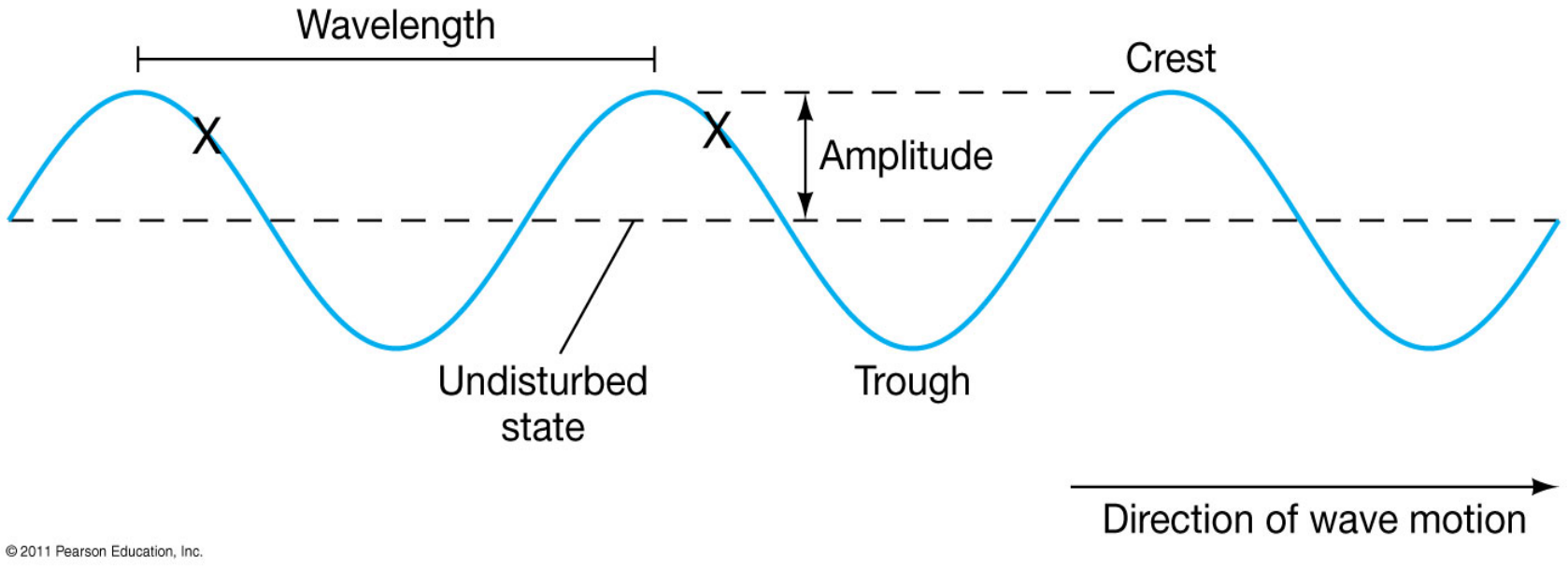
Waves R ‘ Us

What are Waves?

- Waves: moving disturbances that transmit energy without the physical transport of material

  -waves in a pool or waves in a wheat field or waves of people in a football field.

- Waves have wavelength and wave speed

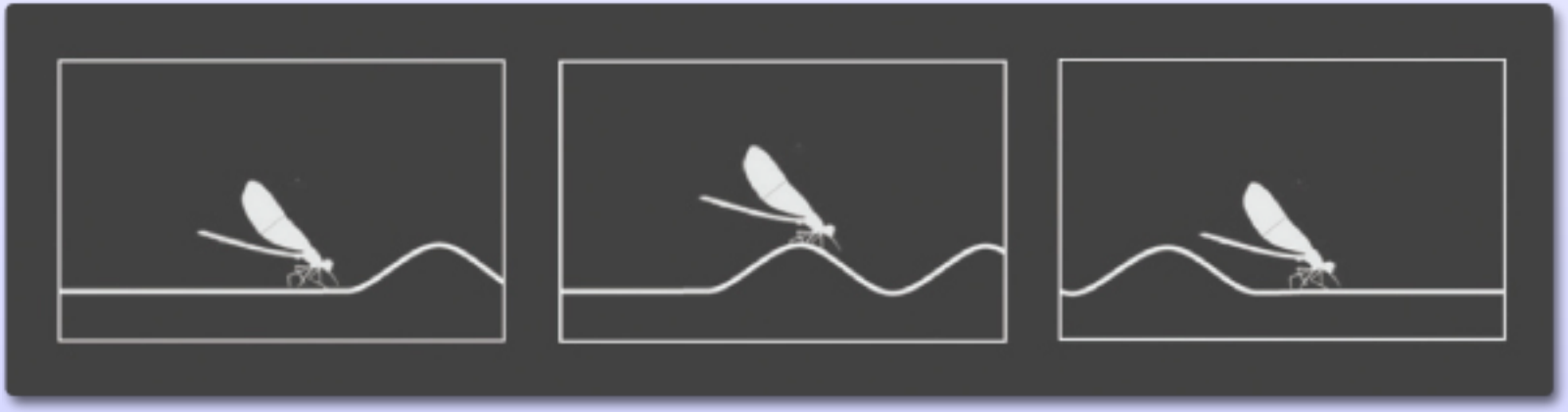


More on Waves?

- Waves DOT NOT transport material in order to transport energy

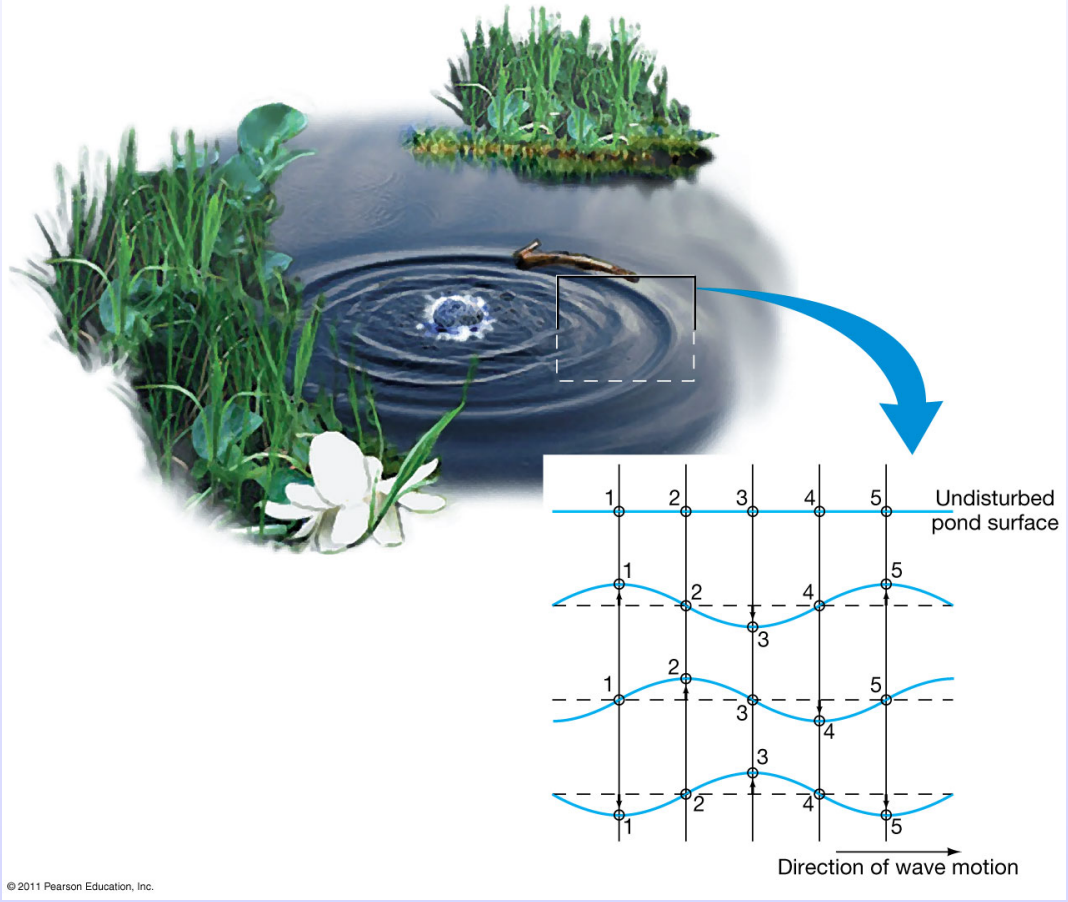
  -waves in a pool just make the water move up and down

  - this effect is best seen if you watch a fly resting on the water or if you throw wood chips on the water



Example: Water wave

- Water just moves up and down
- Wave travels and can transmit energy (tsunami)



waves

- all these waves travel through “something”
  - water waves: ocean surface
  - sound waves: air
  - slinky waves: slinky
  - string waves: string
- this is called the “medium”
- In pre-modern physics: no medium: no wave

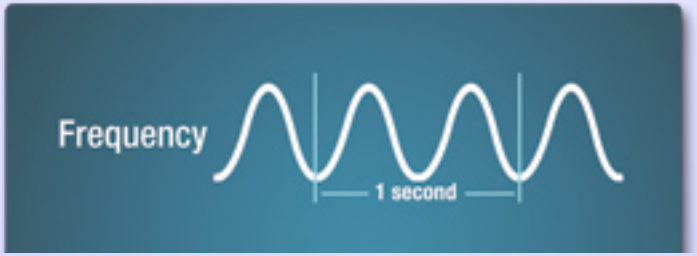
Properties of waves

Frequency: Number of wave crests that pass a given point per second

Period: Time between passage of successive crests

Relationship:

Period = 1 / Frequency



Properties of waves

Wavelength: Distance between successive crests

Velocity: Speed at which crests move

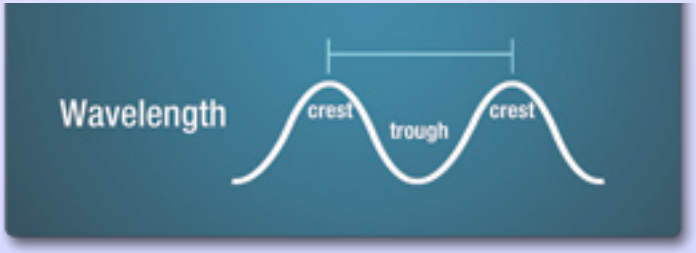
- water and sound waves have different speeds

- electromagnetic waves travel in vacuum with the speed of light (light is an electromagnetic wave)

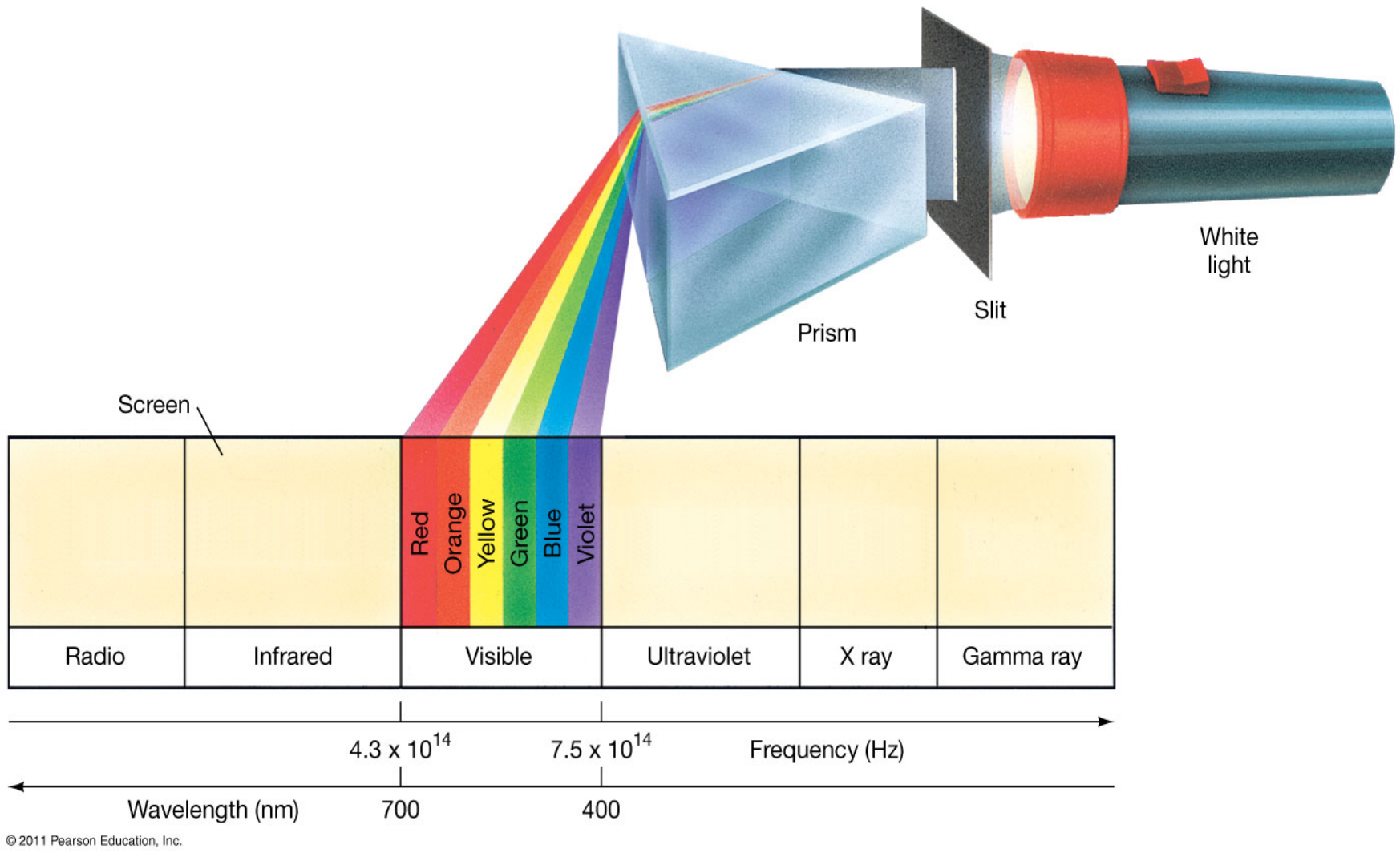
Relationship: Velocity = Wavelength / Period

or

Velocity = Wavelength * Frequency



Visible Electromagnetic waves - Light

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- White light is a mixture of colors (previous slide)
- Colors (seven total) are ranges of frequencies in the electromagnetic spectrum
- It is the human eye and brain that makes us perceive 'colors'
- White color splits into primary colors when it passes through e.g. a prism or any other transparent material (plastic, water etc)
    - Rainbow is an example of white light splitting

Do all Waves need a Medium?

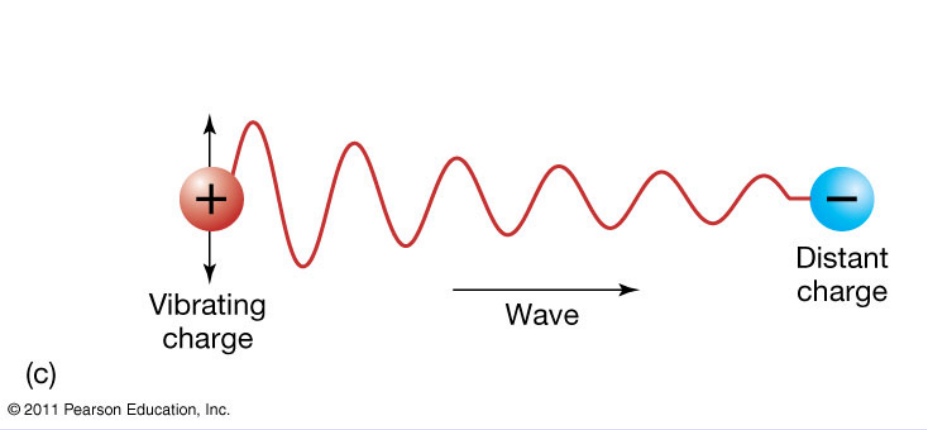
- Many kinds of waves they need a material, matter, to propagate

  - Water waves, sound waves, and so on, travel in a medium (water, air respectively)

- Electromagnetic waves **need no** medium. They travel in vacuum.

  - Initially thought to travel through Ether, some sort of perfect medium, but measurements exclude its existence

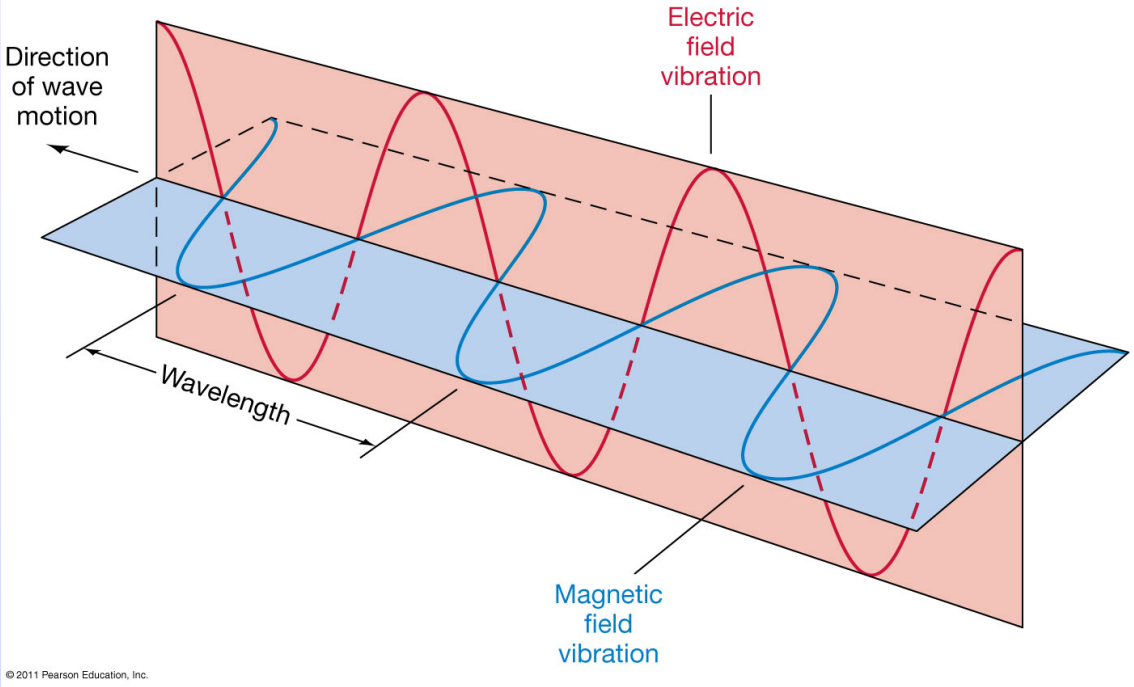
- Created by accelerating charged particles (oscillating currents) and other atomic processes



- Electromagnetic (EM) waves:

- Oscillating electric and magnetic fields normal to each other

- Changing electric field creates magnetic field, and vice versa

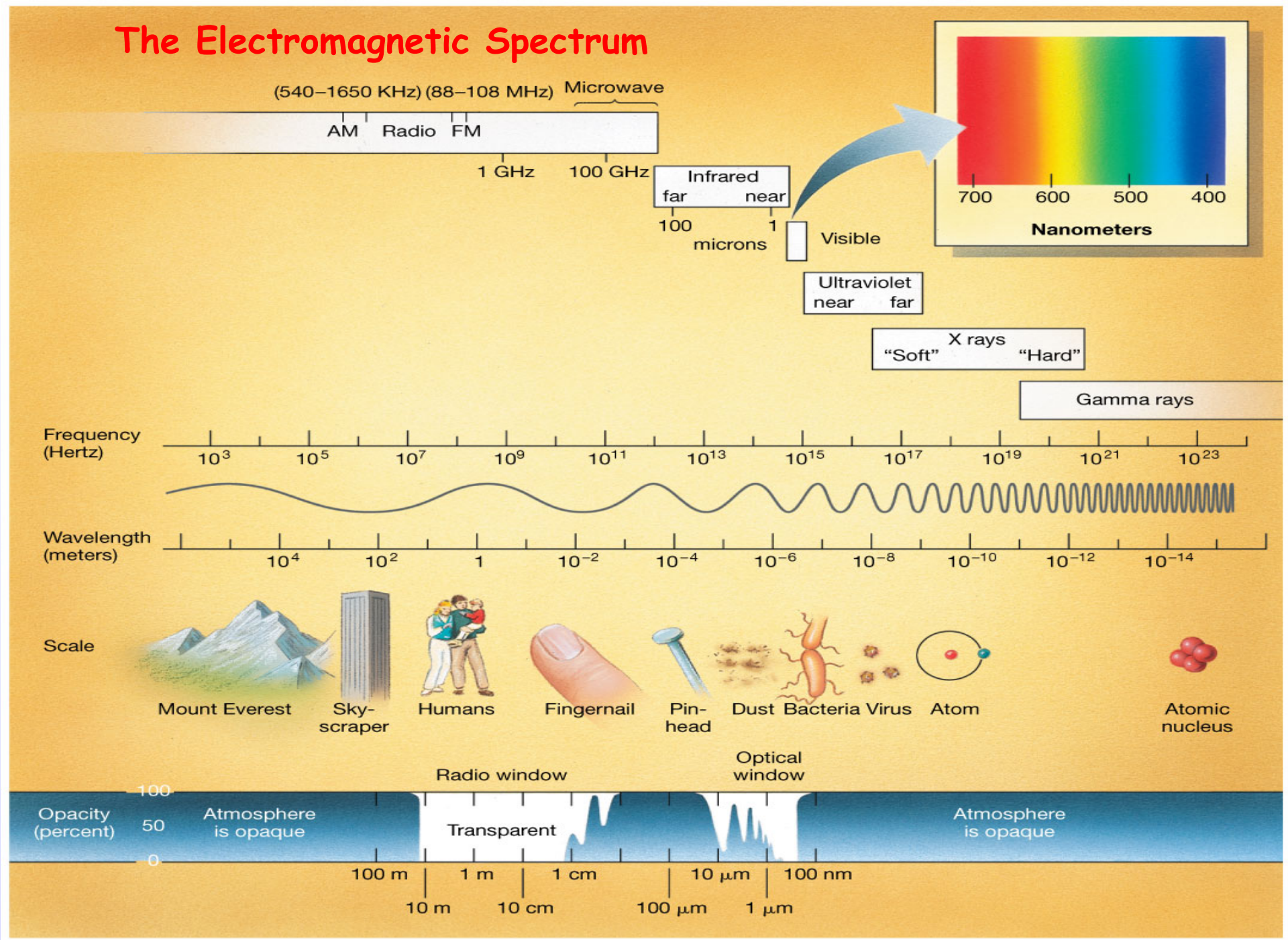


What is the wave speed (c) of electromagnetic waves?

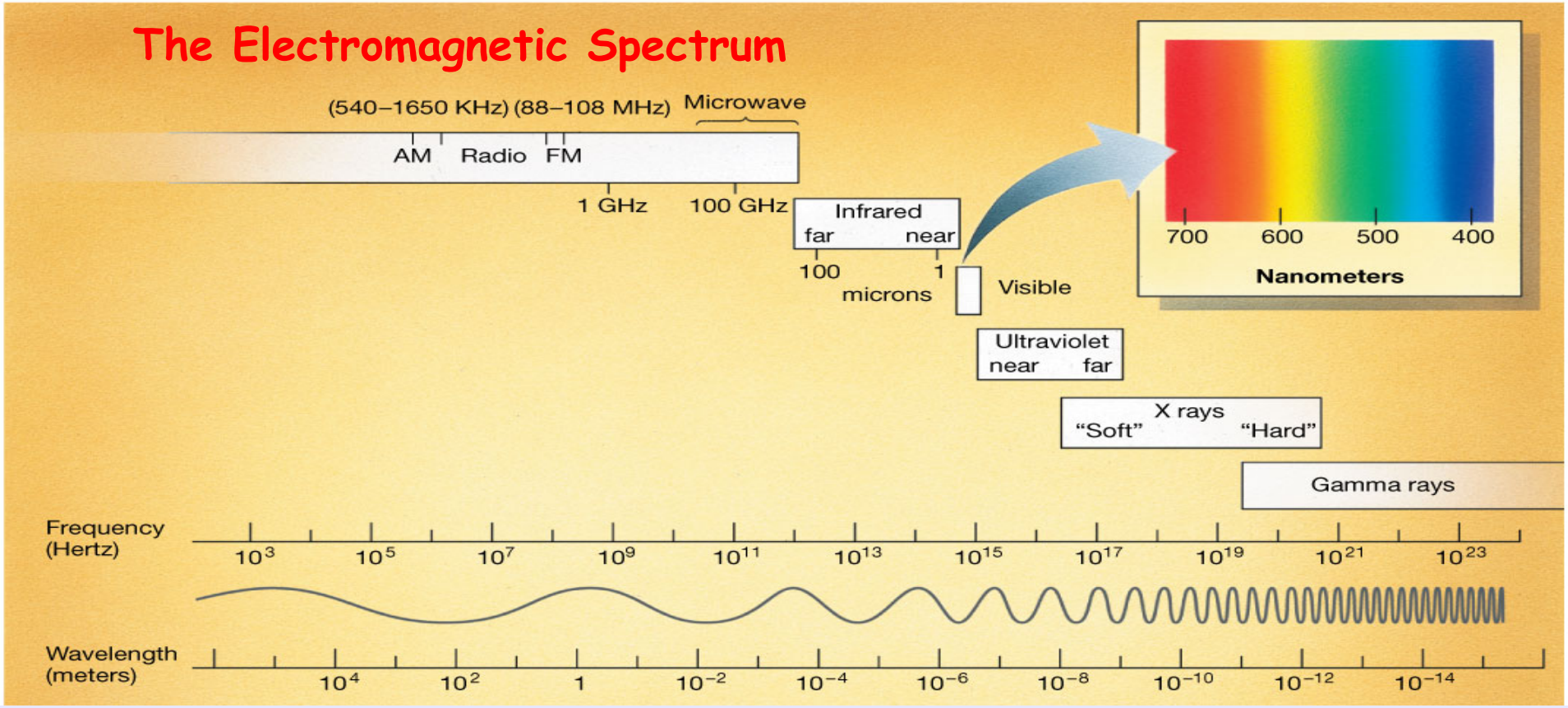
c = 300,000 Km (186,411 miles) per second

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

The Electromagnetic Spectrum



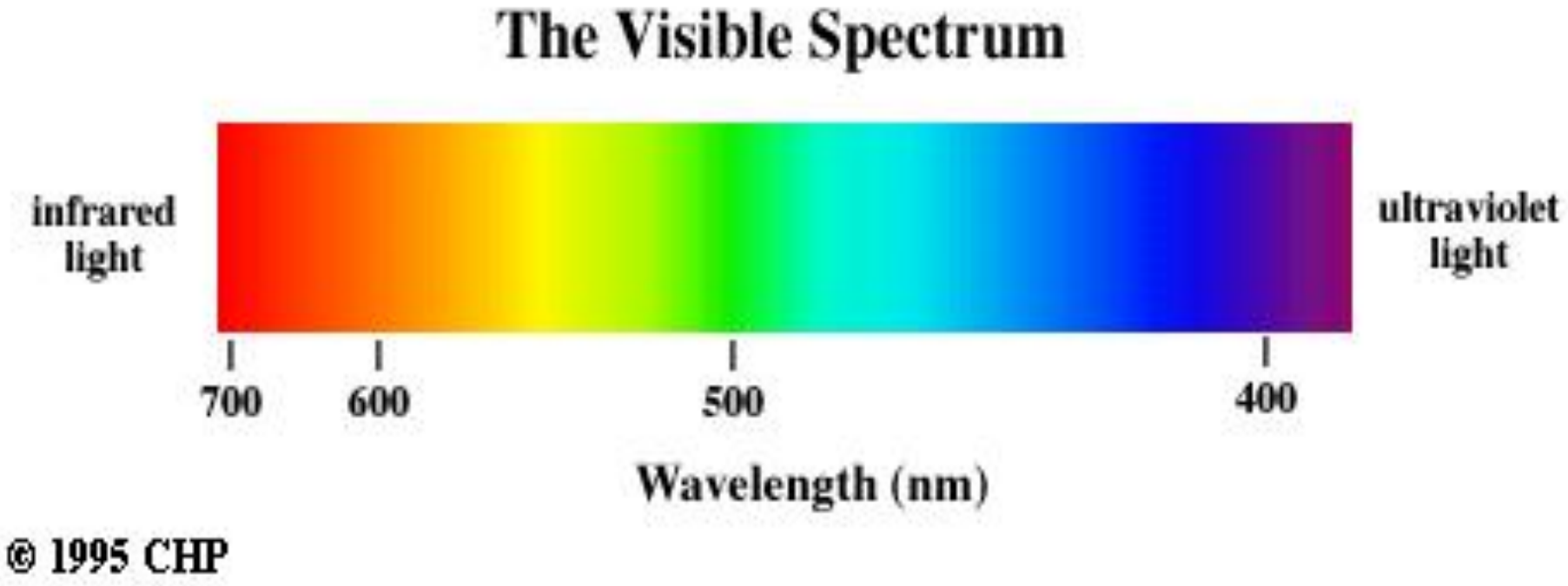
The Electromagnetic Spectrum



So sequence is: increasing frequency/energy, decreasing wavelength

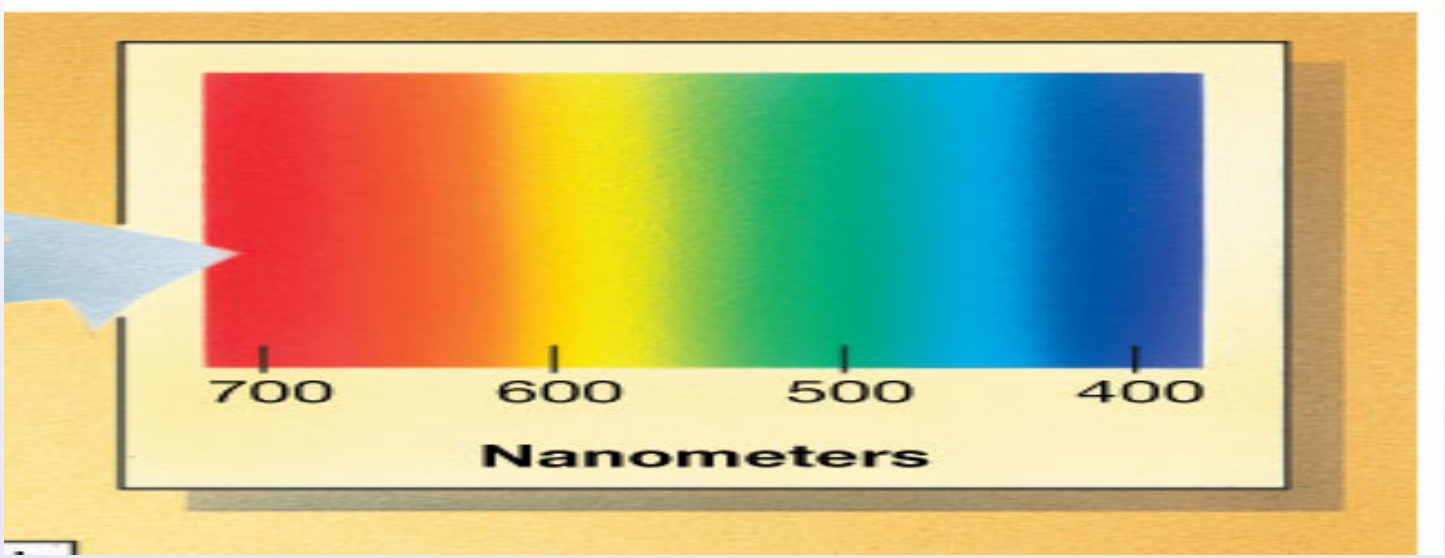
Radio Microwaves Infrared Visible UV X-rays Gamma -rays

Let there be light



- "red" is agreed upon name for light with wavelength at left end
- "violet" is agreed name for light at right end

Red 'feels' warmer and Blue/Purple colder



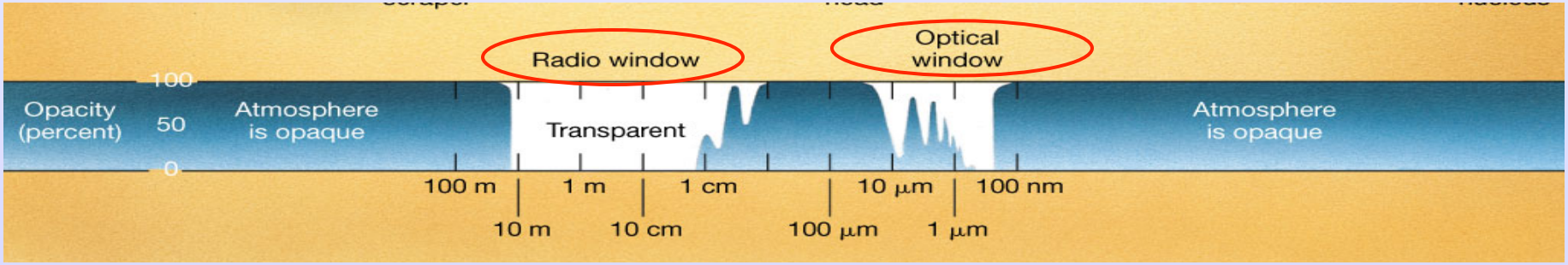
In reality Red carries less energy than Blue !!!
(*Watch this)*

•No limit on wavelengths; different ranges have different names

•Note opacity of atmosphere, it absorbs most radiation with just a few exceptions like some radio waves and visible light.

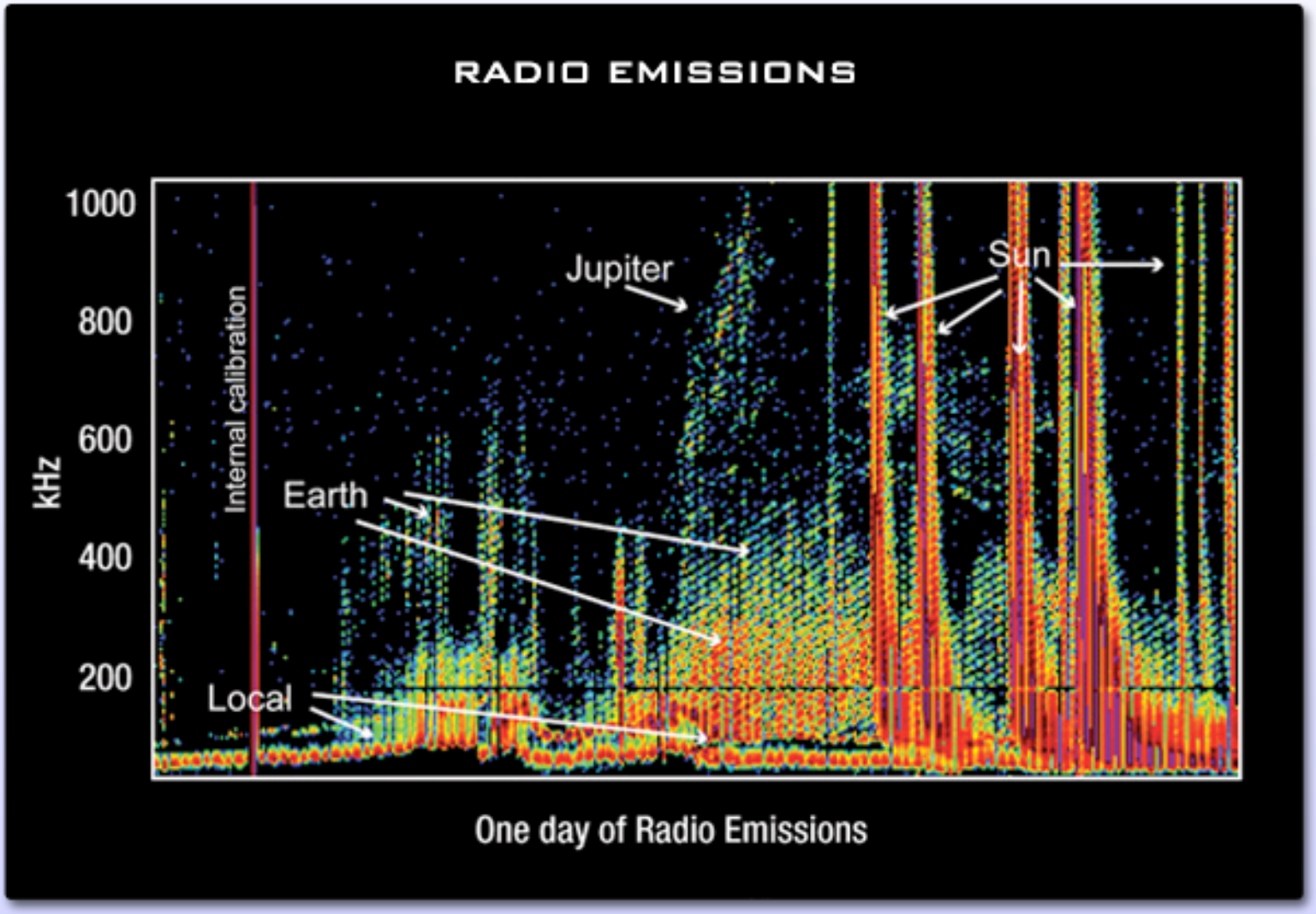
-That is why astronomy detectors in other ranges need to be outside the atmosphere, in orbit.

- Examples are Microwave, X-ray and Gamma-ray detectors

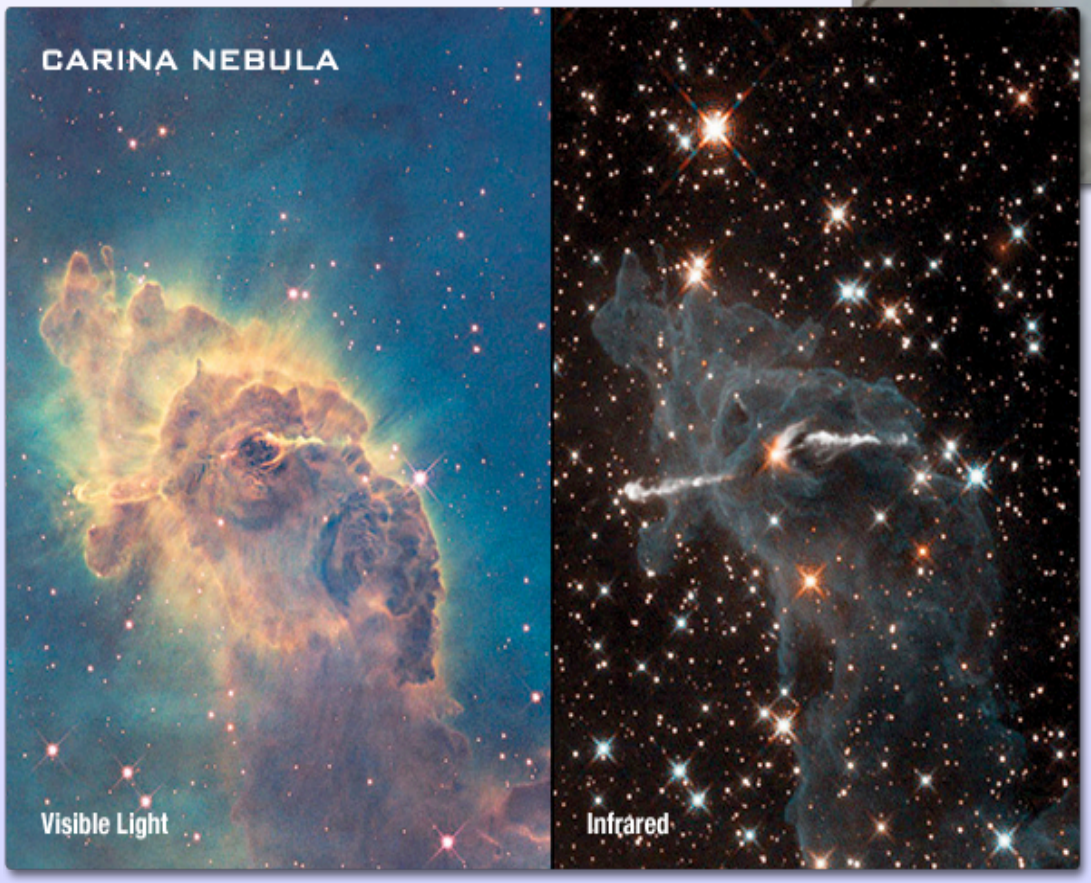


Examples

Example: Radio bursts from the Sun, the Earth, and even from Jupiter's ionosphere. The far right of this graph shows radio bursts from the Sun caused by electrons that have been ejected into space during solar flares moving at 20% of the speed of light.

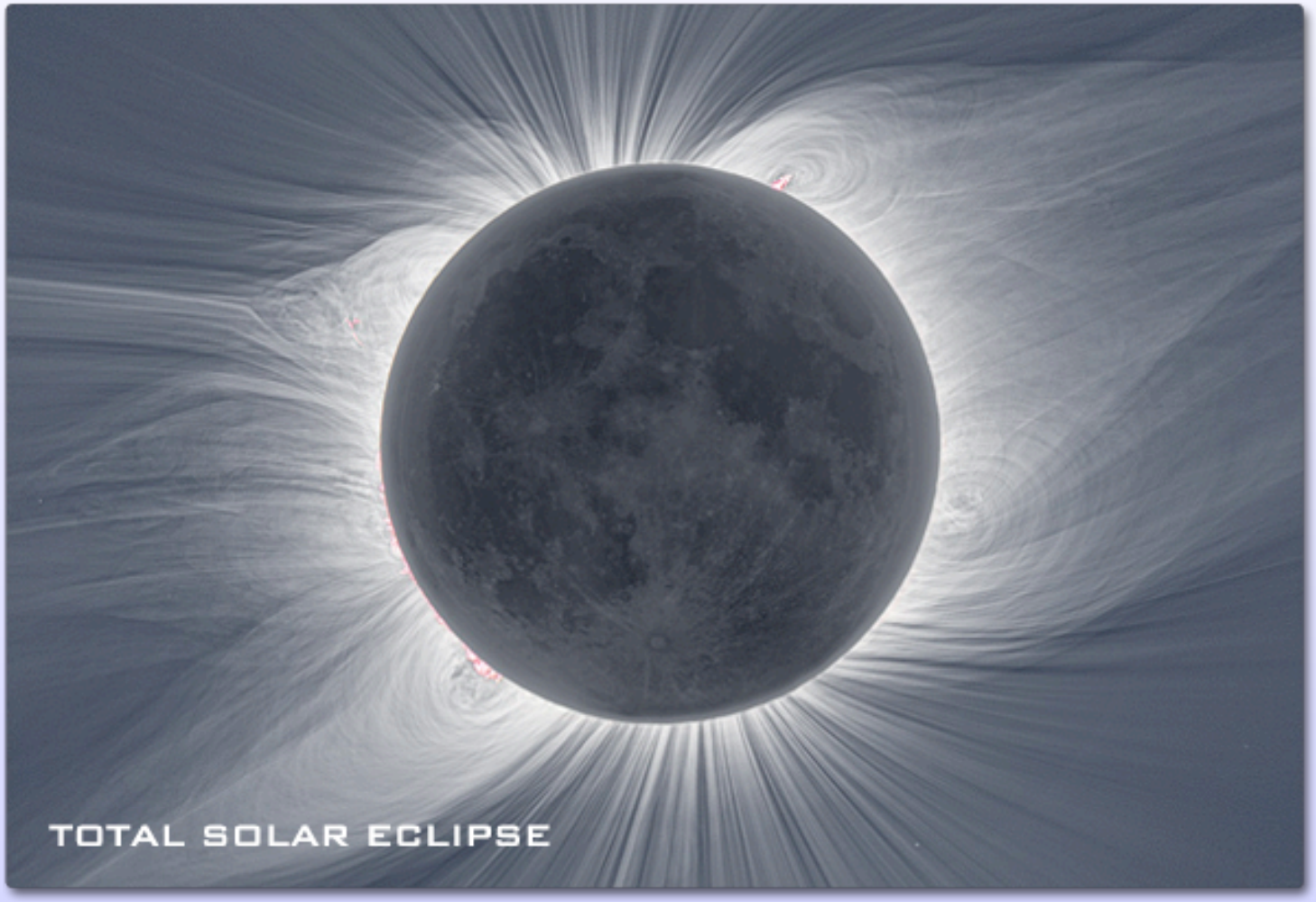


Infrared



In both pictures the left part is taken in the Visual and the right in the Infrared part of the spectrum

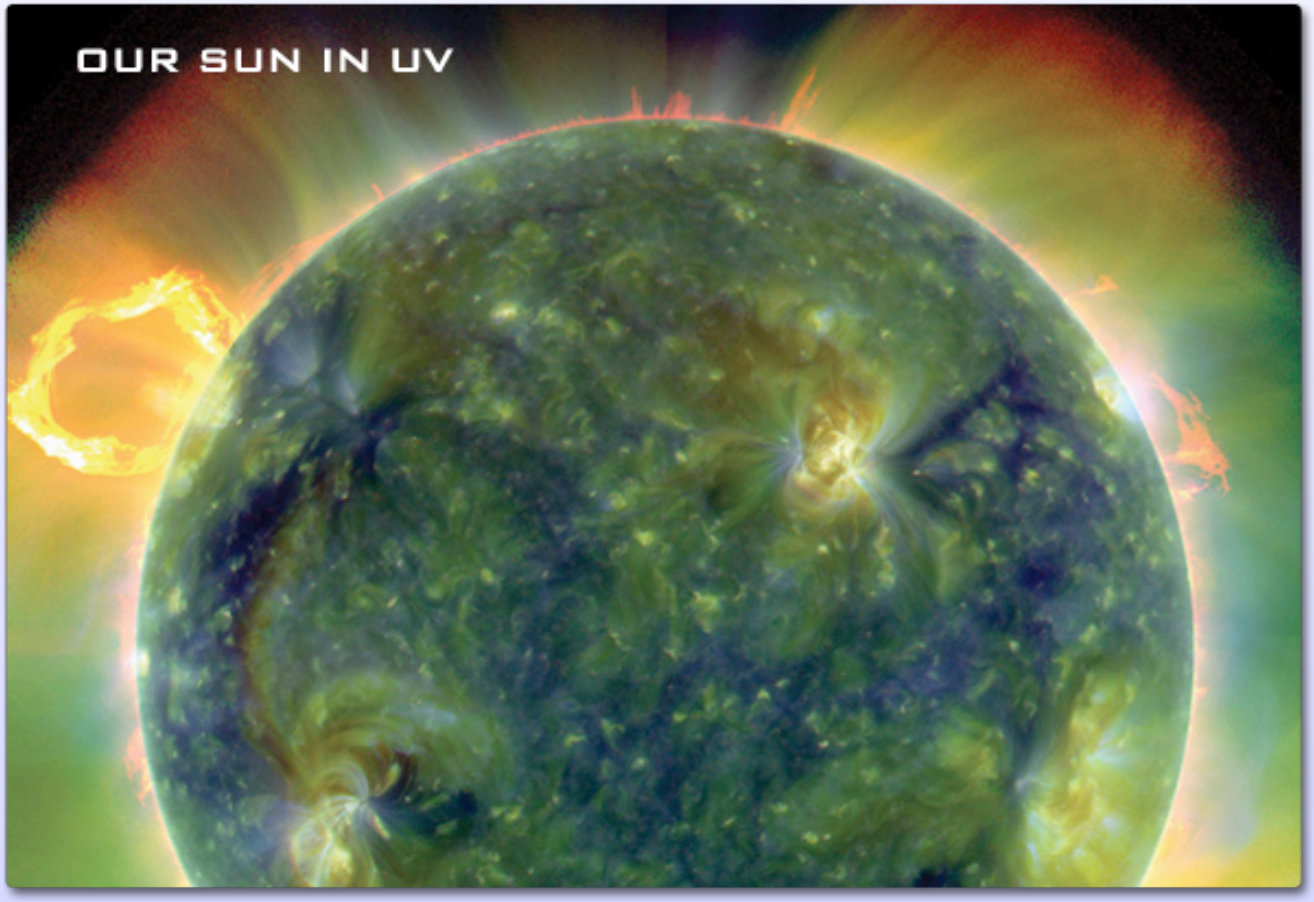
The Sun is the dominant source of visible light that our eyes perceive. Here you see a spectacular view of Sun's corona, during a total Solar eclipse, as it is shaped by its strong magnetic fields



Visible

Ultraviolet (UV) light has shorter wavelengths than visible light. Although UV waves are invisible to the human eye, some insects, such as bumblebees, can see them. This is similar to how a dog can hear the sound of a whistle just outside the hearing range of humans.

The Sun is a source of the full spectrum of ultraviolet radiation

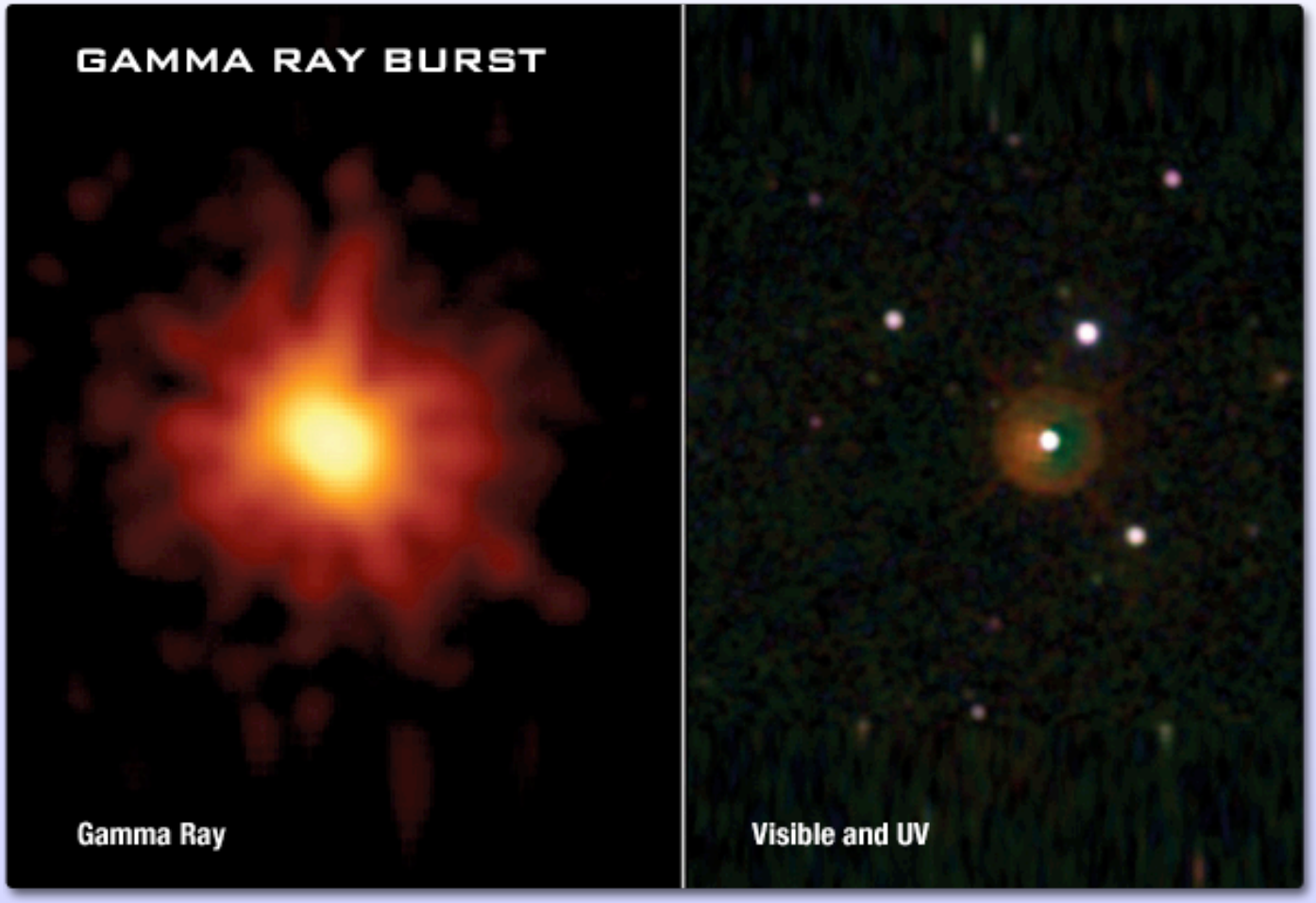


UV

X-rays have much higher energy and much shorter wavelengths than ultraviolet light, and scientists usually refer to x-rays in terms of their energy rather than their wavelength.
X-rays have very small wavelengths, between 0.03 and 3 nanometers, so small that some x-rays are no bigger than a single atom of many elements
Can you see the filling of the tooth in the picture in the right?

X-rays

Gamma rays have the smallest wavelengths and the most energy of any wave in the electromagnetic spectrum. They are produced by the hottest and most energetic objects in the universe.
On Earth, gamma waves are generated by nuclear explosions, lightning, and the less dramatic activity of radioactive decay.



Gamma-rays

IT IS ALL ABOUT LIGHT - OPTICS

Albert Einstein

I spent my life on the question “What is the photon”. Every rascal thinks he knows but he deceives himself

The Particle/Wave nature of Light

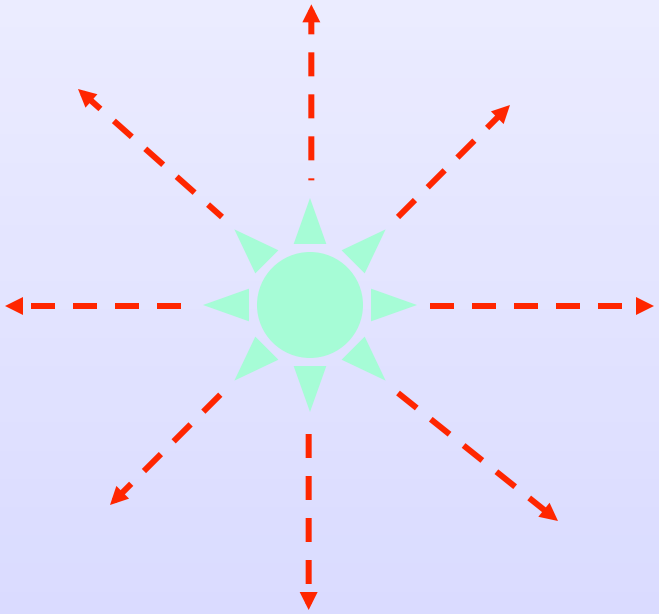
Light-waves come in lumps! Photons

- "photons" -- quanta (pieces) of light energy, pieces of electromagnetic packets

- very, very small lumps

Light/photons move on a straight line

- So as light travel away from a source (lamp) it can be though of moving on a straight line (light rays)



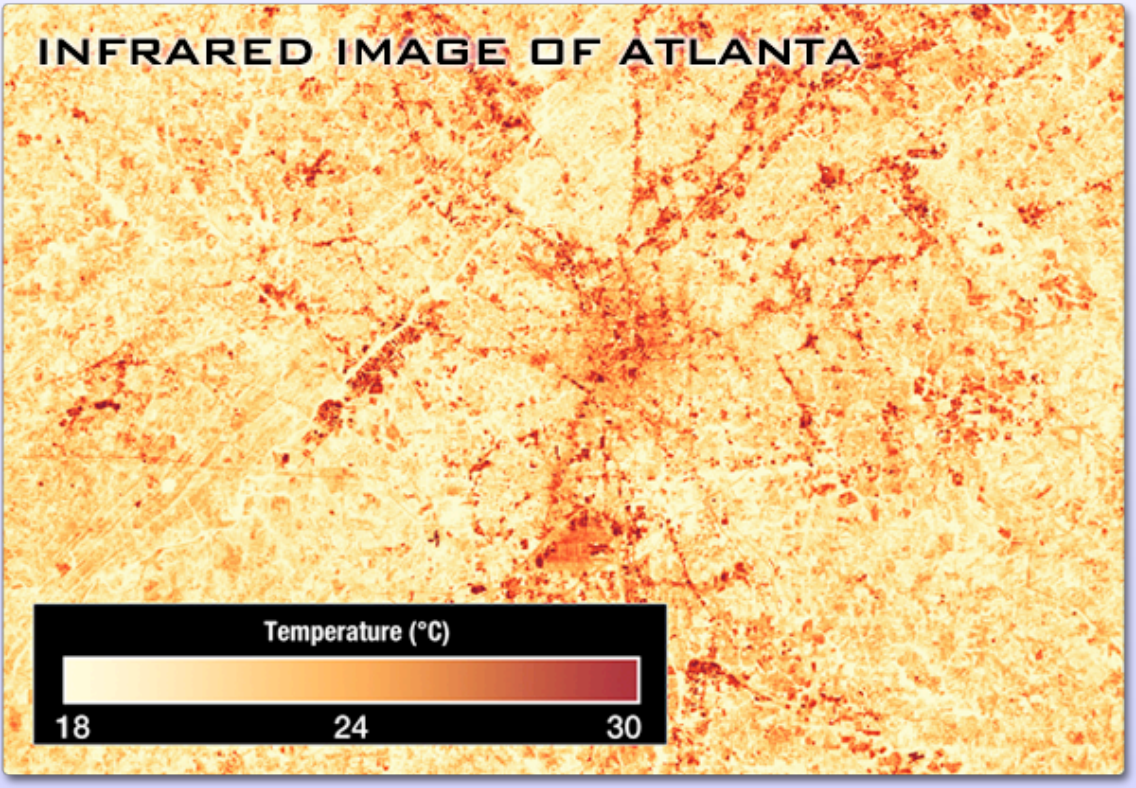
- Light waves across the electromagnetic spectrum behave in similar ways.
- When a light wave encounters an object, they are either
    - transmitted, (like through a piece of glass)
    - reflected, (like in a mirror)
    - absorbed,
    - refracted, (from a prism)
    - diffracted, or
    - scattered

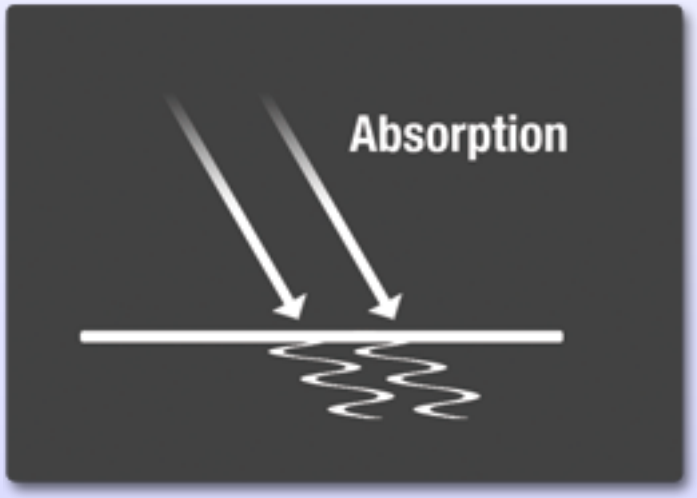
    depending on the composition of the object and the wavelength of the light.

- Let's examine some of these properties

Wave Properties- Absorption

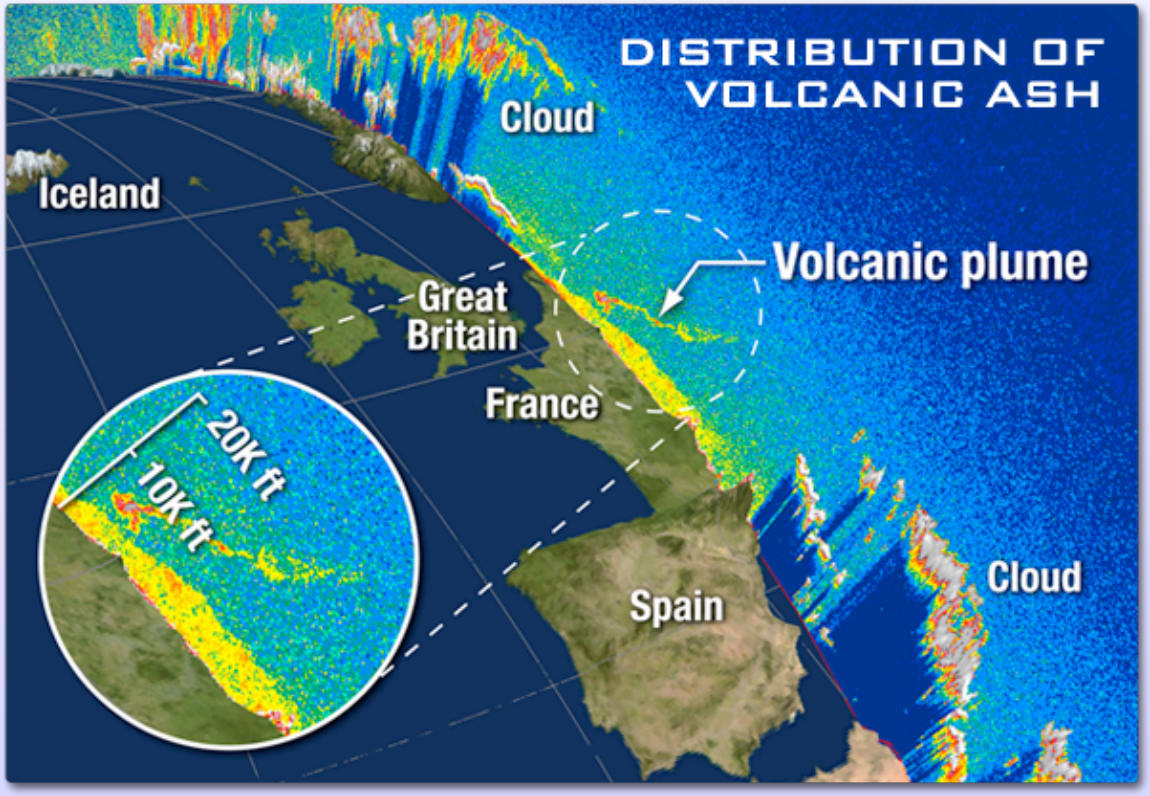
- Waves can be absorbed by a surface thus depositing its energy
- In this infrared image roads and dark surfaces are 'hotter' since asphalt etc absorb the energy of light and heat up

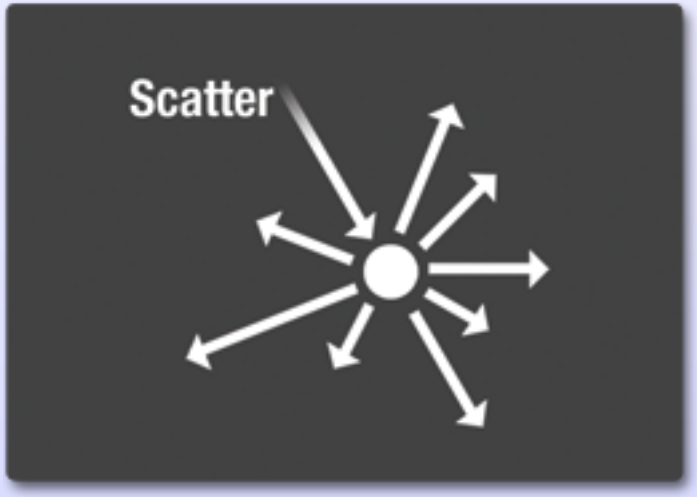




Wave Properties- Scatter

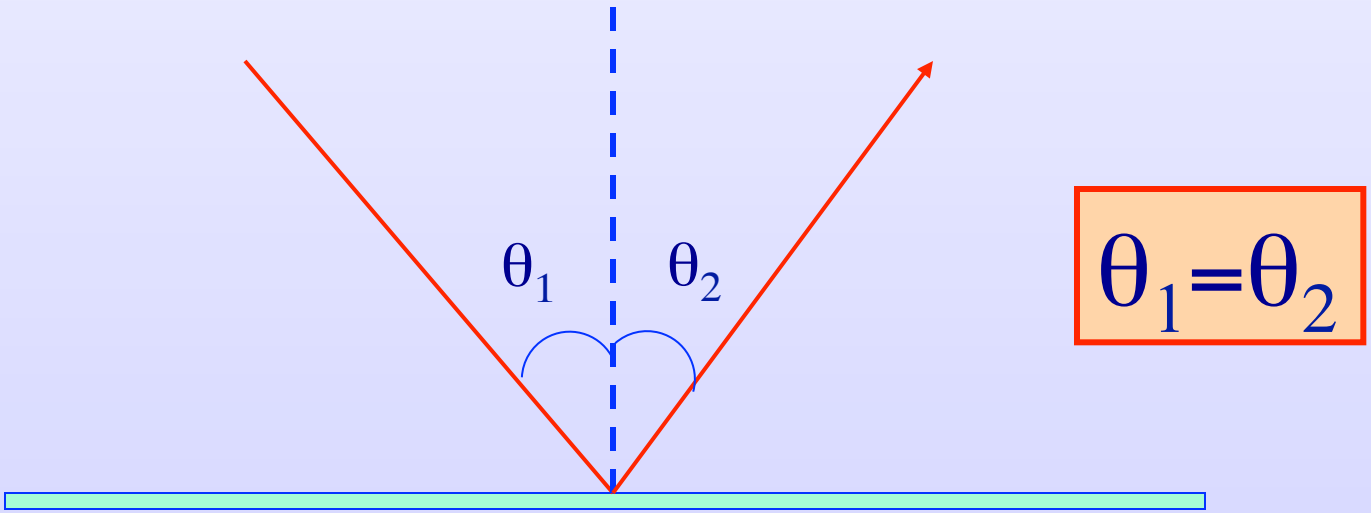
- Scattering occurs when light bounces off an object in a variety of directions. The amount of scattering that takes place depends on the wavelength of the light and the size and structure of the object
- In the picture light scattering is used to detect the amounts and distribution of volcanic ash





Reflection of Light

- If light encounters a flat/polished surface part of it changes direction, i.e. gets **reflected**
  - Example: light reflection from a mirror
  - RULE: Angle of incidence is equal to angle of reflection
    - Light follows the shortest distance path



$\theta_1 = \theta_2$

Wave Properties- Reflection

In this image laser light was reflected on Moon's surface

Different heights are shown as different colors