Analysis of Point-Like Sources

By Doug Burke

Overview

- Use the CIAO documentation at

    http://cxc.harvard.edu/ciao/threads/

    http://cxc.harvard.edu/ciao/guides/

    http://cxc.harvard.edu/ciao/why/

This talk is aimed at thse users analysing ACIS imaging, "Timed Exposure" (TE) mode, data. However, most of the information presented here is still valid if you have HRC imaging data, or are analysing the zero-order image from a grating observation. And some points are important for *all* types of *Chandra* data...

1: Data

The observation data comes on CD from the CXC or from the Chandra Data Archive, via *ChaSeR* – see **http://cxc.harvard.edu/cda/**.

What issues affect my data?

- Observation date (DATE-OBS)
- Pipeline/processing version (ASCDSVER)
- CALDB version (CALDBVER)
- Observing mode (DATAMODE, READMODE)

```
unix% dmlist acisf00548N002_evt2.fits header,clean | egrep \
        'DATE |DATE-OBS|ASCDSVER|CALDBVER|READMODE|DATAMODE'
```

ASCDSVER	R4CU5UPD12.1	ASCDS version number
DATE	2000-11-29T10:39:06	Date and time of file creation
DATE-OBS	2000-02-27T03:25:15	Date and time of observation start
CALDBVER	1.8	
DATAMODE	FAINT	Data mode
READMODE	TIMED	Read mode

More recent ASC DS VER keywords look like DS 6.0.0.

Where are the issues listed?

● **http://cxc.harvard.edu/ciao/data/**

● **http://cxc.harvard.edu/ciao/caveats/**

● **http://cxc.harvard.edu/ciao/caveats/acis_caveats.html** (pipeline issues)

● **http://cxc.harvard.edu/proc_stat/rel_notes/** (SDP release notes)

● Workshop pages (CIAO & CAL)

It's also important to understand any issues that may be present in the current CALDB:

   http://cxc.harvard.edu/caldb/version_release_notes.html

   http://cxc.harvard.edu/cal/Cal_Status_Report.html

http://cxc.harvard.edu/ciao/threads/data.html

2: Data preparation

To avoid worrying, *re-process* your data:

Thread: Create a New Level=2 Events File

● Apply the latest gain correction (PHA to ENERGY/PI)

This is **TIME DEPENDENT** (CIAO 3.0.2/CXC Software Exchange page)

● Correct for CTI in your data (FI chips at -120°C only)

● "Randomize" the PHA values (yes) and pixel positions (?)

● Apply the "L2" filters (grade, status, GTI)

It's more complicated for grating data since you have to create the L1.5 file as well.

Optional filters are:

- Flag background events if in VFAINT mode
- Flag "after glow" events (acis_detect_afterglow)
- Flag "streak" events on ACIS-S4 (destreak)

The acisreadcorr tool can be used to flag "out-of-time" events (i.e., those associated with the readout streak, which is different from the

streaks that destreak removes).

Thread: Use Observation-specific Bad Pixel Files

Use the bad-pixel mask appropriate for your dataset. Be careful when analyzing multiple datasets: always reset ardlib or have a parameter directory for each dataset.

Common ACIS issues:

● How good is the astrometry?

Thread: Improving the astrometry of your data

Some ACIS-I observations show an offset of up to 1.5" for which there's a simple fix. You may also want to cross-correlate X-ray sources with those from another catalogue to improve the positions. The align_evt software (available from the Software Exchange page via the thread) allows you to easily combine multiple observations of the same field.

● Are there any background flares?

Thread: Filtering Light Curves

The ACIS chips (particularly the BI ones) are susceptible to flares in the proton background. These flares *can* impact your science analysis, particularly for *extended sources*. A lightcurve (count rate as a function of time) of the background (if you have any) can be used to search for flares.

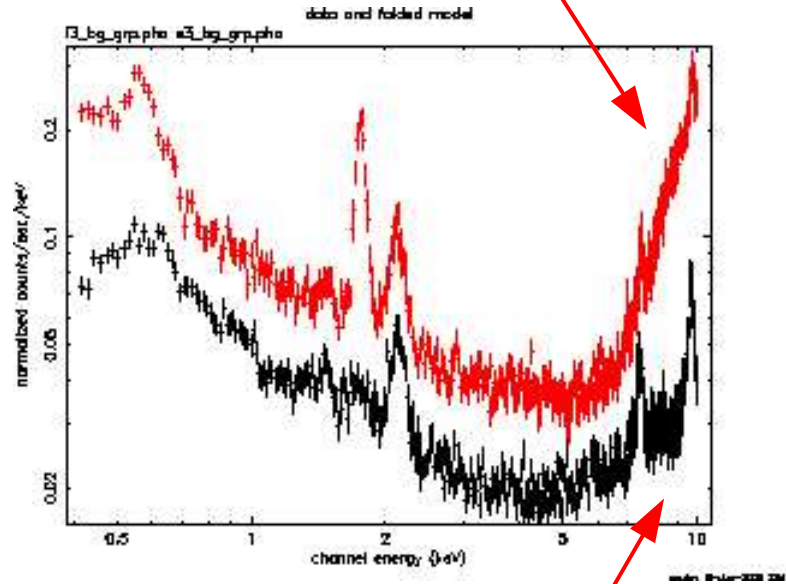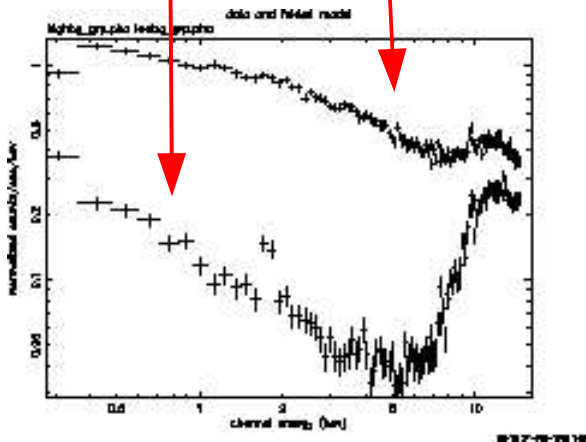**Thread:** ACIS Background Subtraction (Blank-Sky Files)

If you are going to be using the "blank-sky files" available from the CALDB then you *must* filter your data in the same manner as the background files.

http://cxc.harvard.edu/cal/Links/Acis/acis/Cal_prods/bkgrnd/current/background.html
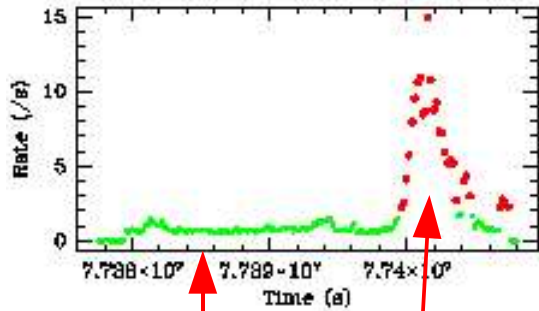
BI quiescent

Quiescent

Flare

FI quiescent

Some figures from M. Markevitch

http://cxc.harvard.edu/ciao/threads/timing.html

- Timing Analysis

Thread: Apply Barycenter Correction
Thread: Create a Phase-binned Spectrum

Thread: Basic Lightcurves
Thread: Filtering Lightcurves

SITAR – S-Lang/ISIS Timing Analysis Routines – which currently provide routines for performing a Bayesian Blocks decomposition of a lightcurve (e.g. Does your source vary within an observation? Does your source vary between observations?).

http://space.mit.edu/CXC/analysis/SITAR/

http://cxc.harvard.edu/ciao/threads/imag.html

3: Image Analysis

● What does the data look like?

ds9 is your friend, as are dmcopy & DM filters.

Thread: Using SAOImage ds9
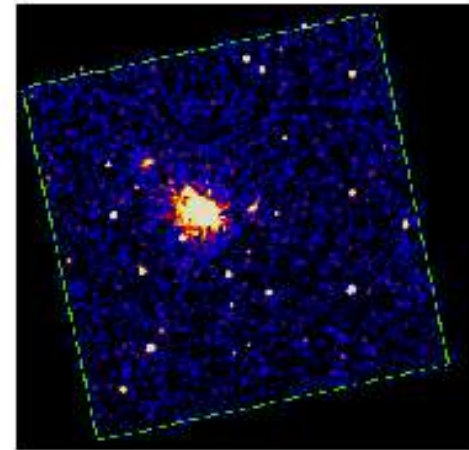
● Where are the individual chips?

A simple way is to use dmstat and a DM filter:

unix% dmstat evt2.fits" [ccd_id=3][cols sky]" median- sigm a- | egrep 'min|max'

       min: (3722.4834 3036.44702)

       max: (4954.45459 4273.25586)

The skyfov tool can be used to create a region file which gives the edge of each chip.

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Regions are also your friend (for imaging and spectroscopy)

Thread: Using CIAO Region Files
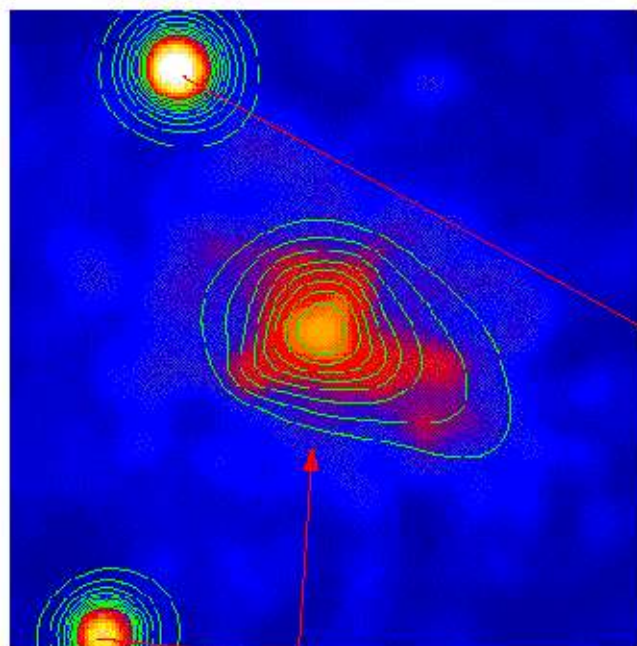
● Source detection

Thread: Detecting Sources in Imaging Observations – Overview
**Threads:** Exposure maps (reduce "edge effects")

● Diffuse emission

wavdetect and vtpdetect may detect extended emission, depending on the extent and surface brightness. Smooth the data to highlight such regions, using aconvolve or csmooth, which can be done with *or* without point sources (dmfilth).

Thread: Create an Image of Diffuse Emission

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contours: csmooth run on output of dmfilth
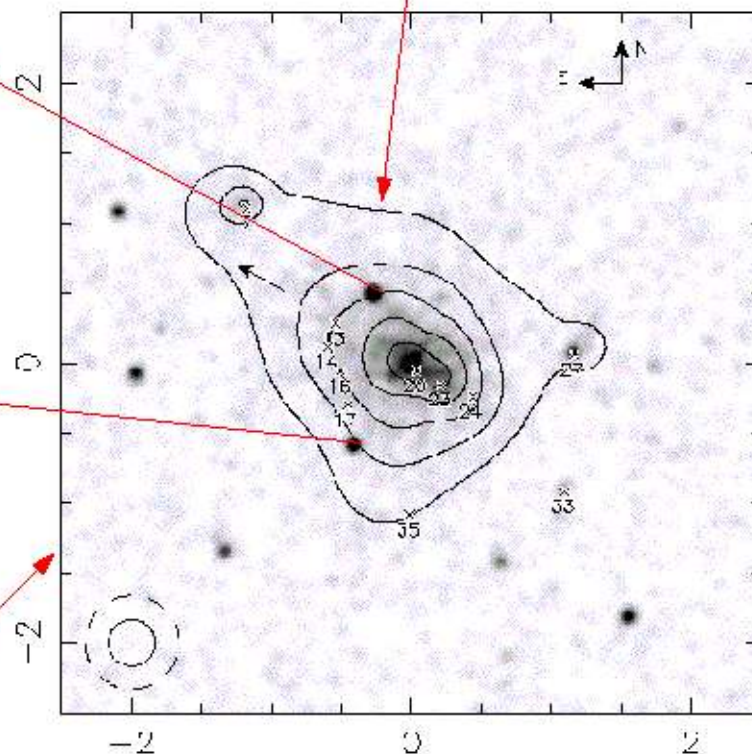
contours: output of wavdetect

Image smoothed by a gauss-ian (aconvolve)

● Spatial analysis

The counts within a region can be as simple as dmstat + DM filter. The detect tools provide a list of source properties that can be used (these tools are designed to detect, rather than characterise, sources).

The dmextract tool is versatile: as well as binning on PI or PHA to produce a spectrum, it can bin on TIME to create a lightcurve and can even handle vector columns such as SKY which allows it to be used to calculate source counts for regions. Since radial profiles are just counts within annular regions, it can therefore create radial profiles of your source.
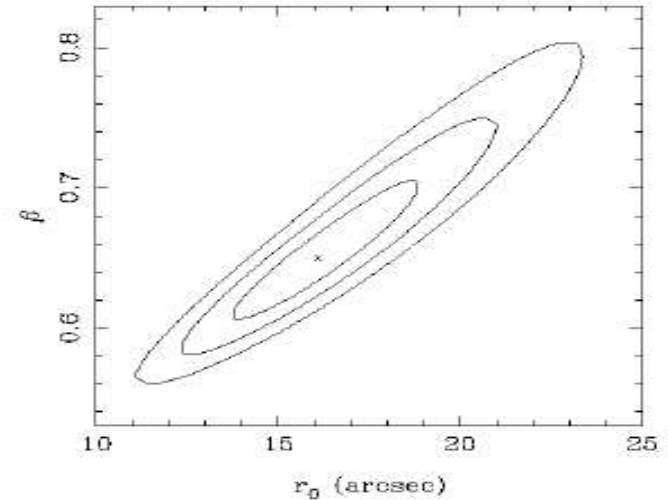
Thread: Estimate Source Counts in an Image
Thread: Obtain and Fit a Radial Profile

You may want to check the exposure map for features (bad pixels/columns or chip gaps) in your source region.
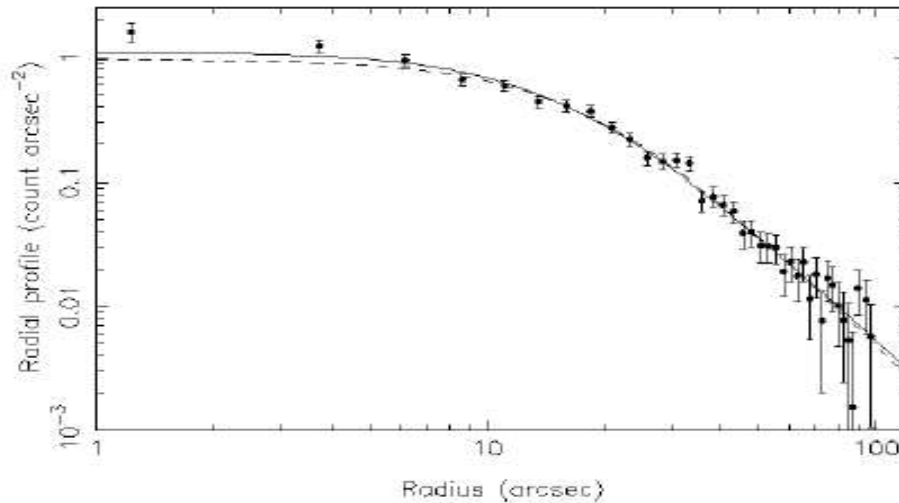
Radial profile with best fit models   Confidence contours from Sherpa

It is also possible to fit two-dimensional spatial models to your images with Sherpa and analyze the residuals (e.g. smooth them with aconvolve to look for substructure). You can include the exposure map to model instrumental effects, and the PSF may be of interest too.

**Threads:** Create a PSF + Sherpa threads + ChaRT threads

● Fluxes

The exposure map (units: count photon^{-1} cm^2 s) can convert from counts to flux. It is both spatially and energy dependent (mirror area, QE of chips, bad pixels). The ACIS contamination makes it a function of time too.

The exposure map depends on how you decide to deal with the energy dependence since you can: pick a single energy; use a spectral model to weight the ARF before combining; or analyze your data in "small" energy bands over which you assume the response is flat.

Threads: Create an Exposure Map and Fluxed Image + Calculating Spectral Weights
Threads: ACIS Contamination (we do *not* have information on spatial variation)

You may need to consider the PSF size if your extraction region is small.
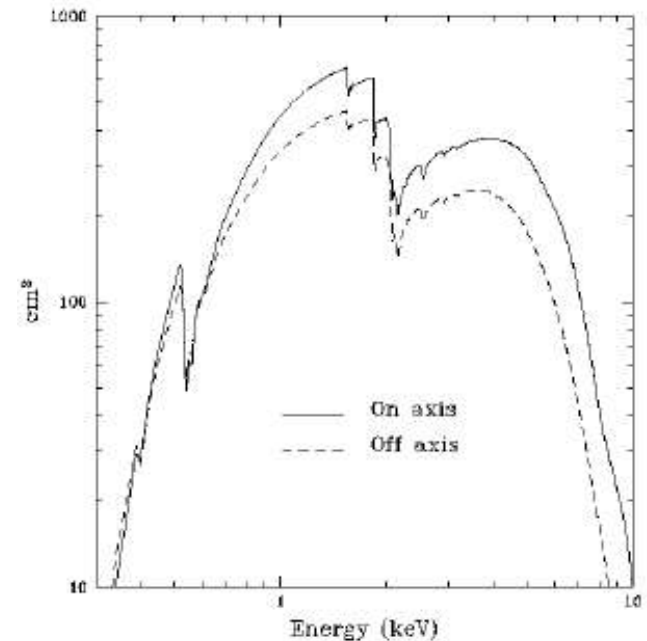
4: Imaging spectroscopy

An easy/quick way to understand the spectral differences (e.g. "hard" or "soft") of source regions in your data is to create a "true color" image.

Thread: Create A True Color Image

Some of the variation is "instrumental," since the PSF and ARF change with off-axis distance.

Note that the three images need not all be X-ray images; dmimg2jpg has been used to combine X-ray and radio data.

http://cxc.harvard.edu/ciao/threads/ispec.html
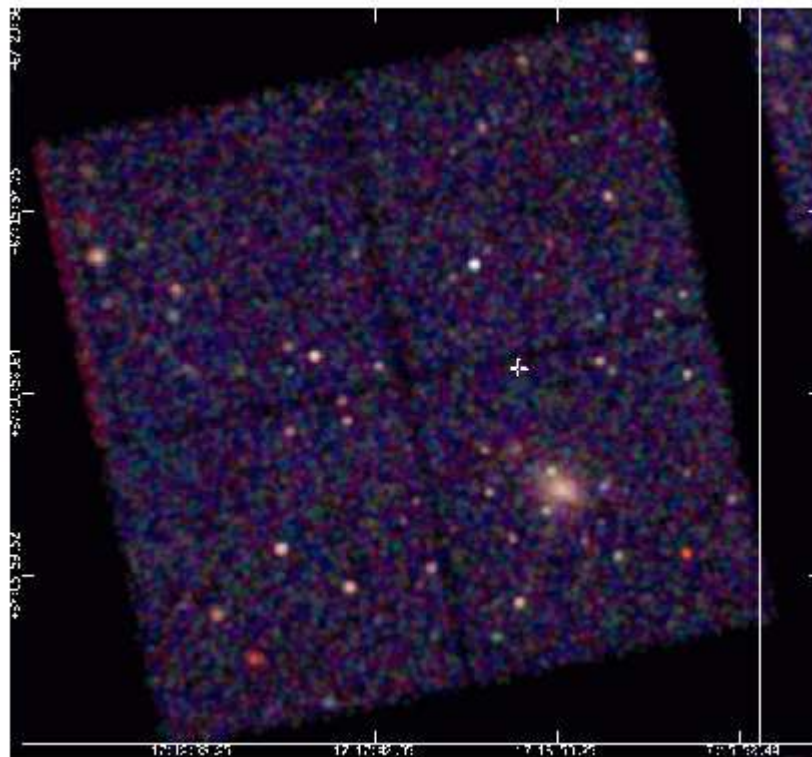
● Obtaining a source spectrum

For point-like sources, the psextract script provides a simple means of obtaining the spectrum and necessary response files (ARF and RMF).

Thread: Extract ACIS Spectra for Pointlike Sources (+ ARFs & RMFs)

The acisspec script - **http://cxc.harvard.edu/ciao/download/scripts/** - can be used to coadd spectrum (even though Peter Freeman tells us not to do this) and calculate spectra of extended sources using weighted responses.

Thread: Extracting Extended Source Spectra and Responses
Thread: Coadding Spectra and Weighted Responses

● Is my source an "extended" source? (technical *not* physical definition here!)

We do not have calibration data for each pixel, so the RMF is assumed constant over small regions (for a focal-plane temperature of -120 C the smallest-such region is 32x32 pixels for S3, the largest is 256x32 for the FI devices). By looking at the photon distribution in CHIP coordinates we can see how many such response regions our source covers.

Thread: Displaying the FEF Regions
           Covered by a Source

Thread: Weighting ARFs and RMFs:
             multiple sources

(the weightfile created by mkwarf also shows how the source counts are distributed across these "response tiles")