
Chapter 3
Radiations
Dr. Tariq Al-Abdullah

Learning Goals:

3.1 Information from the Skies

3.2 Waves in What?

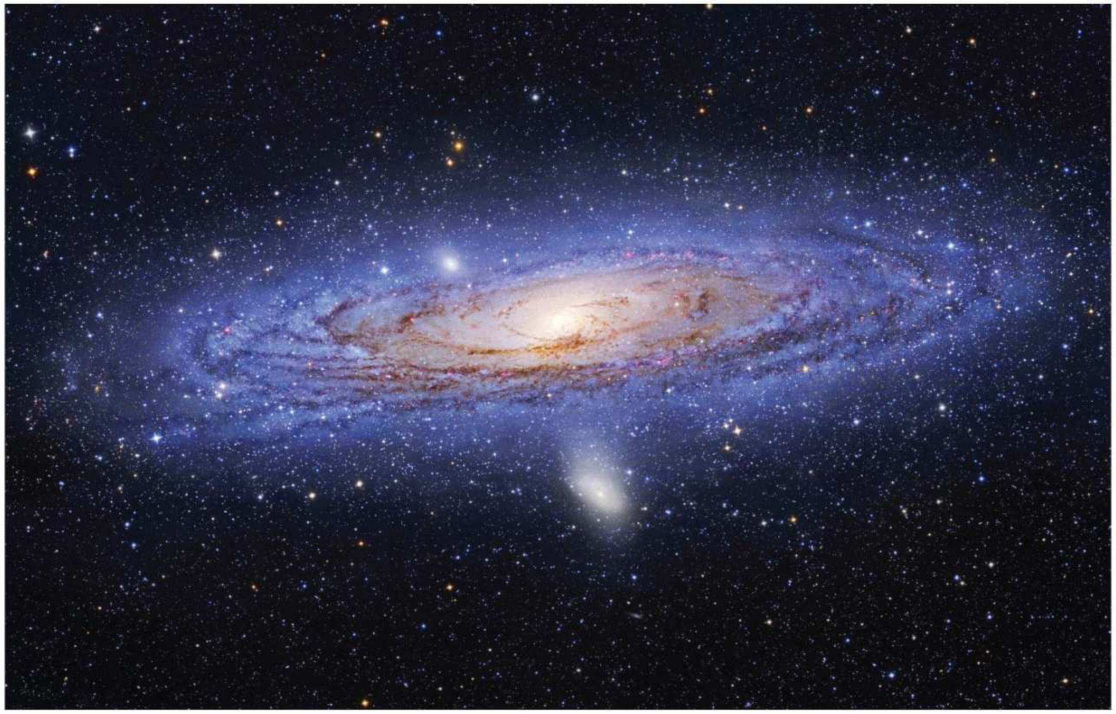
3.3 The Electromagnetic Spectrum

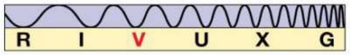
3.4 Thermal Radiation

3.5 The Doppler Effect

3.1 Information from the Skies

- **Far Objects are inaccessible in any realistic human sense!**
- **EM radiations = Transmitted Energy through space.**
- **Light , Radiation, Rays, waves → same thing**
- **Radiations: Radio, Infrared, Visible, Ultraviolet, X-ray, γ-ray**

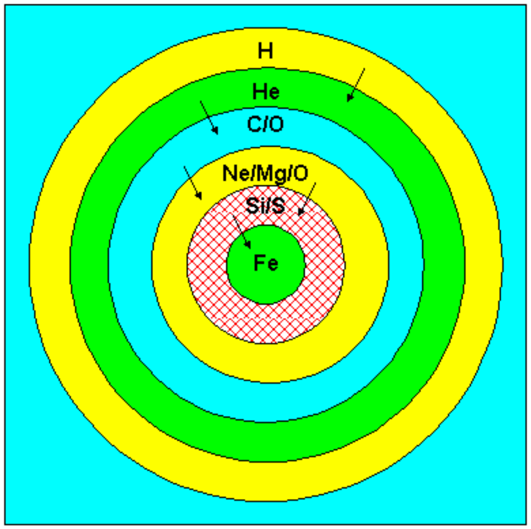


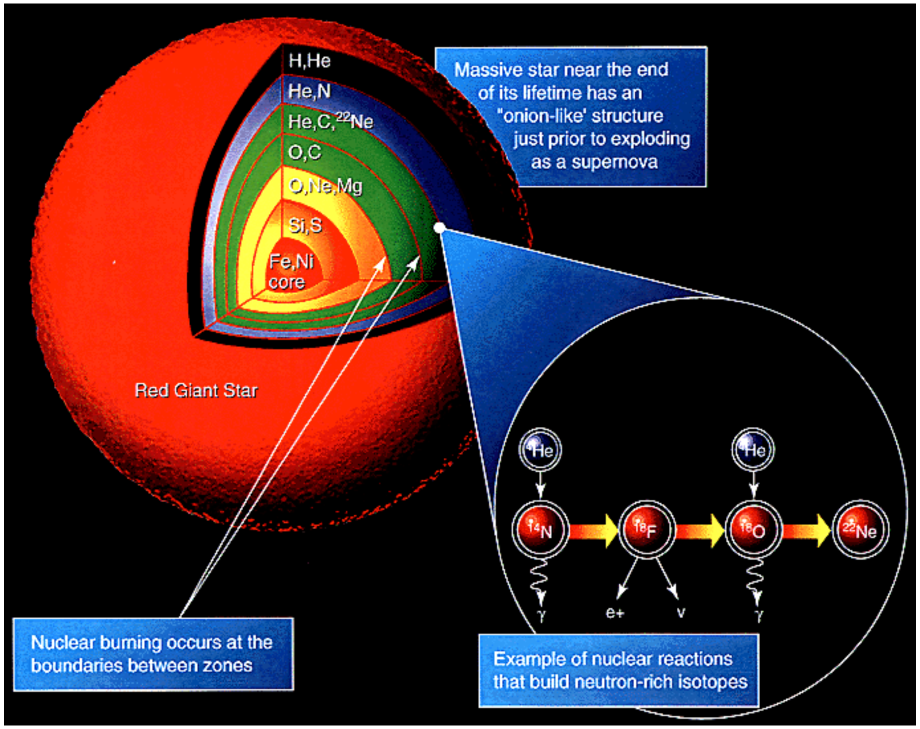


3.1 Information from the Skies

Questions??

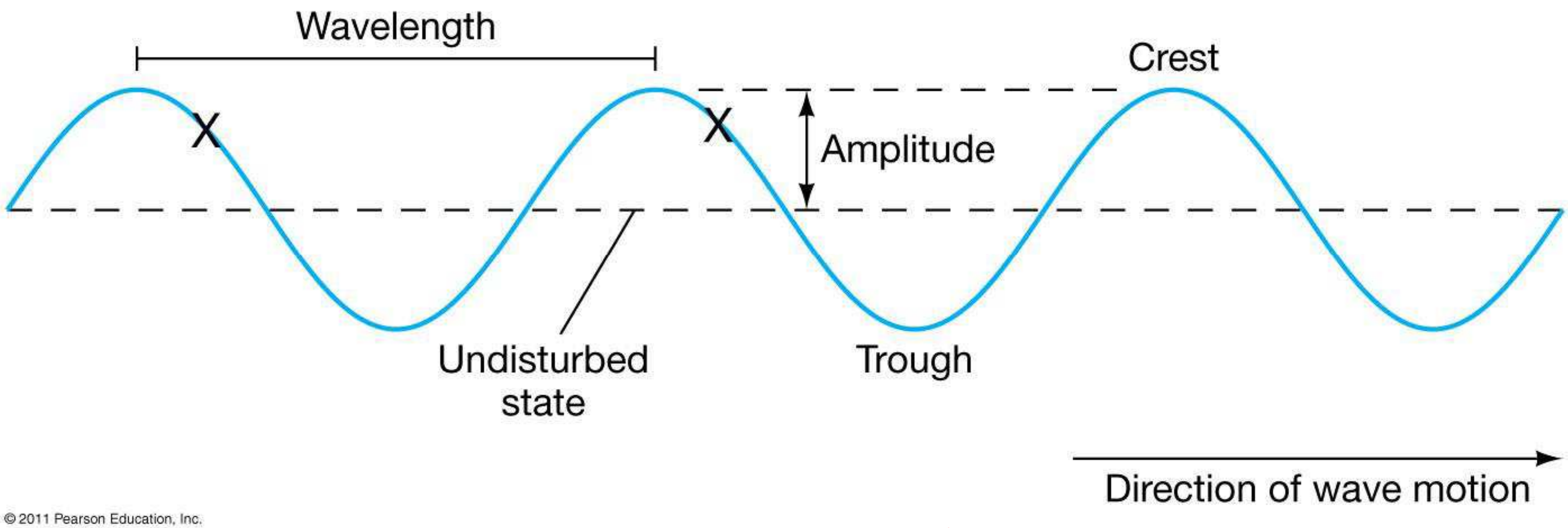
- How bright are the stars, galaxies, …?
- What are their masses?
- How fast do they spin?
- What is their motion through space?
- What are they made of? WHY!!





3.1 Information from the Skies

Wave motion: Transmits energy without the physical transport of material

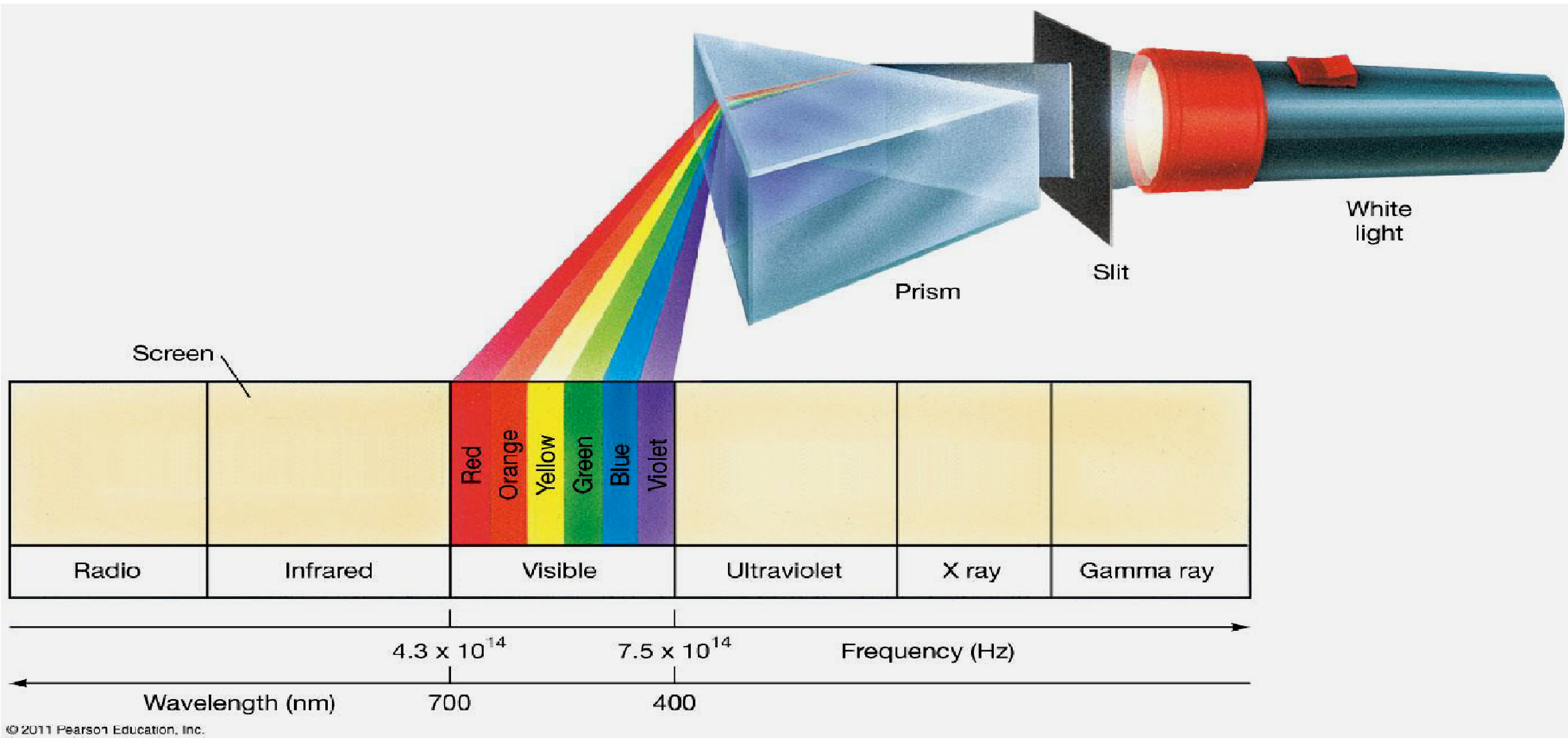


$$\text{frequency} = \frac{1}{\text{period}}$$

$$\text{wavelength} \times \text{frequency} = \text{velocity}$$

3.1 Information from the Skies

- **White light is a mixture of colors:**
  red, orange, yellow, green, blue, violet



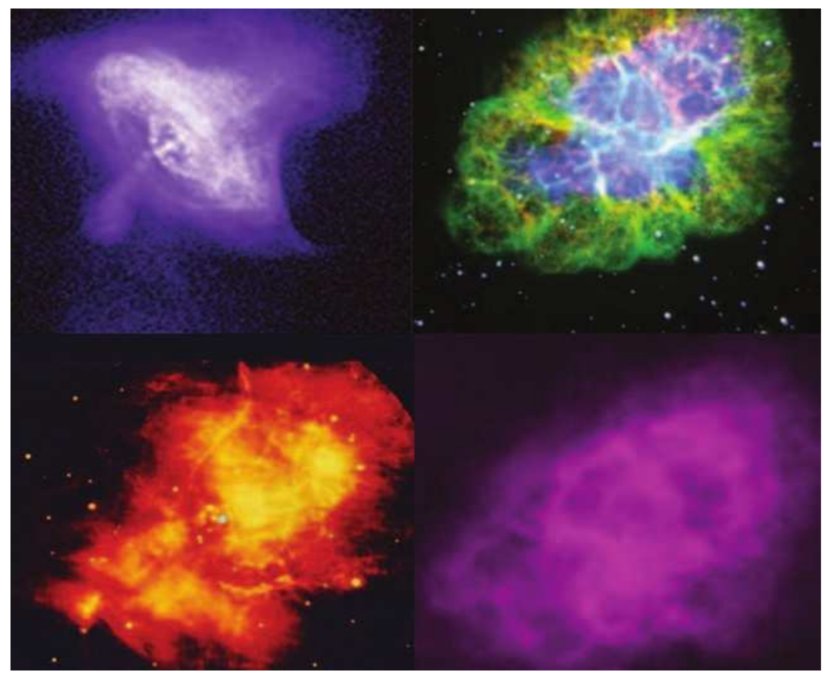
3.2 Waves in What?

Waves of radiation:-

- **Waves of radiation needs no source of medium.**
- Other waves cannot exist without physical medium.

Mechanical Waves

Electromagnetic waves



Interactions Between Charged Particles:-

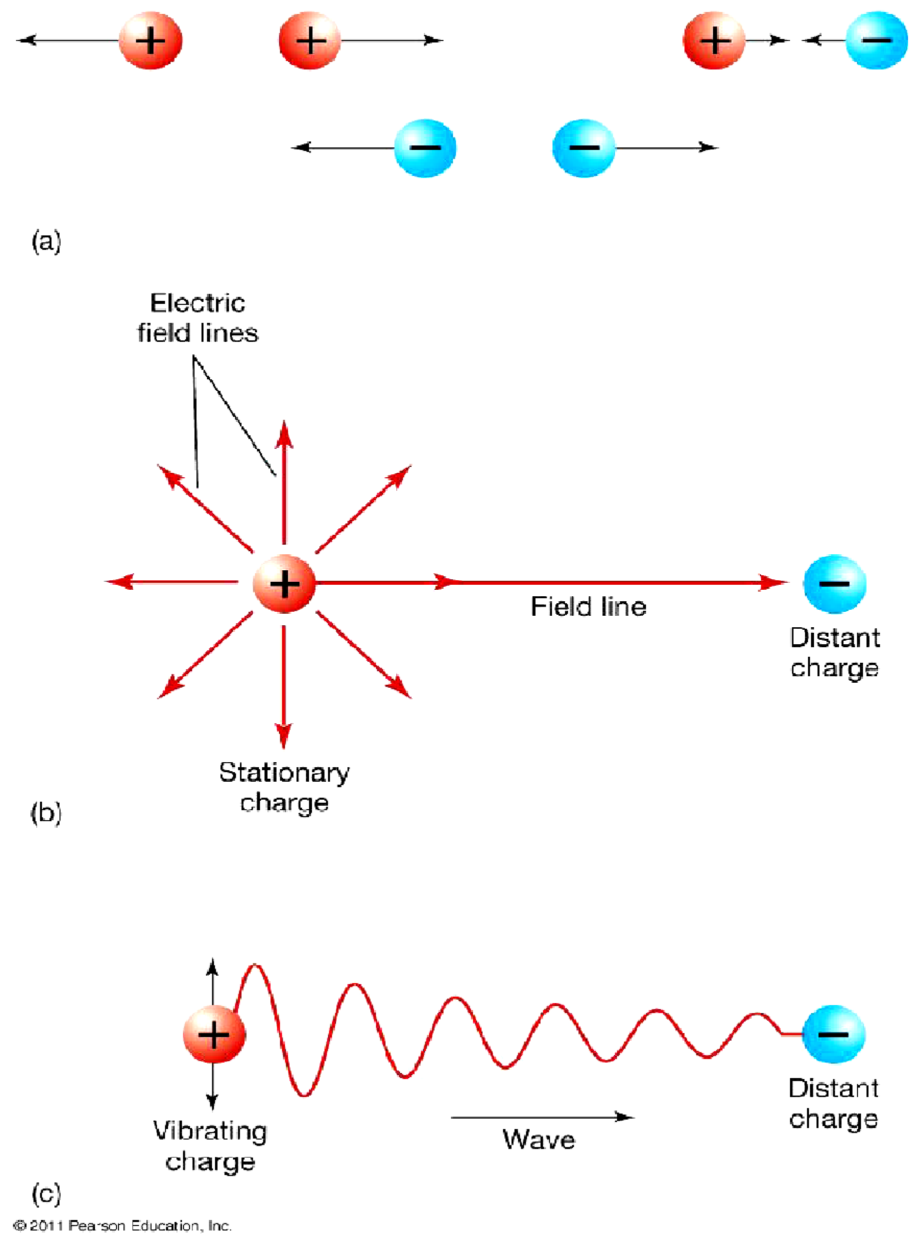
- The charged particle exerts an electrical force on other charged particle in The universe.

- How is the electrical force transmitted through space?

- The inverse-square law for the electrical force.

- If a charged particle begins to vibrate, its electric field changes.

-This disturbance in the particle's electric field travels through space as a wave.



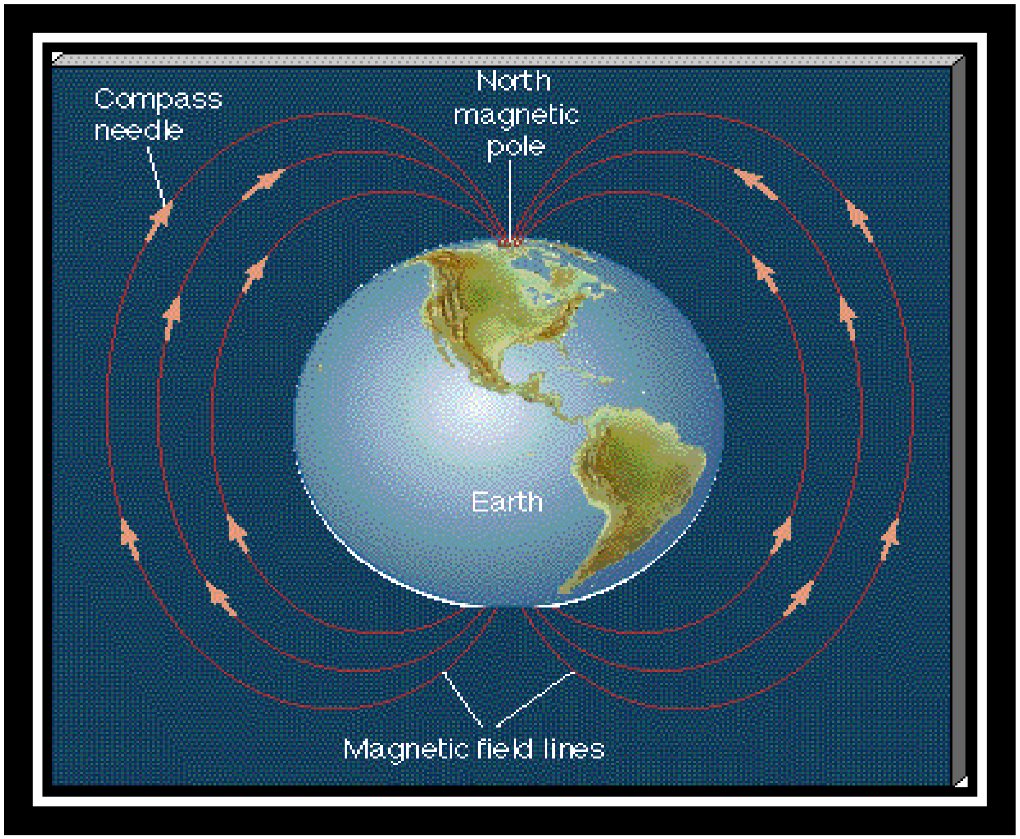
Electromagnetic Waves:-

-A magnetic field must accompany every changing electric field.

-A compass needle always points to magnetic north.

-Electric and magnetic fields vibrate perpendicularly to each other.

-Electromagnetic radiation transfers energy and information .



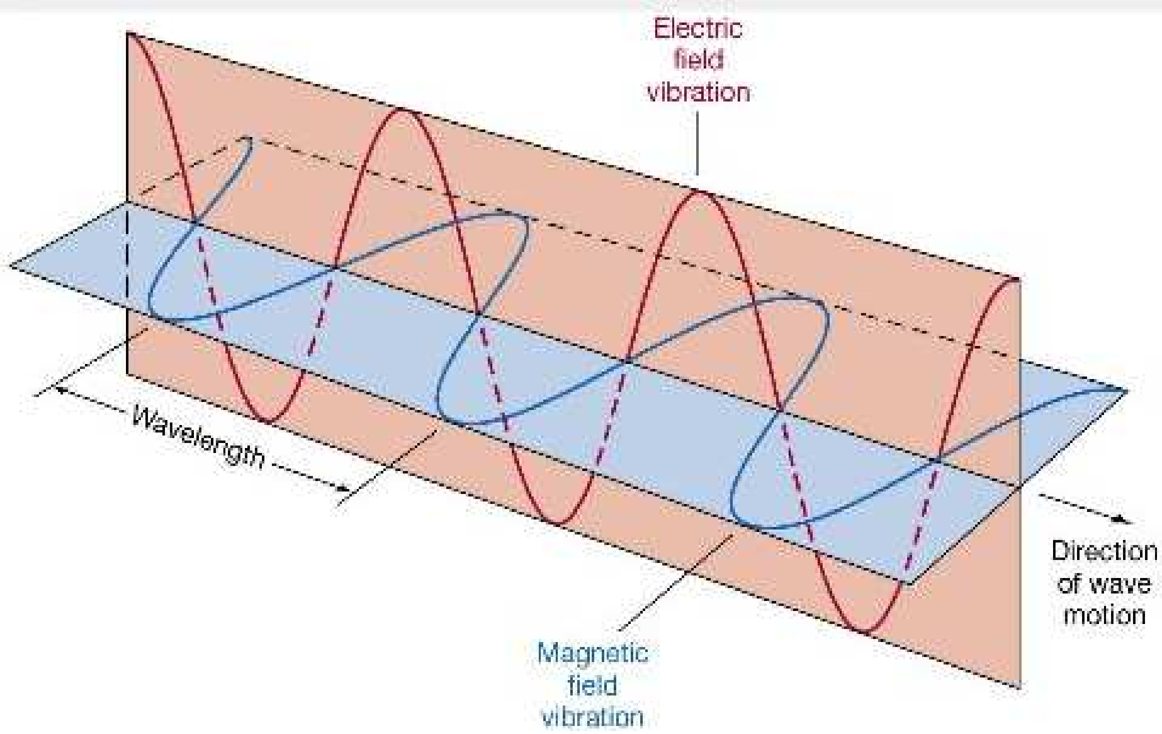
Electromagnetic Waves

-All electromagnetic waves move at the speed of light .

-The speed of light is the fastest speed possible (300,000 km/s).

- Light does not travel instantaneously from place to place.

- The wave theory of radiation is a successful scientific theory.



3.2 Waves in What?

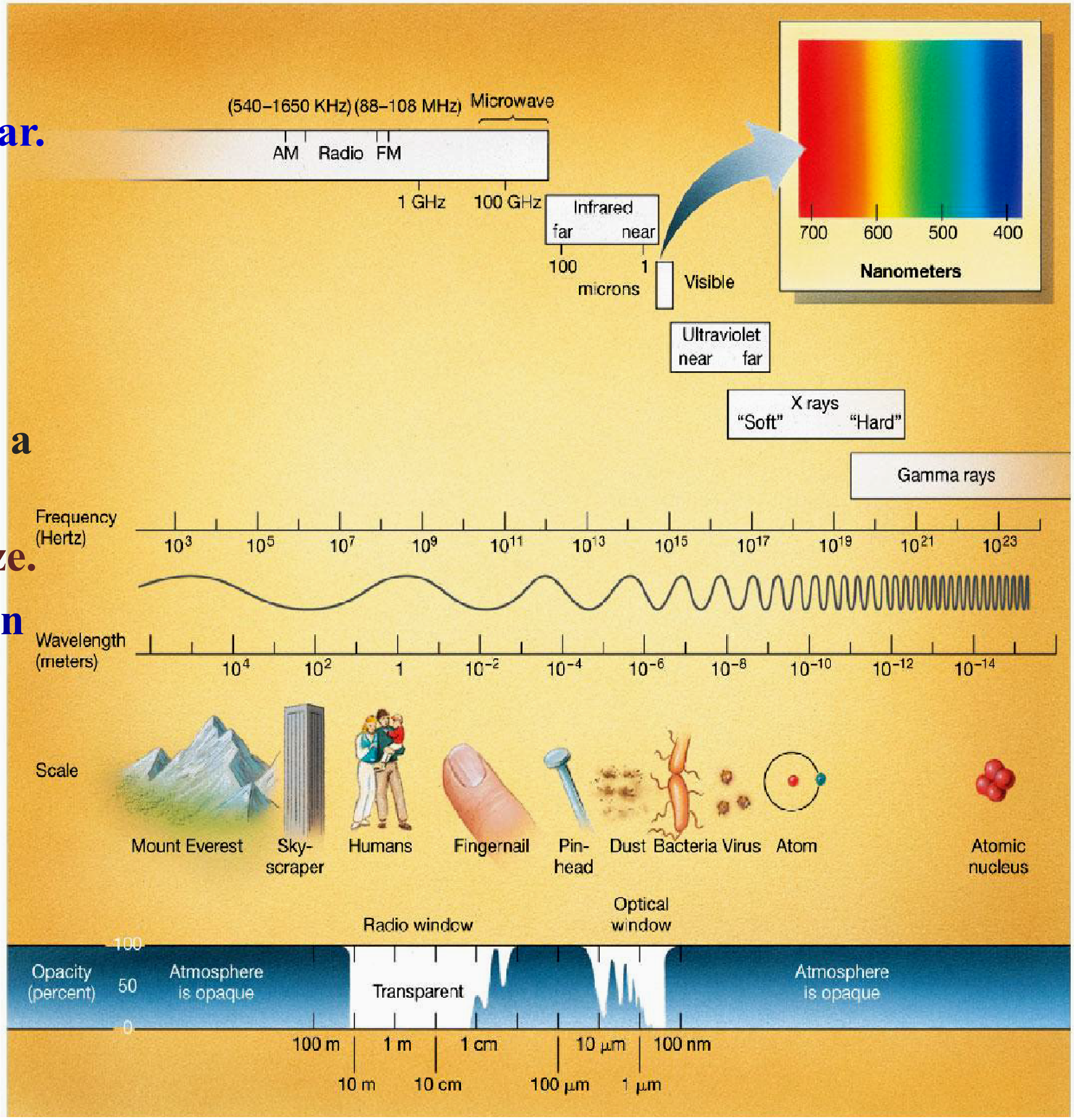
What is the wave speed of electromagnetic waves?

This speed is very large, but still finite; it can take light millions or even billions of years to traverse astronomical distances

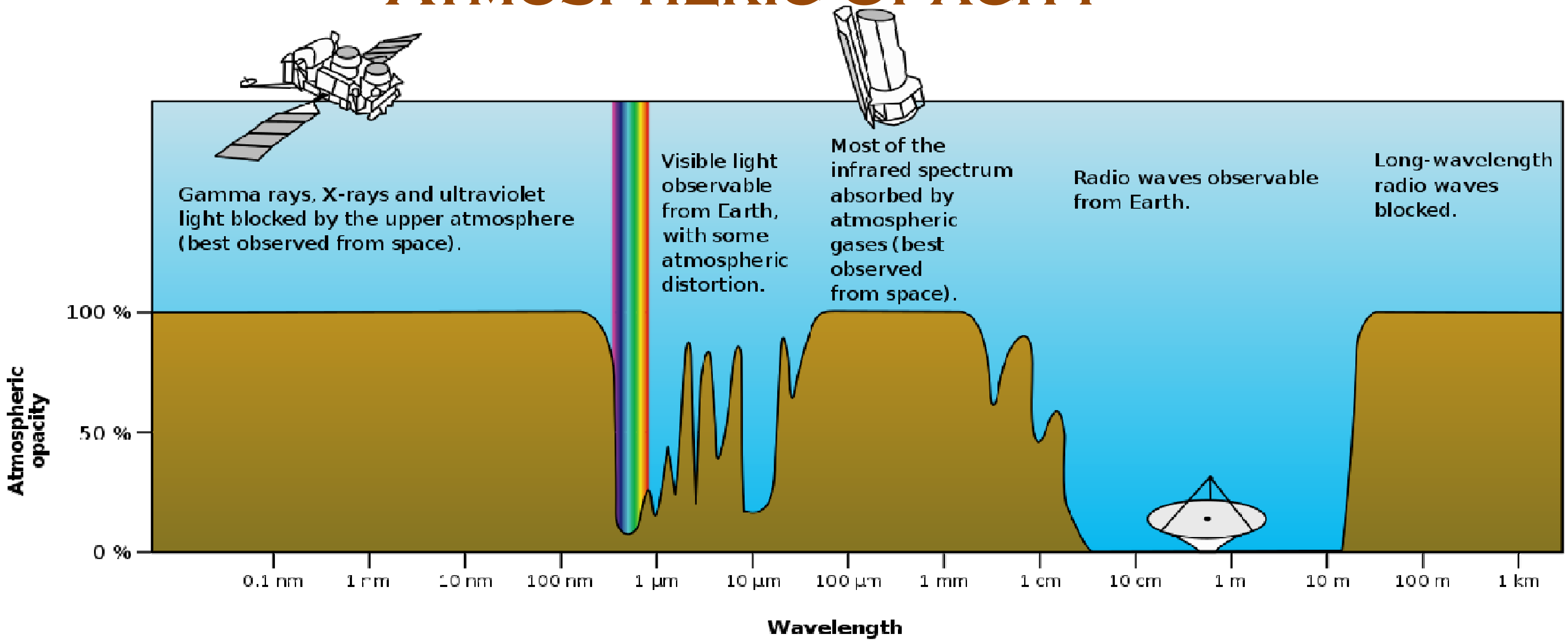
Electromagnetic Theory of Radiation: The description of electromagnetic waves traveling through the space

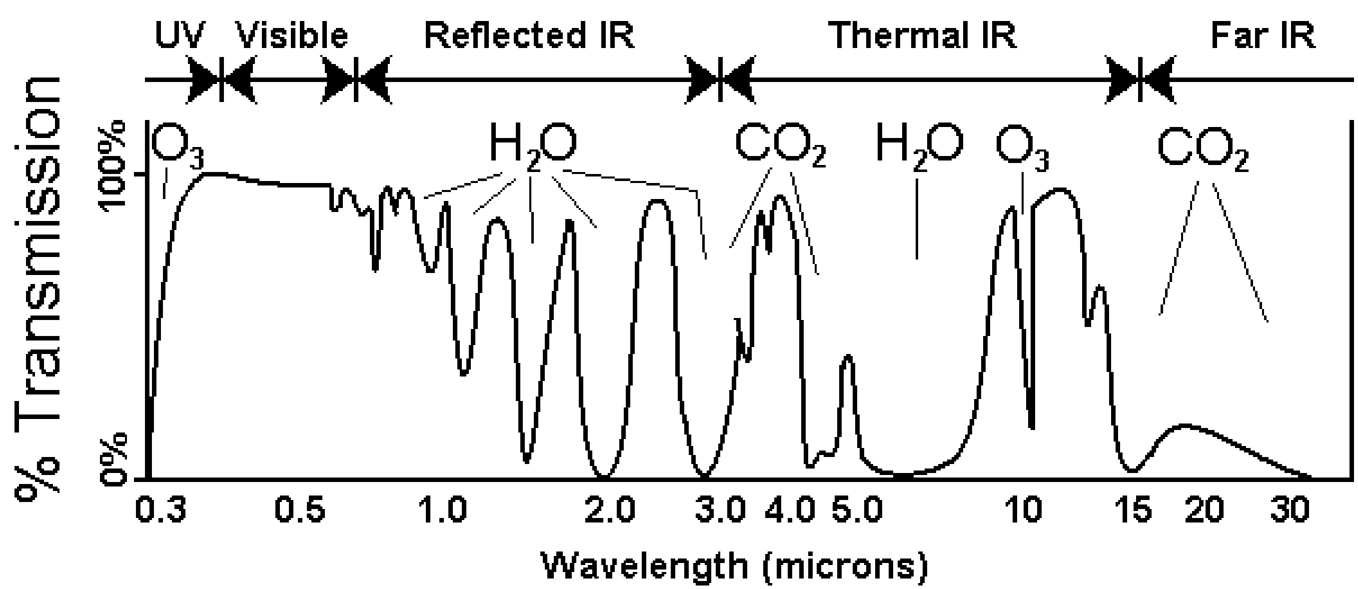
3.3 Electromagnetic Spectrum

- **Radio: Microwave, radar.**
- **UV: suntan, sunburn.**
- **X ray: penetrable.**
- **Gamma: shortest, radioactivity**
- **Frequency increases by a factor of 10.**
- **Mountain to nucleus size.**
- **Fraction of the radiation is detected on earth.**
- **Spectral windows & opacity**
- **Ionosphere, ozone**



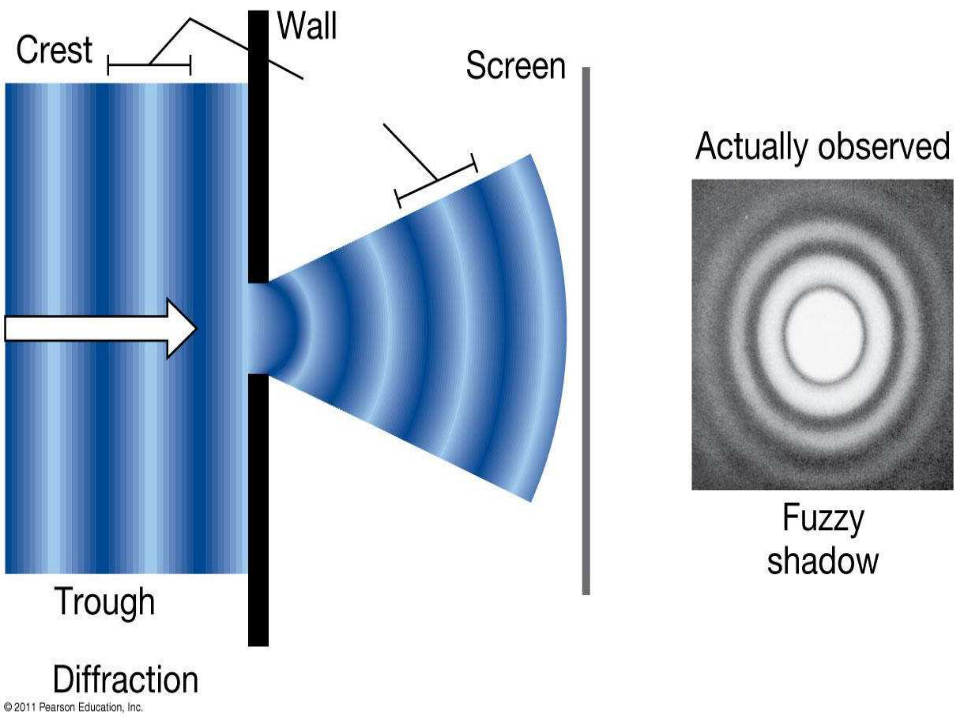
Atmospheric Opacity

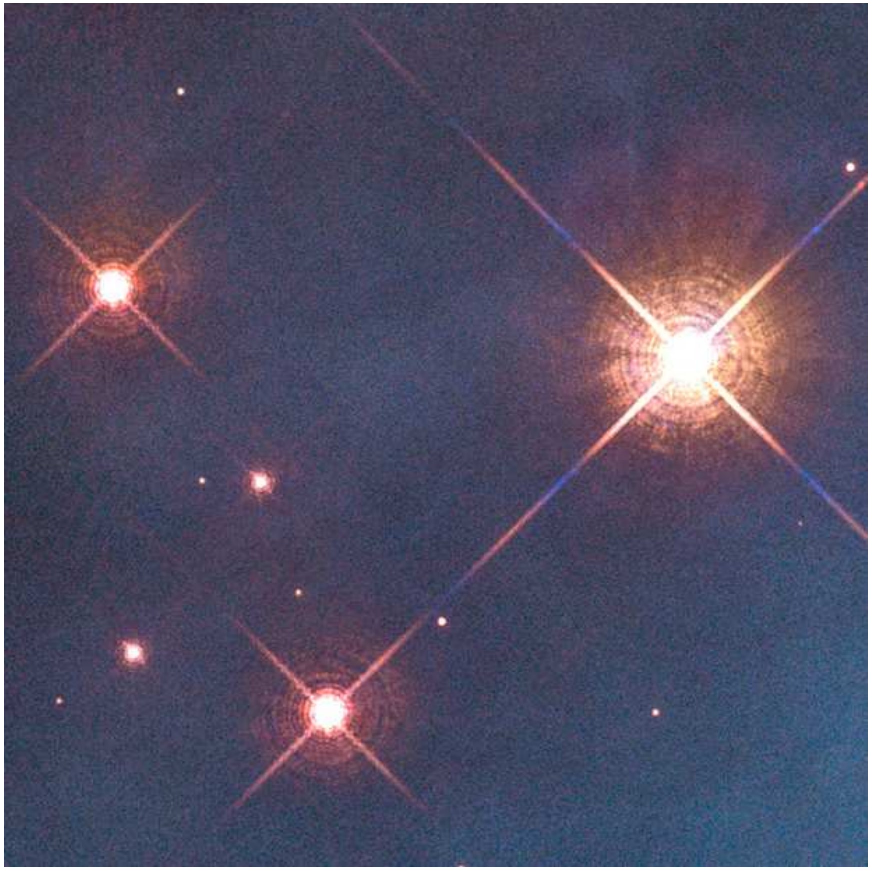




The Wave Nature of Radiations

Diffraction is purely a wave phenomenon. If light were made of particles, we would see a spot the size of the hole, with no fuzziness.

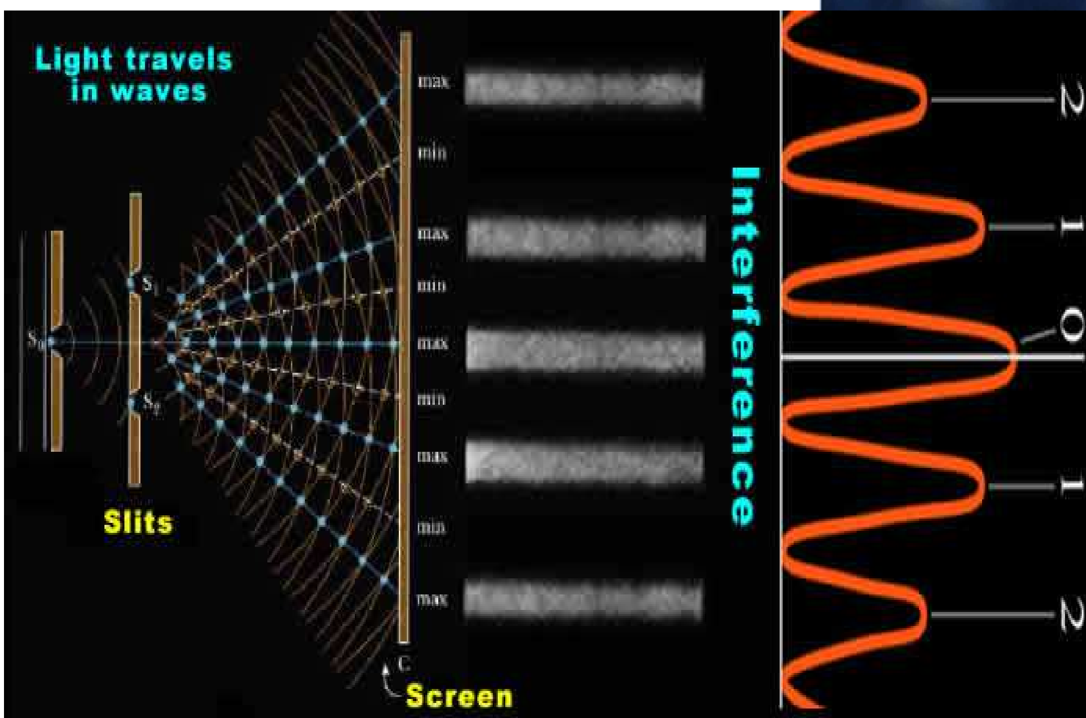


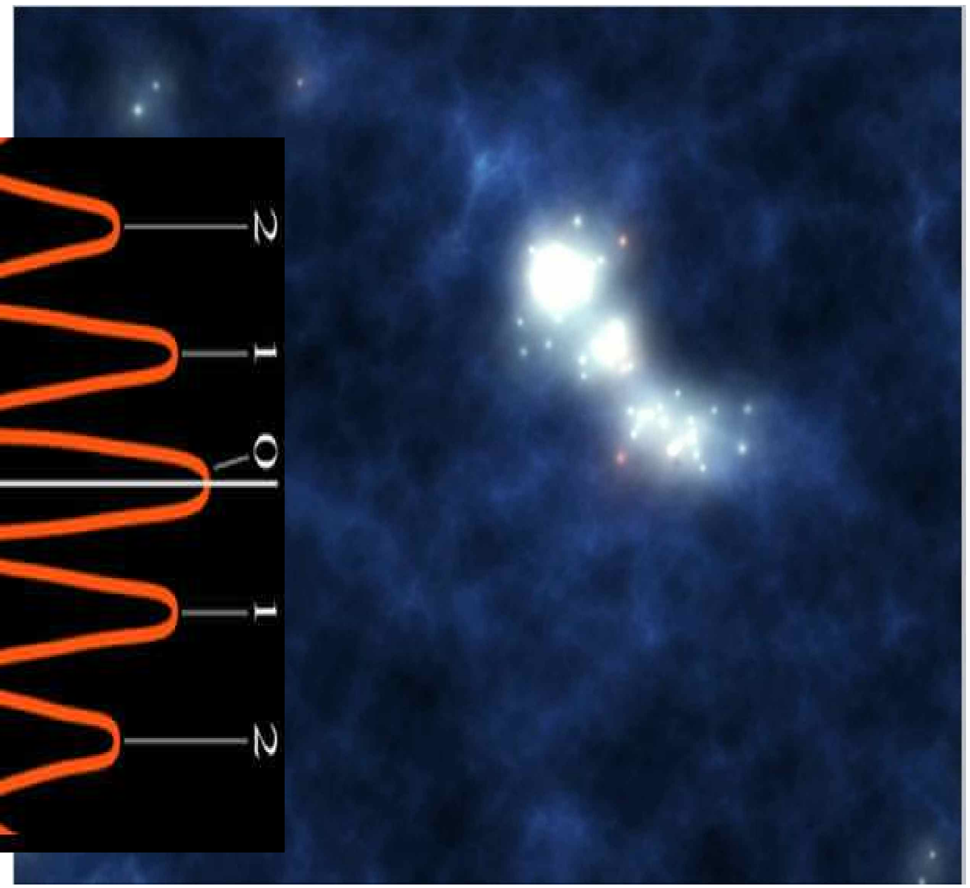


The Wave Nature of Radiations

Interference is the ability of two or more waves to reinforce or diminish each other.

Interference is either constructive or destructive.





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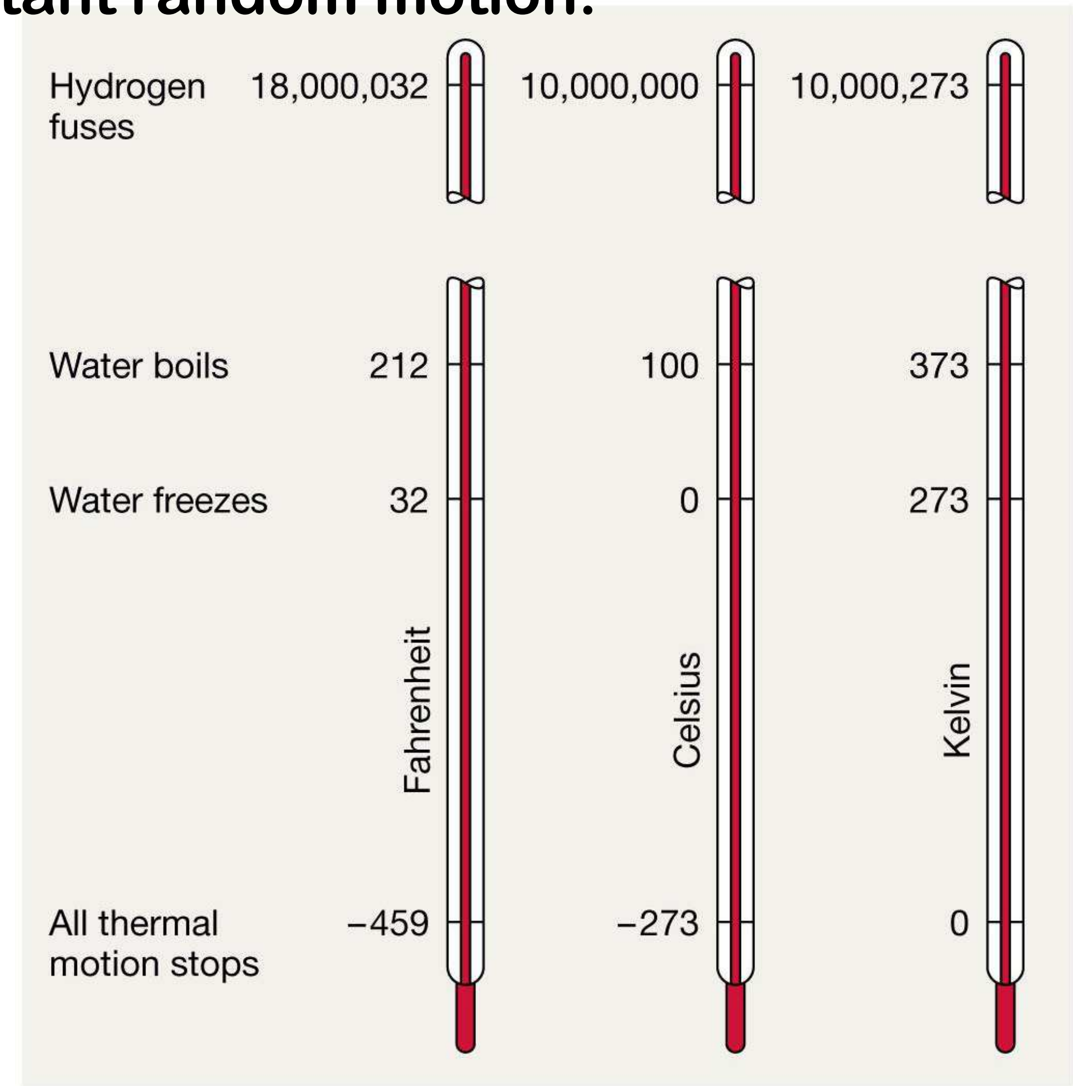
3.4 Thermal Radiation

The atoms and molecules that make any piece of matter are in constant random motion.

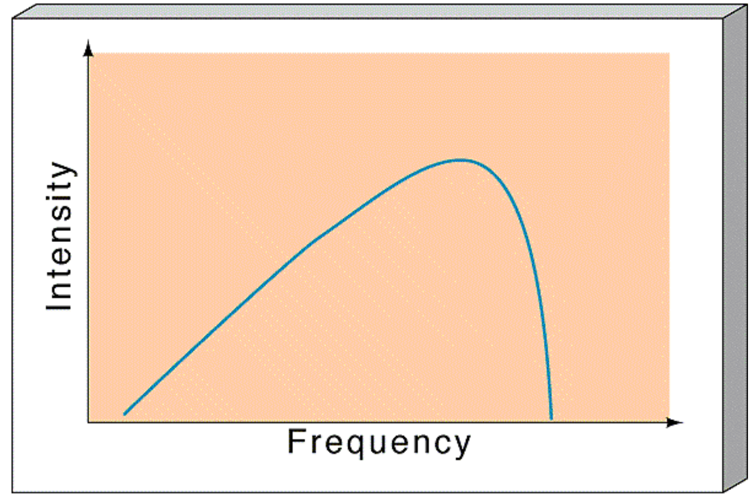
The Temperature Scale

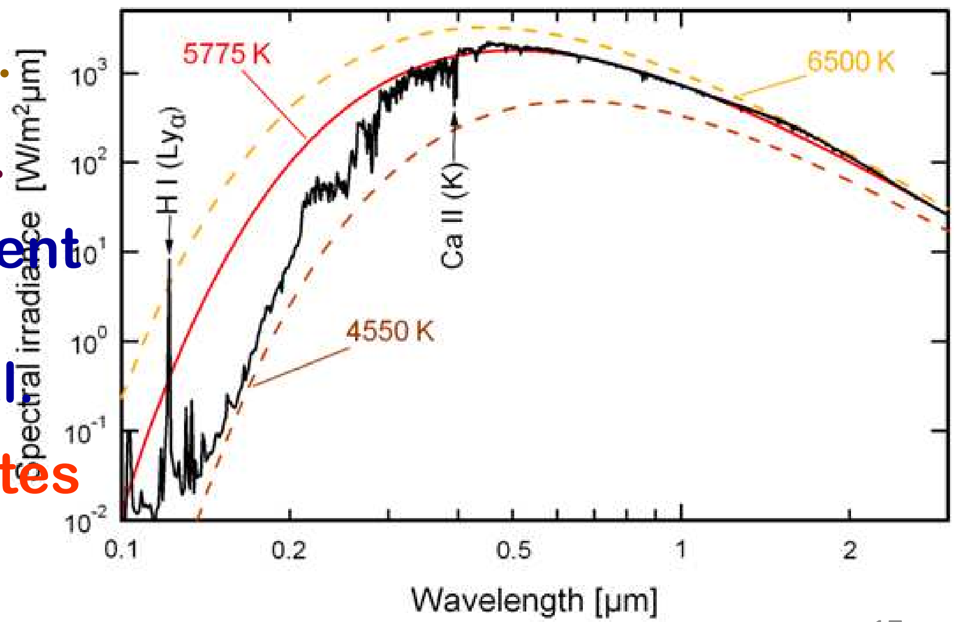
- **Objects in Universe: $T = 2 - 10^8$ K**
- **Moving Objects emit Radiations**
- **All thermal motion ceases at 0 K**



3.4 Thermal Radiation

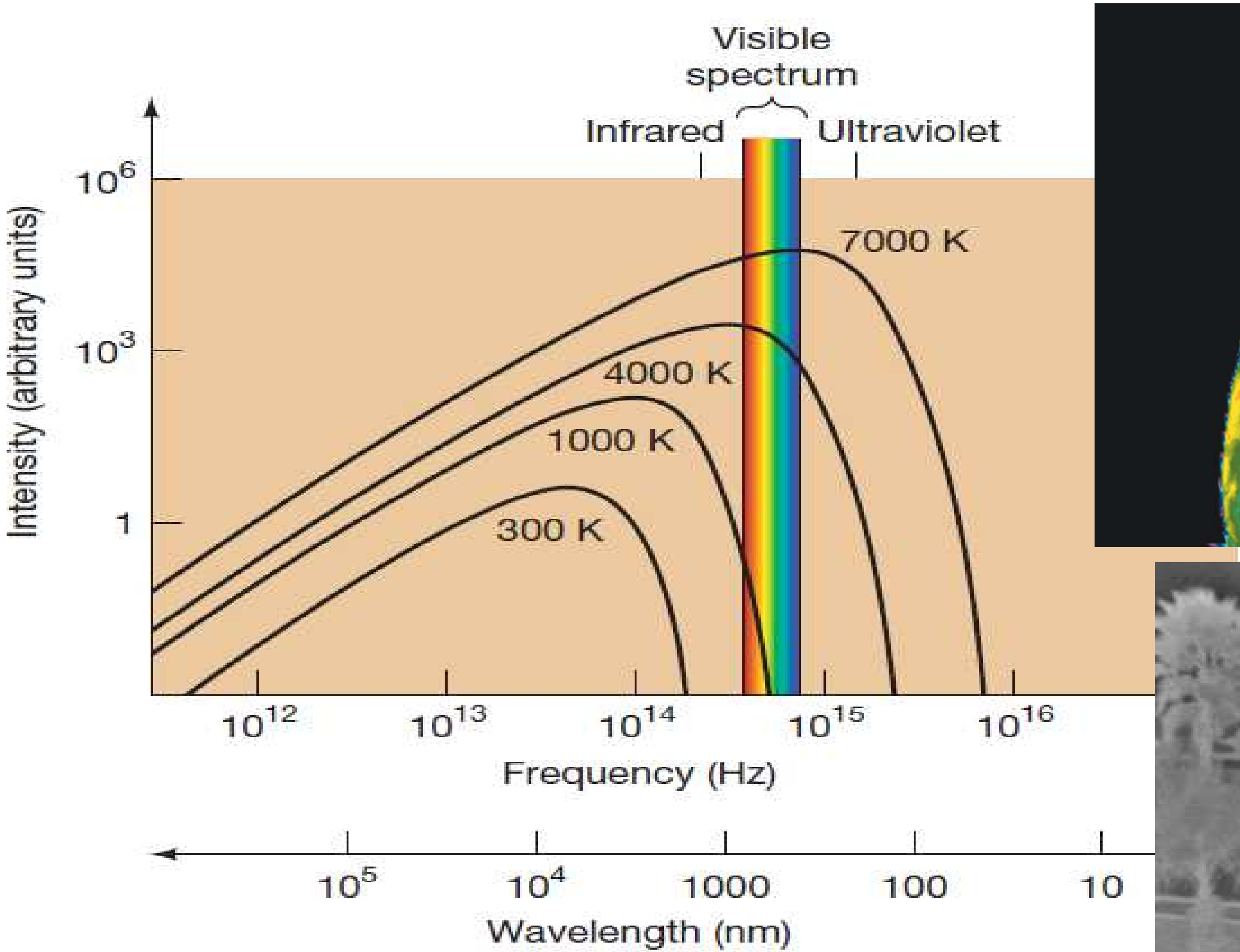
- The Temperature of an object is a direct measure of motion.
- Intensity → strength of radiation.
- No natural object emits all its radiation at a single frequency.
- The curve peaks at a single, well-defined frequency.
- Intensity falls slower at low freq.
- The curve ➔ Blackbody (Plank).
- The radiation curve is independent of the size, shape, composition, and temperature of the material.
- No Real object absorbs or radiates as a perfect black body.

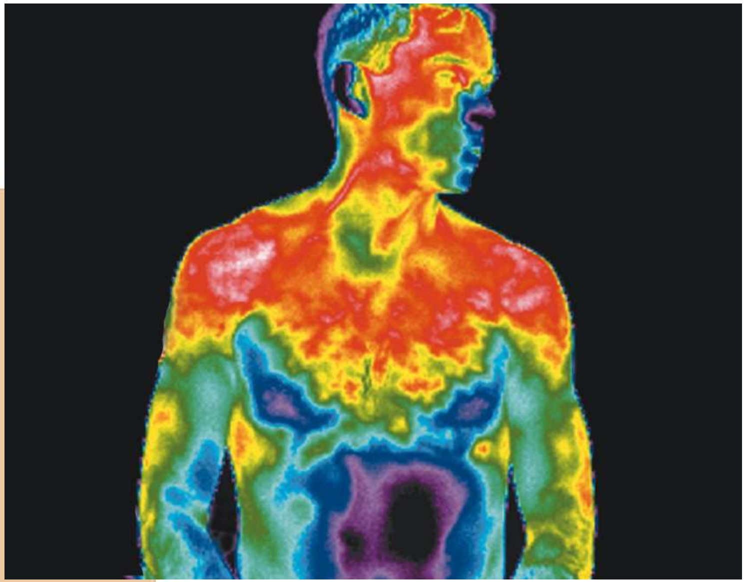




3.4 Thermal Radiation

- If T increases → shifts to higher frequency and greater Intensities.
- The shape of the curve remains the same.
- Hot objects ➔ visible light.: red-orange-yellow-white.





3.4 Thermal Radiation

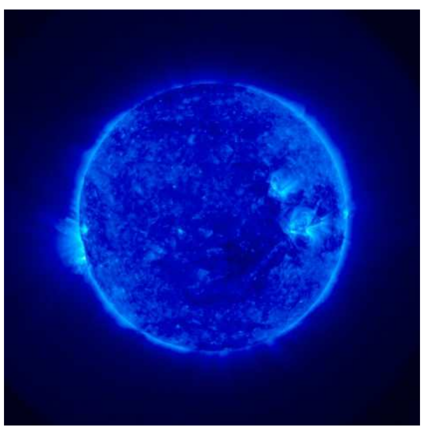
- **Wien's Law:** **Sun Surface → 5800K**

$$\text{wavelength of peak emission}\,(\text{cm}) = \frac{0.29\ \text{cm}}{\text{Temperature}\ (\text{K})}$$

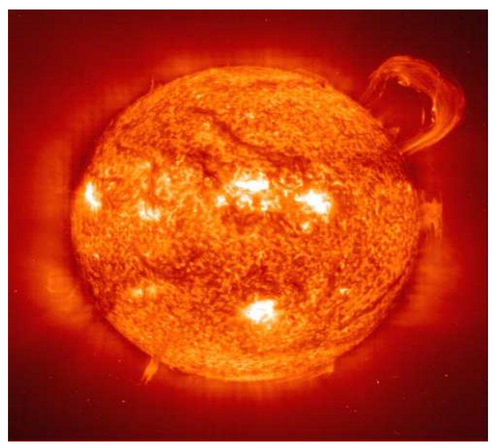
- **Stefan's Law:** $\sigma = 5.67 \times 10^{-8}\ \text{W/m}^2 \cdot \text{K}^4$

$$F\,(\text{Energy per unit area}) = \sigma T^4$$

- **Astronomical Applications: The Sun.**



Radio waves



Infrared

Visible

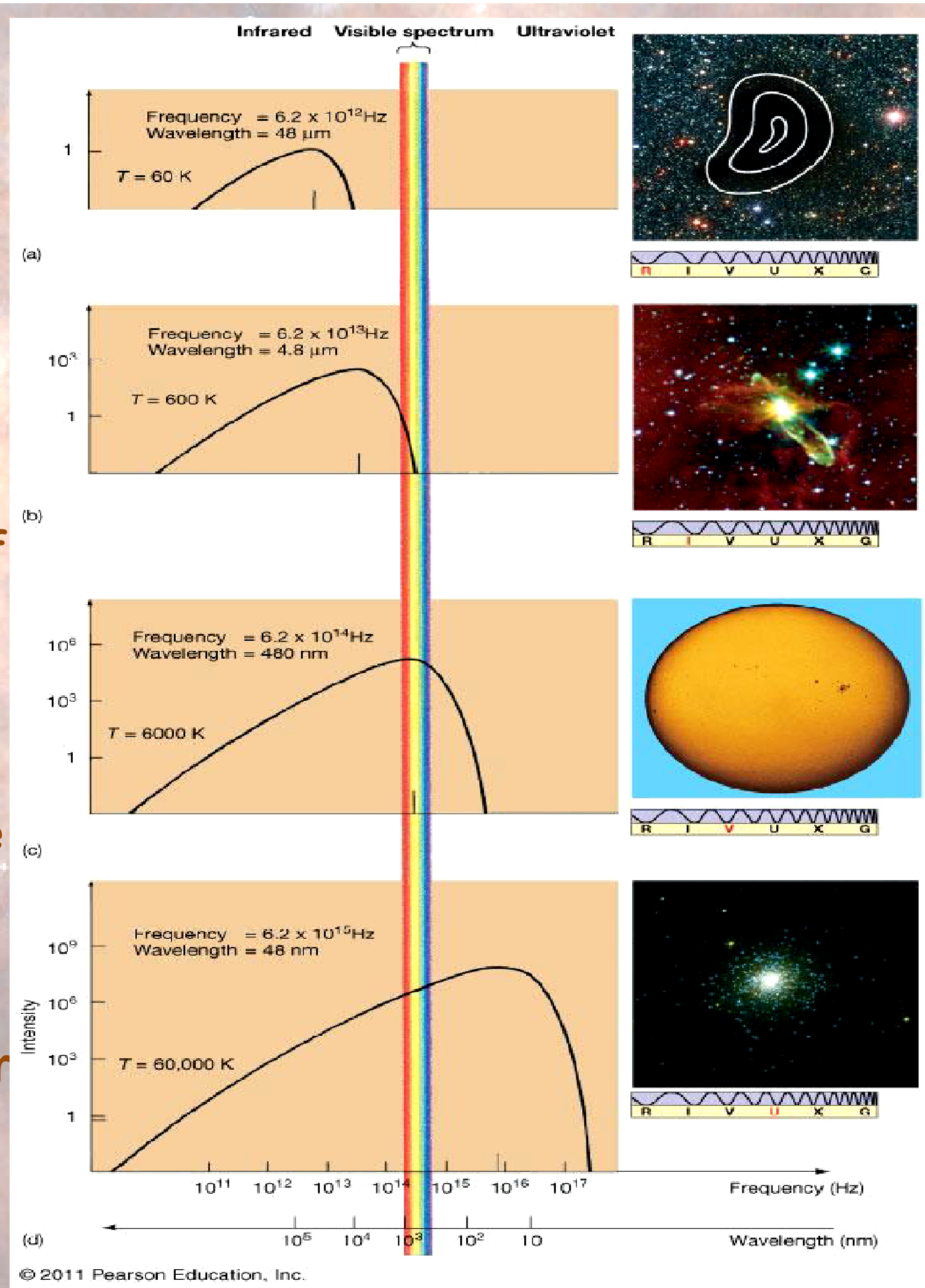
3.4 Thermal Radiation

(a) **T = 60 K**; clouds from which the star formed ➔ Radio and Infrared

(b) **T = 600 K**; Cool surface of a very young star ➔ Infrared

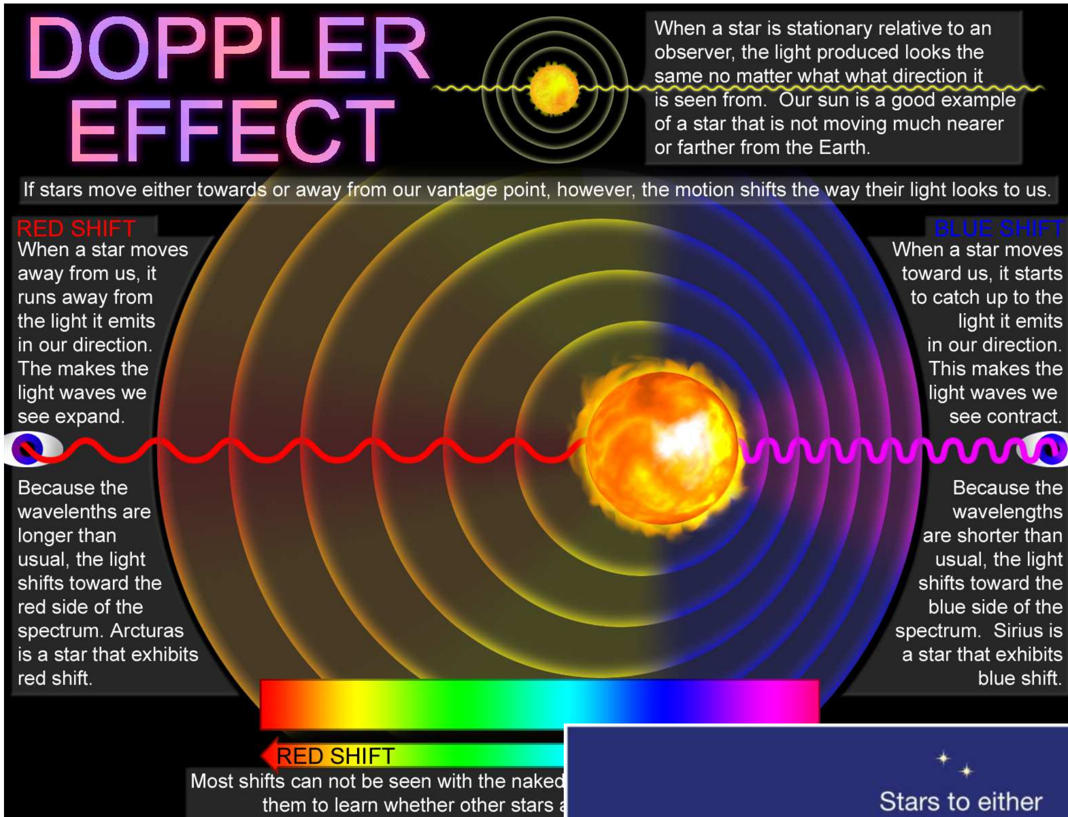
(c) **T = 6000 K**; Sun's Surface ➔ Visible

(d) **T = 60 000 K**, A bright star ➔ Ultraviolet

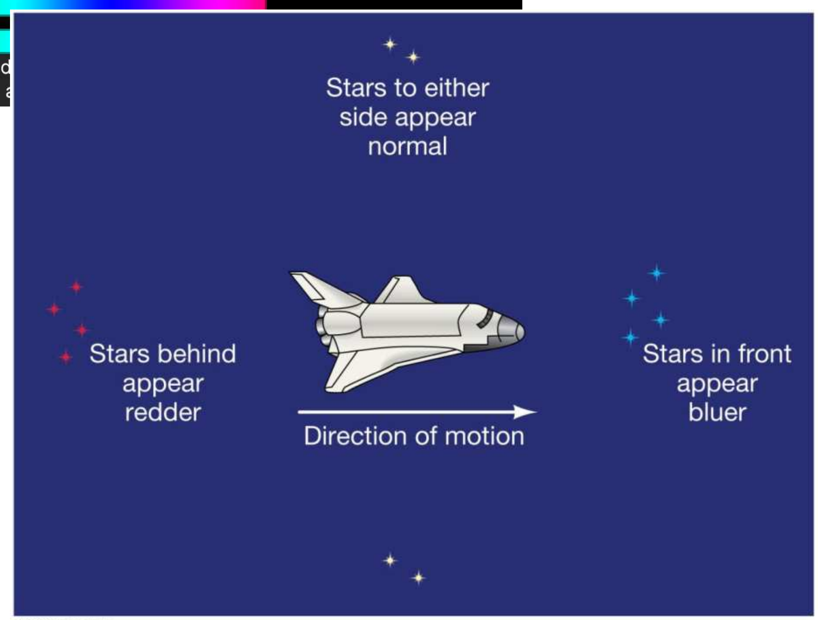


3.5 Doppler Effect

Red Shifted



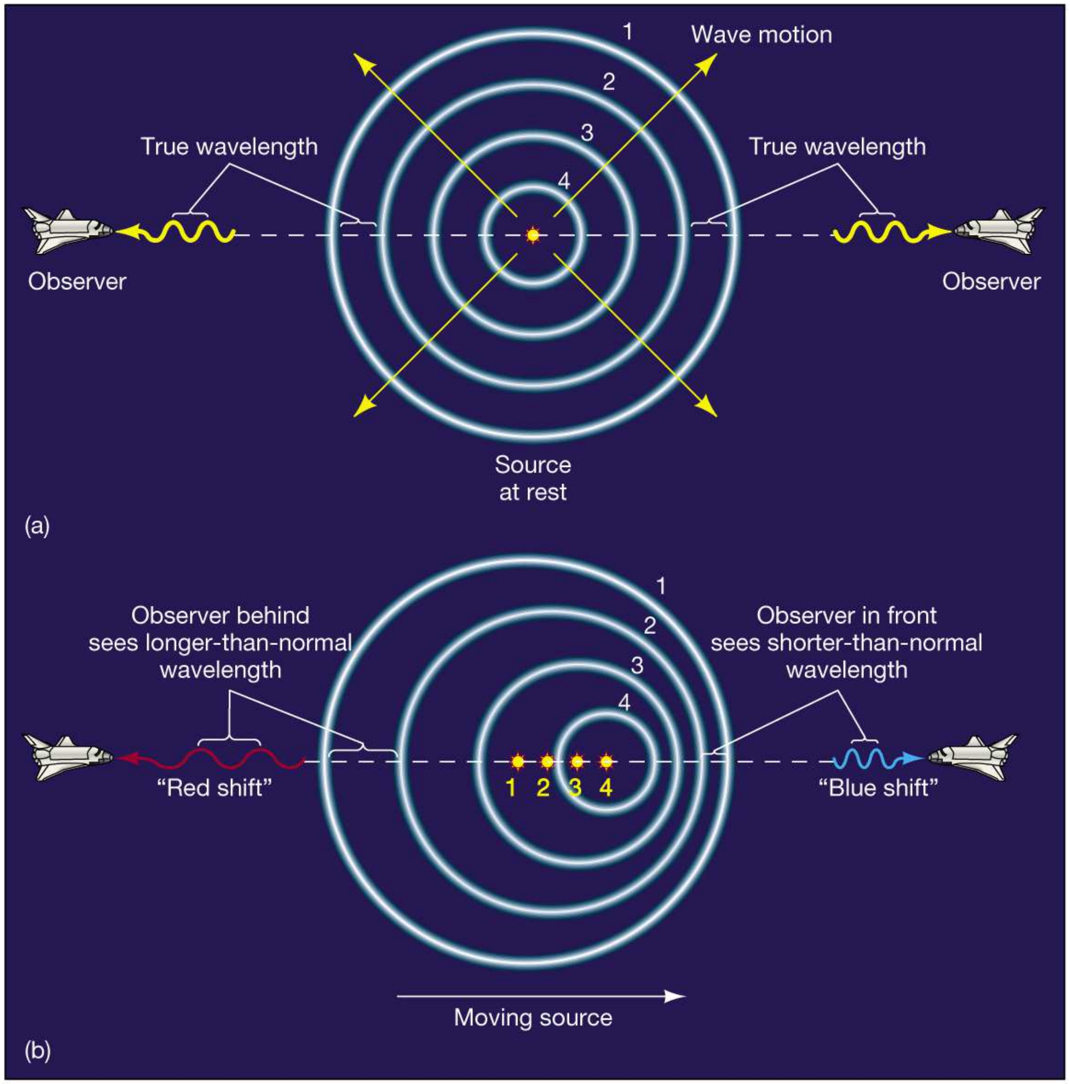
Blue Shifted



3.5 Doppler Effect

$$\frac{\text{apparent } \lambda}{\text{true } \lambda} = \frac{\text{true } \nu}{\text{apparent } \nu}$$

$$= 1 + \frac{\text{recession } \upsilon}{\text{wave } \upsilon}$$



Its importance is allowing to determine the speed of any cosmic object.

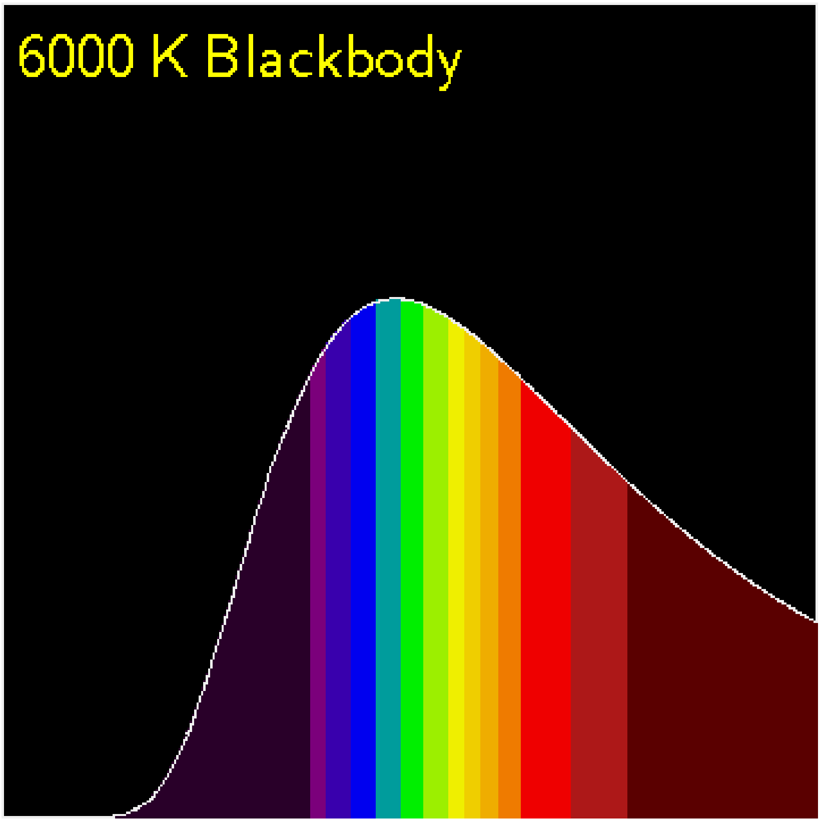
More Precisely 3-3: Measuring Velocities with the Doppler Effect

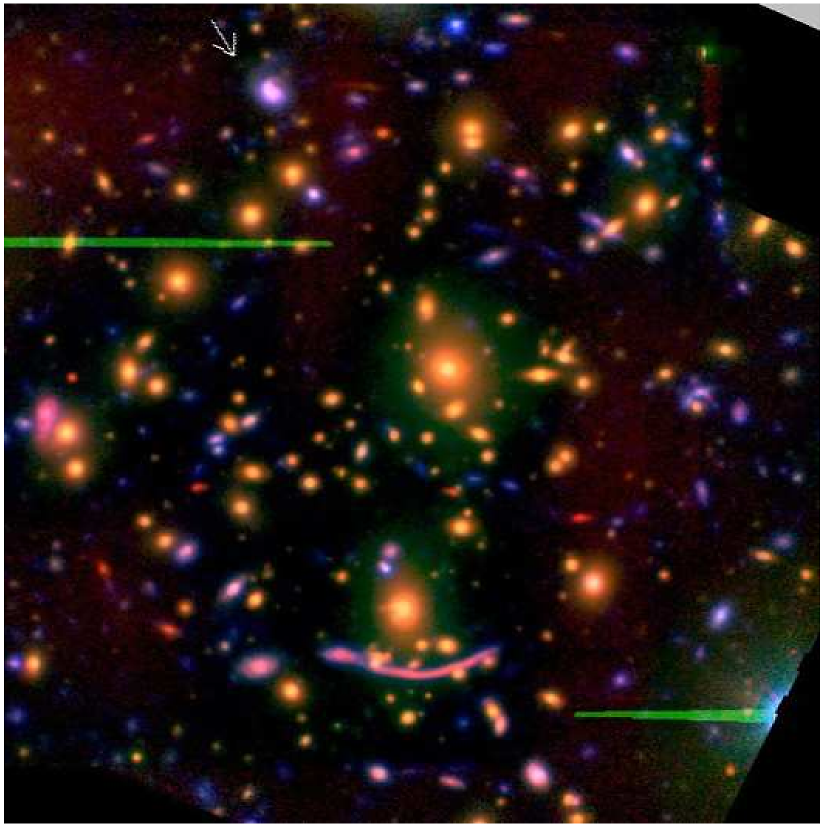
Example: For a speed of 30 km/s, the Doppler shift is given by

$$\frac{\text{change in wavelength}}{\text{true wavelength}} = \frac{\text{recession velocity}}{\text{wave speed}}$$

$$= \frac{30 \text{ km/s}}{300{,}000 \text{ km/s}} = 0.01 \text{ percent.}$$

Important Question??

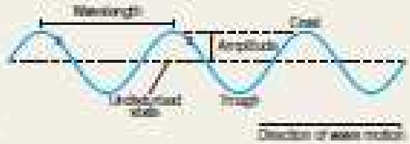




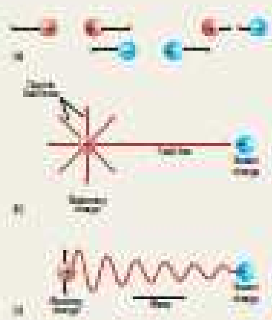
Black Body curve **Red shifted stars!**

SUMMARY

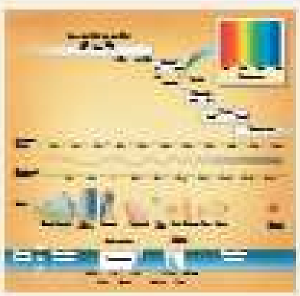
1 **Electromagnetic radiation (p. 60)** travels through space in the form of a **wave (p. 60)**. A wave is characterized by its **period (p. 61)**, the length of time taken for one complete cycle; its **wavelength (p. 61)**, the distance between successive wave crests; and its **amplitude (p. 61)**, which measures the size of the disturbance associated with the wave. A wave's **frequency (p. 61)** is the number of wave crests that pass a given point in one second.



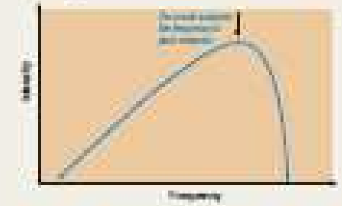
2 Any electrically charged object is surrounded by an **electric field (p. 63)** that determines the force the object exerts on other charged objects. When a charged particle moves, information about its motion is transmitted via the particle's changing **electric** and **magnetic fields (pp. 63, 64)**. The information travels at the **speed of light (p. 64)** as an electromagnetic wave. **Diffraction (p. 67)** and **interference (p. 67)** are properties of radiation that mark it as a wave phenomenon.



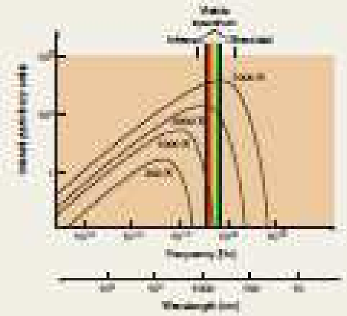
3 The color of visible light is simply a measure of its wavelength—red light has a longer wavelength than blue light. The entire **electromagnetic spectrum (p. 65)** consists of (in order of increasing frequency) **radio waves**, **infrared radiation**, **visible light**, **ultraviolet radiation**, **X-rays**, and **gamma rays (p. 60)**. Only radio waves, some infrared wavelengths, and visible light can penetrate the atmosphere and reach the ground from space.



4 The **temperature (p. 68)** of an object is a measure of the speed with which its constituent particles move. The intensity of radiation emitted by an object has a characteristic distribution, called a **blackbody curve (p. 68)**, which depends only on the object's temperature.



5 **Wien's law (p. 70)** tells us that the wavelength at which the object radiates most of its energy is inversely proportional to its temperature. Measuring that peak wavelength tells us the object's temperature. **Stefan's law (p. 70)** states that the total amount of energy radiated is proportional to the fourth power of the temperature.



6 Our perception of the wavelength of a beam of light can be altered by the source's velocity relative to us. This motion-induced change in the observed frequency of a wave is called the **Doppler effect (p. 73)**. Any net motion of the source away from the observer causes a redshift—a shift to lower frequencies—in the received beam. Motion toward the observer causes a blueshift. The extent of the shift is directly proportional to the source's radial velocity relative to the observer.


End Ch 3