Module 2, Exploring the stars

 Assignment 3 –Stars: A "Black Body" Spectrum

 In the Stellar_spectroscopy.pdf in assignment 1 you learned about blackbody spectra, and how the spectrum of a star can be described. Let's explore this further by introducing the Stefan-Boltzman law, and then see how these relations allow us to determine the temperatures of stars.

 For additional background, read the material on the electromagnetic spectrum at: http://astro.unl.edu/naap/blackbody/spectra.html
 Then, at the same site: http://astro.unl.edu/naap/blackbody/blackbody.html
 click on "blackbody simulator" at the bottom of the page. The curve in this simulator represents the amount of light emitted versus the wavelength of light for an object of a given temperature: we will call this the *spectral energy distribution (SED)*. The horizontal axis gives the wavelength of light in nanometers. The vertical axis is given in flux, which is just the energy per unit time per unit area per unit wavelength. (Please insure that you are on the tab labeled "curves", not "filters –that's for the next assignment!)

The Stefan-Boltzman law is expressed as an equation that describes the blackbody curve and how it changes with temperature: in its simplest form it says that the total energy emitted by a blackbody is proportional to temperature to the 4th power. Use the slider to try different temperatures of your choice and observe how these changes affect the continuous spectrum. In particular, try the sun's surface temperature: 5800K. Note that you can vary both the horizontal and vertical scale. Try to demonstrate Wien's Law and show why hot stars appear predominantly blue while cool stars seem red. Describe your best simulations and your interpretations on the Blog. Also demonstrate the Stefan-Boltzmann Law by answering the following: when you double the temperature, by how much does its total energy increase?

Assignment 4: Imaging Stars: Temperatures through the Use of Filters

So, if we can measure the *spectral energy distribution (or SED)* of a star and compare with our models (from the simulator), we have the star's temperature. However, we have to work hard to get the SED. So astronomers have come up with a way to measure a few points along the SED, which is enough to get a good estimate of the temperature. This involves taking images with a telescope and a CCD camera, but adding a filter in front of the CCD camera.

To learn how telescopes, cameras and filters work together, try this website: Chris Martin helped develop it. http://stc-mditr.org/thepoint/ Choose *devices* and click on *telescopes* to explore how images are taken, and how light filters work. You might also want to experiment with the colored filters and grating that we used in module 1.

We can measure the brightness of the star at several different wavelengths by inserting a filter of the appropriate color (wavelength) in front of the CCD image. Then we can match our measurements to the blackbody curves and get the star's temperature. We record the brightness in each CCD image using some appropriate unit of measurement: say, DNs (from module 1).

 Return to the applet from assignment 3,
http://astro.unl.edu/naap/blackbody/blackbody.html
Read more about filters under background information, "filters"
Go to "blackbody simulator" and choose the tab in the upper right labeled "filters". This represents 4 different filters: U,B,V and R which represent ultraviolet, blue, visual and red light. (Yes, visual light includes all the colors, but this label is historical…) Answer the following in the blog: At what temperature is the light in the B filter equal to the light in the R filter (i.e. the peak of the curves are the same height)? What is the lowest temperature at which U>B>V>R?

(An aside on astronomer's magnitudes, shown on the right hand box in the simulator: Magnitudes, the measure of brightness used throughout astronomy, are very non-intuitive. They are logarithmic, which approximates human vision. They increase as the object gets fainter. A bright star or planet is about magnitude 0, the faintest star you can see without a telescope is about 6, and so on. That system was set up several thousand years ago. When astronomers started observing through different filters, they further defined the system according to the temperature of the star such that the magnitudes were defined to be equal when the curve is at 10,000K. If you enter this temperature you will see that the values for U, B, V and R are about the same, although the peak of the curves are very different from each other.)

Now let's apply this reasoning to some real stars. To make it simple, we will only use two filters, but in this case two will suffice. Using ImageJ , open the image M26_r.fits. Next, open image M26_b.fits These images of a cluster called M26 were taken through R and B filters with the 0.9M telescope at Kitt Peak. (You can take a virtual tour of the telescope at: www.noao.edu/outreach/kptour/).
 Adjust the images: "Image",>"Adjust", >"Brightness/Contrast." You should see that the star patterns are the same. But the relative brightness of the stars may look different to you. We want to quantitatively measure the ratio of their brightness in each image: this will be our indication of the relative temperature.

 Let's look at a particular pair of stars in both images in about the center of the frames. Magnify to about 200% and identify the stars A and B from the figure below. First try to estimate how bright star A is compared to star B in the B image. (Brighter? Fainter? About the same?) Repeat for the R image. Which star do you think is brighter in the B image? Which is brighter in the R image?

Now let's do science, by measuring. Click on the straight line segment on the tool bar and draw a line through the stellar image. Use the ImageJ tool Analyze/plot profile to see a plot of the cross section of the star. Repeat for each of the 4 stars. What can you conclude about the relative brightness in the different filters? You should be able to use this to say which star is hotter. (If we had used three filters you would be able to actually estimate a temperature.)
Send a screen shot of the 4 profiles to Chris Martin and post your analysis of which star is the hotter, A or B, on the blog.