Summary of Lecture 14

Key points include:

1. Visible light is only one part of the electromagnetic (or EM) spectrum. The EM spectrum also includes X-rays, radio waves, and so on.
2. We understand that light can act like a wave (e.g., ripples on a pond) or like a particle (e.g., billiard balls). Particles of light are called photons.
3. Each photon has a wavelength λ and a frequency f. The energy E of a photon is proportional to its frequency: $E = hf$, where $h = 6.626 \times 10^{-34}$ Joule s is Planck's constant.
4. The wavelength λ is the distance between crests of a wave; the frequency f is how often the crests come by in a unit of time. The speed of the wave is λf.
5. For light in a vacuum, of any wavelength, the speed is always the speed of light $c \approx 3 \times 10^8$ m s^{-1}. Thus, for example, $E = hf = hc/\lambda$. Shorter wavelength means higher frequency and thus higher energy.
6. From long wavelength to short, and thus from low frequency and energy to high, the bands of the EM spectrum are called radio, microwave, infrared, visible (this is what we can see with our eyes), ultraviolet, X-ray, and gamma ray. The universe has many marvels beyond what we can see with our eyes!
7. Light interacts with matter in a few ways: (a) light can be *emitted* from matter, (b) light can be *absorbed* by matter, (c) light can be *transmitted* through matter (i.e., can go through matter without interacting), (d) light can be *reflected* or *scattered* off of matter.
8. Earth's atmosphere is opaque to most EM radiation (i.e., most of the radiation does not get to the ground). Exceptions are visible light and radio waves. This is bad for astronomers but probably good for life; the high-energy radiation (X-rays and gamma rays) do damage.
9. Thermal radiation is heat radiation, and depends only on the temperature of an object. A particular type of thermal radiation is called *blackbody* radiation. For blackbody radiation, (a) hotter objects emit more EM radiation at *all* frequencies, per unit area, than cooler objects, and (b) hotter objects emit photons with a higher average energy than cooler objects.
10. The peak wavelength λ_p of emission is inversely proportional to the temperature (Wien's law). Quantitatively, $\lambda_p T = 2.9 \times 10^9$ nm K, where nm=nanometer (nano=10^{-9}) and

T is in degrees Kelvin. This means that if we measure the peak of a blackbody, we know how hot the object is. Take a moment to appreciate that: we can measure the temperature of a star thousands of light years away! Smaller T means longer wavelength, so cool objects are red and hot objects are blue. This is contrary to our normal thinking (blue=ice=cold, red=fire=hot).

11. For a spherical object (like most stars or planets) of radius R and temperature T, emitting like a blackbody, the luminosity of the object (luminosity = energy emitted per time) is $L = 4\pi R^2 \sigma T^4$. Here $\sigma = 5.67\times10^{-8}$ J m^{-2} s^{-1} K^{-4} is the Stefan-Boltzmann constant, which is needed to make the units work out right so that we end up with an energy (J, or Joules) per time (s^{-1}.

12. This means that if you fix everything else but double the temperature, the luminosity goes up by a factor of $2^4 = 16$. That's a lot!

13. The energy flux, or often just *flux* of radiation is the energy per area per time flowing through a region. The total amount of energy per time flowing out from a source is independent of the distance from the source. However, the area a distance d from the source is proportional to d^2 (think about a sphere, which has an area of $4\pi d^2$ if its radius is d). Thus the flux of radiation is proportional to the inverse square of the distance from the source.

14. Spectra of astronomical objects usually combine three types: (a) continuum spectrum (broad and smooth), (b) emission line spectrum (lines sticking above the broad smooth region), (c) absorption line spectrum (narrow lines dipping below the broad smooth region).

15. Kirchoff's laws: (a) hot, dense objects emit a continuous spectrum, (b) hot, diffuse gas produces an emission line spectrum, (c) a cool gas obscuring a continuum source will absorb specific wavelengths and thus produce an absorption line spectrum.