Astro 121, Spring 2014
Week 12 (April 17)

Topic: Spectroscopy, continued
Break: Eric

We were heavy on theory last week, so we'll shift the balance this week. We'll do some work in class (but less than this past week), and then spend somewhat more time working on data reduction, and looking at a couple of spectrographs in more detail.

Reading for next week:

We'll read the remainder of Chromey, Chapter 11: Sections 11.5 through 11.7. There are a lot of other resources listed on last week's assignment, which I won't list again here.

Important concepts and problems to hand in.

I've carried number 1 over from last week, since we didn't really have time to talk about it. You don't have to re-write your answer, but just be prepared to talk about it.

1. *Echelle spectroscopy*. What is an echelle spectrograph? What are the basic optical elements in an echelle spectrograph, and how do they differ from a simple single-order spectrograph? What are the advantages and disadvantages of an echelle?

2. To get a better idea of why a cross-disperser is required for an echelle spectrograph, let's look at a specific example. The echelle that used to be on the 4-meter telescope at CTIO had a grating that was ruled with 31.6 lines / mm and had a blaze angle of 63.5°. Assume that light is incident at an angle of 69.5° (close to the blaze angle for efficiency, but slightly off to avoid the light path being blocked within the spectrometer). This means that in Chromey's Figure 11.5, the angle β is 6°, i.e. the incident light is 6° from the facet normal.

    a. Thinking back to our discussion of blazed gratings in seminar this week, what is the significance of the term $2\,\sigma\,\sin(\varepsilon)$ from Chromey's Equation 11.5? (Looking at Figure 11.5 may help.)

    b. The CTIO 4-meter echelle was designed to work with visible light. Taking the parameters above, at what order m does the blaze wavelength (i.e. the wavelength of maximum efficiency for that order) fall closest to 650 nm? What are the blaze wavelengths for orders $m \pm 1$ (i.e. adjacent orders to the value of m you found)?

    c. Now invert this reasoning. Referring to the grating equation, what will be the outgoing angles for constructive interference of the three wavelengths you found above, assigning each to its corresponding order? That is, where would those wavelengths land on a detector, assuming that no cross-disperser is present?

3. *Integral field spectroscopy*. What is integral field spectroscopy? How does it work? There's no detailed information on this in any of our reading, but you can find information on existing spectrographs (sometimes called integral field units, or IFUs) on-line. Look on the websites of the major observatories and find an example of an integral-field spectrograph in use at a large telescope. Show the basics of how it works (i.e. how it gets both spatial and spectral information) and show some example data if you can find some.

4. *Design of a spectrograph:* Do Chromey, problem 11.9.

5. *Observation planning*. To get some hands-on experience with spectroscopy, we're going to measure the rotation rate of Jupiter by taking spectra at opposite limbs of the planet and finding the Doppler shift. This week, you'll do some advance planning to determine the feasibility of doing this.

   a) Determine when Jupiter will be observable for us in the next few weeks. Determine at what time we should make our observations, and explain your reasoning.

   b) What spectral resolution will we need in order to be able to detect the Doppler shift between the approaching and receding limbs? Note that while spectral resolution refers to distinguishing closely-spaced spectral features, what we need to do in order to measure a Doppler shift is not to distinguish features, but to be able to find the precise center of individual features. As a very rough rule of thumb, you can find the centroid of a line to a precision of roughly 1/10 of the spectral resolution.

   c) Does our spectrograph have the required resolution? It's the eShel echelle spectrograph, manufactured by Shelyak Instruments.