Astronomy 16 – Modern Astrophysics

Fall 2014
Week 3

Questions for the week:

1. How bright is the full Moon relative to the Sun? (from last week)

By the end of the week, you will be able to answer these questions.

Topics:

Basics of electromagnetic radiation, wavelength and frequency, photon energy, the parts of the spectrum
Three types of spectra, connection to atomic physics
Doppler shift

We started radiation – and looked at some spectra – last Thursday; and we began discussing atomic structure. This Tuesday, we'll see *why* there are three types of spectra and see what the connection to atomic physics is.

Reading:

We will mostly covering the material I assigned from Ch. 5 last week:

Read the first page of Ch. 5 (p. 111) carefully, and study Table 5.1 on p. 112. Then skim the next few pages, which are a pretty careful derivation of the quantized energy levels of a single electron atom (like neutral hydrogen). Start reading carefully again at the bottom of p. 115, which quotes the energy level formula result (eq. 5.21) and read through the end of the section (p. 118). Study Fig. 5.2 and its description. I'm hopeful we'll have time to discuss this material on Tuesday, but if you're pressed for time, it's OK to simply have this read by Thursday.

And read Sec. 5.2 and 5.3.

We likely won't get to it in our next class, but after these topics, we'll be discussing radiation transport, and so you can start reading Sec. 5.4 (or if you're too busy, you can wait a few days).

You should also read a little bit on-line about the Doppler shift. Note that the Doppler shift has some complicated aspects related to special relativity, but we'll be ignoring those. And note also that the Doppler shift of sound is actually more complicated than that of light (because sound travels through a medium that defines an absolute reference frame, unlike light). So, take a look at the Wikipedia page on the Doppler shift:

http://en.wikipedia.org/wiki/Doppler_effect

but, don't get bogged down in the math at the top (about the Doppler shift of sound) or the applications at the bottom. The cartoons and images (I love that Swan image – see how the waves are closer together in the direction it's swimming?) are worth checking out.

Here's a short and very straight-forward page:
http://zebu.uoregon.edu/~soper/Light/doppler.html

And here's the basic, classical Doppler shift formula that we'll use in class:

$$\frac{v_{radial}}{c} = \frac{\boldsymbol{\lambda_{obs}} - \boldsymbol{\lambda_{rest}}}{\boldsymbol{\lambda_{rest}}}$$

Here, v_{radial} is the component of the velocity vector of the light-emitting object that lies along the line-of-sight to the observer and c is the speed of light. And $\boldsymbol{\lambda_{rest}}$ is the wavelength the light *would* have if the emitter and observer were both at rest with respect to each other, while $\boldsymbol{\lambda_{obs}}$ is the wavelength the light is actually observed to have.

Note: class will not meet this Thursday. So we'll try to cover all this material on Tuesday.

Important concepts and related facts to keep in mind as you re-read, and make sure you can answer while/after you've done the reading. We will discuss all of these in class this week.

Here are left-over topics from last week's assignment:

Light has wave-like and particle-like properties.

Photons are particles of light with a particular amount of energy (which does not have to do with the photon's speed – all photons have the same speed, and a photon is massless and so does not have kinetic energy in the classical sense). The photon's energy is related to the frequency of the wave description of the photon by Planck's constant, *h*.

The wave description of light relates the frequency to the wavelength (their product is the speed of the wave).

The quantized energy levels of an atom lead to line spectra as electrons make transitions from one discrete (i.e. having a specific energy) level to another. See eqs. 5.22, 5.23 and Fig. 5.2. Upward transitions in the electric potential of the nucleus require (so, *absorb*) photons with energy equal to the energy level difference, while downward transitions can produce (so, *emit)* photons with that energy.

Because energy levels do not have totally precise energies (due to the Heisenberg uncertainty principle) and for other reasons as well, such as random thermal motion of the emitting or absorbing atoms, spectral lines have finite widths (and particular shapes).