Astro 121, Spring 2014
Research Techniques in Observational Astronomy

Week 1 (January 23, 2014): Review of astronomical concepts; intro to CCD imaging

Snacks: I'll provide food for seminar break this week (unless someone e-mails me in advance to volunteer), and then during seminar we'll make up a schedule for the rest of the semester.

Due date/time: Bring your completed, written solutions for these problems with you to seminar on Thursday. Normally they will be turned in a little earlier, but for this week, just bring them to seminar.

Resources and reading:

- The main goals this week are: (1) to brush up on some basic astronomical knowledge (magnitudes, blackbodies, flux, luminosity, etc.) in case those concepts have faded a bit; (2) to start thinking about astronomical problems as an observer, not just theoretically; and (3) to learn enough about the basics of CCD data that you can start taking data with our telescope and camera very soon.

- Reading: Chromey, *To Measure the Sky*, Chapter 1. This should be mostly review, but it is helpful to review these essential concepts for astronomy. Also, I find that Chromey gives good historical context, and also an interesting, somewhat philosophical perspective on what we are trying to do as astronomers.

Important concepts:

- Understanding/reviewing how to use *magnitudes*, a commonly-used but sometimes-confusing way of expressing flux.

- Understanding/reviewing some basics of light: flux, luminosity, blackbodies, and the electromagnetic spectrum.

- Learning the basics of the kinds of CCD calibration images called biases, darks, and flats.

Problems/exercises

Unless otherwise stated, all Chromey problems listed below are from Chapter 1. For this week, bring written solutions to these problems to seminar on Thursday – we'll talk then about our weekly schedule and deadlines for coming weeks.

1. Chromey, problem 2, on photon wavelengths necessary for ionization or dissociation of various atoms and molecules. In addition to giving the wavelength, also state in what part of the electromagnetic spectrum (e.g. visible, infrared, etc.) that wavelength lies.

2. Chromey, problem 9, on adding magnitudes.

3. Chromey, problem 10, on surface brightness vs. total brightness.

4. Chromey, problem 14, on doing photometry (by hand!) from image pixel values.

Note on the following problem – this is a problem that you've seen before, since I believe David assigned it in Astro 16. I'm including it again here because (a) I think that now you have the tools to take it up a notch, i.e. to do a more sophisticated solution than you may have in the past, and (b) although the problem involves theoretical calculations, I want you to tackle it from an *observational* standpoint. As you work it through, think, "how would I measure this? If I went to the telescope, what sort of data would I have to take? Would I need any calibration? Would the atmosphere make a difference? Would it be a relative or absolute measurement?" and so on.

5. (This is based on Chromey, problem 5, but revised and expanded.) Using a spreadsheet or other graphing program (e.g, python, IDL, Mathematica/Wolfram Alpha, Excel), answer the following questions. Note: any time you produce code for answering a problem this semester, even if it's only a few lines, I'd like you to turn that in along with your solution.

    a) Compute and plot a blackbody spectrum of a 5800 K star, from λ = 100 nm to 1500 nm (i.e. 1.5 microns). Mark on your plot the boundaries of the visible part of the electromagnetic spectrum. Do the same for a 20,000 K star and for a 2500 K star. (You may want to extend your wavelength scale for the cooler star.) [Note: this part is quite easily done in Wolfram Alpha, which will automatically shade the visible part of the spectrum for you – type 'blackbody' and go from there.]

    b) Compute A(T), the slope of the Planck function B_λ, as a function of temperature. Approximate the slope between 400 nm (violet) and 600 nm (yellow), as $A(T) = \frac{\partial B}{\partial \lambda} \approx \frac{B(600\text{ nm},T) - B(400\text{ nm},T)}{200\text{ nm}}$. Compute and plot A over a temperature range of 2000 K to 30,000 K. What happens to A at infinite temperature? What happens at very small T? Since your computer can't calculate infinite temperature functions, you will want to do a little analytic thinking here about how these functions behave at high T. Calculate the limit as $T \rightarrow \infty$, and as $T \rightarrow 0$. Also think carefully about your plotting. What will be most revealing – a log plot? A linear plot? Some of both? Try to think of your plotting as a means to an end (namely, understanding what is going on with these functions) and not an end in an of itself. Use it as a tool, and think about how to make that tool useful to you.

c) Repeat part b., but this time compute and plot $C(T) = \log\left[B(600\text{ nm},\ T)\right] - \log\left[B(400\text{ nm},\ T)\right]$, over the same range of temperatures. Again, what happens to C at extreme temperatures?

d) Comment on the usefulness of A and C as indicators of the temperature of a blackbody. For example, think about what you would need to measure in order to calculate each one, say for a star. Thinking also simply about the *units* on each quantity may help here.

e) Which of these is most similar to the magnitude difference $B - V$ that is often used in stellar astronomy as a temperature indicator for stars?

6. CCD basics: Skim through Chromey pp. 286–292 to get the big picture ideas (not worrying too much about details; we'll return to these concepts in much more detail) and then *briefly* define each of the following terms:

    a) Bias frame

    b) Dark frame

    c) Flat-field

    d) For each the above three types of calibration data, what sort of arithmetic operation should you perform with these calibration frames and your main image frames of interest? That is, should you subtract them from the data? Multiply them by the data? Divide the data images by these frames, or vice-versa? Why? (The answer is not the same for all three cases.)