Topics: Atomic structure (one-electron atoms), hydrogen spectrum, atomic processes: collisional and photo-excitation, de-excitation mechanisms; Kirchoff's three types of spectra; Doppler shift

Reading:

- Ryden and Peterson Ch. 5: pp. 111-122; you can read ahead through p. 127 if you have the time (some of the commentary near the end of this document refers to the material beyond p. 122).
- Review your knowledge of the classical Doppler shift of light. (No need to worry about relativity.) The Wikipedia page is a fine place to do a quick review: https://en.wikipedia.org/wiki/Doppler_effect but please ignore all the mathematical stuff about the Doppler effect of sound – light is actually simpler, since for sound, you have to worry about velocities with respect to the medium, while light has no particular medium. See my commentary below.

Remember: The textbook is on reserve behind the front desk at Cornell.

Summary of work to submit:

- Nothing to submit for Thursday's class.

Light (electromagnetic radiation) brings nearly all the information we have about the cosmos to us. So, we need to understand how to decode the information in it, which involves not only understanding light but also atoms and atomic processes (since electrons moving between energy levels governs a lot of what we see when we measure the spectra of stars, the ISM, and galaxies).

Commentary on the reading:

When reading (for Tuesday's class) about the inverse square law, the luminosity and flux (unless otherwise specified) refer to light at all wavelengths. In practice, however, there is a huge amount of information in the *distribution* of wavelengths present in light. Breaking the light into its constituent colors and then analyzing the resulting brightness as a function of wavelength (or color) is referred to as *spectroscopy*. Spectroscopy provides us with information about the composition of the object emitting its light as well as, potentially, its temperature and its kinematics, among other things we'd like to know. To interpret this spectral information, we have to understand how the atomic properties and processes that lead to the emission and absorption of light operate.

Ch. 5 starts with basic information about atomic structure, focusing on the Bohr model of the hydrogen atom (extendable to any atom with only one electron; note eqn. 5.23 with its inclusion of Z, representing the charge (number of protons) in the atom's nucleus).

Although the Bohr model is simplistic and leaves out a lot of important effects, it is a basically correct functional description of the quantum mechanical atom. Note the similarities in the derivation of its structure to circular orbits – a central $1/r^2$ force (here electricity rather than gravity); energy conservation considerations; angular momentum conservation. These factors combine to give the *quantized energy levels* that are one of the primary results of quantum mechanics. Unlike a satellite in orbit, and electron in an atom can only exist at specific orbital distances (and thus, energies). These *energy levels* are conveniently visualized in an energy level diagram, like that shown in Fig. 5. Electrons can move up or down between energy levels (but never to a point in between them) absorbing or emitting photons in the process.

Study the various atomic processes in the second section of the chapter. Note that some involve photons (with therefore, observable consequences) and some don't (and so aren't directly observable).

And pay special attention to Kirchoff's "laws" that describe the three types of spectra. Note that these so-called laws are just descriptions of phenomena. Kirchoff didn't know why they worked because quantum mechanics hadn't been discovered yet. Neither had the electron. But with our knowledge of quantum mechanics, we can begin to understand how and why those laws work. By the way, please do look at Color Figure 2 (coincidentally, embedded within the Ch. 13 reading) for a very useful diagram showing how the three types of spectra are produced.

One thing to pay special attention to is the division of the electromagnetic spectrum into various regions (Table 5.1). Note what a narrow range of wavelengths is visible to the human eye. Meters are the mks units of length, but we usually are considering wavelengths much shorter than that. Common units for describing the wavelength of light include the micron (μm $= 10^{-6}$ m), the nanometer (nm $= 10^{-9}$ m), and the Angstrom Unit (Å $= 10^{-10}$ m). The visible part of the spectrum goes from 4000 Å (blue) to 7000 Å (red).

And note the basic relationships among wavelength, frequency, and (photon) energy (eqn. 5.22).

Regarding the Doppler shift, the key point is that it always exists when the light source is moving with respect to the observer. And it is simply due to the source being closer (or farther) at the time it emits each successive wave. Please look carefully of the image of the swan on the Wikipedia page – do you see how the wavelength of the water-waves it's making is smaller in front of the swan (the direction of motion) and bigger off to the sides (and presumably even bigger behind it, but it's hard to see). The four-frame animation a little further down the page is excellent, too. The second-from-left frame is the basic Doppler effect. And the "Change in frequency" equation right above it is the key (and really, only) Doppler shift equation you need to know/remember. Combine it with $\lambda\nu = c$ to turn it into an equation in terms of wavelength.

The reason we're learning about the Doppler shift now is that it can affect observed spectra in important ways; especially line (as opposed to continuous) spectra. A source that's moving with respect to the observer will have its whole spectrum – including the positions of any spectral emission or absorption lines – shifted. *And* even a stationary source can be affected by the Doppler shift, if the individual atoms in it are moving with respect to each other. Specifically, any substance with a temperature greater than absolute zero has random thermal motions (we call that "heat") which will impose a Doppler shift on every photon emitted or absorbed by those moving atoms. Taken together, this leads to each spectral line being broader than it otherwise would be. This is the thermal broadening described on pp. 125-6. That's the most important part of the reading; it's where you should focus your preparations for class.

It's important to get comfortable with the basic concept that when you see photons from more than one atom at a time, the individual Doppler shifts of each photon combine into a single observed spectral line that is *broadened*.