Astro 121, Fall 2005
Week 10 (November 9)

Topic: Infrared astronomy
Break: Micah (the following week: Blair and Jennifer)

Reading for this week:

I've suggested reading from two sources. Glass gives a good introduction to the infrared and covers much of the practical material about filter systems, etc. McLean then fills in more details of practicalities of instrumentation for the infrared and how it is different from the optical.

- Glass, *Handbook of Infrared Astronomy*. In the same series as the book by Howell, this is a relatively new book with excellent coverage of infrared astronomy. Reading: Chapter 2 (The Infrared Sky); Chapter 3 (Photometry) through 3.4; and Chapter 6 (Instrumentation). You may also want to skim the rest of Chapter 3 and all of Chapter 4; they concentrate on applications of infrared photometry and spectroscopy, respectively.

- McLean, *Electronic Imaging in Astronomy*. Ian McLean was one of the people most closely involved in the development and use of the early infrared arrays, and this is an area where this book stands out. Read Chapter 8, skipping pp. 216–222; Chapter 9, bottom of p. 235 through p. 244; and pp. 256–267.

Important concepts and problems:

1. We'll start off with Steve's presentation about integral field spectroscopy, which we didn't get to last week. To make a smooth transition, I'm sure Steve will have found at least one integral field unit that works in the infrared, bridging the gap between last week's topic and this week's.

2. The Johnson I filter stands for "Infrared", and indeed it is beyond the range of light visible to the human eye. But in many ways observing in the I band is much more like optical observing than observing at other infrared wavelengths is. What might be a better (and more fundamental) definition of the beginning of the infrared waveband?

3. Why bother with infrared astronomy? As we'll see, some aspects of observing in the IR are much more difficult than observing in the optical. What are our astrophysical motivations for wanting to observe at infrared wavelengths? (I can think of two broad categories here, though there may be more.)

4. Our reading talks about instruments for infrared observing, but it doesn't say much about how the telescope itself should be designed differently from an optical telescope in order to be efficient in the infrared. How should an infrared telescope be designed differently? (I'll probably fill in some extra information on this topic, but do the best you can with what you come across in your reading. More generally, think about what the issues are for an infrared telescope, especially at wavelengths of 10 microns and longer.)

5. Arrays that work in the mid-infrared tend to have fairly high read noise compared to optical CCDs. Why doesn't this make much difference in the total noise of the image? In general, how are infrared arrays different from CCDs?

6. Describe the basic technique by which a bolometer detects light, i.e. how it goes from the arrival of a photon to recording an electrical signal.

7. One of the first infrared telescopes was constructed by Bill Hoffman at Columbia University, and it was launched on a balloon to survey for interstellar dust. The design constraints were as follows:

   a. The detector was a germanium bolometer that was 1 mm in diameter.

   b. The field of view needed to be 2° in diameter to encompass most of the width of the Milky Way in one pass.

   c. The fastest telescope mirror that they could easily build was f/1.

   Calculate the diameter of the primary mirror. Express your answer in centimeters.

8. Glass and McLean give some examples of infrared instrumentation, but such lists tend to go out of date quickly. Look at the web sites of some of the major observatories that do work in the infrared (UKIRT, IRTF, Keck, Gemini, VLT) and see what the state-of-the-art is in terms of both near-infrared (JHK) and mid-infrared (10–25 μm) arrays. Also take a look at the instrumentation for the Spitzer Space Telescope. How many pixels do such arrays have, what is their read noise, etc.? Do any of these facilities still have single-pixel bolometers listed among their instrumentation, or have they all gone completely to arrays?

9. As you may have found in the previous problem, Gemini South is currently commissioning an infrared camera called T-ReCS. Let's use the exposure time estimator for this camera (linked from the course web page) to get a sense of how much background vs. source flux you get at 10 and 20 microns. Calculate the exposure time necessary to get a S/N = 5 detection of a K7 star (effective temperature of 4060 K) with a V magnitude of V=12. Do the calculation for both 10 microns (N band) and 20 microns (Q band). For both bands, note the total exposure time, as well as how much of the observed flux is from the source vs. from the background. (There are lots of parameters that you could set in the calculator, but just leave everything at its default value except for the things I've specified above.)

10. I have placed two raw images from UKIRT's IRCAM3 infrared array on disk in /data/astro121/infrared/. The files are dq_m_1.fits and dq_m_2.fits. (These are images of the star DQ Tau in the M filter.) Take a look at the data in IRAF and see how the images compare to optical CCD data. (You may also find it useful to look at the IRCAM documentation on the UKIRT web site; you'll need to look at their web page anyway for #7 above.)

    a. First examine each raw image. Can you find the star? Now subtract the two frames from each other and examine them again.

    b. Look at the image header parameters EXPOSED, DEXPTIME, and NEXP. What do you think these mean? Why was the observation made in this way? What is different about an infrared array that allows such fast readout times?

    c. Check the background level in the raw frames. Is this mostly bias or mostly sky background? How can you tell? (Think about how the processes that produce bias and sky counts are statistically different.)