Ay 105 Lab Experiment #7: Infrared Array Camera

In this week's lab, you will study the characteristics of an InSb near-/thermal-infrared array camera, and examine features in a near-infrared spectrum. In the first part, you will acquire images of various infrared sources and analyze them on the computer. In the second part, you will measure a spectrum of a hot wire and the atmosphere using a simple grating spectrograph.

As there is a single camera, Both groups can acquire the first set of images together. Then, while one group is analyzing the first set of images, the other group can obtain the wire spectrum images.

Setup Fill the IRC-160 camera dewar with LN_2. Use the "vented" funnel, and take care not to freeze any part of yourself with the nitrogen. Connect and power up the camera (see p. C4 of the manual). Leave the gain and offset controls at their default settings to start. The chip, if previously warm, takes several minutes to cool down. Two fills of the camera dewar are typically required to obtain a steady temperature.

The camera has two outputs, a VGA video output and a parallel port. When the camera was new back in the mists of the early 1990's, a coal-burning PC with a dedicated parallel input card converted the camera output into data files. Now, a modern VGA-USB converter and software are used to capture images. The downside of this that captured images have (modest) additional noise, and have a format of 640×480, rather than the native 120×160 array size of the camera.

Part 1 We want to evaluate the response of the array to zero radiation (a "bias" or reference frame, really a combination of bias and background signal). Try putting various objects in front of the camera–it turns out that finding a source of zero radiation is not easy, in the infrared. This camera is sensitive in the near-infrared from $\sim 2-4\mu$m. What is the ratio of radiant energy at 4 microns between a 310 K and 77 K blackbody? One possible source of zero infrared energy might be a 100% reflectivity mirror, to force the camera to "look" at its cold interior. Real mirrors are not that efficient, however. Compute the effective temperature, over the wavelength range the camera is sensitive, of a mirror with a uniform 97% reflectivity at room temperature. (That is, what temperature would a blackbody need to be to have the same power received by the detector?)

One good source for a low background is probably the cold side of the lid from the dewar, if it has been on for a while, or the fill funnel.

Check that the background level in a captured image is small and not negative. Adjust the offset if necessary. Would it make sense to take an average of several images?

To capture images used the 'VGA2USB' application. It stores files in .bmp or .jpg format. From the msdos command prompt window, these files can be converted to .fits using Imagemagick's `convert XX.bmp YY.fits` command. ds9 runs to display images on the PC.

Fill a coffee cup with water at $30°C$, and image the cup close up but with the focus set to infinity (this tends to blur out detailed structure and give you a local average, which is what we want here). Use the microwave in the lab behind to heat the water. Take a frame or two here with of this source. Repeat this process for many different water temperatures, stopping at the hot end when the detector becomes saturated. What happens if you slide a sheet of Plexiglas between the camera and the coffee cup?

Analysis (can also be done after class if necessary)

Use your knowledge of IRAF to analyze images under Unix. Copy them over to the ay105user account using SSH Secure File Transfer.

Using IRAF subtract the reference frame from each of the data frames. (It is a good idea to keep a copy of your raw images, in case you make a mistake.) Then, estimate the mean and standard deviation for a $\sim 10 \times 10$ camera-pixel analysis box; try to make many measurements over various regions, avoiding those with bad pixels. Get at least 10 of these, in areas with different mean levels, and plot the mean vs. the variance.

How can you compute the gain (in photoelectrons per digital number) from this data? Is the camera limited by photon (shot) noise? How does the signal change as a function of temperature? Does this correspond with what you predict?

Part 2 Remove the coffee cup, and make yourself a spectrograph for infrared light, using radiation from a hot wire/lamp collimated by the mirror used in the optical spectroscopy class, then to the grating and into the camera. You'll want to set the grating on top of a rotational stage so that you can make some accurate angle measurements. What do you notice when the grating is directly facing the camera ($\beta = 0$)?

Find the zero-order image and first-order spectrum of the wire lamp. Note that you may be able to see, with your eye, some optical light shining to the side of the camera lens, with the (of course not visible) infrared spectrum entering at the center. You may need to put the Plexiglas at various positions (and/or walk around) to block stray infrared light emitted by hot sources from entering the camera.

Investigate the configuration and the spectrum of the wire lamp you see. Record the zero-angle of the grating (at which the camera sees its own reflection), the angle at which the zero order (reflection) appears at the array center, and the angle where the first order spectrum begins.

Measure the position angles of any absorption lines (or sets of lines) you see, and also the point where the spectrum cuts off. This provides you with a chance to check the reported specifications of the camera against the detected spectrum. Identify any absorption lines you can see with those expected from the atmospheric spectrum.