SIMG-217: Fundamentals of Astronomical Imaging
Roger Easton – Spring 2005
Lab 2: Multiwavelength Imaging of the Orion Nebula

Materials and Equipment:

- Network-ready PC running Windows, equipped with web browser and DS9 software (available from the website http://hea-www.harvard.edu/RD/ds9)

(available in the Carlson Center Computing Lab in room 76-2205 – enter through 76-2125) Infrared and X-ray images centered on the Trapezium star cluster in the *Great Nebula* in Orion (Messier #42). These are available from class website: http://www.cis.rit.edu/class/simg217/labs/

  - ***Orion_2MASS_1micron.fits***: near-infrared image obtained by the *Two-Micron All Sky Survey* project at a wavelength $\lambda = 1.25\ \mu m$ ("micrometers" = "microns") = 1250 nm ("nanometers," 1 nm = $10^{-3}\ \mu m$) The image was taken through a broad-band filter)
  - ***Orion_Chandra_Xray.fits***: X-ray image obtained by the Chandra X-ray Observatory; covers a wavelength range $0.1\ nm \leq \lambda \leq 10\ nm$. Note that this image "measures" light with a much shorter wavelength than the 2MASS image.

PROCEDURE

1. A) Examine the infrared (IR) and X-ray images of Orion using DS9 and note their appearances. You should examine both images using both the "linear" and "log" (logarithmic) scales in DS9. Note in particular whether each image contains stars and/or "nebulosity" (glowing gas).
   B) Estimate the pixel scale (number of arcseconds per pixel), and the field of view of each image (number of arcseconds or arcminutes across the image). Use these to determine the "angular resolution" (number of pixels per unit angle). Determine if the pixel scale is constant across both images? *Hint:* You can use the tools under ds9's "analysis" menu, such as "pixel table" and/or "horizontal/vertical cut graph", to estimate the diameters of typical stars (i.e., "point sources") in each image. These estimates also serve as estimates of image angular resolution, which could be loosely defined as the "half-diameter" (radius, or "semidiameter") of each point source.)
2. Measure the *celestial coordinates* -- Right Ascension (RA = α) and Declination (dec = δ) for each of about 20 stars in the IR image. Recall that RA is measured in hours:minutes:seconds, and declination in degrees:arcminutes:arcseconds. (*Hint*: the easiest way to do this is to use the "regions" feature of ds9, and mark your selected stars with circles. Then save the set of circular regions to a file, making sure that you choose "equatorial" and "sexigesimal" under "file coordinate system.") Try to select a set of stars that cover a wide range in intensity level and are distributed throughout the image.
3. Compare the IR and X-ray images to determine whether there are *X-ray counterparts* to the stars you selected in the IR image. In other words, find X-ray sources that match the coordinates (RA,dec) of the stars detected in the infrared image. (Again, this is easily done by re-loading the regions for your selected infrared stars that you saved from the IR image – as long as you had chosen to save these regions in the

“equatorial” system in part 2!) Record the maximum intensity level of each star in IR and X-ray.

4. Now reverse the process: select 20 sources (stars) in the X-ray image and determine whether they have IR counterparts, and record the results. (It’s OK if you find a star that is detected in the IR but not in the X-ray, or vice versa.).

Lab Report Elements

Your lab writeup should include the following information

1. Objective of the laboratory (in your own words)
2. Observations
   - Pixel scale, field of view, and angular resolution of images. Determine if pixel scale and angular resolution are constant across both images.
   - Description of the appearance of the IR and X-ray images. Do the images contain stars? Nebulosity (glowing gas)? Both? How bright is the typical background sky, and how should you go about estimating this sky background?
3. Analysis and Results
   - Lists (tables) of positions and peak IR and X-ray intensities of your two sets of stars – one table for IR-selected stars, and one table for X-ray-selected stars. Don’t forget to take into account the background sky levels. (For each image, do you think this background is due to Earth’s atmosphere, to the Great Nebula, or to some other source…?)
   - Scatter Plot of these results (peak X-ray vs. peak IR intensity) – this is likely best shown on a graph where both axes are plotted as logarithms (a “log-log scale”).
   - Demonstration (“proof”) that there is (or is not) a relationship between the IR and X-ray emission intensities for the stars you’ve selected
4. Conclusions
   - Is the Great Nebula in Orion or its stars (or both) a source of X-rays?
   - Is IR intensity a good predictor of X-ray intensity, for the young stars in the Great Nebula?
   - What might the above tell you about where the very hottest (X-ray-emitting) gas is found, in this star-forming region?