Module 1   Assignments 1 & 2

Before we begin, note that some of the activities require posting answers and results on the Blog. In the document below, the Blog assignments are written in green for ease of access. In order to keep the Blog as orderly as possible, please answer **all** the questions for each assignment in **one** posting. This will make it easier for all of us to follow the postings!

Assignment 1 – Examining the Solar Spectrum with a diffraction grating

a. Experiment with the 5-inch square diffraction grating from your kit. (You may want to construct a cardboard holder for the grating. A piece of shirt cardboard with about a 4.5 inch by 4.5 inch square cut out at one end works fine. You can tape the grating to the cardboard. This will make it easier to keep fingerprints off the grating.)

 Look at different light sources (light bulbs, car headlights, neon signs, etc.) and carefully note what you observe. If you haven't worked with a diffraction grating before, it will help to start with a single light source in a dark room. Hold the grating in front of you and look toward the light source. Now look to both sides, or above and below to find the spectra. For easier viewing, you many want to rotate the grating 90^0 so the spectra fall on either side of the light source. Now describe carefully what you see. Repeat with different light sources.

Finally, try outside on a sunny day when there are no clouds covering the Sun. Of course, you NEVER want to look directly at the sun, but from your previous experiments you have probably found where the spectrum lies with respect to the light source. I find that the shirt cardboard holder then allows the direct sun to be blocked by the cardboard. You could also try standing in the shade and looking through the grating at a sunlit wall if this is easier: this will even work from inside if the weather does not encourage outdoor experiments!

On the Blog describe the light sources and spectra that you have projected in detail as well as any experimental difficulties you encountered in the process. How do the different light sources compare with each other?

b. To understand how astronomers characterize light, download the PDF file Stellar_spectroscopy.pdf. Read the background material (pp 3-6). (We will return to the introductory section on graphical analysis later.) If this material is new to you, don't worry about absorbing it all: we will be returning to these concepts again in later modules.

Assignment 2 – Using image processing software (ImageJ) to examine a CCD image of the sun

You downloaded and tried out ImageJ during the precourse test. Now let's explore further. Image processing is becoming more and more important in all branches of science. The purpose of this assignment is to try some image processing techniques with an image of the sun to acquaint you with some basic processing tools.

To learn something about the sun, and in particular to read about sunspots, try this site:
fusedweb.llnl.gov/CPEP/Chart_Pages/5.Plasmas/SunLayers.html

The image we use here, and in the precourse test, were taken with a CCD camera. This is similar to the digital camera that almost everyone has these days. To understand how a CCD camera works, and therefore what an image consists of, please download and read CCD_intro_Abits.pdf   Next try the following:

1. Using your ImageJ software, open the solar image (solar_image.fits.zip) and unzip it. You will see an image of the Sun within a circular aperture associated with the instrument that obtained the image. This image was obtained at a specific color (or wavelength, referred to as hydrogen-alpha 6563 Angstroms) useful for investigating the Sun's chromospheric activity.

2. Adjust the image contrast. Select the following item from the ImageJ menu pulldown bar: "Image",>"Adjust", >"Brightness/Contrast." A new sub-window ("B&C") will appear on your screen and you can use the various slider bars to adjust the appearance of the image. Note that a histogram is displayed at the top of the "B&C" window. This shows the range of pixel values currently being displayed by the shades of gray in your image, and where the pixel values fall along that line. Play with the minimum and maximum sliders until you see the maximum amount of detail on the solar image. Choose "Set" and enter the min and max values you just measured. The image should now be displayed with good contrast. Be sure that the actual edge (astronomers refer to this as the "limb") of the Sun is still clearly apparent. Now move the cursor around the image and notice how the values x =…, y= .., value = in the ImageJ bar change. When you are in the black part of the image, the value (the measure of the amount of light) is zero. What is the largest value you can find within the image of the sun? Let's call these "Data Numbers" or DN value. (There is another number in parentheses following this value: you will notice that this is 32768 larger than the first one, and is related to a processing method used for this CCD image: let's ignore it.)

3. <u>Make some measurements of distance</u> In the small "ImageJ" toolbar, select the "line" drawing tool; it's the fifth little box in that window as you look from left to right. Measure the Sun's diameter by drawing a line across the full diameter of the Sun while holding down the left mouse button. As you do this, you will see various interesting values change in real time below the ImageJ bar. Now select the "Analyze" function in the top toolbar, then select "Measure." A new sub-window will open displaying the diameter you measured in pixels. (You may have to stretch the size of this sub window by stretching the lower right corner.) This window has various columns that we will address in step 4. The final one titled "length" is the diameter of the sun in pixels. Repeat this routine to see how your measurements compare. Notice that ImageJ gives you a measurement to 3 decimal places. That means you are recording a measurement to 0.001 pixels. Do you believe that is reliable? The units here are in pixels: when you zoom in, as we have done, what do you think your accuracy is? This involves thinking about uncertainty in your measurement, and significant figures, or 'sigfigs". If you are not familiar with "sigfigs" you may want to explore them. This web site, www.teacherbridge.org/public/bhs/teachers/Dana/SigFig.html may be helpful for you.
   Comment on what you estimate is your measurement accuracy. How many significant figures are meaningful? (In other words, can you measure the diameter to an accuracy of one pixel? One tenth of a pixel? One hundredth of a pixel? None of these?)

4. <u>Examine the brightness in different parts of the image</u>. Select "analyze", then "plot profile" to see a profile of the pixel value across the solar disk along the line you defined. You will notice that the maximum value in this plot corresponds to the maximum in the subwindow in step 3. (If you are having difficulty with the various windows, figure 1 at the end of this document shows what my screen looks like: if you are nowhere close, you may want to ask for help.) Use this to draw a line through the sunspot centered at about pixel 778,788 and plot the profile. Move your cursor around inside the plot. How much fainter in DN units is the sunspot than its surroundings?

5. Now use the "Analyze" menu to "Set Scale" and measure solar diameter in kilometers. In the "Set Scale" menu, enter your average diameter from step 3 in the window labeled "Distance in Pixels", the actual diameter of the Sun (1392000 km) in the "Known Distance" and units of "km" in the "Unit of Length." (Repeat your measurement of the Sun's diameter several times and post your average value of the diameter in kilometers on the Blog. Include a comment about sig figs.

6. Again, look at the sunspot centered near 778, 788). Using the "magnifier" icon, magnify this region to 300% or higher (as displayed at the top of the image). On the Blog describe the general nature of the Sun's surface around the location of this sunspot.

We have only used a few of the functions in ImageJ: you may want to download the documents at the ImageJ website to learn about other functions, or just experiment. In the final modules we will introduce other astronomical images that you can manipulate using ImageJ. For now, you may want to use the "false color" technique to make this solar image more appealing. Astronomers often use colors to represent different brightness levels in an image even though the actual data itself may refer to a very narrow range of wavelengths. In the main toolbar go into the "Image" menu and then into the "Lookup Table" to see a choice of colors you can select. Technically this particular image would be red because of the wavelength, or color of the light selected to observe (6563 Angstroms or 656.3 nanometers).