

Constructing Radial Profiles in CIAO

The CIAO tool DMEXTRACT now has the ability to compute background-subtracted, exposure-corrected net counts in multiple regions in a single pass. It can thus be used to construct radial profiles. The sequence of operations is:

1. define multiple concentric annular regions using DS9,
2. generate exposure maps if necessary,
3. run DMEXTRACT, inputting the annular regions **as a stack**,
4. run DMTCALC on the output FITS binary table to normalize by region areas,
5. use SHERPA to display the profile and fit models to it.

CIAO Workshop, Radial Profiles

For this talk, I'll consider two cases:

- A simple case where the annuli fall within a single chip; I'll assume the exposure is uniform over the regions.
- A more complicated case where the regions span multiple chips.

For reference, see the threads

<http://asc.harvard.edu/ciao2.1/threads/getcnts.thread.html#RadProj>

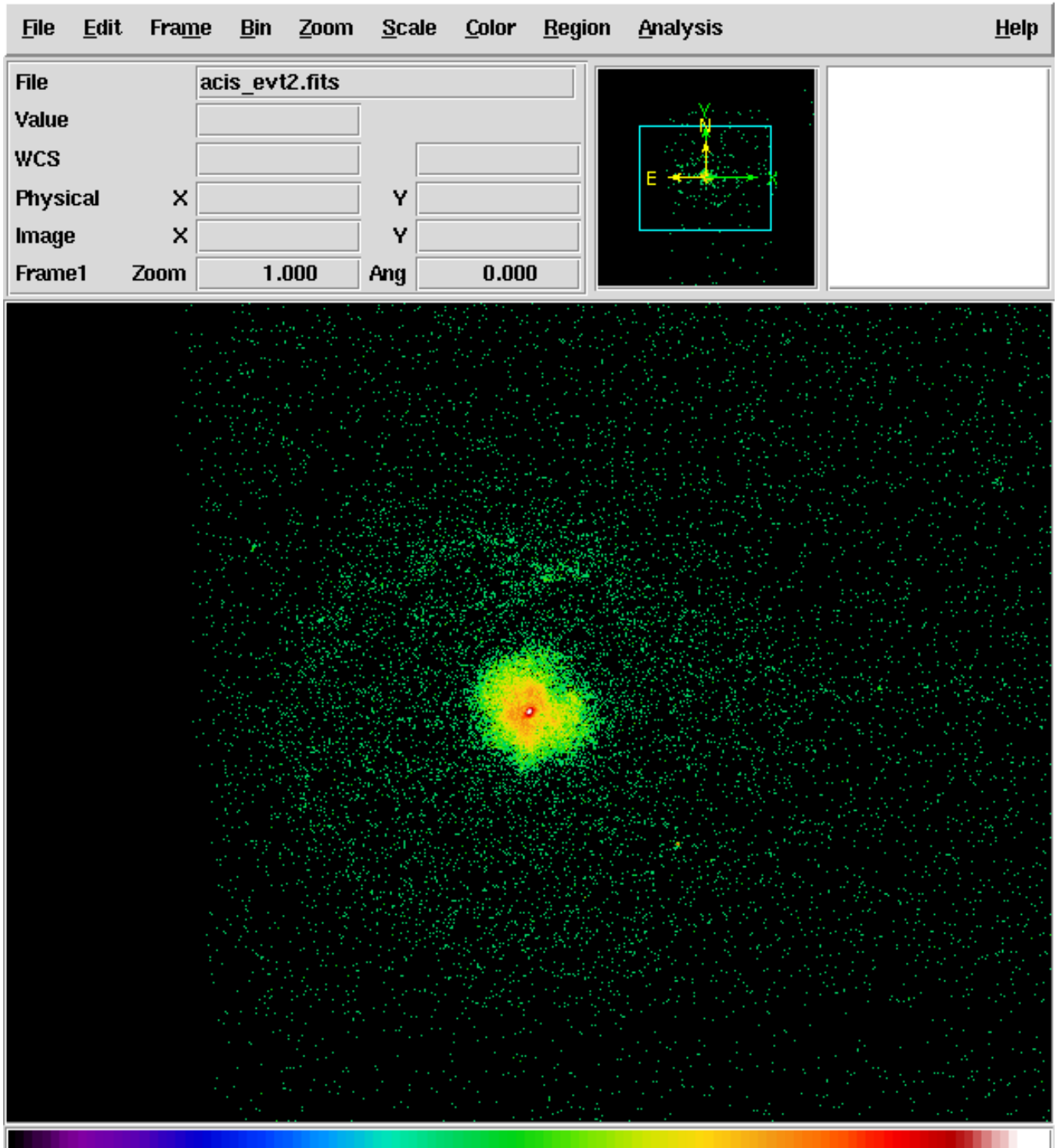
and

<http://asc.harvard.edu/ciao2.1/threads/expmap.multi.html>

I'll use the same data and in general follow those procedures closely.

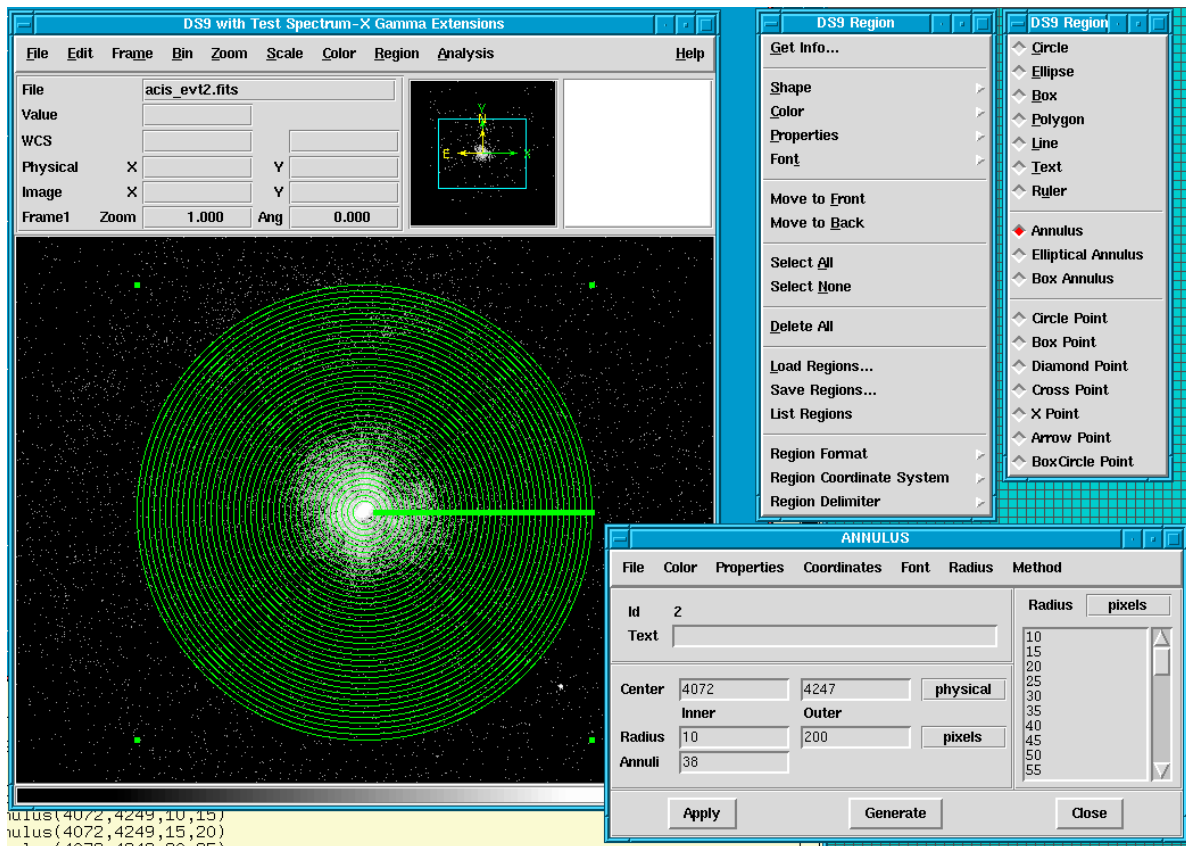
A Simple Case (1)

Consider the ACIS exposure of the Supernova Remnant G21.5-0.9, shown here:



A Simple Case (2)

We use DS9 to define multiple concentric annuli by selecting the “annulus” shape under the **Region** menu and then editing it using the **Get Info...** button. We select 5 pixel wide annuli, from 10-200 pixels, excluding the bright, central source.



A Simple Case (3)

Saving the regions (remember to select CIAO Format) results in the following file

```
moose-28: more annuli.reg
# Region file format: CIAO version 1.0
annulus(4072,4249,10,15) & annulus(4072,4249,15,20) & \
annulus(4072,4249,20,25) & annulus(4072,4249,25,30) & \
annulus(4072,4249,30,35) & annulus(4072,4249,35,40) & \
annulus(4072,4249,40,45) & annulus(4072,4249,45,50) & \
.
.
```

This needs to be converted to a **stack** of annuli using the **fixannuli** script (note, this step will no longer be necessary once DS9 Version 2.1 is incorporated into CIAO):

```
moose-29: fixannuli < annuli.reg
annulus(4072,4249,10,15)
annulus(4072,4249,15,20)
annulus(4072,4249,20,25)
annulus(4072,4249,25,30)
.
.
```

We also create a single background annulus:

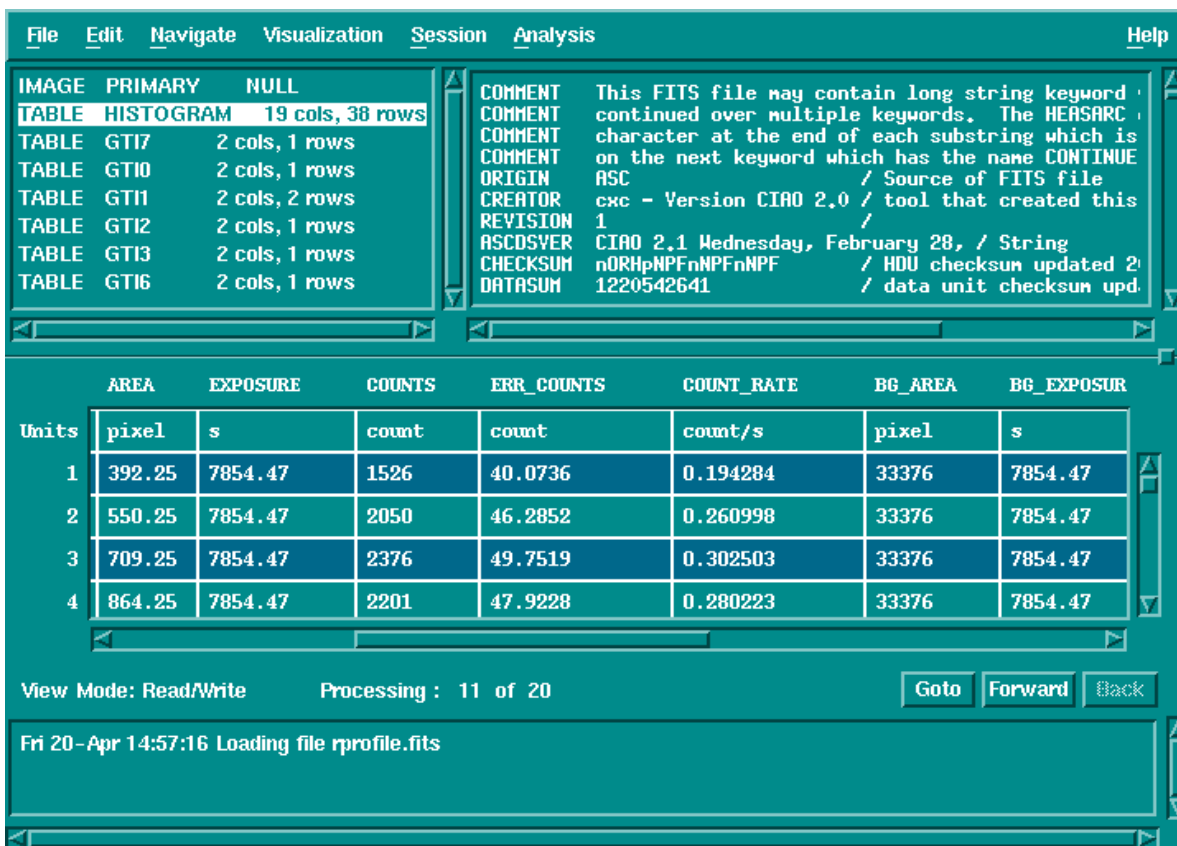
```
moose-31: cat annuli_bgd.reg
# Region file format: CIAO version 1.0
annulus(4071,4249,200,225)
```

A Simple Case (4)

We're now ready to extract counts in the individual annular regions:

```
moose-32: dmextract \  
infile="acis_evt2.fits[bin sky=@annuli.fixed.reg]"\  
bkg="acis_evt2.fits[bin sky=@annuli_bgd.reg]"\  
outfile=rprofile.fits
```

The output can be examined with PRISM:



The screenshot shows the PRISM software interface. The top menu bar includes File, Edit, Navigate, Visualization, Session, Analysis, and Help. The main window is divided into two panes. The left pane displays a table of FITS tables:

IMAGE	PRIMARY	NULL
TABLE HISTOGRAM		19 cols, 38 rows
TABLE GTI7		2 cols, 1 rows
TABLE GTI0		2 cols, 1 rows
TABLE GTI1		2 cols, 2 rows
TABLE GTI2		2 cols, 1 rows
TABLE GTI3		2 cols, 1 rows
TABLE GTI6		2 cols, 1 rows

The right pane displays FITS header information:

```
COMMENT This FITS file may contain long string keyword  
COMMENT continued over multiple keywords. The HEASARC  
COMMENT character at the end of each substring which is  
COMMENT on the next keyword which has the name CONTINUE  
ORIGIN ASC / Source of FITS file  
CREATOR cxc - Version CIAO 2.0 / tool that created this  
REVISION 1 /  
ASCDSVER CIAO 2.1 Wednesday, February 28, / String  
CHECKSUM nORHpNPFnNPFnNPF / HDU checksum updated 2  
DATASUM 1220542641 / data unit checksum upd.
```

Below the panes is a table with columns: AREA, EXPOSURE, COUNTS, ERR_COUNTS, COUNT_RATE, BG_AREA, and BG_EXPOSUR. The table has 4 rows of data:

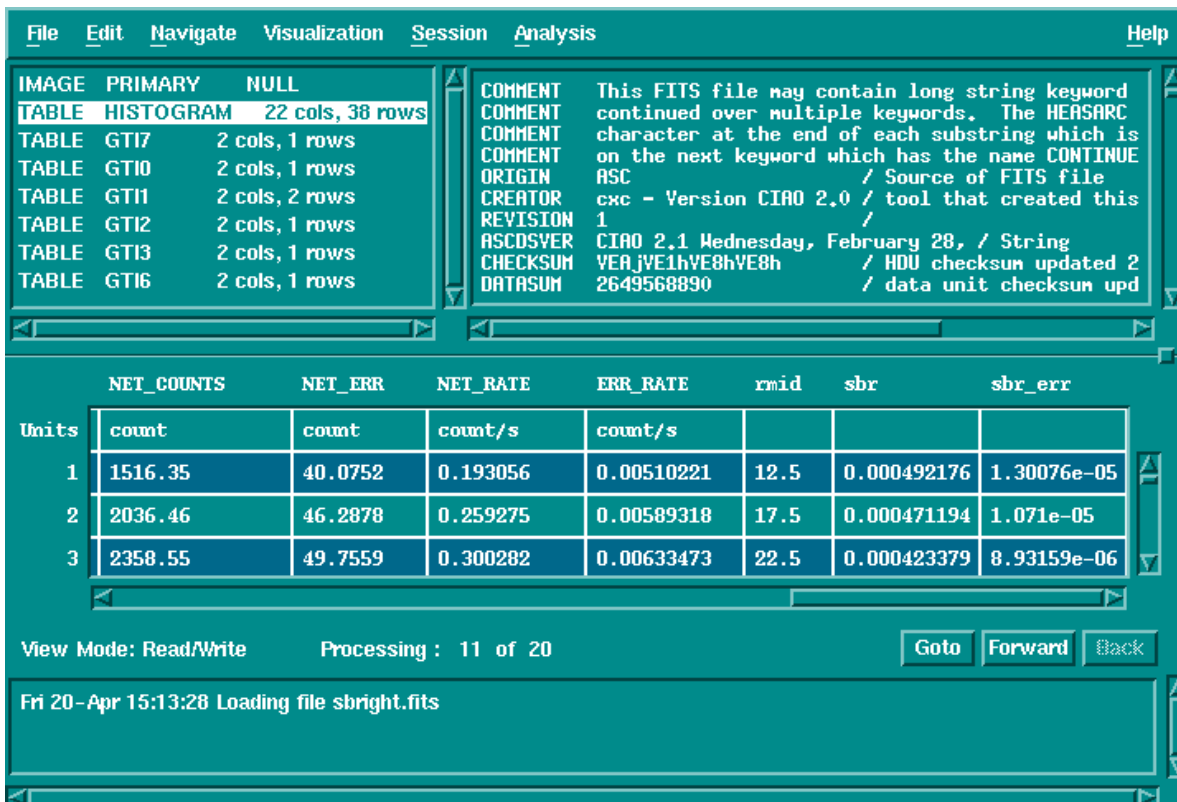
	AREA	EXPOSURE	COUNTS	ERR_COUNTS	COUNT_RATE	BG_AREA	BG_EXPOSUR
Units	pixel	s	count	count	count/s	pixel	s
1	392.25	7854.47	1526	40.0736	0.194284	33376	7854.47
2	550.25	7854.47	2050	46.2852	0.260998	33376	7854.47
3	709.25	7854.47	2376	49.7519	0.302503	33376	7854.47
4	864.25	7854.47	2201	47.9228	0.280223	33376	7854.47

At the bottom of the interface, there are buttons for View Mode: Read/Write, Processing: 11 of 20, and buttons for Goto, Forward, and Back. A status bar at the very bottom shows: Fri 20-Apr 14:57:16 Loading file rprofile.fits

A Simple Case (5)

Finally, we need to normalize the counts in each annulus by the area, using the DMTCALC expression file rpcolumns.lis:

```
moose-33: cat rpcolumns.lis
.rmid=R[0]+R[1]
rmid=.rmid/2.0
sbr=NET_RATE/AREA
sbr_err=ERR_RATE/AREA
moose-34: dmtcalc infile=rprofile.fits \
outfile=sbright.fits expression=@rpcolumns.lis
```



The screenshot shows a software interface with a menu bar (File, Edit, Navigate, Visualization, Session, Analysis, Help) and a main window. The main window is divided into two panes. The left pane shows a list of FITS tables:

IMAGE	PRIMARY	NULL
TABLE HISTOGRAM		22 cols, 38 rows
TABLE GT17		2 cols, 1 rows
TABLE GT10		2 cols, 1 rows
TABLE GT11		2 cols, 2 rows
TABLE GT12		2 cols, 1 rows
TABLE GT13		2 cols, 1 rows
TABLE GT16		2 cols, 1 rows

The right pane shows FITS header information:

```
COMMENT This FITS file may contain long string keyword
COMMENT continued over multiple keywords. The HEASARC
COMMENT character at the end of each substring which is
COMMENT on the next keyword which has the name CONTINUE
ORIGIN ASC / Source of FITS file
CREATOR cxc - Version CIAO 2.0 / tool that created this
REVISION 1 /
ASCDSVER CIAO 2.1 Wednesday, February 28, / String
CHECKSUM VEAjVE1hVE8hVE8h / HDU checksum updated 2
DATASUM 2649568890 / data unit checksum upd
```

Below the panes is a table with columns: NET_COUNTS, NET_ERR, NET_RATE, ERR_RATE, rmid, sbr, sbr_err. The data is as follows:

Units	NET_COUNTS	NET_ERR	NET_RATE	ERR_RATE	rmid	sbr	sbr_err
1	1516.35	40.0752	0.193056	0.00510221	12.5	0.000492176	1.30076e-05
2	2036.46	46.2878	0.259275	0.00589318	17.5	0.000471194	1.071e-05
3	2358.55	49.7559	0.300282	0.00633473	22.5	0.000423379	8.93159e-06

At the bottom, there are buttons for "View Mode: Read/Write", "Processing: 11 of 20", "Goto", "Forward", and "Back". A status bar at the very bottom reads "Fri 20-Apr 15:13:28 Loading file sbright.fits".

A Simple Case (6)

The radial profile can be plotted and fit using SHERPA:

```
moose-35: sherpa
```

```
Welcome to Sherpa: CXC's Modeling and Fitting Program
```

```
Version: 2.1 (1 Dec 2000)
```

```
Type HELP for help options.
```

```
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 the variable ASCDS_WORK_PATH in your  
$HOME/.cxcds.*sh setup script.
```

```
Solar abundances set to Anders & Grevesse
```

```
sherpa> read data 1 "sbright_pos.fits[columns rmid,sbr]"  
FITSBIN
```

```
sherpa> read errors 1 "sbright_pos.fits[columns  
rmid,sbr_err]" FITSBIN
```

```
sherpa> beta1d[sbr1]
```

```
sbr1.r0 parameter value [102] 50
```

```
sbr1.beta parameter value [0]
```

```
sbr1.xpos parameter value [0]
```

```
sbr1.ampl parameter value [2.14602e-06] 5.0e-4
```


Warning: Parameter is out of range, please reset maximum range

if you intend to fit.

Warning: Parameter sbr1.ampl is out of range.

```
sherpa> sbr1.ampl.max=1.0e-3
```

```
sherpa> show sbr1
```

```
beta1d[sbr1] (integrate: off)
```

	Param	Type	Value	Min	Max	Units
1	r0	frozen	50	1	192.5000	
2	beta	thawed				0-3.4028e+38 3.4028e+38
3	xpos	thawed				0-3.4028e+38 3.4028e+38
4	ampl	thawed	0.0005	2.1460e-08	0.0010	

```
sherpa> source=sbr1
```

```
sherpa> thaw sbr1.r0
```

```
sherpa> fit
```

```
powll: v1.2
```

```
powll: initial function value = 4.66941E+02
```

```
powll: converged to minimum = 1.44025E+02 at  
iteration = 15
```

```
powll: final function value = 1.44025E+02
```

```
sbr1.r0 107.889
```

```
sbr1.beta 3.21701
```

```
sbr1.xpos 0
```

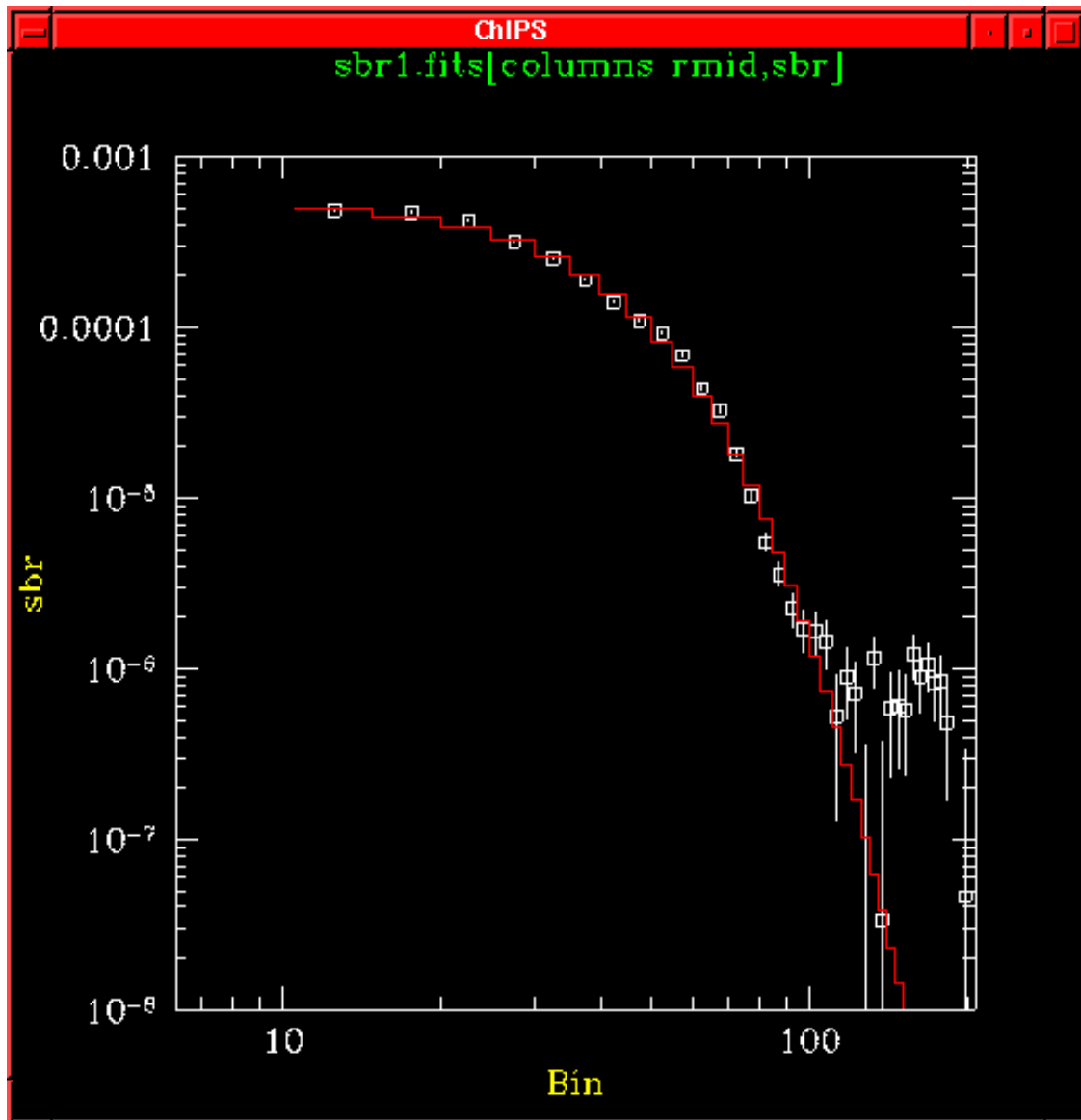
```
sbr1.ampl 0.000581895
```

```
sherpa> lplot fit
```

```
sherpa> log
```

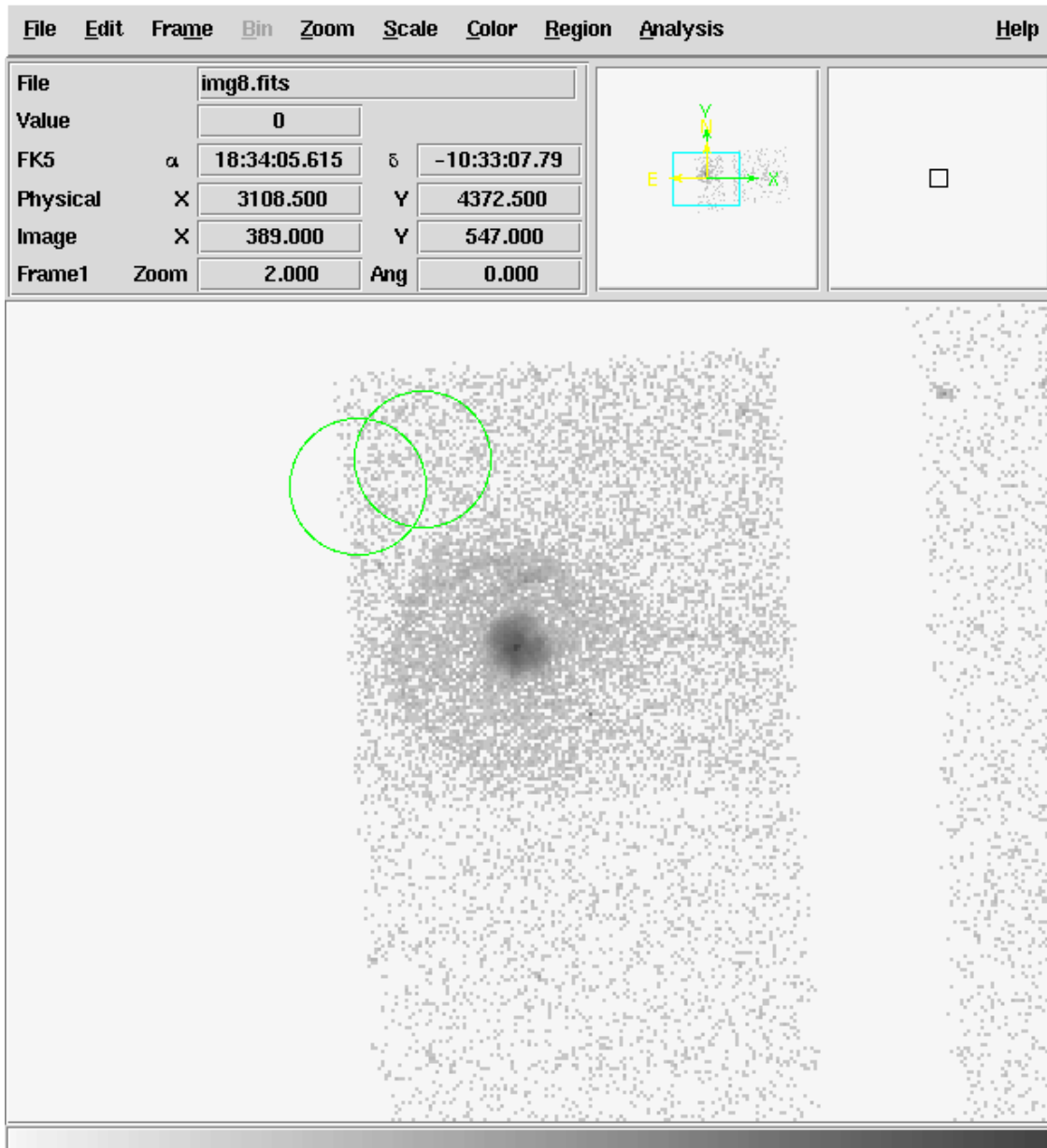
```
sherpa> limits y 1.0e-8 1.0e-3  
sherpa> redraw
```

to produce the following plot:



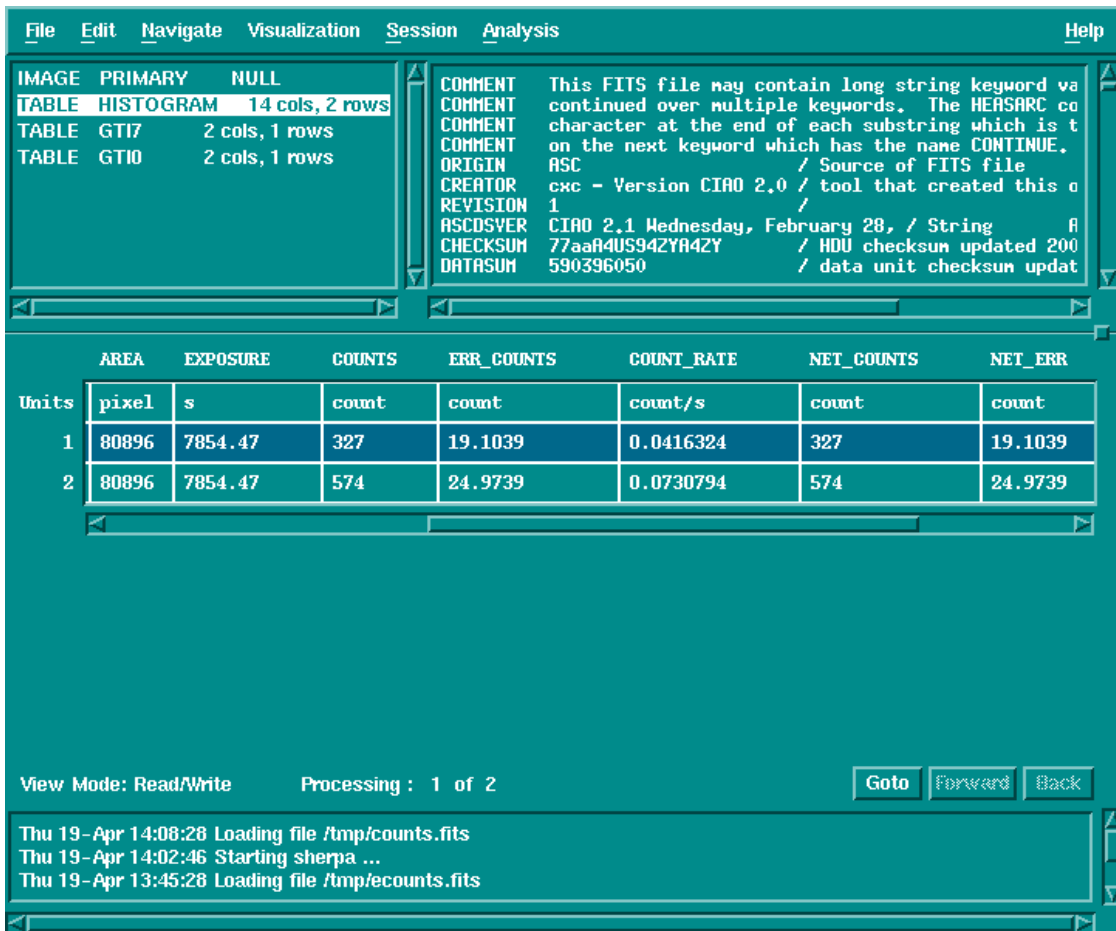
What Happens Near Chip Edges (1)

If you want to extract counts from regions near detector boundaries, you need to be careful. Consider the following case:



Edges (2)

If we simply run `dmextract` as before, we get the wrong answer, i.e., the counts in the two circles are different by $\sim \times 2$:



The screenshot shows a software window with a menu bar (File, Edit, Navigate, Visualization, Session, Analysis, Help) and a main display area. The display area is divided into two panes. The left pane shows FITS header information:

IMAGE	PRIMARY	NULL
TABLE	HISTOGRAM	14 cols, 2 rows
TABLE	GTI7	2 cols, 1 rows
TABLE	GTI0	2 cols, 1 rows

The right pane shows FITS header comments:

```
COMMENT This FITS file may contain long string keyword va
COMMENT continued over multiple keywords. The HEASARC co
COMMENT character at the end of each substring which is t
COMMENT on the next keyword which has the name CONTINUE.
ORIGIN ASC / Source of FITS file
CREATOR cxc - Version CIAO 2.0 / tool that created this o
REVISION 1 /
ASCDSVER CIAO 2.1 Wednesday, February 28, / String A
CHECKSUM 77aaA4US94ZYA4ZY / HDU checksum updated 200
DATASUM 590396050 / data unit checksum updat
```

Below the panes is a table with the following data:

	AREA	EXPOSURE	COUNTS	ERR_COUNTS	COUNT_RATE	NET_COUNTS	NET_ERR
Units	pixel	s	count	count	count/s	count	count
1	80896	7854.47	327	19.1039	0.0416324	327	19.1039
2	80896	7854.47	574	24.9739	0.0730794	574	24.9739

At the bottom of the window, there is a status bar with the text "View Mode: Read/Write Processing : 1 of 2" and buttons for "Goto", "Forward", and "Back". A log window at the very bottom shows the following messages:

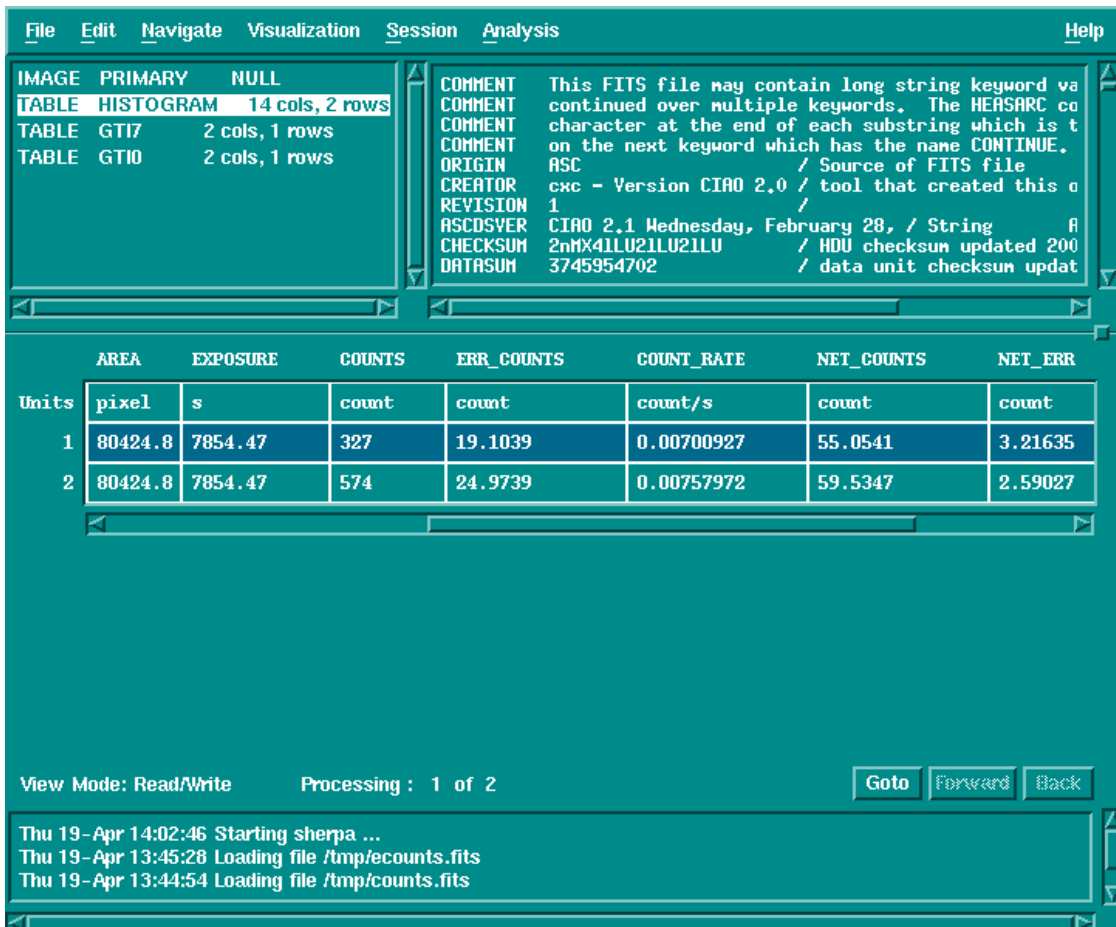
```
Thu 19-Apr 14:08:28 Loading file /tmp/counts.fits
Thu 19-Apr 14:02:46 Starting sherpa ...
Thu 19-Apr 13:45:28 Loading file /tmp/ccounts.fits
```

Edges (3)

We need to correct by the exposure, using an exposure map congruent with the image. Here, we use `expmap_1.7kev.fits`, made for these data, and in the multi-chip exposure map thread:

```
moose-16: dmextract \  
infile="img8.fits[bin sky=@img8_edge.reg]"\  
outfile=counts.fits exp=expmap_1.7kev.fits  
# 11897: dmextract:  
WARNING: TLMIN and TLMAX not found for column sky  
moose-17:
```

which results in the following:



The screenshot shows the Sherpa software interface. The top menu bar includes File, Edit, Navigate, Visualization, Session, Analysis, and Help. The main window is divided into two panes. The left pane displays the FITS header information:

IMAGE	PRIMARY	NULL
TABLE	HISTOGRAM	14 cols, 2 rows
TABLE	GTI7	2 cols, 1 rows
TABLE	GTID	2 cols, 1 rows

The right pane displays the FITS header text:

```
COMMENT This FITS file may contain long string keyword va  
COMMENT continued over multiple keywords. The HEASARC co  
COMMENT character at the end of each substring which is t  
COMMENT on the next keyword which has the name CONTINUE.  
ORIGIN ASC / Source of FITS file  
CREATOR cxc - Version CIAO 2.0 / tool that created this o  
REVISION 1 /  
ASCDYSYR CIAO 2.1 Wednesday, February 28, / String A  
CHECKSUM 2nHX41LU21LU / HDU checksum updated 200  
DATASUM 3745954702 / data unit checksum updat
```

Below the header panes is a table with the following columns: AREA, EXPOSURE, COUNTS, ERR_COUNTS, COUNT_RATE, NET_COUNTS, and NET_ERR. The table has two data rows:

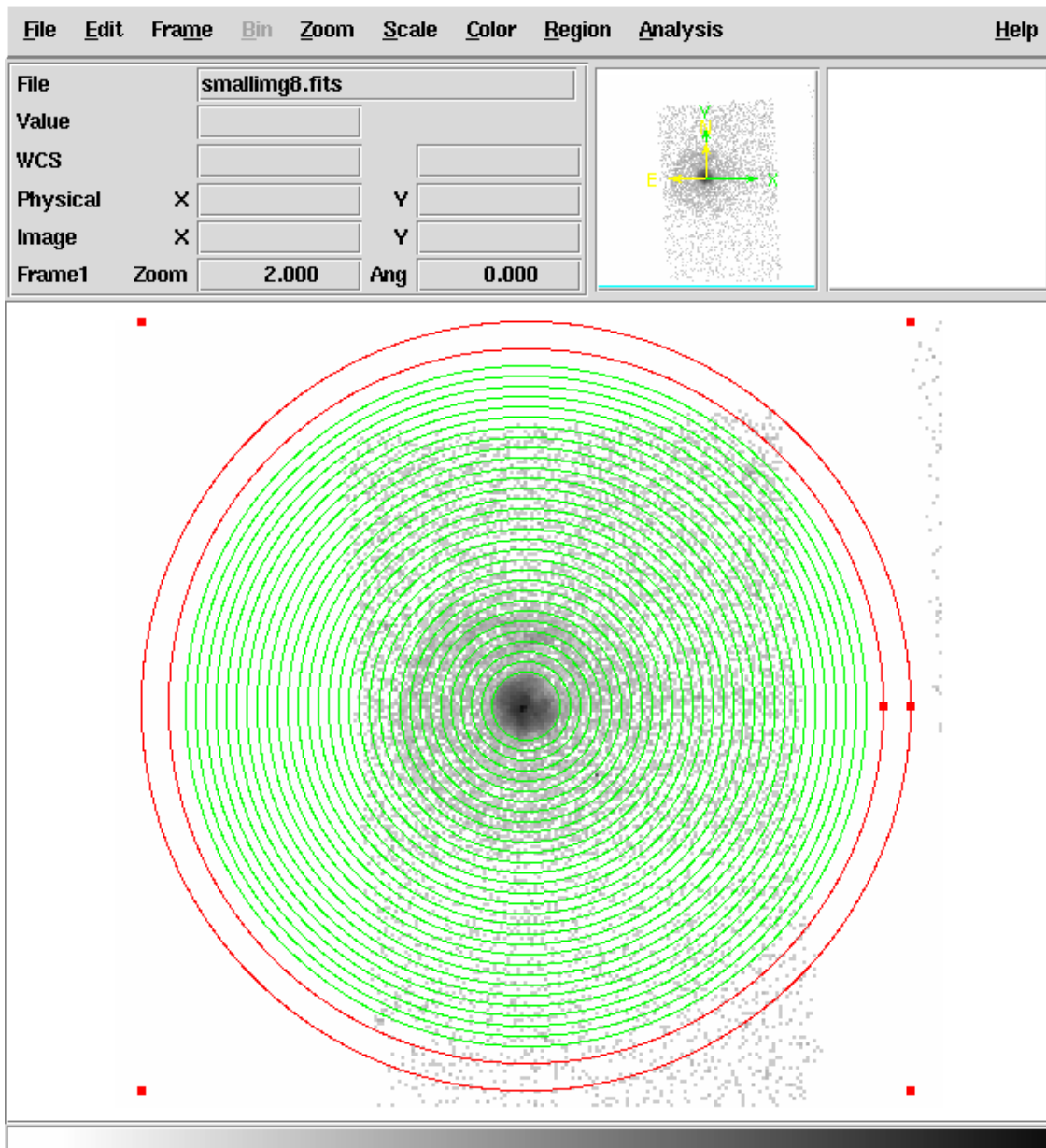
Units	pixel	s	count	count	count/s	count	count
1	80424.8	7854.47	327	19.1039	0.00700927	55.0541	3.21635
2	80424.8	7854.47	574	24.9739	0.00757972	59.5347	2.59027

At the bottom of the interface, there is a status bar showing "View Mode: Read/Write" and "Processing: 1 of 2". There are also buttons for "Goto", "Forward", and "Back". The bottom-most pane shows a log of recent events:

```
Thu 19-Apr 14:02:46 Starting sherpa ...  
Thu 19-Apr 13:45:28 Loading file /tmp/counts.fits  
Thu 19-Apr 13:44:54 Loading file /tmp/counts.fits
```

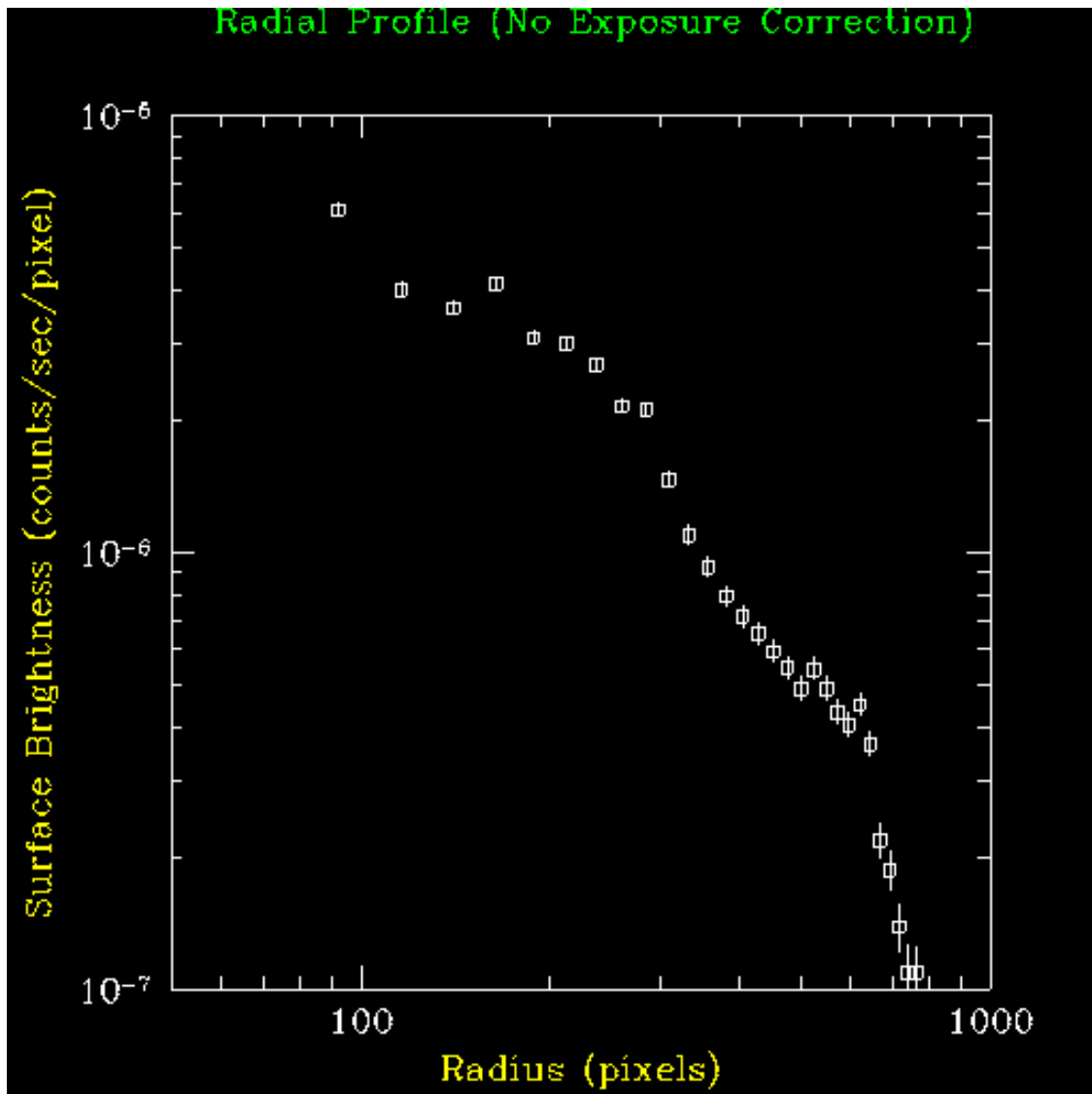
Edges (4)

Of course, what we're really interested in is something like:



Edges (5)

Without exposure corrections, the radial profile looks like:



Edges (6)

With exposure corrections for both source and background:

```
dmextract infile="smallimg8.fits[bin sky=@img8.reg]" \  
bkg="smallimg8.fits[bin sky=@img8_bgd.reg]" \  
exp=smallexp.fits bkgexp=smallexp.fits \  
outfile=counts.fits
```

