ASTR 1120 Section 1 (3 credit hours): Spring 2006

SUMMARY OF KEY CONCEPTS: WEEK #4

Lecture #7 – textbook Chapter 5 (4th edition) or Chapter 6 (3rd edition) on `Light'

The wave / particle properties of light are connected via a famous formula of quantum theory:

Photon energy = Planck's constant x wave frequency

…written as $E = hf$. This means that high frequency (short wavelength) waves correspond to photons with high energy – e.g. X-ray photons have more energy than visible light photons.

The electromagnetic spectrum goes (in order of increasing wavelength) from gamma-rays, X-rays, ultraviolet, visible light, infra-red, to radio waves. These are all basically the same phenomena, but practically we use different techniques to detect photons in different parts of the spectrum. The short wavelength radiation (X-rays and gamma-rays), in particular, is blocked by the atmosphere.

A spectrum is a graph of the intensity of radiation at different wavelengths. There are two basic types of spectrum you need to be aware of – line spectra and thermal spectra. Line spectra come from `transparent' sources (e.g. diffuse clouds of gas in space), whereas thermal spectra are emitted by `opaque' objects (ones you can't see through – like planets or stars).

Line spectra arise due to transitions of electrons between a set of energy levels within atoms. Due to energy conservation, when an electron makes a transition between energy levels, a photon is emitted or absorbed with an energy that matches the change in energy level. Since the pattern of energy levels is unique to each chemical element, a line spectrum provides a fingerprint of the chemical composition of the gas.

A thermal spectrum depends only upon the temperature of the emitting surface (strictly, the shape of the spectrum depends only on temperature – how much radiation is emitted also depends on the area of the star or other source emitting the radiation). As the temperature increases, the *peak* of a thermal spectrum moves to shorter wavelengths (e.g. from red to blue). However, more radiation is actually emitted at every wavelength.

Lecture #8 – textbook Chapter 15 (4th edition) or Chapter 16 (3rd edition) on `Stars'

The easiest quantity to measure for a star is its *apparent brightness* – how bright it appears in the sky. Apparent brightness has units of power per unit area (watts per m^2), but for historical reasons astronomers use a related measure called the *magnitude*. Bright stars have **low magnitudes** (a first magnitude star is brighter than one of tenth magnitude). A difference of 5 magnitudes means a factor of 100 difference in apparent brightness.

Apparent brightness is *not* the same as stellar luminosity (how much power a star produces), because a dim star could either be intrinsically weak or powerful but far away. To distinguish these possibilities we must measure the distance, which is often difficult, though for nearby stars the method of parallax is feasible. The luminosity, distance and apparent brightness (or flux) are related via the inverse square law:

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

Note the d^2 factor – a star that is twice as far away is not half as bright, but one quarter as bright.

A plot of the luminosity of stars against their surface temperatures is called a Hertzprung-Russell diagram. The diagram shows that stars cannot have any combination of luminosity and surface temperature (or color) – most stars follow a **main sequence** that extends from cool dim stars (conventionally in the lower right corner) to hot very luminous stars (to the top left). There are also giant stars above the main sequence and white dwarfs below.

The main sequence is where stars of different masses sit while fusion of hydrogen into helium proceeds within their cores. Massive stars need higher pressure in their cores to support themselves against gravity, which translates into higher core temperatures and faster nuclear fusion. As a consequence, massive stars are much more luminous than low mass stars, and exhaust their fuel supply earlier. Counter-intuitively, high mass stars have (much) shorter lives than low mass stars.