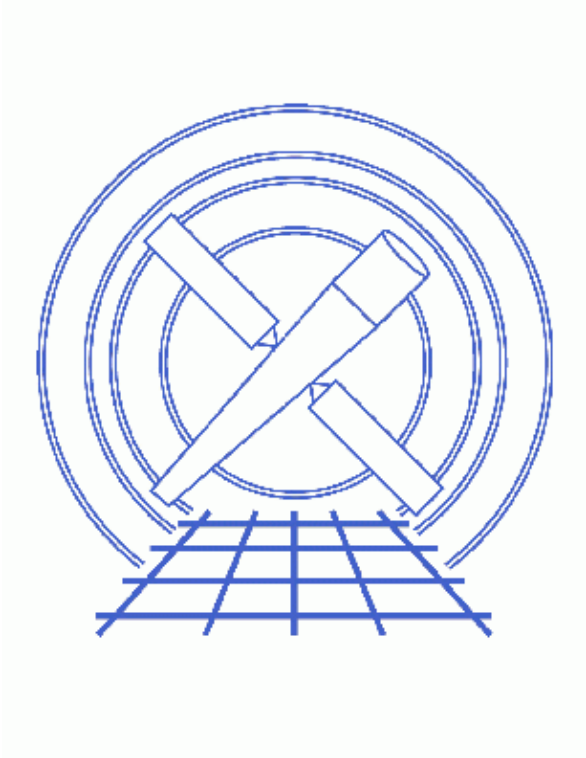
Obtain and Fit a Radial Profile



CIAO 3.4 Science Threads

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Overview

Last Update: 1 Dec 2006 − updated for CIAO 3.4: ChIPS and Sherpa versions

Synopsis:

The surface brightness flux is determined by finding the net counts in a stack of concentric annuli and then dividing by the respective areas. A specified analytic model may be fit to the resultant histogram in *Sherpa*. This information can be used, for instance, to provide evidence for extended emission and calculate the hardness ratio thereof.

Purpose:

To produce radial profiles, then fit a model to them in *Sherpa*.

Read this thread if:

you would like to create a radial profile of an HRC or ACIS imaging observation.

Related Links:

- Analysis Guide: HRC Imaging
- Analysis Guide: Extended Sources

Proceed to the HTML or hardcopy (PDF: A4 | letter) version of the thread.

Get Started

Sample ObsID used: 1838 (ACIS−S, G21.5−09)

File types needed: evt2

In the following examples, restrict the energy range of the events:

```
unix% dmcopy "acisf01838N001_evt2.fits[energy=300:8000]" acis_1838_evt2.fits
```

Creating Radial Profiles

The ability of `dmextract` to operate on a stack of regions makes it possible to compute radial profiles simply by defining multiple concentric annuli.

1. Creating Multiple Annuli

Display the file:

```
unix% ds9 acis_1838_evt2.fits &
```

Select Region −> Shape −> Annulus and left−click on the image. A singular annular region will appear. To edit the region, make it active (left−click) and select ``Get Info..." from the Region menu.

A region editing window will appear, in which one can adjust the number of annuli and their sizes. Thirty−eight equal−radii annuli, with minimium and maximum of 10 and 200 pixels respectively, which are located around (but exclude) the core of G21.5−09, are shown in Figure 2. We also created a background annulus from 200 to 225 pixels.

Save the annuli:

- Create the annuli
- Region −> File Format−> Ciao
- Region −> File Coordinate System −> Physical
- Region −> Save Regions... −> Save As "annuli.reg"

Follow similar steps to create a file containing the background annulus, here named "annuli_bgd.reg".

The source region file looks like this:

```
unix% more annuli.reg
# Region file format: CIAO version 1.0
annulus(4072,4246,10,15)
annulus(4072,4246,15,20)
annulus(4072,4246,20,25)
.
. (etc.)
.
annulus(4072,4246,190,195)
annulus(4072,4246,195,200)
```

and the background annulus like this:

```
unix% more annuli_bgd.reg
# Region file format: CIAO version 1.0
annulus(4070,4250,200,225)
```

---

2. Removing Contaminating Point Sources

Suppose that the annuli had a maximum radius of 250 pixels in the previous step. The point source circled in green in Figure 4 would then contribute to a few of the radial profiles.

Having saved the region in ds9:

```
unix% more contam.reg
# Region file format: CIAO version 1.0
circle(4245,4094.5,8)
```

it is easy to remove this point source before generating the radial profiles:

```
unix% dmcopy "acis_1838_evt2.fits[exclude sky=region(contam.reg)]" acis_1838_excl_evt2.fits
```

This command creates a new event file with the point source removed  . Use this event file in the rest of the radial profile analysis. This is not an issue in this example, so we continue using `acis_1838_evt2.fits`.

3. Run dmextract

It is now possible to run `dmextract` to extract the radial profiles:

```
unix% punlearn dmextract
unix% pset dmextract infile="acis_1838_evt2.fits[bin sky=@annuli.reg]"
unix% pset dmextract outfile=1838_rprofile.fits
unix% pset dmextract bkg="acis_1838_evt2.fits[bin sky=@annuli_bgd.reg]"
unix% dmextract
Input event file  (acis_1838_evt2.fits[bin sky=@annuli.reg]):
Enter output file name (1838_rprofile.fits):
```

The contents of the parameter file may be checked using plist dmextract.

The tool calculates several new columns, the surface brightness (`SUR_BRI`) and its error (`SUR_BRI_ERR`) among them:

```
unix% dmlist 1838_rprofile.fits cols

--------------------------------------------------------------------------------
Columns for Table Block HISTOGRAM
--------------------------------------------------------------------------------

ColNo  Name                 Unit        Type            Range
.
. (output omitted)
.
  20   NET_COUNTS           count        Real8         −Inf:+Inf           Net Counts
  21   NET_ERR              count        Real8         −Inf:+Inf           Error on Net Counts
  22   NET_RATE             count/s      Real8         −Inf:+Inf           Net Count Rate
  23   ERR_RATE             count/s      Real8         −Inf:+Inf           Error Rate
  24   SUR_BRI              count/pixel**2 Real8         −Inf:+Inf           Net Counts per squ
  25   SUR_BRI_ERR          count/pixel**2 Real8         −Inf:+Inf           Error on net count
.
.
.
```

`SUR_BRI` is calculated as `NET_COUNTS`/`AREA` (columns 19 and 7, respectively); `SUR_BRI_ERR` is `NET_ERR`/`AREA` (columns 20 and 7).

Note that since the surface brightness is calculated from the `NET_COUNTS` column, the background counts are already removed from it: `NET_COUNTS = COUNTS − [(BG_COUNTS/BG_AREA) * AREA]`. It is therefore not necessary to account for the background separately when fitting this data in *Sherpa*.

Finally, we want to add a column that defines the midpoint of the annular regions (`rmid`):

```
unix% punlearn dmtcalc
unix% pset dmtcalc infile=1838_rprofile.fits
unix% pset dmtcalc outfile=1838_rprofile_rmid.fits
unix% pset dmtcalc expression="rmid=0.5*(R[0]+R[1])"
unix% dmtcalc
Input file (1838_rprofile.fits):
Output file (1838_rprofile_rmid.fits):
expression(s) to evaluate (rmid=0.5*(R[0]+R[1])):
```

The contents of the parameter file may be checked using plist dmtcalc.

The new column has been created in `1838_rprofile_rmid.fits`:

```
unix% dmlist 1838_rprofile_rmid.fits'[cols R,RMID]' data

--------------------------------------------------------------------------------
Data for Table Block HISTOGRAM
--------------------------------------------------------------------------------

ROW    R[2]                                      RMID

     1               [       10.0        15.0]               12.50
     2               [       15.0        20.0]               17.50
     3               [       20.0        25.0]               22.50
     4               [       25.0        30.0]               27.50
     5               [       30.0        35.0]               32.50
...
```

Plotting and Fitting

The radial profile can now be plotted using *ChIPS*:

```
unix% chips

Welcome to ChIPS, version CIAO 3.4
Copyright (C) 1999−2003, Smithsonian Astrophysical Observatory

chips> plot "1838_rprofile_rmid.fits[cols rmid,sur_bri,sur_bri_err]" x 1 y 2 yerr 3
chips> log
Warning: negative and zero values ignored in log scale
```

which produces Figure 6  . Exit *ChIPS* before continuing:

```
chips> exit
```

A model can be fit to the measured surface brightness profile using *Sherpa*. As mentioned before, the background counts are already removed from the surface brightness, so it is not necessary to account for the background separately when fitting the data:

```
unix% sherpa

-------------------------------------------------------
Welcome to Sherpa: CXC's Modeling and Fitting Program
-------------------------------------------------------
Version: CIAO 3.4

Type AHELP SHERPA for overview.
Type EXIT, QUIT, or BYE to leave the program.

Notes:
    Temporary files for visualization will be written to the directory:
    /tmp
    To change this so that these files are not deleted when you exit Sherpa,
    edit $ASCDS_WORK_PATH in your 'ciao' setup script.

    Abundances set to Anders & Grevesse

sherpa> read data 1 "1838_rprofile_rmid.fits[columns rmid,sur_bri]" FITSBIN
sherpa> read errors 1 "1838_rprofile_rmid.fits[columns rmid,sur_bri_err]" FITSBIN

sherpa> beta1d[sbr1]
sbr1.r0 parameter value [105]
sbr1.beta parameter value [1e−05]
```

```
sbr1.xpos parameter value [0]
sbr1.ampl parameter value [0.00993448]
sherpa> sbr1.ampl.max=10
sherpa> show sbr1
beta1d[sbr1]  (integrate: off)
    Param   Type      Value        Min        Max                Units
    -----   ----      -----        ---        ---                -----
 1     r0 thawed        105          1      197.5
 2   beta thawed      1e-05      1e-05         10
 3   xpos frozen          0          0      197.5
 4   ampl thawed 9.9345e-03 9.9345e-05         10

sherpa> source=sbr1
sherpa> fit
 LVMQT: V2.0
 LVMQT: initial statistic value = 18548.3
 LVMQT: final statistic value = 197.351 at iteration 25
          sbr1.r0  116.969
          sbr1.beta  3.67579
          sbr1.ampl  4.50021

sherpa> lplot fit
sherpa> log
Warning: negative and zero values ignored in log scale
sherpa> limits y 0.0001 10
sherpa> limits x 10 200
sherpa> redraw
```

which produces Figure 7  .

```
sherpa> exit
Goodbye.
```

```
Parameters for /home/username/cxcds_param/dmextract.par


#-------------------------------------------------------------------------
#
# DMEXTRACT -- extract columns or counts from an event list
#
#-------------------------------------------------------------------------
        infile = acis_1838_evt2.fits[bin sky=@annuli.reg] Input event file
       outfile = 1838_rprofile.fits    Enter output file name
          (bkg = acis_1838_evt2.fits[bin sky=@annuli_bgd.reg]) Background region file or fixed ba
        (error = gaussian)        Method for error determination(poisson|gaussian|<variance file>
     (bkgerror = gaussian)        Method for background error determination(poisson|gaussian|<var
      (bkgnorm = 1.0)             Background normalization
          (exp = )                Exposure map image file
        (bkgexp = )               Background exposure map image file
      (sys_err = 0)               Fixed systematic error value for SYS_ERR keyword
          (opt = pha1)            Output file type: pha1
     (defaults = ${ASCDS_CALIB}/cxo.mdb -> /soft/ciao/data/cxo.mdb) Instrument defaults file
         (wmap = )                WMAP filter/binning (e.g. det=8 or default)
      (clobber = no)              OK to overwrite existing output file(s)?
      (verbose = 0)               Verbosity level
         (mode = ql)
```

```
Parameters for /home/username/cxcds_param/dmtcalc.par


        infile = 1838_rprofile.fits    Input file
```

```
   outfile = 1838_rprofile_rmid.fits Output file
expression = rmid=0.5*(R[0]+R[1]) expression(s) to evaluate
   (kernel = default)         Data Model creation/copy kernel
  (clobber = no)              Clobber output file if it exists?
  (verbose = 0)               Debug level
     (mode = ql)
```

History

04 Jan 2005	updated for CIAO 3.2: version numbers
20 Dec 2005	updated for CIAO 3.3: default value of `dmextract` `error` and `bkgerror` parameters is "gaussian"
01 Dec 2006	updated for CIAO 3.4: ChIPS and Sherpa versions

URL: http://cxc.harvard.edu/ciao/threads/radial_profile/ Last modified: 1 Dec 2006

Image 1: ds9 region information/edit window

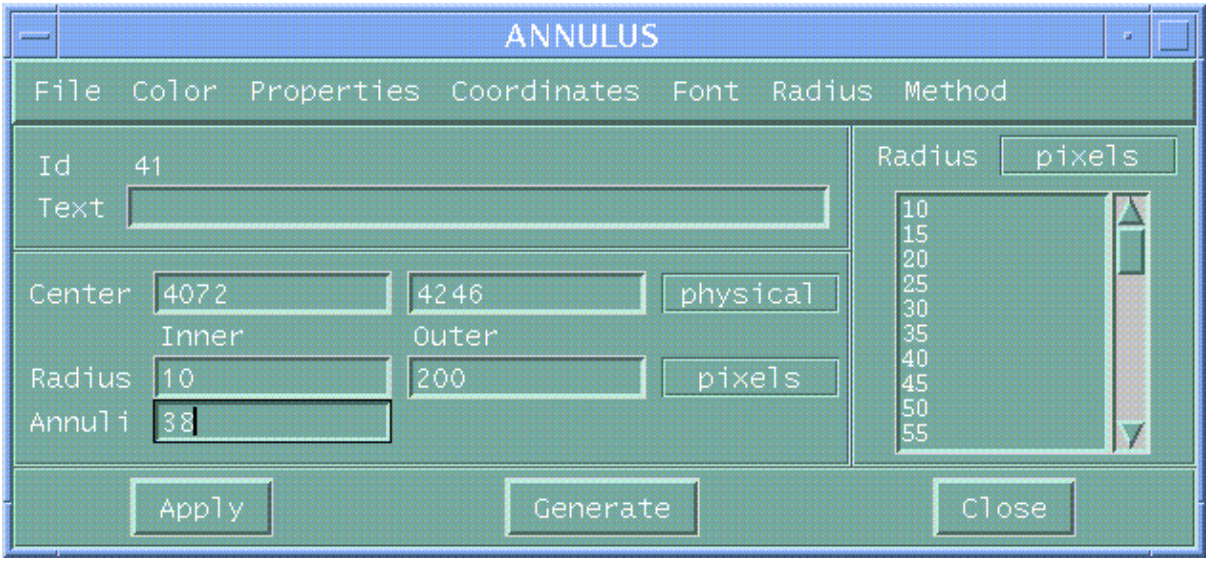
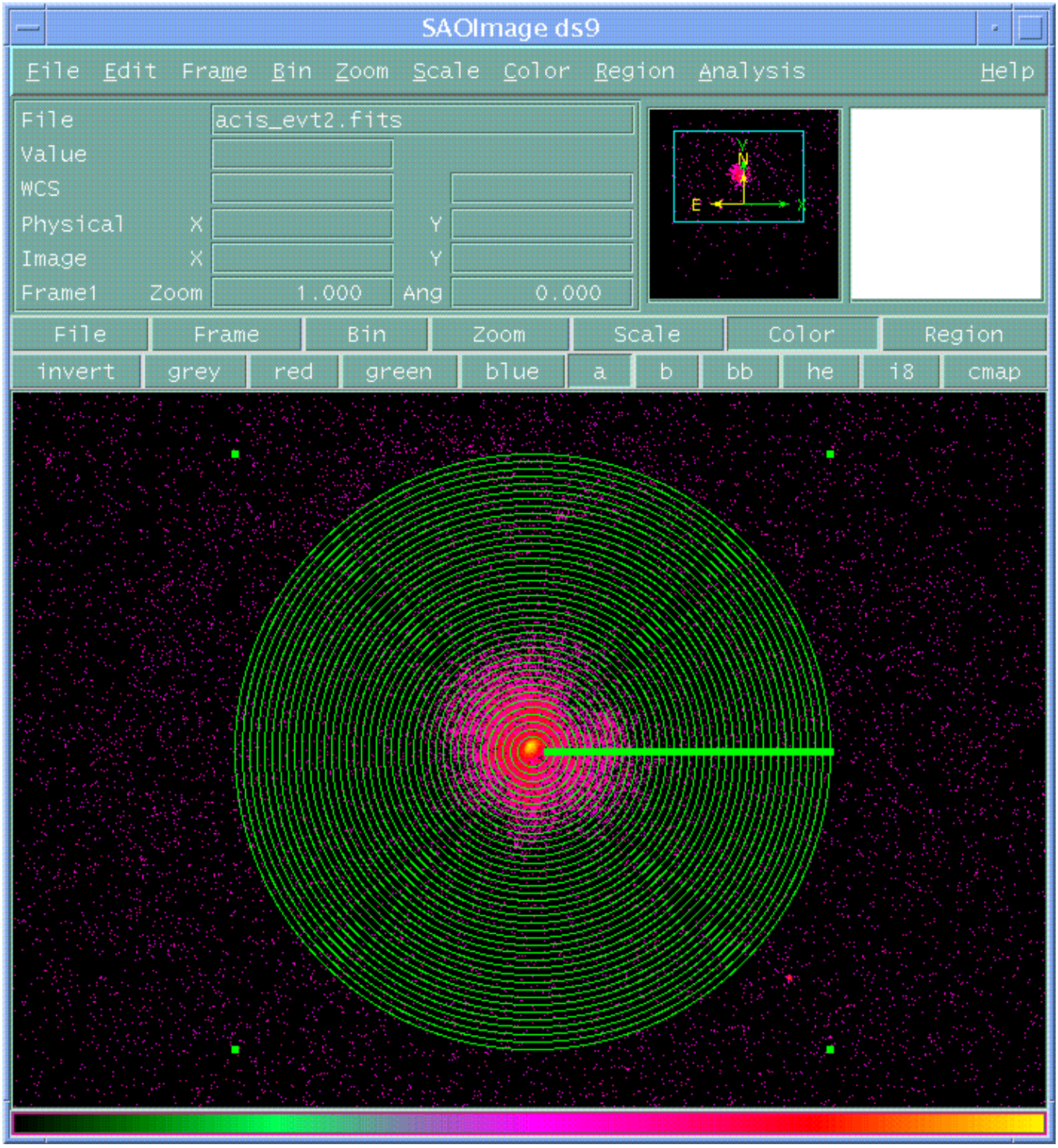
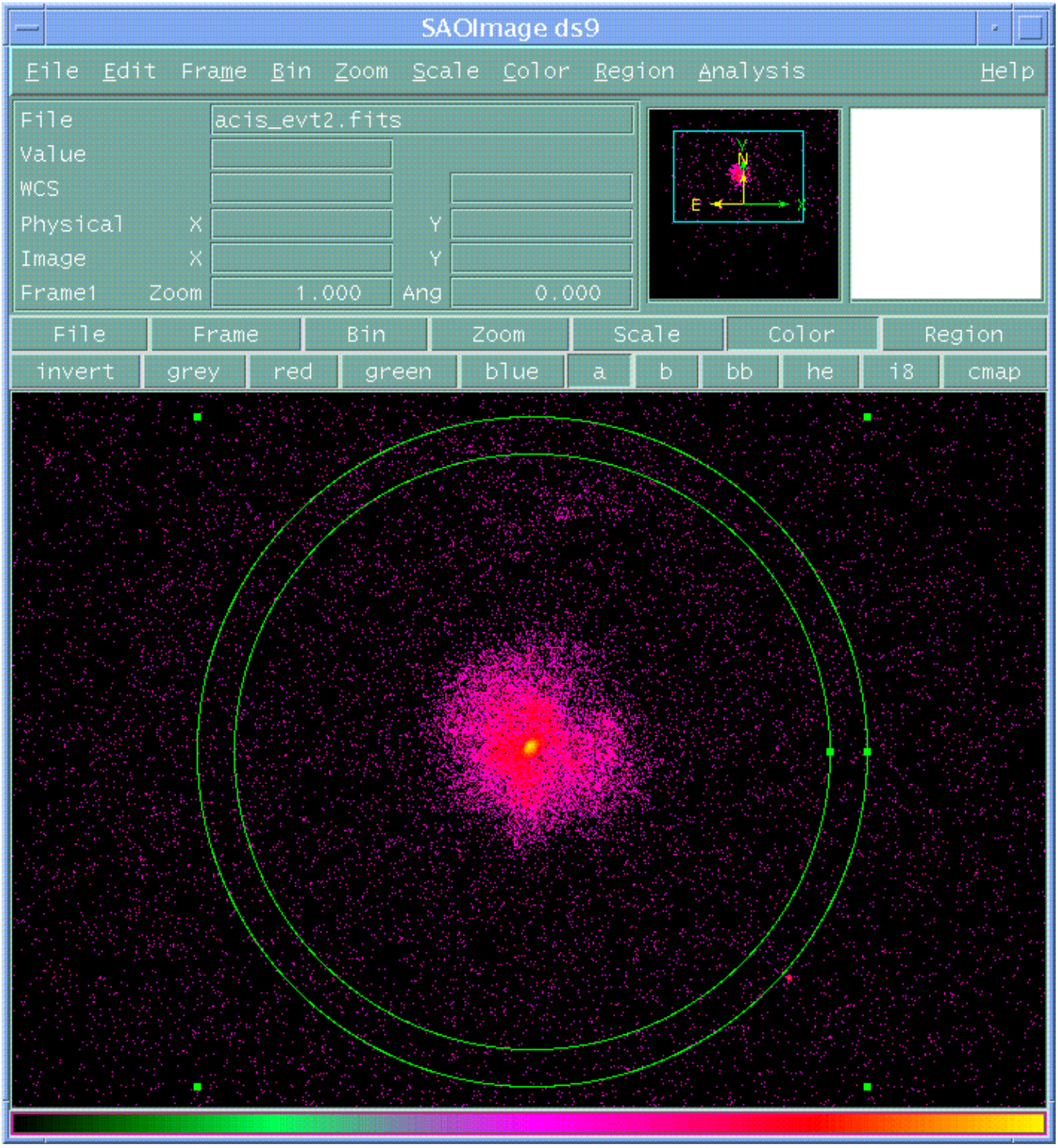


Image 2: Annuli overlaid on source image



There are 38 equal−radii annuli shown here; the minimum and maximum radii are 10 and 200 pixels respectively.

Image 3: Background region



The background region has been chosen as an annulus with inner and outer radii of 200 and 225 pixels.

Image 4: Annuli that contain an unwanted point source

The green circle shows the source that needs to be removed.

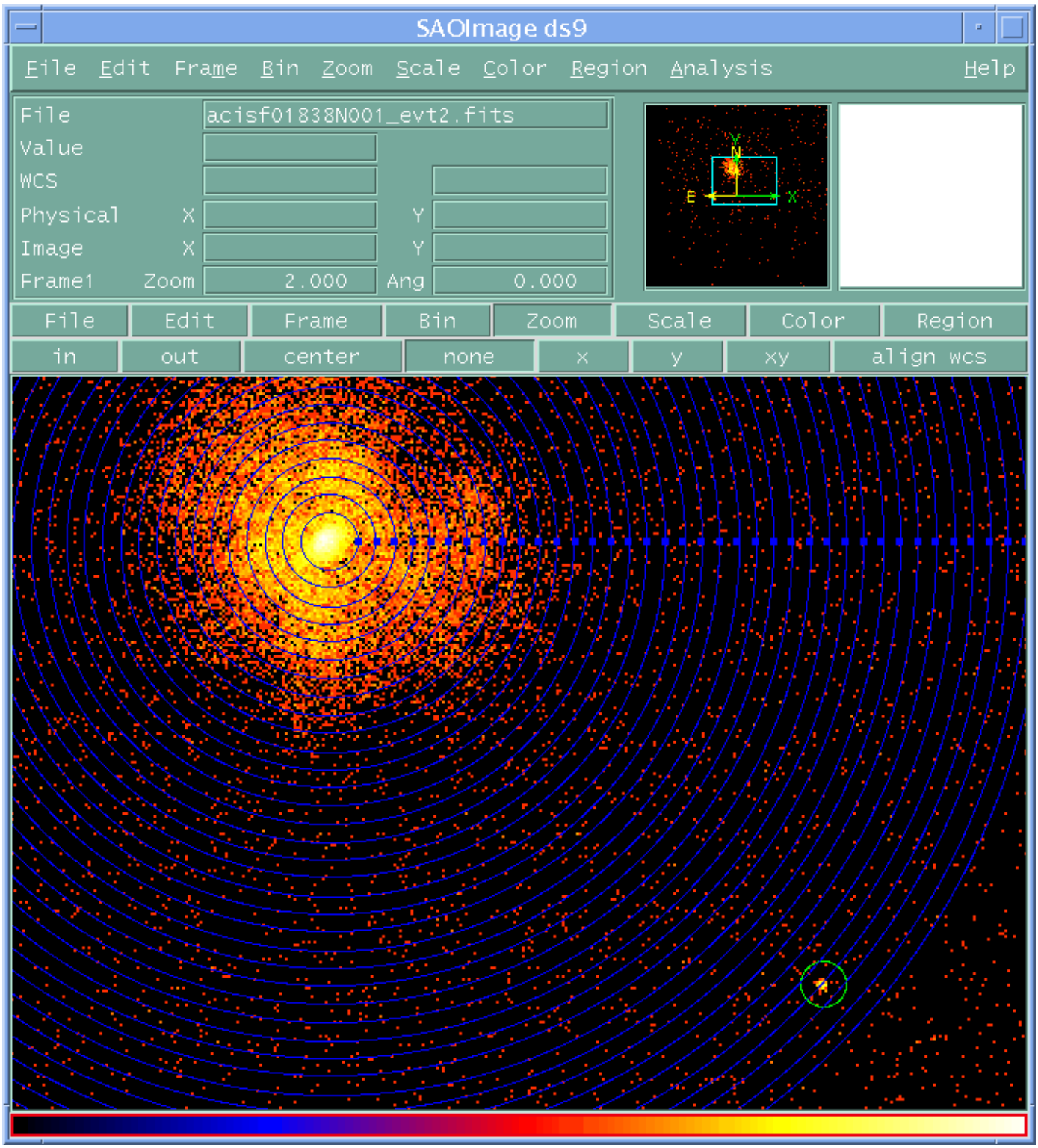


Image 5: New event file with source removed

The green circle shows where the unwanted source used to be located.

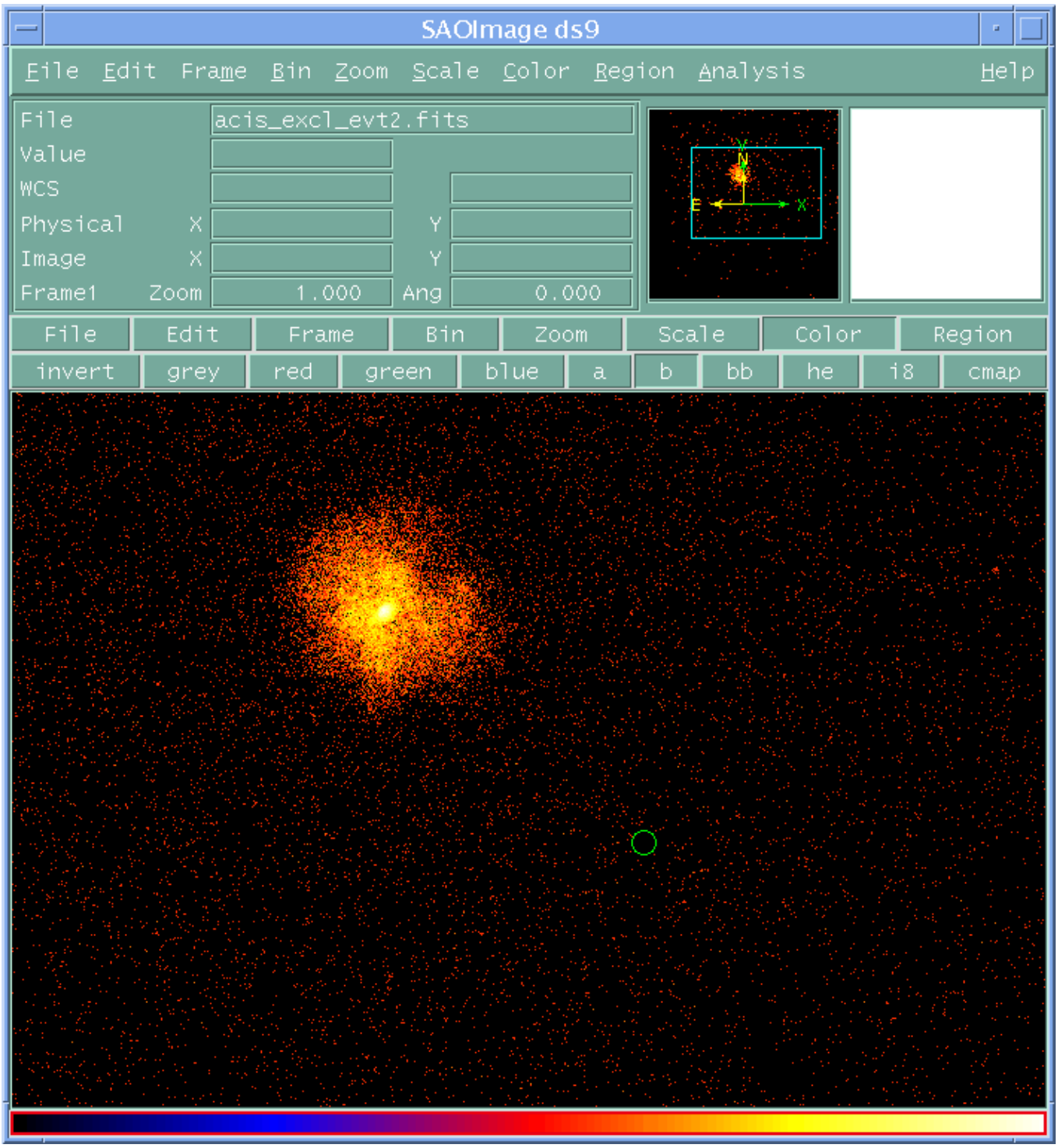


Image 6: Radial profile of source

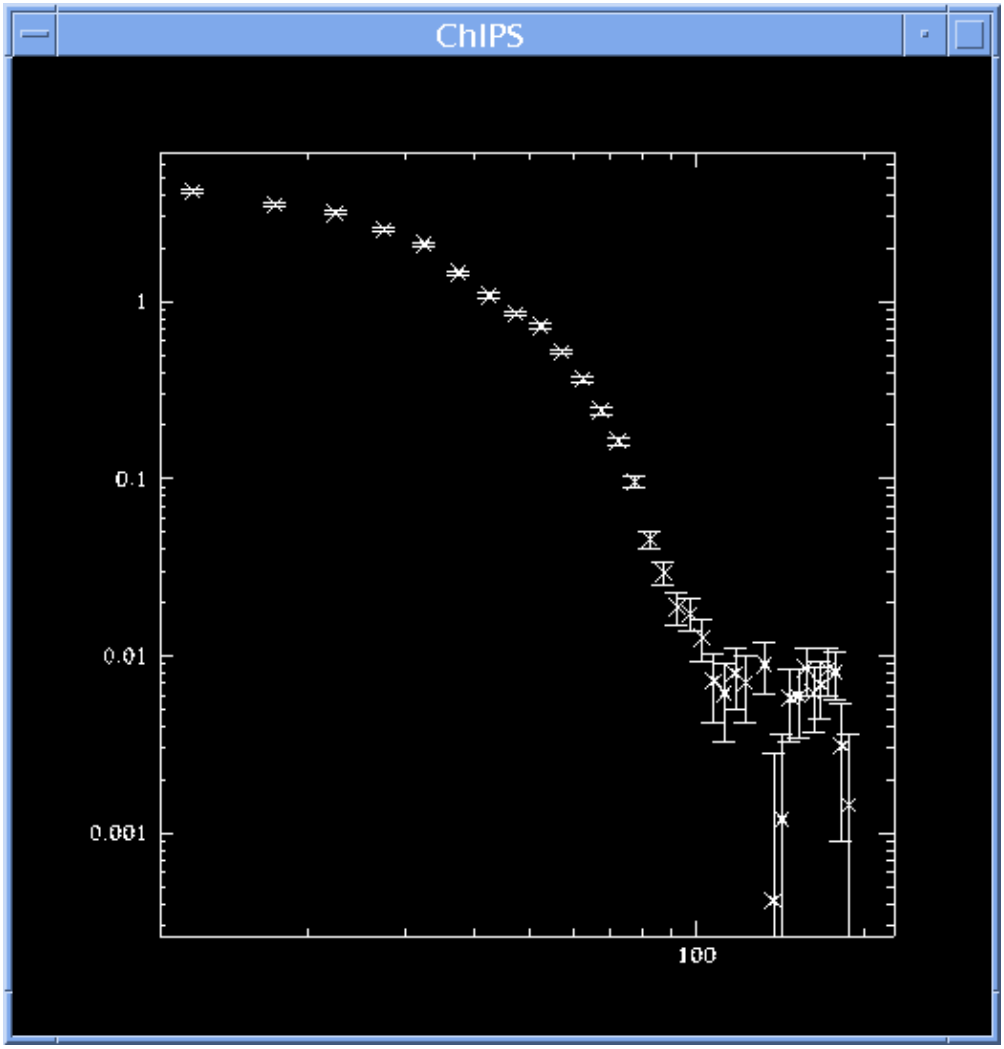
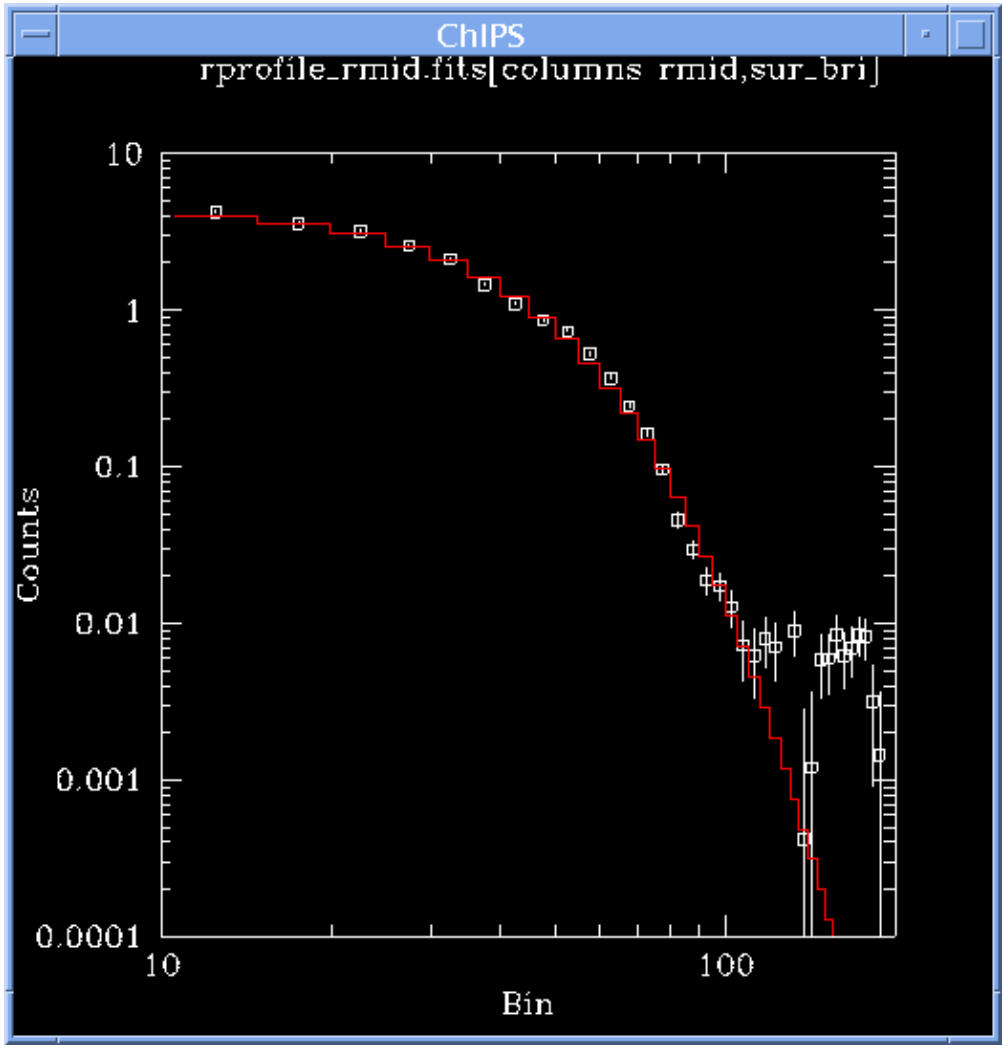


Image 7: Fit to radial profile of source



The red line shows the best−fitting model (here a one−dimensional beta profile) found by *Sherpa*.