

CIAO analysis with ds9



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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







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





Customizing UI



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



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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





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	Apply	\$	Clear		Clo	se

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

Average
• Sum
Block In
Block Out
Block to Fit Frame
Block 1
Block 2
Block 4
Block 8
Block 16
Block 32
Block 64
Block 128
Block 256
128x128
256x256
512x512
• 1024x1024
2048x2048
4096x4096
8192x8192
Binning Parameters
Note: block = bir

Center Image Align Align WCS Zoom In Zoom Out Zoom to Fit Frame Zoom 1/32 Zoom 1/16 Zoom 1/8 Zoom 1/4 Zoom 1/2 • Zoom 1 Zoom 2 Zoom 4 Zoom 8 Zoom 16 Zoom 32 None Invert X Invert Y Invert XY 0 Degrees 90 Degrees 180 Degrees 270 Degrees Pan Zoom Rotate Parameters...





Example Event File



(4,4)

Х	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



Х	Y		2	0
1.5	2.3			
1.8	3.3			
2.2	2.1			
3.4	1.9			
2.3	2.5		6	2
2.6	2.6			
3.0	1.9			
2.5	3.5			
1.2	1.1			
2.9	2.5			
		(1,2	1) ((3,1)

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



Х	Y		0	0	0	1	0	0
1.5	2.3							
1.8	3.3		0	1	0	0	0	0
2.2	2.1			0	4	0		<u> </u>
3.4	1.9		0	0	T	2	0	0
2.3	2.5		0	1	1	0	0	0
2.6	2.6							
3.0	1.9		0	0	0	0	2	0
2.5	3.5							
1.2	1.1		1	0	0	0	0	0
2.9	2.5							
		(1,1	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



Х	Y		1	1	1	1	0	0
1.5	2.3							
1.8	3.3		1	1	1	1	0	0
2.2	2.1		4					•
3.4	1.9		1	1	4	4	0	0
2.3	2.5		1	1	4	4	0	0
2.6	2.6	· · · · · · · · · · · · · · · · · · ·			·		Ũ	
3.0	1.9		1	1	0	0	2	2
2.5	3.5							
1.2	1.1		1	1	0	0	2	2
2.9	2.5							
		(1,1	1)	(2	1,1)			

Zooming replicates the same image pixel to multiple screen pixels



Zoom by 0.5



Х	Y		1	0
1.5	2.3			
1.8	3.3			
2.2	2.1			
3.4	1.9			
2.3	2.5		1	2
2.6	2.6			
3.0	1.9			
2.5	3.5			
1.2	1.1			
2.9	2.5			
		(1,1	1) (3	, 1)

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





Frames

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



New Frame	
New Frame RGB	
Delete Frame	
Delete All Frames	
Clear Frame	
Reset Frame	
Refresh Frame	
• Single Frame	
Tile Frames	
Blink Frames	
Match	Þ
Lock Crosshair	Þ
Goto Frame	⊳
Show/Hide Frames	⊳
Move Frame	⊳
First Frame	
Previous Frame	
Next Frame	
Last Frame	
Data Cube	
RGB	
Frame Parameters	



Frame demo



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















	Control-Z
Cut	Control-X
Сору	Control-C
Paste	Control-V
None	
• Pointer	
Crosshair	
Colorbar	
Pan	
Zoom	
Rotate	
Catalog	
Examine	

New Frame RGB	
Delete Frame	
Delete All Frames	
Clear Frame	
Reset Frame	
Refresh Frame	
Single Frame	
Tile Frames	
Blink Frames	
Match	>
Lock Crosshair	2
Goto Frame	None
Show/Hide Frames	WES
Move Frame	Multiple WCS
First Frame	Image
Previous Frame	Physical
Next Frame	Amplifier
Last Frame	Detector
Data Cube	
RGB	





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



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	<u>caldb</u> <u>calindex</u>		POInt	(xcenter,ycenter)					
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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









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 ...















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





- 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





Blob Adaptive Smooth

Threshold Adaptive Bin L-R Decovoluti

Smoothing Source Fill Powerspectr Autocorrelat







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

dra Source



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



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Clear Analysis Commands	Observation Logs	2

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Thank you

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







- 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 nonsquare physical pixels are very noticeable







Region

-0

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







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,

Note: $a-b = a^{*}b$









Example images



Chip

Grating coords

TDET (WMAP)

Energy v. Time