CIAO analysis with ds9

Kenny Glotfelty

with special thanks to
Bill Joye
and the SAORD team

* Updated 08 September 2011 with local links to screencasts

Outline

- Introduction / History
- ds9 User Interface
- Regions in ds9 and CIAO
- CIAO Analysis Menu
- Catalog tool (if time)

Introduction

- A quick SAOImage ds9 history
  - SAOImage developed at CfA circa 1990. One of the 1st publicly available X10/X11 applications.
  - SAOtng came on the scene 1995 with an “open concept” (think plugins) and client/server communication (XPA)
  - SAOImage ds9 1st released in 1999.
- ds9 is independent of CIAO
  - It has its own release schedule

Under the hood

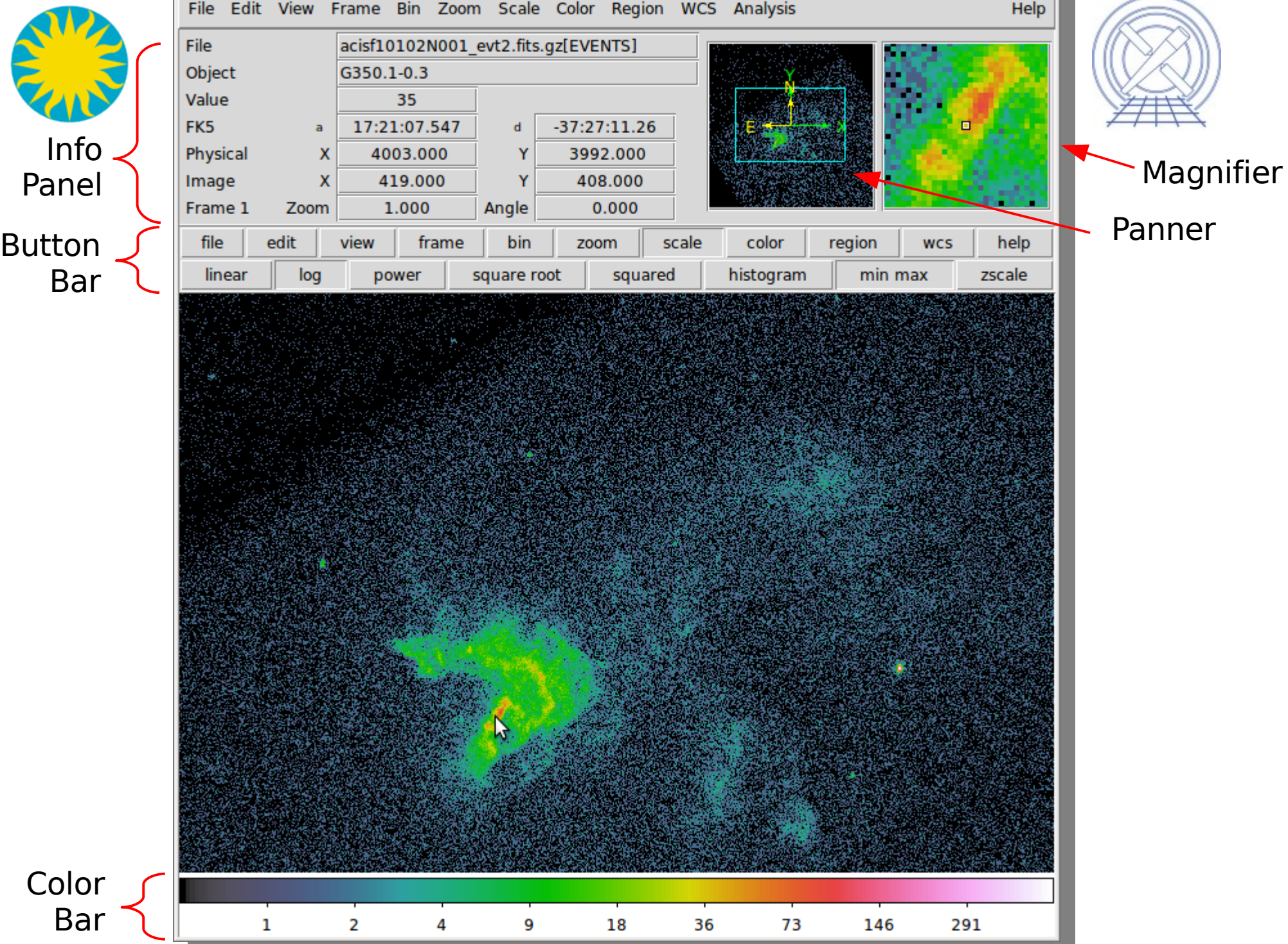
- GUI is written tcl/tk
  - advanced users can modify GUI (add buttons, menus, etc.)
- Open architecture
  - Easily add custom analysis commands, etc.
- Built on top of various off the shelf (OTS) packages
  - I/O comes from FUNTOOLS
    - some differences in syntax compared to CIAO or FTOOLS

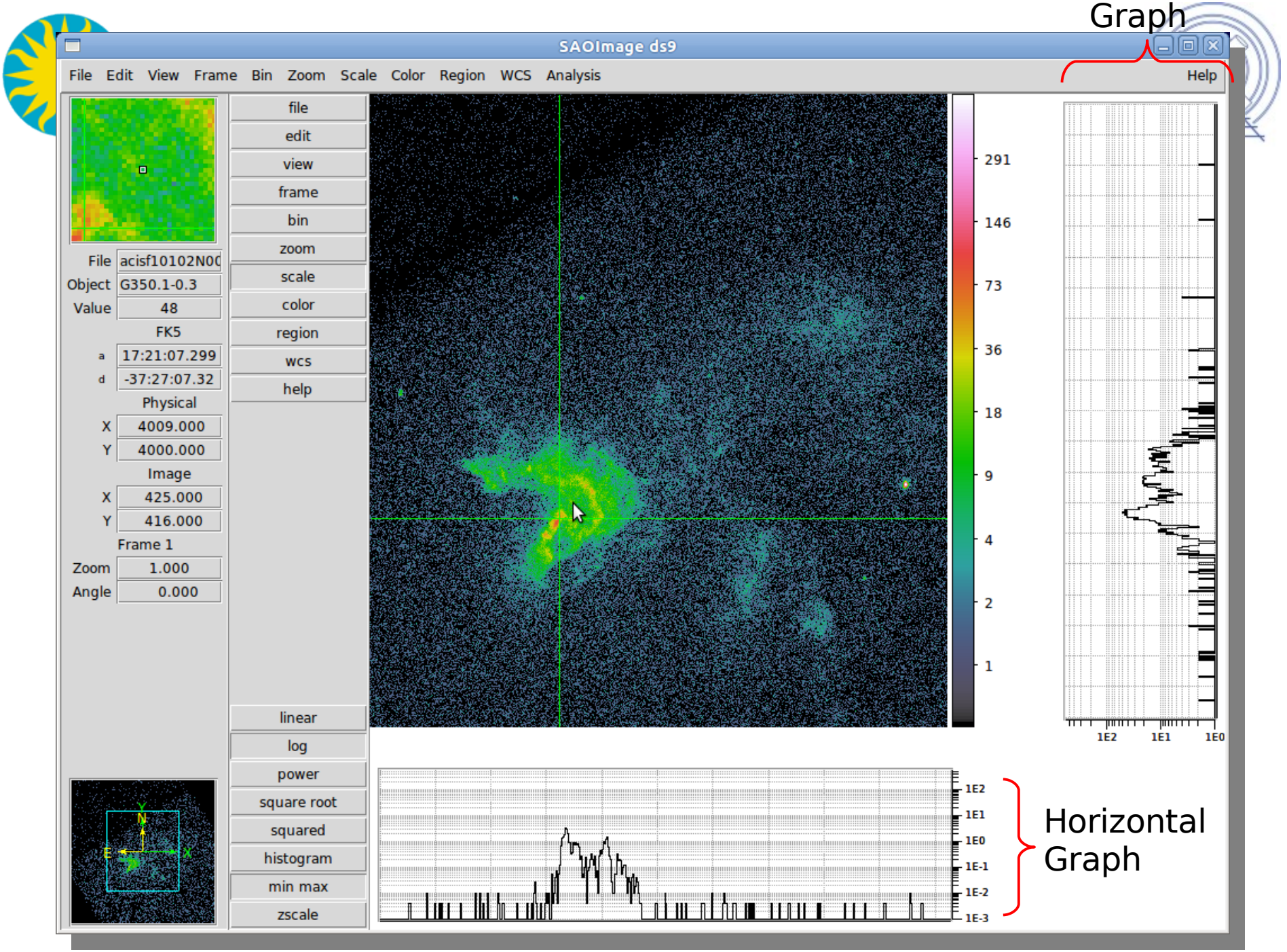
```
unix% dmcopy “event_file[EVENTS][bin x,y]” image.fits

unix% ds9 “event_file[EVENTS,bin=x,y]”
```

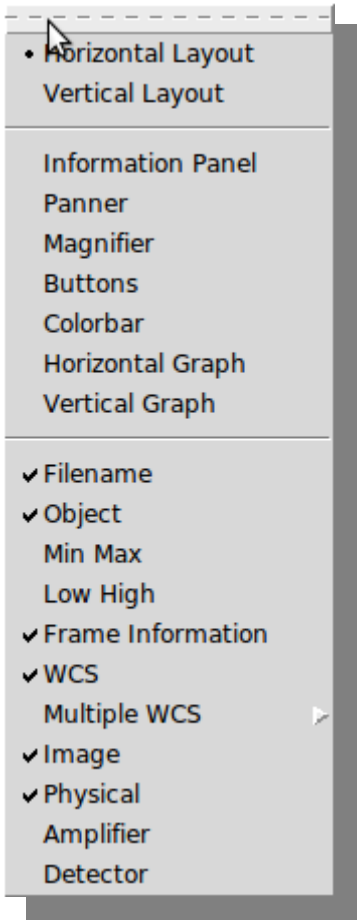
ds9 User Interface

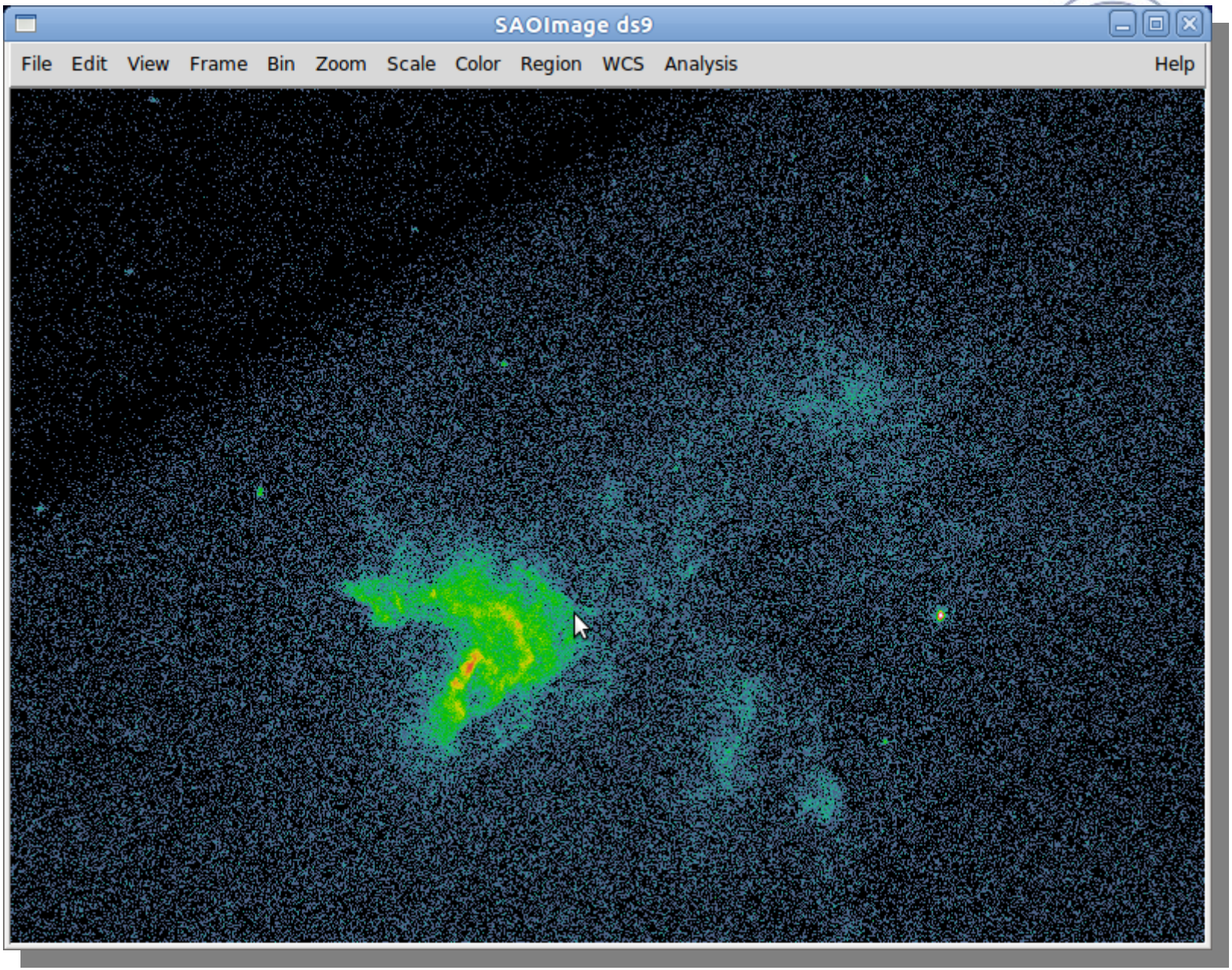
- Standard UI elements
  - Pan/Zoom
  - Button bar
  - Color bar
- View menu
  - Horizontal/Vertical
  - Hide/Show UI elements
    - Maximize real-estate


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
File acisf10102N001_evt2.fits.gz[EVENTS]
Object G350.1-0.3
Value 35
FK5 a 17:21:07.547 d -37:27:11.26
Physical X 4003.000 Y 3992.000
Image X 419.000 Y 408.000
Frame 1 Zoom 1.000 Angle 0.000
file edit view frame bin zoom scale color region wcs help
linear log power square root squared histogram min max zscale
1 2 4 9 18 36 73 146 291
Info Panel
Button Bar
Color Bar
Magnifier
Panner


Vertical Graph
SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
file
edit
view
frame
bin
zoom
scale
color
region
wcs
help
File acisf10102N0(
Object G350.1-0.3
Value 48
FK5
a 17:21:07.299
d -37:27:07.32
Physical
X 4009.000
Y 4000.000
Image
X 425.000
Y 416.000
Frame 1
Zoom 1.000
Angle 0.000
linear
log
power
square root
squared
histogram
min max
zscale
291
146
73
36
18
9
4
2
1
1E2
1E1
1E0
1E-1
1E-2
1E-3
Horizontal Graph

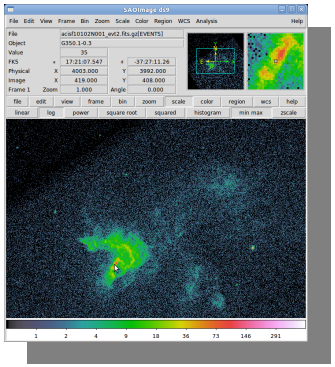
View Menu

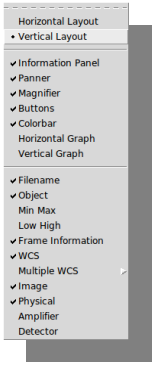

Horizontal Layout
Vertical Layout
Information Panel
Panner
Magnifier
Buttons
Colorbar
Horizontal Graph
Vertical Graph
Filename
Object
Min Max
Low High
Frame Information
WCS
Multiple WCS
Image
Physical
Amplifier
Detector

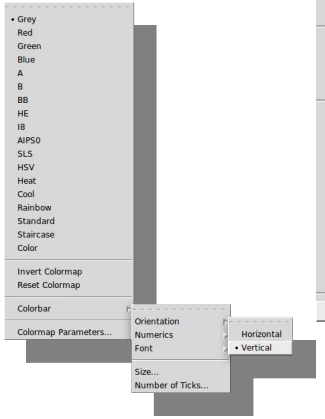

SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help

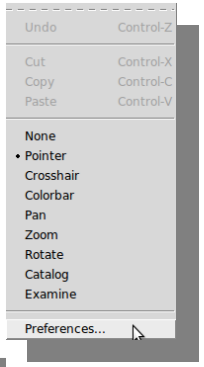
Customizing UI

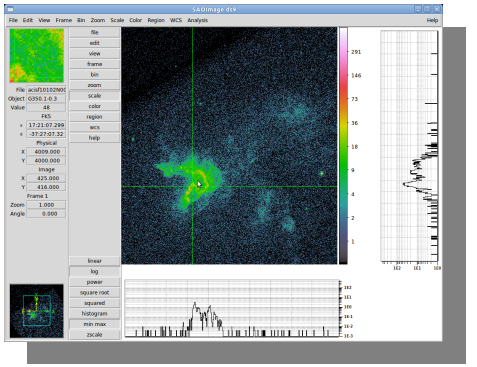
http://hea-www.harvard.edu/~kjg/screencast/ds9_customize_ui.mp4

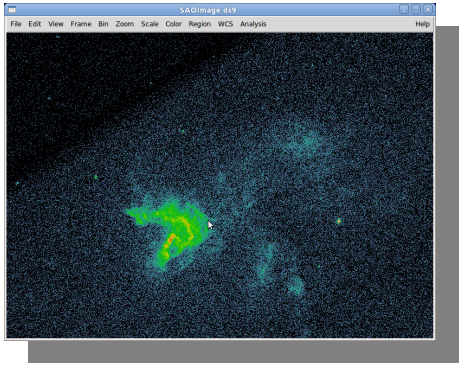


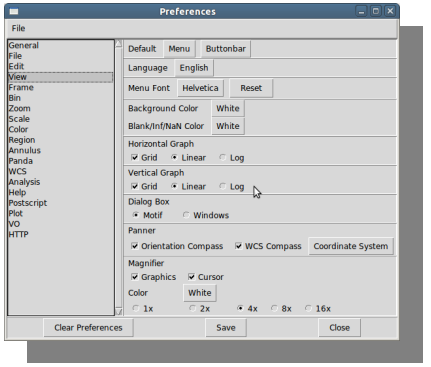












Thank you for muting the audio during the workshop.

X-ray Data

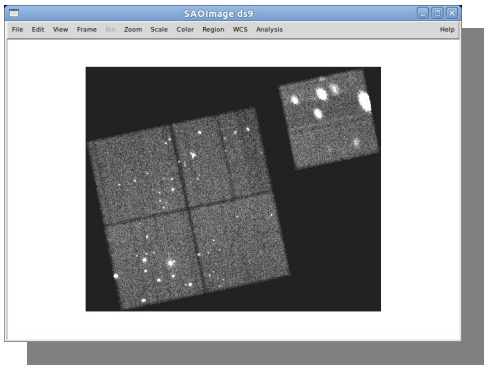
- Chandra primary science data product is the event list
  - Stored as a FITS binary table
  - 4 Dimensional sparse data cube
    - X, Y, Time, and Energy
    - 5-d if we consider Status and Grade (quality)
- ds9 displays images
  - Bins event list into images on-the-fly

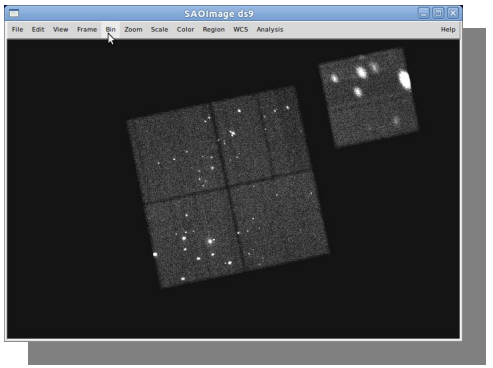
Inputs

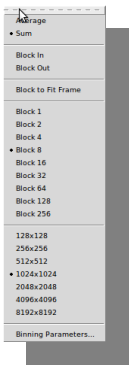
- Image
- Event file
  - Bin menu
  - Binning parameters
  - 3D binning
- RGB
  - Energy, time, Optical/IR/X-ray
- Mask
- Mosaics

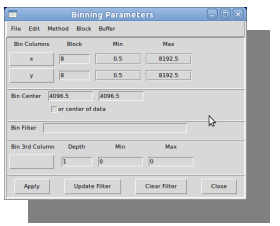
Input: Images vs Events

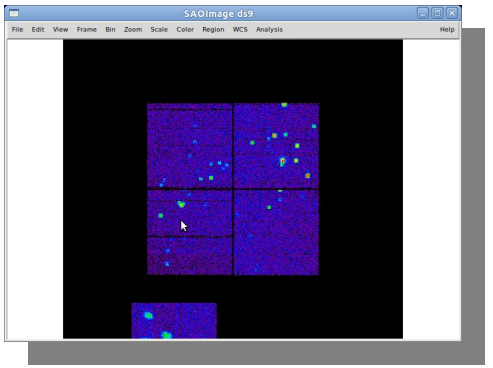
http://hea-www.harvard.edu/~kjg/screencast/ds9_load_image_and_event.mp4







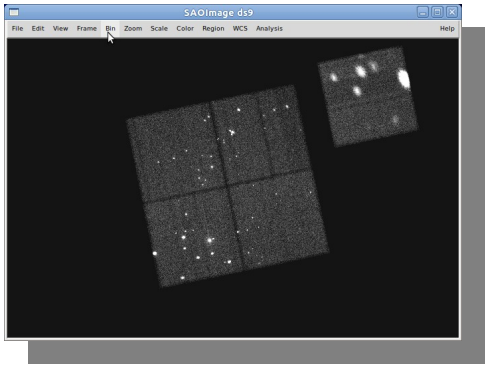


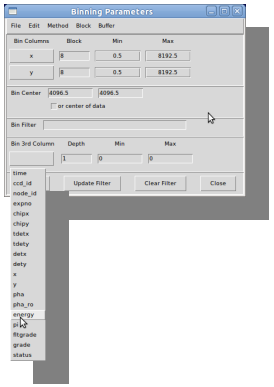


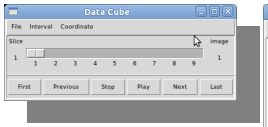
See also ahelp coords

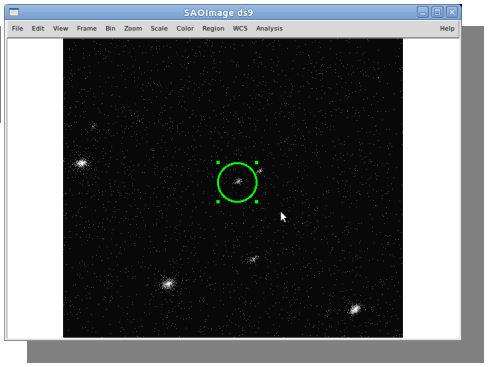
Input: 3D Binning

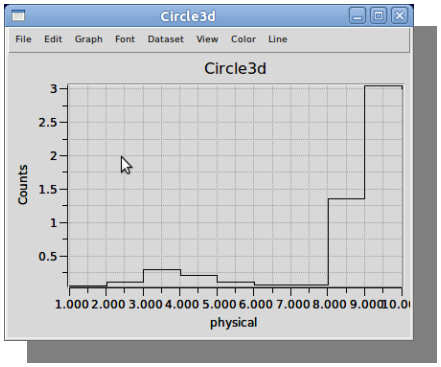
http://hea-www.harvard.edu/~kjg/screencast/ds9_3d_binning.mp4





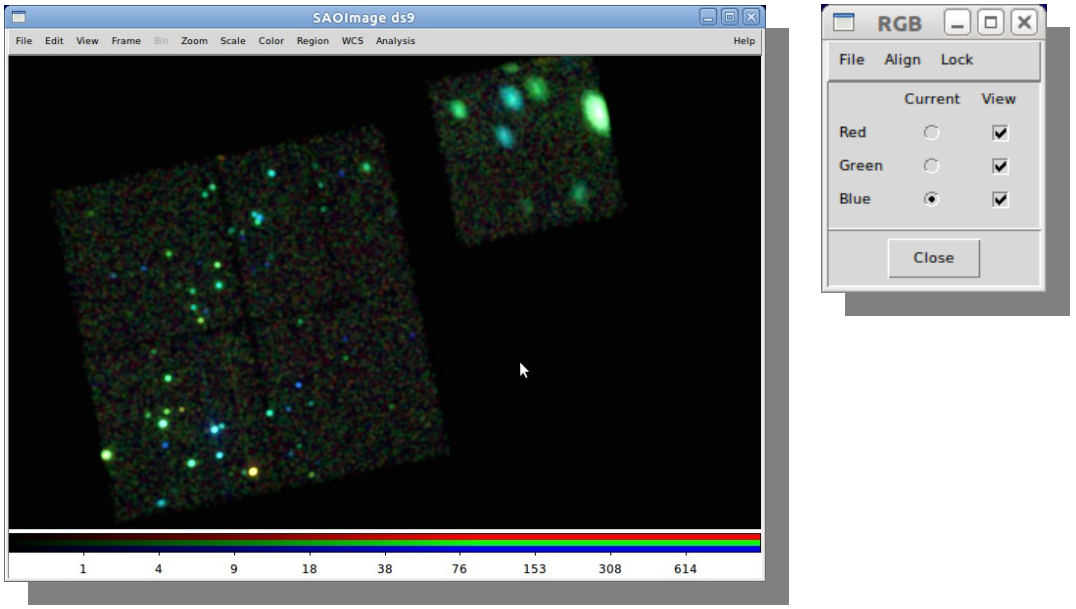






Input: RGB Datasets

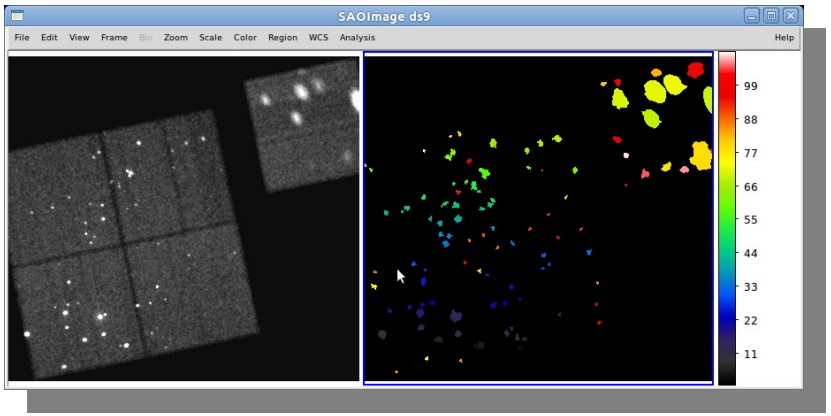
http://hea-www.harvard.edu/~kjg/screencast/ds9_rgb.mp4

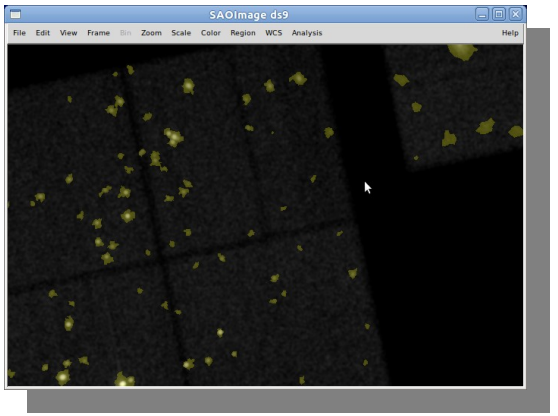


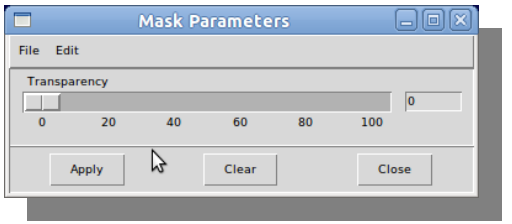
See also ahelp dmimg2jpg and ChIPS gallery

Input: Masks

http://hea-www.harvard.edu/~kjg/screencast/ds9_masks.mp4





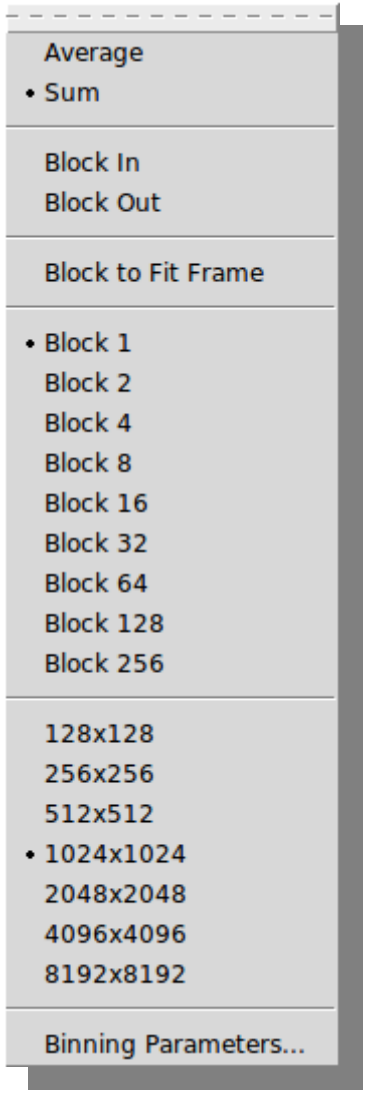


See also ahelp wavdetect

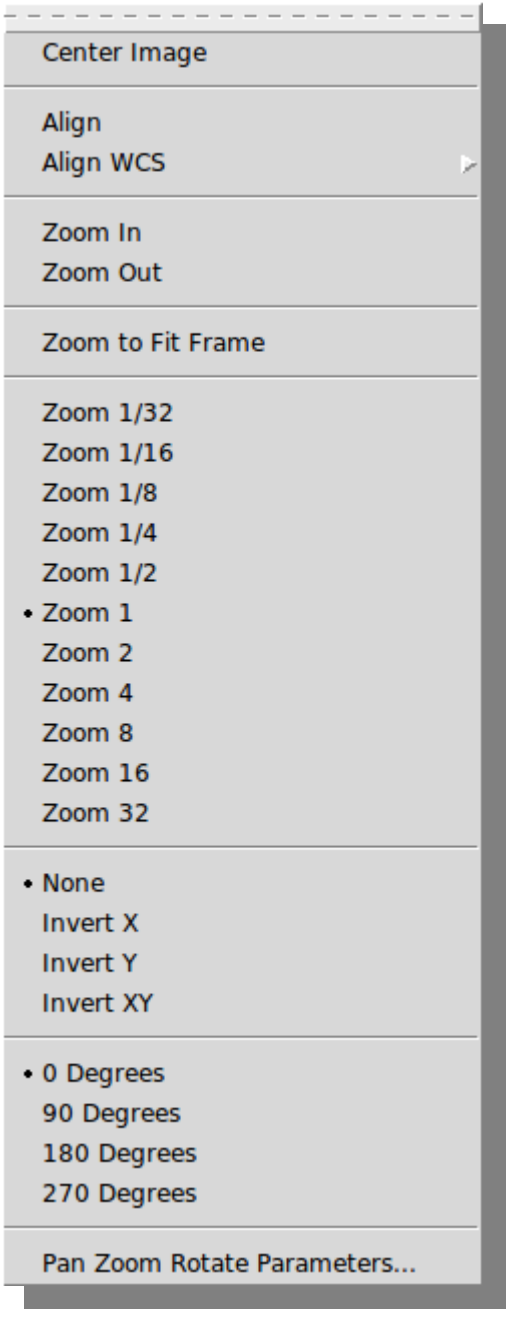
Bin vs Zoom

- Zoom
  - Images
  - sub-sample (<1) or over-sample (>1)
- Bin
  - Tables are binned into Images
    - Images that can be Zoom'ed
  - Arbitrary columns
  - Arbitrary (but fixed) size and resolution
    - Default is to make a 1k x 1k image, at bin=1, centered at the tangent point

Bin vs Zoom Menus

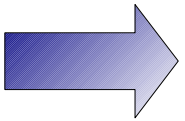


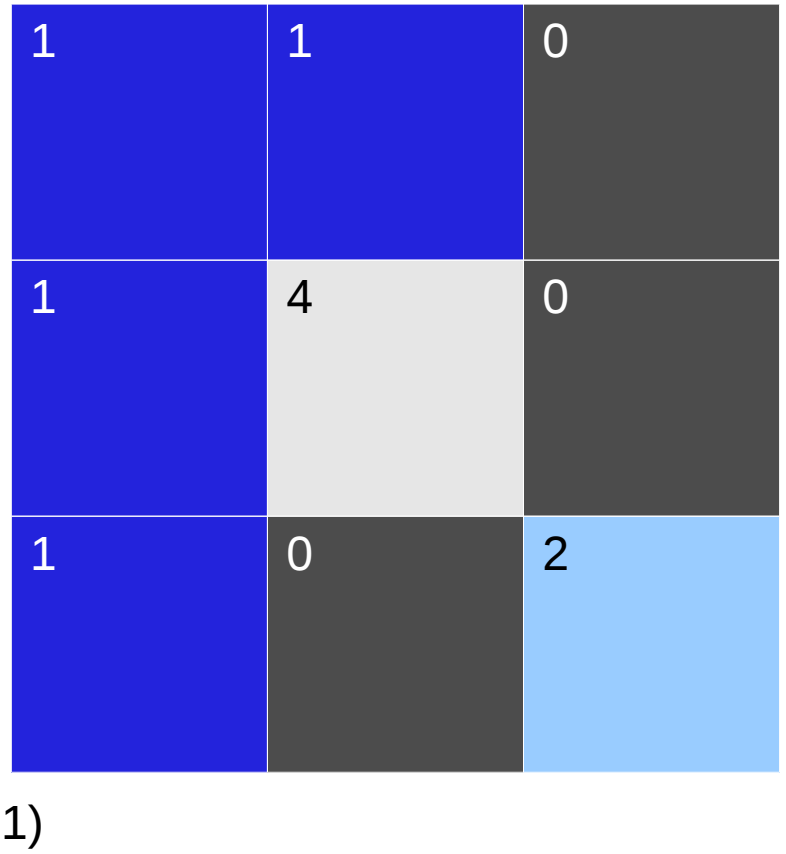
Note: block = bin



Example Event File

X	Y
1.5	2.3
1.8	3.3
2.2	2.1
3.4	1.9
2.3	2.5
2.6	2.6
3.0	1.9
2.5	3.5
1.2	1.1
2.9	2.5

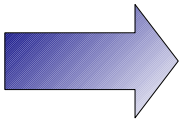


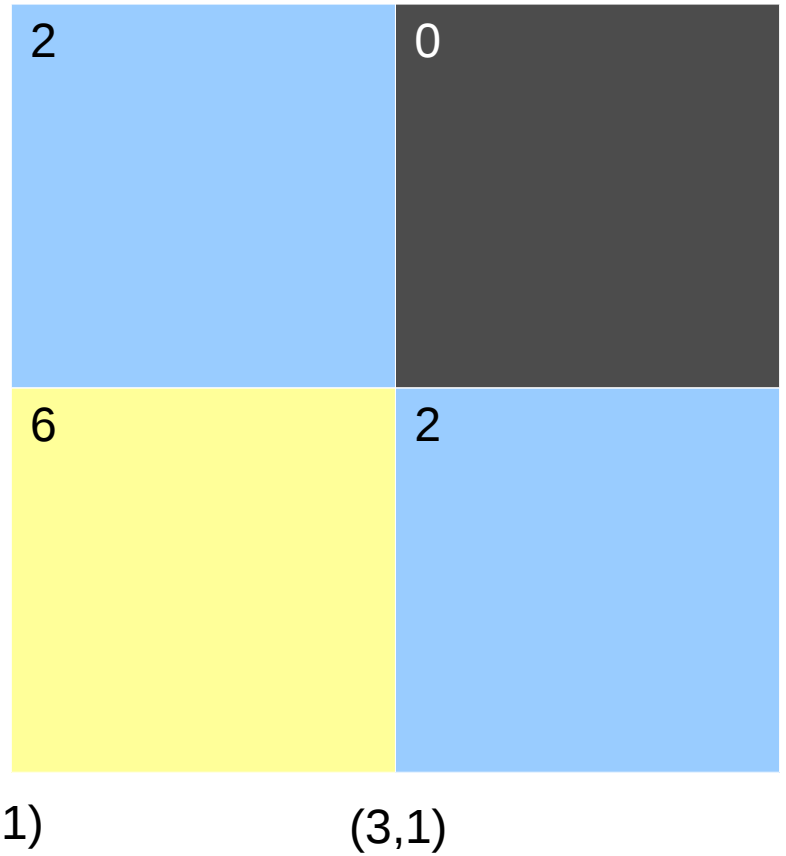


Binning table into an image.

Bin by 2.0

X	Y
1.5	2.3
1.8	3.3
2.2	2.1
3.4	1.9
2.3	2.5
2.6	2.6
3.0	1.9
2.5	3.5
1.2	1.1
2.9	2.5

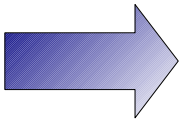




Bin by 2. Each single screen represents 2x2 grid. ds9 default is to sum pixels; can also choose to average pixels.

Bin by 0.5

X	Y
1.5	2.3
1.8	3.3
2.2	2.1
3.4	1.9
2.3	2.5
2.6	2.6
3.0	1.9
2.5	3.5
1.2	1.1
2.9	2.5



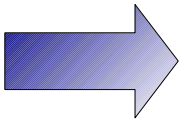
0	0	0	1	0	0
0	1	0	0	0	0
0	0	1	2	0	0
0	1	1	0	0	0
0	0	0	0	2	0
1	0	0	0	0	0

(1,1) (2,1)

Not restricted to binning by integer values (nor powers of 2). X and Y can use different blocking factors.

Zoom by 2

X	Y
1.5	2.3
1.8	3.3
2.2	2.1
3.4	1.9
2.3	2.5
2.6	2.6
3.0	1.9
2.5	3.5
1.2	1.1
2.9	2.5



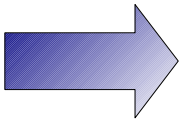
1	1	1	1	0	0
1	1	1	1	0	0
1	1	4	4	0	0
1	1	4	4	0	0
1	1	0	0	2	2
1	1	0	0	2	2

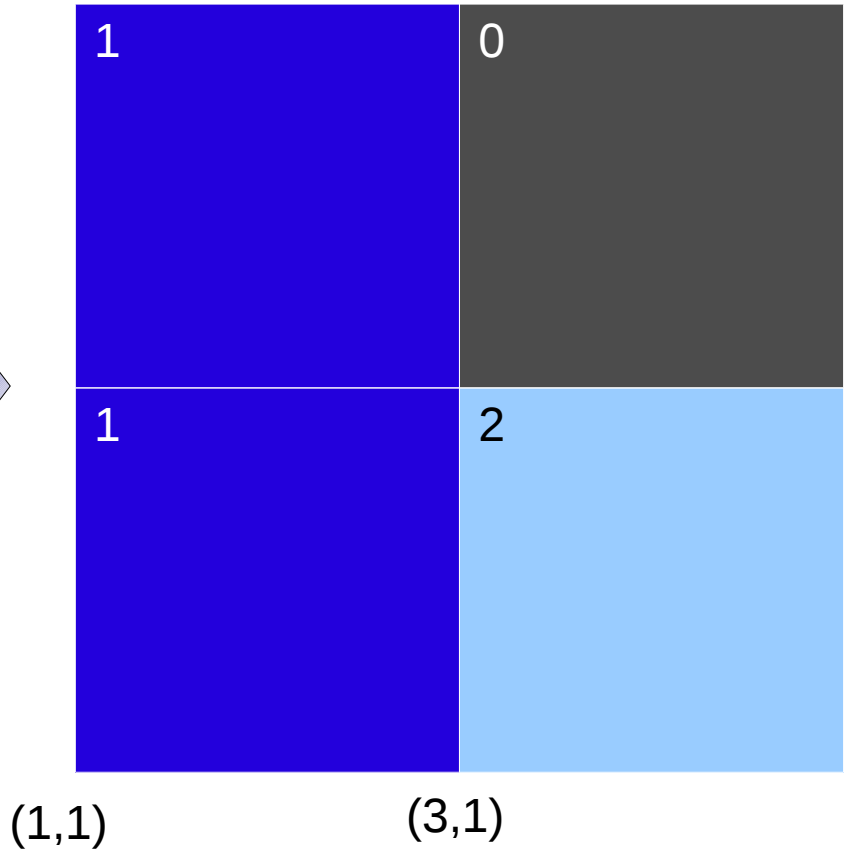
(1,1) (2,1)

Zooming replicates the same image pixel to multiple screen pixels

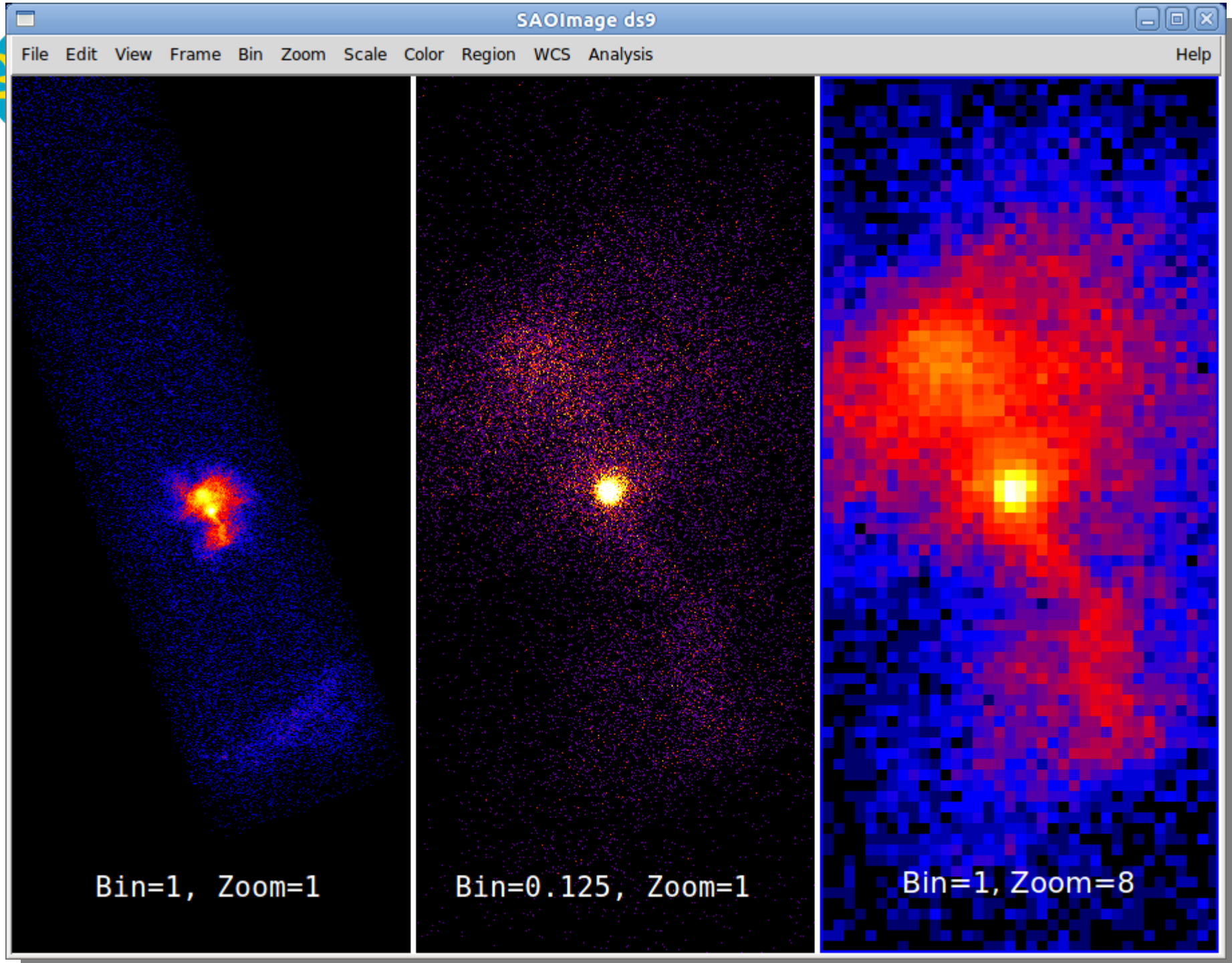
Zoom by 0.5

X	Y
1.5	2.3
1.8	3.3
2.2	2.1
3.4	1.9
2.3	2.5
2.6	2.6
3.0	1.9
2.5	3.5
1.2	1.1
2.9	2.5



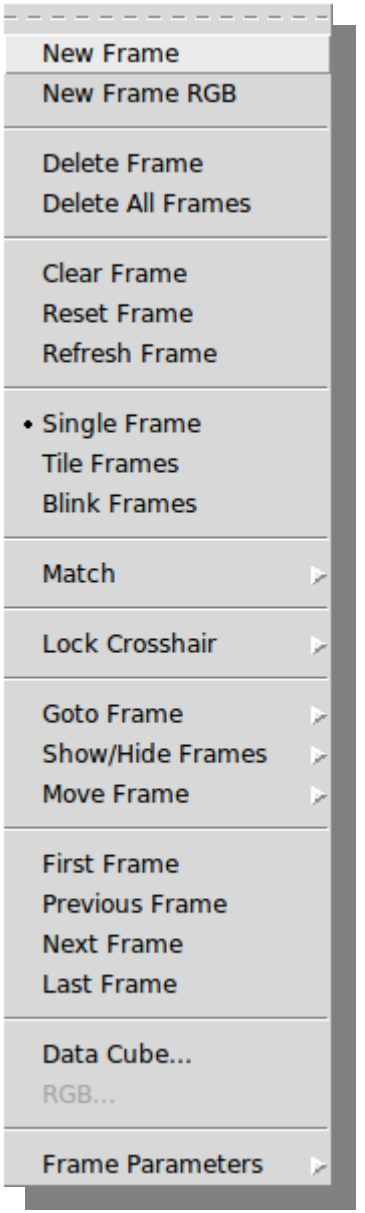


Zooming by < 1 samples every 1/n-th row/column


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
Bin=1, Zoom=1
Bin=0.125, Zoom=1
Bin=1, Zoom=8

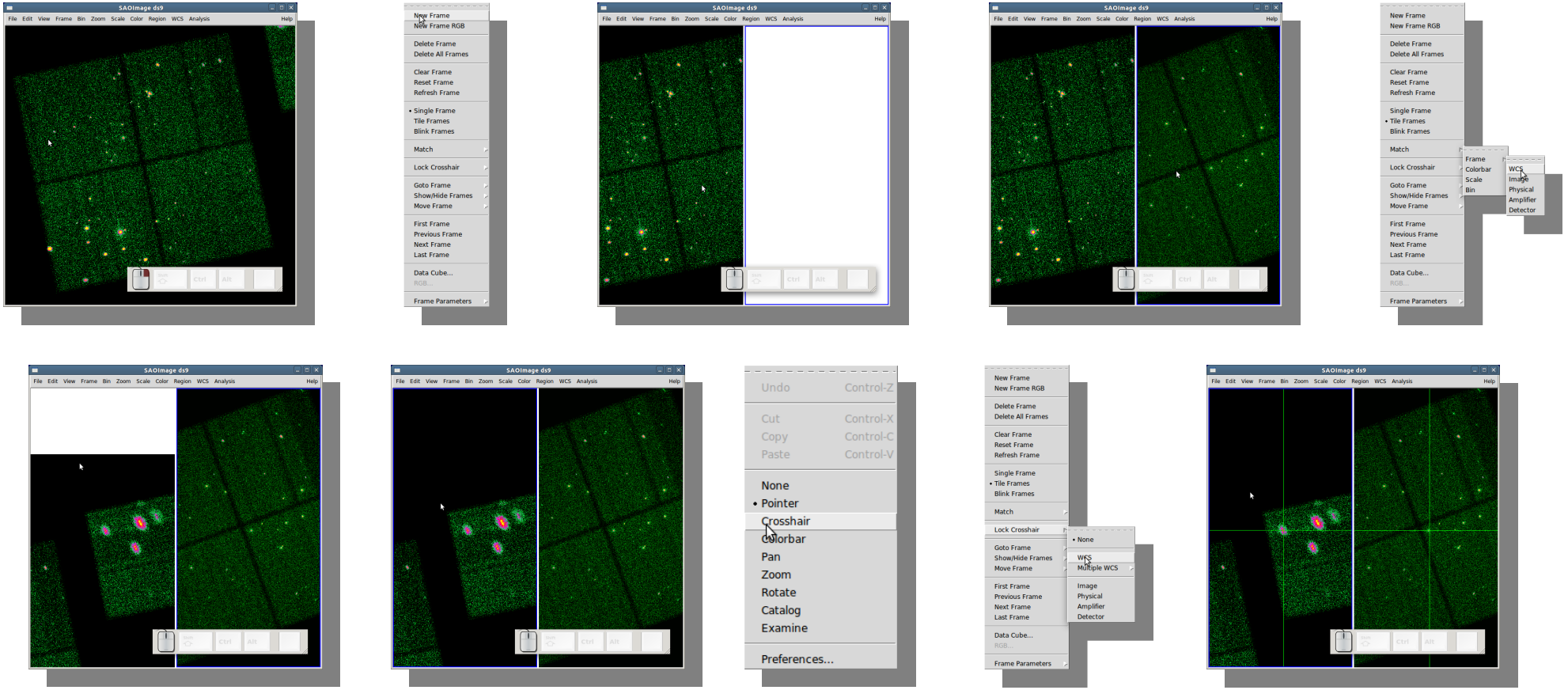
Frames

- Tile / Blink
  - Tile parameters
- Match Frames
  - WCS
- Match color/scale/etc
- Crosshair
  - Lock on WCS
  - Correlate objects in multiple images



Frame demo

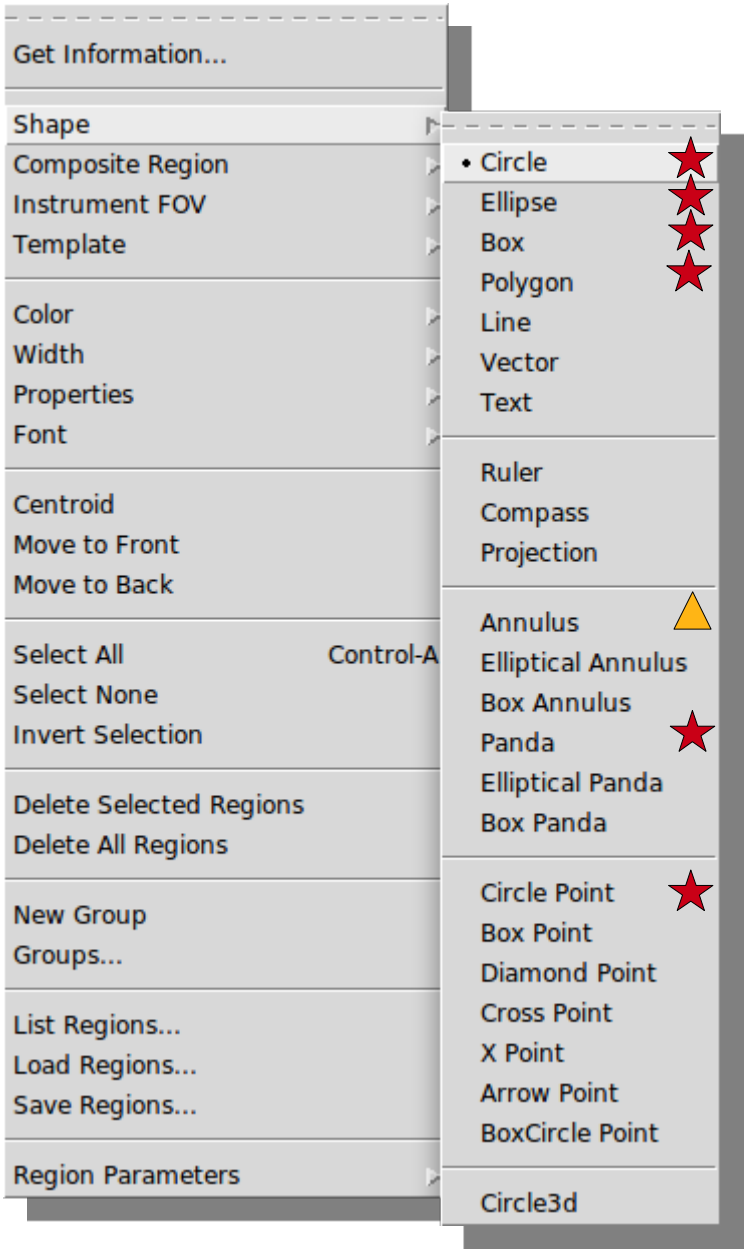
http://hea-www.harvard.edu/~kjg/screencast/ds9_multi_frame.mp4

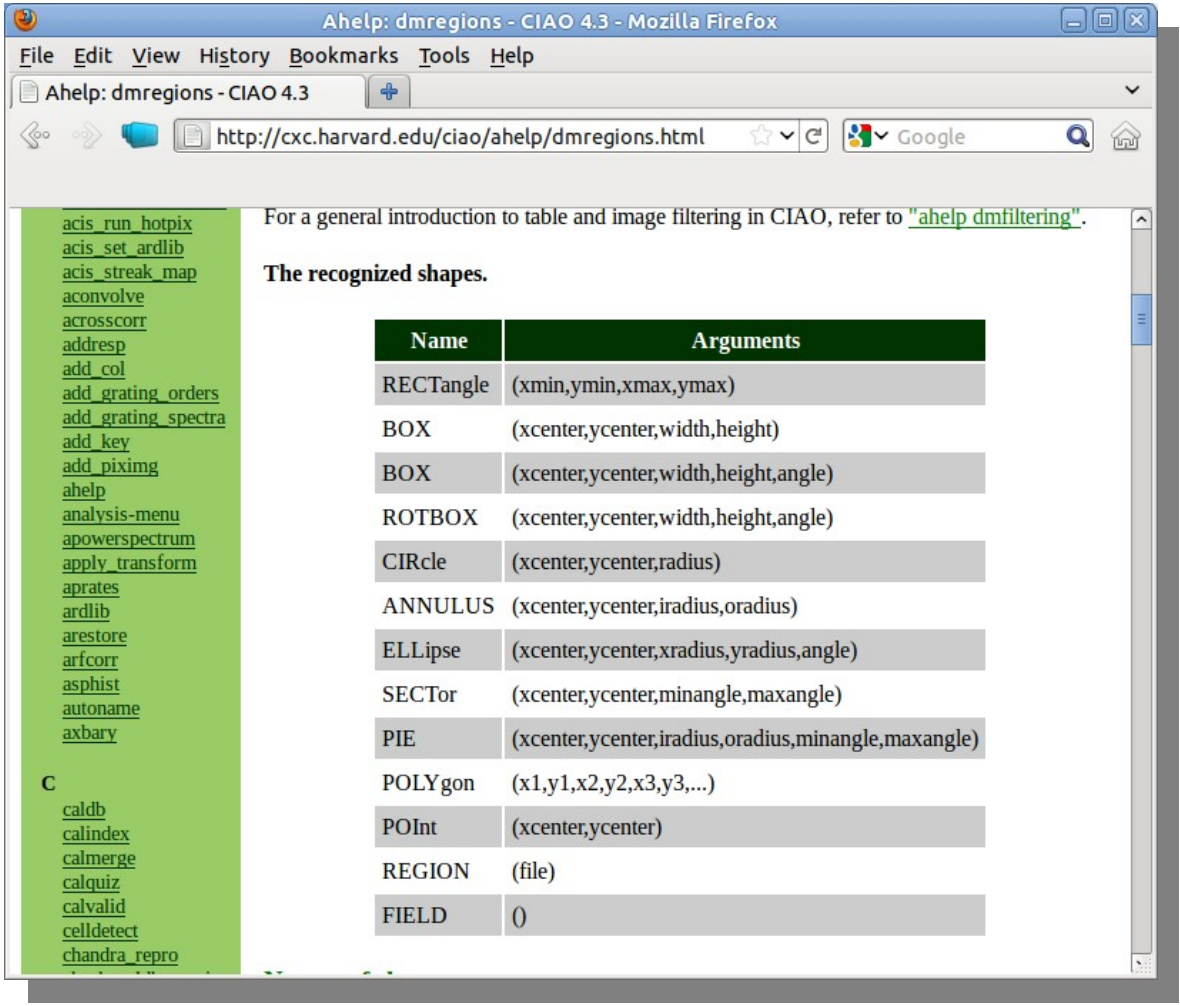


Regions

- ds9 allows users to draw various graphics on top of the image being displayed.
- These can be loosely categorized in two ways
  - Analysis: shapes usable as 2D filters. Examples include circle, polygon, ellipse, box, annulus, etc.
  - Annotation: shapes providing anecdotal information useful when publishing the image. Examples include vector, compass, ruler, text, etc.
- A 3rd category of shapes provides live histograms of pixels and include the projection and the (new) Circle3D

Shapes Supported by CIAO





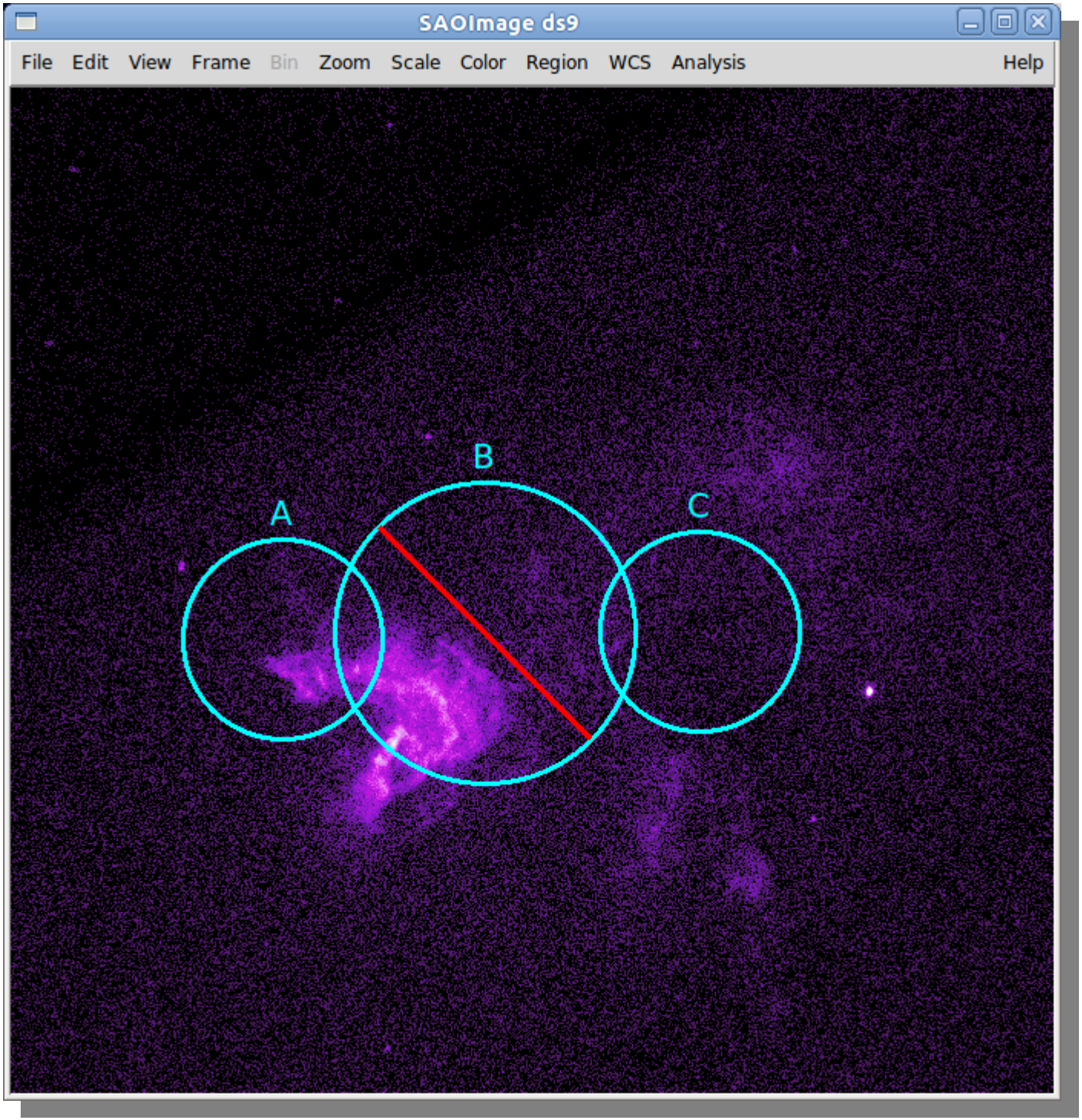
A single ds9 “panda” is a CIAO “pie”

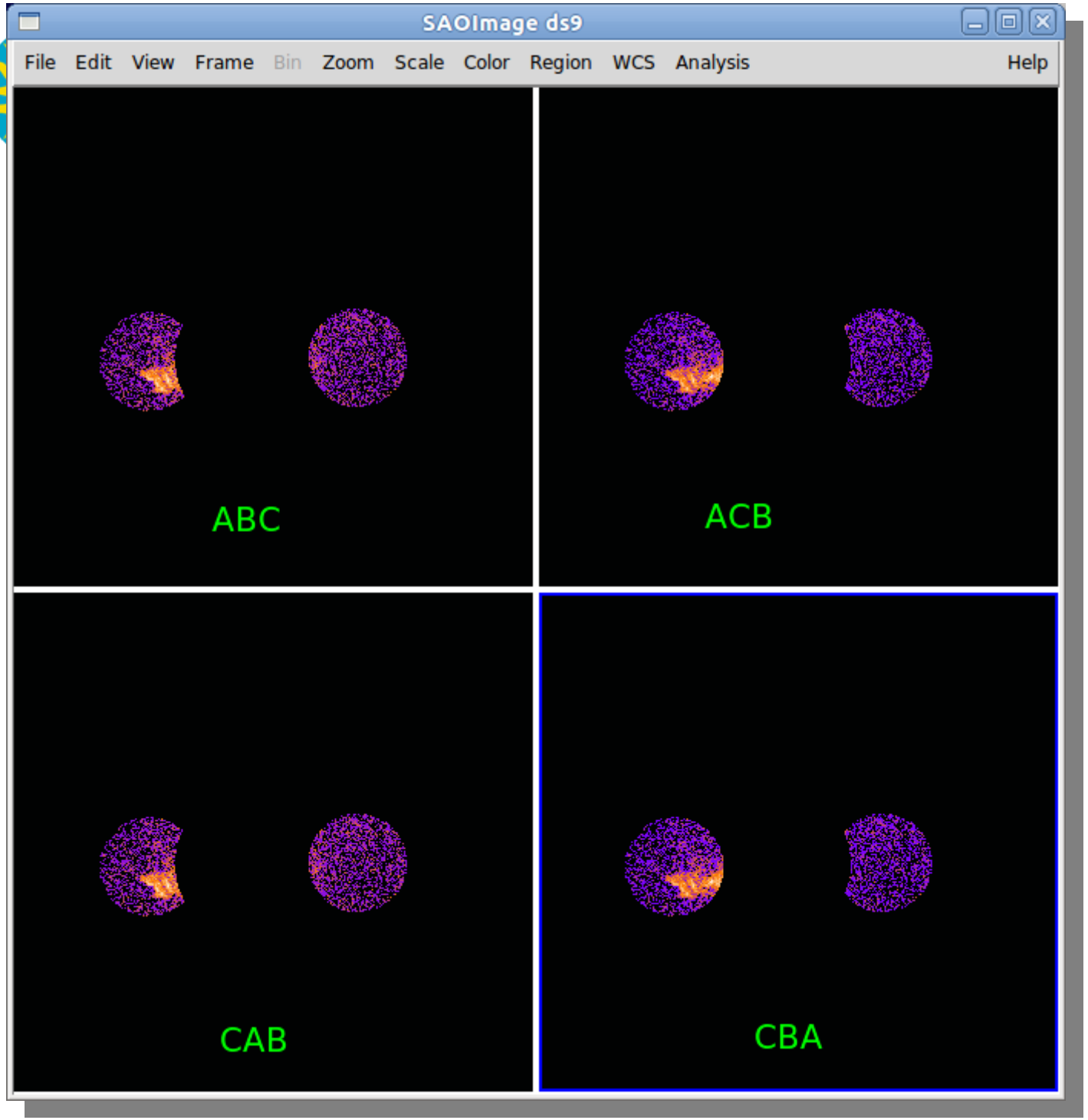
CIAO does not distinguish between “points”

The “annulus” is special, details later

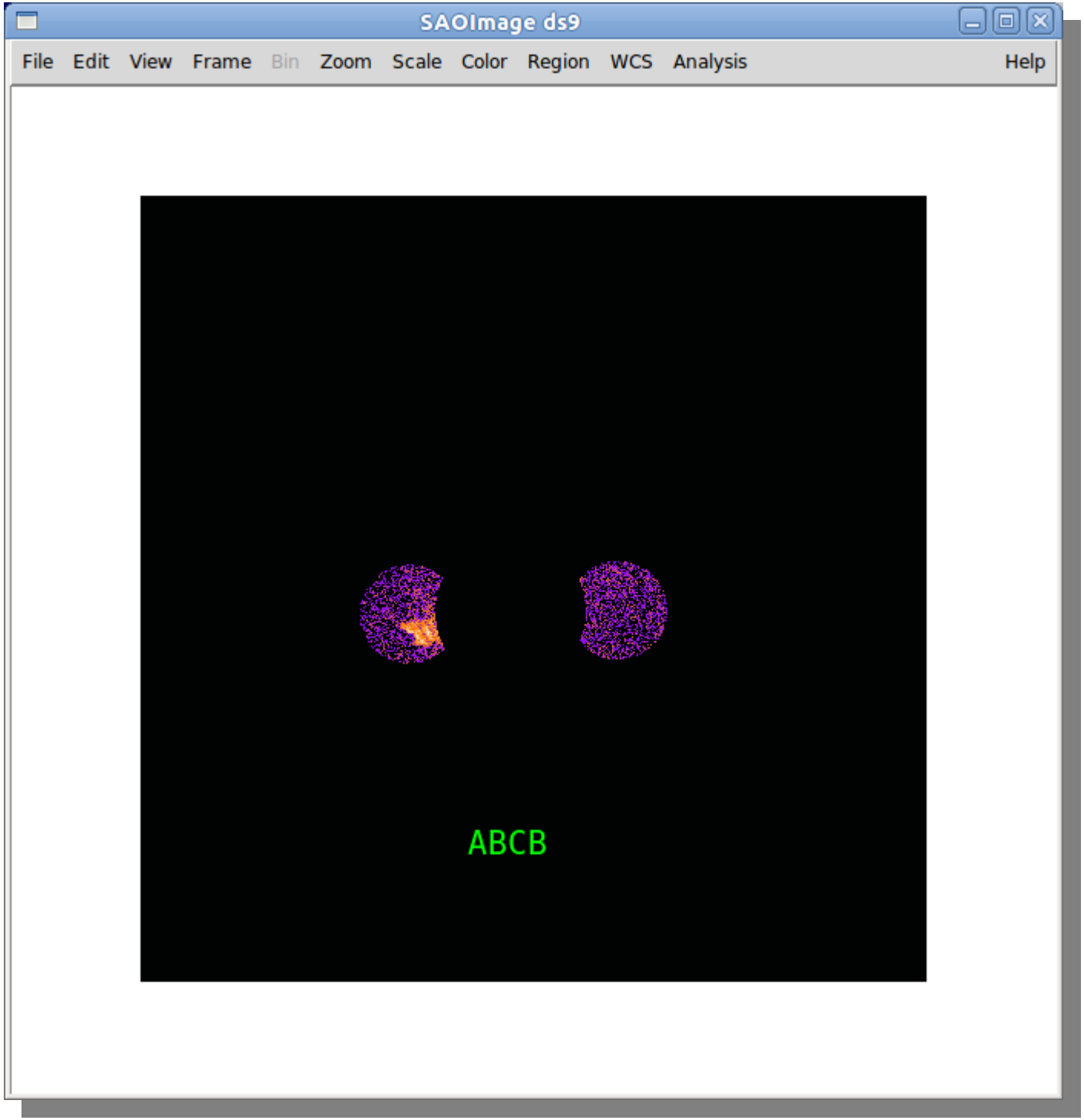
Region logic

- CIAO allows arbitrary combinations of shapes to be combined to make up a single region.
- Why order matters?
  - There are only 3 logic operators: and (“*”), or (“+”), and not (“!”).
  - “-” is expand to be “*!” (and not) that is why a-b+c is not the same as a+c-b
  - This is also why “-” cannot be used with 1st shape in the stack; every exclude must be excluded from something.
    - field() can be useful


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
A
B
C

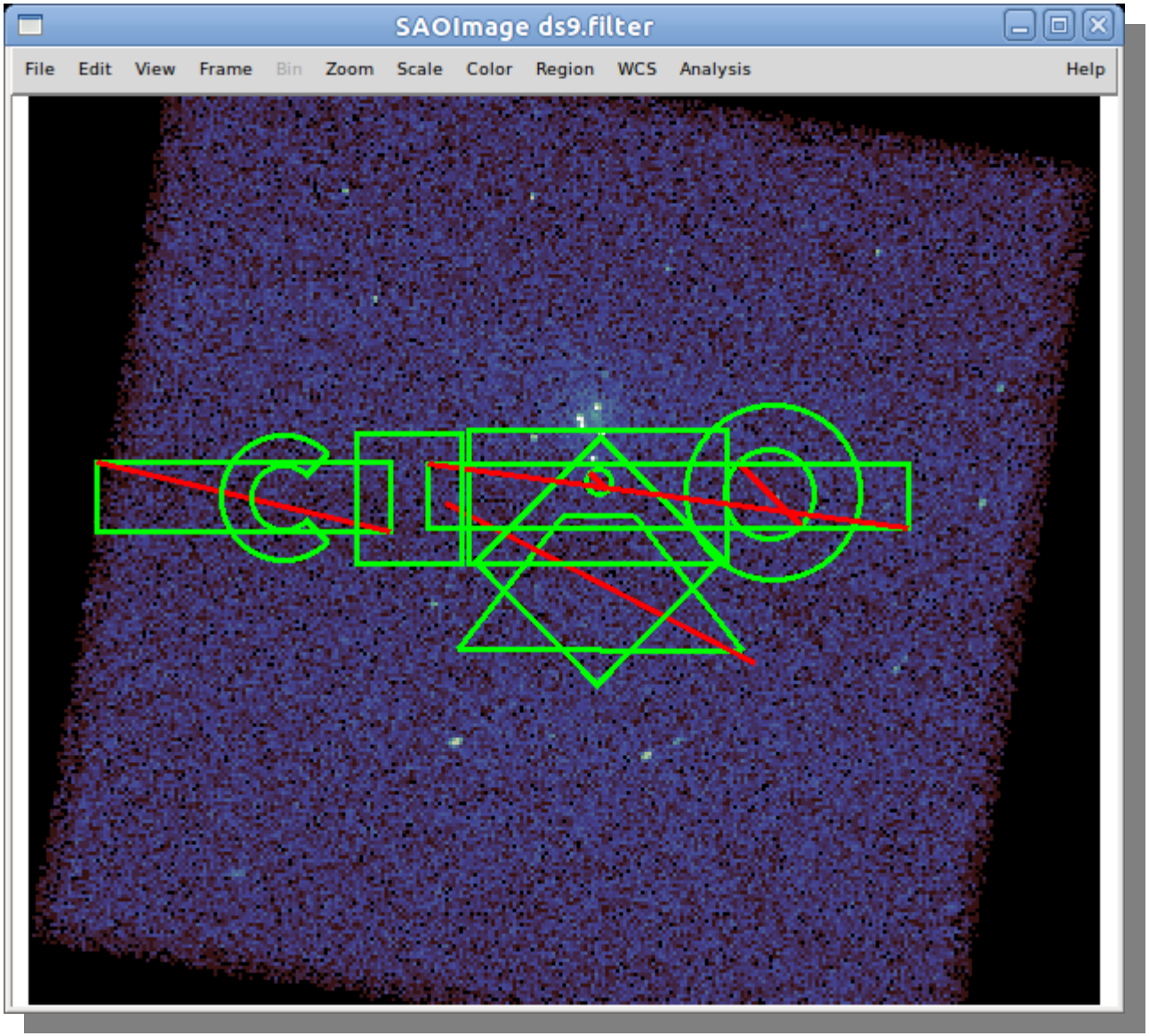


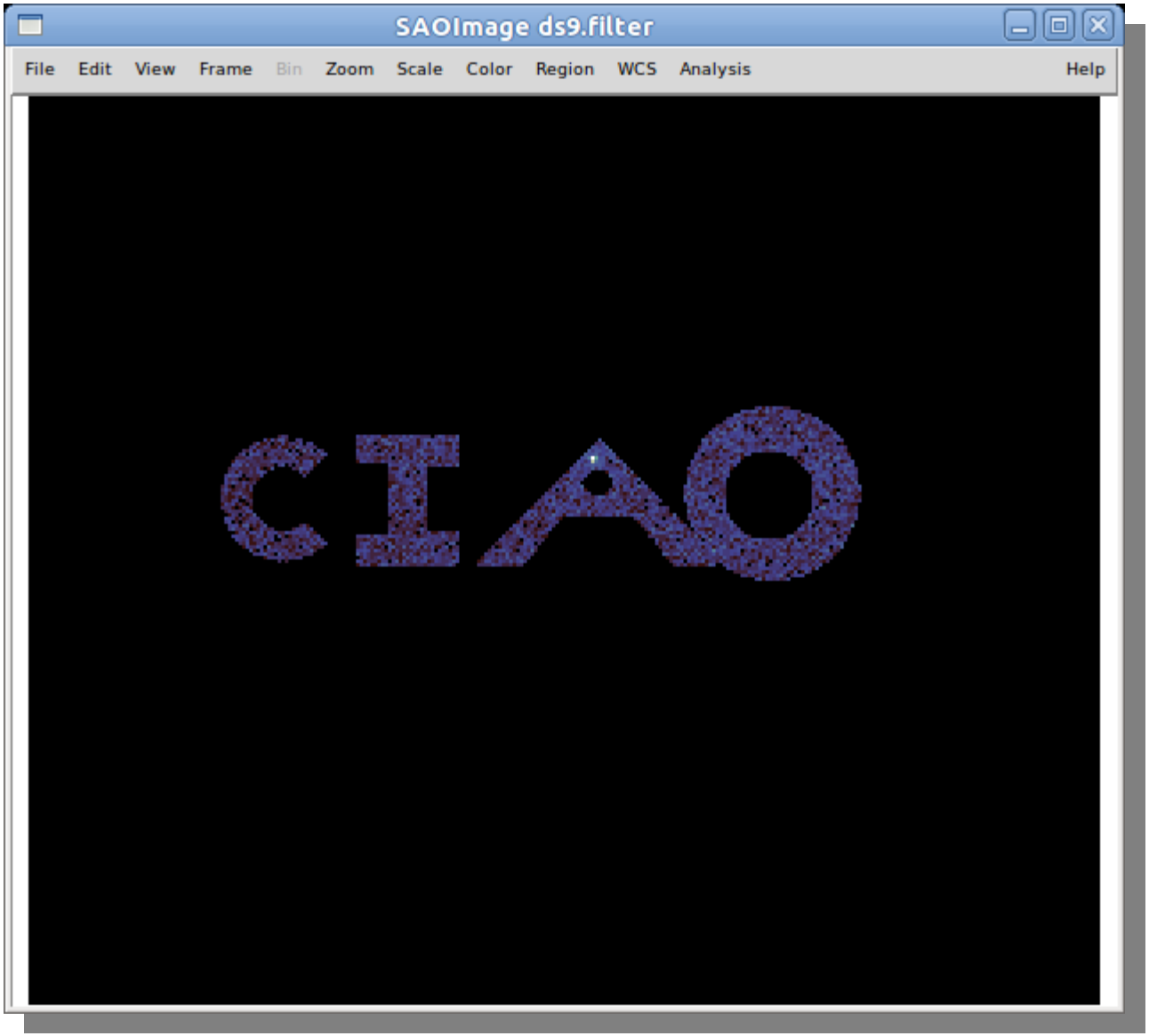
BAC and BCA are both invalid and generate an error message.



To remove B from both, you must specify it explicitly.

This kind of advanced filtering logic allows for extremely complex regions for example ...


SAOImage ds9.filter
File
Edit
View
Frame
Bin
Zoom
Scale
Color
Region
WCS
Analysis
Help


SAOImage ds9.filter
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
CIAO

ds9 Multi-Region Shapes

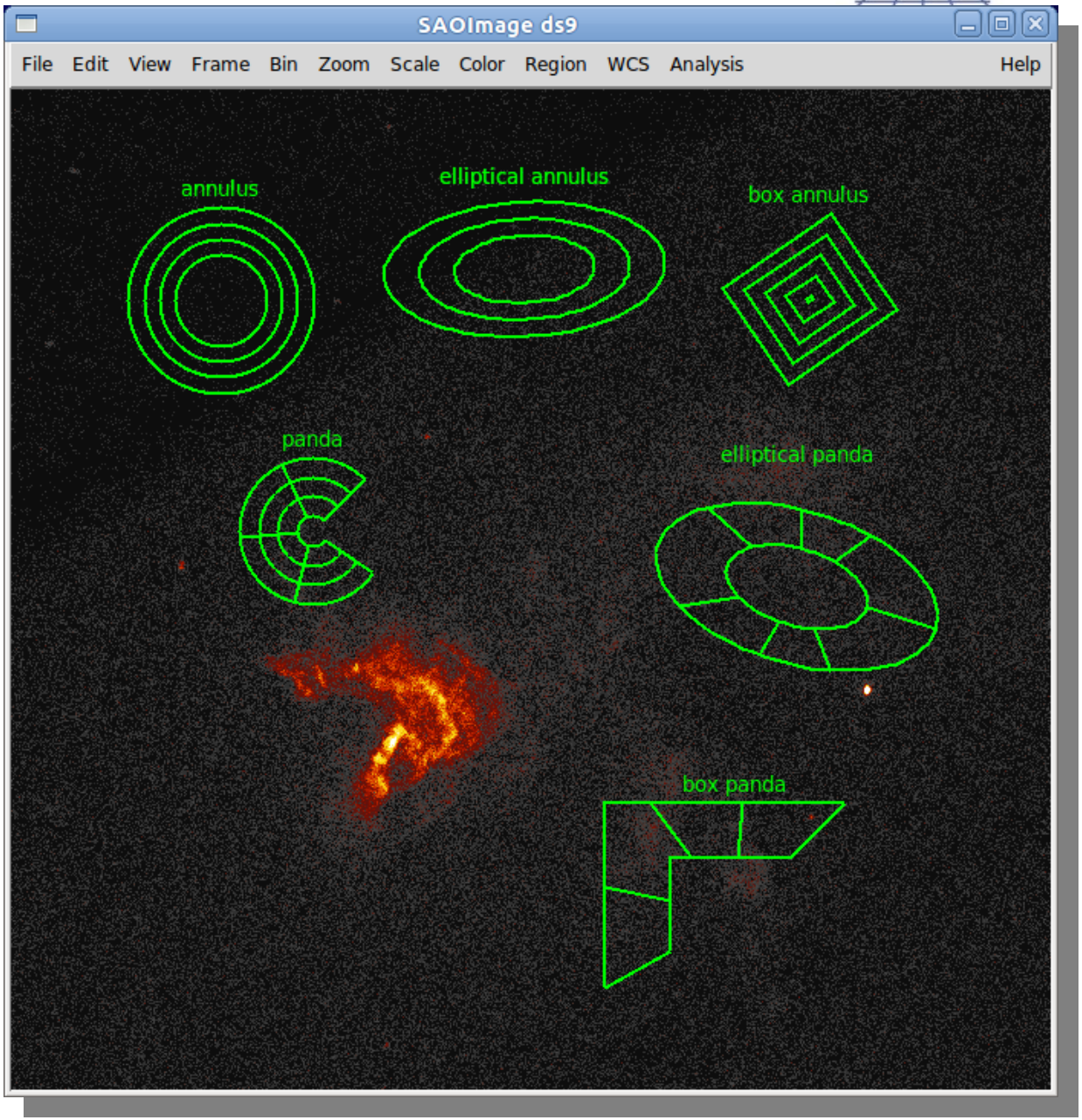
While ds9 can draw stacked shapes, CIAO does not know what the user is expecting and therefore cannot handle them.

All these shapes can be created with CIAO region syntax and input as stacks to the appropriate tools. For example: the box panda can be written as

box(x,y,lx,ly)*
!box(x,y,lxi,lyi)*
sector(x,y,ang1,ang2)

with various start/stop angles.

CIAO tools deal with multiple inputs, including multiple spatial filters via the *stack* concept.



Stacked shapes

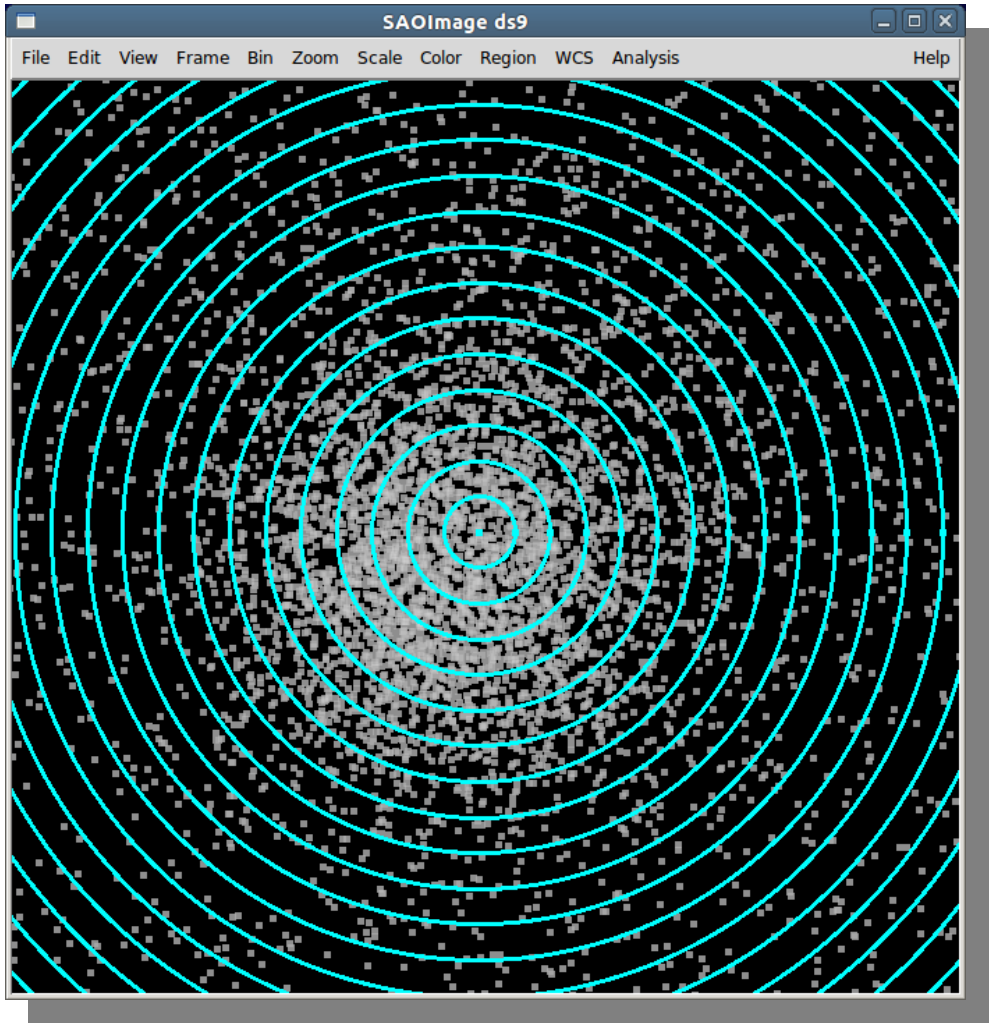
- The “annulus” : a special case
  - Most CIAO tools only know about single slice annulus: `annulus(x,y,r1,r2)`
  - *dmextract* is special and accepts a special stack'ed version of an annulus: `annulus(x,y,r1:r2:step)`

    but **only** as part of the `[bin ...]` syntax.
- No CIAO short hand for *panda*, *epanda*, *banda* but all can be expressed with basic shapes.
  - Advanced CIAO users take note of *pgrid*, *lgrid*, and *igrid* syntaxes from `ahelp stack`

CIAO regions

- Edges are always included.
  - Both inner and outer annulus edges
    - Use circle()-circle() to exclude inner edge
- For images, center of pixel must be inside for pixel to be counted
- Chandra event files use real, floating point precision for sky coordinates.
  - Different results filtering image vs table; especially for small regions.

Radial Profile Comparison



Event File: real values X and Y coordinates

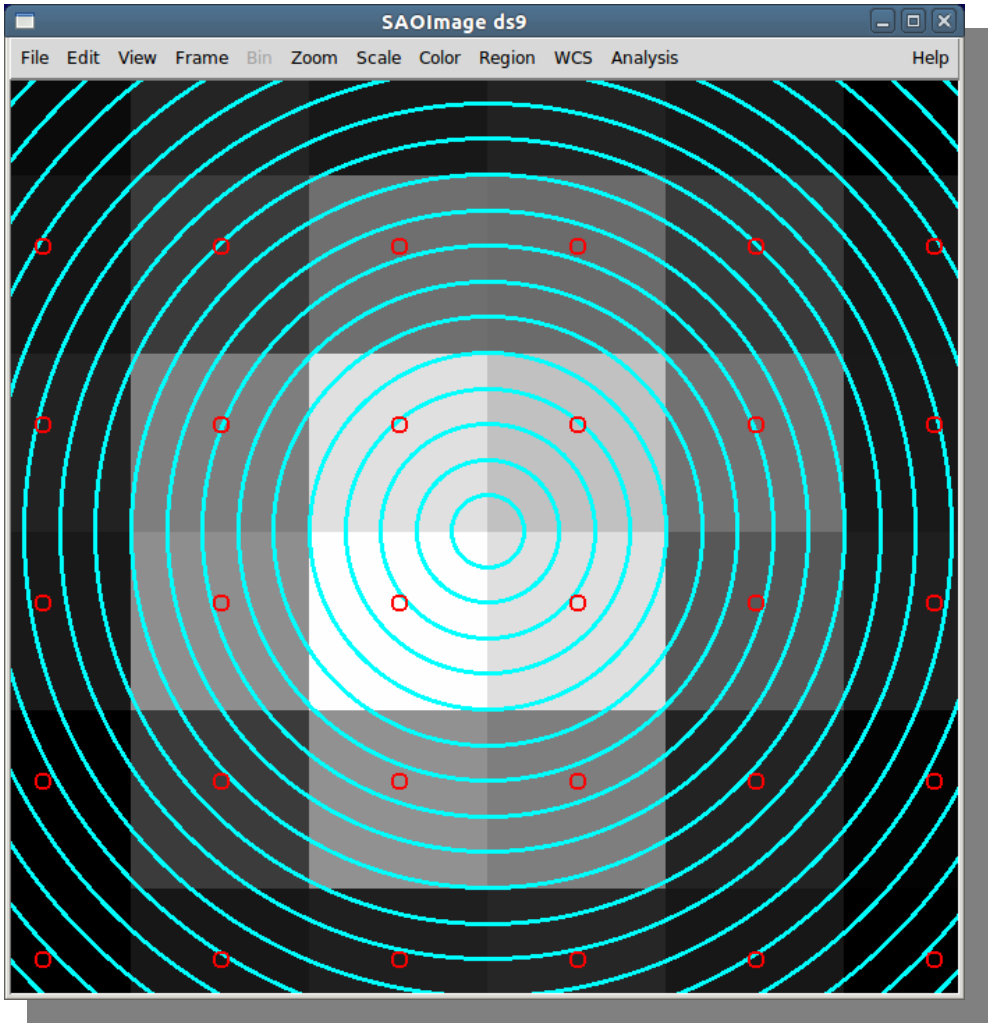
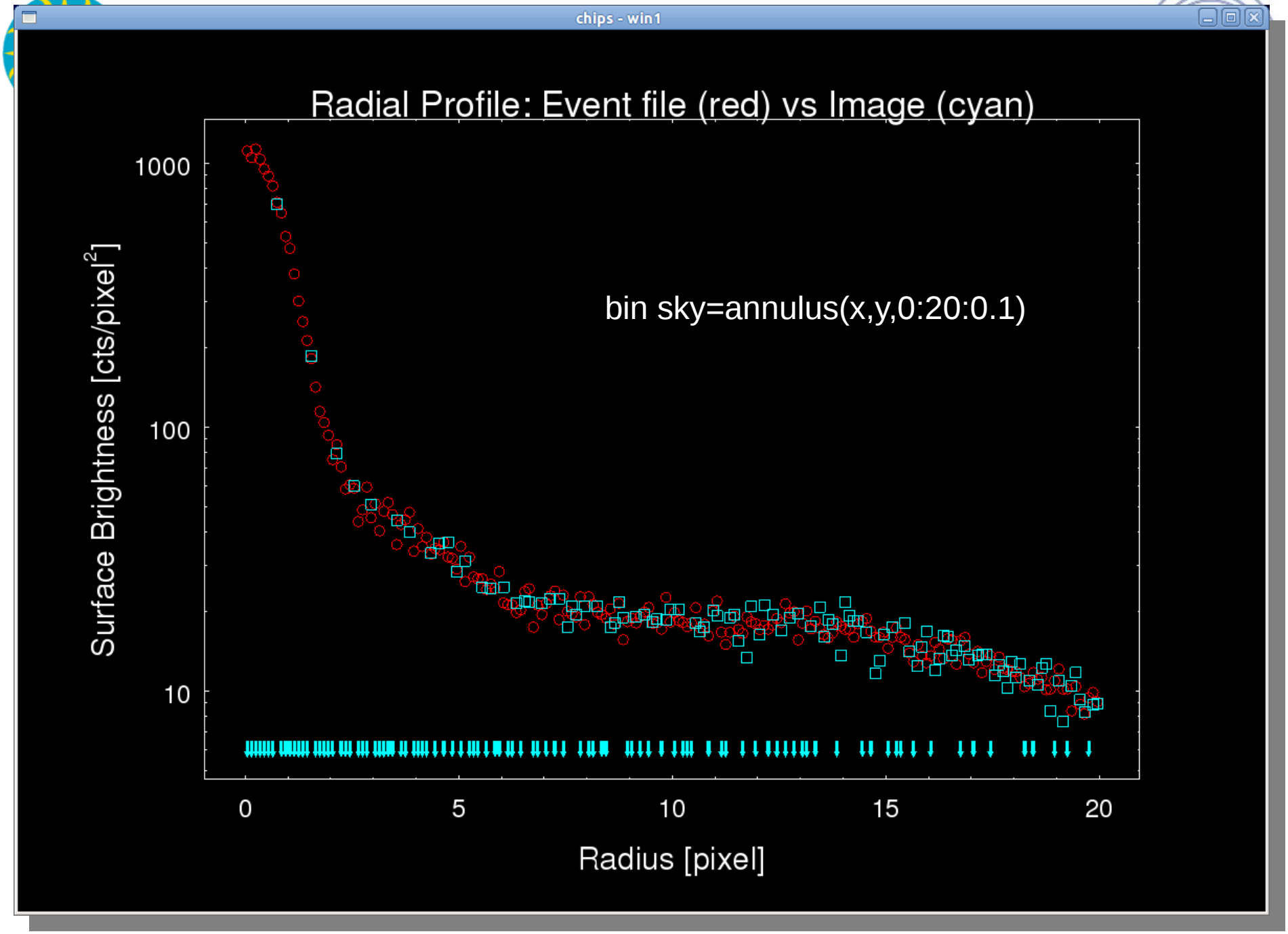


Image binned by 1



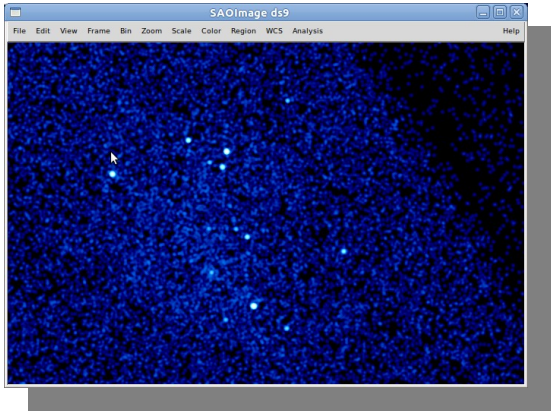
See also ChIPS web site

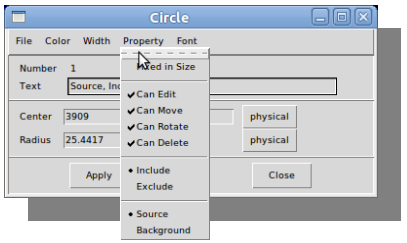
Region Properties

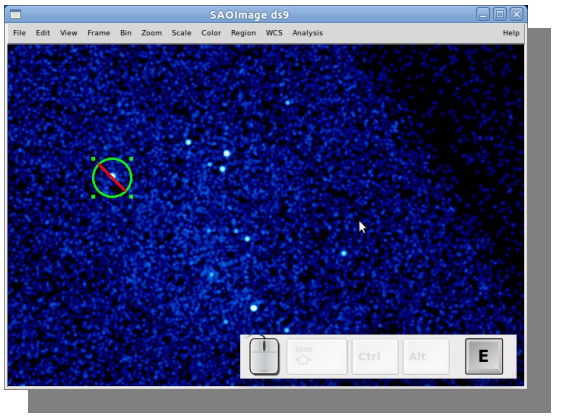
- Include / exclude
- Source / background
- Grouping (tagging)
  - dmgroupreg
- Display properties
  - Color, width
  - text, font

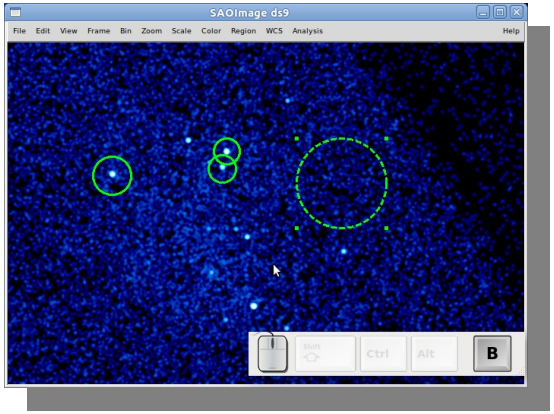
Region Properties Demo

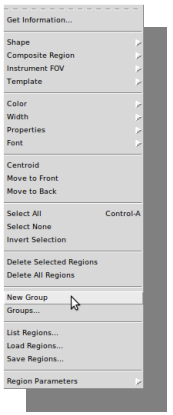
http://hea-www.harvard.edu/~kjg/screencast/ds9_region_properties.mp4

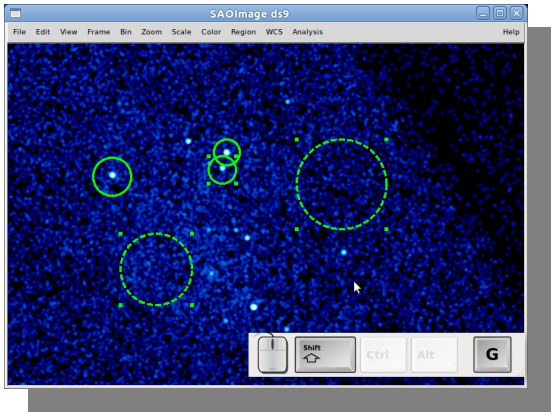


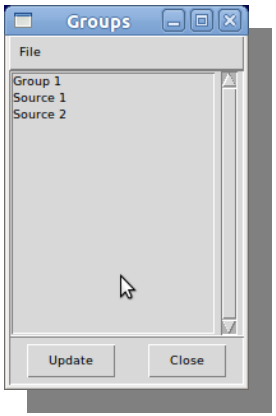












Region Format

- ASCII
  - ds9 : CIAO understand most common ds9 shapes; fine to use.
  - CIAO: shapes but no logic, order matters
- FITS Binary Table
  - ASC-FITS-Region
  - FOV files
  - Source Detect tools
  - Bad-pixel and mask files (chip coordinates)
- Other: votable/xml

Region Coordinates

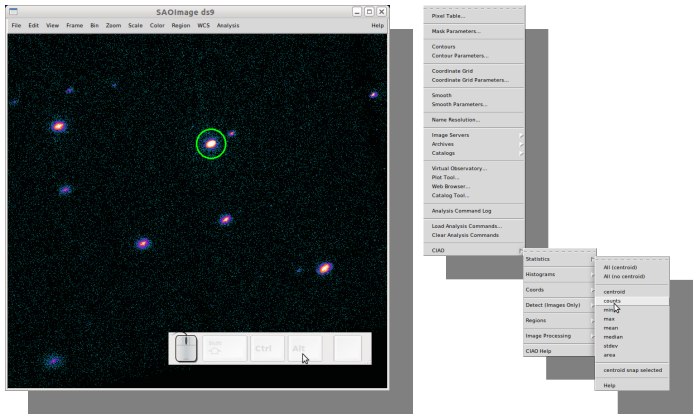
- CIAO understands physical though less useful for multiple observations of same data.
- Celestial is supported by most CIAO tasks;
  - user must supply additional “wcsfile” to some programs so data can be mapped correctly.
- Not all coordinates are sky/celestial
  - Grating coords masks/filter/windows
  - bad-pixels/masks

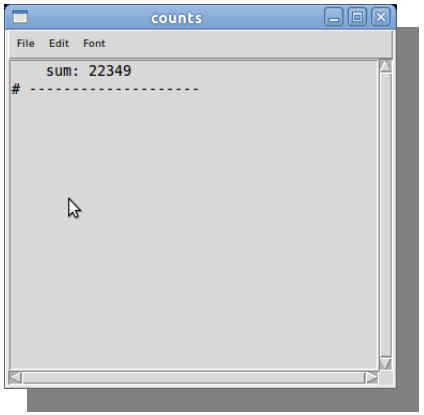
CIAO analysis within ds9

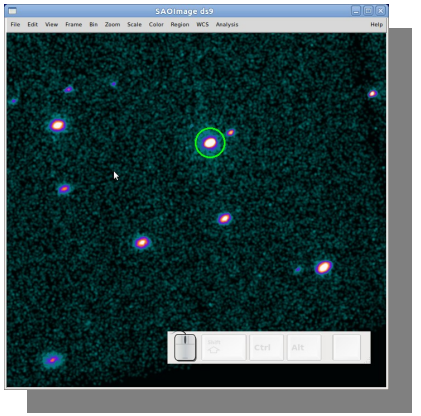
- Code name : dax
- Simple tasks can be performed via preloaded CIAO analysis menu
  - Statistics: counts, min, max, area, etc.
  - Coordinate transforms
  - Simple histograms: light-curves and spectra
  - Source detect
  - Generic image processing: smoothing, filtering, etc.
  - Region creation

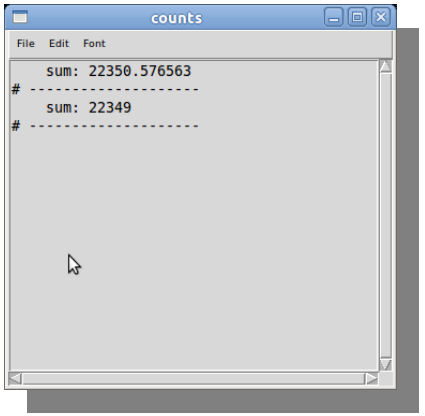
dax statistics

http://hea-www.harvard.edu/~kjg/screencast/dax_statistics.mp4





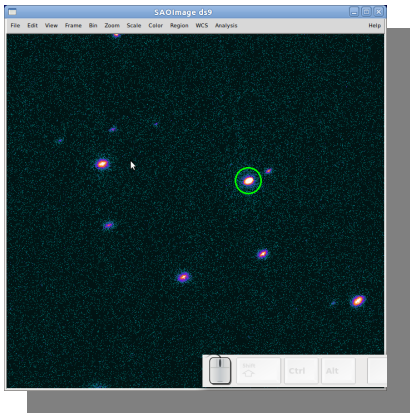


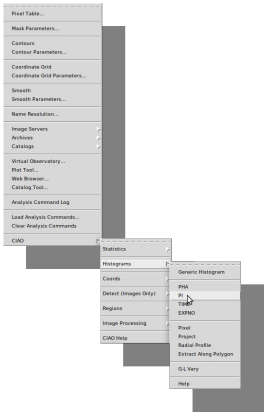


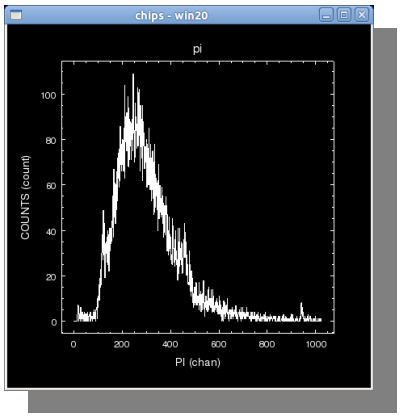
See also ahelp dmstat

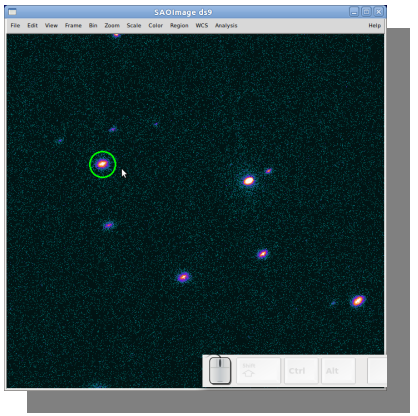
dax histogram example

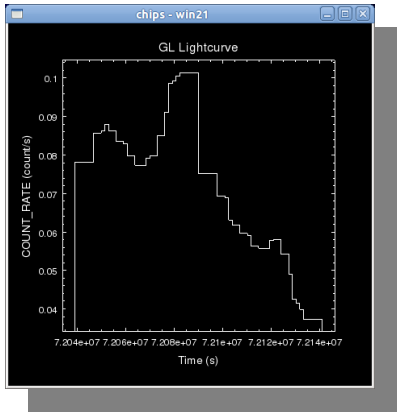
http://hea-www.harvard.edu/~kjg/screencast/dax_histogram.mp4

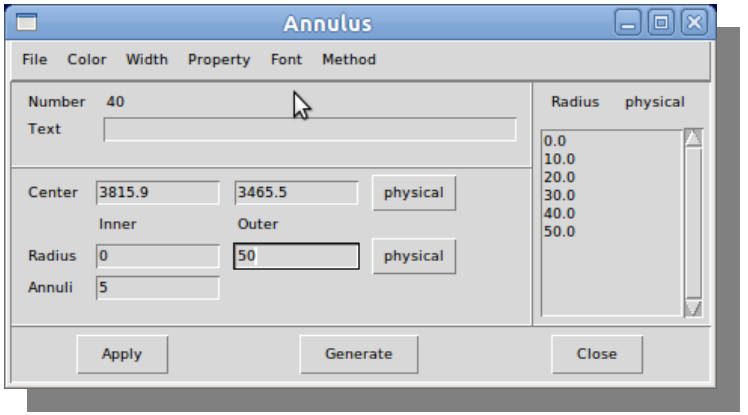


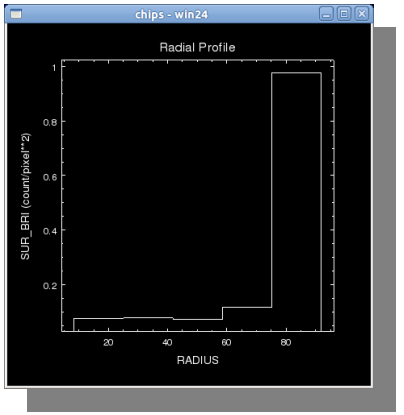








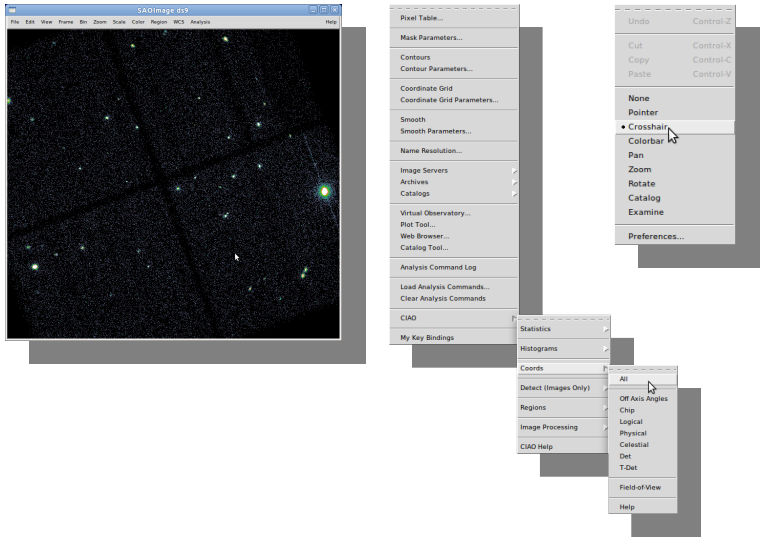


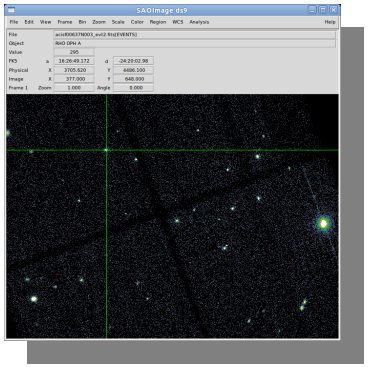


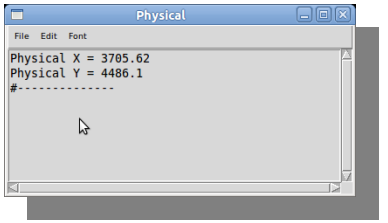
See also ahelp dmextract

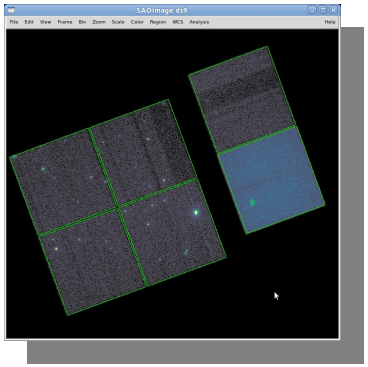
dax coordinate example

http://hea-www.harvard.edu/~kjg/screencast/dax_coords.mp4





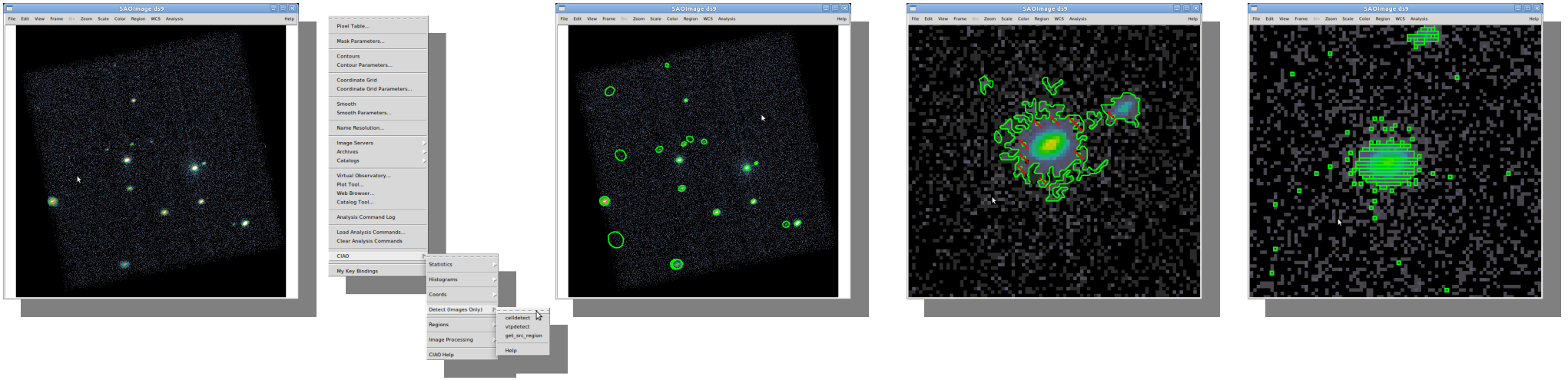




See also ahelp dmcoords

dax source detect

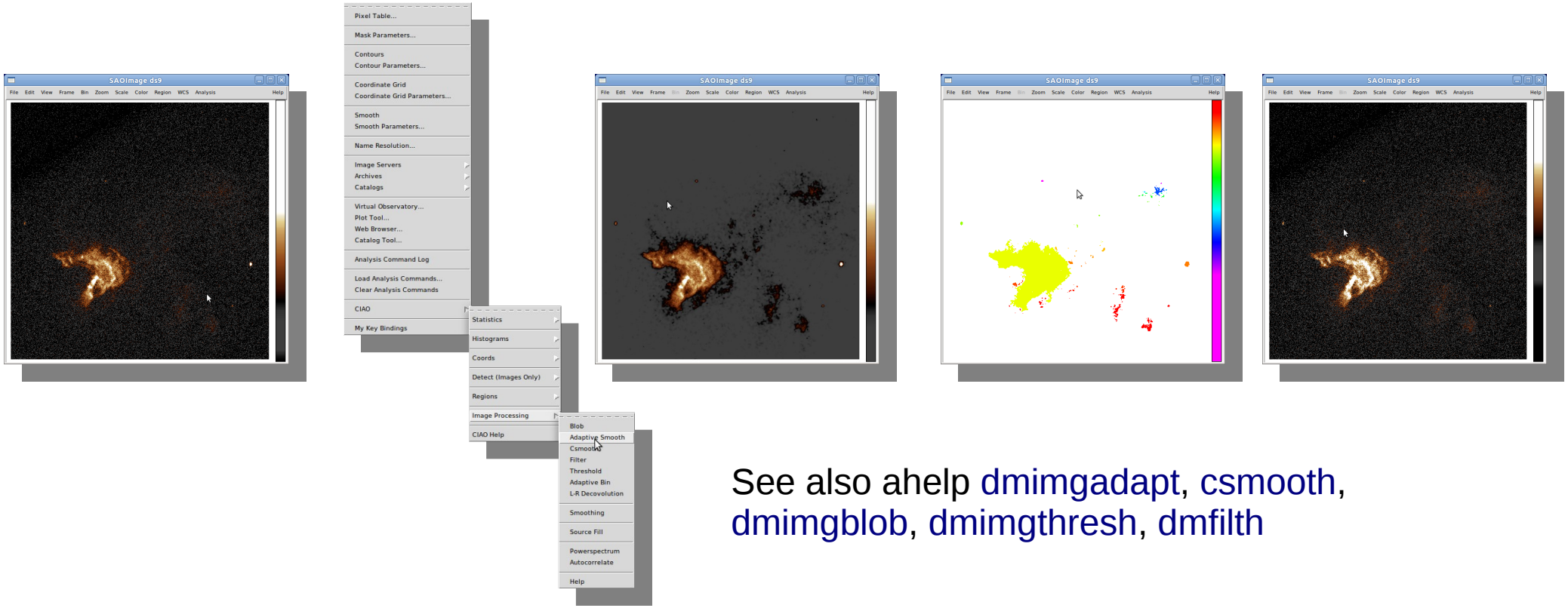
http://hea-www.harvard.edu/~kjg/screencast/dax_detect.mp4



See ahelp celldetect, vtpdetect, and get_src_region

dax image processing

http://hea-www.harvard.edu/~kjg/screencast/dax_image_processing.mp4



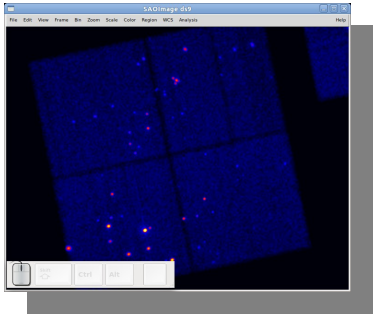
See also ahelp dmimgadapt, csmooth, dmimgblob, dmimgthresh, dmfilth

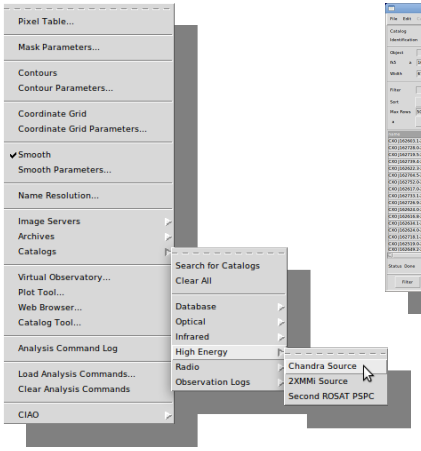
Catalogs

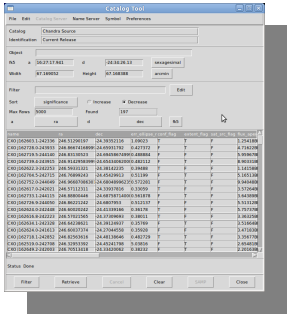
- Overlay tabular data with access to additional columns
- Interactive selection
  - Jump to table row
  - Blink marker for selected row
- Advanced marker editor
  - conditionally mark classes of sources
    - low significance: yellow, high significance : green
- Making use of Virtual Observatory standards
  - votable, registry, etc

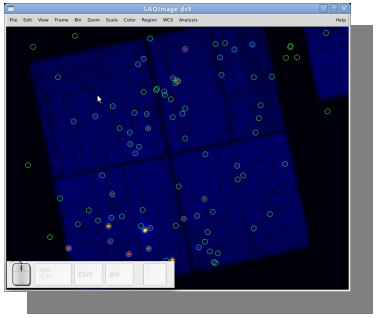
Catalog Demo

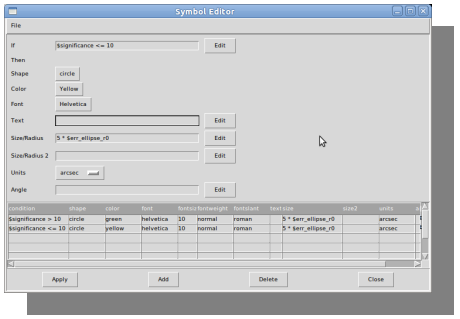
http://hea-www.harvard.edu/~kjg/screencast/ds9_catalog_intro.mp4

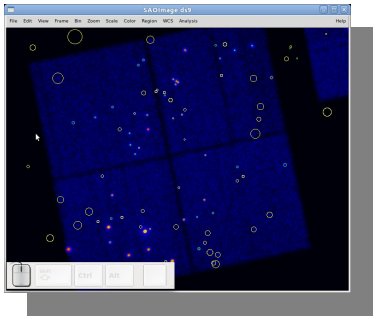












Questions?

Thank you

Please remember to include acknowledgements for Chandra and cite CIAO and ds9

About the name “ds9”

ds9 is short for “Deep Space Nine”, the title of a television series based in the Star Trek universe. In the show, ds9 is a space station, the 9th, deep space, space station located at the mouth of a worm hole connecting our side of the galaxy with the Delta Quadrant.

ds9 is the 3rd Star Trek television series coming after The Next Generation (ie 'tng') and the original series from 1966.

Quick Disclaimer

All images and screen shots are with ds9 version 6.2 as packaged with CIAO 4.3.

The exact menu and UI layout sometimes changes with ds9 releases.

Catalogs

- CSC
- Catalog tool
- Topcat / SAMP

backup/restore

Script it with XPA

- Wouldn't be a software talk without the phase “client/server” at least once.

Where filters are applied

Most of the time users filter in sky coordinates (aka physical coordinates), even if region is in celestial coordinates.

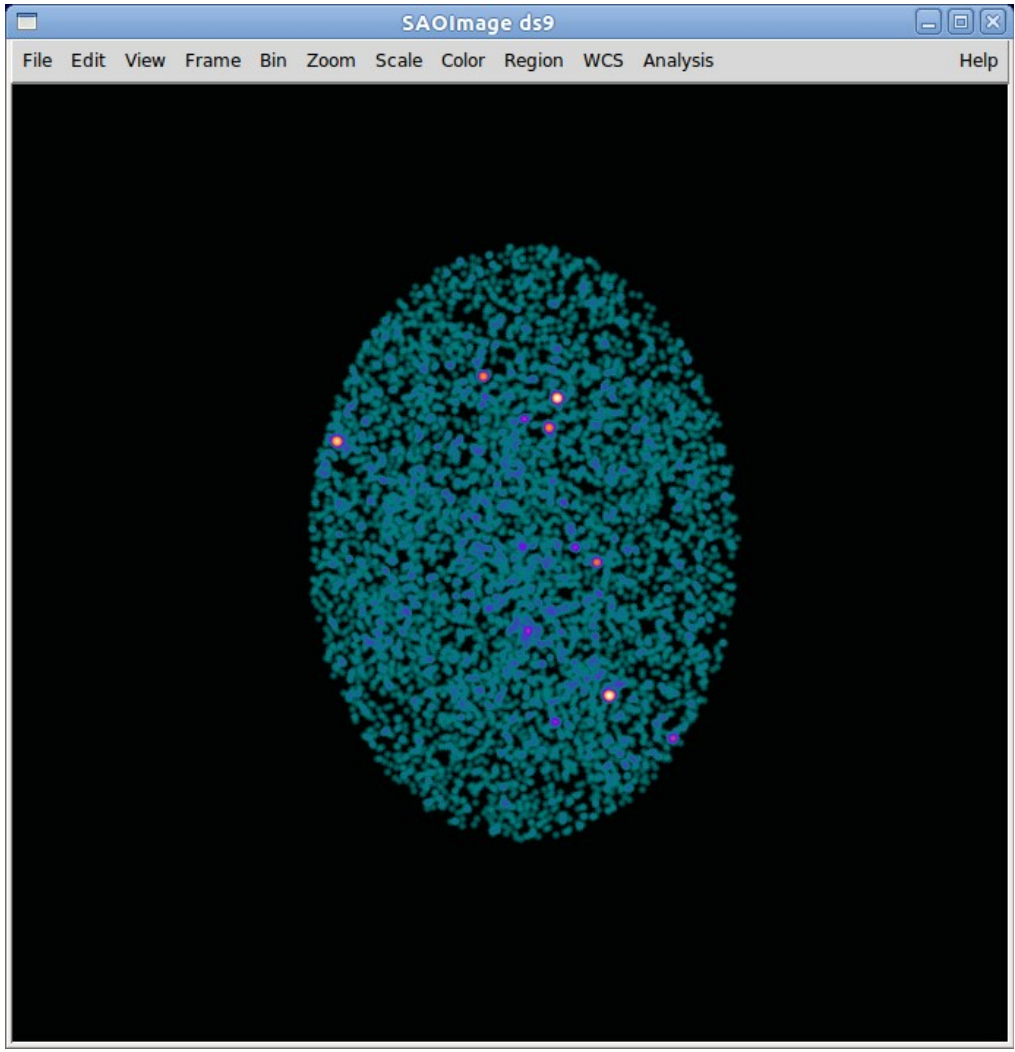
```
dmcopy \
“evt[sky=circle(12:28:12.03,+44:06:00.08,1.5')]” \
circle_sky.fits
```

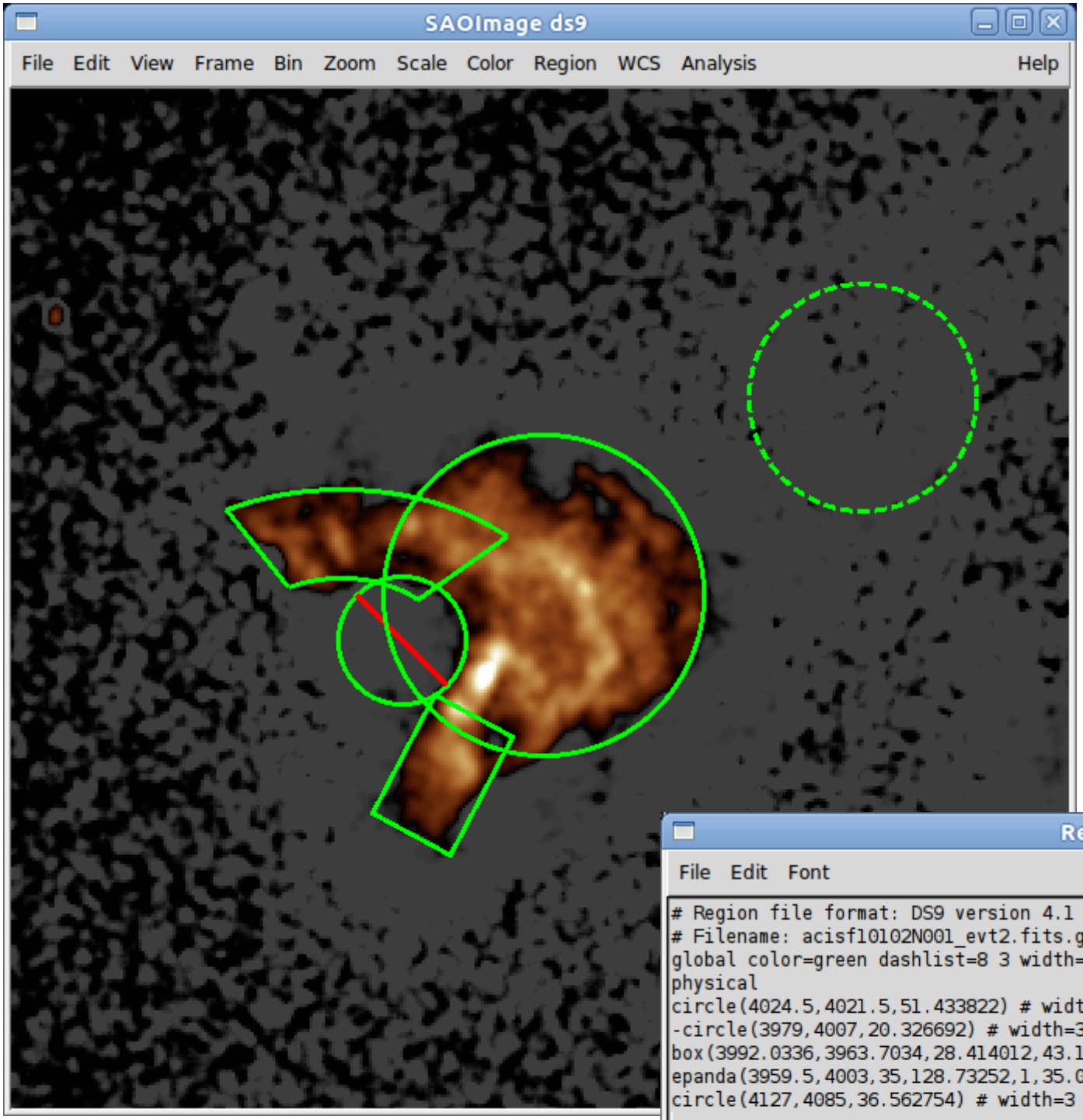
This image is the result of a circle filter on an event file on ra,dec and then binning sky coordinates, eg:

```
dmcopy \
'evt[(ra,dec)=circle(187.05,44.1,100”)]'\
circle_events.fits
```

and then displayed in ds9.

Since events were filtered in celestial coordinates but then binned in sky coordinates, the non-square physical pixels are very noticeable

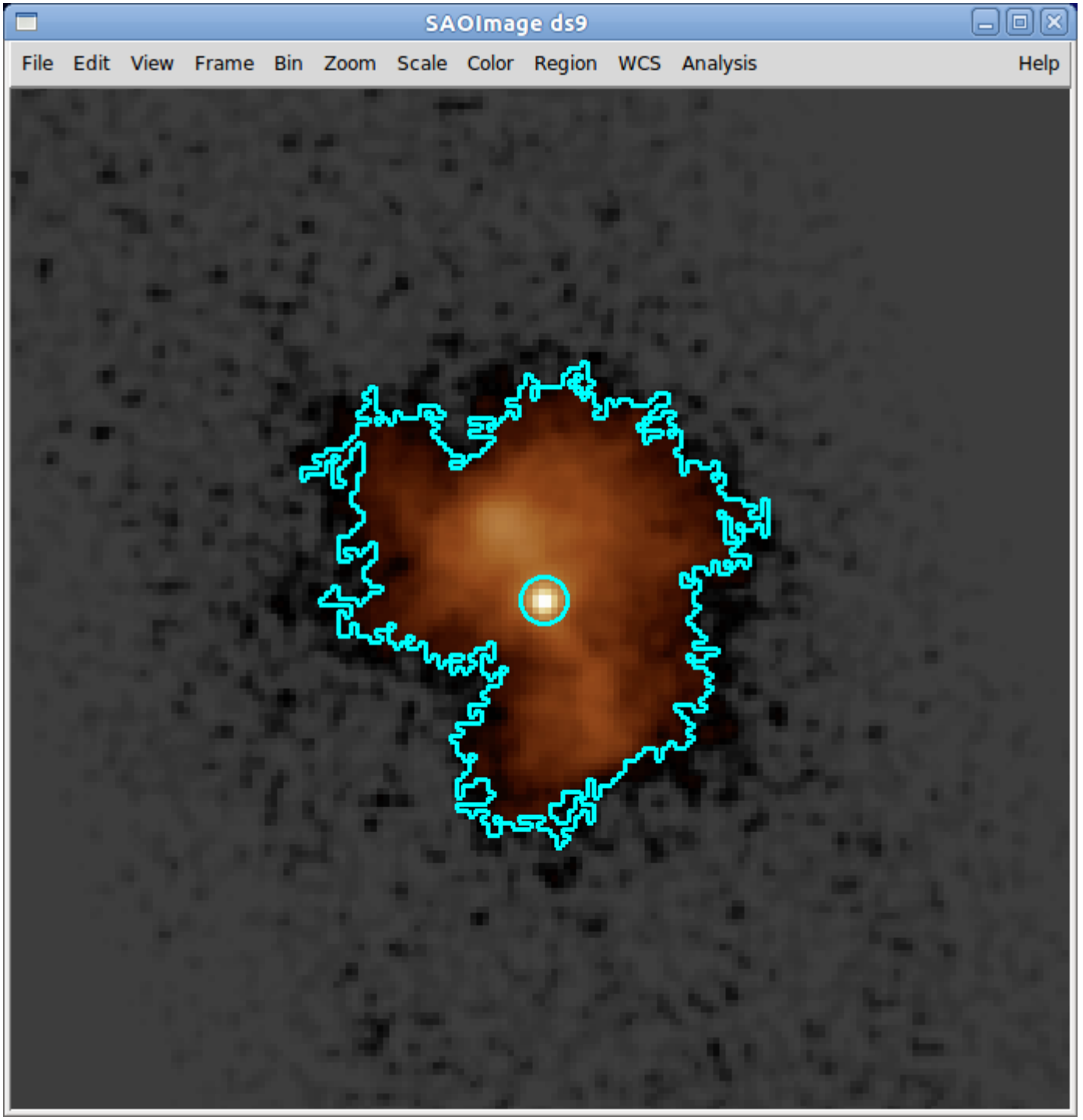


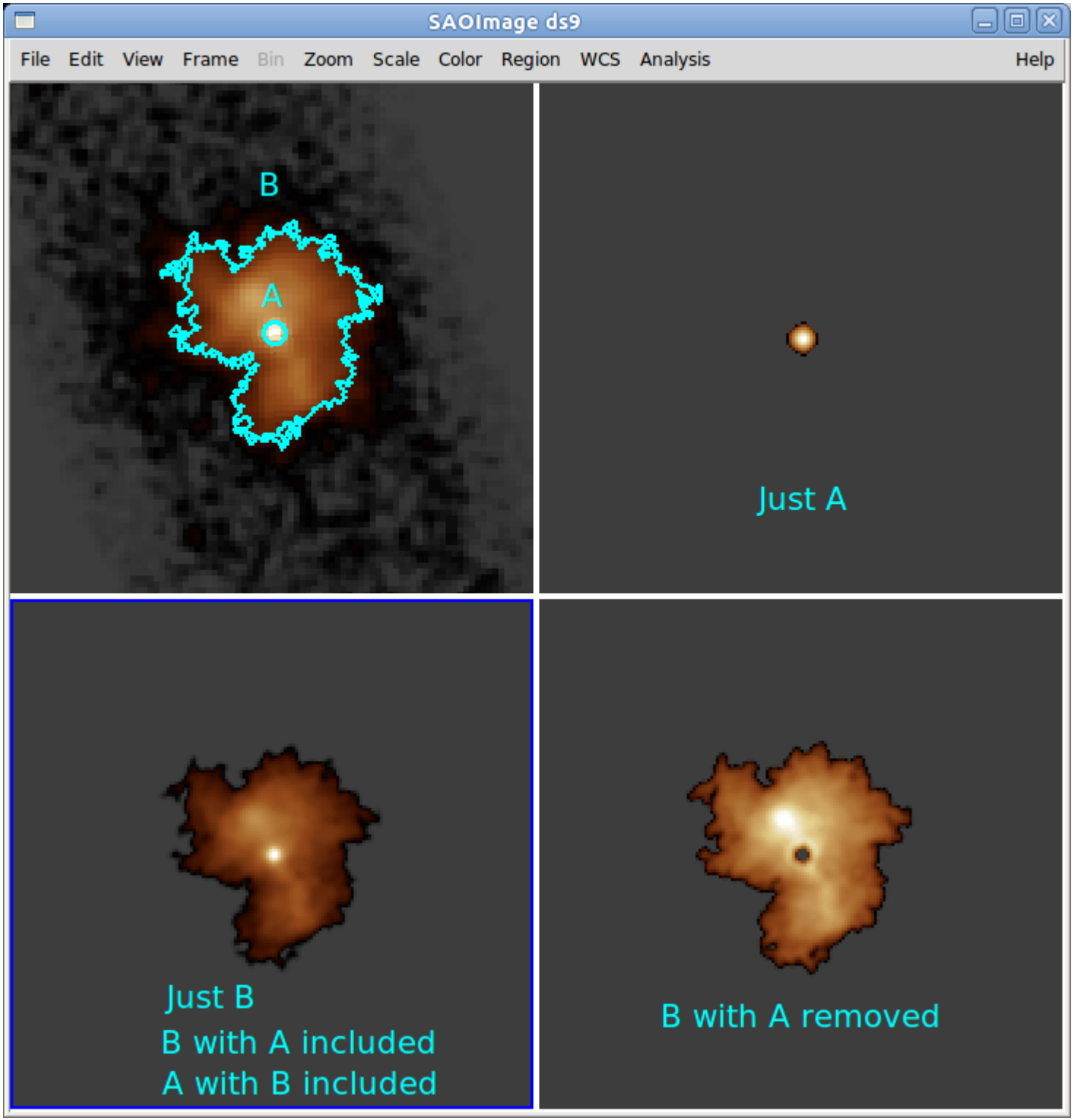


Region

File Edit Font

```
# Region file format: DS9 version 4.1
# Filename: acisf10102N001_evt2.fits.gz[EVENTS]
global color=green dashlist=8 3 width=1 font="helvetica 10 normal roman" select=1 h
physical
circle(4024.5,4021.5,51.433822) # width=3
-circle(3979,4007,20.326692) # width=3
box(3992.0336,3963.7034,28.414012,43.123571,332.1003) # width=3
epanda(3959.5,4003,35,128.73252,1,35.052914,24.214184,76,52.5,1,0) # width=3
circle(4127,4085,36.562754) # width=3 background
```


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help



What data does the user want?

Just A?

Just B?

Union of A and B?

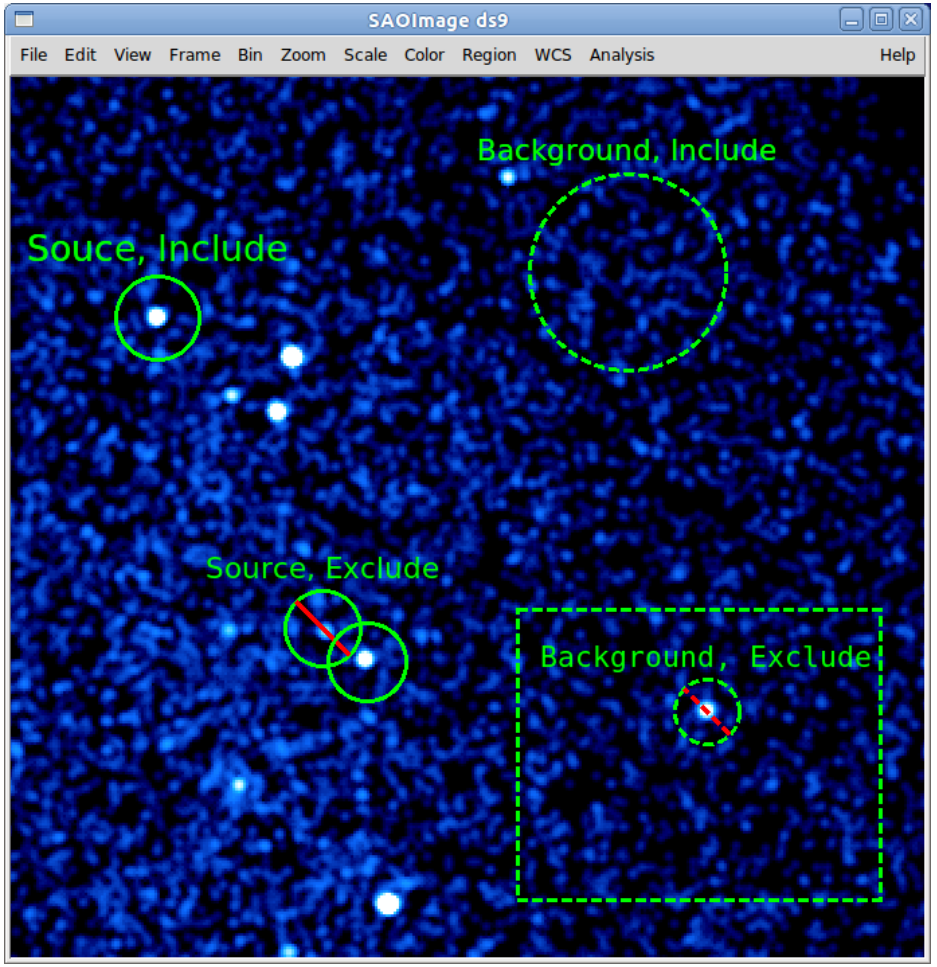
Intersection of A and B?

A with B excluded?

B with A excluded?

The intent of of multi-shape filters must be conveyed explicitly to CIAO via logical syntax: a, a+b, a*b, a-b, etc.

Note: a-b = a*!b


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Analysis Help
Background, Include
Souce, Include
Source, Exclude
Background, Exclude

Example images

Chip

Grating coords

TDET (WMAP)

Energy v. Time