

Introduction to CIAO

(Chandra Interactive Analysis of Observations)

From "*ahelp ciao*"....

- A powerful data analysis system originally written for the needs of users of the *Chandra X-ray Observatory*.
- Built to handle N-dimensional data without concern about which particular axes are being analyzed: Chandra is the first mission with 4-dimensional data (2 spatial, time, energy) in which each dimension has many independent elements.
- It is mission independent (a part from a few instrument specific tools).



- Provides users with the ability to filter down and project the 4-D Chandra event data to manageable sizes and convenient arrays: all CIAO tools take a *'filtering and binning'* specification on the command line, making use of a general purpose *'regions'* syntax: *"ahelp dm"* for information on the Data Model that makes all this possible.
- To keep track of how the data had been filtered and binned CIAO relies on the *'data subspace'*. The tools keep track of this subspace automatically and allow users to review previous data processing: see *"ahelp subspace"*.
- The CIAO design allows close interconnection of tools. For example, the output of any of source detection program can be fed into *dmextract* to create a summed spectrum which can then be fit in *Sherpa*.



- The modeling and fitting tool *Sherpa* is central to the CIAO system. *Sherpa* performs forward fitting of models to data in N-dimensions. *Sherpa* includes the "S-Lang" language which can be used for scripting and data manipulation. GUIDE links *Sherpa* results to the APEC/APED plasma database, enabling the identification of spectral lines and the use of their properties in further fitting. See "*ahelp sherpa*", "*ahelp slang*", "*ahelp guide*".
- In order to allow users of Chandra data to use pre-existing tools, all CIAO tools read and write several formats, including FITS images and tables (which includes event files) and IRAF qpoe and imh files.

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News

(17 April)
CIAO software now available on CD. Email the [CXC Helpdesk](#) for more info.

(5 April) New [data caveat](#) regarding potential degradation of the low energy QE.

from "s'sciavo", "I am your servant" in Venetian dialect-

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The [Chandra X-Ray Center](#) is pleased to introduce the *Chandra Interactive Analysis of Observations* (CIAO) version 2.2.1 on 13 December, 2001.

The remarkable science capabilities of the Chandra X-ray Observatory demanded new, flexible, multi-dimensional, software to analyze the data it returned. The result is CIAO, a system that has proven itself useful for the analysis of data from other, non-X-ray missions, because of the mission independence that is the basis of the CIAO design.

Use the links at left to navigate, or you may use the quick-links above. Beginners may find the [Introduction Pages](#) helpful. Also the [Threads](#) describe many typical data analysis procedures.

CIAO 2.2.1 Improvements

- **Sherpa background filtering** has been generalized, simplifying background fitting of source and background data



100%

<http://asc.harvard.edu/atomdb/>





CIAO help!

AHELP

CIAO comes with its own help system called **ahelp**. Tools (e.g. dmcopy, wavdetect), applications (e.g. sherpa) and numerous concepts (e.g. regions, coords, dmsyntax) have their own help text. (The entire collection of ahelp files is currently about 500 pages!)

The **ahelp** command accesses the CIAO on-line documentation:

% **about** <word> (e.g. about contour) gives a list of subjects related to the query

% **ahelp** <name> (e.g. ahelp tgextract) provides by default the ASCII version of the help file



% **ahelp -w <name>** loads into a browser the HTML version supplied with the CIAO distribution

NEW in CIAO 2.2:

% **ahelp -i <name>** access the CIAO site which contains HTML and PDF versions of the help files (often more up-to-date than the released ones).

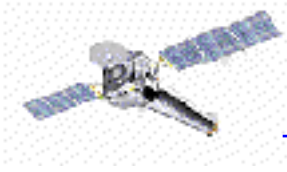
DATA ANALYSIS THREADS

More than 90 CIAO processing recipes designed to teach users by leading step-by-step through a procedure.

More added weekly (look for the **"new"** or **"updated"** icons!).

Several threads and groups of threads have been or will be made more automated in the form of scripts.

PDF version available on-line.



MANUALS

CIAO manuals are currently being written or updated: major updates for CIAO2.2 were done to the DM (Data Model/Data Manipulation), Detect, Sherpa and Chips Manuals. A CIAO-SLANG manual is in progress.

CIAO WEB PAGES

Read the *Dictionary, FAQ, Bugs, Caveats*

HELPDESK

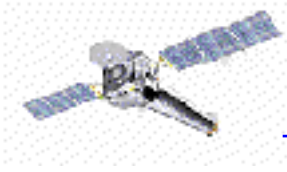
When everything else fails....

<http://cxc.harvard.edu/helpdesk/>



What is CIAO?

- Collection of programs (both "atomic": tools, and "complex": applications).
- Generally run from the shell; some part can be run from a GUI.
- Source code is available.
- Available on several platforms; currently supported:
 - Solaris 2.6 (2.7, 2.8)
 - Red Hat Linux 6.2, 7.1
 - Slackware 7.1
 - SuSE 7.2 (7.x)
 - Alpha OSF4.0f



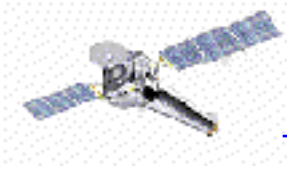
What formats does it work with?

- 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” (e.g. GTI, weight map, regions) stored in “blocks”.
- Blocks can contain image or table data. Table columns can be vectors.
- Use `dmlist` or `prism` to view file contents.

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



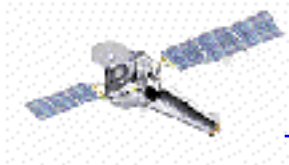
Parameter Files

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 (e.g. when using the GUIs)
- set parameters that rarely change (e.g. a bad-pixel mask for an observation)

Be careful when analyzing more than one dataset!



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](#)
- 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`.



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

Modeling/Fitting: (*) Sherpa

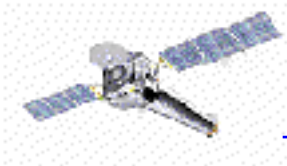
Spectral Line Identification: GUIDE, ISIS

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



The “Data Model” and the Data Manipulation Tools

- The CXC analysis and processing software is built on a common versatile interface library called the CXC Data Model (or just DM).
- The DM provides users with a powerful built-in data filtering and binning capability.
- The name “Data Model” reflects the fact that the interface can be used on data files of different format (all described by a single abstract description - the same “model”) in a transparent way.



- As of CIAO2.2, the format supported by the DM library include: FITS, IRAF QPOE and IRAF IMH.
- An important characteristic of the DM is that ANY program that asks for a data file name as input, will accept a virtual file string which will cause the program to see a filtered version of the file in question.
- The “virtual file” syntax is also commonly used to create on disk a filtered version of the input file.
- Another important characteristic of the DM is that all columns of event lists are treated “equally”: for example binning is allowed not only in spatial coordinates but also in e.g. time, or energy coordinate, giving the ability of creating multidimensional images in space-energy, or space-time, etc.



SUMMARY OF MAIN DATA MODEL PROPERTIES:

FORMAT INDEPENDENT

POWERFUL FILTERING AND BINNING

USAGE OF "VIRTUAL FILES"



Data Manipulation Tools

The four DM “core” tools are:

dmlist: list contents or structure of a file

dmcopy: filter and bin tables and images

dmextract: make a histogram table file (e.g. PHA file) from a table column. Generate count histogram on supplied regions for a spatial table or image file.

dmgti: create custom Good Time Intervals (GTIs) from a constraint expression

30+ “dmttools” are included in CIAO2.2

CXC



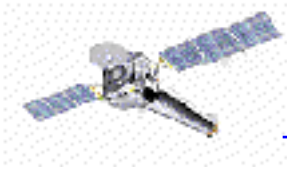
DATA MODEL SYNTAX

(See [ahelp dmsyntax](#))

- All CIAO tools use the DM library and therefore accept as input “virtual files” described using the DM syntax.
- In the DM context a “virtual file” is represented by a filename followed by a series of optional qualifiers in square brackets []:

filename[block][filter][columns/binning][options][rename]

where:



block - is the "section" of the file to use

filter - is the filter to be applied

columns/binning - specifies either the columns from a table to be included in an output table or the binning. When binning the data to generate an n-dimensional image, the range and binsize (min:max:bin) must be specified.

options - a sequence describing special options for the DM library

rename - specifies a name for the new block

Note that:

- the order of the qualifiers generally matters, however...
- not all qualifiers need to be present always



Simple examples of “virtual files”:

● Select the first three columns of the EVENTS block by number:
acisf01843N001_evt2.fits[EVENTS][time=84245787:84247000][cols #1,#2,#3]

or by name:

acisf01843N001_evt2.fits[EVENTS][grade=0,2,3][cols time,ccd_id,node_id]

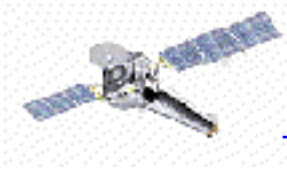
after filtering in time or grade

● Bin an events file to create a PI spectrum for a specified region (input of dmextract):

acisf01843N001_evt2.fits[sky=region(mysrc.reg)][EVENTS][bin pi=1:1024:1]

or an image (input of dmcoppy):

acisf01843N001_evt2.fits[EVENTS][pha<100][bin x=320:480:4,y=320:480:4]



In the examples above:

block: [EVENTS]

filter: [time=84245787:84247000]
[grade=0,2,3]
[sky=region(mysource.reg)]
[pha<1000]

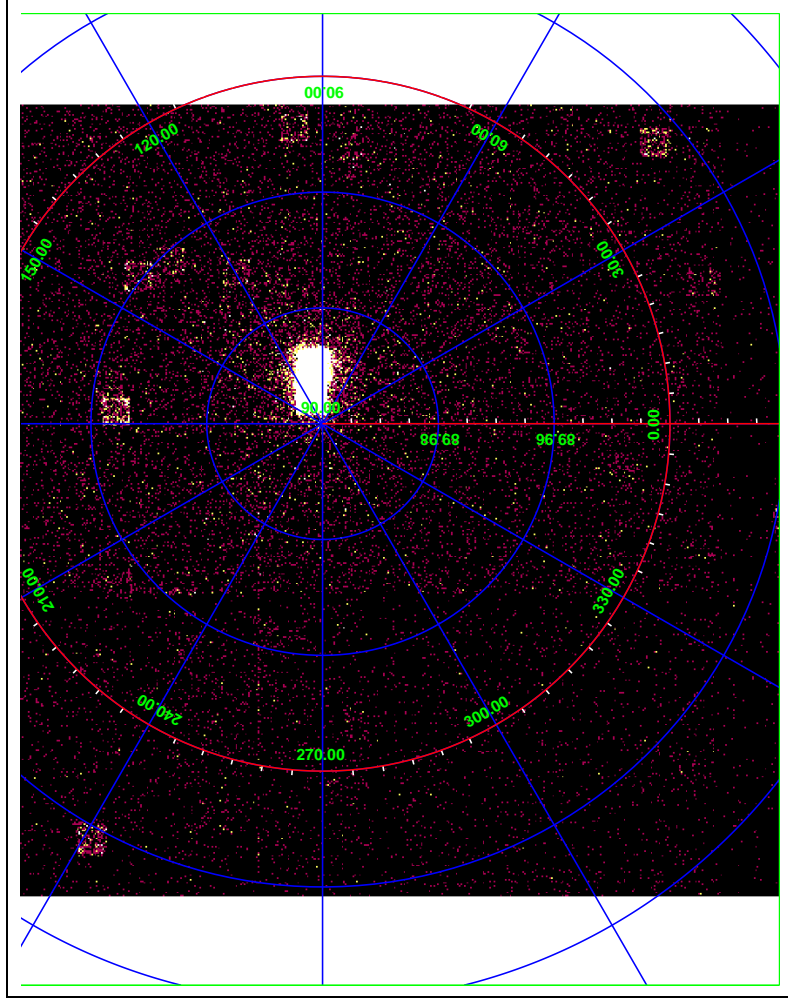
columns/binning:

[cols time,ccd_id,node_id]
[cols #1,#2,#3]
[bin pi=1:1024:1]
[bin x=320:480:4,y=320:480:4]

DM Examples 1: Detector Image

Imaging on multiple coordinate systems: first, let's look at a region in detector coordinates, filtered on energy and time.

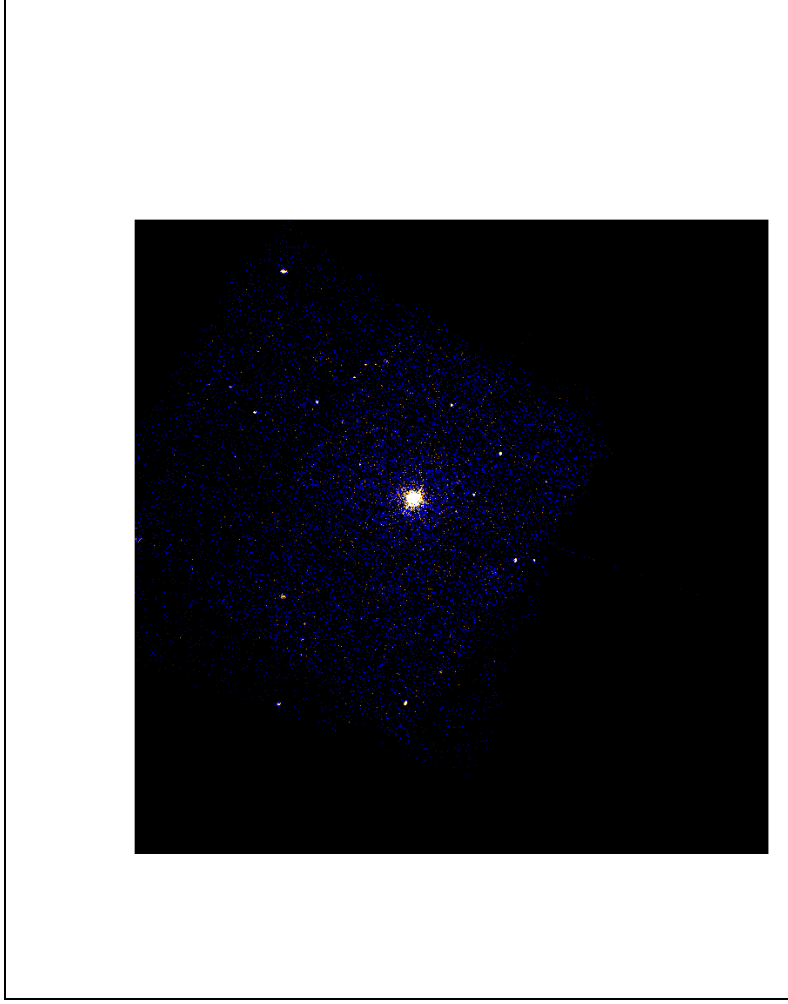
```
dmcoppy "merge3e.fits[energy=500:2000,  
time=:63940080,63940180:] [bin detx=3500:4500:2,  
dety=3500:4500:2]" det.img
```



DM Examples 2: Sky Image

Now look at the same photons but in sky coordinates

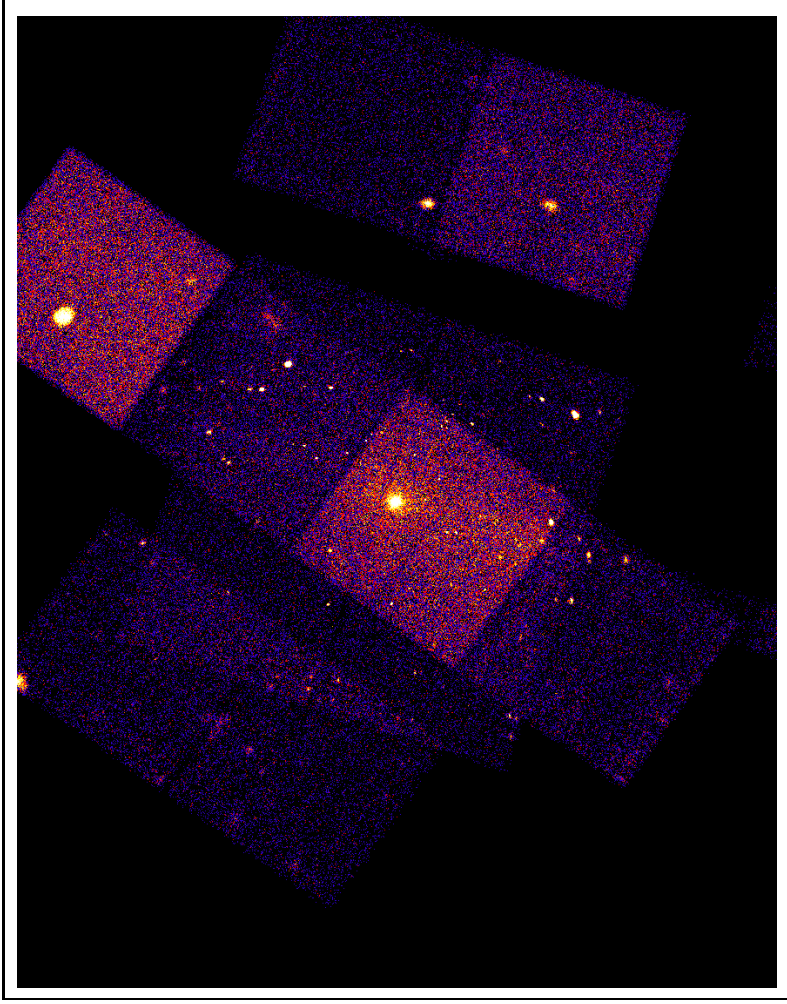
```
dmcopy "merge3e.fits[energy=500:2000,time=:63940080,63940180:,  
      detx=3500:4500,dety=3500:4500]  
      [bin x=3200:4800:2,dety=3200:4800:2]" sky.img
```



DM Examples 3: Merged sky image

The whole field was created by merging three separate observations.

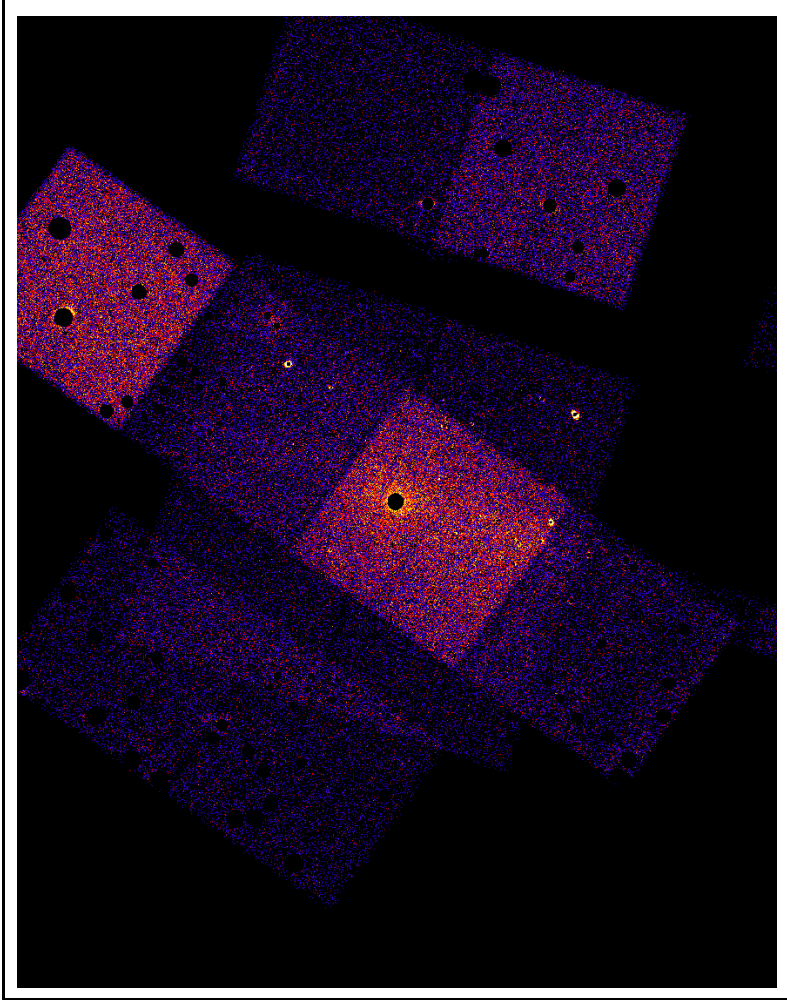
```
dmmerge "786.fits,787.fits,1730.fits" outfile=merge3e.fits
```



DM Examples 4: Removing sources

We can generate a background image by removing sources found by the automatic source detection program.

```
dmcopy "merge3e.fits[exclude sky=region(gg.reg)]" exclude.fits
```



DM Examples 5: Infrared spectroscopy data

- ISO data: LWS LSAN file. This is a very simple file but wavelength and flux for the different detectors and scans are mixed together. We can use the DM tools to isolate a single scan and dump wavelength versus flux for it.

```
dmcopy "lsan59901083.fits[lsanscnt=4][cols lsanwav,lsanflx]"  
      subset.fits  
dmlist "lsan59901083.fits[lsanscnt=4][cols lsanwav,lsanflx]"  
      data,raw outfile=lis.asc
```

