Use merge_all Script to Compute ACIS Exposure Maps and Fluxed Images

CIAO 3.4 Science Threads

Table of Contents

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Overview

Last Update: 16 Apr 2007 – merge_all v3.6: "[subspace –expno]" filter was added to the dmmerge command in `merge_all` as a workaround for the extra GTIs in merged event files problem

Synopsis:

`mkexpmap` generates an exposure map which may be used to convert a counts image of a source to an image in flux units. The computed exposure map is essentially an image of the effective area at each sky position, accounting for the effects of dither motion which are especially important near the edges of the detector.

Purpose:

To create a wide variety of exposure maps using the script `merge_all`.

Read this thread if:

you are working with an ACIS imaging observation and would like to create an exposure map. If you are interested in having an accurate exposure map at the very edge of a CCD, subarray or window, this thread cannot be used. Instead, run one of the step–by–step exposure map threads that include the use of the mask file.

Calibration Updates:

- *CALDB v3.0.0* *(15 Dec 2004):* The ACIS QE degradation model has been enhanced to account for spatial variations in the contamination on the ACIS optical blocking filters. The contamination is now expressed as a function of time, energy, and ACIS chip coordinate. The ACIS QE Degradation why topic contains further details.
- *CALDB v2.26* *(2 Feb 2004):* The ACIS contamination files were added to the CALDB. The Correcting Responses for ACIS Contamination thread describes how this is taken into account in the data analysis.

Related Links:

- An Introduction to Exposure Maps (PS, 12pp): a general discussion of exposure maps.

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

Getting Started

Sample ObsIDs used: 1842 (ACIS–I, G21.5–09); 1843 (ACIS–I, G21.5–09)

File types needed: evt2; asol1

This thread uses the `merge_all` script; for information about the script, consult the help file ("<u>ahelp merge_all</u>"). The most recent version of `merge_all` is v3.6 (11 April 2007):

```
unix% egrep '(Version|Date)' `which merge_all`
# Version: 3.6
# Date:    11 April 2007
```

Please check that you are using the most recent version before continuing. If you do not have the script installed or need to update to a newer version, please refer to the <u>Scripts page</u>.

Also, make sure that you have set up ardlib to use the <u>bad pixel file</u> for your observation before following this thread. Note that `ardlib.par` will only accept the bad pixel file for a single observation. If you are merging two or more observations which do not have similar bad pixel files (e.g. Faint vs. Very Faint mode observations), you will have to create the merged exposure map manually. This can be accomplished by following the <u>Multiple Chip</u> example and using <u>dmregrid</u> to combine the final products.

We begin by restricting the <u>energy range</u> from 0.3 keV to 10 keV:

```
unix% dmcopy "acisf01842N001_evt2.fits[energy=300:10000]" 1842_evt2.fits
unix% dmcopy "acisf01843N001_evt2.fits[energy=300:10000]" 1843_evt2.fits
```

Caveat: extra GTIs in merged event files

When event files that have different ranges of exposure numbers (`expno` column) are merged, the output file will have more than one GTI block for each chip. This causes incorrect exposure values later in the analysis, as the CIAO tools cannot use multiple GTI blocks for a single chip. Further details are available on the <u>dmmerge bug page</u>.

A "[subspace –expno]" filter was added to the `dmmerge` command in `merge_all` v3.6 as a workaround for this problem.

Note that the addition of the subspace filter means that any user who intends to create lightcurves binned on exposure number from the merged output cannot use `merge_all`, since that information is eliminated from the subspace. (In general, lightcurves are binned on time.)

The ACIS dead area correction

There is a fractional area loss per unit time due to cosmic ray flux incident on the ACIS detector. Calibration to account for this ACIS "dead area" was included in CALDB 3.3.0 on 15 December 2006. The correction is non–zero for the 8 front–illuminated ACIS chips; the effect is not detectable for the BI chips, so the nominal calibration value is 0.0. The resulting chipy–dependent reduction in the EA will be approximately 2.2% at the readout, and 4.0% at the top of the chip. Refer to the <u>ACIS Dead Area Correction why topic</u> for technical details.

Since `merge_all` runs <u>mkinstmap</u> with a merged event file, it *is not* appropriate to try to apply the ACIS dead area correction while running this script. Users who wish to apply this calibration should use the

step−by−step exposure maps threads available from the Imaging threads page.

Create a Single−Chip, Single Observation Exposure Map and Fluxed Image

Sample ObsID used in this section: 1843, chip I3 (`ccd_id=3`) only

Since we are only creating an exposure map and fluxed image for a single observation, we do not need to set the parameters `refcoord` or `merged`.

The xygrid parameter is chosen so that the resulting exposure map includes the region of the I3 chip and is effectively binned by 2.

Finally, we choose to make the map monoenergetic with an energy of 1 keV (see the Create a Single Chip ACIS Exposure Map Step−by−Step thread for details). You may optionally input an ASCII spectral weights file here, see the Calculating Spectral Weights thread for more information.

Set the necessary parameters and run the script:

```
unix% punlearn merge_all
unix% pset merge_all evtfile=1843_evt2.fits
unix% pset merge_all asol=pcadf084271087N001_asol1.fits
unix% pset merge_all chip=3
unix% pset merge_all xygrid=2480.5:3680.5:#600,3940.5:5140.5:#600
unix% pset merge_all energy=1
unix% pset merge_all expmap=1843_I3_expmap.fits
unix% pset merge_all expcorr=1843_I3_expcorr.fits
unix% merge_all
Input event file(s) (1843_evt2.fits):
Input asol file(s); time-sorted (pcadf084271087N001_asol1.fits):
Input Live Time Correction list files for HRC-I ():
ACIS CCD ID(s), comma-separated or range; or 'HRC-I' or 'HRC-S' (3):
Reference coordinates or evt2 file for reproject_events ():
XY grid (e.g., 0.5:8192.5:#1024,0.5:8192.5:#1024) (2480.5:3680.5:#600,3940.5:5140.5:#600):
Energy or spectral weights file for mkinstmap (1):
Output merged event file ():
Output merged exposure map (1843_I3_expmap.fits):
Output exposure-corrected image (1843_I3_expcorr.fits):

Creating aspect histogram for CCD 3...

Making instrument map for CCD 3...
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere

Making exposure map for CCD 3...
Exposure map limits: 0.000000e+00, 3.039603e+06

Creating image

Normalizing image

All done!
```
The warning may be ignored as it does not adversely affect the output.

In some cases there will be more than one asol1.fits file for an observation. *All* the files must be input to the <u>asol</u> parameter, either as a list or as a stack (see <u>ahelp stack</u> for more information).

The output exposure map is shown in <u>Figure 1</u> and the output fluxed image is shown in <u>Figure 2</u>.

Check the parameter file that was used with <u>plist merge_all</u>.

Create a Multiple–Chip, Single Observation Exposure Map and Fluxed Image

Sample ObsID used in this section: 1843, all chips:

```
unix% dmkeypar 1843_evt2.fits DETNAM echo+
ACIS-012367
```

Since we are only using a single observation, the parameters refcoord and merged do not need to be set.

The xygrid parameter is chosen so that the resulting exposure map is effectively binned by 8.

Finally, we choose to make the map monoenergetic with an energy of 1 keV (see the <u>Create a Single Chip ACIS Exposure Map Step–by–Step</u> thread for details). You may optionally input an ASCII spectral weights file here, see the <u>Calculating Spectral Weights</u> thread for more information.

Set the necessary parameters and run the script:

```
unix% punlearn merge_all
unix% pset merge_all evtfile=1843_evt2.fits
unix% pset merge_all asol=pcadf084271087N001_asol1.fits
unix% pset merge_all chip=0,1,2,3,6,7
unix% pset merge_all xygrid=0.5:8192.5:#1024,0.5:8192.5:#1024
unix% pset merge_all energy=1
unix% pset merge_all expmap=1843_all_expmap.fits
unix% pset merge_all expcorr=1843_all_expcorr.fits
unix% merge_all
Input event file(s) (1843_evt2.fits):
Input asol file(s); time-sorted (pcadf084271087N001_asol1.fits):
Input Live Time Correction list files for HRC-I ():
ACIS CCD ID(s), comma-separated or range; or 'HRC-I' or 'HRC-S' (0,1,2,3,6,7):
Reference coordinates or evt2 file for reproject_events ():
XY grid (e.g., 0.5:8192.5:#1024,0.5:8192.5:#1024) (0.5:8192.5:#1024,0.5:8192.5:#1024):
Energy or spectrum file for mkinstmap (1):
Output merged event file ():
Output merged exposure map (1843_all_expmap.fits):
Output exposure-corrected image (1843_all_expcorr.fits):

Creating aspect histogram for CCD 0...
Creating aspect histogram for CCD 1...
Creating aspect histogram for CCD 2...
Creating aspect histogram for CCD 3...
Creating aspect histogram for CCD 6...
Creating aspect histogram for CCD 7...

Making instrument map for CCD 0...
```

```
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere
Making instrument map for CCD 1...
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere
Making instrument map for CCD 2...
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere
Making instrument map for CCD 3...
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere
Making instrument map for CCD 6...
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere
Making instrument map for CCD 7...
***ARDLIB warning: Filename 1843_evt2.fits does not specify an extension. Assuming the first "intere

Making exposure map for CCD 0...
Exposure map limits: 0.000000e+00, 3.115892e+06
Making exposure map for CCD 1...
Exposure map limits: 0.000000e+00, 3.154063e+06
Making exposure map for CCD 2...
Exposure map limits: 0.000000e+00, 3.070792e+06
Making exposure map for CCD 3...
Exposure map limits: 0.000000e+00, 3.037846e+06
Making exposure map for CCD 6...
Exposure map limits: 0.000000e+00, 2.560520e+06
Making exposure map for CCD 7...
Exposure map limits: 0.000000e+00, 3.584601e+06

Merging exposure maps

Creating image

Normalizing image

All done!
```

The warnings may be ignored as they do not adversely affect the output.

In some cases there will be more than one asol1.fits file for an observation. *All* the files must be input to the asol parameter, either as a list or as a stack (see ahelp stack for more information).

The output exposure map is shown in Figure 3 and the output fluxed image is shown in Figure 4.

Check the parameter file that was used with plist merge_all.

Create a Multiple–Chip, Multiple Observation Exposure Map and Fluxed Image

Sample ObsIDs used in this section: 1842, 1843, chips I0–I3 (ccd_id=0,1,2,3) for both

The script is now used to merge the two observations and to create an exposure map and fluxed image. The second observation (ObsID 1842) is reprojected to the coordinate system of the first. Instead, one could choose to reproject both file to a new new tangent point in R.A. and Dec. [degrees].

The xygrid parameter is chosen so that the resulting exposure map is effectively binned by 8.

Finally, we choose to make the map monoenergetic with an energy of 1 keV (see the Create a Single Chip ACIS Exposure Map Step–by–Step thread for details). You may optionally input an ASCII spectral weights file here, see the Calculating Spectral Weights thread for more information.

Note that it is also possible to use a combined evt2 file (which was created by `merge_all`) as the `evtfile` and leave `refcoord` and `merged` blank. The script will then produce an exposure map and image using the combined evt2 file. The evt2 file *must* have been produced by the script since `merge_all` uses a modified version of the header lookup table to merge the two event files; the tools used by the script need this modified header.

Set the necessary parameters and run the script:

```
unix% punlearn merge_all
unix% pset merge_all evtfile=1843_evt2.fits,1842_evt2.fits
unix% pset merge_all asol=pcadf084271087N001_asol1.fits,pcadf084280882N001_asol1.fits
unix% pset merge_all chip=0:3
unix% pset merge_all refcoord=1843_evt2.fits
unix% pset merge_all xygrid=0.5:8192.5:#1024,0.5:8192.5:#1024
unix% pset merge_all energy=1
unix% pset merge_all merged=merged_evt2.fits
unix% pset merge_all expmap=merged_expmap.fits
unix% pset merge_all expcorr=merged_expcorr.fits
unix% merge_all
Input event file(s) (1843_evt2.fits,1842_evt2.fits):
Input asol file(s); time-sorted (pcadf084271087N001_asol1.fits,pcadf084280882N001_asol1.fits):
Input Live Time Correction list files for HRC-I ():
ACIS CCD ID(s), comma-separated or range; or 'HRC-I' or 'HRC-S' (0:3):
Reference coordinates or evt2 file for reproject_events (1843_evt2.fits):
XY grid (e.g., 0.5:8192.5:#1024,0.5:8192.5:#1024) (0.5:8192.5:#1024,0.5:8192.5:#1024):
Energy or spectrum file for mkinstmap (1):
Output merged event file (merged_evt2.fits):
Output merged exposure map (merged_expmap.fits):
Output exposure-corrected image (merged_expcorr.fits):

Reprojecting 1842_evt2.fits to 1843_evt2.fits

Merging data...

SIM_Z of event file: -245.8572931324

SIM_Z of pcadf084271087N001_asol1.fits: -245.8572931324
Difference is 0 mm: SIM_Z differs by less than ~1/4 pixel.

SIM_Z of pcadf084280882N001_asol1.fits: -231.2390639692
Difference is 14.6182291632 mm: SIM_Z differs by more than ~1/4 pixel.
Modifying DZ in pcadf084280882N001_asol1.fits

Creating aspect histogram for CCD 0...
Creating aspect histogram for CCD 1...
Creating aspect histogram for CCD 2...
Creating aspect histogram for CCD 3...

Making instrument map for CCD 0...
***ARDLIB warning: Filename merged_evt2.fits does not specify an extension. Assuming the first "interestin
Making instrument map for CCD 1...
***ARDLIB warning: Filename merged_evt2.fits does not specify an extension. Assuming the first "interestin
Making instrument map for CCD 2...
***ARDLIB warning: Filename merged_evt2.fits does not specify an extension. Assuming the first "interestin
Making instrument map for CCD 3...
```

```
***ARDLIB warning: Filename merged_evt2.fits does not specify an extension. Assuming the first "inte

Making exposure map for CCD 0...
Exposure map limits: 0.000000e+00, 5.985148e+06
Making exposure map for CCD 1...
Exposure map limits: 0.000000e+00, 6.078366e+06
Making exposure map for CCD 2...
Exposure map limits: 0.000000e+00, 5.889566e+06
Making exposure map for CCD 3...
Exposure map limits: 0.000000e+00, 5.831895e+06

Merging exposure maps

Creating image

Normalizing image

All done!
```

The warnings may be ignored as they do not adversely affect the output.

In some cases, as shown here, there will be more than one asol1.fits file for an observation. *All* the files must be input to the asol parameter, either as a list or as a stack (see ahelp stack for more information).

The combined evt2 file is shown in Figure 5 📷, the exposure map is shown in Figure 6 📷, and the fluxed image is shown in Figure 7 📷. Note that for these observations, the SIM_Z value (position of the Scientific Instrument Module with respect to the aimpoint) differed significantly. This is the reason for the modification of DZ that the script made, but will not be the case for all of observations.

Check the parameter file that was used with plist merge_all.

Calculate the Source Flux

Since the units of the fluxed image are [$photon/cm^2/s/pixel$], adding up the pixel values around a source results in the source flux in [$photon/cm^2/s$]. Note that this flux is an *approximation* – as discussed in An Introduction to Exposure Maps (PS, 12pp) – since a spectral shape was assumed when using mkinstmap (in this thread, a monochromatic source).

The Create a Single Chip ACIS Exposure Map Step–by–Step thread shows how to approximate the source flux from the normalized image.

Analysis Caveats

Users should be cautious about analyzing the data for sources near the edges of the ACIS CCDs.

1. For X–rays passing through the mirrors, the very bottom of each CCD is obscured by the frame store. As a result, some of the events in rows with CHIPY <= 8 are not detected. (The set of rows affected varies from CCD to CCD.) Since the CIAO tools do not compensate for this effect, the ARFs and exposure maps for sources in these regions may be inaccurate.

2. For sources within about thirty–two pixels of any edge of a CCD, the source may be dithered off the CCD during part of an observation. The aspect histogram, which is used to create ARFs and exposure maps, is designed to compensate for this effect.

3. A contaminant has accumulated on the optical–blocking filters of the ACIS detectors, as described in the ACIS QE Degradation why topic. Since there is a gradient in the temperature across the filters (the edges are colder), there is a gradient in the amount of material on the filters. (The contaminant is thicker at the edges.) Within about 100 pixels of the outer edges of the ACIS–I and ACIS–S arrays, the gradient is relatively steep. Therefore, the effective low–energy (' 1 keV) detection efficiency may vary within the dither pattern in this region. The ARF and instrument map tools are designed to read a calibration file which describes this spatial dependence.

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


##
## Parameter file for merge_all script
##
       evtfile = 1843_evt2.fits   Input event file(s)
          asol = pcadf084271087N001_asol1.fits Input asol file(s); time-sorted
       dtffile =                   Input Live Time Correction list files for HRC-I
          chip = 3                 ACIS CCD ID(s), comma-separated or range; or 'HRC-I' or 'HRC-S'
      refcoord =                   Reference coordinates or evt2 file for reproject_events
        xygrid = 2480.5:3680.5:#600,3940.5:5140.5:#600 XY grid (e.g., 0.5:8192.5:#1024,0.5:8192.5:#1024)
        energy = 1                 Energy or spectral weights file for mkinstmap
        merged =                   Output merged event file
        expmap = 1843_I3_expmap.fits Output merged exposure map
       expcorr = 1843_I3_expcorr.fits Output exposure-corrected image
        (intdir = /tmp)            Directory for intermediate files
       (clobber = no)              OK to overwrite existing output file(s)?
          (mode = ql)
```

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


##
## Parameter file for merge_all script
##
       evtfile = 1843_evt2.fits   Input event file(s)
          asol = pcadf084271087N001_asol1.fits Input asol file(s); time-sorted
       dtffile =                   Input Live Time Correction list files for HRC-I
          chip = 0,1,2,3,6,7       ACIS CCD ID(s), comma-separated or range; or 'HRC-I' or 'HRC-S'
      refcoord =                   Reference coordinates or evt2 file for reproject_events
        xygrid = 0.5:8192.5:#1024,0.5:8192.5:#1024 XY grid (e.g., 0.5:8192.5:#1024,0.5:8192.5:#1024)
        energy = 1                 Energy or spectral weights file for mkinstmap
        merged =                   Output merged event file
        expmap = 1843_all_expmap.fits Output merged exposure map
       expcorr = 1843_all_expcorr.fits Output exposure-corrected image
        (intdir = /tmp)            Directory for intermediate files
       (clobber = no)              OK to overwrite existing output file(s)?
          (mode = ql)
```

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


##
## Parameter file for merge_all script
##
      evtfile = 1843_evt2.fits,1842_evt2.fits Input event file(s)
         asol = pcadf084271087N001_asol1.fits,pcadf084280882N001_asol1.fits Input asol file(s); tim
      dtffile =                     Input Live Time Correction list files for HRC-I
         chip = 0:3                ACIS CCD ID(s), comma-separated or range; or 'HRC-I' or 'HRC-S'
     refcoord = 1843_evt2.fits   Reference coordinates or evt2 file for reproject_events
       xygrid = 0.5:8192.5:#1024,0.5:8192.5:#1024 XY grid (e.g., 0.5:8192.5:#1024,0.5:8192.5:#1024)
       energy = 1                Energy or spectral weights file for mkinstmap
       merged = merged_evt2.fits Output merged event file
       expmap = merged_expmap.fits Output merged exposure map
      expcorr = merged_expcorr.fits Output exposure-corrected image
      (intdir = /tmp)            Directory for intermediate files
     (clobber = no)              OK to overwrite existing output file(s)?
        (mode = ql)
```

History

04 Jan 2005 updated for CIAO 3.2: added Caveats section

12 Jan 2005 usage warning added to Overview; replaced Create a Multiple–Chip, Multiple Observation
Exposure Map and Fluxed Image section with warning note

23 Jun 2005 CIAO 3.2.2 patch: bug fix to asphist means it is again possible to use the merge_all script
to create exposure maps for multiple observations; updated images

19 Dec 2005 updated for CIAO 3.3: the merge_all script has been updated to version 3.3 for the new
asphist tool syntax; corresponding changes to screen output

01 Dec 2006 updated for CIAO 3.4: version 3.4 of merge_all (removed "punlearn mkinstmap" to allow new
CIAO 3.4 mkinstmap parameters (pbkfile, dafile) to be set before running the script, if desired;
parameters supplied on the command line will not be prompted)

26 Feb 2007 merge_all v3.5: added a test to determine whether "energy" value is monochromatic or a spectrum
file; temporary filenames have a timestamp value as the root, rather than hardwired names.

03 Mar 2007 added Caveat: extra GTIs in merged event files; added ACIS dead area correction section

16 Apr 2007 merge_all v3.6: "[subspace –expno]" filter was added to the dmmerge command in merge_all
as a workaround for the extra GTIs in merged event files problem

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URL: http://cxc.harvard.edu/ciao/threads/merge_all/   Last modified: 16 Apr 2007

Image 1: Single chip, single observation exposure map

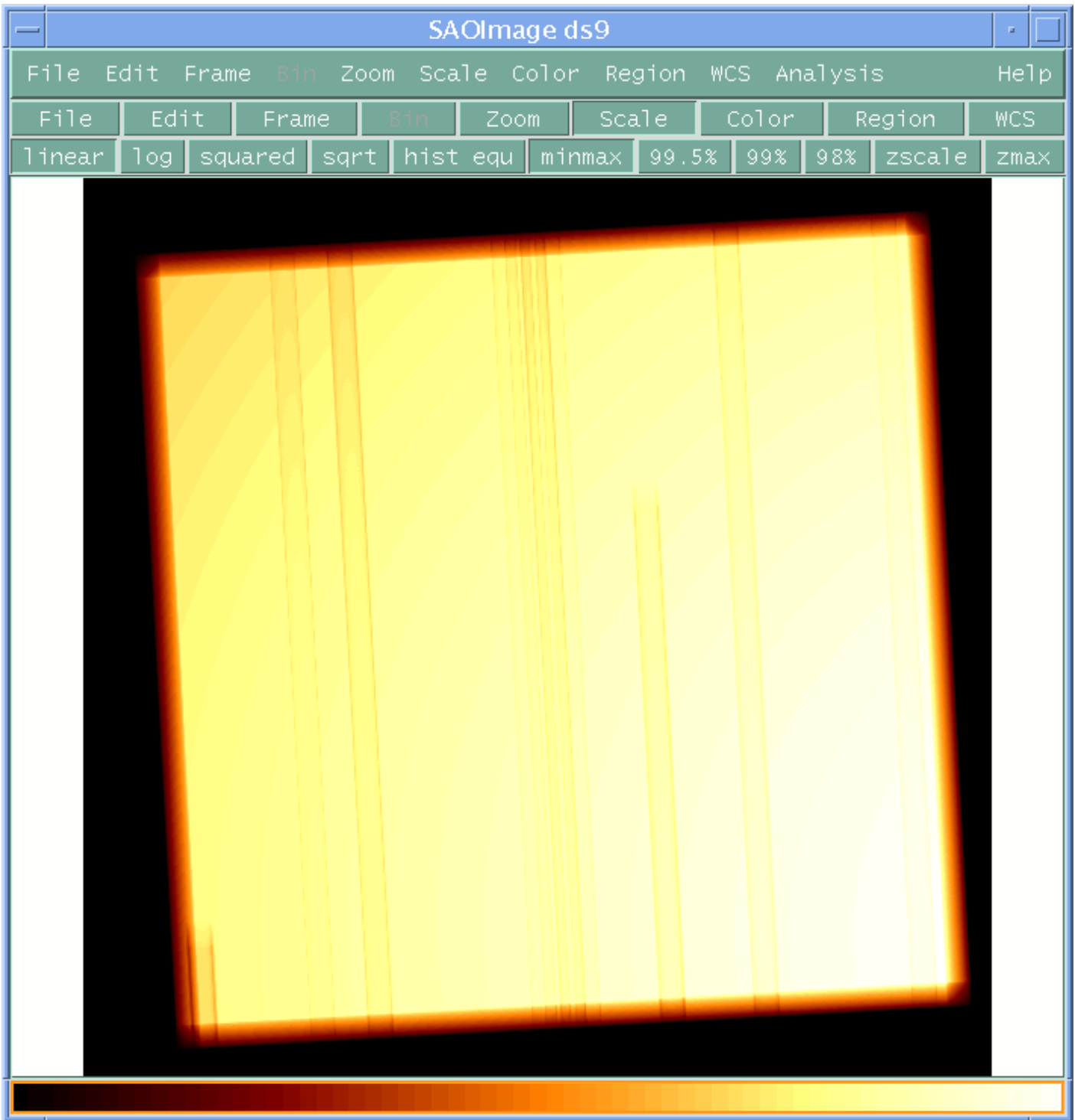Image 1: Single chip, single observation exposure map

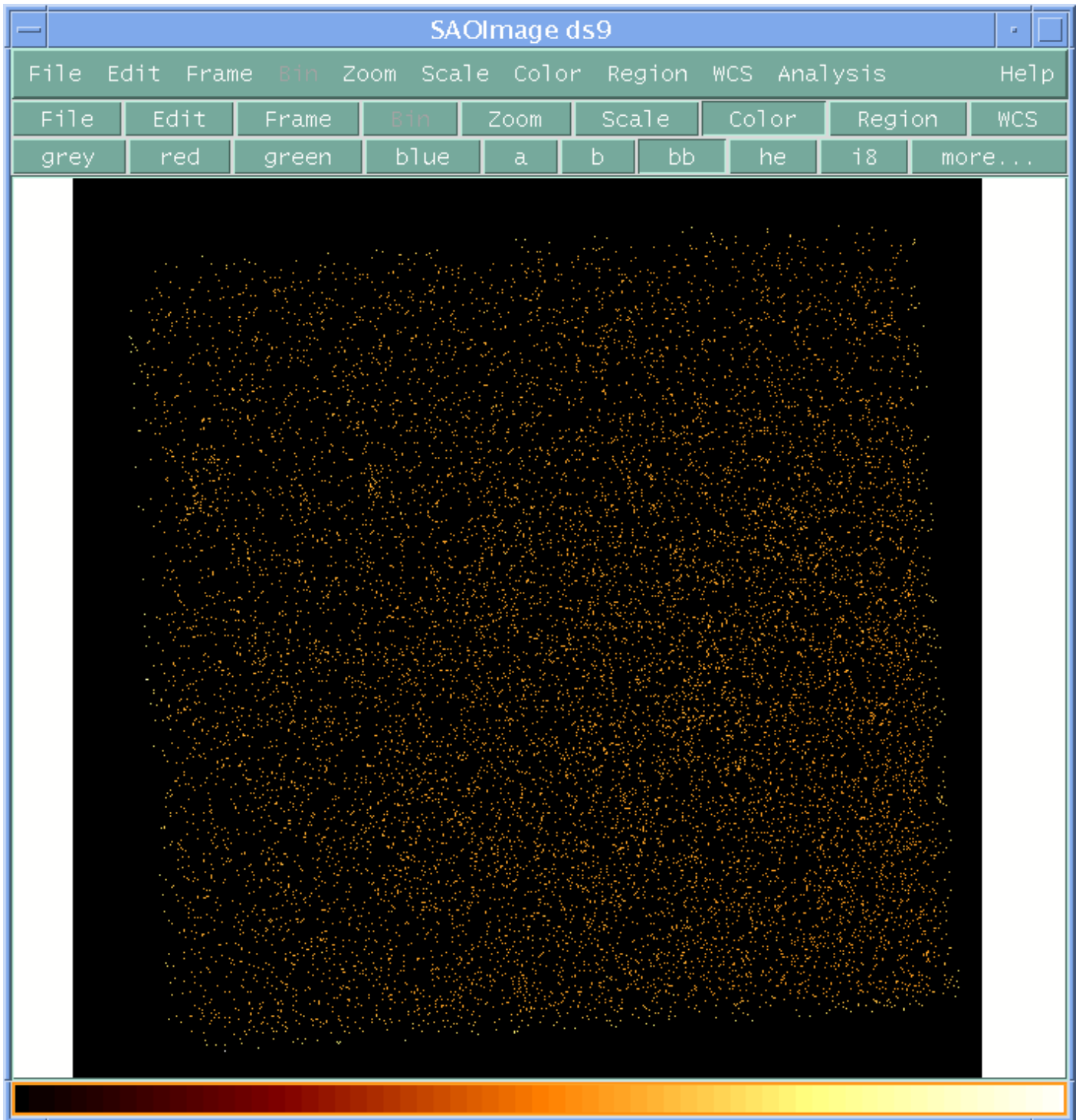# Image 2: Single chip, single observation fluxed image

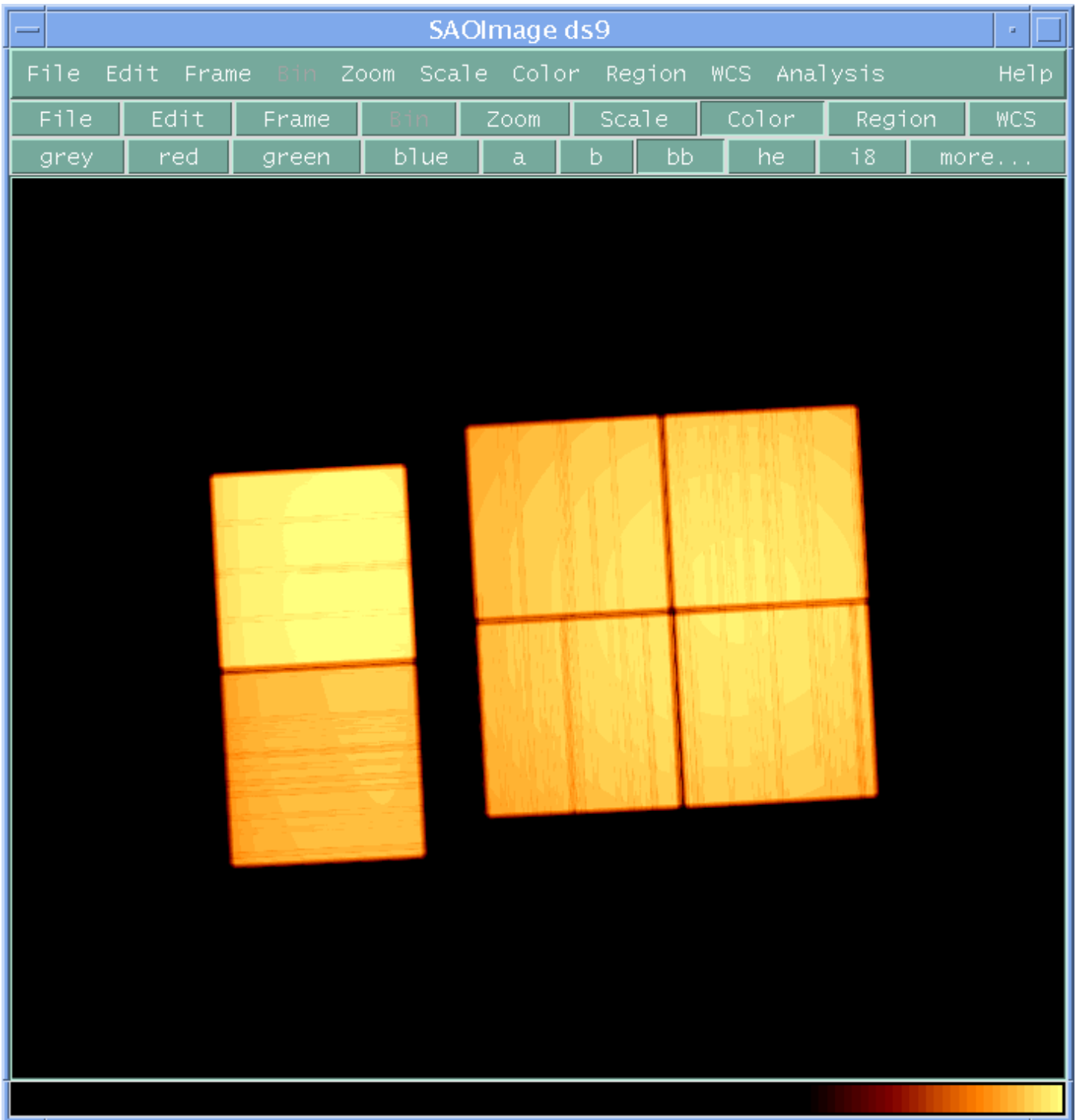## Image 3: Multiple chip, single observation exposure map

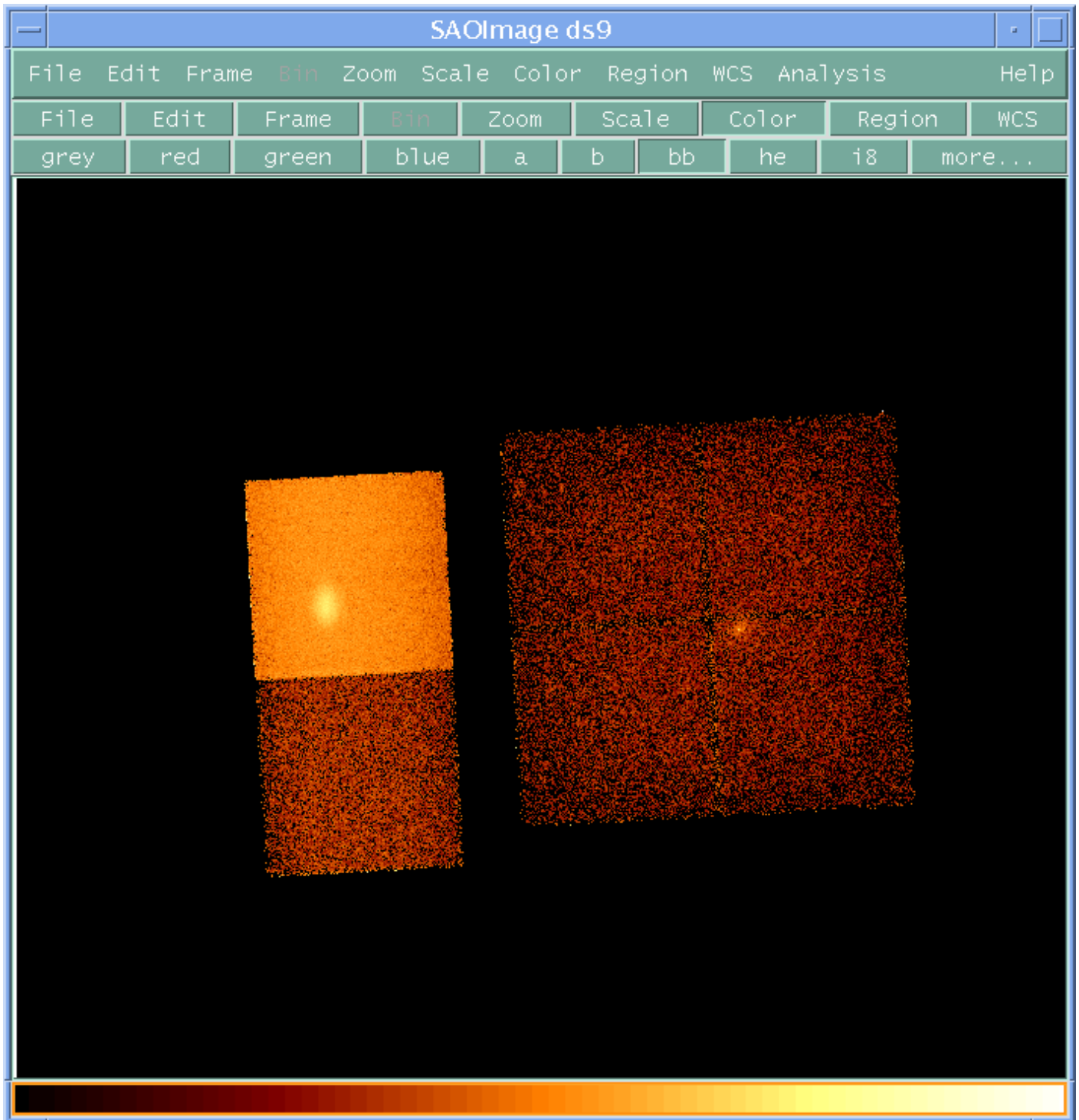**Image 4: Multiple chip, single observation fluxed image**

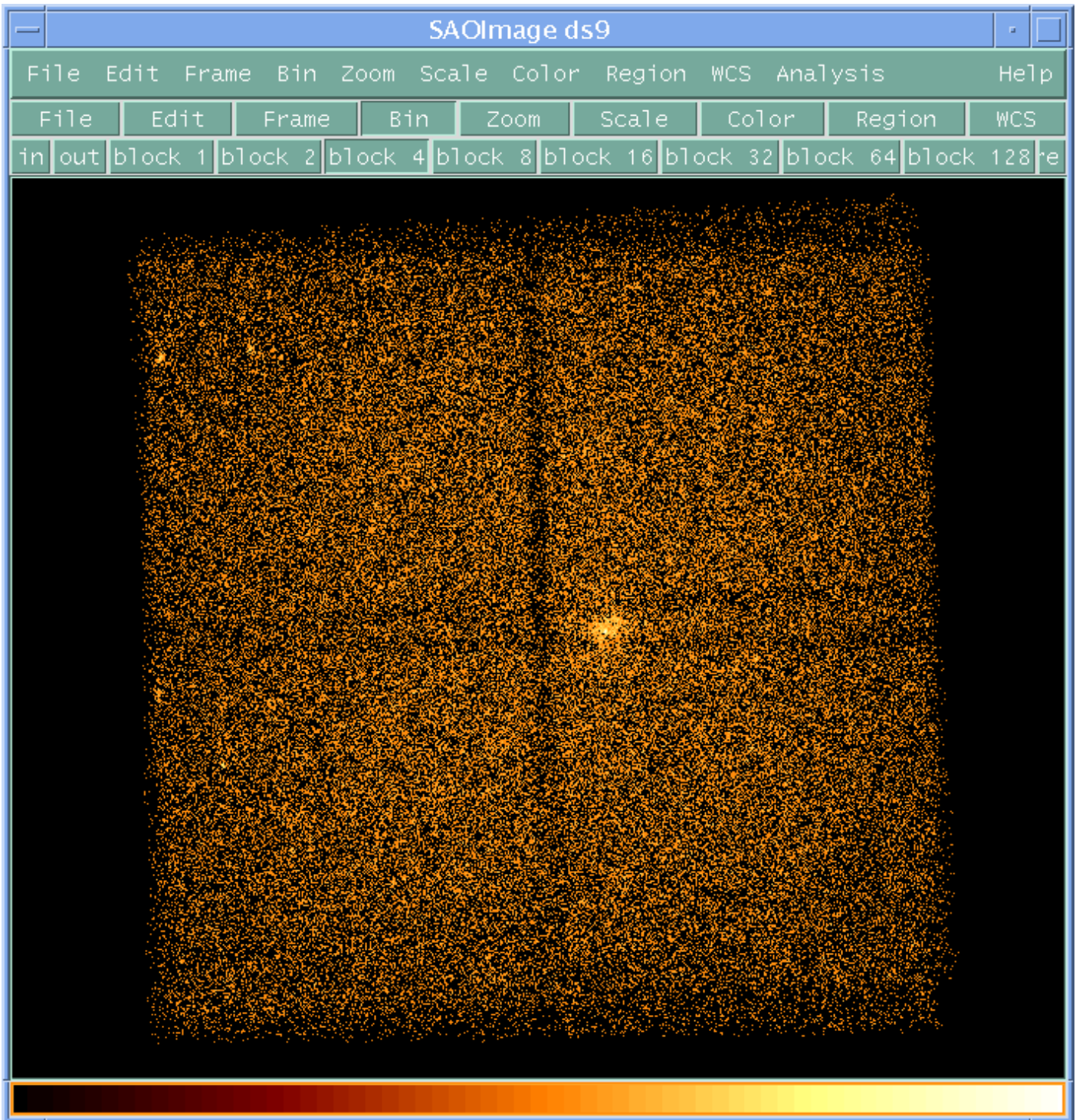## Image 5: Multiple chip, multiple observation event file
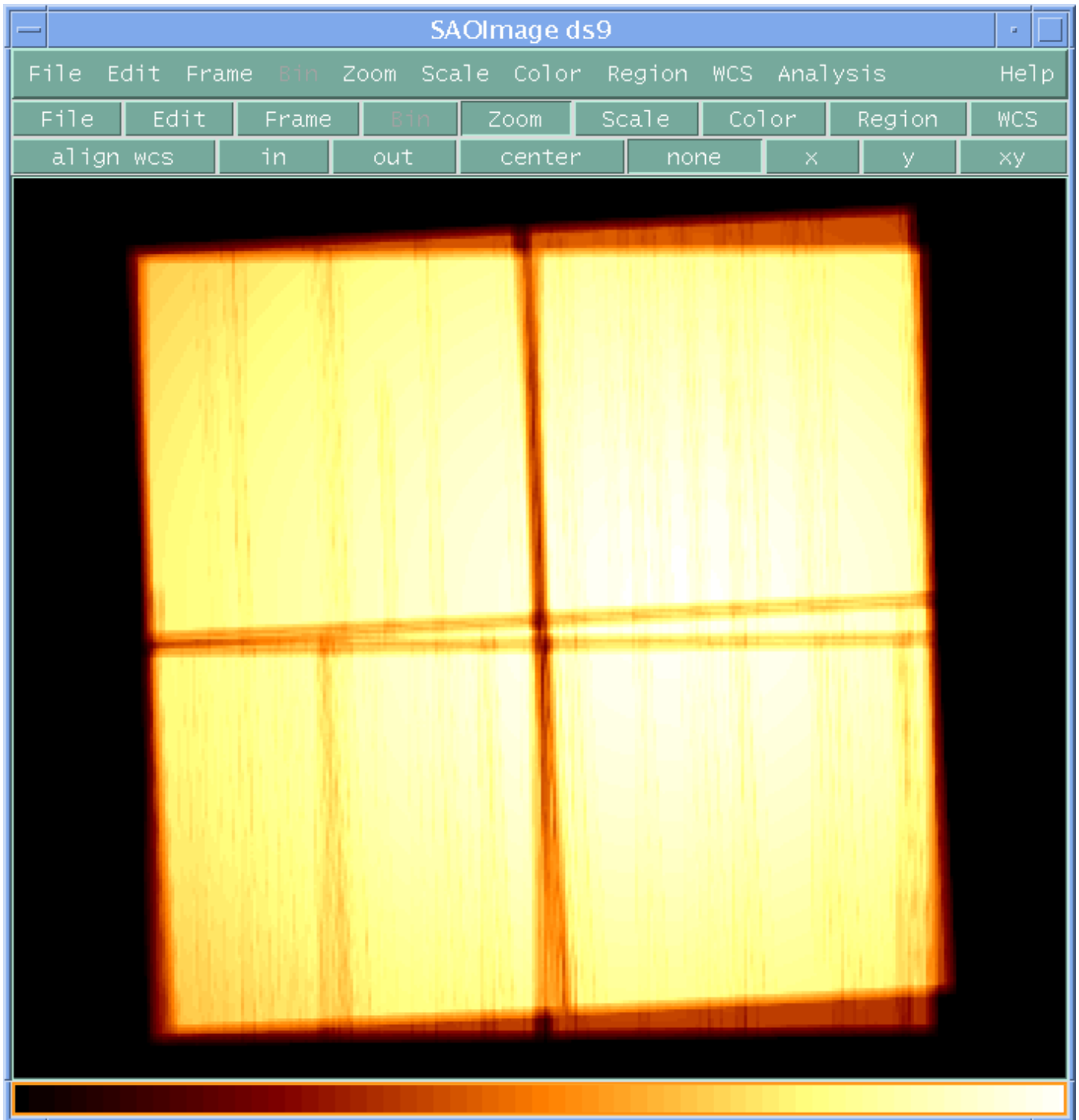
Image 6: Multiple chip, multiple observation exposure map

Image 7: Multiple chip, multiple observation fluxed image

Image 7: Multiple chip, multiple observation fluxed image