Lecture 2: Light the Messenger

Readings: Sections 5-1, 5-2, 5-5, and 5-9

Because of the vast distances involved in astronomy, we can't rely on laboratory investigations to study the Universe. How can we learn about things that are so distant?

Answer➔ LIGHT!

Doesn't need a medium to travel in, so it can travel through the vacuum of space, unlike sound or water waves.

Everything we know, we know from the light emitted by astronomical objects with the exceptions of

ν (neutrinos)

nearby space stuff (solar wind, comets, planets)

Key Ideas About Light:

Light is Electromagnetic Radiation

Light as Waves and Photons

Electromagnetic Spectrum
- sequence of photon energies

Doppler Effect
- Relative motion between source & observer
- Way to measure speeds at a distance

Electromagnetic Radiation

Light is a self-propagating electromagnetic disturbance that moves at the speed of light (see Section 5-2 in the book and Figure 5-6)

We can treat light as either

Electromagnetic Waves

Photons (particles of light)

because it has properties of both.

Wave Nature of Light

Electromagnetic Waves

Periodic changes in the strengths of electric & magnetic f fields

Travels through a vacuum at the speed of light

Speed of light is a constant for all light waves

c=299,792.458 km/sec

Independent of wavelength or frequency

We can measure the wavelength and frequency of light.
They are related to the speed of light c by the equation

$$\nu = \frac{c}{\lambda}$$

Photons: Particles of Light

Can also treat light as particles or *photons*

Photon: massless particle that carries energy at the speed of light.

This particle has energy that depends on the frequency/wavelength of the light.

$$E = h\nu$$

$$E = \frac{hc}{\lambda}$$

ν = frequency
h = Planck's constant
c = speed of light
λ = wavelength

The Electromagnetic Spectrum (see Figure 5-7)

Sequence of photon energies from low to high is called the *Electromagnetic Spectrum*

Low energy=low frequency=long wavelength

High energy=high frequency=short wavelength

The different "types" or "bands" in the electromagnetic spectrum interact with matter in different ways. For example, our eyes are very focusing viual light, but not X-rays. One of the major ways they are different is their ability to come through the Earth's atmosphere.

Visual light can penetrate our atmosphere.
- Light we can see with our eyes
  - Wavelengths: 400-700 nm
  - Frequencies: $7.5\text{x}10^{14}$-$4.3\text{x}10^{14}$ waves/sec

Observing at different wavelengths

Gamma-rays – must be observed from space

X-rays – must be observed from space

Ultraviolet – must be observed from space

Visible – observed from the ground or space. In the daytime, it's really tough.

Infrared – observed from the ground or space. Detectors must be kept really cold.

Radio – observed from the ground

How Bright is a Light Source?

Luminosity: total energy (photon) output of a source per second
Apparent Brightness: how bright it appears from a distance

I will use "faint" and "bright" to refer to the apparent brightness of a source. For example, the Sun is very bright, but it turns out that it is not very luminous. Rigel is much more luminous than the Sun, but it is much fainter than the Sun.

Luminosity is measured in Power Units (Energy/second). It is an intrinsic property of the source and is independent of our distance from it.

Apparent Brightness is measured in Flux Unites (Energy/area/second) and measures how bright an object appears to be as seen from a distance. It does depend on the distance from an object and is what we can actually measure.

Inverse Square Law of Brightness

$$B = \frac{L}{4\pi d^2}$$

The Doppler Effect (see section 5-9)

Shift in the observed wavelength when the source is moving relative to the observer.

Amount of the shift and its sign depend on

Relative speed of the source & the observer

Direction (towards or away)

Examples:

Sound

Light

Cats & Mouse

The Doppler effect for light

Moving away from the observer, wavelength gets longer, redshift

Moving towards the observer, wavelength gets shorter, blueshift

Note that this does not mean the light becomes red or blue!

We can use this to measure the speed (v) of an object by noting the $\lambda_{o\beta\sigma}$ of the light that hits us and knowing the λ_{em} (the known emitted wavelength)

$$\frac{\lambda_{obs} - \lambda_{em}}{\lambda_{obs}} = \frac{v}{c}$$

A Note about Equations

You do not need to memorize the equations for the exam, but you do need to know qualitatively how the quantities are related.

For example, for the equation $\nu = \frac{c}{\lambda}$

you can remember that $\text{frequency} = \frac{\text{some number}}{\text{wavelength}}$

or the words “higher frequency=shorter wavelength, lower frequency=longer wavelength”

or have a mental image of a wave in your head

or whatever works for you.