



CIAO Analysis

Archive & Data Preparation

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Overview

Chandra Information

Getting Help

Data Acquisition

reprocess

source detect

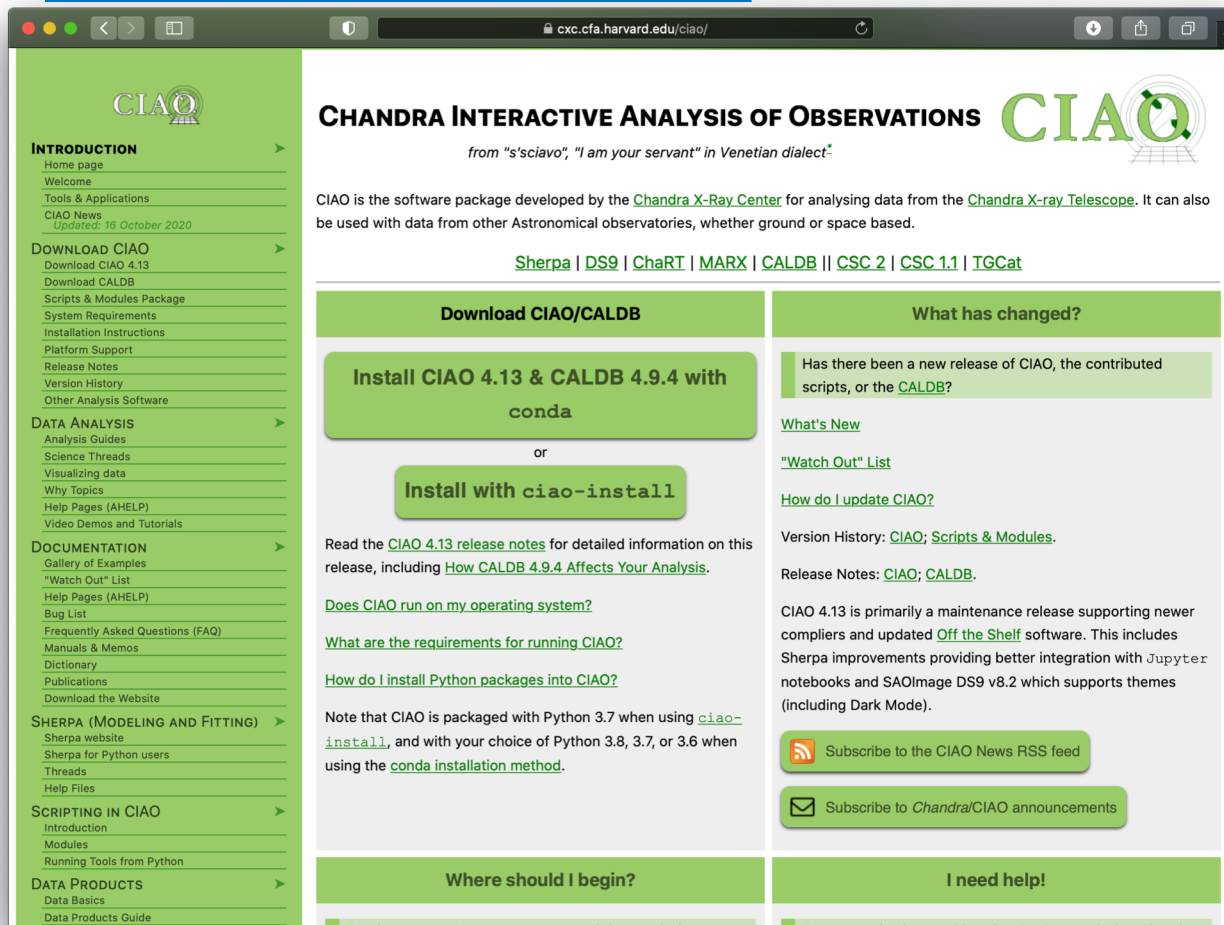
deflare

Data Preparation



First, a quick detour on documentation and getting help...

cxc.harvard.edu/ciao



The screenshot shows the CIAO website documentation page. The main heading is "CHANDRA INTERACTIVE ANALYSIS OF OBSERVATIONS CIAO" with a subtitle "from 's'sciavo', 'I am your servant' in Venetian dialect". Below this, it states that CIAO is software developed by the Chandra X-Ray Center for analyzing data from the Chandra X-ray Telescope. A navigation bar lists various observatories: Sherpa | DS9 | ChaRT | MARX | CALDB | CSC 2 | CSC 1.1 | TGCat.

The page is divided into two main columns. The left column contains a sidebar with a table of contents including sections like INTRODUCTION, DOWNLOAD CIAO, DATA ANALYSIS, DOCUMENTATION, SHERPA (MODELING AND FITTING), SCRIPTING IN CIAO, and DATA PRODUCTS. The right column contains the main content area with sections: "Download CIAO/CALDB" (offering installation options for conda and ciao-install), "What has changed?" (providing links for "What's New", "Watch Out" List, "How do I update CIAO?", and "Version History"), and "Where should I begin?" and "I need help!" (with RSS and email subscription options).

Science Analysis “Threads”



- ▶ Science Threads are the most important document type.
 - ▶ over 150 CIAO and Sherpa threads, designed to teach users the approach and concerns that go along with analysis
 - ▶ organized primarily based on science analysis categories
 - ▶ updated and added to as needed; look for “new” and “updated” icon tags
- ▶ A thread is *just an example* on approaching a problem.

CHANDRA
X-RAY OBSERVATORY

Last modified: 10 December 2020

CIAO

INTRODUCTION ▶

- Home page
- Welcome
- Tools & Applications
- CIAO News
Updated: 16 October 2020

DOWNLOAD CIAO ▶

- Download CIAO 4.13
- Download CALDB
- Scripts & Modules Package
- System Requirements
- Installation Instructions
- Platform Support
- Release Notes
- Version History
- Other Analysis Software

DATA ANALYSIS ▶

- Analysis Guides
- Science Threads
- Visualizing data
- Why Topics
- Help Pages (AHELP)
- Video Demos and Tutorials

DOCUMENTATION ▶

- Gallery of Examples
- "Watch Out" List
- Help Pages (AHELP)
- Bug List
- Frequently Asked Questions (FAQ)
- Manuals & Memos
- Dictionary
- Publications
- Download the Website

SHERPA (MODELING AND FITTING) ▶

- Sherpa website
- Sherpa for Python users
- Threads
- Help Files

SCRIPTING IN CIAO ▶

- Introduction





“Guides” and “Why” Pages

- ▶ Analysis Guides are a roadmap to broad categories of analyses.
- ▶ Why Topics supplement threads with more detailed information.
 - ▶ some topics highlight common pitfalls and nuances in the software
 - ▶ others topics discuss aspects of *Chandra* and the data obtained with it
 - ▶ some of these topics will also discuss why certain science decisions are made, enabling the user to tailor the analysis to a particular dataset



“ahelp” — *AXAF* Help in CIAO



- ▶ CIAO and Sherpa comes with the command-line “ahelp” system.
 - ▶ `ahelp` has corresponding online counterpart, which is updated between software releases
[cxc.harvard.edu/ciao/ahelp & cxc.harvard.edu/sherpa/ahelp]
- ▶ Python-environments also supports document strings; Sherpa’s primary documentation system.

```
unix% ahelp <toolname>
unix% ahelp <context>
unix% ahelp -c
```

- ▶ In Sherpa the string must be in quotes:

```
sherpa> ahelp "toolname"
sherpa> ahelp("toolname")
sherpa> help("docstring")
```

Tip: if you run a tool in the default interactive mode, when prompted for a parameter, entering '?' opens the tool's ahelp file.

```
unix% dmextract
Input event file (): ?
```





A Typical *Chandra*-user's Focus...

- ▶ Threads answer more detailed issues that may affect science
- ▶ `ahelps` give the details behind the tool itself

Don't blindly follow the examples verbatim, the threads are not strict recipes!



CIAO Release Notes

- ▶ CIAO release notes are revised whenever a new version or patch of a package is updated.

- ▶ CalDB components are updated periodically, but will vary from one release to the next.

- ▶ more details on the CalDB can be found at:

`cxc.harvard.edu/caldb`

- ▶ Details of changes to contributed scripts can be seen at:

`cxc.harvard.edu/ciao/download/scripts/history.html`



The screenshot shows the CIAO 4.13 Release Notes page. The sidebar on the left contains the following sections:

- INTRODUCTION**
 - Home page
 - Welcome
 - Tools & Applications
 - CIAO News (Updated: 16 October 2020)
- DOWNLOAD CIAO**
 - Download CIAO 4.13
 - Download CALDB
 - Scripts & Modules Package
 - System Requirements
 - Installation Instructions
 - Platform Support
 - Release Notes
 - Version History
 - Other Analysis Software
- DATA ANALYSIS**
 - Analysis Guides
 - Science Threads
 - Visualizing data
 - Why Topics
 - Help Pages (AHELP)
 - Video Demos and Tutorials
- DOCUMENTATION**
 - Gallery of Examples
 - "Watch Out" List
 - Help Pages (AHELP)
 - Bug List
 - Frequently Asked Questions (FAQ)
 - Manuals & Memos
 - Dictionary
 - Publications
 - Download the Website
- SHERPA (MODELING AND FITTING)**
 - Sherpa website
 - Sherpa for Python users
 - Threads
 - Help Files
- SCRIPTING IN CIAO**
 - Introduction
 - Modules
 - Running Tools from Python
- DATA PRODUCTS**
 - Data Basics
 - Data Products Guide
 - Data Caveats
 - Chandra Data Archive
 - TGCat: Gratings Catalog & Archive
- PSF CENTRAL**
 - Understanding the Chandra PSF
 - Modeling the Chandra PSF

The main content area is titled "CIAO 4.13 Release Notes" and includes the following text:

Version History

CIAO 4.13 is distributed for the following platforms:

- Linux 64 bit
- Apple macOS 10.13 (High Sierra) through macOS 10.15 (Catalina)

Visit our platform support page for [our statement about support for macOSX 11: Big Sur](#).

CIAO is available using the [conda package manager](#): conda builds are available for Linux and Mac for Python 3.8, 3.7, and 3.6. More information can be found in the [conda section of the Installation notes](#) below.

There is no support for 32 bit operating systems, older Linux (CentOS 6 era) or older macOS platforms (macOSX Sierra and earlier). More details can be found on the [Platform Support page](#).

Notable changes and improvements in CIAO 4.13

- [Notable changes and improvements in CIAO 4.13](#)
- [How CALDB 4.9.4 Affects Your Analysis](#)
- [Installation](#)
- [Tools](#)
- [Parameter Files](#)
- [Sherpa](#)
- [Graphical User Interfaces](#)
- [Analysis Scripts](#)
- [Python Modules](#)
- [Libraries](#)
- [Environment](#)
- [Documentation](#)
- [ChIPS](#)

Notable changes and improvements in CIAO 4.13

- CIAO 4.13 is primarily a bug fix release and includes updates to support newer compilers. There have been several enhancements to sherpa and CIAO 4.13 also provides updates to Off The Shelf (OTS) packages like SAOImage DS9.
- CIAO can be installed using the [conda package manager](#). Users can install the conda edition with Python 3.8, 3.7, or 3.6 on Linux and Mac. The [ciao-install](#) script can also be used to install CIAO 4.13 without conda, now with Python 3.7.
- [Sherpa](#) includes both the changes made in the [Sherpa 4.12.1 release](#) and [Sherpa 4.12.2 releases](#). Notable changes include:
 - The XSPEC library has been updated to version 12.10.1s of the [XSPEC Model library](#), from version 12.10.1n in CIAO 4.12 (so there is essentially no change).

A Word of Caution...

cxc.harvard.edu/ciao

▶ forwards to the most recent release version of CIAO

▶ version-specific website can be found at:

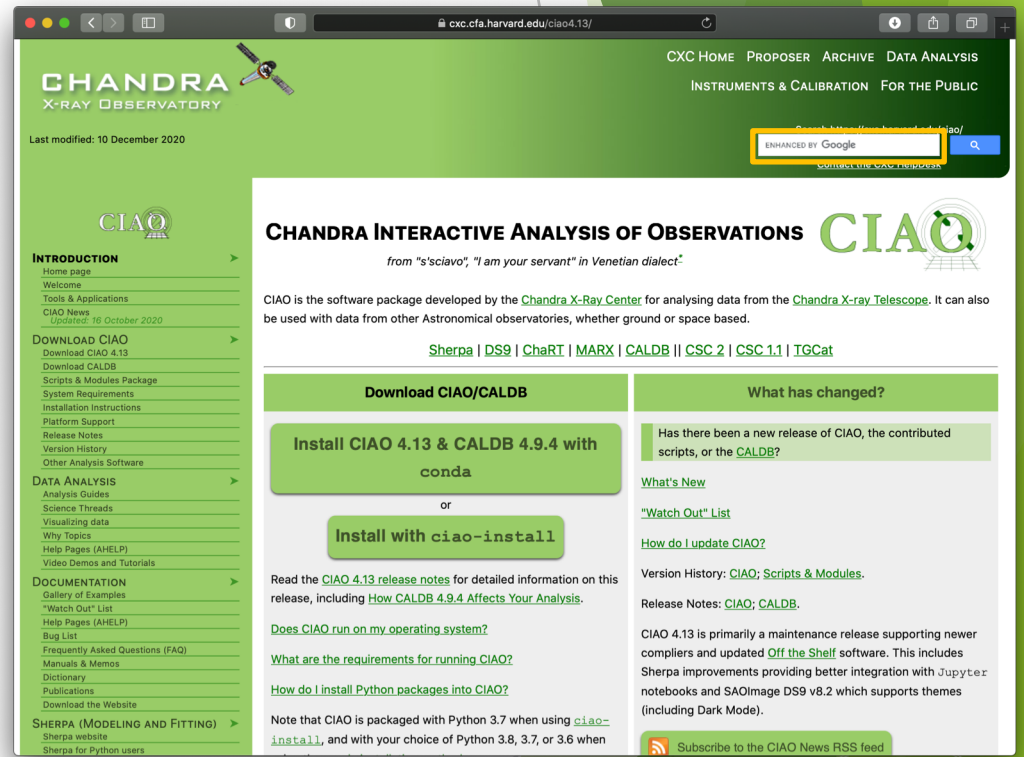
cxc.harvard.edu/ciaoX.Y

▶ similar address structure for Sherpa pages:

cxc.harvard.edu/sherpa

cxc.harvard.edu/sherpaX.Y

▶ Be careful with search engine results!



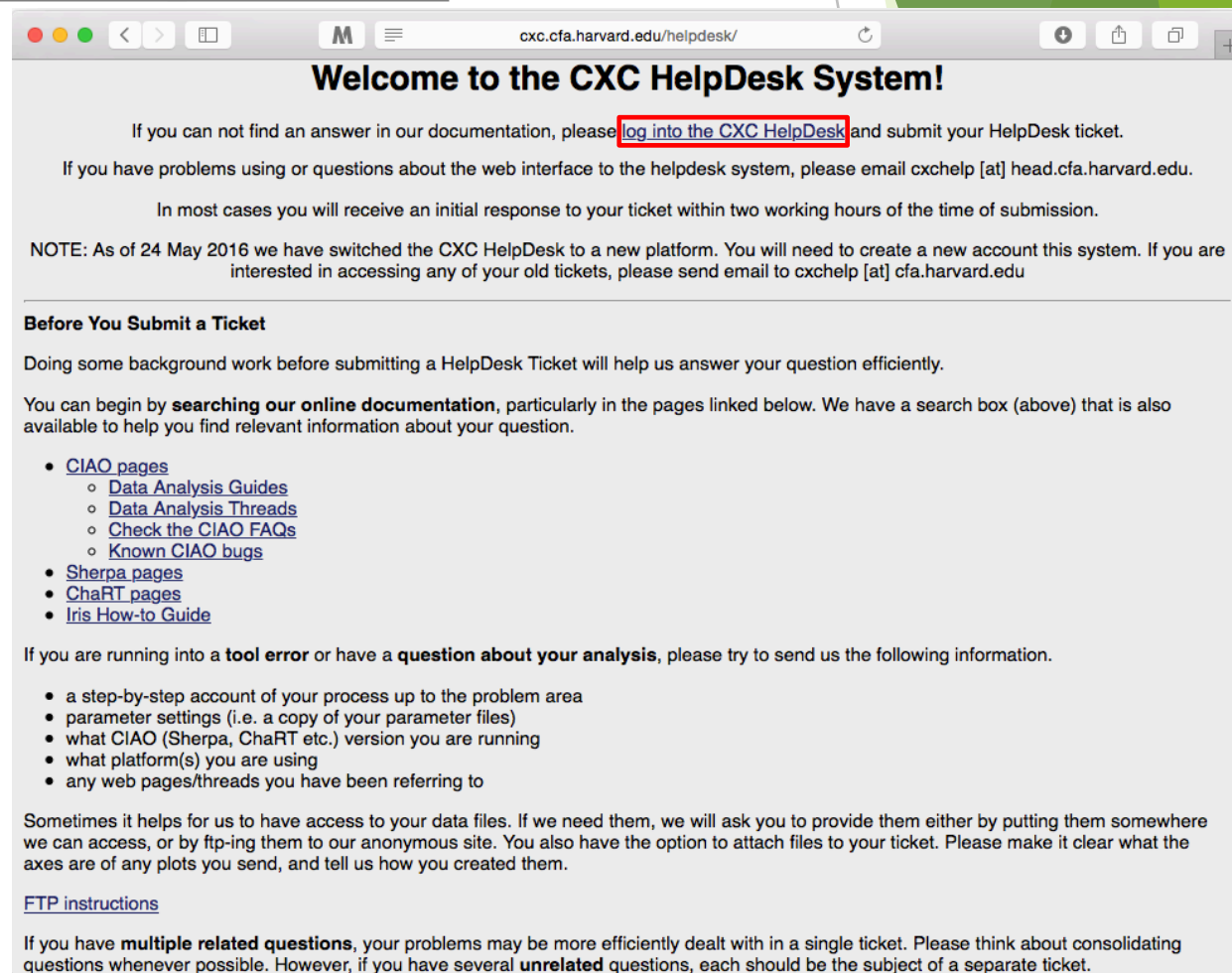


The *Chandra* Helpdesk

cxc.harvard.edu/helpdesk

Provides support for:

- ▶ proposals & proposal planning
- ▶ observation scheduling and issues
- ▶ proprietary data
- ▶ data archive
- ▶ data analysis and DS9



cxc.cfa.harvard.edu/helpdesk/

Welcome to the CXC HelpDesk System!

If you can not find an answer in our documentation, please [log into the CXC HelpDesk](#) and submit your HelpDesk ticket.

If you have problems using or questions about the web interface to the helpdesk system, please email [cxchelp \[at\] head.cfa.harvard.edu](mailto:cxchelp[at]head.cfa.harvard.edu).

In most cases you will receive an initial response to your ticket within two working hours of the time of submission.

NOTE: As of 24 May 2016 we have switched the CXC HelpDesk to a new platform. You will need to create a new account this system. If you are interested in accessing any of your old tickets, please send email to [cxchelp \[at\] cfa.harvard.edu](mailto:cxchelp[at]cfa.harvard.edu)

Before You Submit a Ticket

Doing some background work before submitting a HelpDesk Ticket will help us answer your question efficiently.

You can begin by **searching our online documentation**, particularly in the pages linked below. We have a search box (above) that is also available to help you find relevant information about your question.

- [CIAO pages](#)
 - [Data Analysis Guides](#)
 - [Data Analysis Threads](#)
 - [Check the CIAO FAQs](#)
 - [Known CIAO bugs](#)
- [Sherpa pages](#)
- [ChaRT pages](#)
- [Iris How-to Guide](#)

If you are running into a **tool error** or have a **question about your analysis**, please try to send us the following information.

- a step-by-step account of your process up to the problem area
- parameter settings (i.e. a copy of your parameter files)
- what CIAO (Sherpa, ChaRT etc.) version you are running
- what platform(s) you are using
- any web pages/threads you have been referring to

Sometimes it helps for us to have access to your data files. If we need them, we will ask you to provide them either by putting them somewhere we can access, or by ftp-ing them to our anonymous site. You also have the option to attach files to your ticket. Please make it clear what the axes are of any plots you send, and tell us how you created them.

[FTP instructions](#)

If you have **multiple related questions**, your problems may be more efficiently dealt with in a single ticket. Please think about consolidating questions whenever possible. However, if you have several **unrelated** questions, each should be the subject of a separate ticket.

Contents of a Ticket



- ▶ software information
 - ▶ CIAO version
 - ▶ CalDB version
 - ▶ Sherpa—stand alone or CIAO distribution

- ▶ platform and operating system

- ▶ question
 - ▶ what is the problem or concern encountered?
 - ▶ contextualize the question: what are you trying to do, what is your goal?
 - ▶ if referencing a document, include citation beyond just the authors (journal, volume, page)

- ▶ what did you do?
 - ▶ describe what you've done and the steps taken
 - ▶ provide commands used
 - ▶ copy-and-paste text or provide a log file; no screenshots of terminal, please
 - ▶ include any messages returned by tool, including warning and error messages
 - ▶ provide supporting data files



Finally...

- ▶ Please reply back if you're satisfied with the answer/solution so we can go ahead and close the ticket.
- ▶ If you have a completely unrelated question, instead of adding to an existing ticket, just open a new ticket.
- ▶ Help us help you!
 - ▶ the more information you're able to provide up front means a quicker resolution to the concern
- ▶ Ultimately, the documentation, software, and helpdesk are meant to help you get to a specific data product.
 - ▶ what you do with the data product will be determined by your science goals and judgement
 - ▶ doing science is outside the scope of what helpdesk can support





The *Chandra* Data Archive

cxc.harvard.edu/cda




ChaSeR: *Chandra* Search and Retrieval System

cda.harvard.edu/chaser

CHANDRA
X-RAY OBSERVATORY



Chandra X-ray Center [New Search](#) [Retrieval List](#) [Help](#) 

Observation Search

Search Reset

[File Upload](#) no file selected

[Cone Search](#)

[Target Name](#) [RA/Long/l](#) [Dec/Lat/b](#)

[Name Resolver](#) [Coord System](#) [Equinox](#) [Radius](#) arcmin

[Observation ID](#) [Sequence Number](#) [Proposal Number](#)

[Proposal Title](#) [PI Name](#) [Observer Name](#)

[Start Date](#) [Public Release Date](#)

[Exposure Time \(ks\)](#) [Approved Time \(ks\)](#) [Avg. Count Rate \(hz\)](#)

[Status](#)

[Science Category](#)

[Type](#)

[Observing Cycle](#)

[Instrument](#)

[Grating](#)

[Exposure Mode](#)

[Joint Observatories](#)

[Proposal Cycle](#)

Customize Output:

[Sort Order](#) ascending descending

[Row Limit](#)

[Coord System](#) [Equinox](#) [Format](#)

[Save As](#)

For online support please contact the [CXC Helpdesk](#).





ChaSeR: *Chandra* Search and Retrieval System

cda.harvard.edu/chaser

- ▶ browse the observation catalog with a variety of search criteria
- ▶ cone search or range of coordinates around a celestial position or target name
 - ▶ target name can be resolved to a position with SIMBAD and NED
 - ▶ a list of up to 5000 positions can also be supplied to query the catalog
- ▶ syntax for a range of dates: T_1/T_2 , $T_1/$, $/T_2$
 - ▶ T_n format: YYYY-MM-DD
 - ▶ between T_1 and T_2 , after T_1 , before T_2



ChaSeR (continued)



source name
and name
resolver

Chandra X-ray Center **Observation Search** [New Search](#) [Retrieval List](#) [Help](#)

Search Reset

[File Upload](#) Choose File | no file selected

[Target Name](#) [Resolve Name](#) [Cone Search](#)

[Name Resolver](#) [RA/Long!](#) [Dec/Lat/b](#)

[Coord System](#) [Equinox](#) [Radius](#) arcmin

[Observation ID](#) [Sequence Number](#) [Proposal Number](#)

[Proposal Title](#) [PI Name](#) [Observer Name](#)

[Start Date](#) [Public Release Date](#)

[Exposure Time \(ks\)](#) [Approved Time \(ks\)](#) [Avg. Count Rate \(hz\)](#)

Status	<input type="text" value="Archived"/> <input type="text" value="Observed"/> <input type="text" value="Scheduled"/> <input type="text" value="Unobserved"/> <input type="text" value="Untriggered"/>	Science Category	<input type="text" value="Solar System"/> <input type="text" value="Stars and WD"/> <input type="text" value="WD Binaries and CV"/> <input type="text" value="BH and NS Binaries"/> <input type="text" value="SN, SNR and Isolated NS"/>	Type	<input type="text" value="ER"/> <input type="text" value="GO"/> <input type="text" value="GTO"/> <input type="text" value="TOO"/> <input type="text" value="DDT"/> <input type="text" value="CAL"/>	Observing Cycle	<input type="text" value="00"/> <input type="text" value="01"/> <input type="text" value="02"/> <input type="text" value="03"/> <input type="text" value="04"/>			
Instrument	<input type="text" value="ACIS"/> <input type="text" value="ACIS-I"/> <input type="text" value="ACIS-S"/> <input type="text" value="HRC"/>	Grating	<input type="text" value="None"/> <input type="text" value="LETG"/> <input type="text" value="HETG"/>	Exposure Mode	<input type="text" value="ACIS TE"/> <input type="text" value="ACIS CC"/> <input type="text" value="HRC Timing"/>	Joint Observatories	<input type="text" value="None"/> <input type="text" value="HST"/> <input type="text" value="NOAO"/> <input type="text" value="NRAO"/> <input type="text" value="NuSTAR"/>	Proposal Cycle	<input type="text" value="00"/> <input type="text" value="01"/> <input type="text" value="02"/> <input type="text" value="03"/> <input type="text" value="04"/>	Grid <input type="text"/>

Customize Output:

[Sort Order](#) ascending descending

[Row Limit](#)

[Coord System](#) [Equinox](#) [Format](#)

[Save As](#)

For online support please contact the [CXC Helpdesk](#).

data
public
release
date

observation
start date

maximum number of rows
returned

ChaSeR (continued)



M87

Chandra X-ray Center **Observation Search** [New Search](#) [Retrieval List](#) [Help](#)

Search Reset

[File Upload](#) Choose File no file selected

Target Name **RA/Long/l** 12 30 49.42 **Dec/Lat/b** +12 23 28.04

Name Resolver **Coord System** Equatorial J2000 **Equinox** 2000 **Radius** 10 arcmin

Observation ID **Sequence Number** **Proposal Number**

Proposal Title **PI Name** **Observer Name**

Start Date 2003-01-01/2021-01-05 **Public Release Date** /2021-01-06

Exposure Time (ks) **Approved Time (ks)** **Avg. Count Rate (hz)**

Status Archived Observed Scheduled Unobserved Untriggered

Science Category Solar System and Exoplanets Stars and WD WD Binaries and CV BH and NS Binaries SN, SNR and Isolated NS

Type ER GO GTO TOO DDT CCT

Observing Cycle

Instrument ACIS ACIS-I ACIS-S HRC

Grating None LETG HETG

Exposure Mode ACIS TE ACIS CC HRC Timing

Joint Observatories None HST NOAO NRAO NuSTAR

Proposal Cycle **Grid**

Customize Output:

Sort Order ascending descending

Row Limit

Coord System Equatorial J2000 **Equinox** 2000 **Format** Sexagesimal (hh/dd mm ss.ss)

Save As

For online support please contact the [CXC Helpdesk](#).

ChaSeR Query Results



Chandra X-ray Center [New Search](#) [Search Results](#) [Retrieval List](#) [Help](#)

View Observation Information Primary package Secondary package Custom selection

[Select all](#) | [Unselect all](#)

Select	Row	Seq Num	Obs ID	Instrument	Grating	Appr Exp	Exposure	Target Name	PI Name	RA	Dec	Status	Data Mode	Exp Mode	Avg Cnt Rate	Evt Cnt
<input type="checkbox"/>	1	700656	3977	ACIS-S	NONE	5.0	5.28	M87	Harris	12 30 49.00	+12 23 30.00	archived	FAINT	TE	12.10	638
<input type="checkbox"/>	2	700657	3978	ACIS-S	NONE	5.0	4.85	M87	Harris	12 30 49.00	+12 23 30.00	archived	FAINT	TE	12.42	602
<input type="checkbox"/>	3	700658	3979	ACIS-S	NONE	5.0	4.49	M87	Harris	12 30 49.00	+12 23 30.00	archived	FAINT	TE	12.34	554
<input type="checkbox"/>	4	700659	3980	ACIS-S	NONE	5.0	4.79	M87	Harris	12 30 49.00	+12 23 30.00	archived	FAINT	TE	12.07	578
<input type="checkbox"/>	5	700660	3981	ACIS-S	NONE	5.0	4.68	M87	Harris	12 30 49.00	+12 23 30.00	archived	FAINT	TE	11.77	550
<input type="checkbox"/>	6	700661	3982	ACIS-S	NONE	5.0	4.84	M87	Harris	12 30 49.00	+12 23 30.00	archived	FAINT	TE	11.91	576
<input checked="" type="checkbox"/>	7	700998	4917	ACIS-S	NONE	5.0	5.03	M87	Biretta	12 30 49.00	+12 23 30.00	archived	FAINT	TE	13.02	654
<input type="checkbox"/>	8	700686	4007	ACIS-S	NONE	40.0	36.18	NGC 4486B	Fabbiano	12 30 31.80	+12 29 26.00	archived	VFAINT	TE	6.97	2522
<input type="checkbox"/>	9	700999	4918	ACIS-S	NONE	5.0	4.68	M87	Biretta	12 30 49.00	+12 23 30.00	archived	FAINT	TE	12.45	582
<input type="checkbox"/>	10	701000	4919	ACIS-S	NONE	5.0	4.7	M87	Biretta	12 30 49.00	+12 23 30.00	archived	FAINT	TE	12.91	607
<input type="checkbox"/>	11	701002	4921	ACIS-S	NONE	5.0	5.25	M87	Biretta	12 30 49.00	+12 23 30.00	archived	FAINT	TE	13.29	697

112 observations found
 Position=cone of radius 10 arcmin around RA: 12 30 49.42, Dec: +12 23 28.04 (frame=j2000 equinox=2000)
 Start Date=2003-01-01/2021-01-05
 Public Release Date=/2021-01-06
 Status=archived; observed; scheduled; unobserved; untriggered
 Instrument=ACIS
 Grating=NONE
 Type=GO; GTO; TOO; DDT; CCT; CAL
 Exposure Mode=TE
 Sort Order=Start Date ascending

For online support please contact the [CXC Helpdesk](#).



ChaSeR ObsID Entry



details of the instrument configuration for the observation

V&V—Verification and Validation—report includes a summary of any anomalies during the observation, usually noted in the Comments section

list of ADS links to publications that have made use of the observation data

Chandra X-ray Center [New Search](#) [Search Results](#) [Retrieval List](#) [Help](#)

Chandra Data Archive
Not logged in [Login](#)

Observation ID: **4917**

Observation ID: 4917

 [Primary package](#)
 [Secondary package](#)
 [Custom selection](#)

[→ Summary](#)
[Details](#)
[V&V Report](#)
[Proposal Abstract](#)
[Images](#)
 Data packages
 [Primary](#)
 [Secondary](#)
 External links
 [Publications](#)
 [Processing Status](#)
 [Sequence Summary](#)
 Related Observations
 [By Sequence](#)
 [By Proposal](#)
 [By Monitor/Followup](#)
 [By Group](#)
 [By Grid](#)

Sequence Number:	700998	Status:	archived
Observation ID:	4917	Proposal Number:	05701072
Type:	GO	Proposal Cycle:	05
PI Name:	Biretta	Observer:	Harris
Science Category:	ACTIVE GALAXIES AND QUASARS	Joint Observatories:	CXO-HST
Target Name:	M87	Grid Name:	
RA (J2000):	12 30 49.00	Data Mode:	FAINT
Dec (J2000):	+12 23 30.00	Observing Cycle:	05
Instrument:	ACIS-S	Public Release Date:	2004-11-14 16:28:26
Grating:	NONE		
Start Date:	2003-11-11 19:45:02		
Approved Time:	5.00 ks		
Exposure Time:	5.03 ks		

For online support please contact the [CXC Helpdesk](#).

ChaSeR ObsID Entry



- ▶ for non-proprietary data:
 - ▶ option to stage primary, secondary, or customized set of data products for retrieval
 - ▶ for typical analysis, once you have the ObsID of interest, just use:
`download_chandra_obsid`

- ▶ ChaSeR is required to obtain proprietary data.
- ▶ If the existing archive interfaces do not meet your needs, the archive team may consider a special request:
cxc.harvard.edu/cgi-gen/cda/specreq

The screenshot shows the Chandra X-ray Center Observation Viewer interface. The browser address bar is `cda.harvard.edu/chaser/dispatchOcatResults.do`. The page title is "Observation Viewer". The Chandra X-ray Center logo is on the left, and navigation links for "New Search", "Search Results", "Retrieval List", and "Help" are in the top center. On the right, there is a "Chandra Data Archive" logo and a "Not logged in Login" button. The main content area displays "Observation ID: 4917" and a table of observation details. A red box highlights the "Add to Retrieval List" button and the selection options: "Primary package" (checked), "Secondary package" (checked), and "Custom selection" (unchecked). A sidebar on the left contains a list of links for "Summary", "Details", "V&V Report", "Proposal Abstract", "Images", "Data packages", "External links", "Publications", "Processing Status", "Sequence Summary", and "Related Observations".

Observation ID: 4917	Sequence Number: 700998	Status: archived
Add to Retrieval List	Observation ID: 4917	Proposal Number: 05701072
<input checked="" type="checkbox"/> Primary package	Type: GO	Proposal Cycle: 05
<input checked="" type="checkbox"/> Secondary package	PI Name: Biretta	Observer: Harris
<input type="checkbox"/> Custom selection	Science Category: ACTIVE GALAXIES AND QUASARS	Joint Observatories: CXO-HST
	Target Name: M87	Grid Name:
	RA (J2000): 12 30 49.00	Data Mode: FAINT
	Dec (J2000): +12 23 30.00	Observing Cycle: 05
	Instrument: ACIS-S	Public Release Date: 2004-11-14 16:28:26
	Grating: NONE	
	Start Date: 2003-11-11 19:45:02	
	Approved Time: 5.00 ks	
	Exposure Time: 5.03 ks	

For online support please contact the [CXC Helpdesk](#).

Beyond ChaSeR:

find_chandra_obsid

```
unix% find_chandra_obsid 4C19.44
# obsid  sepn  inst grat  time  obsdate  piname  target
2140      0.0 ACIS-S NONE   9.1 2001-01-08 Sambruna 1354+195
6903      0.1 ACIS-S NONE  43.7 2006-04-01  Harris  4C19.44
6904      0.1 ACIS-S NONE  34.8 2006-03-20  Harris  4C19.44
7302      0.1 ACIS-S NONE  68.9 2006-03-28  Harris  4C19.44
7303      0.1 ACIS-S NONE  41.5 2006-03-30  Harris  4C19.44
```

Parameters for `${HOME}/cxcds_param4/find_chandra_obsid.par`

arg =	RA, ObsId, or name of source
dec =	Dec of source if arg is not the ObsId/name
(radius = 1.0)	Radius for search overlap in arcmin
(download = none)	What ObsIDs should be downloaded?
(instrument = all)	Choice of instrument
(grating = all)	Choice of grating
(detail = basic)	Columns to display
(mirror =)	Use this instead of the CDA FTP site
(verbose = 1)	Verbose level
(mode = h)	

CHANDRA
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CENTER FOR **ASTROPHYSICS**

HARVARD & SMITHSONIAN

Beyond ChaSeR: Chandra Footprint Service

cxcfps.cfa.harvard.edu/cda/footprint/cdaview.html

CHANDRA
X-RAY OBSERVATORY



A search by position or object name overlays the footprints of *Chandra* Observations on Digitized Sky Survey images, allowing further selection and retrieval of observations.

The screenshot shows the Chandra Footprint Service web interface. At the top, there is a search bar with the text "CenA" and a search button. Below the search bar, there are navigation tabs: "Footprints", "Image Inventory", "Preview Images/Download Data", "Help", and "FAQ". The main content area displays a star field with overlaid footprints in various colors (red, blue, green, yellow). Below the star field, there is a table of results. The table has columns for ObsID, Target, Observation Date, RA, DEC, Proposal ID, PI Last Name, Instrument, Exposure, Grating, and JPEG Preview. The table contains 20 rows of data, with the first row being highlighted.

ObsID	Target	Observation Date	RA	DEC	Proposal ID	PI Last Name	Instrument	Exposure	Grating	JPEG Preview
316	NGC 5128	1999-12-05T21:36:00	13:25:27.62	-43:01:09.0	1600065	Murray	ACIS-I	35.72	NONE	JPEG
463	CEN A	1999-09-10T07:48:00	13:25:27.61	-43:01:11.0	1700108	Calibration	HRC-I	19.52	NONE	JPEG
806	CEN A FILAMENTS	2000-01-23T07:46:00	13:26:03.71	-42:57:08.3	1700171	Evans	HRC-I	64.91	NONE	JPEG
962	NGC 5128	2000-05-17T22:57:00	13:25:27.62	-43:01:09.0	1600065	Murray	ACIS-I	36.5	NONE	JPEG
1253	CEN A	1999-09-10T14:06:00	13:25:27.61	-43:01:11.0	1700108	Calibration	HRC-I	6.83	NONE	JPEG
1412	CEN A	1999-12-21T18:11:00	13:25:27.61	-43:01:11.0	700006	Calibration	HRC-I	14.97	NONE	JPEG
1600	CENTAURIUS A	2001-05-09T20:00:00	13:25:27.41	-43:01:11.0	2700083	Murray	ACIS-S	46.85	HETG	JPEG
1601	CENTAURIUS A	2001-05-21T17:07:00	13:25:27.41	-43:01:11.0	2700083	Murray	ACIS-S	51.51	HETG	JPEG
2978	CEN-A	2002-09-03T02:42:00	13:25:28.7	-43:00:59.7	3700075	Murray	ACIS-S	44.59	NONE	JPEG
3965	CENTAURIUS A	2003-09-14T13:44:00	13:25:28.7	-43:00:59.7	4700217	Kraft	ACIS-S	49.52	NONE	JPEG
7797	Centaurus A Jet	2007-03-22T08:59:00	13:25:19.15	-43:02:42.4	8700512	Kraft	ACIS-I	96.89	NONE	JPEG
7798	Centaurus A Jet	2007-03-27T09:53:00	13:25:51.8	-43:00:04.5	8700512	Kraft	ACIS-I	90.84	NONE	JPEG
7799	Centaurus A Jet	2007-03-30T02:32:00	13:25:51.8	-43:00:04.5	8700512	Kraft	ACIS-I	94.78	NONE	JPEG
7800	Centaurus A Jet	2007-04-17T15:00:00	13:25:46.01	-42:58:14.6	8700512	Kraft	ACIS-I	90.84	NONE	JPEG
8489	Centaurus A Jet	2007-05-08T18:41:00	13:25:32.8	-43:01:35.2	8700512	Kraft	ACIS-I	93.94	NONE	JPEG
8490	Centaurus A Jet	2007-05-30T02:01:00	13:25:18.8	-43:03:01.8	8700512	Kraft	ACIS-I	94.43	NONE	JPEG
10407	CEN A	2009-04-04T05:29:00	13:25:27.62	-43:01:08.9	10700750	Karovsky	HRC-I	14.98	NONE	JPEG
10408	CEN A	2009-09-14T11:04:00	13:25:27.62	-43:01:08.9	10700750	Karovsky	HRC-I	14.97	NONE	JPEG
10722	Centaurus A	2009-09-08T20:05:00	13:25:27.61	-43:01:09.1	10700038	Murray	ACIS-S	49.4	NONE	JPEG
10723	Centaurus A	2009-01-04T12:32:00	13:25:49.67	-42:59:14.8	10700038	Murray	ACIS-I	5.08	NONE	JPEG

Beyond ChaSeR:

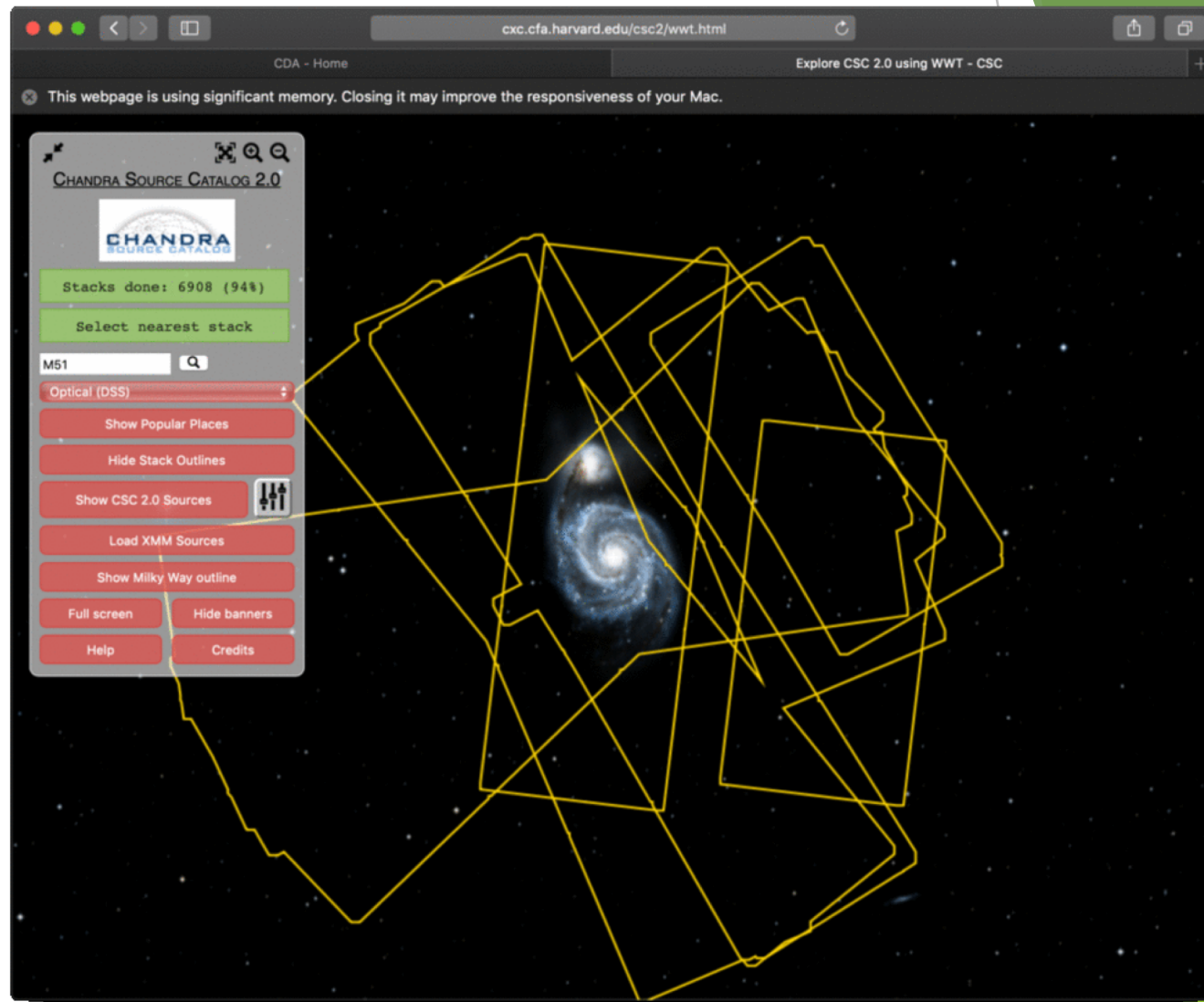
Chandra Source Catalog-Worldwide Telescope

cxc.harvard.edu/csc2/wwt.html

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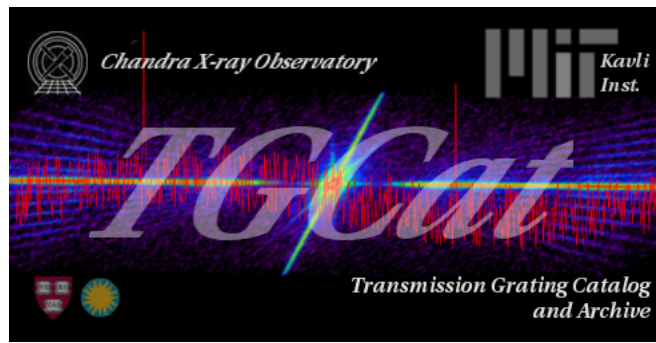


- ▶ Uses the AAS's WWT interface to explore the sky coverage and source properties of CSC 2.0
- ▶ Provides links for ObsIDs to ChaSeR
- ▶ Provides info to access catalog data products via CSCView



Beyond ChaSeR: TGCat

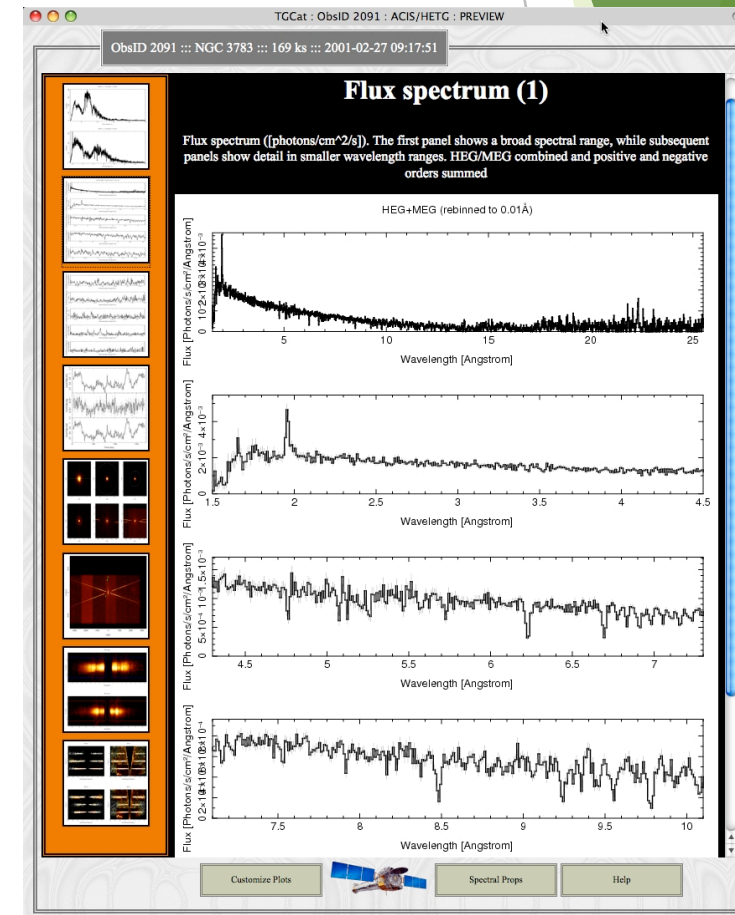
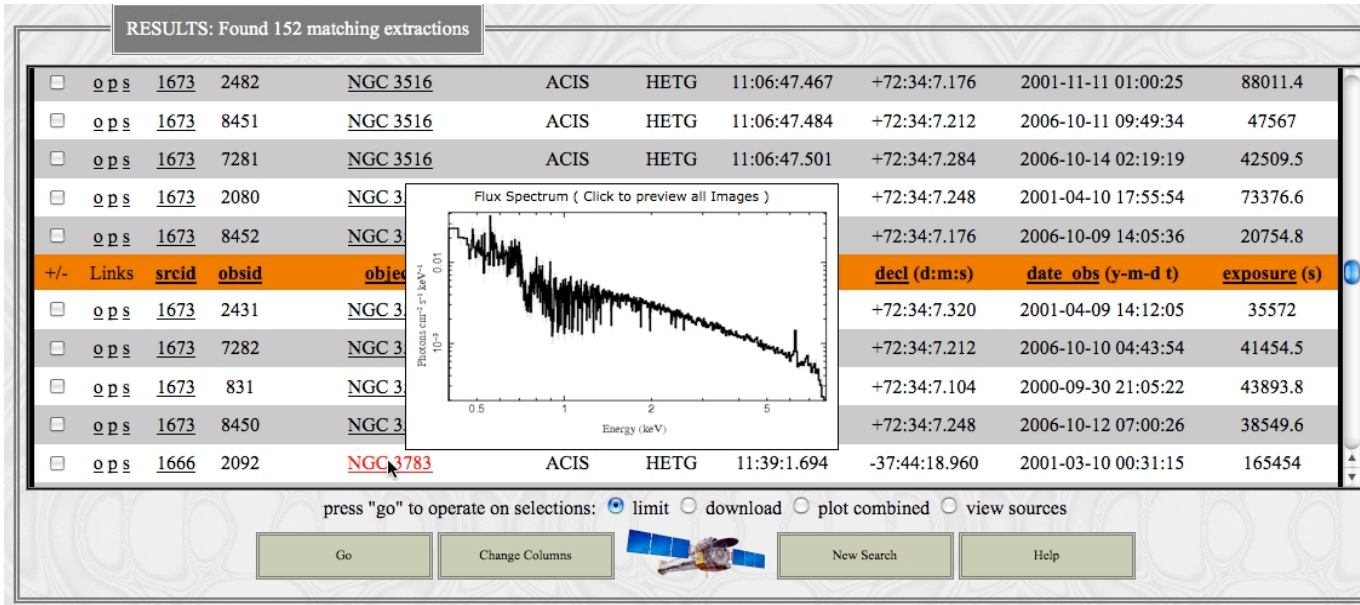
tgcat.mit.edu



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- ▶ Includes all publicly available gratings observations
- ▶ Provides calibrated spectra and responses
- ▶ Provides quick-look visualization and summary products



NASA's HEASARC Archive

(High-Energy Astrophysics Science Archive Research Center)

heasarc.gsfc.nasa.gov/docs/archive.html

- ▶ Primary portal to all data from EUV/X-ray/ γ -ray missions (past and present) with NASA involvement and supported with public funds.
 - ▶ also provides access to data archives of other space agencies
- ▶ NASA's primary repository of the observations of relic CMB radiation from space missions, balloons, and ground-based facilities in the sub-mm, mm, and cm bands.





Threads of Analyses

cxc.harvard.edu/ciao/threads

cxc.harvard.edu/sherpa/threads



Analyses:

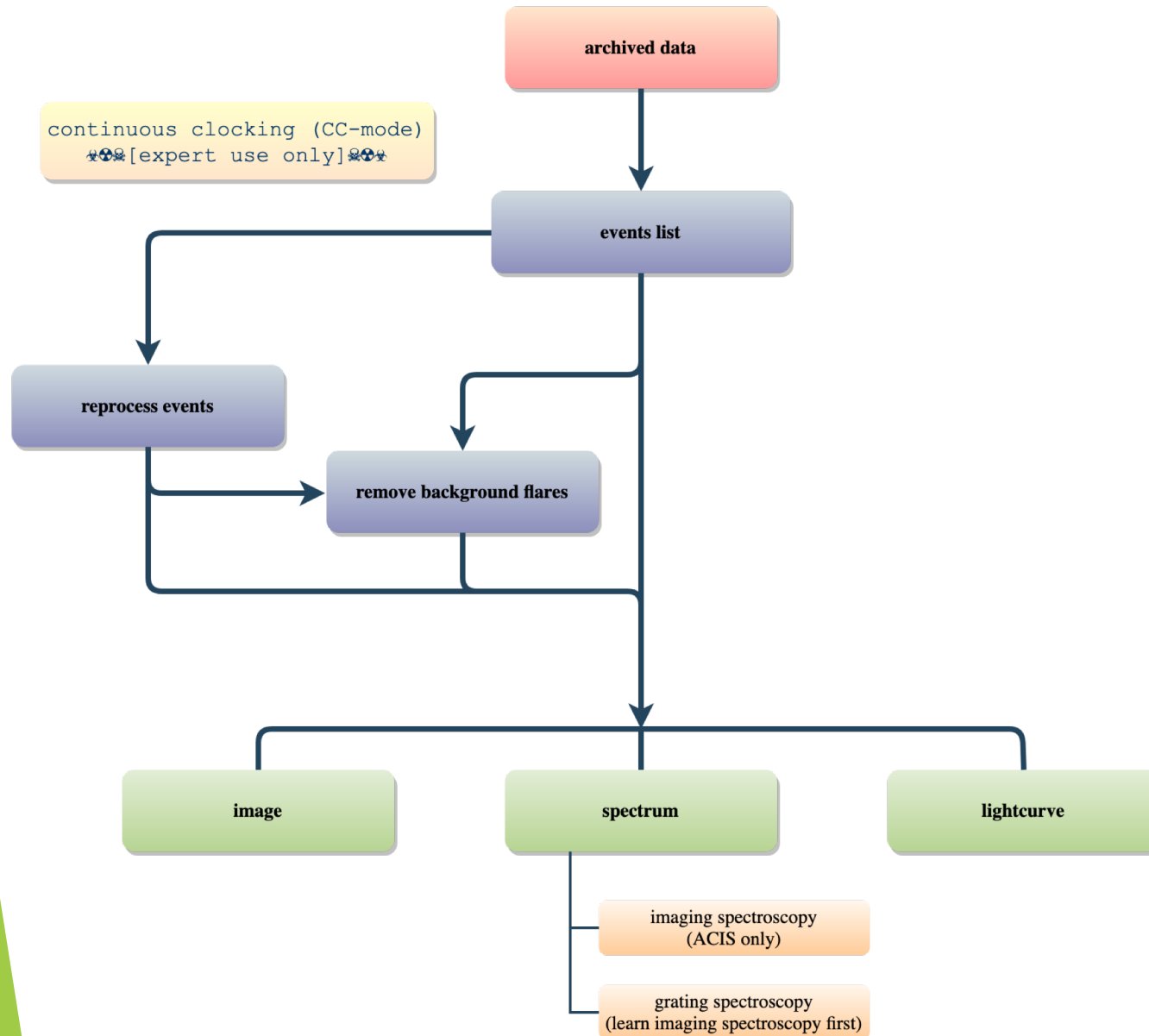
Initial Data Preparation

- ▶ The data contained in the events list informs us of the types of data products we can generate.
 - ▶ **Image**—bin on spatial-axes, lose energy and temporal information
 - ▶ **Spectra**—bin on spectral-axis, lose spatial and temporal information
 - ▶ **Lightcurves**—bin on time-axis, lose spatial and energy information
 - ▶ **Source Lists**—identify regions in spatial, energy, and time coordinates corresponding to sources

```
unix% dmlist evt.fits cols
```

- ▶ Available data products determine possible types of analysis.
 - ▶ cxc.harvard.edu/ciao/data_products_guide/ provides description of files and columns from standard archive download

Analyses Paths



▶ image

- ▶ radial profiles
- ▶ smoothing & PSFs
- ▶ cross-correlation & auto-correlation
- ▶ flux maps

▶ spectrum

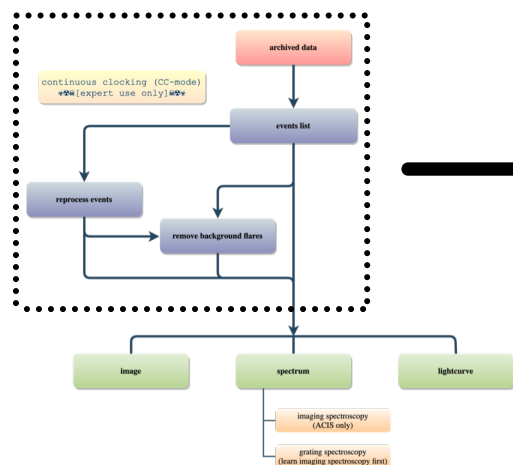
- ▶ model fitting
- ▶ spectral deprojection for 3D source properties

▶ lightcurve

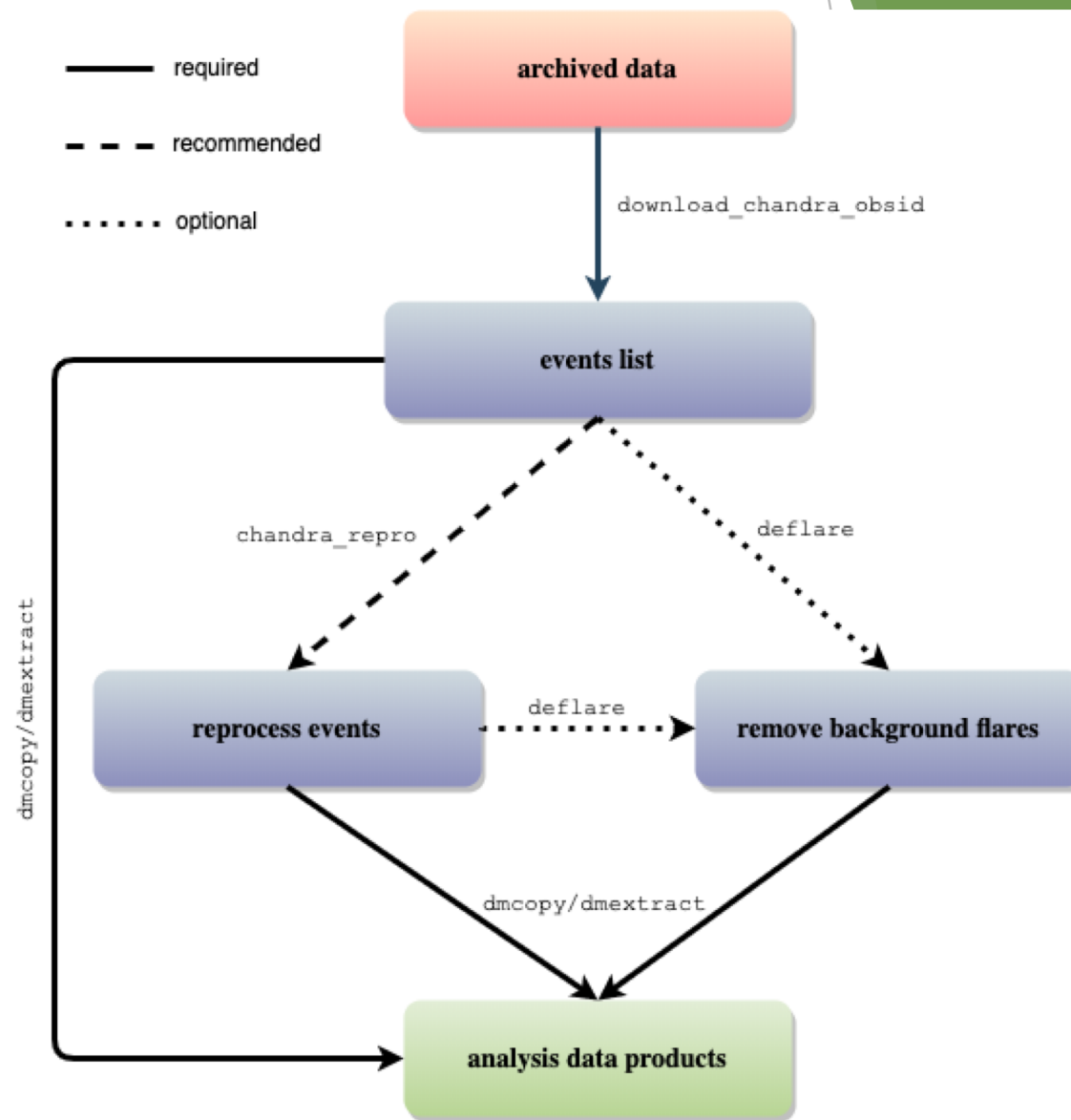
- ▶ Gregory-Loredo variability tests
- ▶ power spectrum
- ▶ phase-resolved spectroscopy



Data Product Extraction



- ▶ reprocess downloaded data to ensure latest calibration products are applied to the data set
- ▶ background flares
 - ▶ most likely to affect extended sources, particularly diffuse features
 - ▶ weak point sources more likely to be affected than bright point sources





Download and Reprocess (single ObsID)

```

unix% download_chandra_obsid 7302

. . . SCREEN OUTPUT (DOWNLOAD PROGRESS) . . .

unix% dmkeypar primary/acisf07302N002_evt2.fits.gz DATAMODE echo+
FAINT

unix% chandra_repro indir=7302 outdir=7302/repro check_vf_pha=no
Processing input directory '${HOME}/Work/Example/7302'

. . . MORE SCREEN OUTPUT . . .

The data have been reprocessed.
Start your analysis with the new products in
${HOME}/Work/Example/7302/repro
  
```

- ▶ Can download multiple datasets using a comma-separated string of ObsIDs and specify file types.
- ▶ `check_vf_pha` controls whether `acis_process_events` flags potential events near the VFaint event island as cosmic rays that are filtered out by the tool. For faint, diffuse objects, this may be beneficial, but if the source of interest is a point source, the reduction in source flux from the filtering can result in poorer uncertainties than if the higher background (and source) levels are retained.





[almost] always: reprocess, reprocess, reprocess

```
unix% chandra_repro indir=7302 outdir=7302/repro check_vf_pha=no  
Processing input directory `${HOME}/Work/Example/7302'
```

```
. . . MORE SCREEN OUTPUT . . .
```

```
The data have been reprocessed.  
Start your analysis with the new products in  
`${HOME}/Work/Example/7302/repro
```

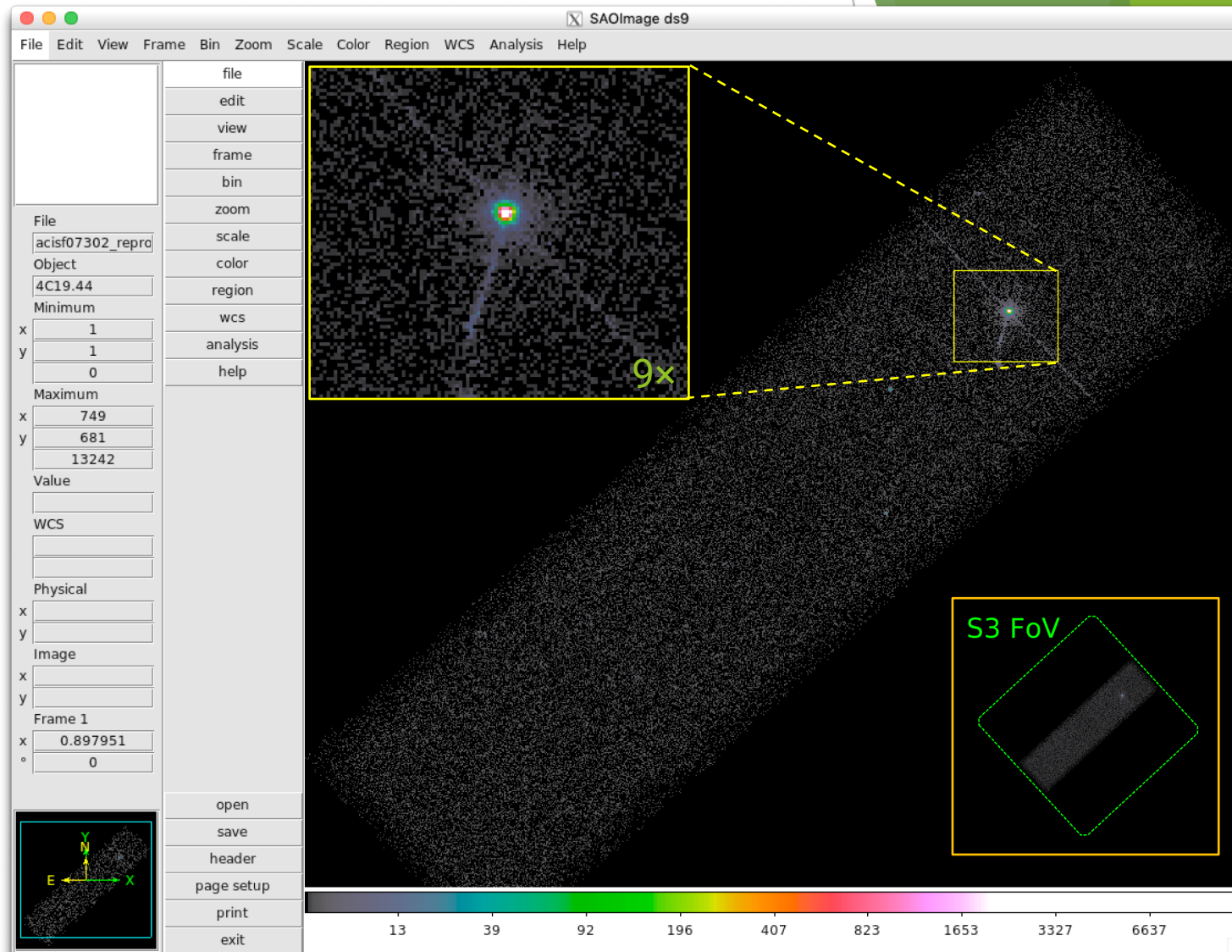
- ▶ Latest version of time-dependent gain applied.
- ▶ Latest temperature-dependent CTI correction applied.
- ▶ Ensures common set of calibration files used.
- ▶ Caveat: check new CalDB warning notes for use cases to avoid.



Quick Glance:

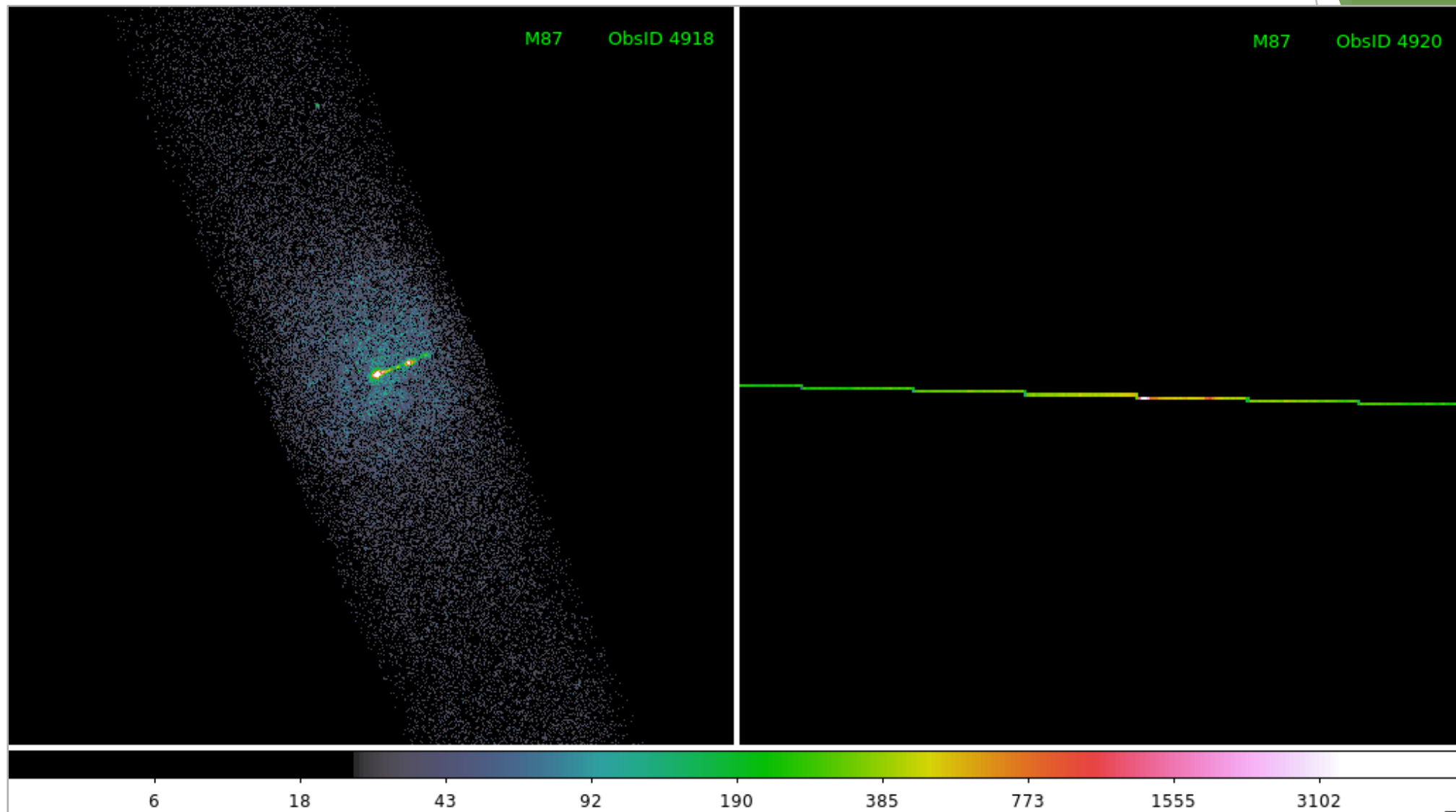


- ▶ quasar 4C + 19.44/PKS 1354 + 195
 - ▶ ~69 ks observation of a ~190 ks joint CXO program with *HST* and VLA
- ▶ ACIS-S3, sub-array
 - ▶ other special cases:
 - ▶ multi-ObI
 - ▶ Interleaved (aka "alternating exposure") mode
 - ▶ spatial window
 - ▶ ACIS CC-mode and HRC-S Timing mode
- ▶ readout streak
 - ▶ events detected during frame readout have correct column, random row
 - ▶ source bright enough to have readout streak will have some degree of pile up



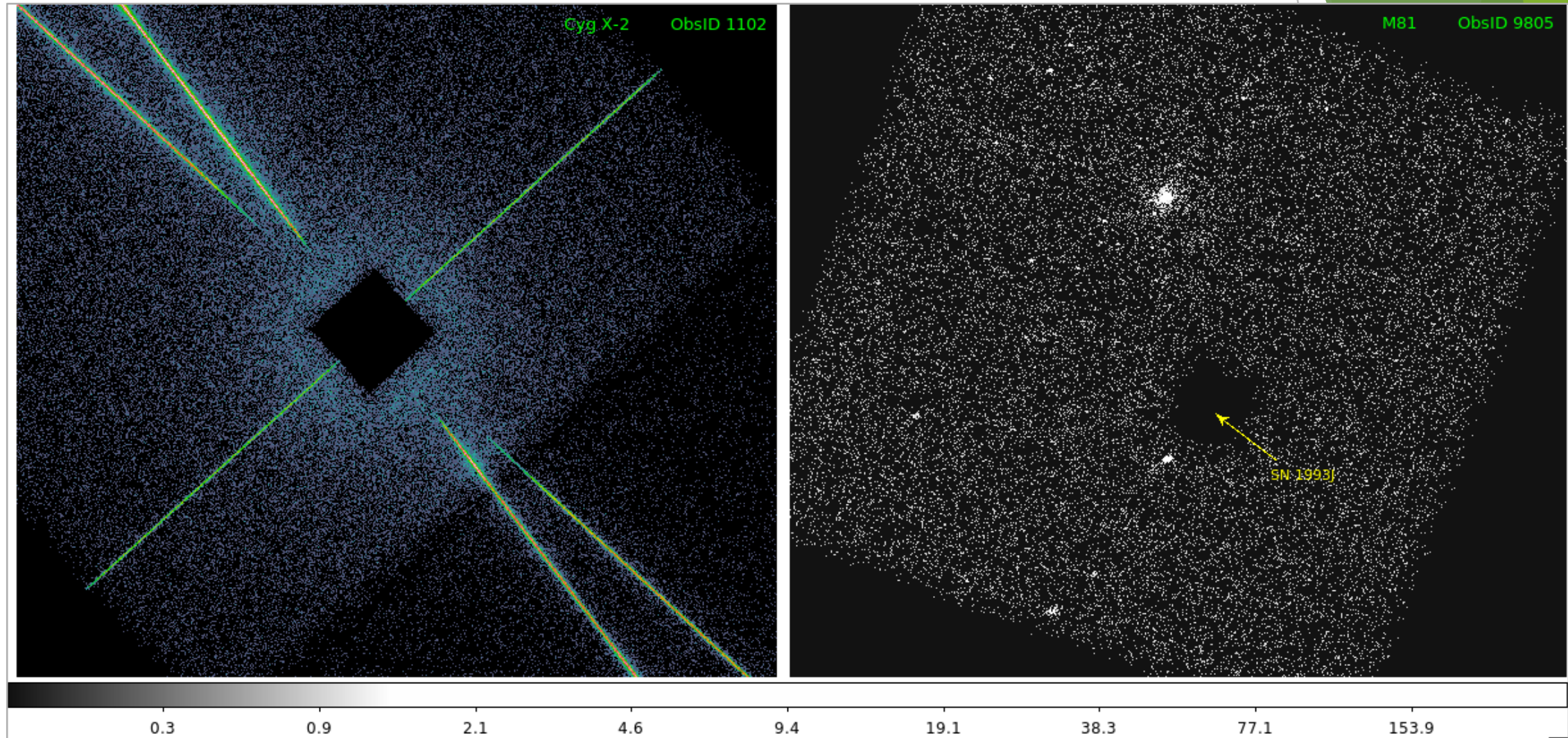
ACIS Continuous-Clocking Mode

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Spatial Window Filters



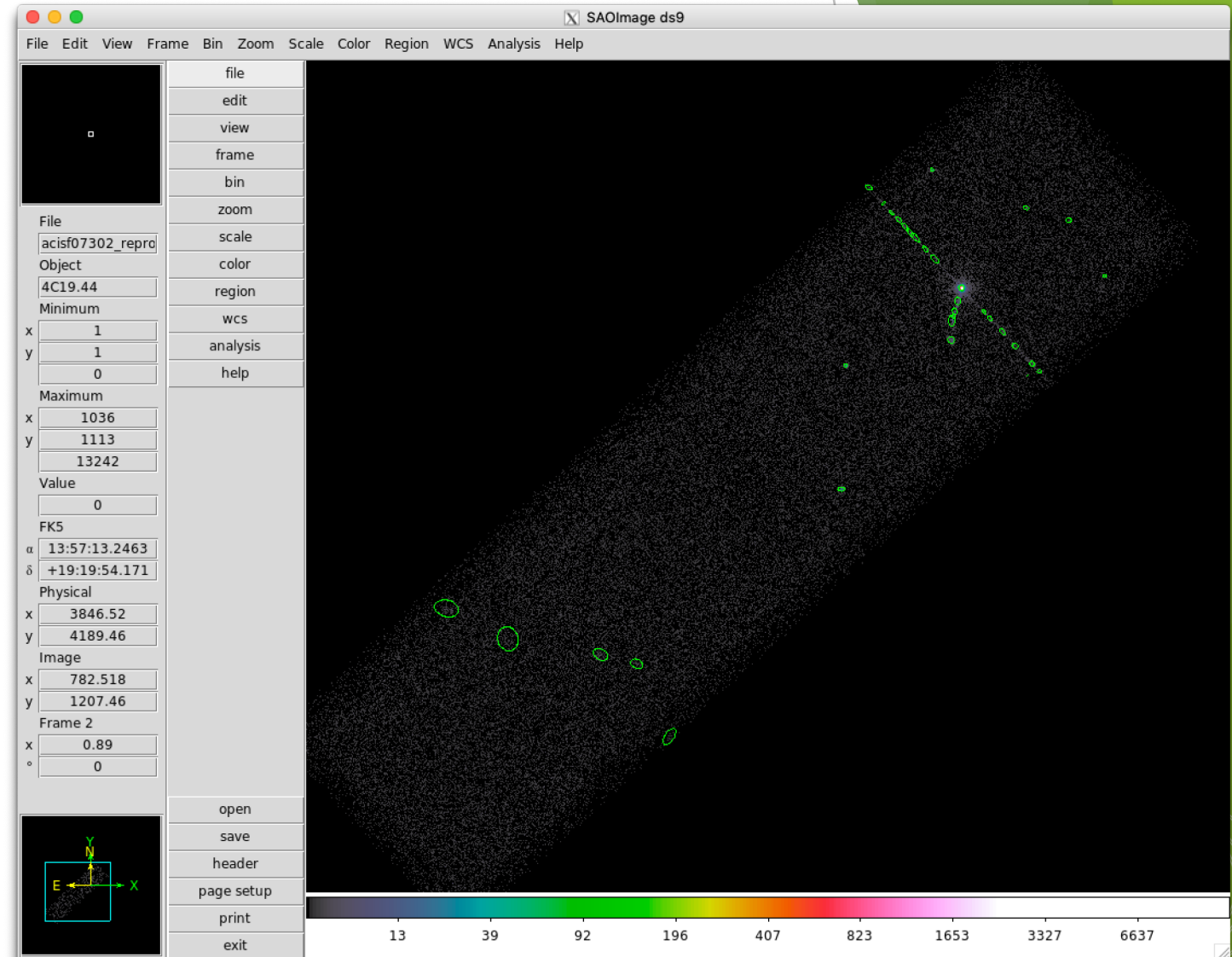
Background Flares and Source Detection



- ▶ Create lightcurve of the background events.
 - ▶ exclude sources in the field
 - ▶ exclude readout streak

- ▶ X-ray source detection
 - ▶ identify statistically significant brightness enhancements over local background
 - ▶ source properties, like intensity and size, may also be reported, but may be more reliably evaluated separately

Note: source properties derived from source detection aren't intended for photometric usage!



Background Flares and Source Detection



► CIAO source detection algorithms

► wavdetect—wavelet correlation

Pros

- works well in crowded fields
- works well with point sources embedded in diffuse emission
- only requires an approximate PSF shape
- not strongly affected by detector edge effects

Cons:

- slow, especially if many wavelets are used
- memory intensive
- no recursive blocking built-in, so running on entire image may require multiple, binned images. Source lists must then be combined.

► celldetect—sliding cell

Pros

- fast and robust
- works well for point sources
- only requires an approximate PSF shape
- can handle very large images easily

Cons

- extended sources are difficult without careful cell size selection
- can get confused in crowded fields
- exposure maps needed to reduce edge effects
- not very sensitive unless background maps are used, which may be difficult to construct

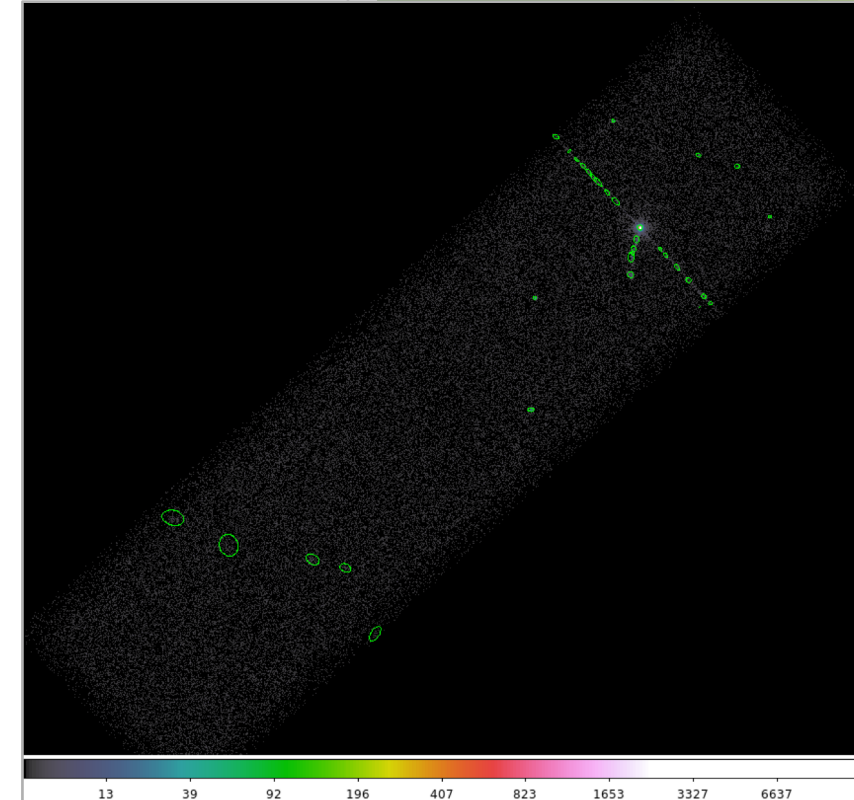
► vtpdetect—Voronoi tessellation and percolation

Pros

- works well for extended sources and irregularly shaped sources
- works on large areas at full resolution
- works well on low surface brightness extended sources

Cons

- can get confused in crowded fields
- slow, especially if there is a large number of photons and the contrast between background and sources is low



Reality is X-ray source detection is often a difficult – or at least challenging – task. A reliable source list may require running more than one tool, or one tool multiple times.

Source Detection (cont.)



- ▶ Reducing spurious source detections
 - ▶ All CIAO detection tools can use an optional exposure map *reduces false source detections from detector effects*
 - ▶ PSF maps can be used by `celldetect` and `wavdetect` *PSF info allows for more reliable characterization of source; does not affect detection*
- ▶ `fluximage` provides an easy interface to generate these data products

```
unix% fluximage acisf07302_repro_evt2.fits \
? outroot=flux/7302 binsize=1 bands=broad psfecf=0.393
```

. . . SCREEN OUTPUT . . .

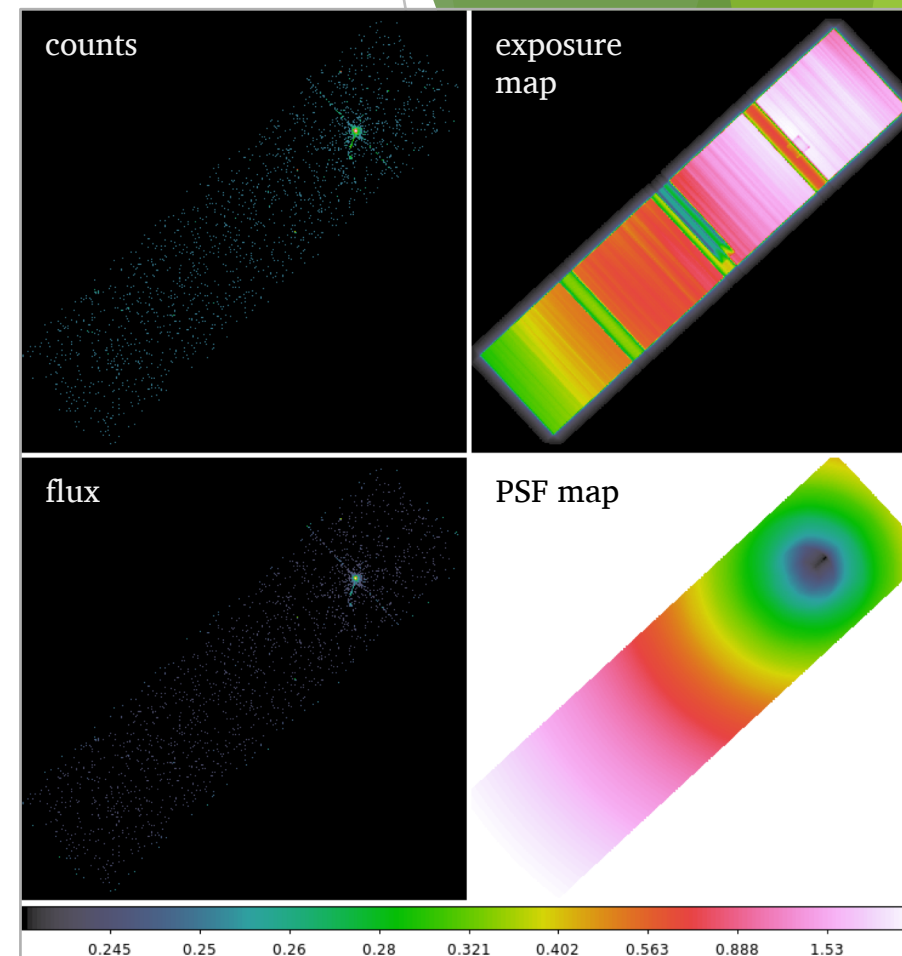
The following files were created:

The clipped counts image is:
flux/7302_broad_thresh.img

The clipped exposure map is:
flux/7302_broad_thresh.expmap

The PSF map is:
flux/7302_broad_thresh.psfmap

The exposure-corrected image is:
flux/7302_broad_flux.img



Note: ECF=0.393 corresponds to the 1σ integrated volume of a 2D Gaussian



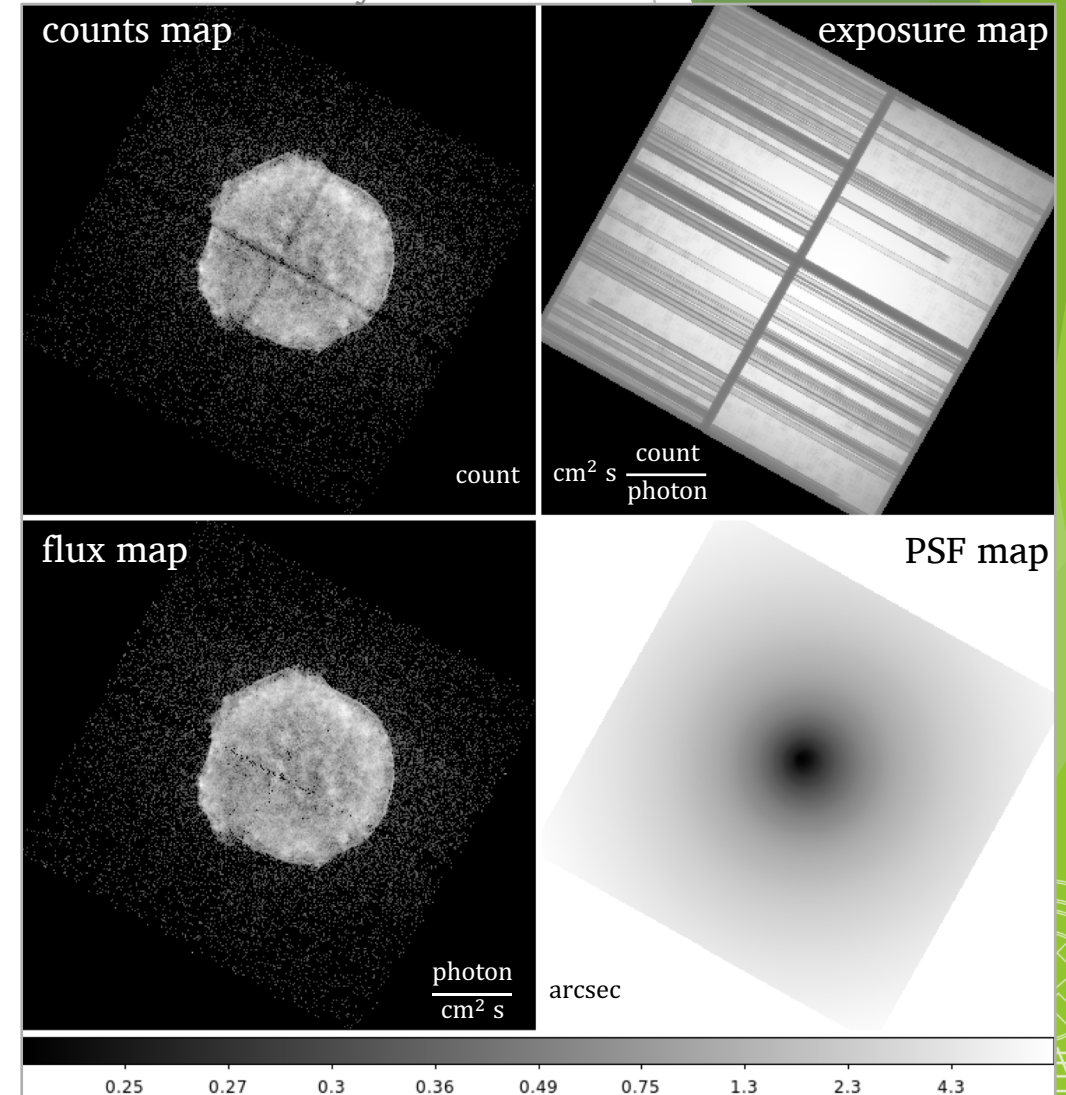
Source Detection Inputs

fluximage Data Products

- ▶ Binned counts map with clipping
- ▶ Exposure map (matching counts map)
 - ▶ units of $\text{cm}^2 \cdot \text{s} \cdot \frac{\text{count}}{\text{photon}}$ or $\text{cm}^2 \cdot \frac{\text{count}}{\text{photon}}$
 - ▶ analogous to optical/IR flat field image
- ▶ Exposure-corrected image (flux map): $\frac{\text{counts map}}{\text{exposure map}}$
- ▶ PSF map
 - ▶ provides the PSF size at each pixel of an image
 - ▶ size is the radius of an ECF circular region centered at the observation's aimpoint



ObsID 10095: Tycho's SNR



Source Detection

by way of `wavdetect`

```

unix% punlearn ardlib
unix% acis_set_ardlib 7302/repro/acisf07302_repro_bpix1.fits

unix% pset wavdetect infile=7302_broad_thresh.img
unix% pset wavdetect psffile=7302_broad_thresh.psfmap
unix% pset wavdetect expfile=7302_broad_thresh.expmap
unix% pset wavdetect outfile=detect/.
unix% pset wavdetect scellfile=detect/.
unix% pset wavdetect imagefile=detect/.
unix% pset wavdetect defnbkgfile=detect/.
unix% pset wavdetect regfile=detect/.
unix% pset wavdetect scales="1.0 2.0 4.0 8.0 16.0 32.0"
unix% pset wavdetect sigthresh=1e-6
unix% wavdetect clobber+ verbose=1 mode=h

. . . SCREEN OUTPUT . . .

Output background image: detect/7302_broad_nbkg.img
Output source image: detect/7302_broad_image.img
Output source cell image: detect/7302_broad_scell.img
Output source list file: detect/7302_broad_src.fits
Output source regions file: detect/7302_broad_src.reg
  
```

set bad pixel file for the tool
to use in the terminal

Note: `infile` requires Z-valued
pixels for valid results

fluximage results

output files, the "." in the arguments
automatically names output files for
`wavdetect` based on `infile` string

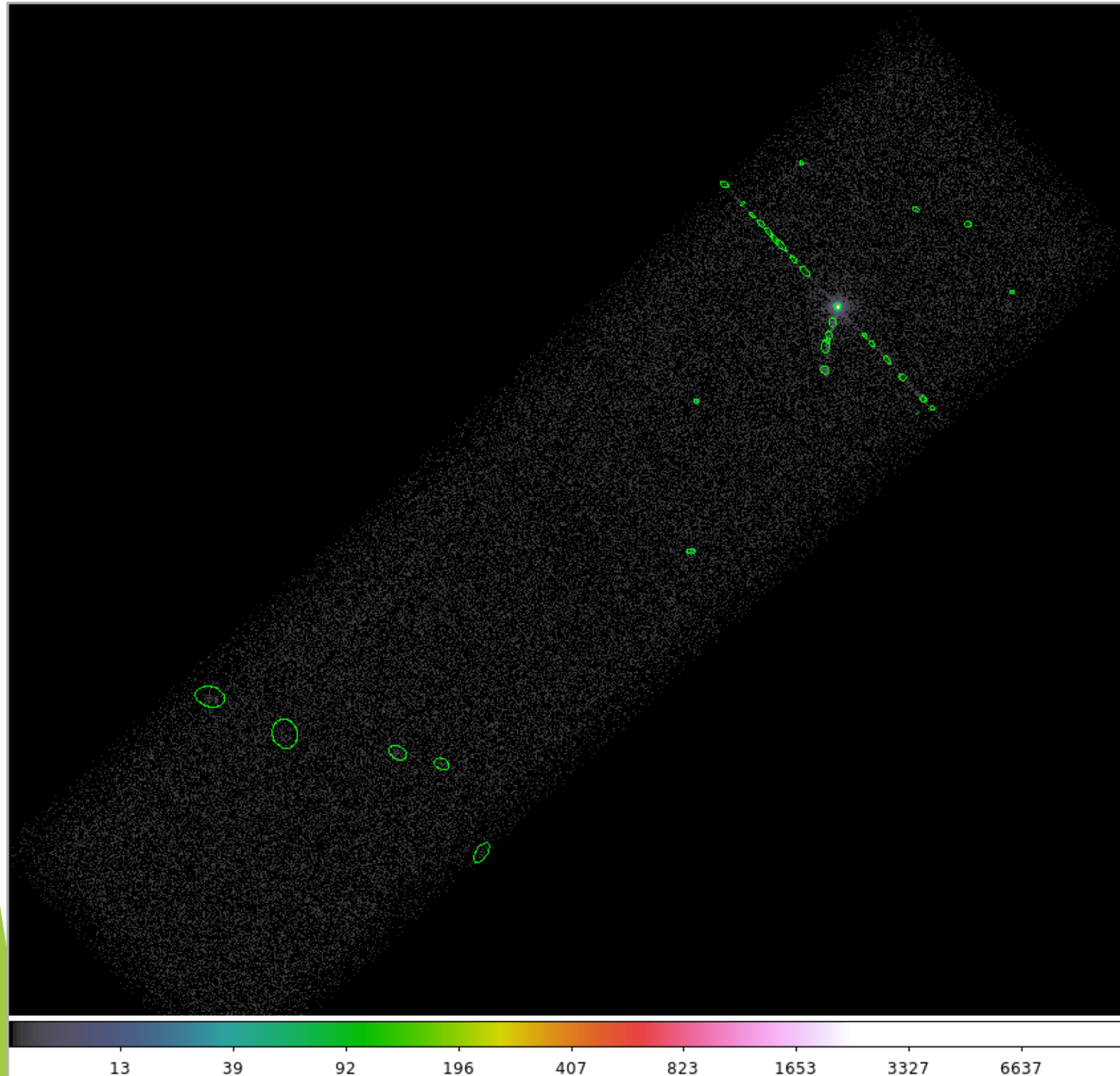
set of wavelet scales

`regfile` is the ASCII region file
and `outfile` is the source list





wavdetect Results



- Explore the source list with DS9 and `dmlist`.

```
unix% dmlist detect/7302_broad_src.fits blocks
```

```
-----  
Dataset: detect/7302_broad_src.fits
```

```
-----  
Block Name                                Type          Dimensions  
-----  
Block   1: PRIMARY                          Null  
Block   2: SRCLIST                          Table         26 cols x 33 rows
```

```
unix% dmlist 7302_src.fits cols
```

```
-----  
Columns for Table Block SRCLIST  
-----
```

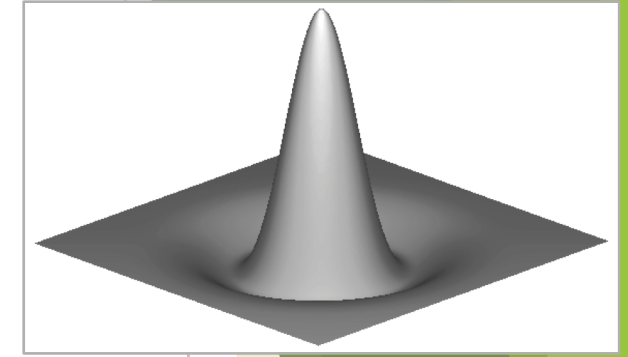
ColNo	Name	Unit	Type	Range	
1	RA	deg	Real8	0: 360.0	Source Right Ascension
2	DEC	deg	Real8	-90.0: 90.0	Source Declination
3	RA_ERR	deg	Real8	-Inf:+Inf	Source Right Ascension Err
4	DEC_ERR	deg	Real8	-Inf:+Inf	Source Declination Error
5	POS (X, Y)	pixel	Real8	3386.50: 4354.50	Physical coordinates
6	X_ERR	pixel	Real8	-Inf:+Inf	Source X position error
7	Y_ERR	pixel	Real8	-Inf:+Inf	Source Y position error
8	NPIXSOU	pixel	Int4	-	pixels in source region
9	NET_COUNTS	count	Real4	-Inf:+Inf	Net source counts
10	NET_COUNTS_ERR	count	Real4	-Inf:+Inf	Error in net source counts
11	BKG_COUNTS	count	Real4	-Inf:+Inf	Background counts
12	BKG_COUNTS_ERR	count	Real4	-Inf:+Inf	Error in BKG_COUNTS

```
. . . MORE INFO . . .
```



Source Detection (cont.)

by way of `wavdetect`—wavelet scales



- ▶ Wavelets are correlated with data image at each scale size.
 - ▶ scales are the radii of the Ricker (aka “Mexican Hat” or Marr) wavelet function
 - ▶ scales in units of image pixels
 - ▶ minimum and maximum scales chosen w.r.t. instrumental PSF sizes
 - ▶ smaller scales tend to detect small features and larger scales, large features
 - ▶ very large scales may be needed to characterize extended sources
 - ▶ scales typically separated by factor of 2 or $\sqrt{2}$
- ▶ large number of scales or large image size can drastically affect runtime



Source Detection (cont.)

by way of wavdetect

- ▶ `ellsigma` parameter affects the region size in `regfile` for visualization purposes.
 - ▶ scales the major- and minor-axes of the ellipses for each detection
 - ▶ does not affect source detection or source properties
- ▶ `sigthresh` parameter is the threshold that a pixel belongs to a source.
 - ▶
$$\text{sigthresh} \approx \frac{1}{\text{number of image pixels}}$$

```
unix% dmlist flux/7302_broad_thresh.img blocks
-----
Dataset: flux/7302_broad_thresh.img
-----
      Block Name          Type          Dimensions
-----
Block      1: EVENTS_IMAGE  Image          Int4 (968x926)
```

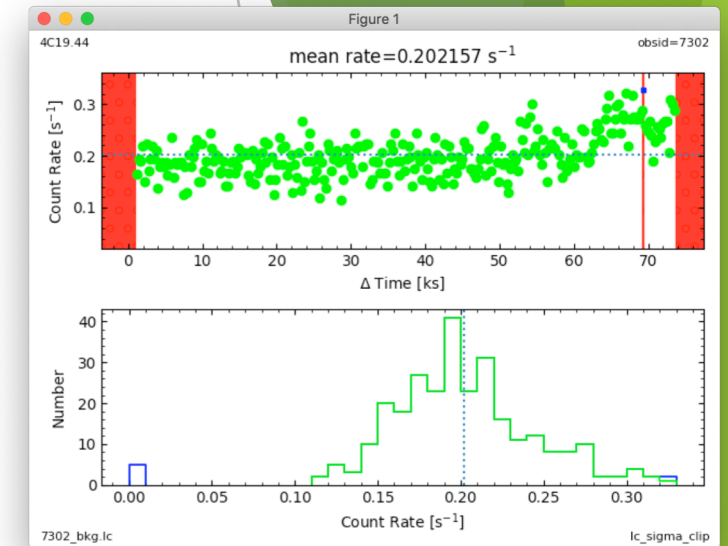
```
unix% python -c 'print(1/(968*926))'
1.1156132302804205e-06
```



Finding background flares

- ▶ The `deflare` script is a command-line interface to the `lightcurves` Python module to apply the `lc_clean` and `lc_sigma_clip` algorithms.
 - ▶ requires an input lightcurve of the background
 - ▶ returns a GTI file that can be used to filter FITS tables
 - ▶ done on a per CCD basis

- ▶ Extract lightcurve for each CCD, excluding the field sources.



```
unix% dmcopu acisf07302_repro_evt2.fits"[energy=500:7000,ccd_id=7]" 7302_0.5-7.0keV.evt
```

```
unix% dmextract "7302_0.5-7.0keV.evt[exclude sky=region(detect/7302_broad_src.fits)][bin time=::259.28]" \
? 7302_bkg.lc opt=ltc1
```


Finding background flares (cont.)

► run deflare

```
unix% deflare infile=7302_bkg.lc outfile=7302.gti \
? method=sigma plot=yes
```

. . . SCREEN OUTPUT . . .

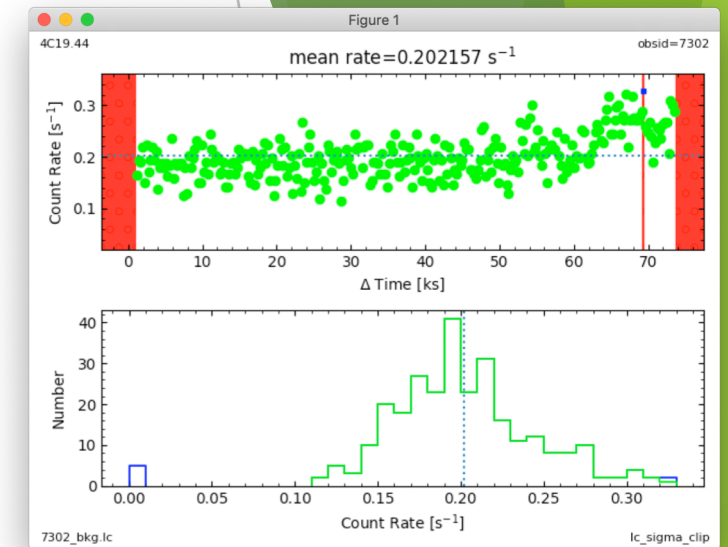
```
Creating GTI file
Created: 7302.gti
Light curve cleaned using the lc_sigma_clip
routine.
```

Optional: Applying GTI to events file

```
unix% dmcoppy "acisf07302_repro_evt2.fits[@7302.gti]" \
? 7302_clean_evt.fits

unix% dmkeypar acisf07302_repro_evt2.fits EXPOSURE echo+
68937.080789336

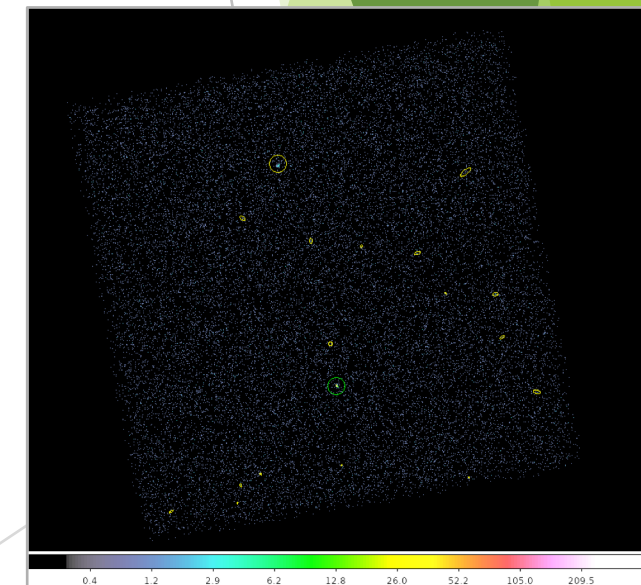
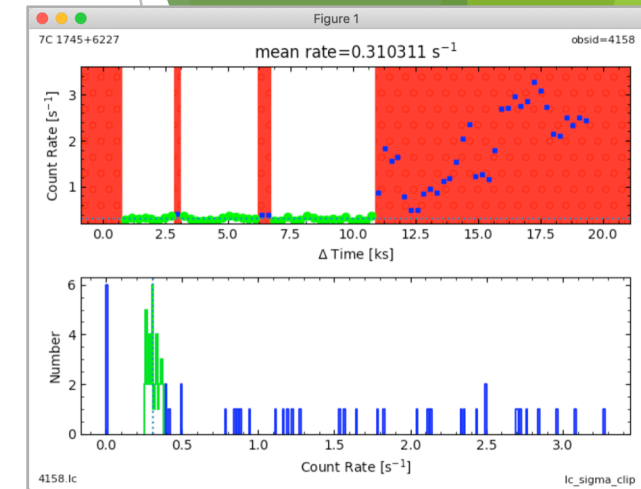
unix% dmkeypar 7302_clean_evt.fits EXPOSURE echo+
68443.824820477
```



Should deflaring always be applied?

Generally: IF we have variable background, AND if it would be significant for the source region, THEN we exclude the affected times.

- ▶ Need to weigh the pros and cons.
 - ▶ reduced exposure time \Rightarrow less source counts
 - ▶ longer exposure time \Rightarrow higher uncertainty from background
- ▶ Point source
 - ▶ how much of the observed background will coincide with the point source?
 - ▶ how much brighter is the apparent surface brightness of the source over the background?
- ▶ Extended source
 - ▶ accounting for background more important than in point source analysis
 - ▶ complex spatial structure in source may dominate over background effects
 - ▶ does effects in embedded structure spillover to ambient background?
 - ▶ how much source free background available in observation?

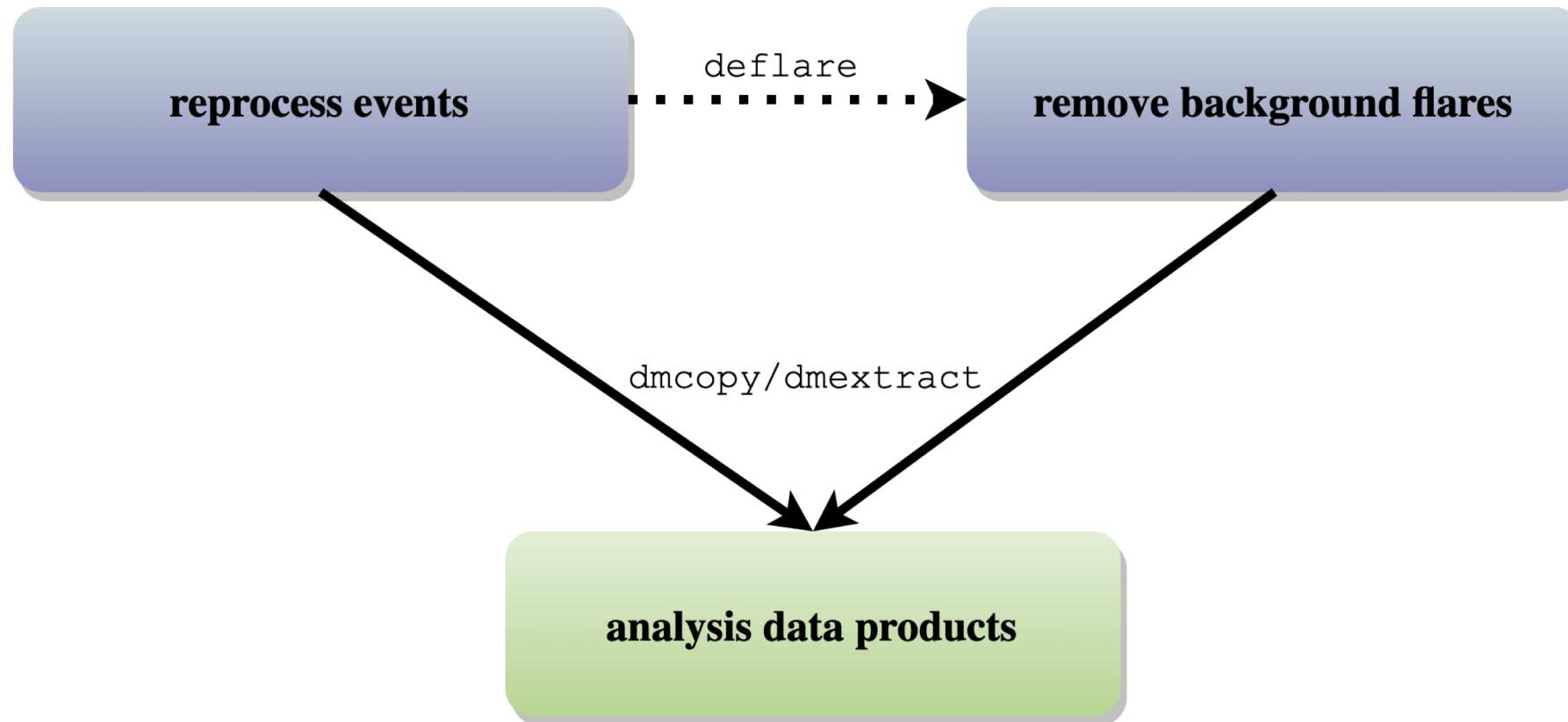




Reprocessed Dataset

`acisf07302_repro_evt2.fits`

`7302_clean_evt.fits`





Finally, a gentle reminder:

How can the CCD_ID be mistaken in an observation?
 It's really easy to, especially if only the ACIS-I array
 is used...

ACIS FLIGHT FOCAL PLANE

