Homework Assignment
High-Energy Databases and Catalogs
Due: 3:30 PM, Wednesday, September 29

For any of the questions involving calculations, you should show the details of these calculations. You will be graded not only on the answers that you provide, but on demonstration of the steps and reasoning involved in deriving those answers.

This assignment will require some further manipulation of the *Chandra* X-ray FITS image of NGC 1399 that you downloaded from the HEASARC database during the Lecture 3 Lab exercise. You will need to use your Unix account, or download and install the ds9 FITS viewer on a personal computer. CSS 1220 is open until 4:30 PM Monday-Friday.

1. a) Navigate to the directory containing the image from the lab, and open the file with **ds9**. Adjust the color table and scale to bring out the point sources.

b) Use the **Zoom** feature to display a region large enough so that multiple point sources are in the field, but small enough so that you can clearly make these out. Note that you can change the center of the field (if you would like to zoom in on an off-center region) by using the **Pan Zoom Rotate Parameters** dialog box that is opened via **Zoom** on the menu bar.

c) **Smooth** the image, experimenting with different smoothing lengths (**kernel radius**) and settling on one that optimizes your ability to identify and locate bright point sources. You may want to adjust the color scale during this process, perhaps iterating once or twice between scaling and smoothing.

d) Choose three bright sources, and draw a **circular shaped region** centered at each source. Using the region dialog box, make the circle **radius** equal to 2.5 arcseconds and express the center of the circle in **sexagesimal WCS coordinates**. Add **text** labels near these circles, using distinct identifiers for each source.

e) At this point, your Chandra image should include three labeled circles of identical radius. Save the regions in WCS coordinates as a *ds9 regions* file. Give the file a suggestive name, maintaining the **.reg** extension.

f) As you did in the lab exercise, select one of the DSS image servers and create a second tiled frame containing the optical image. WCS-align this image with the *Chandra* image.

g) **Load** the regions file onto the DSS image. Note whether there are optical counterparts to the X-ray sources.

h) *Print the regions file and a copy of the ds9 display, and attach to the homework.*

2. What is the peak value of the intensity, *above the typical background intensity,* associated with the diffuse X-ray emission? Overlay a contour with 10% of that peak value on the X-ray image. Based on this contour, what is the approximate angular diameter, in arcseconds, of the diffuse X-ray emission? in parsecs?

3. Overlay the X-ray contour constructed in Question 2 onto the optical DSS image. In general, does the extended optical emission appear to be more or less concentrated than the X-ray emission? Tile the X-ray image in Question 2 with the optical image in this question; *print and attach to this homework*.

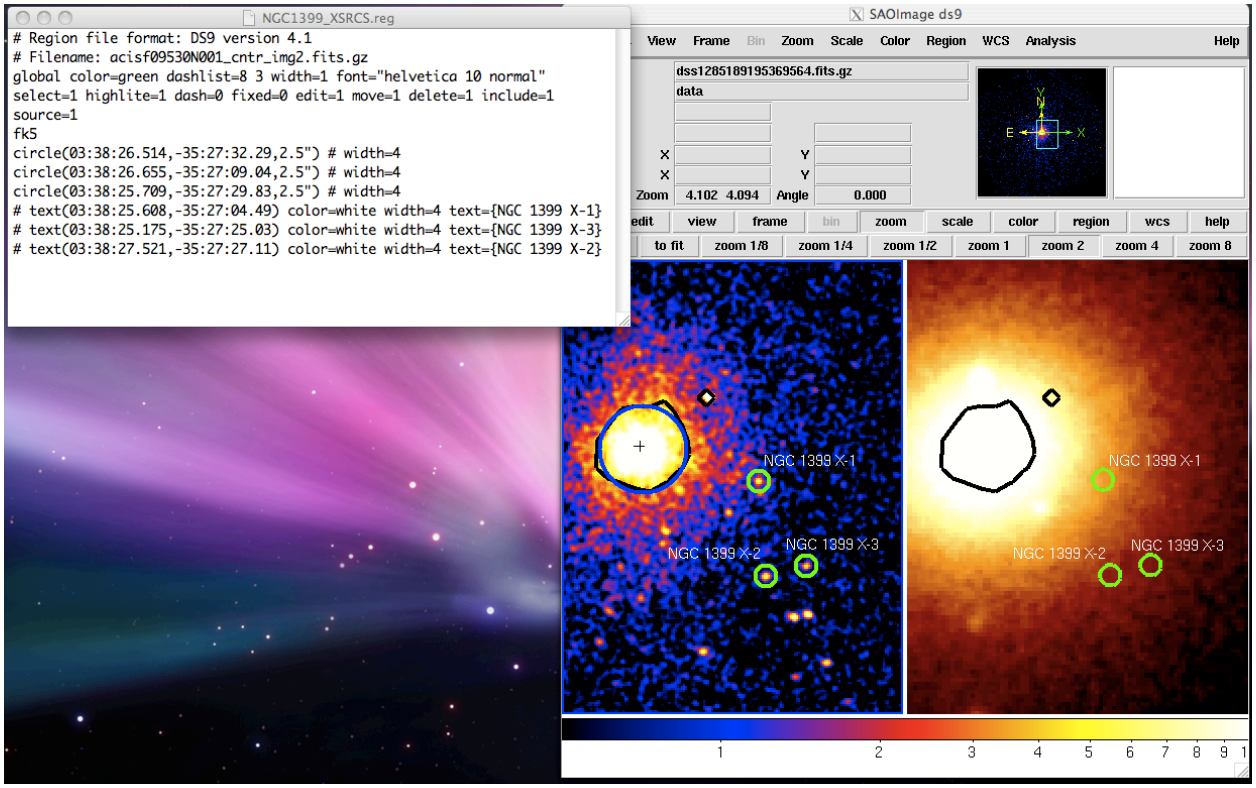
4. a) Use the catalog feature in ds9 to identify the radio source associated with the peak of the NGC 1399 diffuse X-ray emission. *Record the coordinates of this radio source.*

b) Use the NED database at http://nedwww.ipac.caltech.edu/ to search for NGC 1399 "**by name**." Take note of the retrieved coordinates, which will represent the position of the nucleus of the galaxy. What is the separation, in arcseconds, between the nucleus of NGC 1399 and the radio source? What is this separation in parsecs?

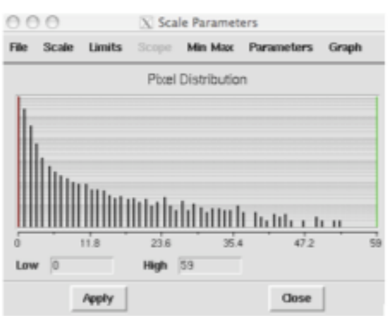
c) Search NED "**near position**" of each of your three X-ray sources, using a 10-arcsecond search radius. Is there a catalogued extragalactic source corresponding to any of these sources*? Print the NED display of your results for each of these searches, and attach to this homework.*

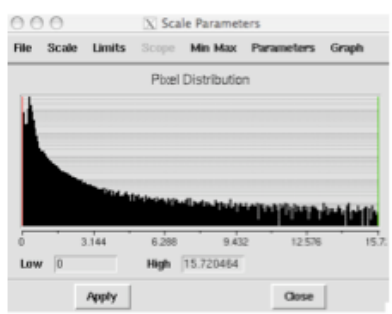
Homework Assignment Solutions
High-Energy Databases and Catalogs

1. Your ds9 and region file should looks something like this (Figure 1) – though without the contour and blue circle (these are for question 3). There probably aren't any optical counterparts to your X-ray sources.



2. It is helpful to examine the pixel distribution histogram that pops up when one sets the scale parameters (alternatively one can simply sample these values by scanning the cursor across the field – if the scale is set so that one can distinguish individual pixels near the peak at the center of the image). This is shown below for the case where the image has not been smoothed (left, Figure 2a), and for the case where it is maximally smoothed (right, Figure 2b).





To estimate the background (the brightness far from the center of the galaxy) for the diffuse X-ray emission, it is more accurate to use a smoothed image. This is because the average value of the background is less than one X-ray photon per pixel, which implies that this mean value may differ from the most typical value (which is 0 photons per pixel). The average value from a smoothed image is ~0.35 photons per pixel – corresponding to the non-zero peak in the distribution in Figure 2b (here, the peak at zero photons per pixel bin corresponds to areas outside the detector).

The peak value of the diffuse X-ray intensity – the maximum value in the pixel distribution -- will depend on how much the image was smoothed. For this exercise, whatever image you used is fine. For the image in Figure 1 this maximum is about 42 photons per pixel. The background is negligible, in comparison.

We may then generate, and apply, a single contour at the level of 4.2 photons per pixel (the closed black curve in Figure 1). We can estimate its diameter by constructing a circular region (blue circle in Figure 1) that approximates the contour, obtain the radius from the "Get Information…" option in the Regions pull-down menu, and multiply by two to get the diameter. This measure of the X-ray diameter is about 21 arcseconds, or

$$(21/60 \text{ arcminutes}) \times (18.863\ 10^6 \text{ parsecs})/(3437.8 \text{ arcminutes}) = 1920 \text{ parsecs},$$

where I have used the distance to NGC 1399 of 18.863 Mpc from NED. This was calculated using the formula derived in the Lecture 3 "supplement" that shows how to derive a physical size or separation from an angular size or separation measured in arcminutes (or radians) if one knows the distance to the source. The units will be the same for the physical size and the distance.

3. The optical emission is less concentrated than this particular definition of the X-ray extent (see the right side of Figure 1). Your image should look something like the ds9 image in Figure 1.

4. a) The NVSS catalog includes a radio source at α=03h38m29.02s, δ=-35d27m00.7s, near the peak of the X-ray emission.

b) The NED position for this object comes from the 2MASS catalog, α=03h38m29.08s, δ=-35d27m02.7s. Notice that this value comes from the "position data points", where it is expressed to higher precision than in the initial source list. Relative to the NVSS position, $\Delta\alpha$=0.06 seconds of time or 0.9 arcseconds, $\Delta\delta$=2.0 arcseconds. The resulting separation is 2.13 arcseconds or 195 parsecs. In reality, the optical/ir and radio nuclei probably coincide, and this offset is a reflection of uncertainties in the accuracy of the 2MASS and (especially) the NVSS positions.

c) For the first source in the region file shown in Figure 1, the results of a NED "near position" search of, using a 10-arcsecond search radius, is shown below. Since NED includes published lists of *Chandra* X-ray sources in external galaxies, there's a very good chance that any bright source you chose yielded a positive hit. Most of the sources in this field are Low Mass X-ray Binary systems in the NGC 1399 galaxy, though some are background active galaxies. You should print out your NED results for all three sources.