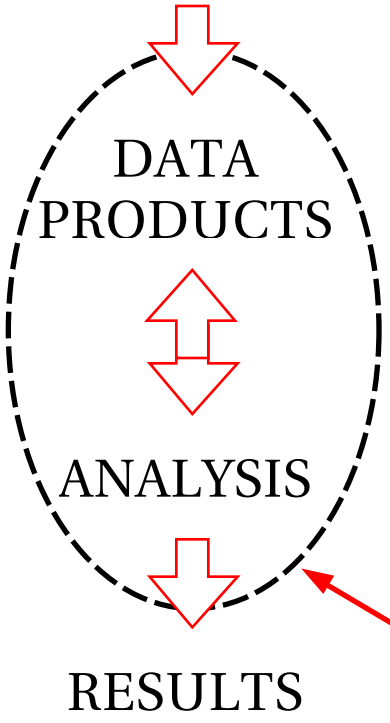
Introduction to CIAO



- Event List + Ancillary Files

- Recalibration
- Image
- Spectrum
- Lightcurve
- ...

- Source Detection
- Spectral Fitting
- Power Spectrum Analysis

CIAO + CALDB + Threads and Scripts

http://asc.harvard.edu/ciao/

- CIAO can handle N-dimensional data, with arbitrary axes. This is necessary to analyze Chandra's high-resolution, multi-dimensional datasets (eg **x**,E,t).

- CIAO is *mission independent*.

An example analysis session:

- filter the data

  lightcurve, dmgti, dmcopy
- create aspect data

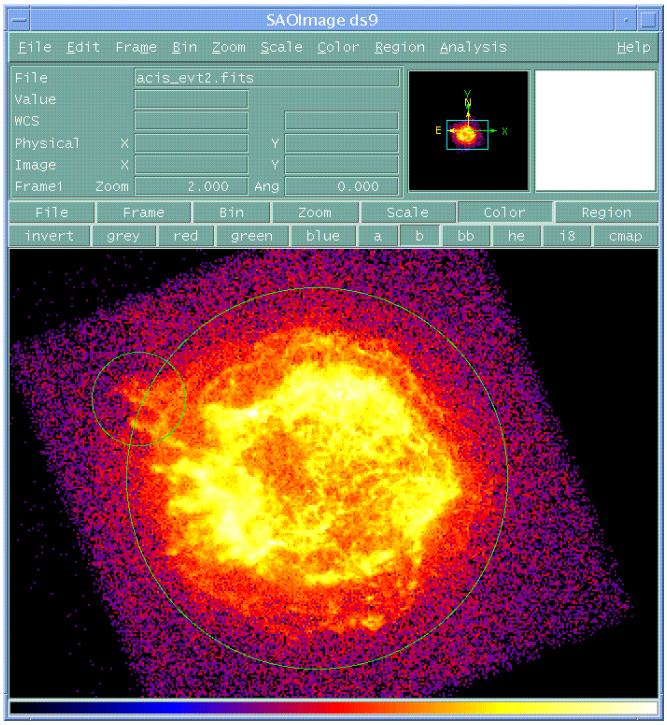
  asp_apply_sim, asphist
- source detection

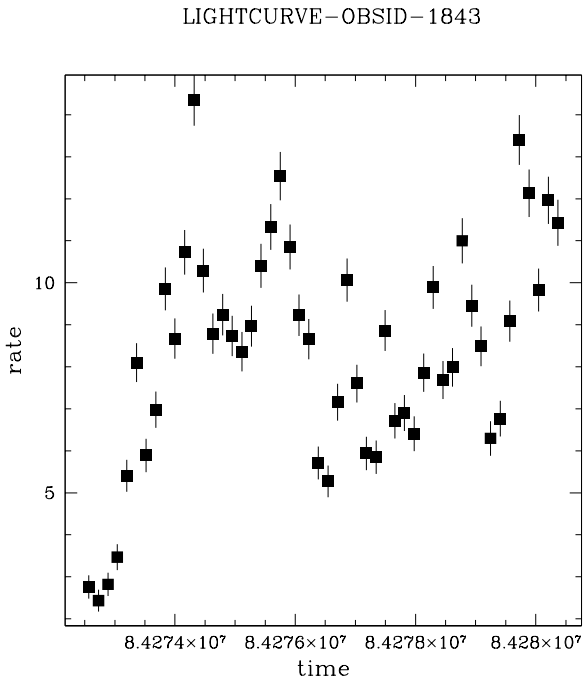
  cell-, wav-, or vtpdetect
- extract spectra

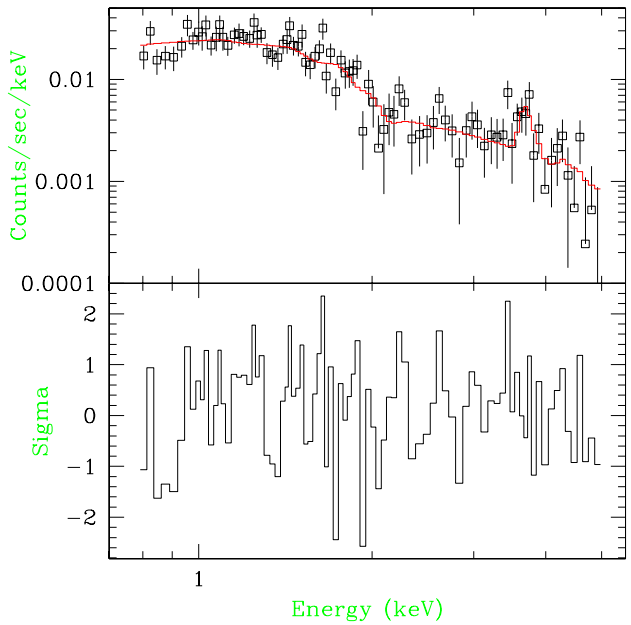
  dmextract
- calculate response

  mkrmf, mkarf
- fit models

  sherpa

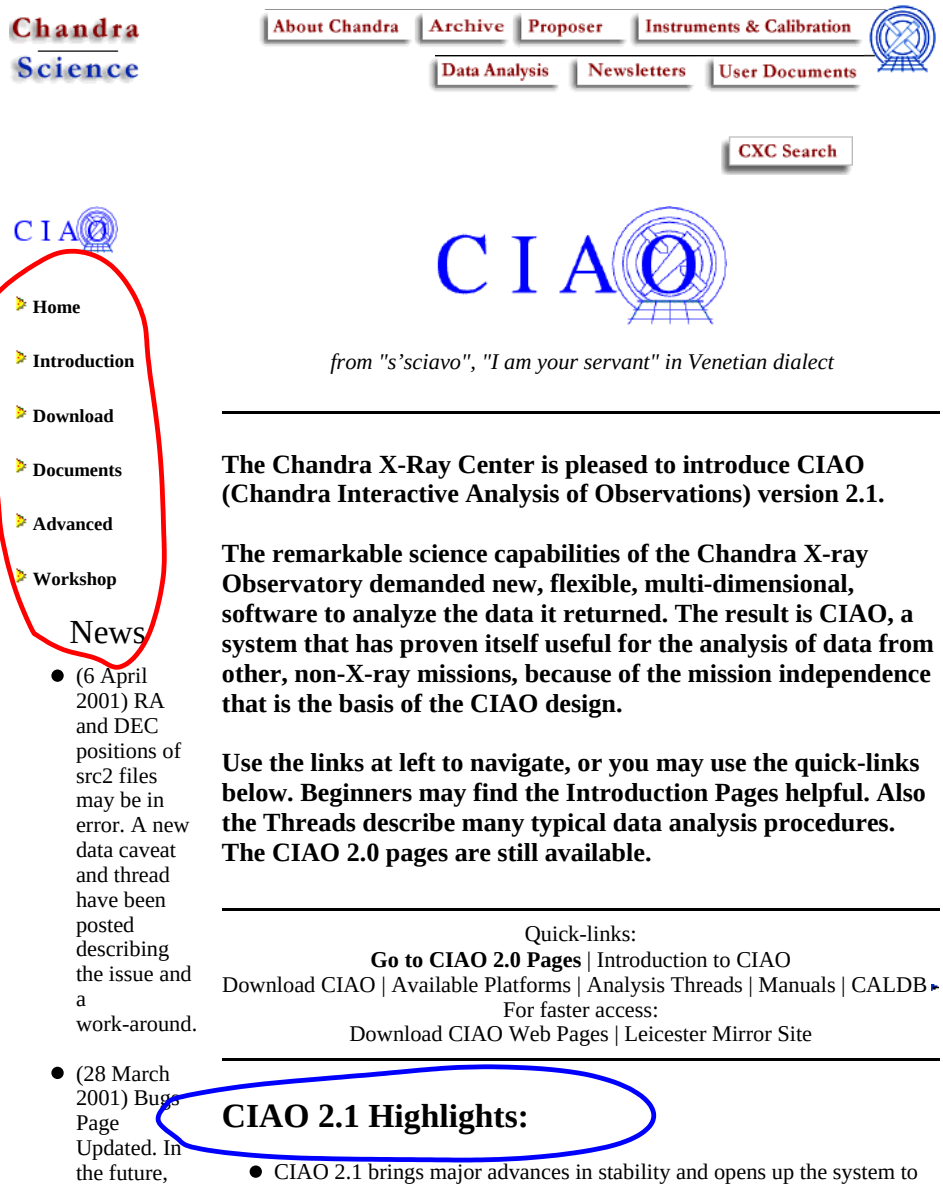






Where to start?

CIAO Data Analysis page
http://asc.harvard.edu/ciao/



In this talk, <Download/Scripts> means that more information can be found using the Scripts submenu of the CIAO Download page.

What is CIAO?

- Collection of programs (both "atomic" and complex).
- Run from the shell or via a GUI.
- Source code is available.
- Available on:
  - Solaris 2.6 (2.7, 2.8)
  - Red Hat Linux 6.2 (6.1, *NOT 7.0*)
  - Slackware 7.0
  - (SuSE 7.0)
  - Compaq Alpha/True64 Unix 4.0f

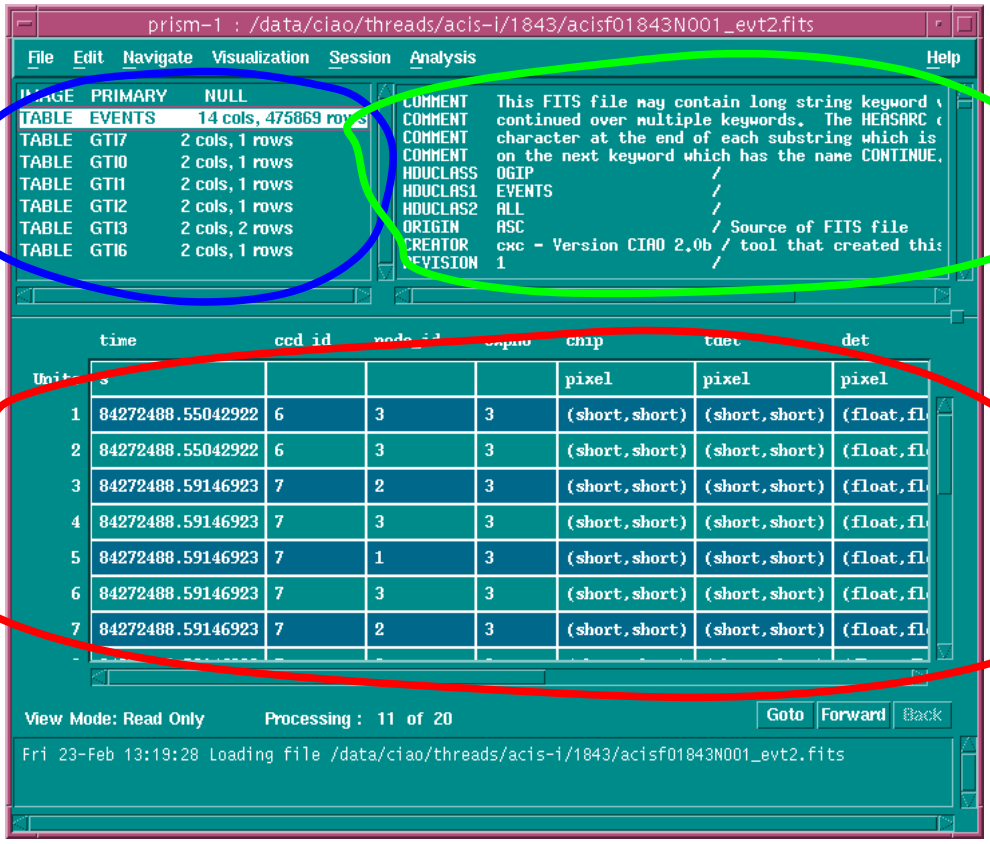
<Download/Platforms>

What formats does it work with?

- Chandra data is stored in FITS format.
- IRAF (IMH & QPOE) and ASCII files can be handled by many tools.

- Stores processing state/information along with data (keywords, subspace).
- A single file can contain multiple "datasets" - eg GTI, weight map - stored in blocks.
- Blocks can contain image or table data. Table columns can be vectors.
- Use dmlist or prism to view file contents.

Blocks **Header**



Data

```
unix% dmlist acisf01843N001_evt2.fits blocks

---------------------------------------------------------------
Dataset: acisf01843N001_evt2.fits
---------------------------------------------------------------
     Block Name          Type          Dimensions
---------------------------------------------------------------
Block    1: PRIMARY      Null
Block    2: EVENTS       Table        14 cols x 475869    rows
Block    3: GTI7         Table         2 cols x 1         rows
Block    4: GTI0         Table         2 cols x 1         rows
Block    5: GTI1         Table         2 cols x 1         rows
Block    6: GTI2         Table         2 cols x 1         rows
Block    7: GTI3         Table         2 cols x 2         rows
Block    8: GTI6         Table         2 cols x 1         rows
```

The CIAO Environment

We recommend the use of an alias called "*ciao*" to start up the system: it sets up a number of environment variables and path assignments.

- ciao -v what version you are using
- ciao -h help on how to setup CIAO

Parameter Files

Parameters to programs can be set on the command line or, as with IRAF and FTOOLS, using parameter files. These are stored in ~/cxcds_param/ by default, are called <tool>.par, and are ASCII files. A number of routines are provided to read and write to these files (e.g. plist, pset, punlearn).

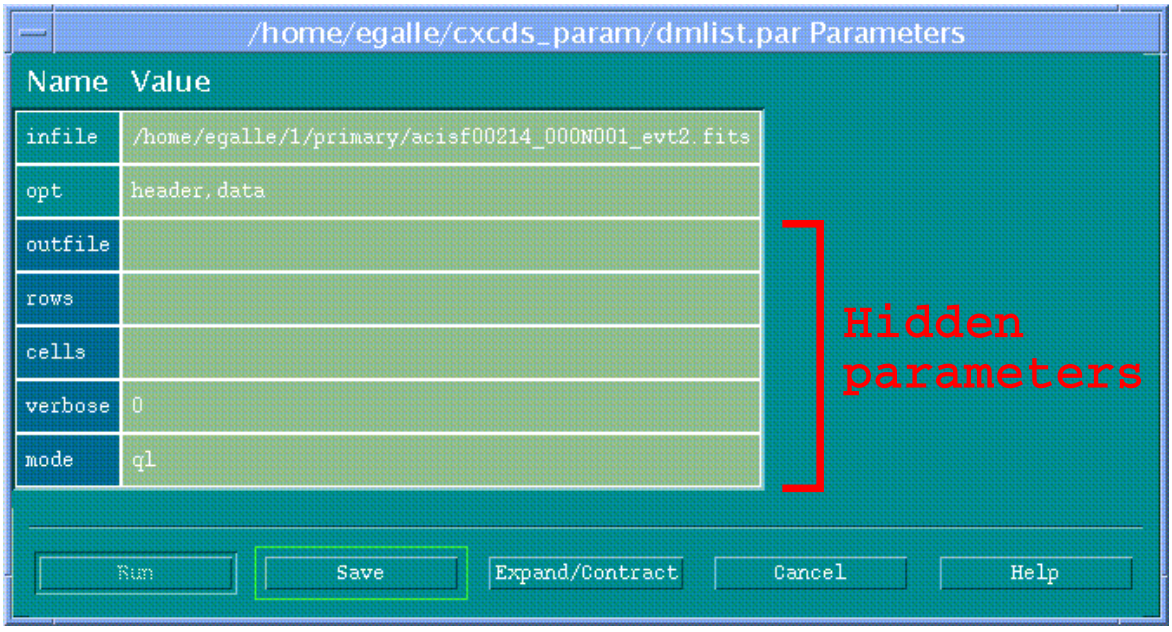
Parameters:

- provide a simple history mechanism (eg when using the GUIs)
- set parameters that rarely change (eg a bad-pixel mask for an observation)

Take care when analyzing more than one dataset!

```
unix% punlearn dmlist
unix% plist dmlist

Parameters for /home/janesmith/cxcds_param/dmlist.par

 infile =          Input dataset/block specification
      opt = data    Option
 (outfile = )       Output file (optional)
    (rows = )       Range of table rows to print
                    (min:max)
   (cells = )       Range of array indices to print
                    (min:max)
 (verbose = 0)      Debug Level(0-5)
    (mode = ql)


unix% pset dmlist infile=acisf01843N001_evt2.fits
unix% pset dmlist rows=1:2
unix% plist dmlist

Parameters for /home/janesmith/cxcds_param/dmlist.par

   infile = acisf01843N001_evt2.fits Input
                    dataset/block specification
      opt = data    Option
 (outfile = )       Output file (optional)
    (rows = 1:2)    Range of table rows to print
                    (min:max)
   (cells = )       Range of array indices to print
                    (min:max)
 (verbose = 0)       Debug Level(0-5)
    (mode = ql)
```

See ahelp parameter for more information (tab completion, redirection, mode values)



The mode parameter controls whether the parameters are prompted for or not:
q=query, h=hidden, a=automatic.

A 'l' means then the input value is "learnt", becoming the new default value.

In general the default of "ql" is the correct choice, although you may wish to use "h" when running scripts.

Getting help

CIAO comes with its own help system called ahelp. All the tools have their own help text, as well as a number of other subjects such as parameter files, the ardlib, coordinate system (coords), and the data model (dm). Each file contains a list of associated help files - to aid browsing - and is also available on the CIAO web site <Documents/Ahelp>. To read them from the command line use the ahelp command:

- ahelp [-s|-m|-l|-w] subject
- ahelp -k keyword

Web site:

- "How Tos" <Documents/Threads>
- Scripts <Download/Scripts>
- Dictionary <Documents/Dictionary>
- Frequently Asked Questions <Documents/CIAO FAQ>
- Manuals <Documents/Manuals>
- Software Exchange & the Chandra Users' Discussion Group <Advanced>

Help Desk at
http://asc.harvard.edu/helpdesk/

Filters, Regions, and GTIs

- filtering (removal of unwanted events) is an *essential* part of X-ray analysis - remove periods of high background or poor aspect solution, or exclude uninteresting sources from an image
- the DataModel (DM) provides great flexibility:

```
dmstat "evt2.fits[EVENTS][energy>300][cols -grade]"
```

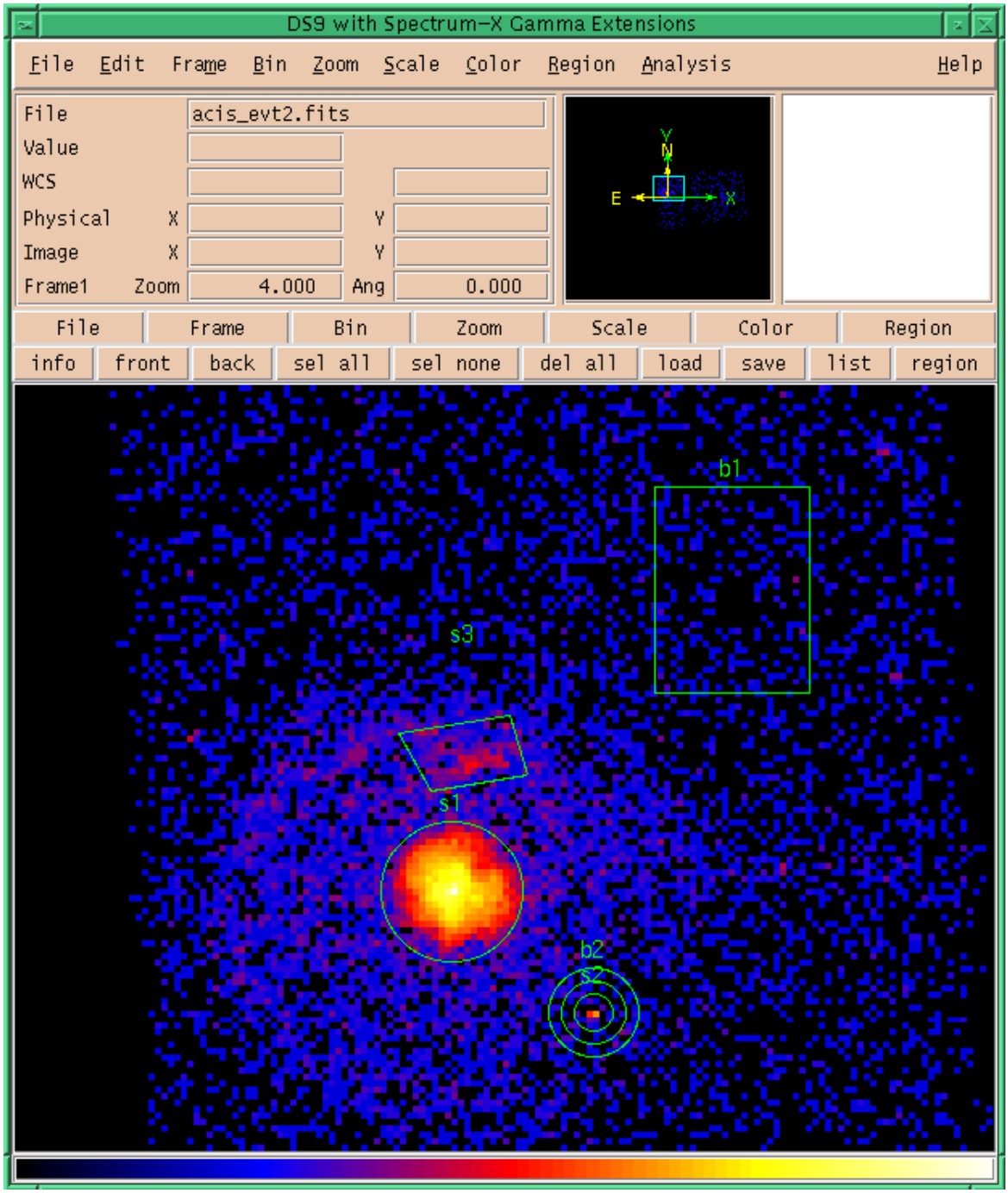
See: ahelp filtering, "Intro to DM" talk

- GTIs (Good Time Intervals) are used to define what times periods of the observation can be used (i.e. contain valid data). They are generally stored as a block in the event list.

- Regions are used to define the source and background areas of an image. They are text files that can be created manually or within ds9, and are used as a filter (e.g. "[sky=region(source.reg)]").

- Subspace records the filters applied to a file; dmlist can read this history using opt=subspace.

```
unix% dmlist "acisf01843N001_evt2.fits[ccd_id=3]" \
      subspace

-------------------------------------------------------
Data subspace for block EVENTS: Components: 1
Descriptors: 15
-------------------------------------------------------

 --- Component 1 ---
   1 time       Real8        TABLE GTI3

                  84272486.16820148: 84275888.48098728
                  84275891.68098728: 84280444.56820889
   2 ccd_id     Int2          3:3
   3 node_id    Int2        0:3
   4 expno      Int4          0:2147483647
   5 chip       [ 1] chipx   1:1024
   5 chip       [ 2] chipy   1:1024
   6 tdet       [ 1] tdetx   1:8192
   6 tdet       [ 2] tdety   1:8192
   7 det        [ 1] detx    0.50: 8192.50
   7 det        [ 2] dety    0.50: 8192.50
   8 sky        [ 1] x       0.50: 8192.50
   8 sky        [ 2] y       0.50: 8192.50
   9 pha        Int4          0:36855
  10 energy     Real4         0: 1000000.0
  11 pi         Int4          1:1024
  12 fltgrade   Int2          0:255
  13 grade      Int2          0:0,2:2,3:3,4:4,6:6
  14 status     Bit
  15 phas       Int2          -4096:4095
```



Several of the available regions displayed by DS9

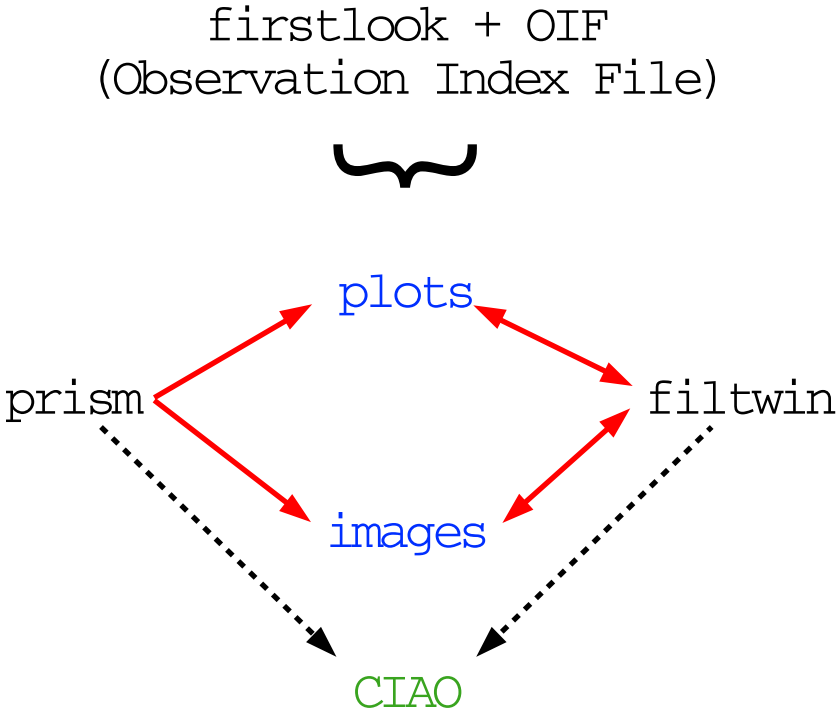
CIAO Overview

Datamodel
 copy, filter, extraction, stats, ...
Chandra Specific
   Instrument tools: update calibration, correct for instrumental effects, find & extract grating data, create aspect histograms
   Response tools: exposure map, PSF, RMF and ARF
Source Detection
   celldetect, wavdetect, vtpdetect
Timing & Background tools
 lightcurve, axbary, get_src_region
Convolutions, Transforms, & Smoothing
 csmooth, aconvolve, acrosscorr, apowerspectrum
Plotting (*)
   ChIPS
Modelling/Fitting (*)
   Sherpa (like XSPEC, but not restricted to spectral data)
Spectral Line Identification
   GUIDE

(*) powerful data manipulation and scripting capabilities are now possible with the inclusion of the S-Lang interpreted language.

<Introduction/Introduction to Tools>

CIAO in use



- prism

  An easy way to examine data files and produce images and plots

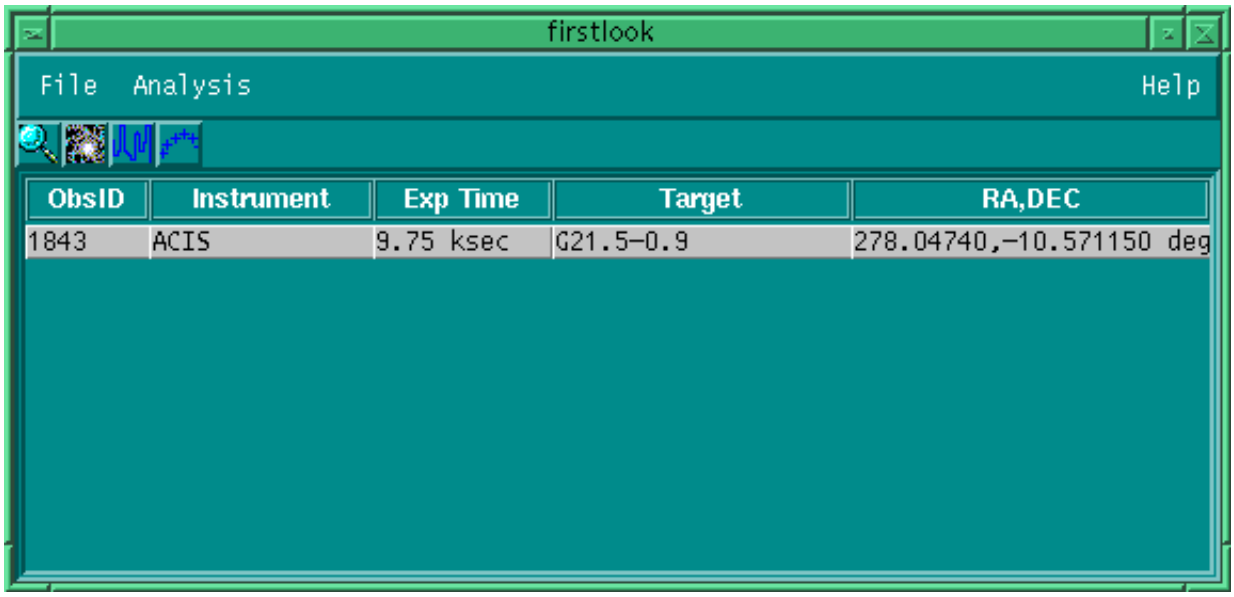
- filtwin

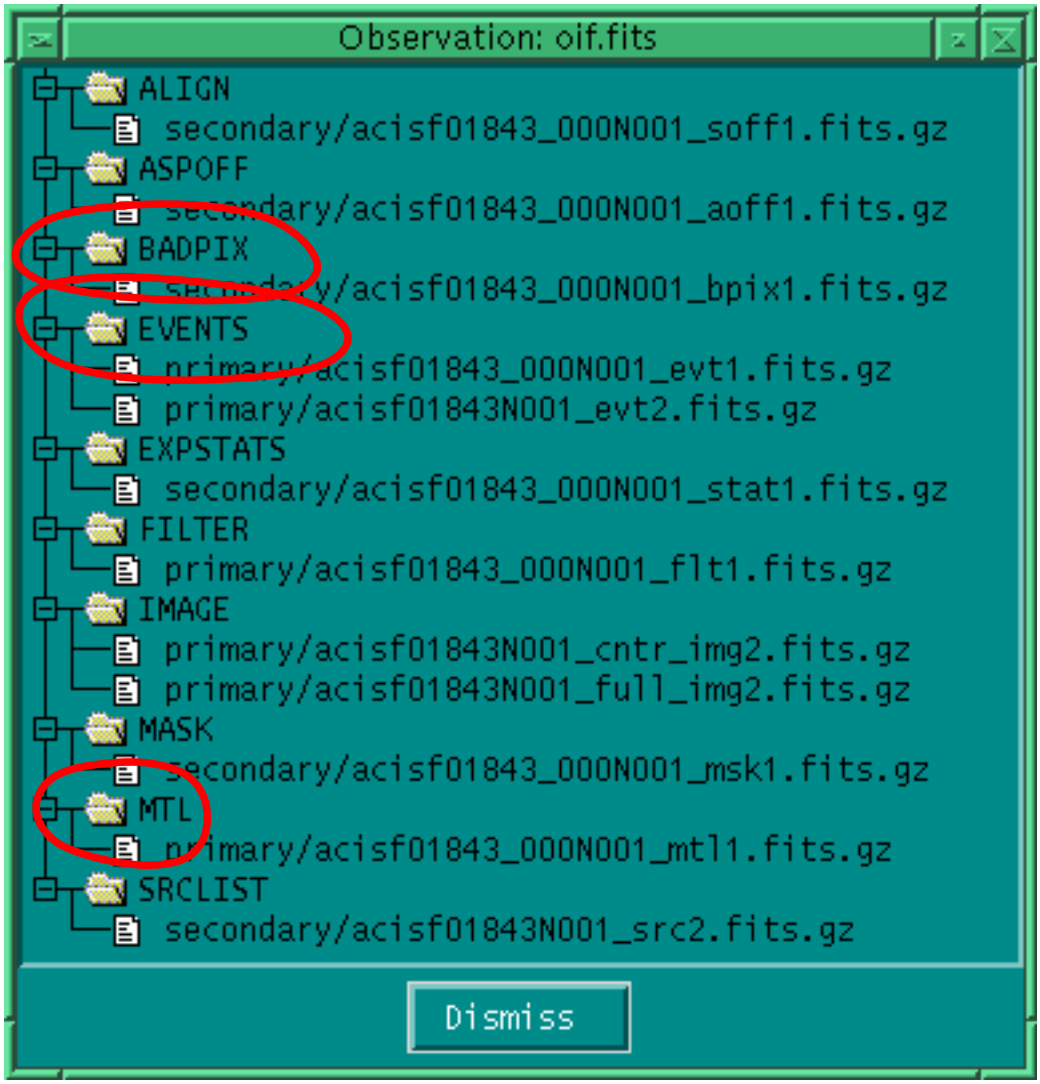
  Interactive filtering of a dataset

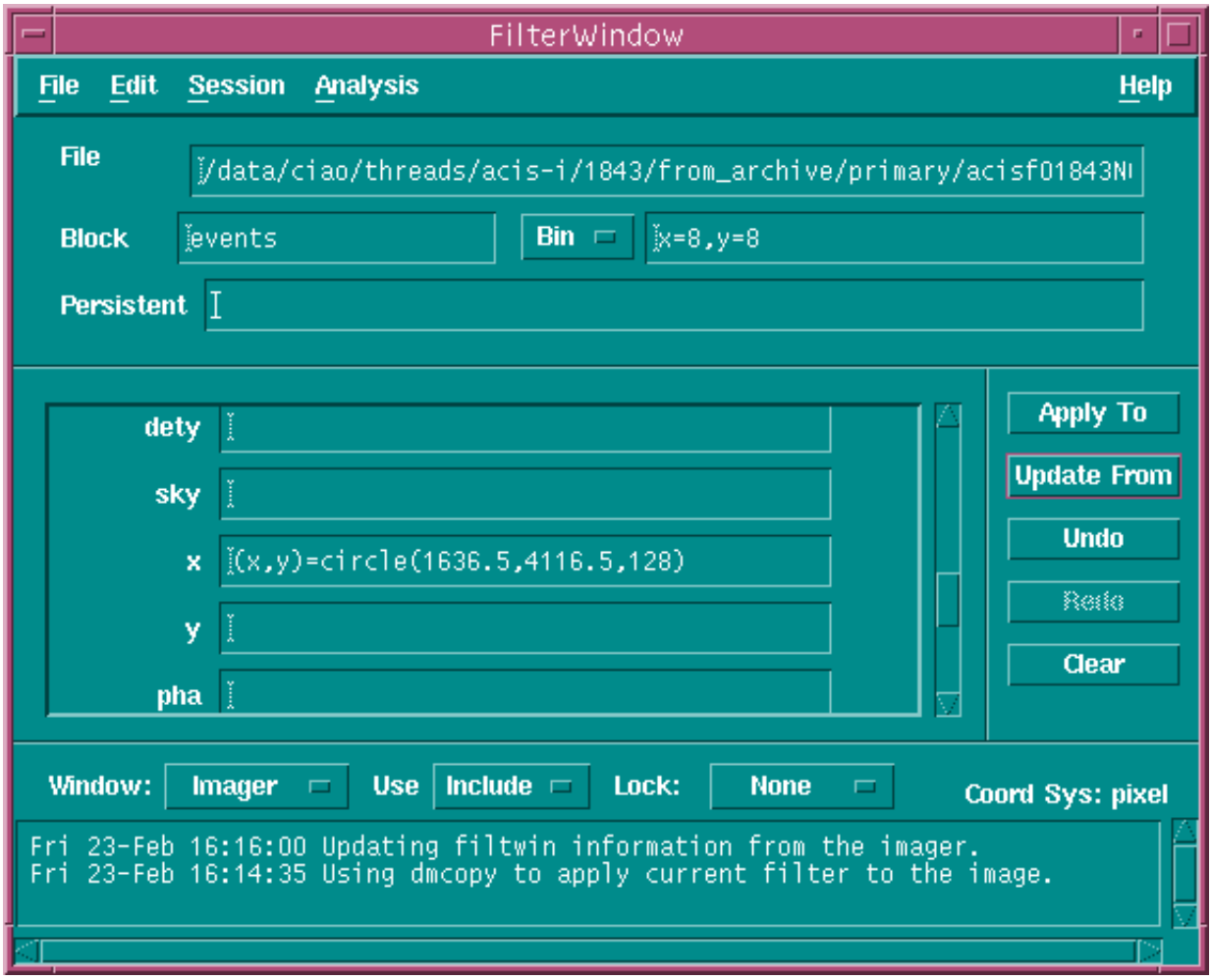
- firstlook

  Create: image, spectrum, lightcurve

The GUI tools are useful for exploratory data analysis. For the most flexibility use the command-line versions.


firstlook
File
Analysis
Help
ObsID
Instrument
Exp Time
Target
RA,DEC
1843
ACIS
9.75 ksec
G21.5-0.9
278.04740,-10.571150 deg


Observation: oif.fits
ALIGN
secondary/acisf01843_000N001_soff1.fits.gz
ASPOFF
secondary/acisf01843_000N001_aoff1.fits.gz
BADPIX
secondary/acisf01843_000N001_bpix1.fits.gz
EVENTS
primary/acisf01843_000N001_evt1.fits.gz
primary/acisf01843N001_evt2.fits.gz
EXPSTATS
secondary/acisf01843_000N001_stat1.fits.gz
FILTER
primary/acisf01843_000N001_flt1.fits.gz
IMAGE
primary/acisf01843N001_cntr_img2.fits.gz
primary/acisf01843N001_full_img2.fits.gz
MASK
secondary/acisf01843_000N001_msk1.fits.gz
MTL
primary/acisf01843_000N001_mtl1.fits.gz
SRCLIST
secondary/acisf01843N001_src2.fits.gz
Dismiss



Filtering an event file using the filtwin GUI (aka *filterwindow*)

Putting it all together: 1

Threads <Documents/Threads> are our "how-to" documents, and provide a *step-by-step guide to common tasks*.

These pages - like the whole site - are often updated, so it is worth visiting them regularly.

Current thread sections:

Introduction
: CIAO and basic tool use

Data Preparation
: Clean data, blank-sky backgrounds, correct for problems

Imaging
: Combine data, source detection, exposure maps, source profiles, ...

Imaging Spectroscopy
: Extract spectra and response data

Grating Spectroscopy
: Handle PHA2 data

Sherpa
: Fitting, and fake-ing, data

Putting it all together: 2

Scripts <Download/Scripts> are provided to automate certain tasks and are often associated with a thread. Many illustrate the capabilities of S-Lang.

General
: find response files, inspect grating data, analyze lightcurves

Imaging
: find image size, create exposure maps, make true-color images, combine obsid's, simple image statistics

Imaging Spectroscopy
: Extract spectra and response data (psextract), display response regions

Grating Spectroscopy
: add orders, extract spectra, make response functions

Reprocessing

The threads are designed to work with data processed using recent calibration data (so-called "reprocessed" data), so be careful if using older data. The estimated completion for reprocessing of old data is April 2001. The web pages contain information on the differences between the various processing versions <Documents/Reprocessing Notes> and <Documents/Data Caveats>.

Calibration

Much of the interaction with the calibration database (CALDB) is now hidden and automatic (e.g. the setting of gain or QE maps), although it can be over-ridden if required. The main times a user will interact with the CALDB is when making a RMF (which needs a Fits Embedded Function file), or when querying the PSF library.

- http://asc.harvard.edu/caldb/
- http://asc.harvard.edu/cal/