

High Energy Astrophysics Workshop

Exercise 1 : Create an image of the supernova remnant Cas A, and compare the distribution of various elements (Fe, Si, S).

The files you will need for this exercise are the event file (evt2.fits) and the bad pixel file (bpix1.fits) for the observation. These files are located on the central server; you should create links to them in your working directory. To do this type the following in a terminal, at the “%” prompt:

```
% mkdir cas-A
% cd cas-A
% ln -s /usr/local/hea-lab/cas-A/1952/primary/*evt2.fits evt2.fits
% ln -s /usr/local/hea-lab/cas-A/1952/primary/*bpix1.fits bpix1.fits
```

Check that the links evt2.fits and bpix1.fits are in your working directory by typing

```
% ls -l
```

We will use CIAO X-ray analysis software in this exercise, so set it up by typing:

```
% ciao
```

Image Display and Analysis

1. Set bad pixel file: In the command line type,

```
% acis_set_ardlib
```

which is a CIAO script. When asked for the bad pixel file type in the file name: *bpix1.fits*

2. The evt2 file contains a list of all photons captured in the Chandra ACIS observation of the source. Since the ACIS detectors are dominated by background counts outside an energy range of about 0.3—7 keV, we need to select photons with energies within that range. To do this we could use the command dmcoppy:

```
dmcoppy “evt2.fits[energy=300:7000]” cas-300-7000.fits    (Don't do this now!)
```

This would create a new file cas-300-7000.fits, but because it is a large data set, the process is slow. Instead, do this:

```
% cp /usr/local/hea-lab/cas-A/cas-300-7000.fits ~/cas-A/
```

3. To view the event file you just created we will use *ds9*:

```
% ds9 cas-300-7000.fits &
```

4. You will see a grayscale image of the supernova remnant Cas-A. Firstly, center the bright point source by playing with the binning. Try options “block 2” and then “block 1”. Now try various scalings: linear, log, histogram equaliser, minmax and zscale options. How does each affect the image? You can add colour to your image by trying the various settings in the color menu: try the bb option, for example.
5. Typically, observed X-ray count rates for astronomical sources are low enough that if a CCD is read out every few seconds, there is rarely more than one photon detected per pixel. For example, the ACIS detector on Chandra is typically read out every 3.2 seconds.

The energy of a detected photon “event” can be inferred from the number of electrons it excites in each CCD pixel. Over a long observation, this allows us to infer the energy spectrum of the source at every pixel in the image. Alternatively, we can create an image over any chosen spectral energy (as we did in step 2).

Create an energy spectrum for the entire Cas A remnant:

In ds9, choose *Region > Circle*. Draw a circle enclosing as much of the remnant as possible while minimizing the background sky enclosed.

With the circle selected, choose *Analysis > Funtools > Histogram plot*. Enter column “Energy” and bins 300:7000:100; OK.

Set the plot scale to be logarithmic in Y; choose thicker lines, and label the axes (Counts vs Energy).

You can save the resulting plot by choosing *File > Print > Print to File* in the plot window.

6. A few prominent spectral lines are listed below: how many can you identify?

Energy (keV)	Line ID	Gas T (10^6 K)
1.0	Ne X	3.2
1.34	Mg XI	3.0
1.46	Mg XII	5.0
1.83	Si XIII	4.6
2.00	Si XIV	7.2
2.16	Si XIII	5.0
2.41	S XV	6.5
2.86	S XV	7.0
3.08	Ar XVII	8.2
3.84	Ca XIX	12
6.4–6.8	Fe XXV	—

7. Now we can investigate how different elements are distributed over the remnant. To begin, extract the photons around the peaks of the Fe XXV, Si XIII and S XV lines.

To extract the photons around the peak of the Fe emission line use `dmcopy`:

```
dmcopy "evt2.fits[energy=6400:6800]" cas-FeXXV.fits
```

Two other prominent lines are Si XIII (1.83 keV) and S XV (2.41 keV). Choose energy ranges centered on these lines, and extract the photons as we did for Fe. A range of about 200 eV around each line is probably good.

8. Load the created fits files for Fe, Si, and S into ds9:

```
Frame > New frame
```

```
File > Open > Select cas-FeXXV.fits
```

Repeat for Si and S, in new frames.

9. For each new frame, roughly center the point source (Use *Bin*, *block 2*, center the image, *block 1*). Then match the frames according to the coordinate system in the header:

```
Frame > Match frames > WCS
```

Blink the frames by selecting,

```
Frame > Blink Frames.
```

You may want to adjust the blink interval. What do you see? How do the element distributions compare?

10. Now we can make a three colour image of Cas A, with Si in red, S in green, and Fe in blue, say. There are many ways to do this; here's one using ds9:

```
Frame > New Frame RGB; then set Current frame to Red.
```

```
File > Open, and open cas-SiXII.fits.
```

```
Select cas-SXV.fits for Green.
```

```
Select cas-FeXXV for Red.
```

Note that each frame is scaled independently; adjust each for a good color image. Finally, *File > Save Image as* and save a jpeg file.

View your image:

```
% xv cas-rgb.jpg
```

Exercises:

- Compare the distributions of the various elements in the supernova remnant. Based on the RGB image, identify locations where you think Iron or Silicon are in excess. For at least two such regions, select small circular regions and create the photon energy spectrum for those regions. Identify the line you predicted to be in excess.
- Cas A has a mysterious jet extending to the North-East (about 10 o'clock). What element has an excess abundance in the jet, compared to the overall remnant spectrum? (Hint: Set an elliptical or box region that encloses the jet, overplot the spectrum of the jet on the spectrum of the whole remnant, and compare the line amplitudes.)
- (Optional) To create a “true color” image, you might assign lowest energies (300 to 1500 eV) to red, the mid range (1500 to 3500 eV) to green, and higher energies (3500 eV to 10 keV) to blue. Create such an image.

Note that in ds9, you can directly specify an energy range for events: *File > Open; cas-300-7000.fits[energy=400:500]* will select and display photons with energies in that range only. So you do not need to dmcop your data.