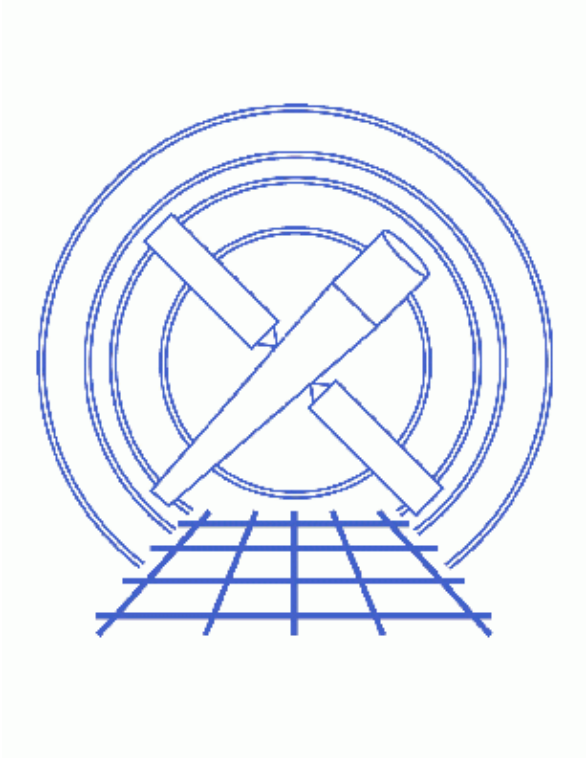
Estimate Source Counts in an Image



CIAO 3.4 Science Threads

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

Estimate Source Counts in an Image

CIAO 3.4 Science Threads

Overview

Last Update: 1 Dec 2006 − updated for CIAO 3.4: CIAO version in warning

Synopsis:

A quick means for estimating source counts, which may be useful as a first step in a more detailed analysis procedure. The thread is not intended to provide accurate photometric results, for which careful exposure and PSF corrections are necessary.

Purpose:

To estimate net source counts in user−defined regions of event lists or image files.

Read this thread if:

you would like to find the number of counts in an HRC or ACIS imaging observations; running this thread on LETG and HETG observations is *not* recommended.

Related Links:

- Analysis Guide: HRC Imaging

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

Getting Started

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

File types needed: evt2

There are essentially two steps required to estimate net counts:

1. Define source and background regions. The ds9 display tool is recommended for interactively creating these regions. Alternatively, a source list (e.g. the output of one of the detect tools or a list of objects from an astronomical catalog) may be used.
2. Use the CIAO tool `dmextract` to determine counts and number of pixels for each region and to compute net counts for the source regions that have associated background regions.

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

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

Estimating Source Counts

`dmextract` can be used to bin on vector columns, such as `sky`. This allows it to perform spatial extractions in regions in order to extract counts. Optional background files and background regions may also be input, in which case `dmextract` will compute net counts as well. Errors can be computed using either Gaussian or Poisson statistics or input via a variance map. For more details on all of these options, refer to `ahelp dmextract`.

A Simple Example

For another simple method of finding source counts, see the Using Analysis Scripts section of the SAOImage ds9 thread.

Display the file:

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

and create regions by left−clicking on the image. Then use the the ``Get Info..." option in the Region menu to find out the dimensions of the regions. More information on creating and modifying regions is given below. Consider a single source region `circle(4072.96,4248.00,20)` and background region `annulus(4072.96,4248.00,86,114)` as displayed in Figure 1.

To extract counts in the source region and compute net counts:

```
unix% punlearn dmextract
unix% pset dmextract infile="acis_1838_evt2.fits[bin sky=circle(4072.96,4248.00,20)]"
unix% pset dmextract outfile=1838_simple.fits
unix% pset dmextract bkg="acis_1838_evt2.fits[bin sky=annulus(4072.96,4248.00,86,114)]"
unix% dmextract
Input event file  (acis_1838_evt2.fits[bin sky=circle(4072.96,4248.00,20)]):
Enter output file name (1838_simple.fits):
```

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

The output may be examined using `dmlist`:

```
unix% dmlist "1838_simple.fits[HISTOGRAM]" cols,data

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

ColNo  Name                 Unit        Type            Range
   1   sky(X,Y)             pixel        Real8          −Inf:+Inf           Position
   2   EQPOS(RA,Dec)        deg          Real8          −360.0:      360.0  Position
   3   SHAPE                             String[16]                         Region shape type
   4   R[2]                 pixel        Real8(2)       −Inf:+Inf           Radius
   5   ROTANG[2]            pixel        Real8(2)       −Inf:+Inf           Angle
   6   COMPONENT                         Int2           −                   Component number
   7   AREA                 pixel**2     Real4          −Inf:+Inf           Area of extraction
   8   EXPOSURE             s            Real8          −Inf:+Inf           Exposure time of source fi
   9   COUNTS               count        Real8          −Inf:+Inf           Counts
  10   ERR_COUNTS           count        Real8          −Inf:+Inf           Error on counts
  11   COUNT_RATE           count/s      Real8          −Inf:+Inf           Rate
  12   COUNT_RATE_ERR       count/s      Real8          −Inf:+Inf           Rate Error
  13   BG_AREA              pixel**2     Real8          −Inf:+Inf           Background Area of Extract
```

```
  14   BG_EXPOSURE          s            Real8          −Inf:+Inf            Exposure time of ba
  15   BG_ERR               count        Real8          −Inf:+Inf            Error on Background
  16   BG_COUNTS            count        Real8          −Inf:+Inf            Background Counts
  17   BG_RATE              count/s      Real8          −Inf:+Inf            Background Rate
  18   BG_SUR_BRI           count/pixel**2 Real8          −Inf:+Inf              Background Counts
  19   BG_SUR_BRI_ERR       count/pixel**2 Real8          −Inf:+Inf              Error on backgrou
  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 sq
  25   SUR_BRI_ERR          count/pixel**2 Real8          −Inf:+Inf              Error on net coun

-------------------------------------------------------------------------------
World Coord Transforms for Columns in Table Block HISTOGRAM
-------------------------------------------------------------------------------

ColNo    Name
7:    CEL_AREA             = +0 [arcsec**2] +0.2421 * (AREA  −0)
18:   BG_CEL_BRI           = +0 [count/arcsec**2] +4.1311 * (BG_SUR_BRI  −0)
19:   BG_CEL_BRI_ERR       = +0 [count/arcsec**2] +4.1311 * (BG_SUR_BRI_ERR  −0)
24:   CEL_BRI              = +0 [count/arcsec**2] +4.1311 * (SUR_BRI  −0)
25:   CEL_BRI_ERR          = +0 [count/arcsec**2] +4.1311 * (SUR_BRI_ERR  −0)

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

ROW    sky(X,Y)                                EQPOS(RA,Dec)                          SHAPE

     1              (     4072.960,     4248.0) (      278.3893176799,
     −10.5692082869) Circle                    [       20.0
     0] [                    0                    0]          1
     1256.6370849609      7854.4664748687               7523.0
     86.7352292901     0.95779898279160                    0
     17592.917968750      7854.4664748687        24.9198715888
     621.0     0.07906329500380     0.03529829452414
     0.00141647176625      7478.6428551599        86.7534919622
     0.95215160432459     0.01104511582547         5.9513147787
     0.06903623408891
```

The counts information is given in the last section of the output.

Alternatively, `prism` may also be used to examine the output:

```
unix% prism 1838_simple.fits &
```

as shown in Figure 2  .

Regions vs. Stacks of Regions

Region descriptors may also be input via files, rather than typed on the command line:

```
unix% dmextract infile="acis_1838_evt2.fits[bin sky=region(source.reg)]" outfile=1838_simple_2.fi
  bkg="acis_1838_evt2.fits[bin sky=region(background.reg)]"
```

where

```
unix% cat source.reg
circle(4072.96,4248.00,20)

unix% cat background.reg
annulus(4072.96,4248.00,86,114)
```

However, if you want to extract counts from a number of source regions contained in a single file, then you must input the region file as a `stack`. If you have two region files:

```
unix% more stack.reg
circle(4072.96,4248.00,20)
circle(4244,4094,6)

unix% more stackbgd.reg
annulus(4072.96,4248.00,40,60)
annulus(4244,4094,10,30)
```

then to compute net counts in each region separately:

```
unix% dmextract infile="acis_1838_evt2.fits[bin sky=@stack.reg]" outfile=1838_stack.fits \
  bkg="acis_1838_evt2.fits[bin sky=@stackbgd.reg]"
```

Examine the output as before:

```
unix% dmlist "1838_stack.fits[cols counts,area,bg_counts,bg_area,net_counts,net_err]" data

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

ROW    COUNTS               AREA                 BG_COUNTS            BG_AREA               NET_COUNTS

     1               7523.0      1256.6370849609               5072.0      6283.1855468750      6508.59
     2                 94.0       113.0973358154                 32.0      2513.2741699219        92.56
```

If you use the `sky=region(stack.reg)` syntax:

```
unix% dmextract infile="acis_1838_evt2.fits[bin sky=region(stack.reg)]" outfile=1838_region.fits \
  bkg="acis_1838_evt2.fits[bin sky=region(stackbgd.reg)]"
```

`dmextract` will interpret the list of regions as a single, connected region. Using this syntax with `verbose` > 0 will print a warning:

```
# dmextract (CIAO 3.4): dsDMEXTRACTREGCOMPWERR -- WARNING:Region #1
contains more than 1 component. Only the first component will be
described in the region columns of the output file.
```

This returns a single row with the sum of the counts in all the individual regions:

```
unix% dmlist "1838_region.fits[cols counts,area,bg_counts,bg_area,net_counts,net_err]" data

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

ROW    COUNTS               AREA                 BG_COUNTS            BG_AREA               NET_COUNTS

     1               7617.0         1369.7343750               5104.0      8796.4589843750      6822.23
```

Exposure Corrections

Exposure maps may be applied to both source and background regions. In this case, in the calculation of the net counts from the source, the background counts are normalized not only by the ratio of the ***areas*** of the source and background regions, but also by the ratio of the ***mean exposures*** in the source and background regions (be sure to read the caveat at the end of this section). The following threads give complete instructions on generating exposure maps:

- Create an ACIS Exposure Map for a Single Chip

- Create an ACIS Exposure Map for Multiple Chips
- Create an HRC Exposure Map

Both normalized [cm^2*counts/photon] and unnormalized [cm^2*sec*counts/photon] exposure maps may be used as input to `dmextract`. Bin the data to a FITS image and generate exposure maps that are congruent to that image. To isolate the S3 chip in this dataset:

```
unix% dmcopy "acis_1838_evt2.fits[bin x=3696.5:4720.5:1,y=3872.5:4896.5:1]" 1838_s3.fits
```

Use `xygrid=3696.5:4720.5:#1024,3872.5:4896.5:#1024` in the `mkexpmap` step to create an ***unnormalized*** exposure map, `s3_expmap.fits`, then run `dmextract` and examine the results:

```
unix% dmextract infile="1838_s3.fits[bin sky=@stack.reg]" outfile=1838_stackexp.fits \
      bkg="1838_s3.fits[bin sky=@stackbgd.reg]" exp=s3_expmap.fits bkgexp=s3_expmap.fits

unix% dmlist "1838_stackexp.fits[cols counts,area,exposure,bg_counts,bg_area,net_counts]" data

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

ROW  COUNTS   AREA    EXPOSURE        BG_COUNTS   BG_AREA   NET_COUNTS

 1   7522.0  1252.0  7854.4664748687   5059.0      6272.0   6512.1358710676
 2     93.0   113.0  7854.4664748687     31.0      2516.0     91.6077107005
```

The `NET_COUNTS` are calculated as the counts in the source region [`COUNTS`] minus the counts in the background region [`BG_COUNTS`] (appropriately normalized by the areas [`AREA/BG_AREA`] and the mean exposure maps in source and background regions) and divided by the mean exposure map in the source regions.

Caveat on Exposure Corrections:
Normalizing counts by mean exposure in regions may lead to errors if there are large exposure variations in the region which are not accompanied by similar variations in counts. Consider a bright point source at the center of a large region whose exposure varies strongly near the boundaries. That loss of exposure is not reflected in the counts, which are concentrated near the point source, but would strongly affect the mean exposure. In cases such as this, it is better to flat field the image by the exposure map and than extract flat−fielded counts in the region. A variance map should also be computed and used to calculate errors in the region.

Defining Source and Background Regions

Source and background regions can easily be defined interactively for small numbers of regions. If the number of sources is large, however, it may be preferable to create a source list.

Interactive Definition

The event file may be viewed directly with ds9:

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

To create a region, left−click once on the image. The default region shape is circle; to select a different shape, use the "Region −> Shape" menus in ds9. The shape must be set *before* creating the region. Click again to make the region "active;" in Figure 3  , the circular region is active, but the rectangular one is not.

To change the size of the region, click and drag on the anchor points which appear when the image is active.

To save the region:

- Create the region(s) to save.
- Region −> File Format−> Ciao
- Region −> File Coordinate System −> Physical
- Region −> Save Regions... −> Save As "source.reg"

Using a Source List

The source lists output by the detect tools can also be used to define regions for estimating source counts. These regions can be read into ds9 using the "Load Regions..." option (if given a FITS file, ds9 automatically looks for a block named `REGION`.) The source regions are saved in the `SRCLIST` block in the DETECT tools output. Note that the source list must end in `.fits` to be recognized by ds9.

To display the region, either rename the block to `REGION`:

```
unix% dmcopy "s3_img_src.fits[srclist][region]" sources.fits
```

or specify the block name when reading it into ds9:

Region −> Load Regions... −> `s3_img.fits[srclist]`

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


#-------------------------------------------------------------------------
#
# DMEXTRACT -- extract columns or counts from an event list
#
#-------------------------------------------------------------------------
        infile = acis_1838_evt2.fits[bin sky=circle(4072.96,4248.00,20)] Input event file
       outfile = 1838_simple.fits      Enter output file name
          bkg = acis_1838_evt2.fits[bin sky=annulus(4072.96,4248.00,86,114)]) Background region file o
        error = gaussian)        Method for error determination(poisson|gaussian|<variance file>)
     bkgerror = gaussian)        Method for background error determination(poisson|gaussian|<variance
      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)
```

History

23 Dec 2004	reviewed for CIAO 3.2: no changes
19 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: CIAO version in warning

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

Image 1: Source and Background regions

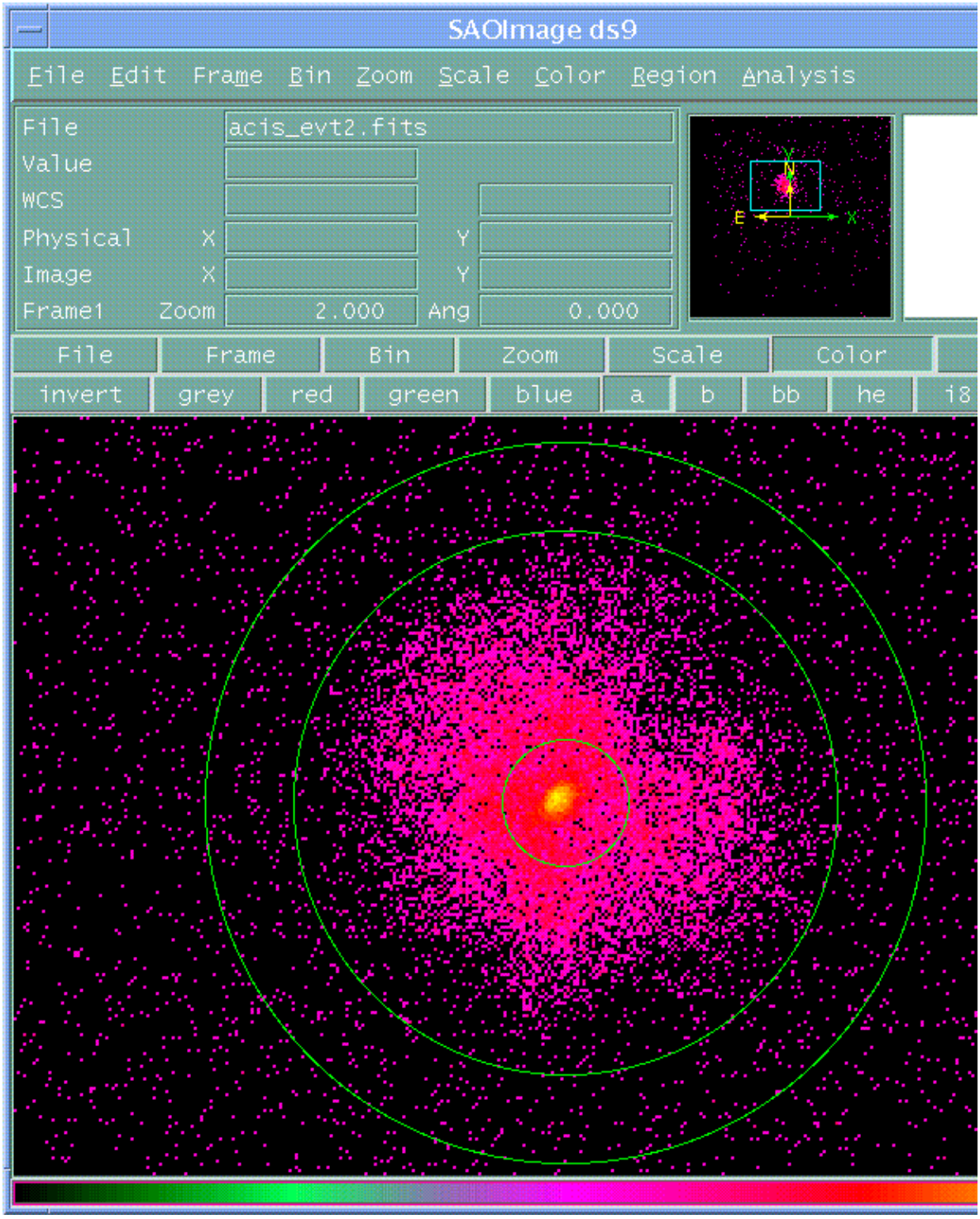


Image 2: Viewing dmextract output in prism

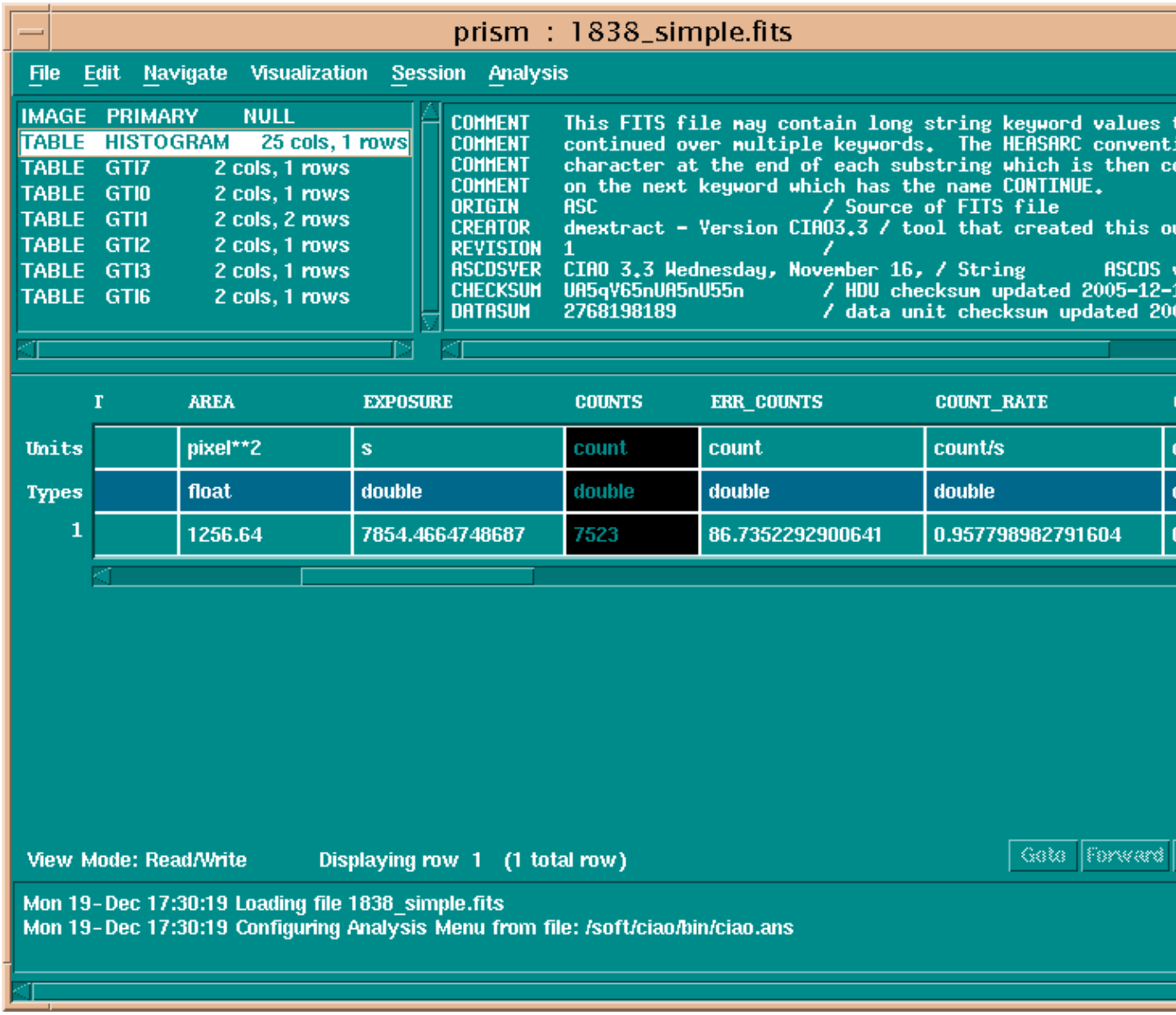
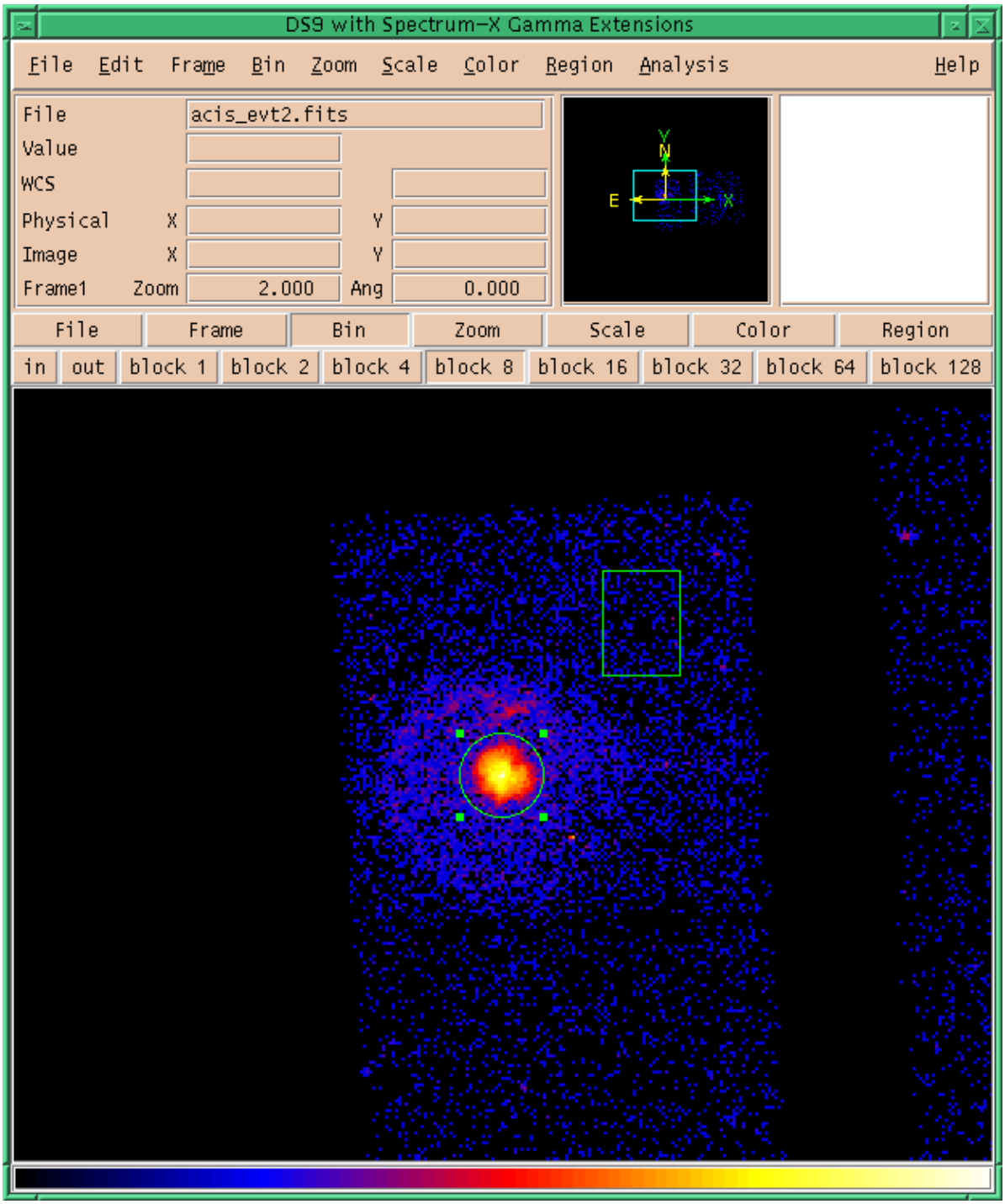


Image 3: Selecting regions in ds9



The circle is the currently−selected region (as indicated by the "handles" around the region).