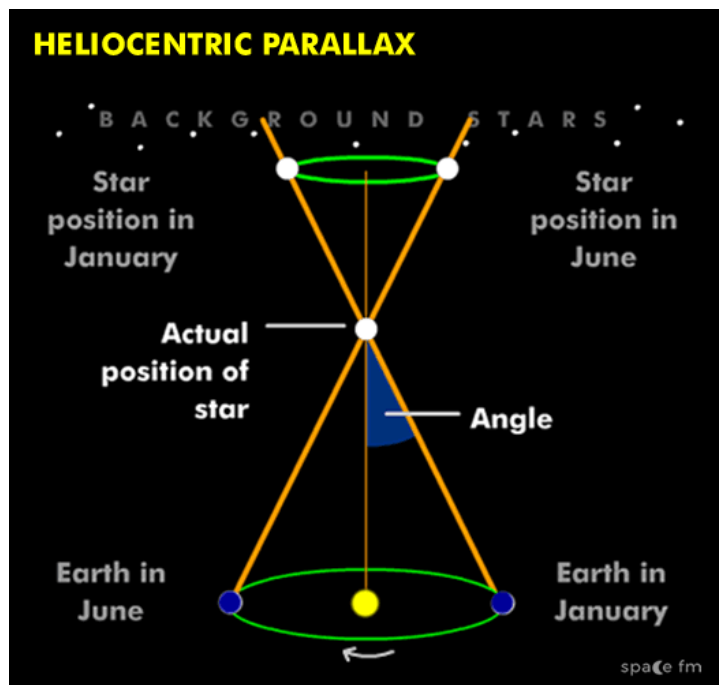
- A star **twice as far** appears **four times dimmer**.
- 

### 13.12 Parallax and Astronomical Distances

- **Parsec (pc)** is a unit of distance:
  - **1 pc = 3.26 light-years.**
- **Heliocentric Parallax:** Nearby stars appear to shift against the background when viewed from different positions in Earth's orbit.

Here's an experiment. Hold your thumb up about 30 centimetres (or one foot) in front of your eyes. Close one eye, look at it with the other and see the background behind it. Now repeat it with the other eye and do this a few times. You can see that swapping eyes makes the angle of the thumb and the background appear differently.

- We measure the distance to stars using a similar method.
- This is called **heliocentric parallax**. We can measure the distance to nearby stars by measuring how much they appear to move against distant stars. How do we on Earth change angles to do this? Easy - we measure it in one month and then again six months later when the Earth is on the opposite side of the Sun (this is the heliocentric bit!).
- By figuring out how much the star moves we can work out the angle and from there the distance using the AU between Earth and Sun as a base to measure by.

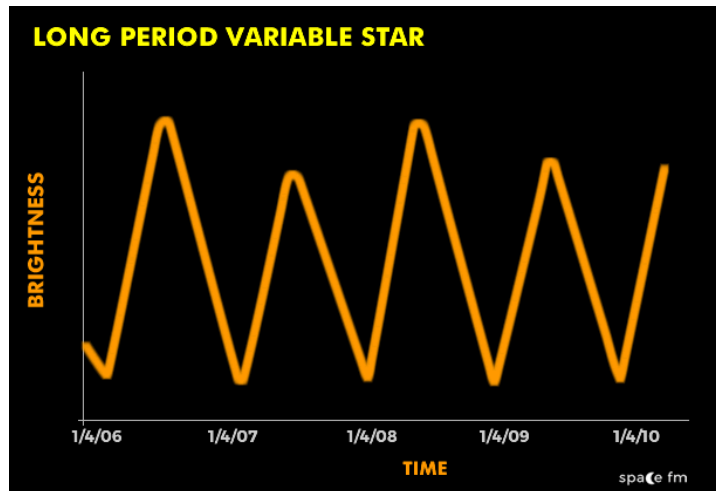


Astronomers use parallax to estimate the spectral type of a star. They calculate the luminosity of the star and can work out its distance using its apparent brightness. They can then place it on the H-R diagram and find its absolute magnitude. We calculate the size of a star using Stefan's Law which relates luminosity and temperature to its radius.

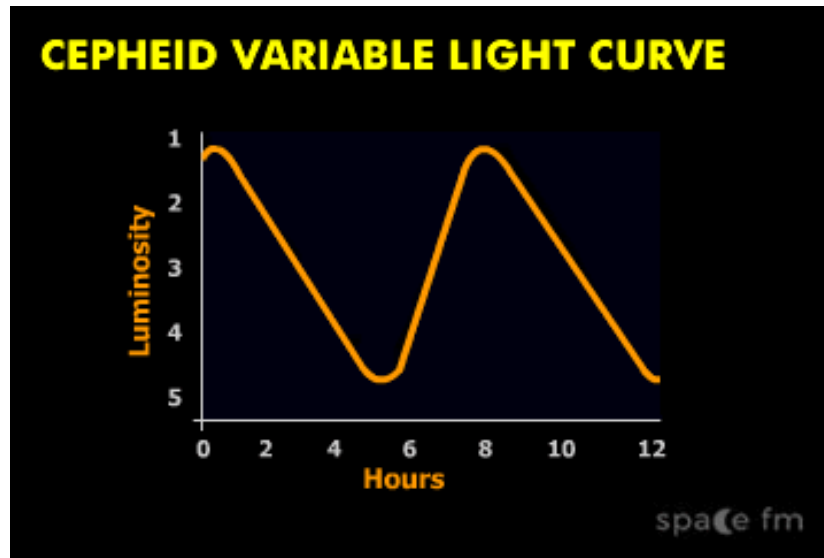
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### 13.14 Light Curves of Variable Stars

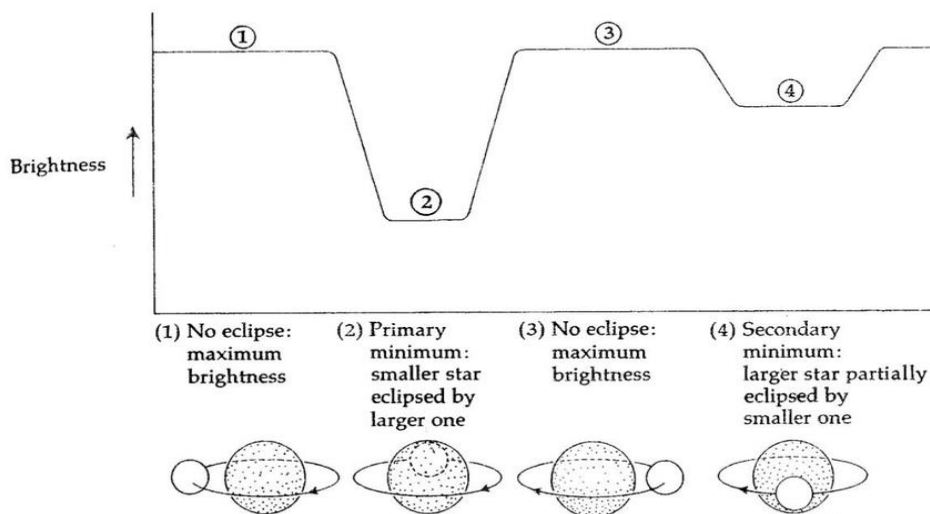
- **Variable stars** change brightness over time.
- Long period variable stars are typically giant stars with periods between a hundred and a thousand days.



- Short period variable stars are usually eclipsing binaries, cepheids or pulsating stars that changes magnitude over several days or weeks.
- Types:
  - **Cepheid variables:** Pulsating stars; We see the light they produce dip and rise over a short period of time, returning to the same luminosity a few days later. They a period-luminosity relation. The longer the period between peaks of brightness the brighter the star is.
  -

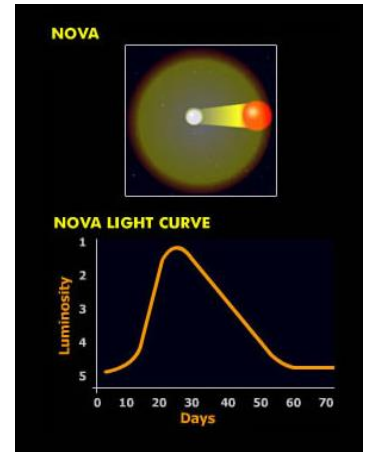


- **Eclipsing binaries:** Two stars orbiting, blocking each other's light.

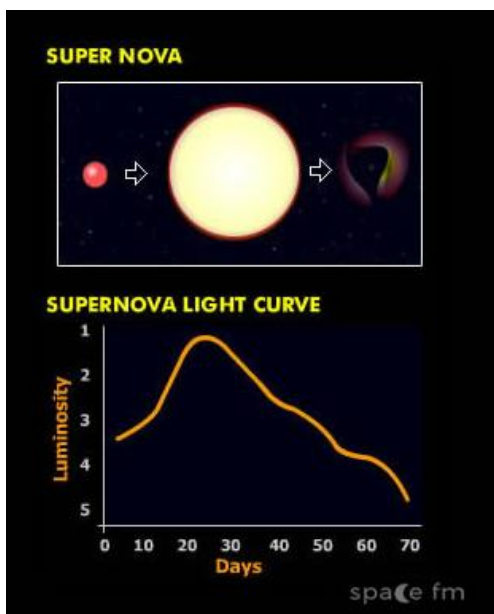


## Nova

- In a binary system where one star is a white dwarf and the other is a large yellow or red giant, the dwarf has stronger gravity and pulls matter from the giant.
- Eventually the dwarf will not be able to hold onto the excess solar material and explodes this matter off its surface. This build up takes place over a short period of time.
- When it explodes, the luminosity increases by many magnitudes. The star reverts back to its former brightness after a period of 30 to 100 days.



## Supernova



A supernova is the brightest event in space. There are two types of supernova.

1 Similar to a nova where a dwarf takes material from a giant. This time the explosion destroys the dwarf.

2 When a star has a mass greater than 8 solar masses. The red giant swells so much it collapses in on itself. These are dramatic events as once they explode the core forms a neutron star or a black hole.

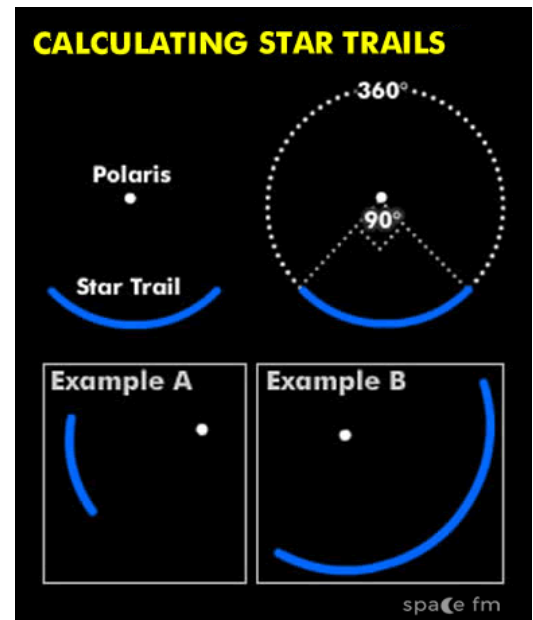
The light curve shows a drastic increase in brightness before receding to a small luminance after a few months.

A planetary nebula is usually seen in the region of a supernova for years, sometimes centuries afterwards.



### 13.14 Star Trails

- You can see evidence of the apparent motion of stars by photographing them over a long time using a long exposure.
- If you photograph a star, any star over a period of time you will find the photograph will be of a bright trail. This is because the Earth is rotating and the camera sees the star moving. If you take a long exposure photo of stars but aim at or near the pole star you will find several circles of light surrounding it.
- By looking at how much a prominent star in a star trail photograph has moved we can work out the exposure time of the image.



$$\frac{\text{Angle of arc}}{360^\circ} = \frac{\text{Time exposure}}{24 \text{ hours}}$$

- Measure the angle between each tip of the trail, using Polaris as the centre guide. You might notice that Polaris is a little blurry. That is because it is just less than a degree away from the true northern rotation point.

### 13.20-13.22 Observing Starlight with Telescopes

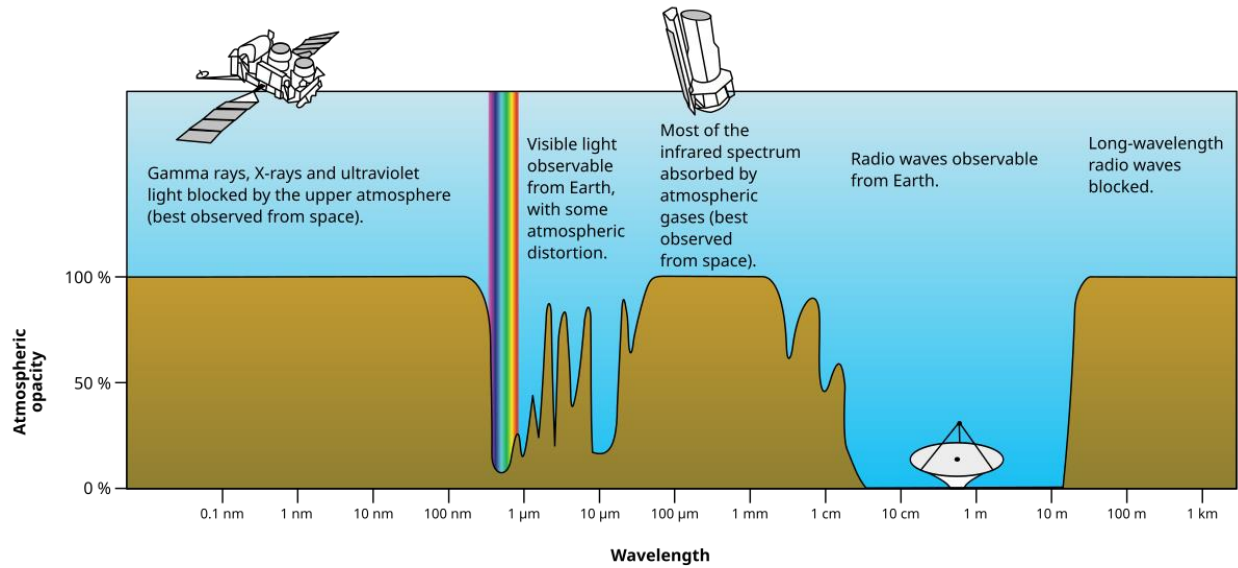
- **Modern telescopes use digital sensors** to collect and analyze light.
  - The Earth's atmosphere **blocks most wavelengths**, except visible light and radio waves.
  - **Radio telescopes** collect radio waves and need large apertures for resolution.
- ◆ **Study Tip:**
- Know why telescopes like **Hubble** are placed in space (to avoid atmospheric distortion).

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### 13.31-13.33 Space Telescopes and Observing Different Wavelengths

- **Infrared telescopes** operate best at high altitudes or in space (e.g., **James Webb Space Telescope**).

- **X-ray and Gamma-ray telescopes** must be **outside Earth's atmosphere** to detect high-energy radiation.
- **Radio telescopes** are best on Earth's surface (e.g., **Arecibo, ALMA**).



◆ **Study Tip:**

- Understand why different telescopes are placed in **different locations**.

### 13.34 Telescopic Observations of Celestial Objects

- A telescope can **resolve** and enhance features of:
  - **Stars** (point sources of light).
  - **Double & Binary Stars** (two stars orbiting).
  - **Open & Globular Clusters** (groups of stars).
  - **Nebulae & Galaxies** (extended deep-sky objects).

◆ **Study Tip:**

- Know how telescopes **enhance details** of celestial objects.