

Creating an Image of the PSF -

Creating an Image of the PSF

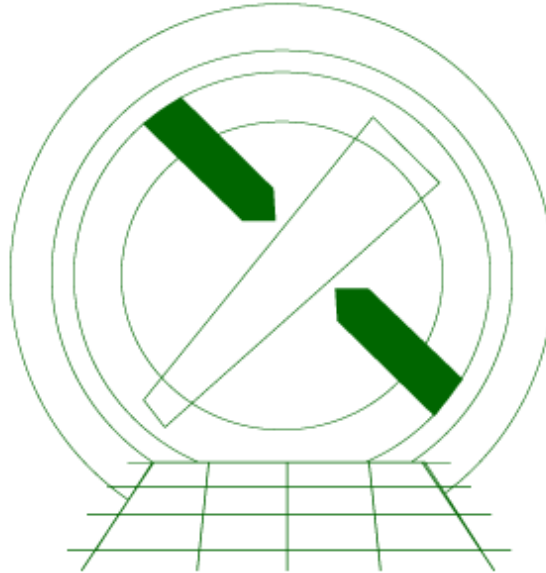


ChaRT Threads

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Creating an Image of the PSF

ChaRT Threads

Overview

Last Update: 17 Feb 2010 - reviewed for CIAO 4.2: minor updates to screen output

Synopsis:

The output of MARX is a pseudo event file containing a list of rays that have been projected onto the detector (recall that MARX includes the instrumental response when doing this). This thread shows how to bin the output file into an image that (optionally) matches that of your data. This image can then be used in your scientific analysis.

Get Started

This example uses `marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits`, which was created in the [Using MARX to Create an Event File](#) thread. Also:

Sample ObsID used: 942 (ACIS-S, NGC 4244)

File types needed: evt2

Examine the Data

The following sections describe how to create an image of the PSF that is either [centered on the PSF](#) or [matches an existing image of the dataset](#).

The projected rayfile (`marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits`) can be examined with `dmlist`:

```
unix% dmlist marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits blocks
```

```
-----  
Dataset: marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits
```

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```
-----
```

Block Name	Type	Dimensions
Block 1: NULL	Null	
Block 2: EVENTS	Table	22 cols x 116315 rows
Block 3: GTI4	Table	2 cols x 1 rows
Block 4: GTI5	Table	2 cols x 1 rows
Block 5: GTI6	Table	2 cols x 1 rows
Block 6: GTI7	Table	2 cols x 1 rows
Block 7: GTI8	Table	2 cols x 1 rows
Block 8: GTI9	Table	2 cols x 1 rows
Block 9: MARX_PAR	Table	1 cols x 480 rows

```
unix% dmlist marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits cols
```

```
-----
```

Columns for Table Block EVENTS

```
-----
```

ColNo	Name	Unit	Type	Range	
1	TIME	s	Real8	362912400.0:362912600.6024336219	time since observ
2	CCD_ID		Int2	0:9	CCD id number
3	NODE_ID		Int2	-	0-4
4	EXPNO		Int4	0:2147483647	Exposure number
5	chip (CHIPX,CHIPY)	pixel	Int2	2:1023	CHIP X
6	tdet (TDETX,TDETY)	pixel	Int4	2:8191	Detector X
7	det (DETX,DETY)	pixel	Real8	0.50: 8192.50	Focal Plane X
8	sky (X,Y)	pixel	Real8	0.50: 8192.50	sky X pixel
9	PHA	adu	Int4	0:36855	Total PHA for event
10	ENERGY	eV	Real4	0: 1000000.0	Nominal energy of event
11	PI	Chan	Int2	-	pulse invariant energy of eve
12	FLTGRADE		Int2	0:255	Event Grade Code
13	GRADE		Int2	-	ACIS grade code
14	STATUS[2]		Bit (2)		status flags
15	SHELL		Int2	-	Mirror Shell (0=1,1=3,2=4,3=6
16	ZCOS		Real4	-Inf:+Inf	Z direction cosine
17	YCOS		Real4	-Inf:+Inf	Y direction cosine
18	XCOS		Real4	-Inf:+Inf	X direction cosine
19	ZPOS	mm	Real4	-Inf:+Inf	Z position in MARX coords
20	YPOS	mm	Real4	-Inf:+Inf	Y position in MARX coord syst
21	XPOS	mm	Real4	-Inf:+Inf	X position in MARX coord syst
22	MARX_ENERGY	keV	Real4	-Inf:+Inf	Energy of ray

```
-----
```

World Coord Transforms for Columns in Table Block EVENTS

```
-----
```

ColNo	Name
8:	EQPOS(RA) = (+184.3430) +TAN[(-0.000136667) * (sky(X)-(+4096.50))] (DEC) (+37.7809) (+0.000136667) ((Y) (+4096.50))

Note that the table contains coordinates for the events in a number of coordinate systems. We shall assume that we want an image of the PSF in SKY coordinates.

Centering the PSF

Get the coordinates

The center of the PSF can be found by using the `dmcoords` tool to convert the input THETA and PHI values used to create the PSF into SKY coordinates. Note that "centering" may be a bit of a misnomer; far off-axis, it is likely that the "center" of the PSF is not coincident with either the centroid and/or the sky pixel matching the off-axis angle.

The necessary values are both recorded in the filename

(`marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits`) and in the header of the original ChaRT output (`HRMA_theta5.949_phi197.7_en1.7_d2.fits`):

```
unix% dmlist HRMA_theta5.949_phi197.7_en1.7_d2.fits header | egrep 'SRC_(THET|PHI) '
0011 SRC_THET                5.9490 [arcmin]          Real8          input THETA
0012 SRC_PHI                 197.740 [degrees]       Real8          input PHI
```

`dmcoords` can now be used to convert between this position (in the `msc coordinate system`) and the sky coordinate system. This conversion depends on the `aspect solution`, which varies with time; we use the nominal aspect solution (as given by the `RA_NOM`, `DEC_NOM`, and `DEC_NOM` keywords in the header of the event file:

```
unix% punlearn dmcoords
unix% dmcoords acisf00942N003_evt2.fits asol=pcadf075214790N003_asol1.fits
dmcoords>: MSC 5.9490 197.740
(RA,Dec):      12:16:57.136    +37:43:35.90
(RA,Dec):      184.23807      37.72664 deg
THETA, PHI     5.949'        197.74 deg
(Logical):     4704.01        3699.93
SKY (X, Y) :    4704.01      3699.93
DETX, DETY    3405.51        3875.45
CHIP ACIS-S2  573.44          753.80
TDET          3448.44        2455.80
```

This step could also be done with `dmcoords` in non-interactive mode:

```
unix% dmcoords acisf00942N003_evt2.fits asol=pcadf075214790N003_asol1.fits opt=msc theta=5.9490 phi=197.740
unix% pget dmcoords x y
4704.010656034712
3699.93423167626
```

Calculate the binning factor

We choose to create a 512 x 512 pixel image around the central position (with a binning factor of 1) in order to encompass most of the PSF signal. To calculate a 512 x 512 region centered at (4704.01, 3699.93):

```
512/2 = 256

X direction: 4704.01-256 = 4448.01
              4704.01+256 = 4960.01

Y direction: 3699.93-256 = 3443.93
              3699.93+256 = 3955.93
```

Rounding to 0.5 pixel, the binning factor is `[bin x=4448.5:4960.5:1,y=3443.5:3955.5:1]`.

Create the image

Now we can use `dmcopy` with the binning syntax to create an image:

```
unix% dmcopu \
    "marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits[bin x=4448.5:4960.5:1,y=3443.5:3955.5:1]" \
    psf_512.fits
```

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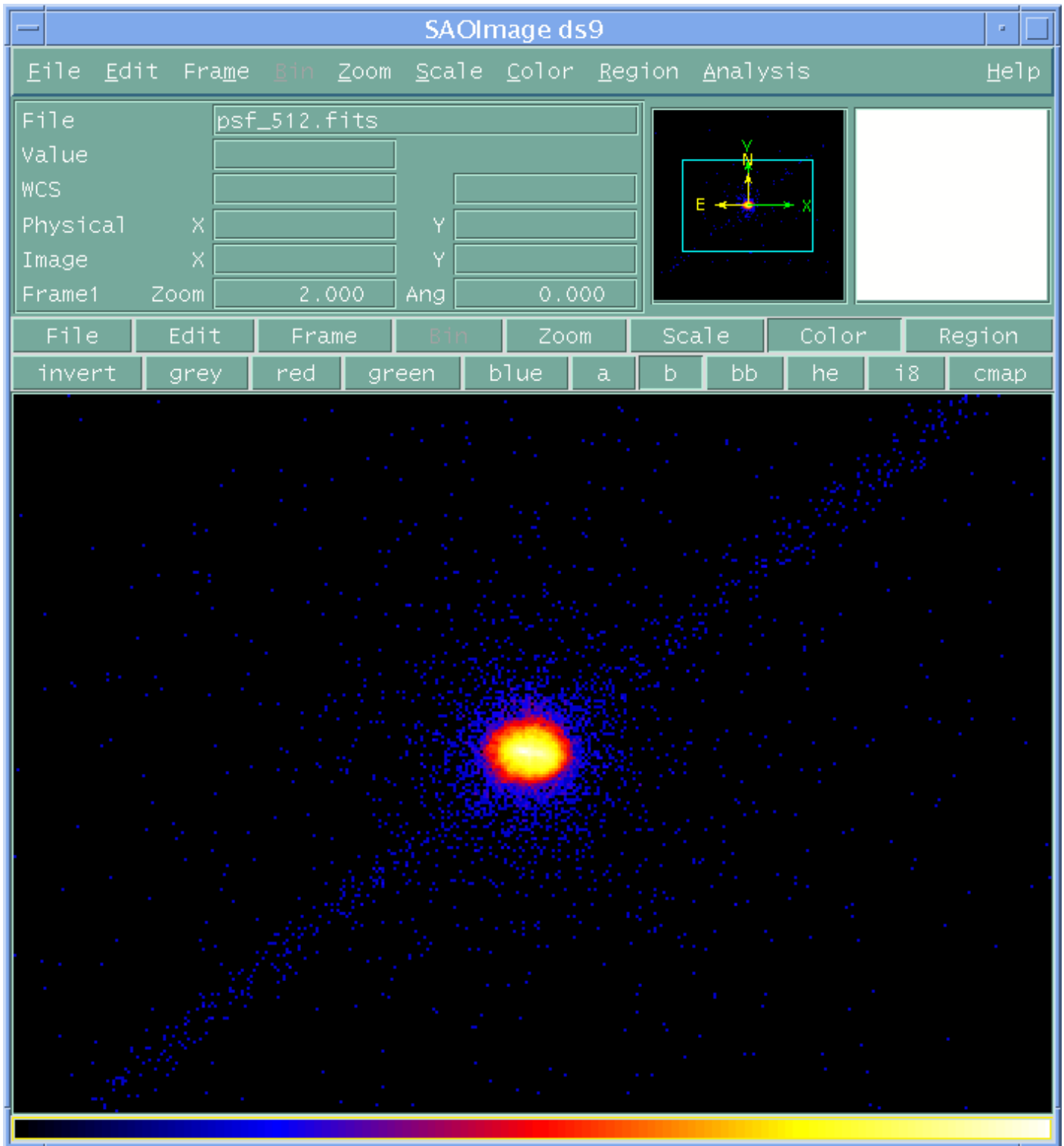


Figure 1: Image of the PSF

The PSF image is 512 x 512 pixels.

Binning the Rayfile to Match an Image

An alternative approach is to bin the PSF image to match an existing image of your data. The image of the data in this example was made by creating an event file of chip S2 (`ccd_id=6`) and simultaneously binning it into an image:

```
unix% more ds9.reg
# Region file format: CIAO version 1.0
rotbox(4552.2734,3517.8837,1071.6108,1064.0118,38.490129)

unix% dmcopy \
    "acisf00942N003_evt2.fits[ccd_id=6,sky=region(ds9.reg)][bin_sky=2]" \
    942_image.fits
```

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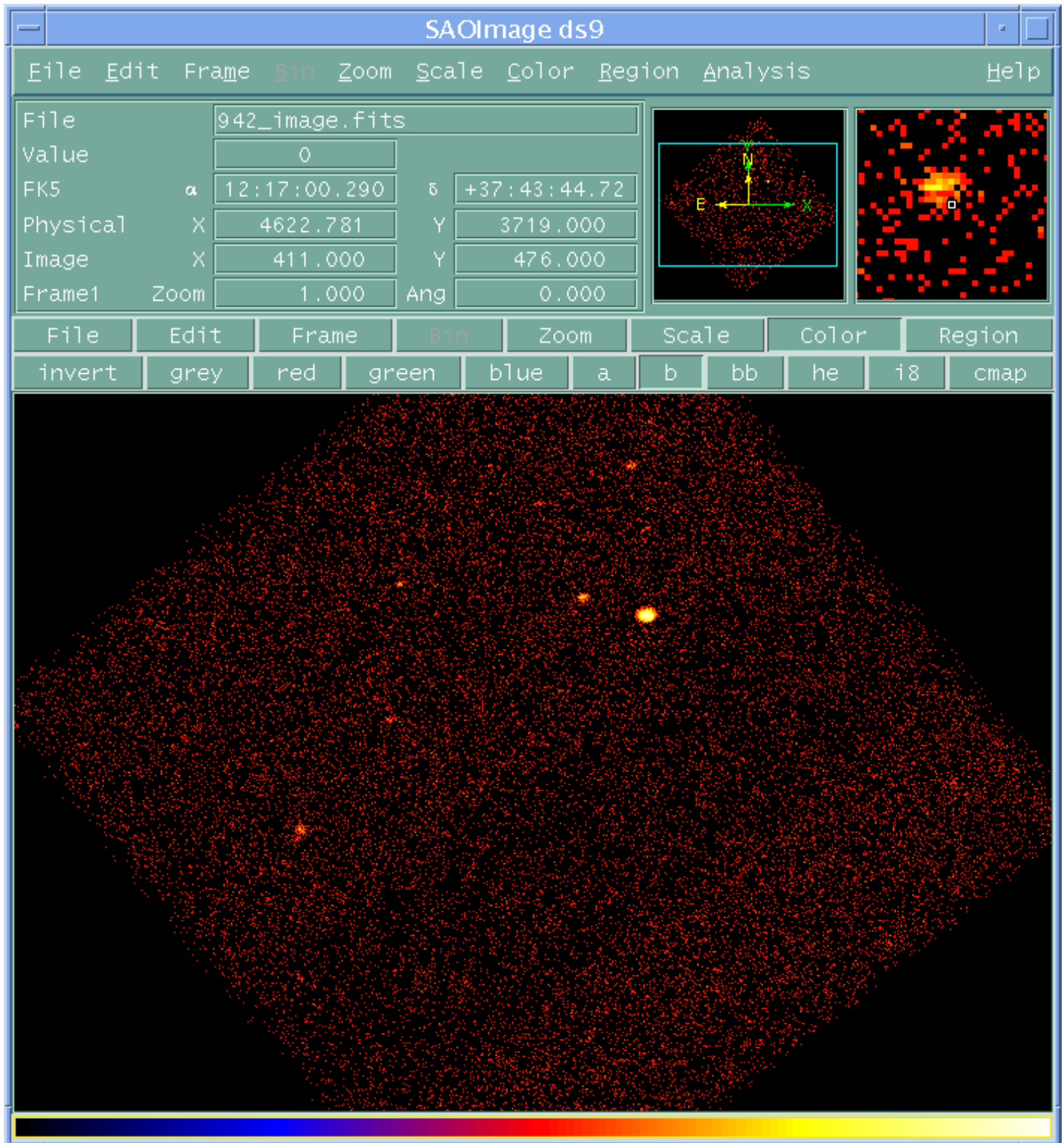


Figure 2: Image of the event data

The event file for ObsID 942 is filtered on `ccd_id=6` and `sky`, then binned by a factor of 2 to create an image.

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The `get_sky_limits` script (part of the [CIAO Scripts distribution](#)) can be used to find out the necessary **DM binning** specification to match the PSF to this image:

```
unix% get_sky_limits 942_image.fits verbose=1
Checking binning of image: 942_image.fits
Image has 751 x 750 pixels
Lower left (0.5,0.5) corner is x,y= 3801.8, 2768.0
Upper right (751.5,750.5) corner is x,y= 5303.8, 4268.0
DM filter is:
  x=3801.8:5303.8:#751,y=2768.0:4268.0:#750
mkexpmap xygrid value is:
  3801.8:5303.8:#751,2768.0:4268.0:#750
```

Finally, use `dmcopy` to create the image:

```
unix% dmcopy \
  "marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits[bin x=3801.8:5303.8:#751,y=2768.0:4268.0:#750]" \
  psf_match.fits
```

Displaying the two images side-by-side:

```
unix% ds9 psf_match.fits 942_image.fits &
```

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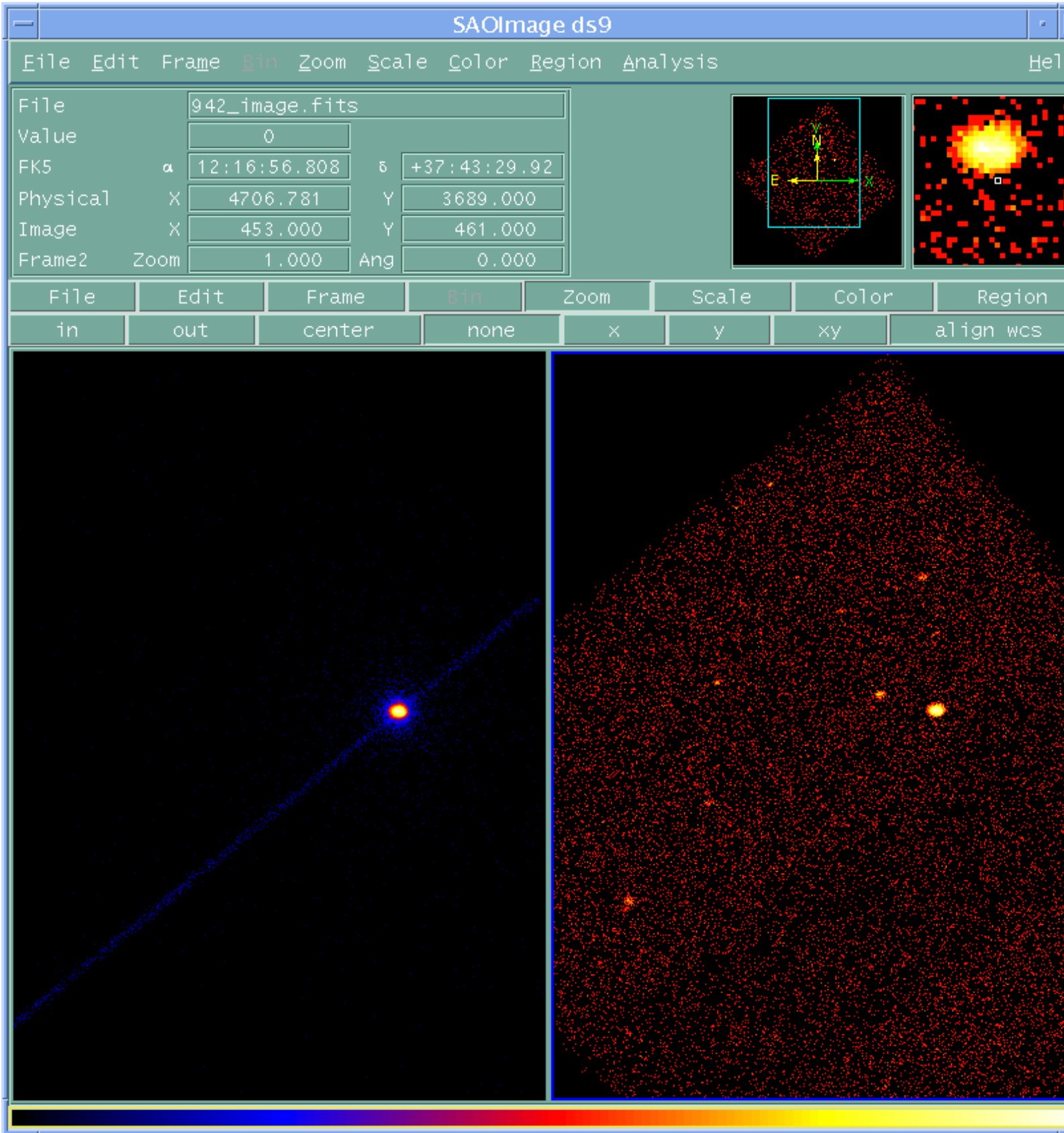


Figure 2: Image of the event data

Figure 3: Image of the PSF matched to the data

The PSF image is on the left and the event data is on the right. It is easy to see that the PSF lines up with the chosen source (see the [Preparing to Run ChaRT](#) thread).

Create a Sub-pixelated PSF Image

Viewing in ds9

Since the projected event file contains X and Y values without any pixel quantization, a 2-D histogram image can be made at any desired sub-pixel scale. To visualize this with ds9, load the event file:

```
unix% ds9 marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits &
```

Using the Bin and Zoom menus, zoom in and center on the object. Select "Bin -> Binning Parameters" from the menu bar. By changing the "Bin Factor" in the pop-up window, you can adjust the scale size of a bin.

[Figure 4](#) shows the sub-pixelated PSF image resulting from a 0.1 pixel bin factor. The smooth distribution of events verifies that the simulation was done correctly.

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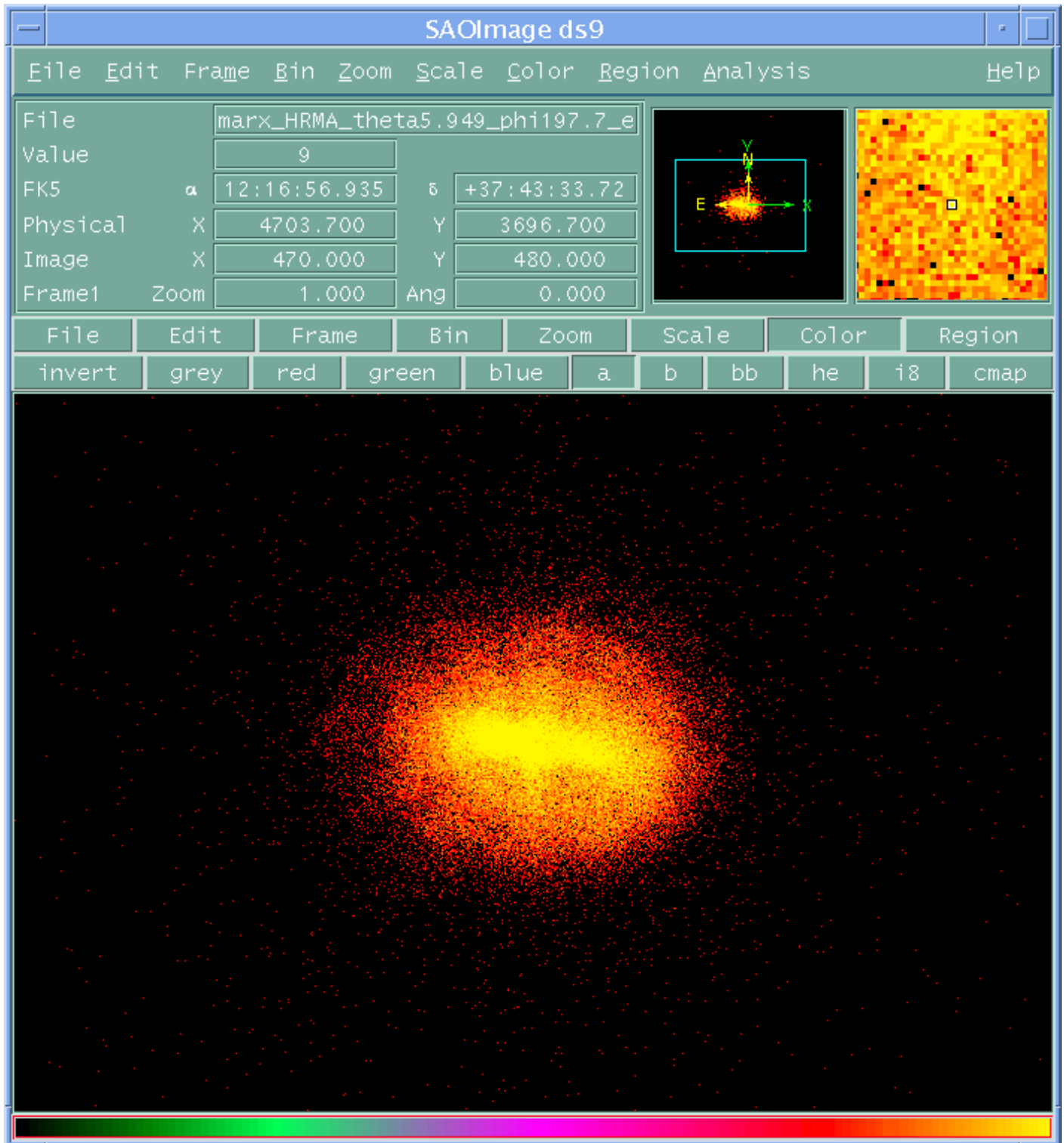


Figure 4: Sub-pixelated PSF image from good event file

This sub-pixelated PSF image was made with a 0.1 pixel bin factor. The smooth distribution of events verifies that the simulation was done correctly.

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If the image has boxy features, as shown in [Figure 5](#), something was done wrong.

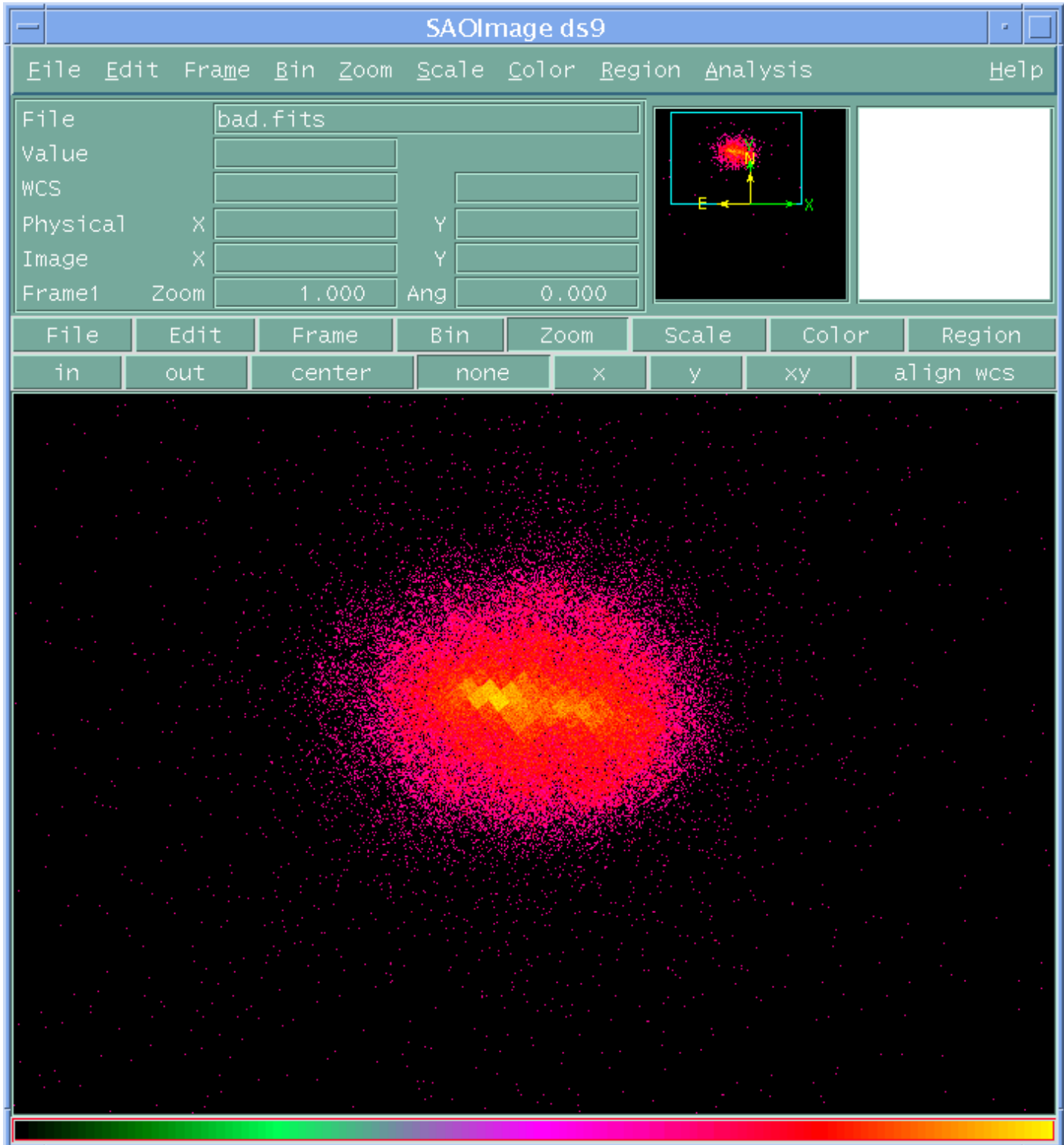


Figure 5: Sub-pixelated PSF image from bad event file

This image was created from a similar MARX run as used in the [Using MARX to Create an Event File](#) thread, but with `DitherModel` set to `NONE`; the event file therefore *does not* contain sub-pixel resolution.

Binning with `dmcopy`

To create the sub-pixelated image with `dmcopy`, use a similar filter to the one given in the [Centering the PSF](#) section. Since the binning factor has been decreased from 1.0 to 0.1, the limits have been changed to ± 25.6 pixels to create the 512 square pixel image:

```
unix% dmcopy \  
      "marx_HRMA_theta5.949_phi197.7_en1.7_d2.fits[bin x=4678.41:4729.61:0.1,y=3674.33:3725.53:0.1]" \  
      psf_subpix.fits
```

Creating an Image of the PSF -

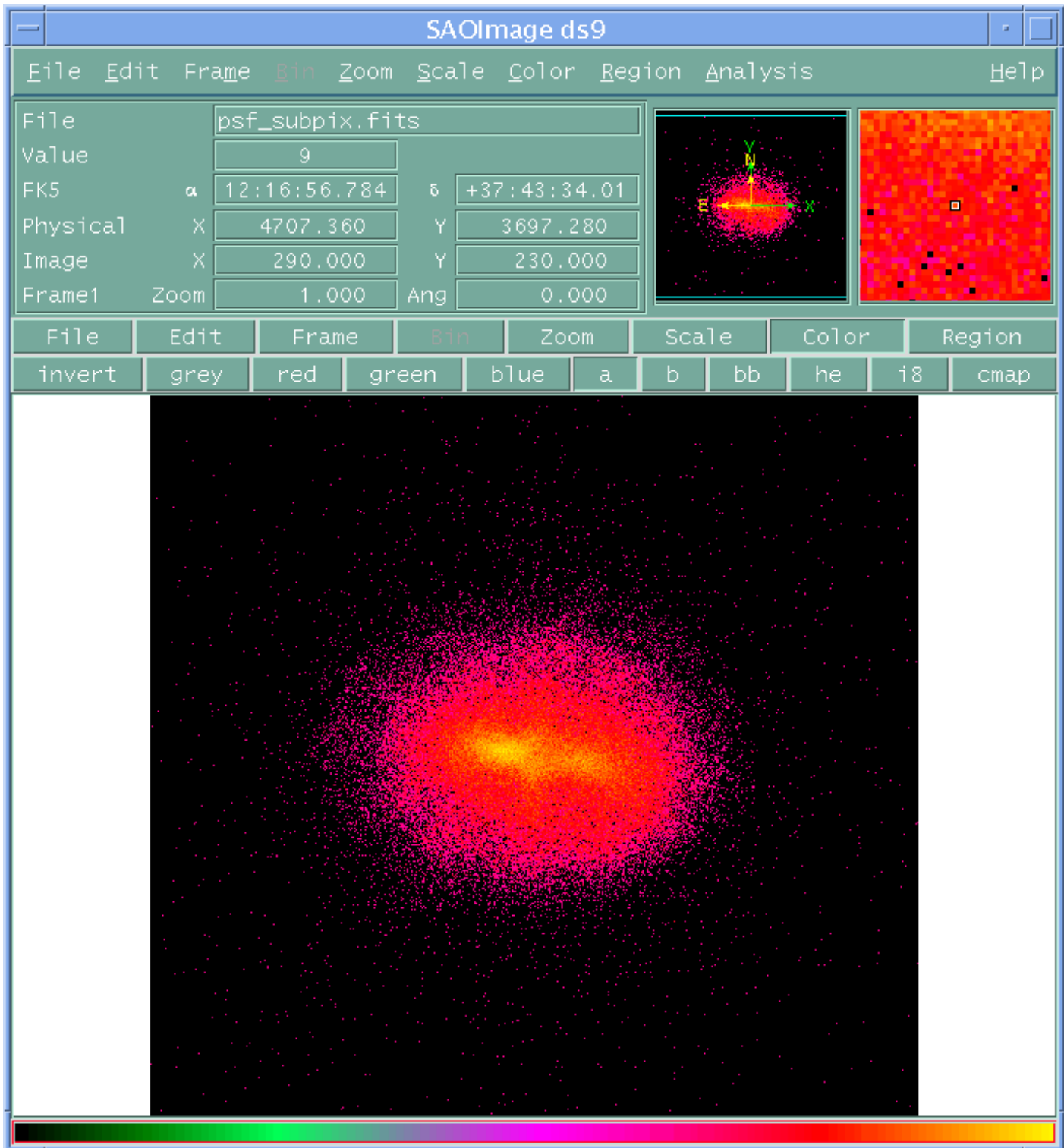


Figure 6: Sub-pixelated PSF image created with dmcoppy

A 512 square pixel image of the PSF created at a binning of 0.1.

Caveats

Encircled-energy fractions

The images created above are unlikely to contain all the flux of the PSF. The output of MARX contains 114776 rays (as shown in the [Examine the Data section](#)). The first image we create from the rayfile contains only 113861 rays, as shown by `dmstat`:

```
unix% dmstat psf_512.fits centroid=no sigma=no
EVENTS_IMAGE
  min:      0           @:      ( 4449 3444 )
  max:     2097         @:      ( 4702 3701 )
  mean:    0.44020843506
  sum:     115398
  good:    262144
  null:     0
```

In comparison, running the same command on `psf_match.fits` reveals a total of 114732 rays in that image:

```
unix% dmstat psf_match.fits centroid=no sigma=no
EVENTS_IMAGE
  min:      0           @:      ( 3802.8 2769 )
  max:     7034         @:      ( 4700.8 3701 )
  mean:    0.2064198846
  sum:     116266
  good:    563250
  null:     0
```

Since we chose a large region around the PSF center, virtually all the rays were included. For smaller regions the loss will be larger. This factor will need to be included in calculations of the encircled-energy fraction for an aperture.

Summary

These images of the PSF can now be used in a CIAO analysis session.

History

27 Jun 2003 original version, updated for CIAO 3.0: layout

16 Feb 2005 reviewed for CIAO 3.3: no changes

18 Aug 2008 updated for CIAO 4.0: version N003 event file, minor changes to screen output; converted images to inline

17 Feb 2010 reviewed for CIAO 4.2: minor updates to screen output

Creating an Image of the PSF -

URL: http://cxc.harvard.edu/chart/threads/psf_image/

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