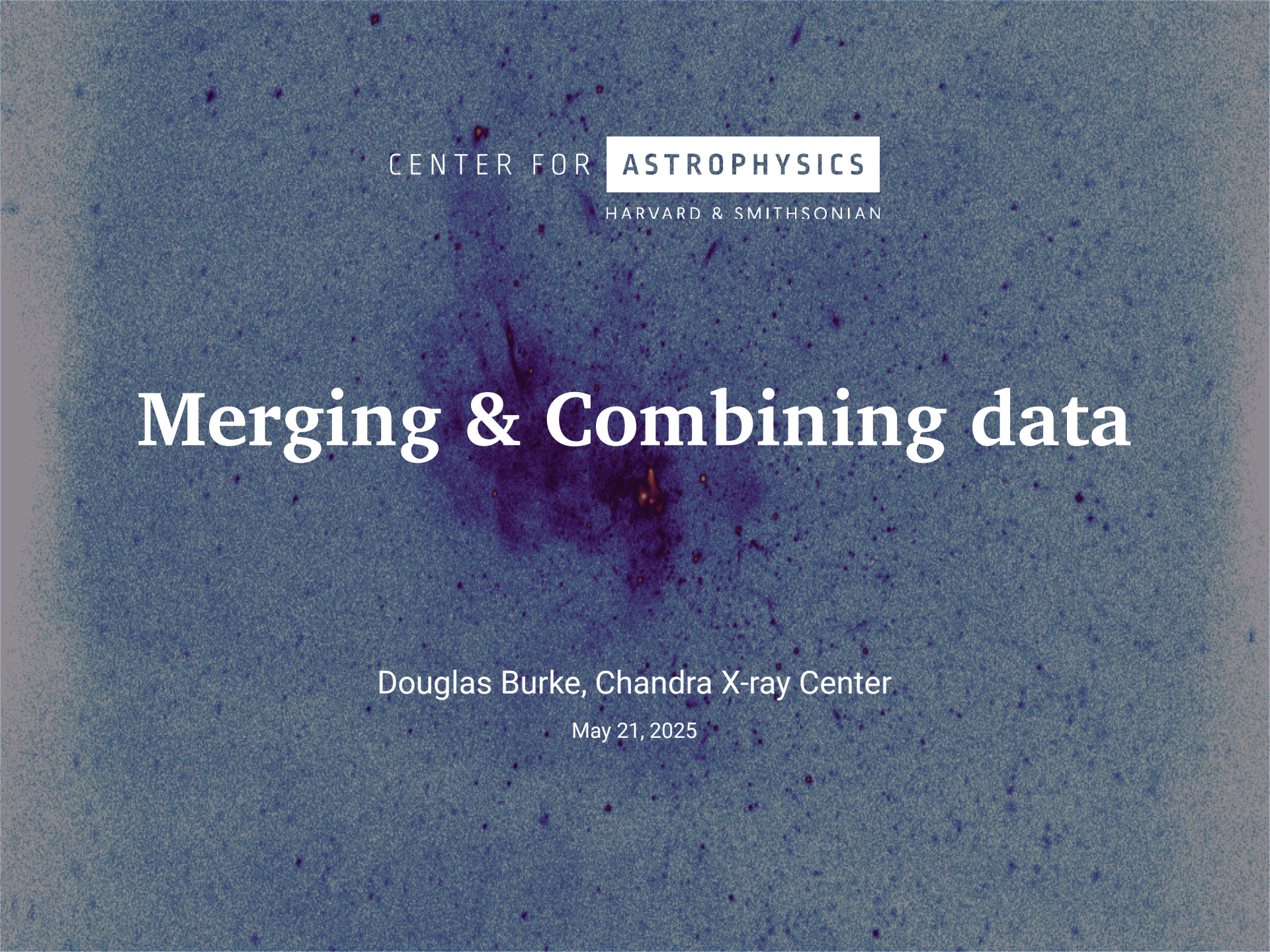

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Merging & Combining data

Douglas Burke, Chandra X-ray Center

May 21, 2025

Merging & Combining data

✔ Easy

✗ Limited
✗ Can go wrong

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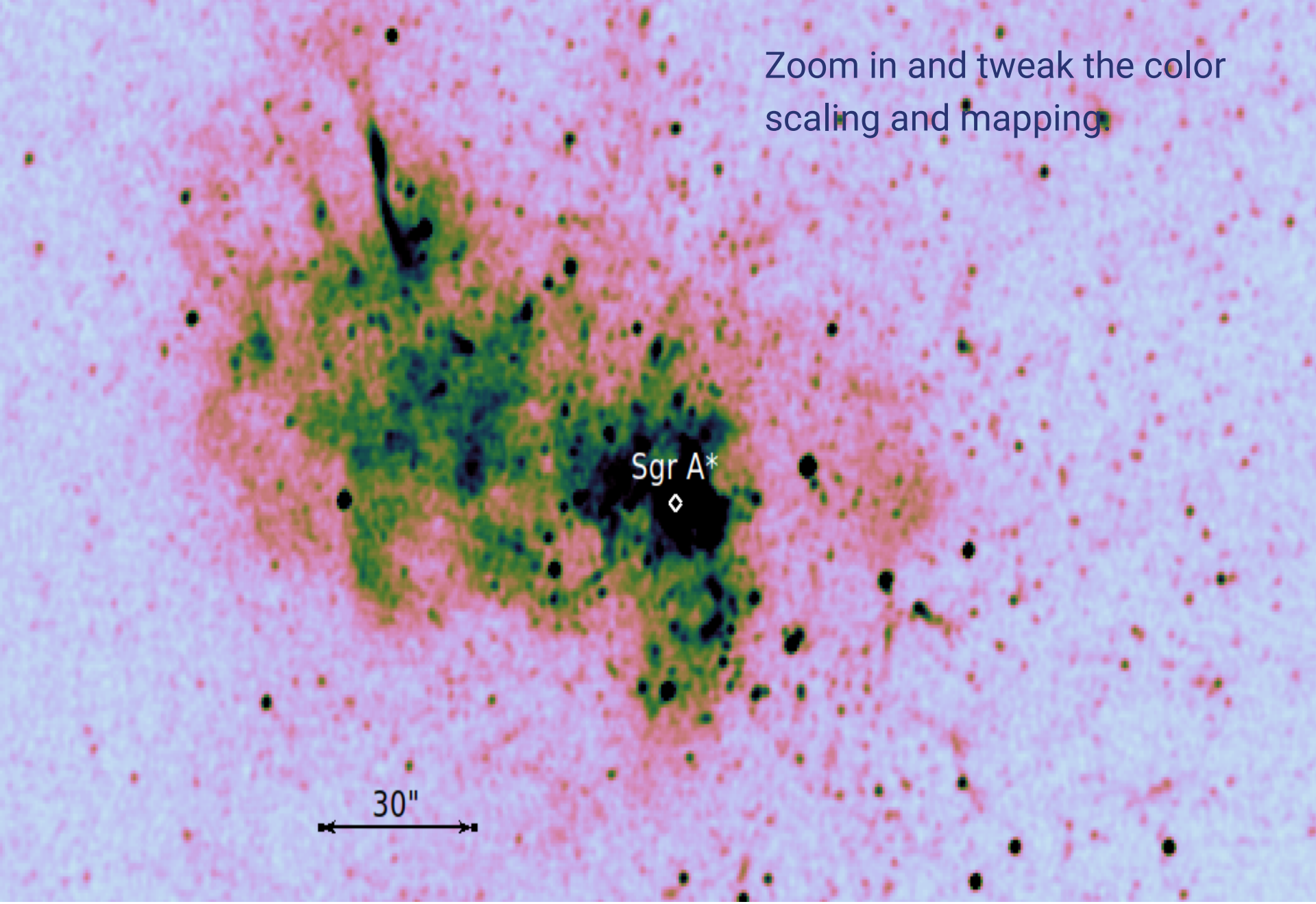
HARVARD & SMITHSONIAN

Merging & Combining data

- ✗ Aspect Correction
- ✗ Reprojection
- ✗ Order of operation matters

- ✔ It works™


A different view of the same
Chandra data.


Zoom in and tweak the color scaling and mapping.
Sgr A*
30"

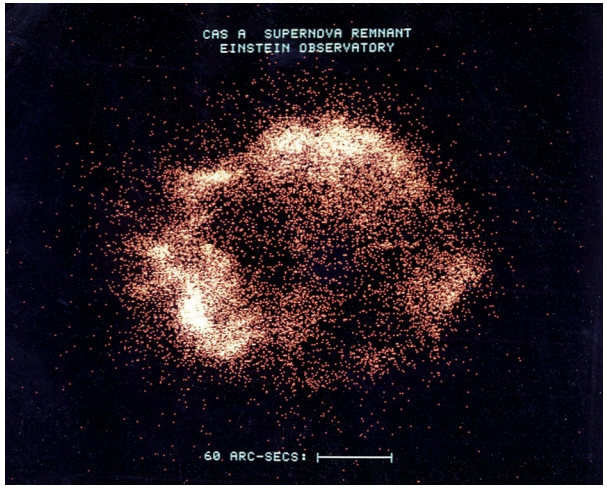
Pop Quiz

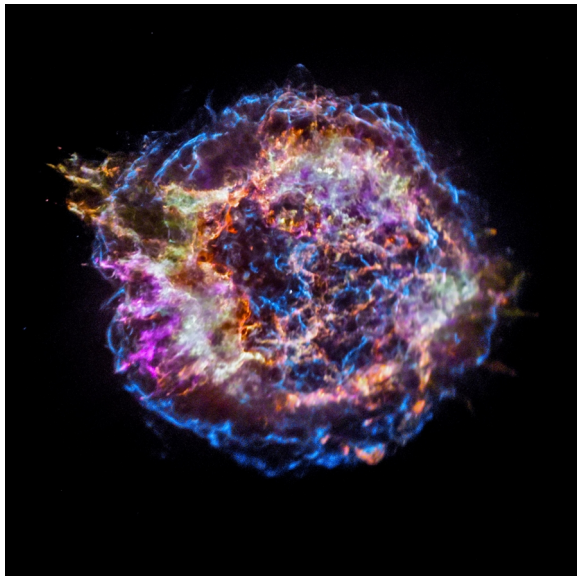
Pop Quiz

The Event File

- Time
- Position (may be 1D)
- Not-quite an energy
- Polarization state, if you are lucky
- Grade (Chandra) or Pattern (XMM, Suzaku)
- Aspect information
- “House Keeping” (HK) data

Chandra's "first-light" target

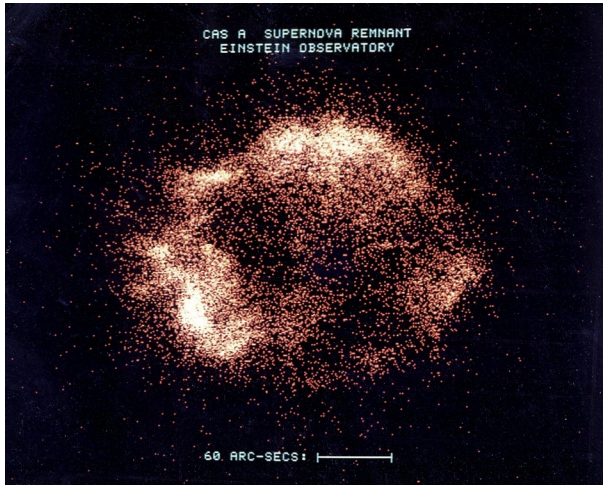


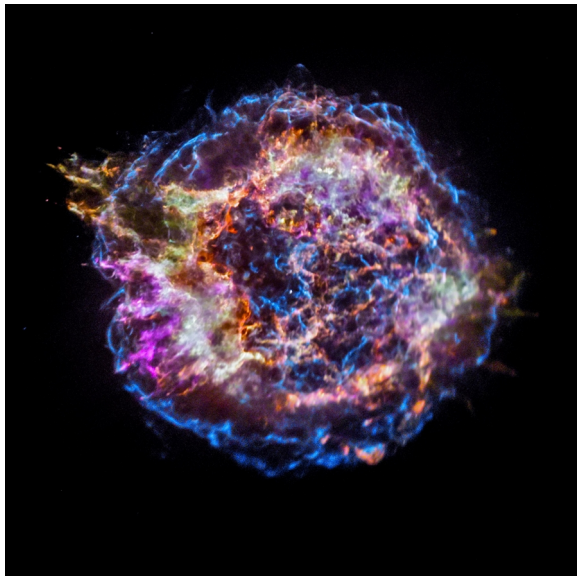


Combining Data

https://astrodon.social/@kellylepo/114467936548251061

Chandra's "first-light" target





Combining Data

"All models are wrong, but some are useful"

https://en.wikipedia.org/wiki/All_models_are_wrong

If your model is "good enough" you generally want to combine the data.

Sometimes you have to throw out data!

https://astrodon.social/@kellylepo/114467936548251061

The One

The Many

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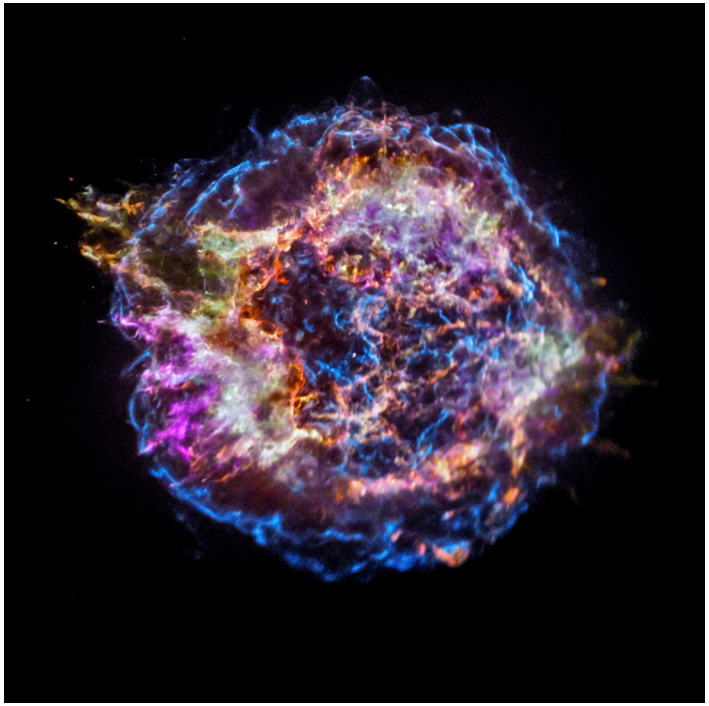
HARVARD & SMITHSONIAN

The One

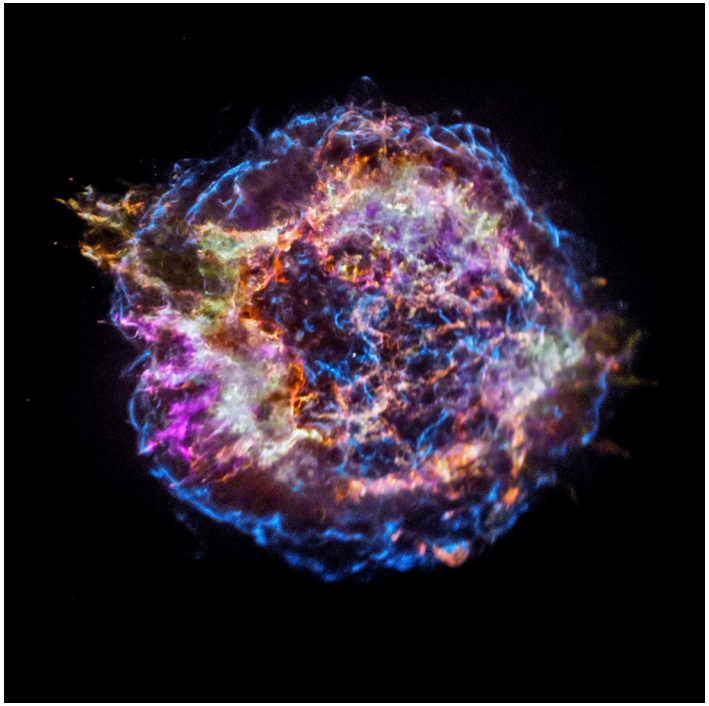
The Many

CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN



Pop Quiz

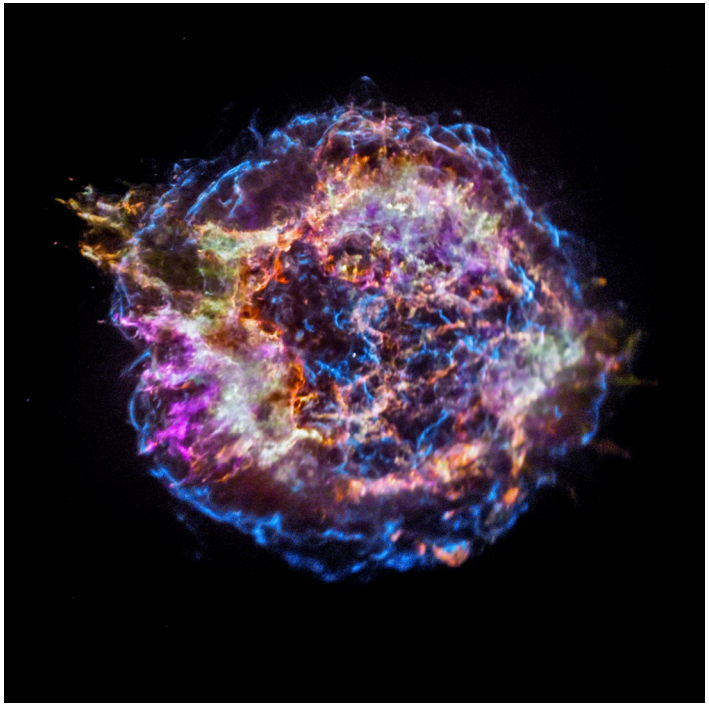
What do the colors mean?



Pop Quiz

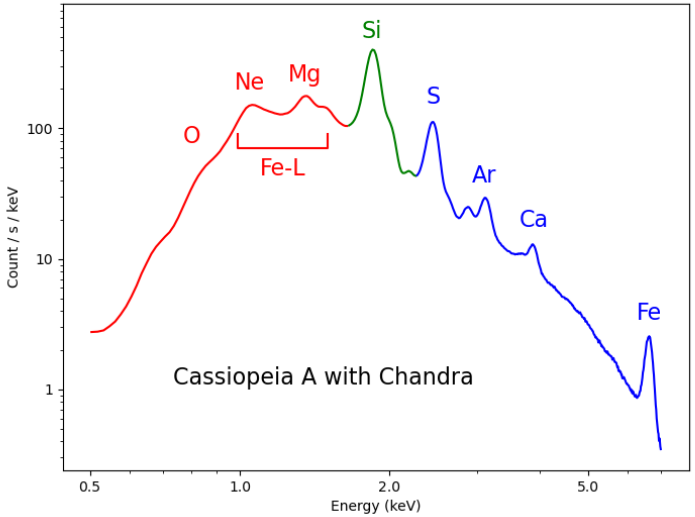
What do the colors mean?

- Not-quite an energy



Pop Quiz

What do the colors mean?



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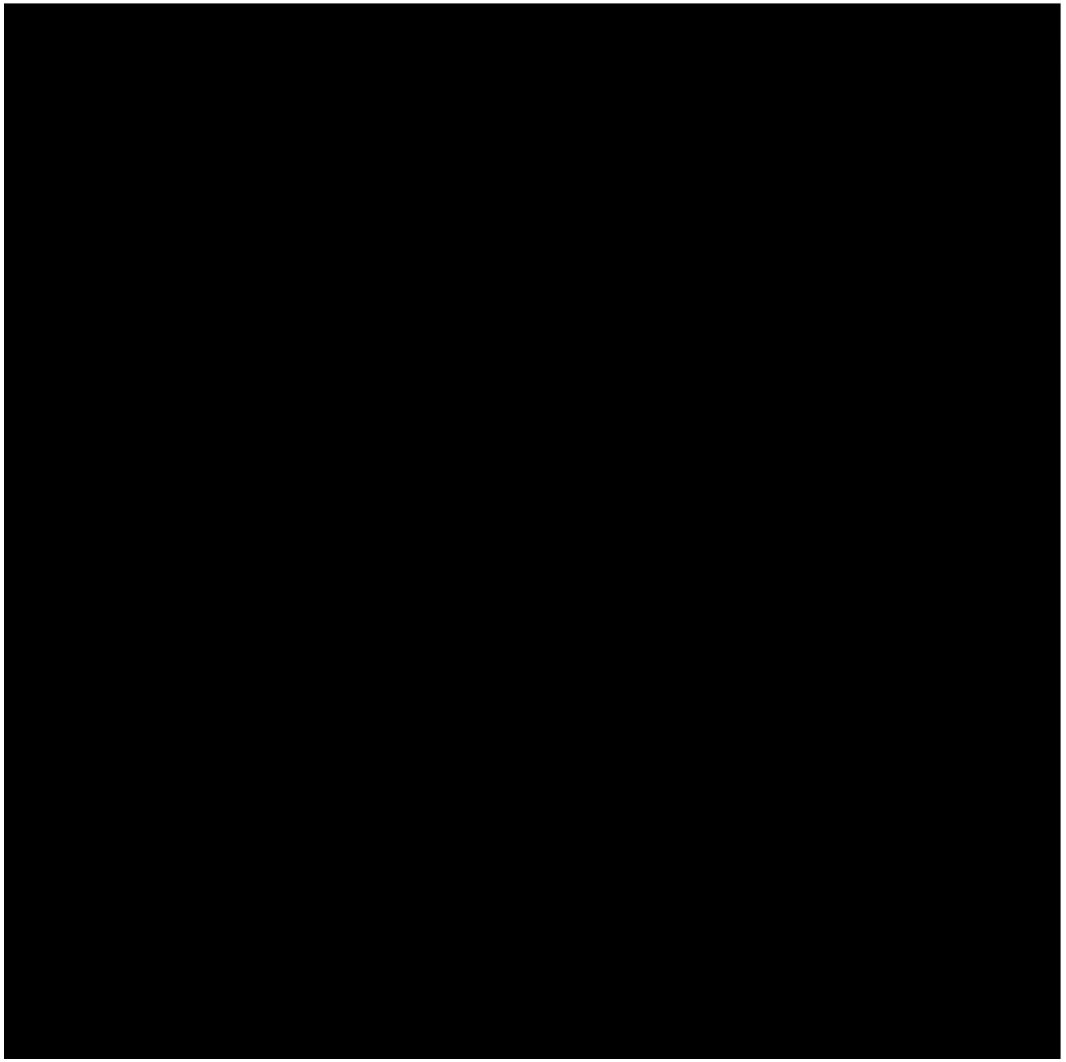
HARVARD & SMITHSONIAN

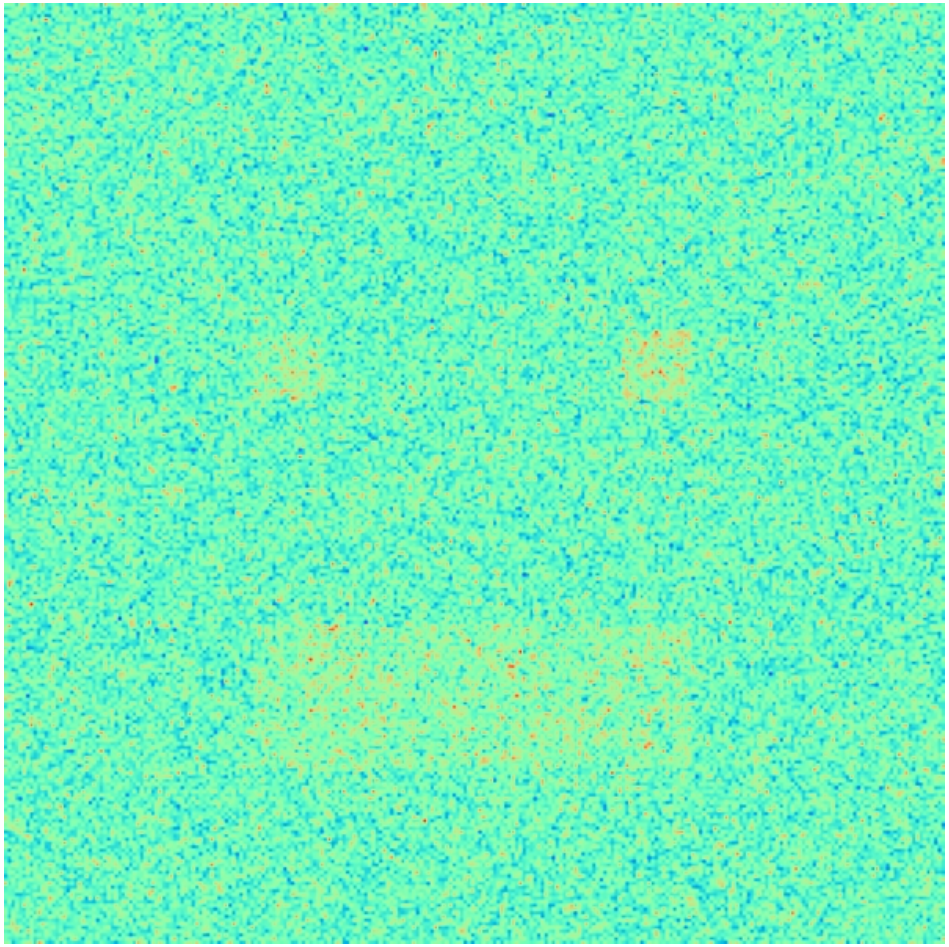
Chandra's Actual First Light



https://www.youtube.com/watch?v=mOsxktrF2d0

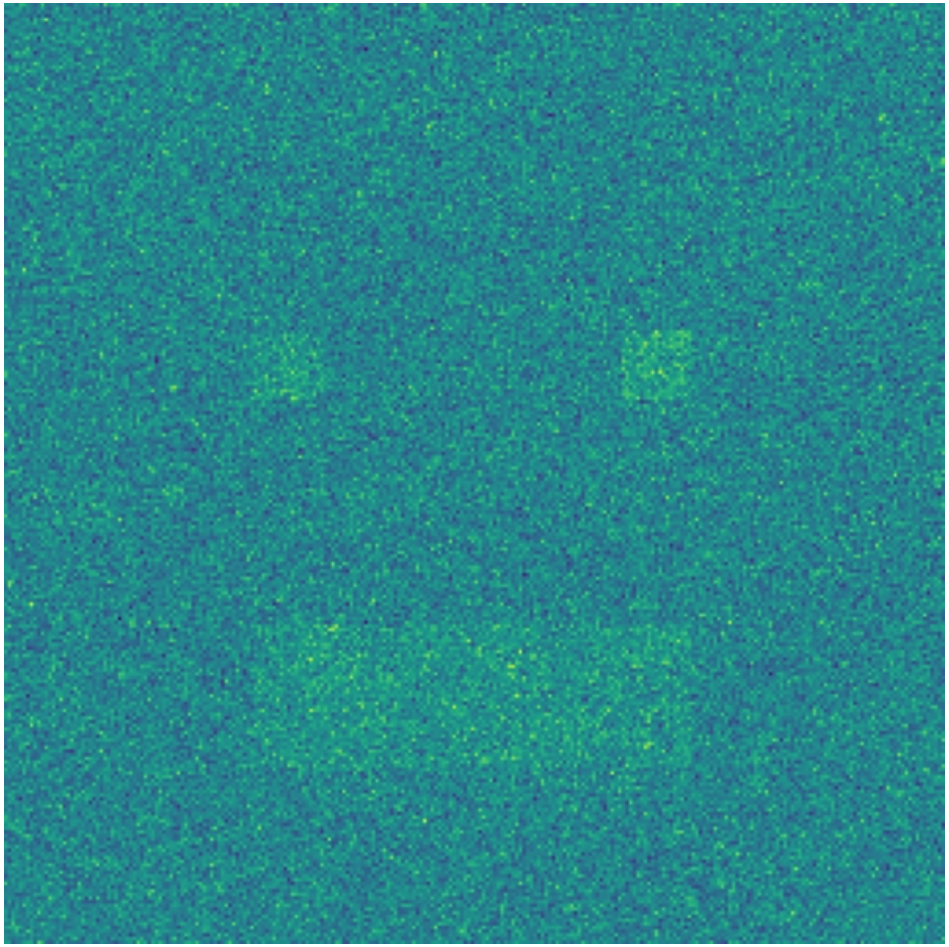
Why Combine?

Colormap: rainbow



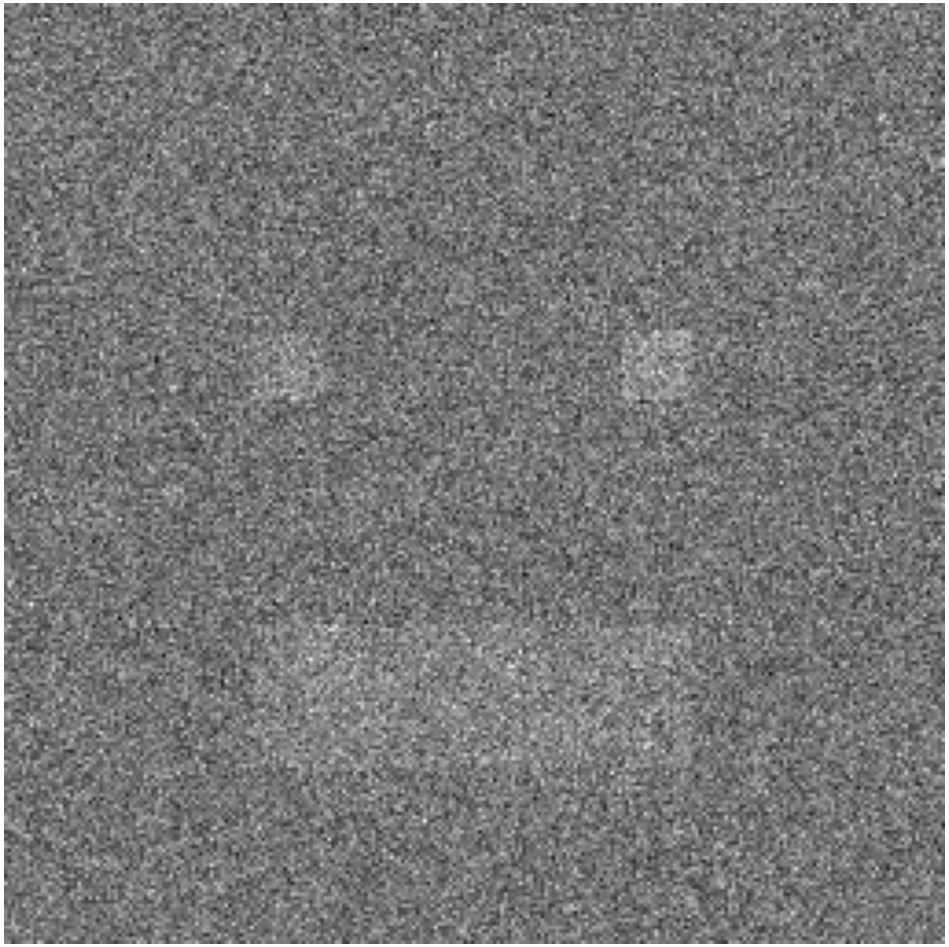
Why Combine?

Colormap: viridis

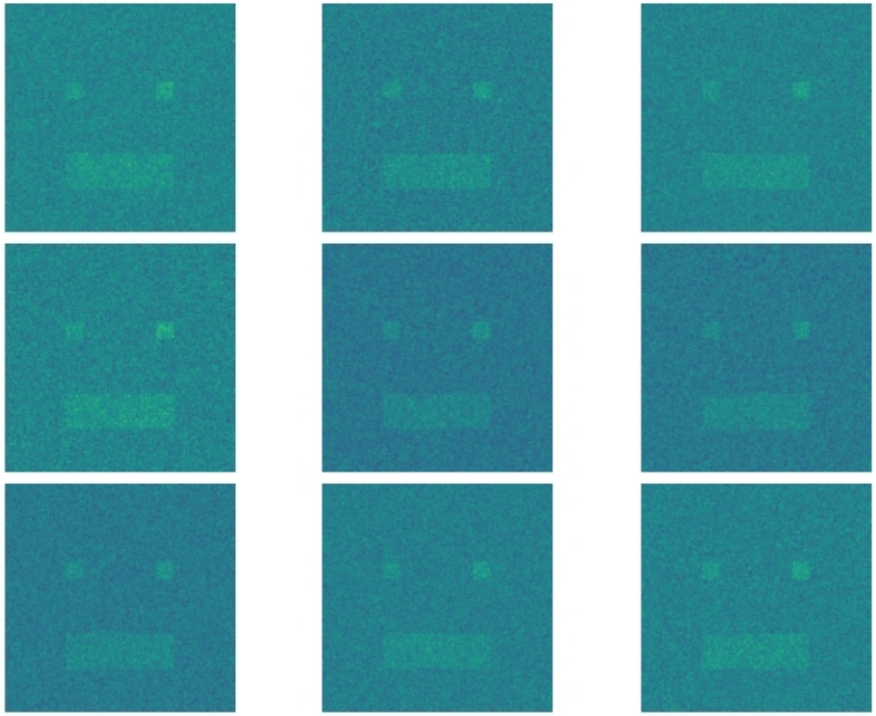


Why Combine?

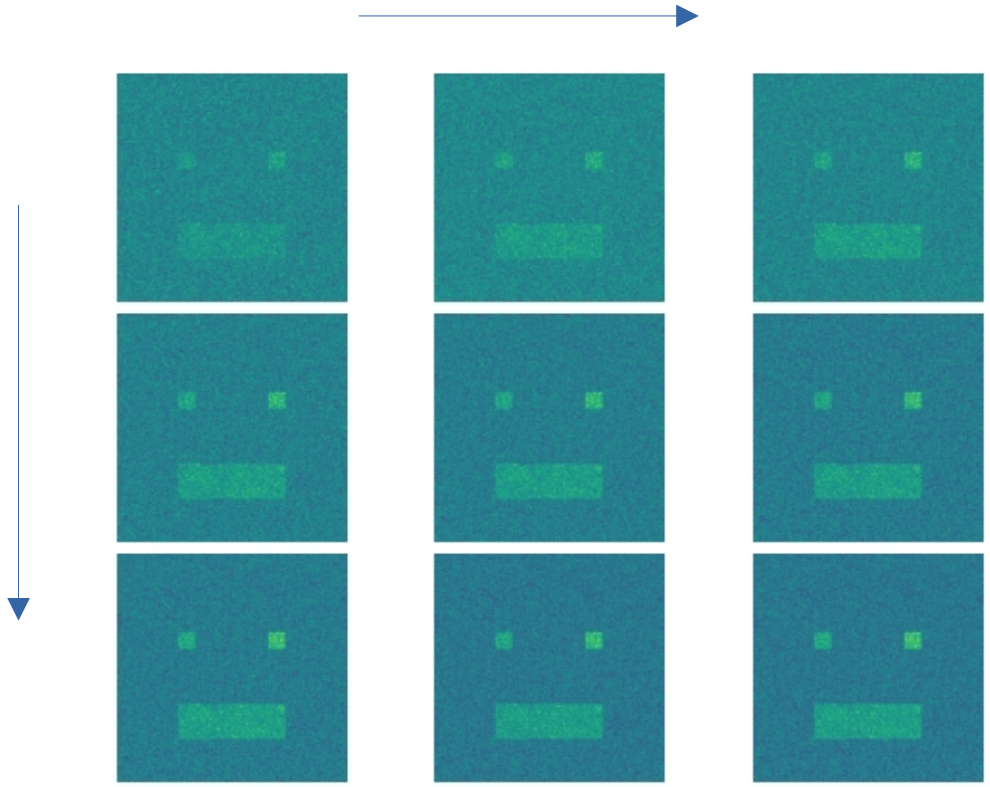
Colormap: gray



Individual

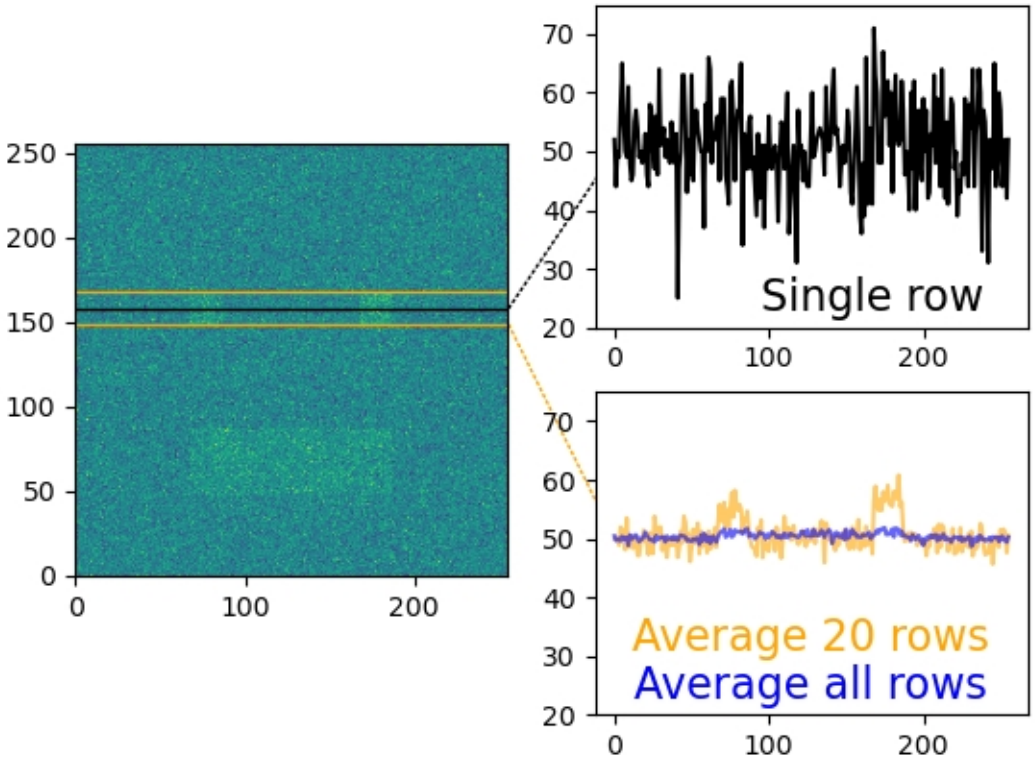


Add

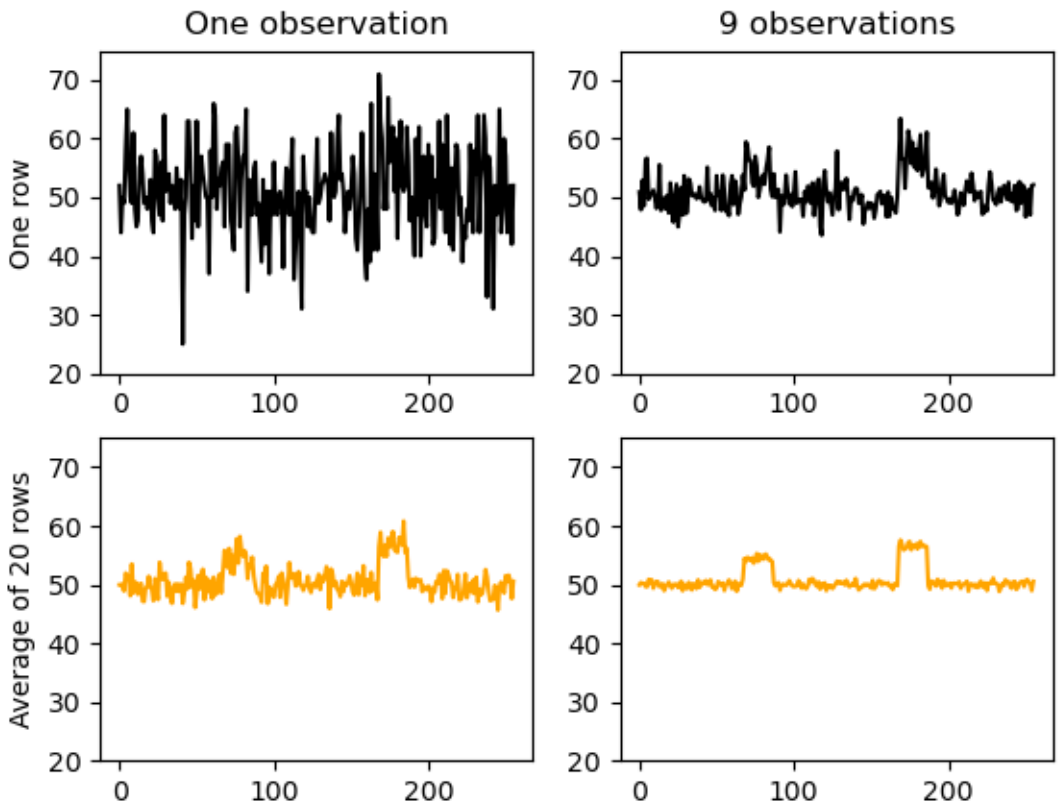



Noise
Signal
imgflip.com
JAKE-CLARK.TUMBLR

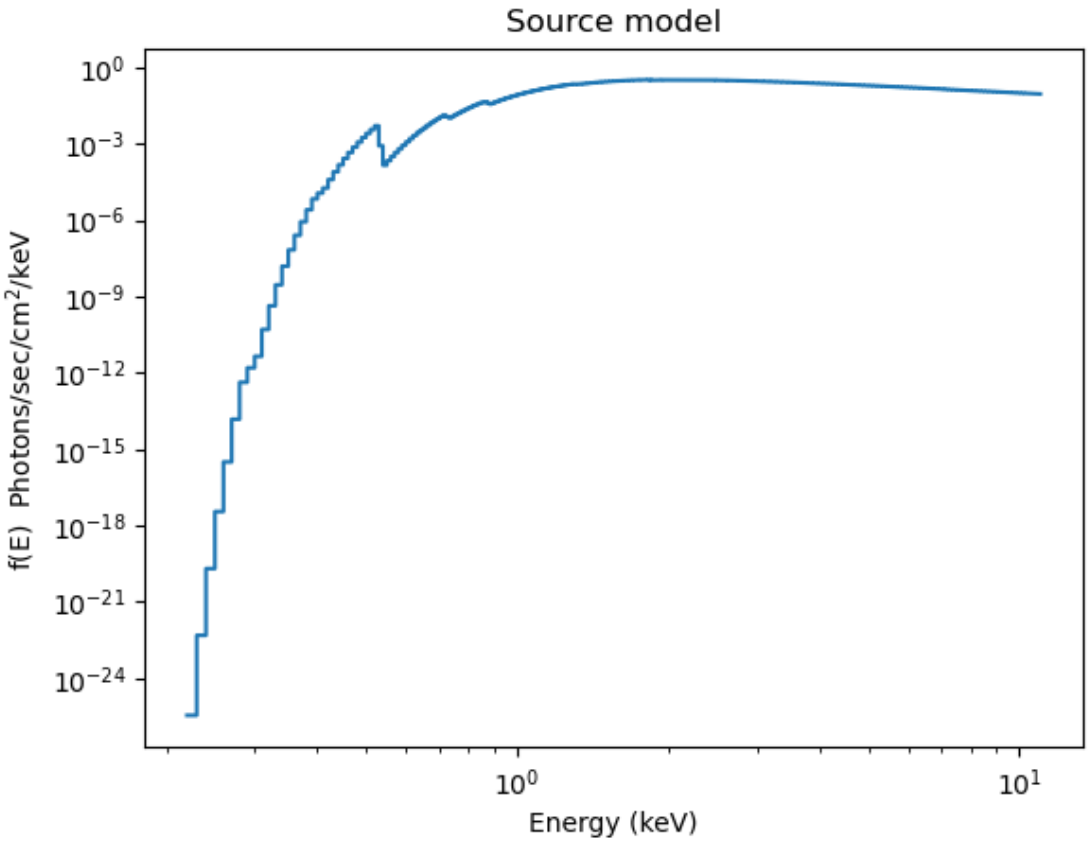
Noise


250
200
150
100
50
0
0
100
200
70
60
50
40
30
20
Single row
Average 20 rows
Average all rows

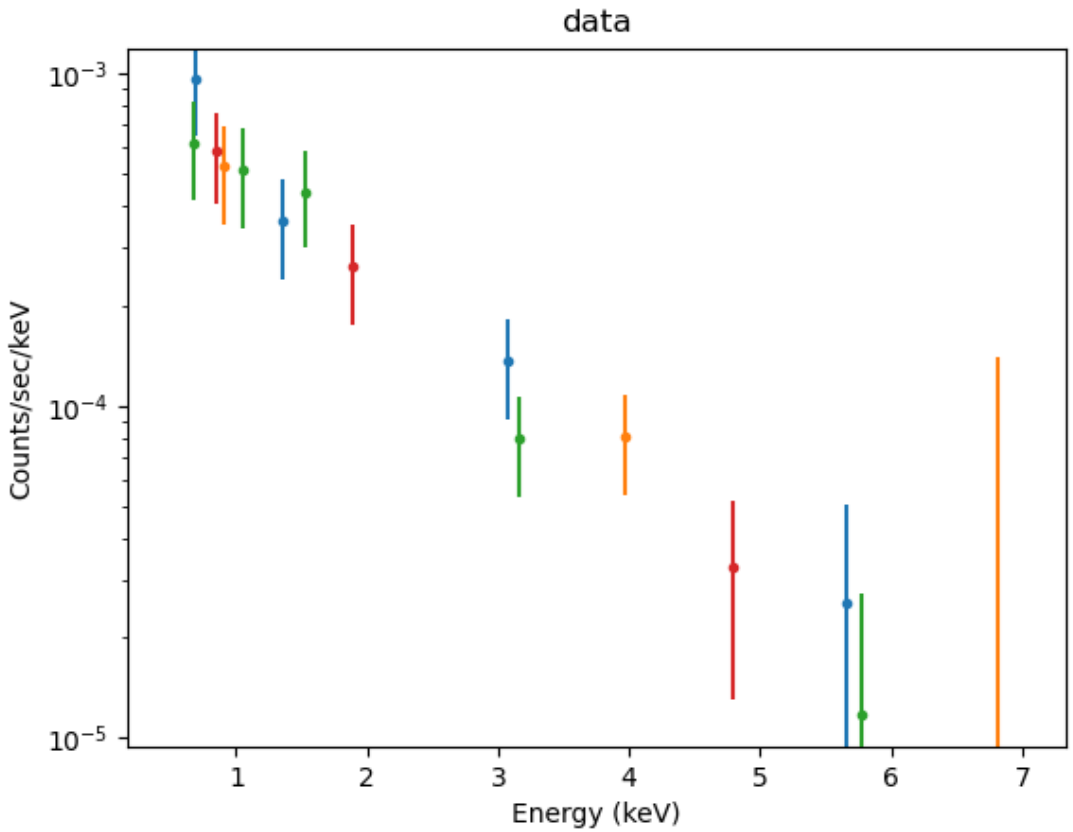
Noise


One observation
9 observations
One row
Average of 20 rows
70
60
50
40
30
20
0
100
200

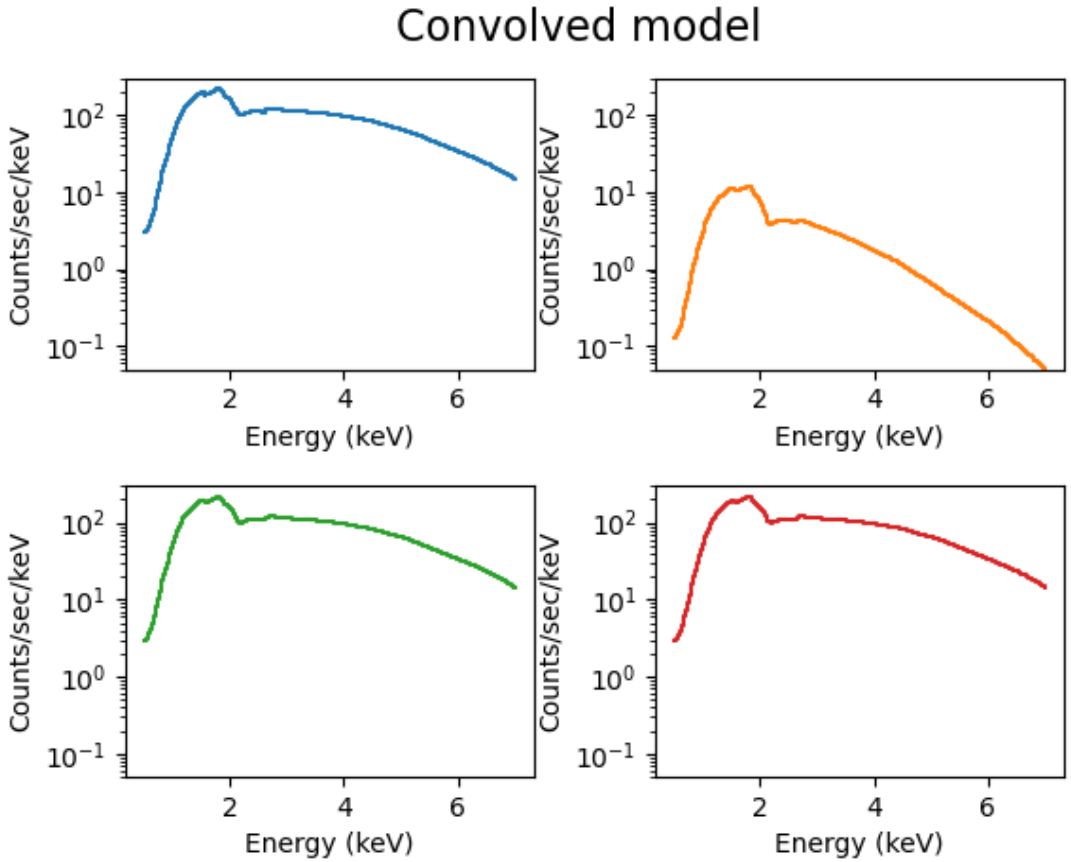
Spectra


Source model
f(E) Photons/sec/cm^2/keV
10^{0}
10^{-3}
10^{-6}
10^{-9}
10^{-12}
10^{-15}
10^{-18}
10^{-21}
10^{-24}
10^{0}
10^{1}
Energy (keV)

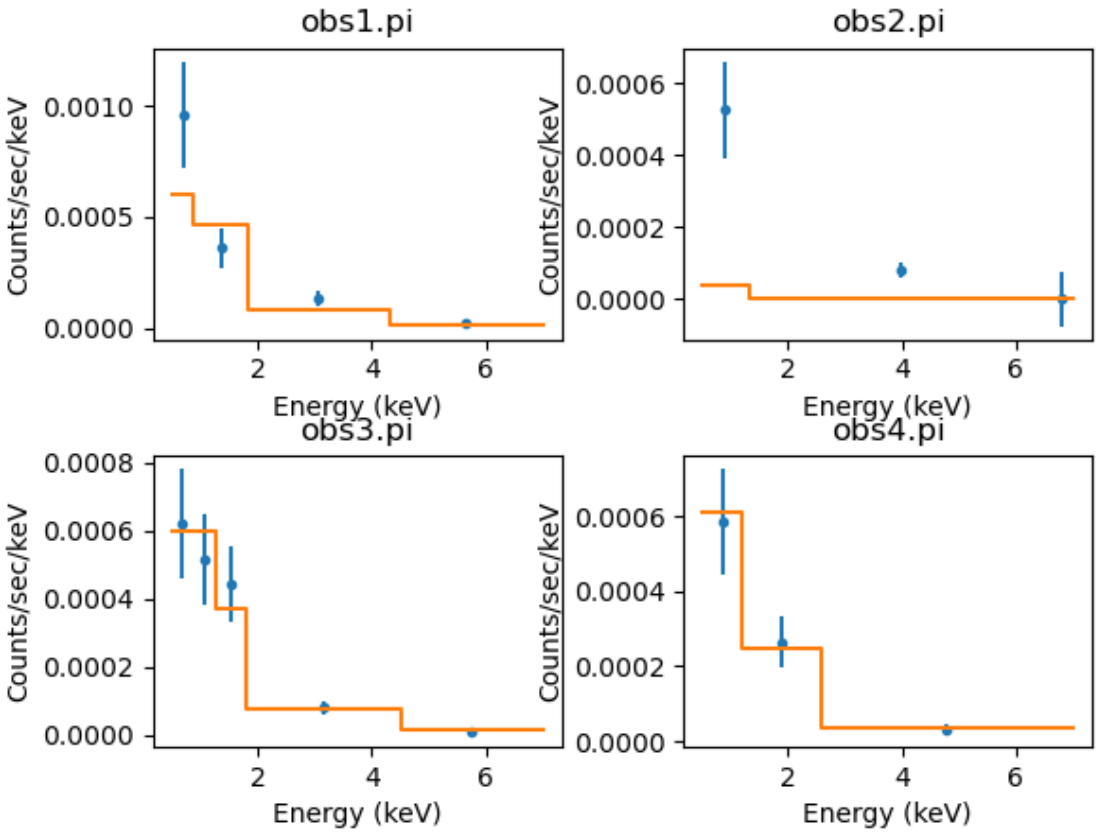
Spectra



Spectra


Convolved model
Counts/sec/keV
Energy (keV)
10^2
10^1
10^0
10^{-1}
2
4
6

Spectra


obs1.pi
obs2.pi
obs3.pi
obs4.pi
Counts/sec/keV
Energy (keV)
0.0010
0.0005
0.0000
0.0006
0.0004
0.0002
0.0008
2
4
6

Images

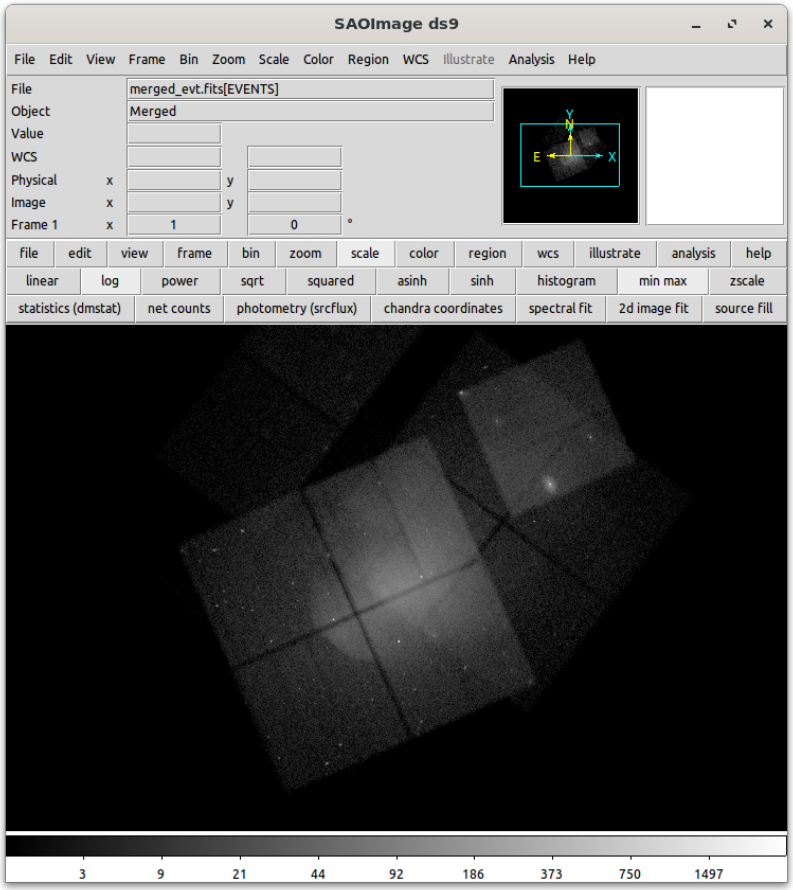
```
% find_chandra_obsid a3667
# obsid  sepn   inst grat   time    obsdate        piname       target
889       6.5 ACIS-I NONE   50.3 2000-09-09 Fusco-Femiano        A3667
7686      1.4 ACIS-I NONE    5.0 2007-06-23       Garmire    ABELL3667
6296      6.6 ACIS-I NONE   49.4 2005-06-19     Vikhlinin "Abell 3667"
6292      6.6 ACIS-I NONE   46.7 2005-06-10     Vikhlinin "Abell 3667"
5752      6.6 ACIS-I NONE   60.4 2005-06-12     Vikhlinin "Abell 3667"
6295      6.6 ACIS-I NONE   49.5 2005-06-15     Vikhlinin "Abell 3667"
5753      6.6 ACIS-I NONE  103.6 2005-06-17     Vikhlinin "Abell 3667"
5751      6.6 ACIS-I NONE  128.9 2005-06-07     Vikhlinin "Abell 3667"
513       3.4 ACIS-I NONE   44.8 1999-09-22        Murray "ABELL 3667"

% download_chandra_obsid 889,5751,7686
Downloading files for ObsId 889, total size is 246 Mb.

  Type     Format      Size  0........H.........1  Download Time Average Rate
  ------------------------------------------------------------------------
  vvref    pdf       101 Mb  ####################           15 s  6935.5 kb/s
...
% % chandra_repro 889,5751,7686
Output directory (default = $indir/repro) ():

Running chandra_repro
version: 25 November 2024
...
```

Images

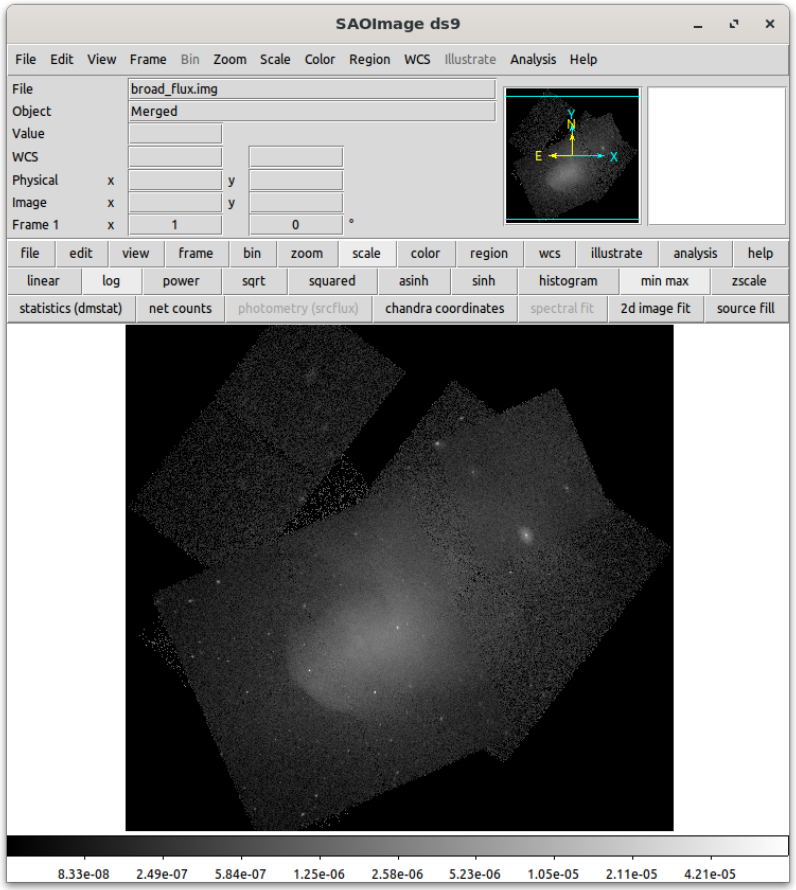
Learning what warnings are important is a life skill...

```
% reproject_obs 889,5751,7686 robs/
Running reproject_obs
Version: 20 October 2023
...

The merged event file:
     robs/merged_evt.fits

Warning: the merged event file robs/merged_evt.fits
   should not be used to create ARF/RMF/exposure maps because
      the RA_NOM keyword varies by 0.3310 (limit is 0.0003)
      the DEC_NOM keyword varies by 0.1254 (limit is 0.0003)
      the ROLL_NOM keyword varies by 260.3 (limit is 1.0)
      the SIM_Z keyword varies by 8.0 (limit is 0.1)
      the EXPTIME keyword contains: 3.1 3.2
        which means that the DTCOR value, and hence LIVETIME/EXPOSURE
        keywords are wrong
      the aim points fall on CCDs: 1 3
        which means that the ONTIME/LIVETIME/EXPOSURE keywords
        do not reflect the full observation length.

% flux_obs robs/ fobs/ bands=broad,csc
Running flux_obs
Version: 05 November 2021
...
```

Images

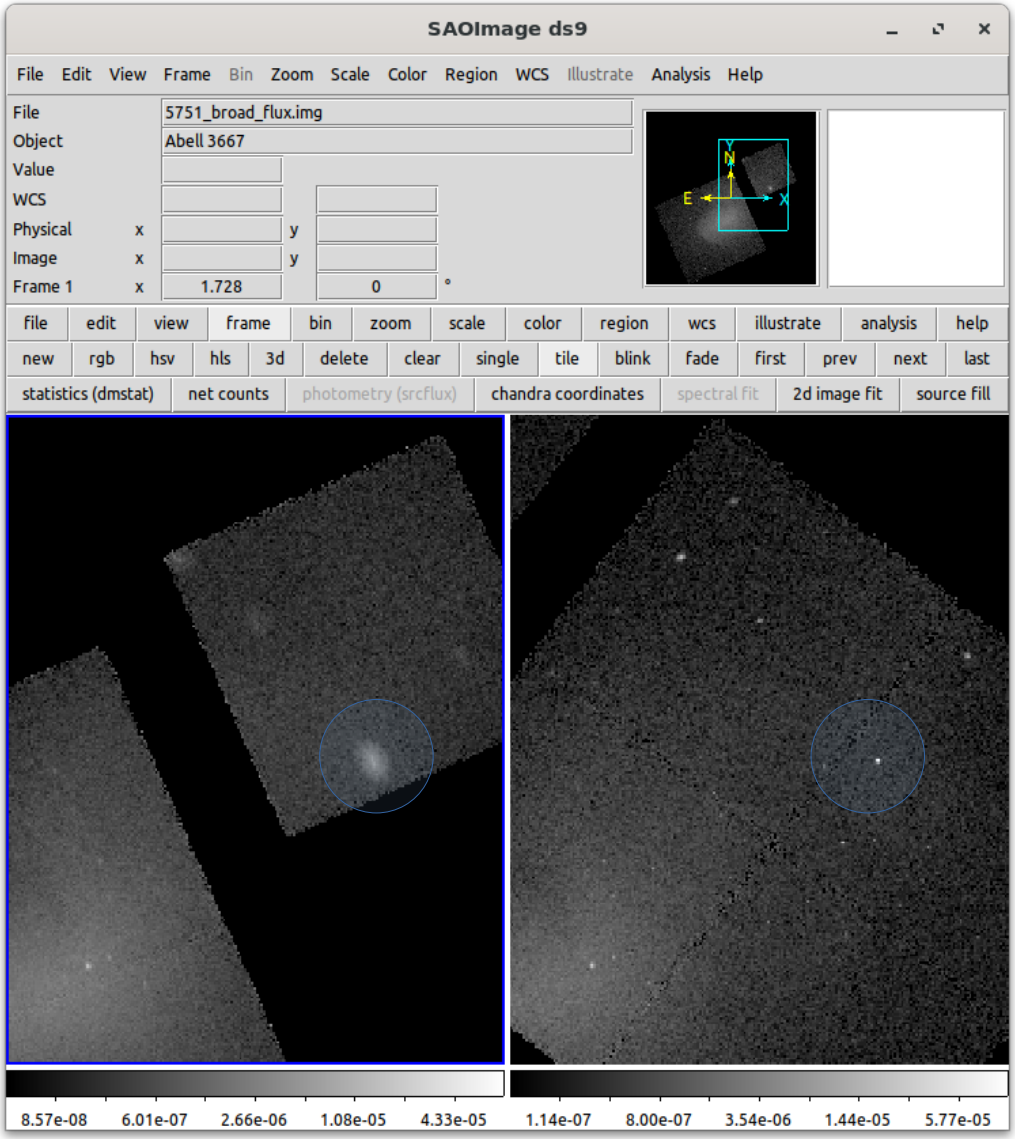


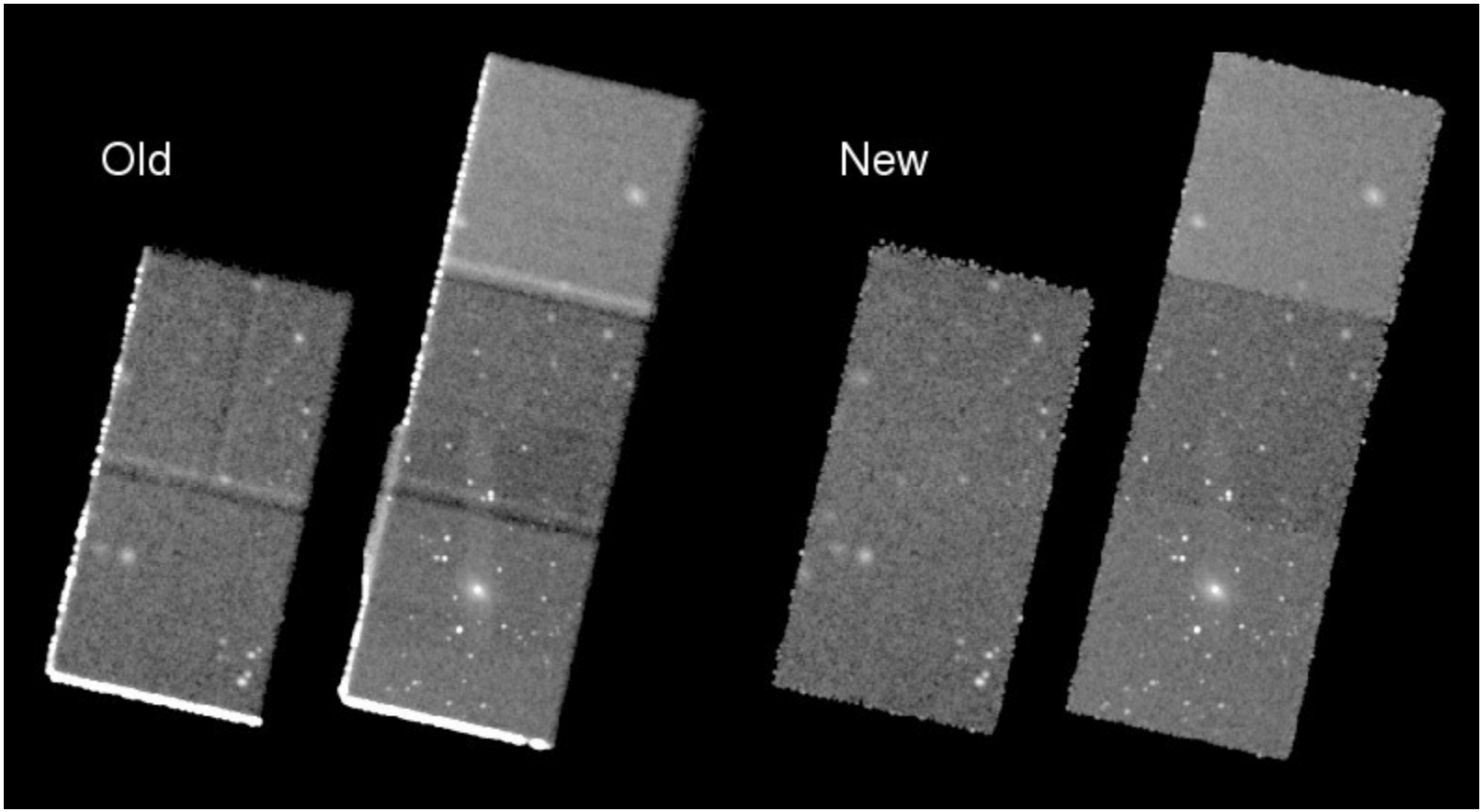
Merged



Combined


WHAT IF I TOLD YOU THAT
THERE IS NO FREE LUNCH?
imgflip.com


SAOImage ds9
File Edit View Frame Bin Zoom Scale Color Region WCS Illustrate Analysis Help
File 5751_broad_flux.img
Object Abell 3667
Value
WCS
Physical x y
Image x y
Frame 1 x 1.728 0 °
N
E
file edit view frame bin zoom scale color region wcs illustrate analysis help
new rgb hsv hls 3d delete clear single tile blink fade first prev next last
statistics (dmstat) net counts photometry (srcflux) chandra coordinates spectral fit 2d image fit source fill
8.57e-08 6.01e-07 2.66e-06 1.08e-05 4.33e-05
1.14e-07 8.00e-07 3.54e-06 1.44e-05 5.77e-05


Old
New

Alignment

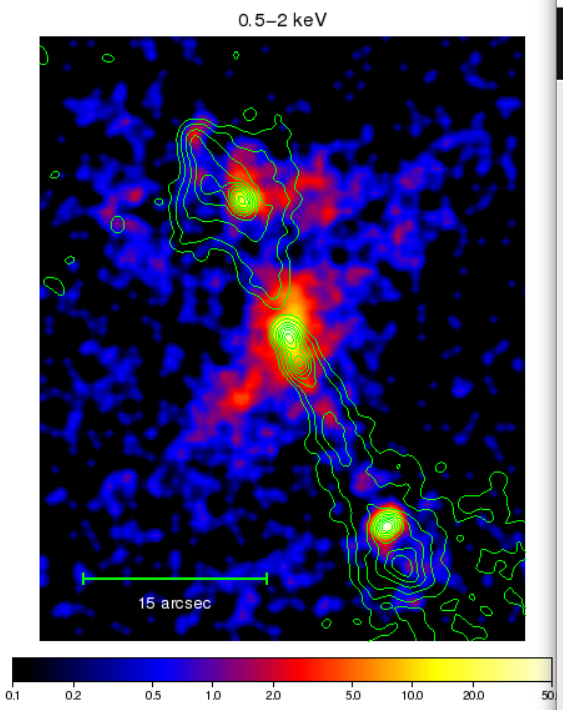


Figure 5 from Deep Ch ×

https://www.astroexplorer.org/details/apj425457f5

astronomy image explorer

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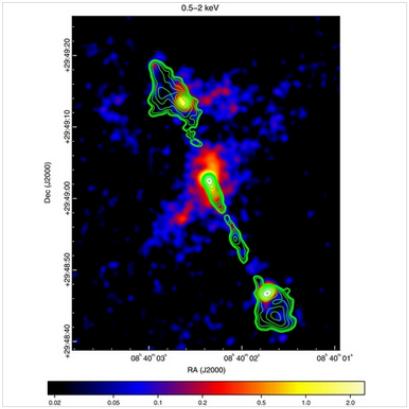


Deep Chandra X-Ray Imaging of a nearby Radio Galaxy 4C+29.30: X-Ray/Radio Connection

Authors: Aneta Siemiginowska, Łukasz Stawarz, Chi C. Cheung, Thomas L. Aldcroft, Jill Bechtold, D. J. Burke, Daniel Evans, Joanna Holt, Marek Jamrozy, and Giulia Migliori

Siemiginowska *et al.* 2012 *The Astrophysical Journal* **750** 124.

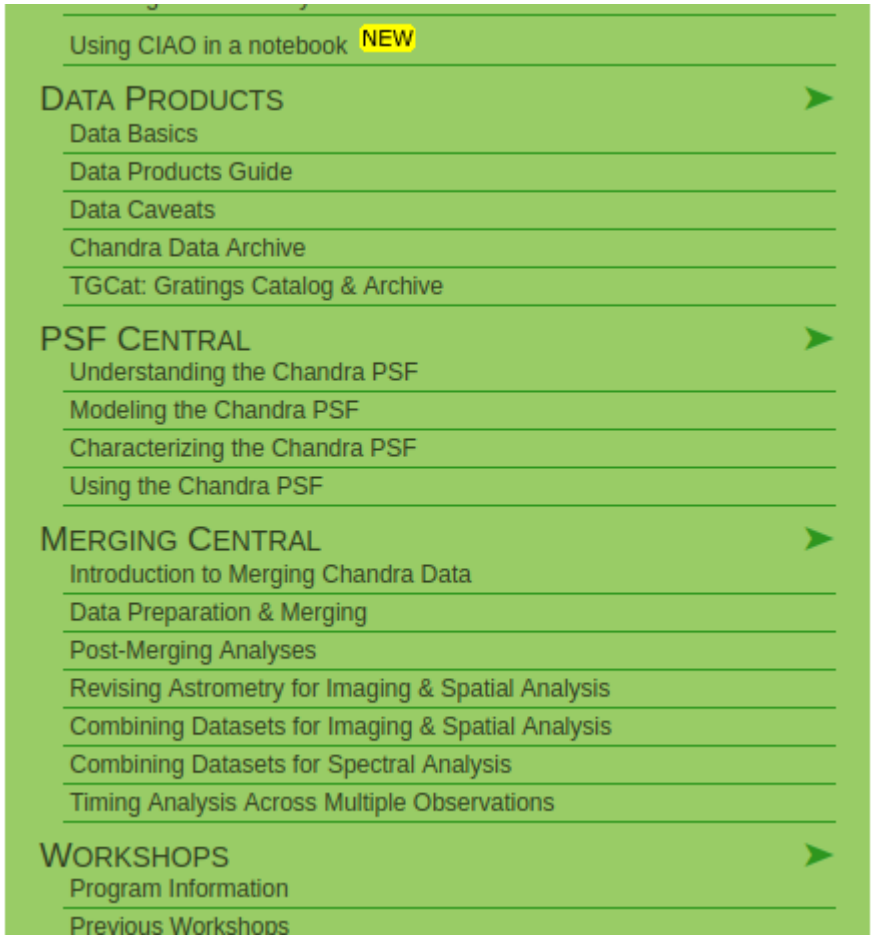
Provider: AAS Journals

Hi-Resolution | Export to PDF | PPT Format

Caption: Figure 5.

Smoothed *Chandra* ACIS-S image overlaid with contours from VLA map at 5 GHz. Only X-ray photons from 0.5to2 keV range were included in the image. The original image was binned by a 1/4 of the original ACIS-S pixel size and then smoothed with the Gaussian function (σ = 0 5). The utilized radio map was initially presented in Sambruna et al. (2004) using archival data originally published by van Breugel et al. (1986). The scale is indicated in the bottom color bar.

Other Images in This Article



Resources

https://cxc.harvard.edu/ciao/merging/merge_central.html

https://cxc.harvard.edu/ciao/workshop/jan21/radial-to-smoothing.html