

XRT Point Spread Function

Off-Axis PSF

On-Axis PSF improvements

1-D & 2-D PSFs

Implications for (Slow) Slew...

Future...



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PSFs that are used in SAS:

- 2-D PSFs – ‘medium’ CCF PSFs – Images
– $\text{fn}(\text{instr}, E, \theta, \phi)$ – used in SAS
source-searching
- 1-D PSFs – ‘extended’ CCF PSFs – King
profile (r_0, α) – $\text{fn}(\text{instr}, E, \theta)$ –
used in ARF generation/spectral fitting



PSFs that are used in SAS:

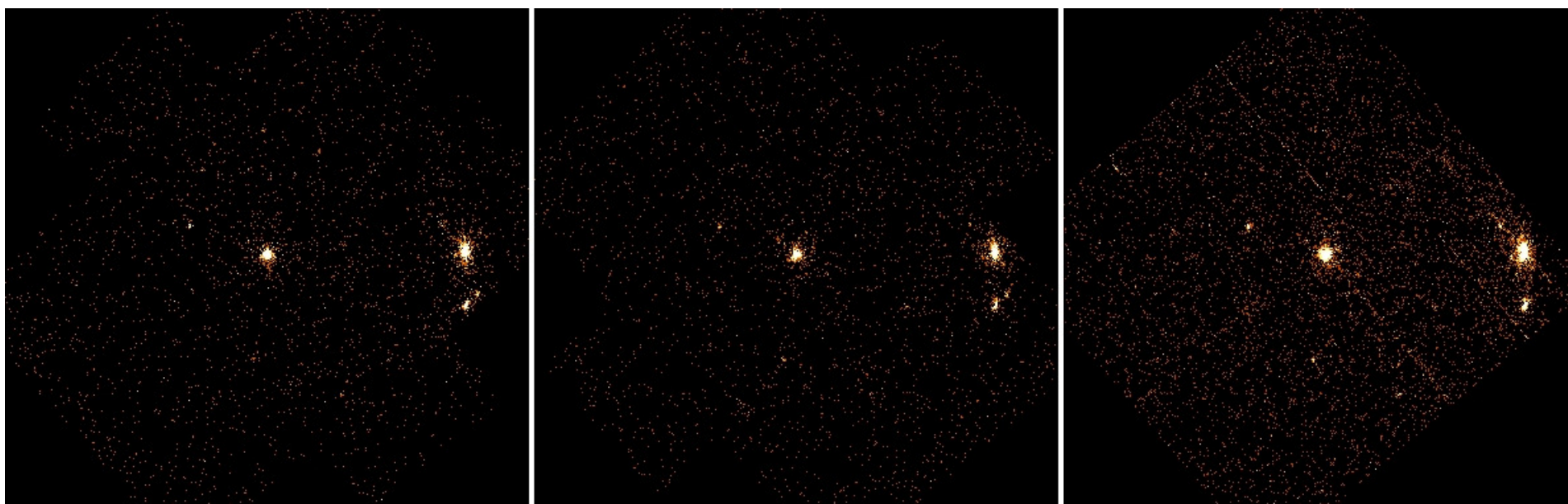
- 2-D PSFs – ‘medium’ CCF PSFs – Images
– $\text{fn}(\text{instr}, E, \theta, \phi)$ – used in SAS
source-searching

Images for each instrument at various Energy and Off-axis angle – presently **all SCISIM-generated, simple, and all the same for each instrument** – SAS-devel, SSC, UG, users etc say these are not good enough.

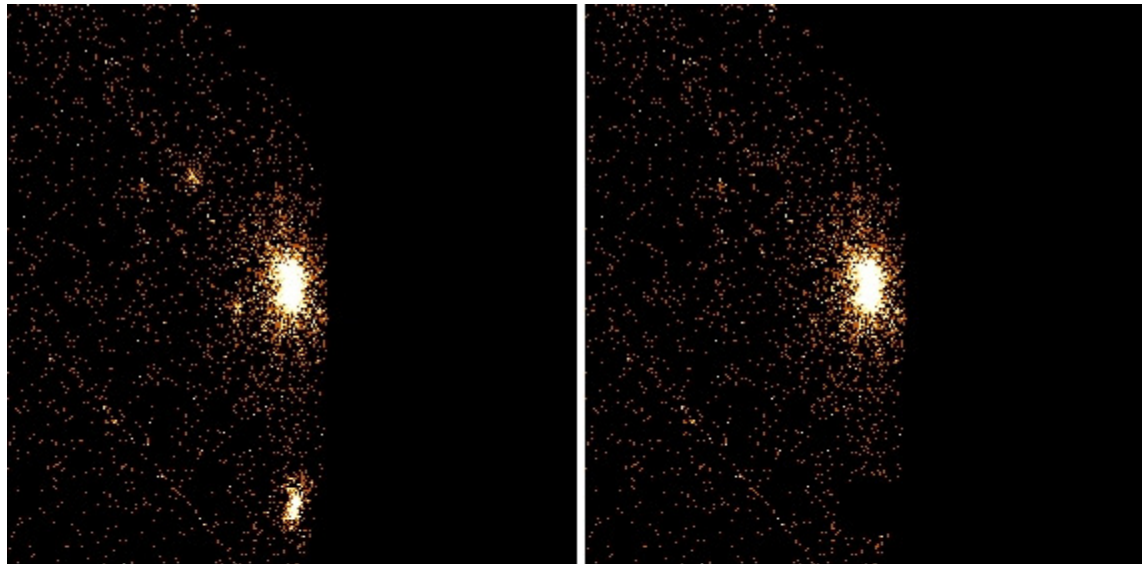


On- and off-axis 2-D PSF - Analysis

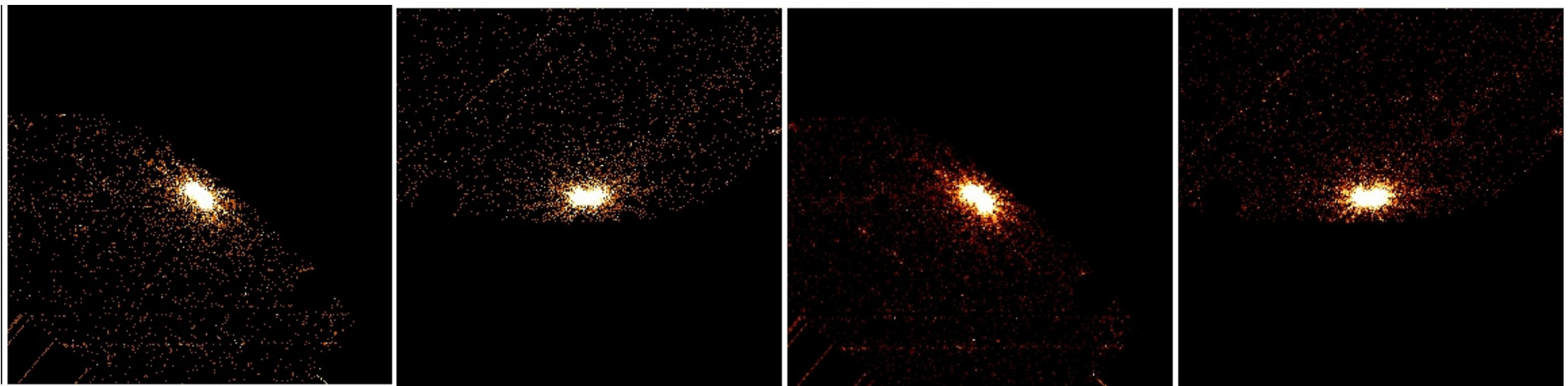
- From 2XMMp source list, select M1, M2, PN point sources that
 - have large numbers of counts
 - are below pile-up limit (mode-dependent)
 - cover full range in off-axis angle (0-15 arcmin)
 - presently (April 2007) ~200 sources/instrument



- Clean event files for times of high-BG, bad events, out-FOV events etc.
- Make large-scale images – find exact position of source – reject if crowded field or there are chip gaps, bad columns etc through source
- Make small CCF (512x512, 1.1'') images around source
 - All E-bands, all instruments
- Subtract other sources



- Rotate image
 - wrt PA (see later)
 - wrt PA and position on the detector
- Gaussian centre and rebin to exact centre of 512x512 image (1'' binning)
- All performed for each source, for each energy-band and for each instrument



Rotate wrt PA

Rotate wrt PA+DetPos

Rotate wrt PA and
rebinned/re-centred

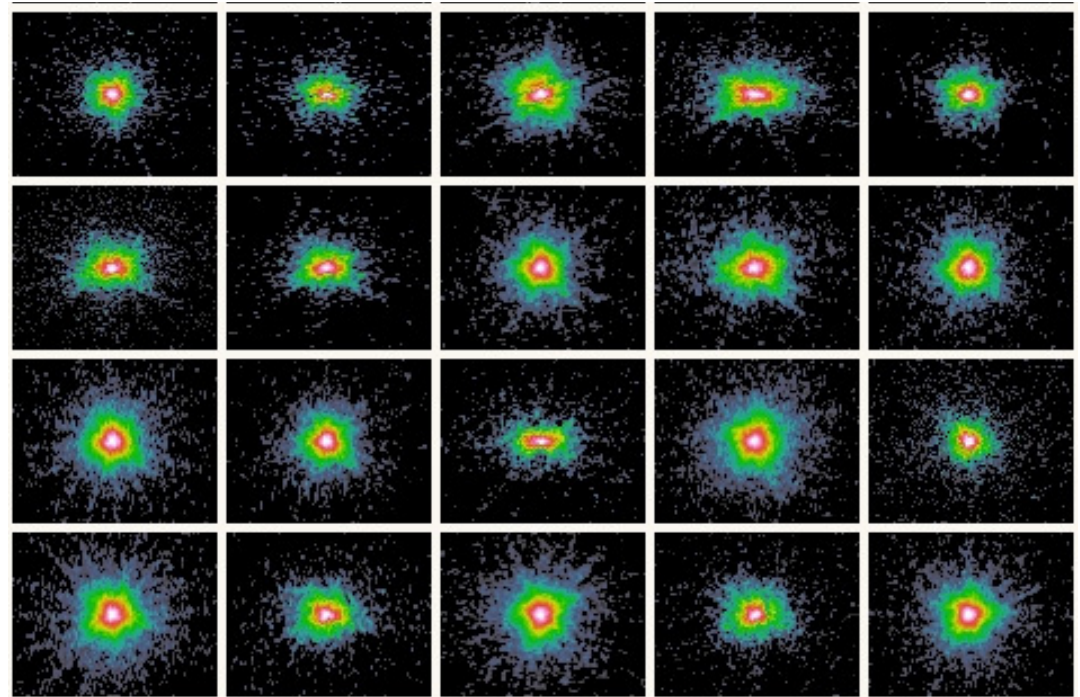
Rotate wrt PA+DetPos
and rebinned/re-centred

- Collect good final rebinned/re-centred/rotated images together for each:

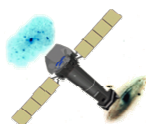
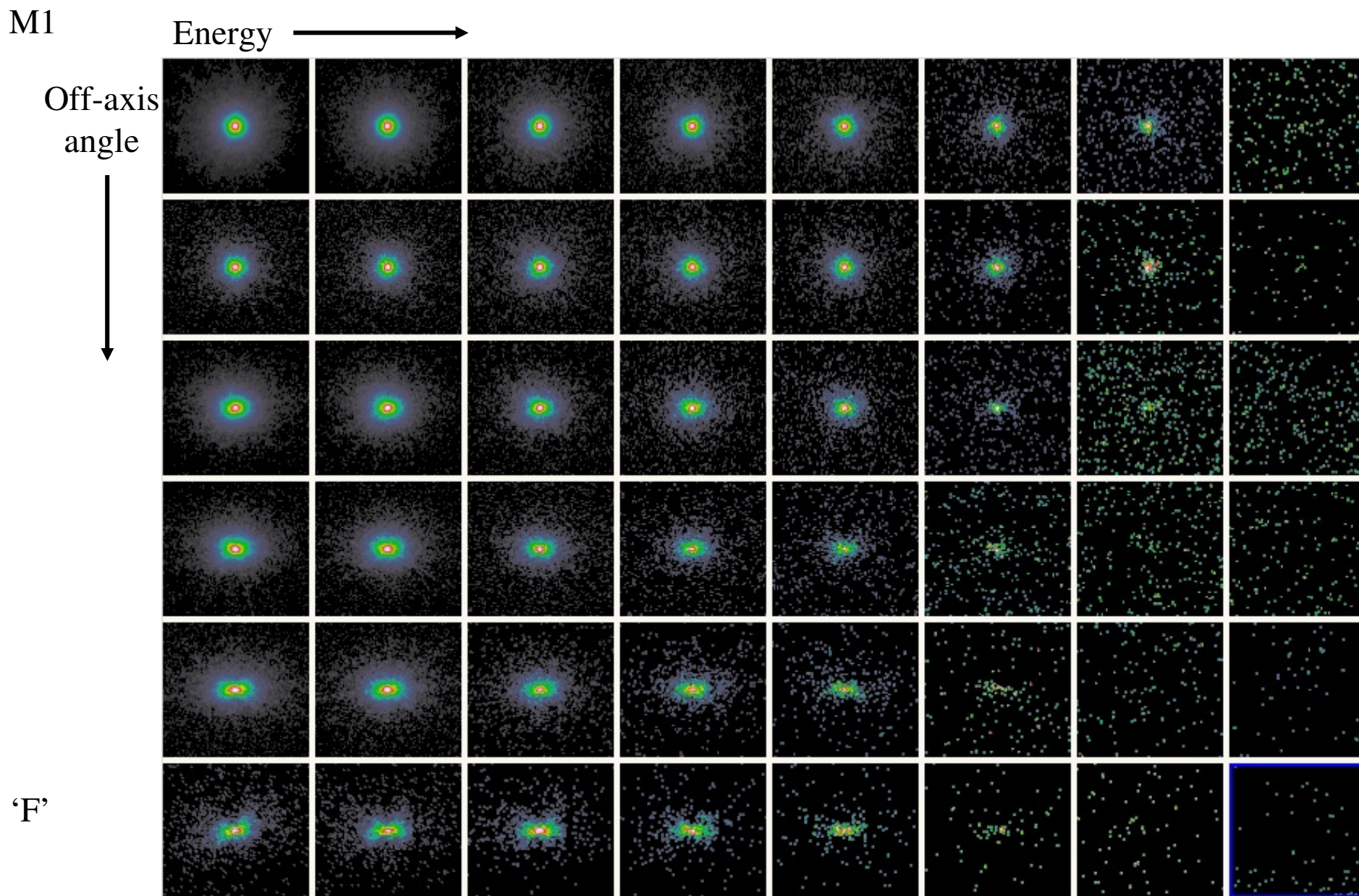
- Instrument (3)
- Energy band (8)
- Off-axis angle band (6)

- Stack images together
- Clean, BG-subtract stacked images

- Clean headers
- Clean outer areas
- Careful BG-subtraction
- Re-normalization



- Create CCF files from final stacked, cleaned, BG-subtracted, re-normalized images
- Note: Can create on- and off-axis (E-dep) 1-D PSFs (i.e. extended mode – arfgen PSFs) by constructing radial profiles from these images and perform King-fitting

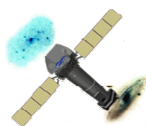
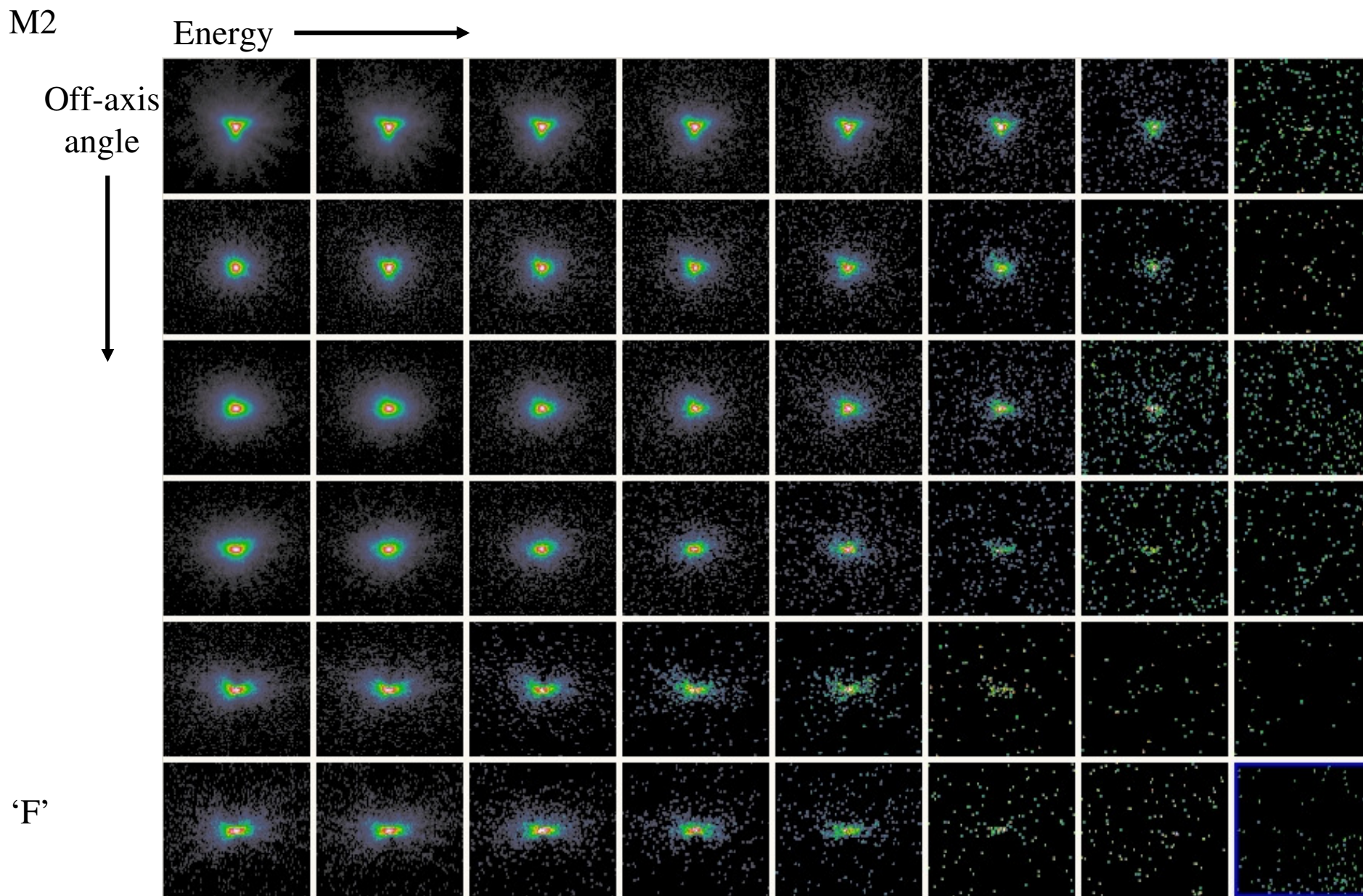


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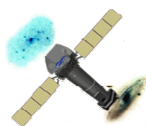
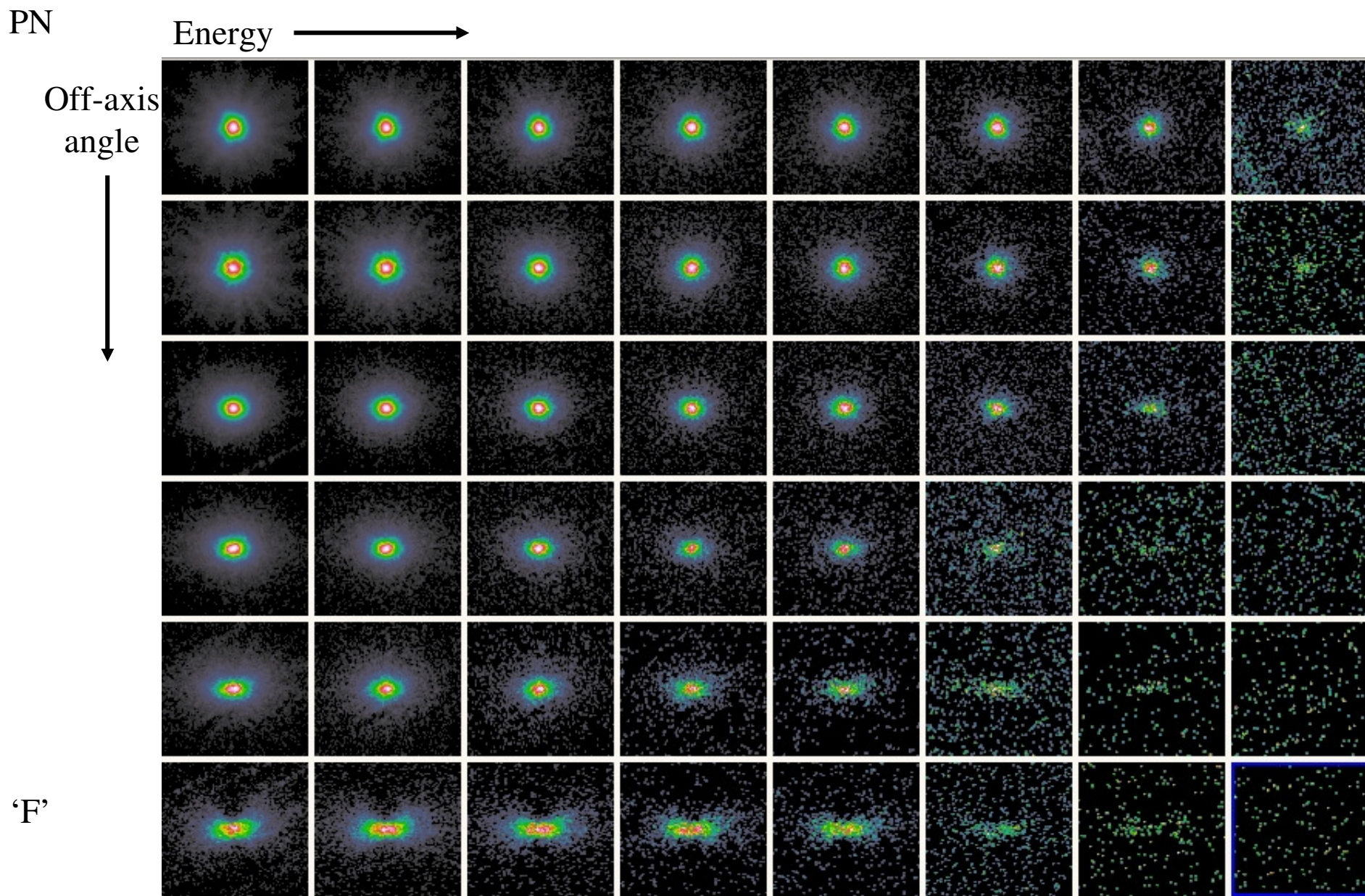


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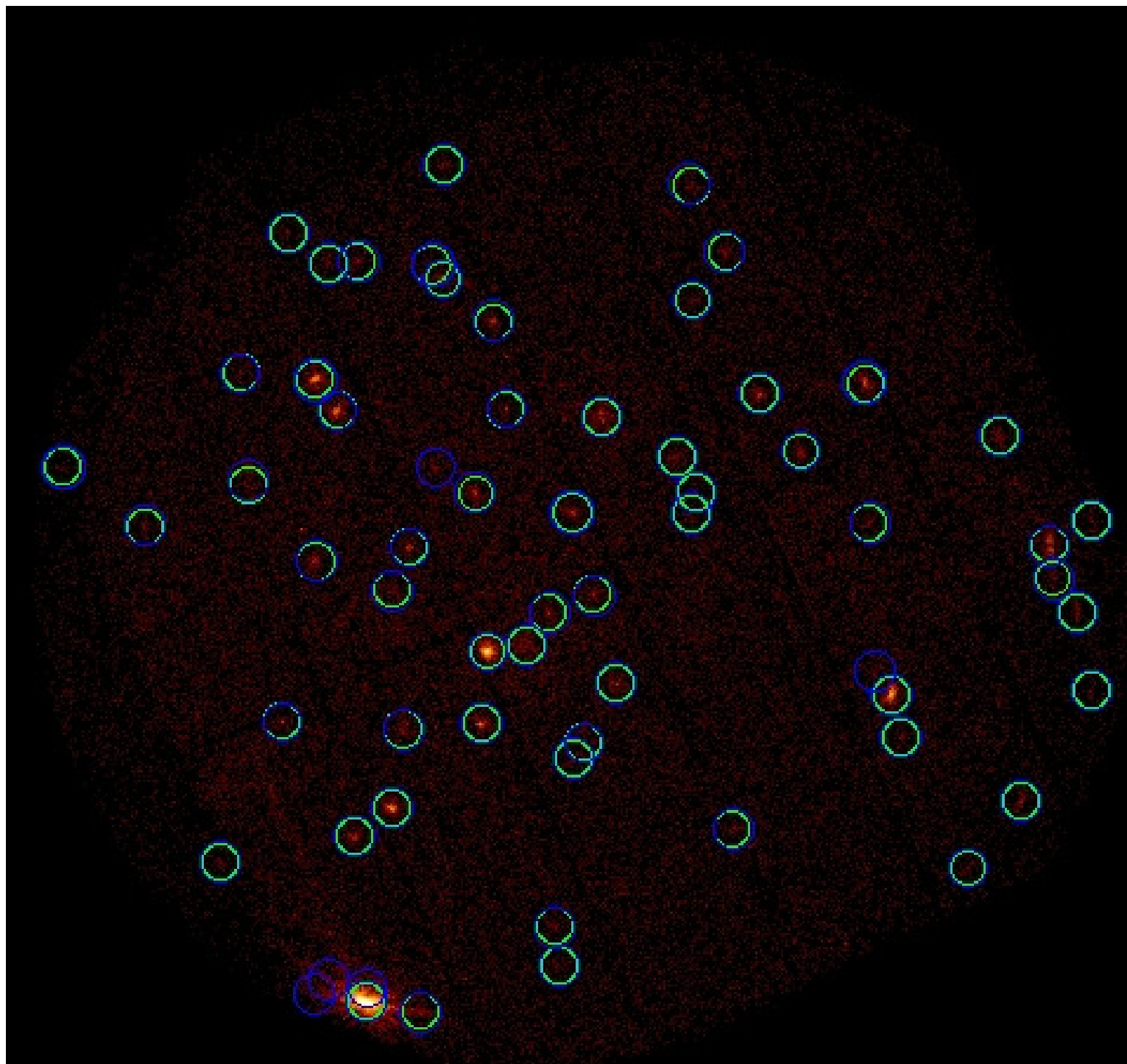
First source-search
with AMR-‘F’
CCFs:

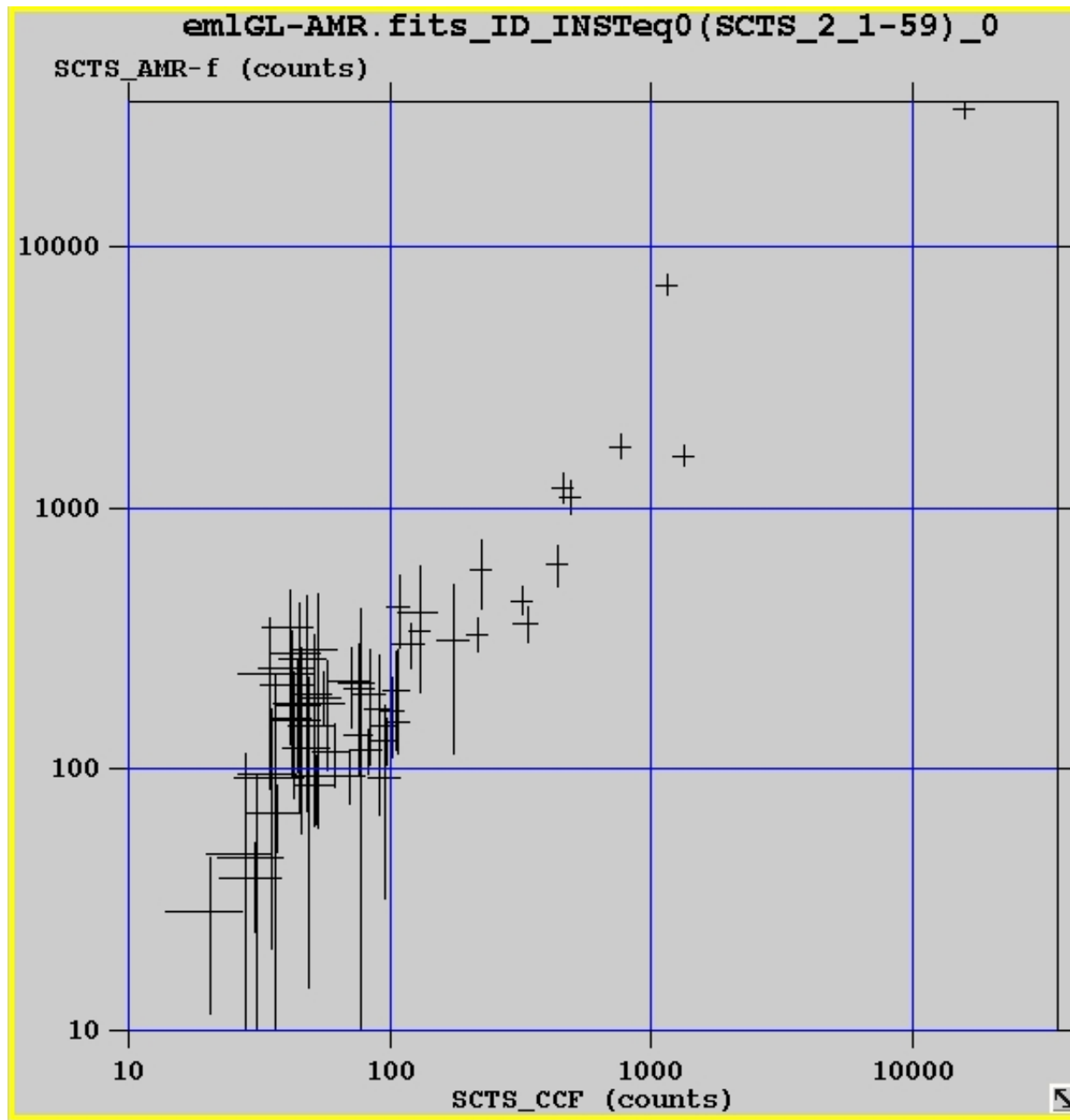
0032141201

Problem source to
bottom-left

Blue – current
CCFs

Green – AMR-‘F’
CCFs



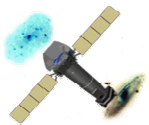


First source-search with AMR-
'F' CCFs:

0032141201

Estimated source counts

AMR-F v current

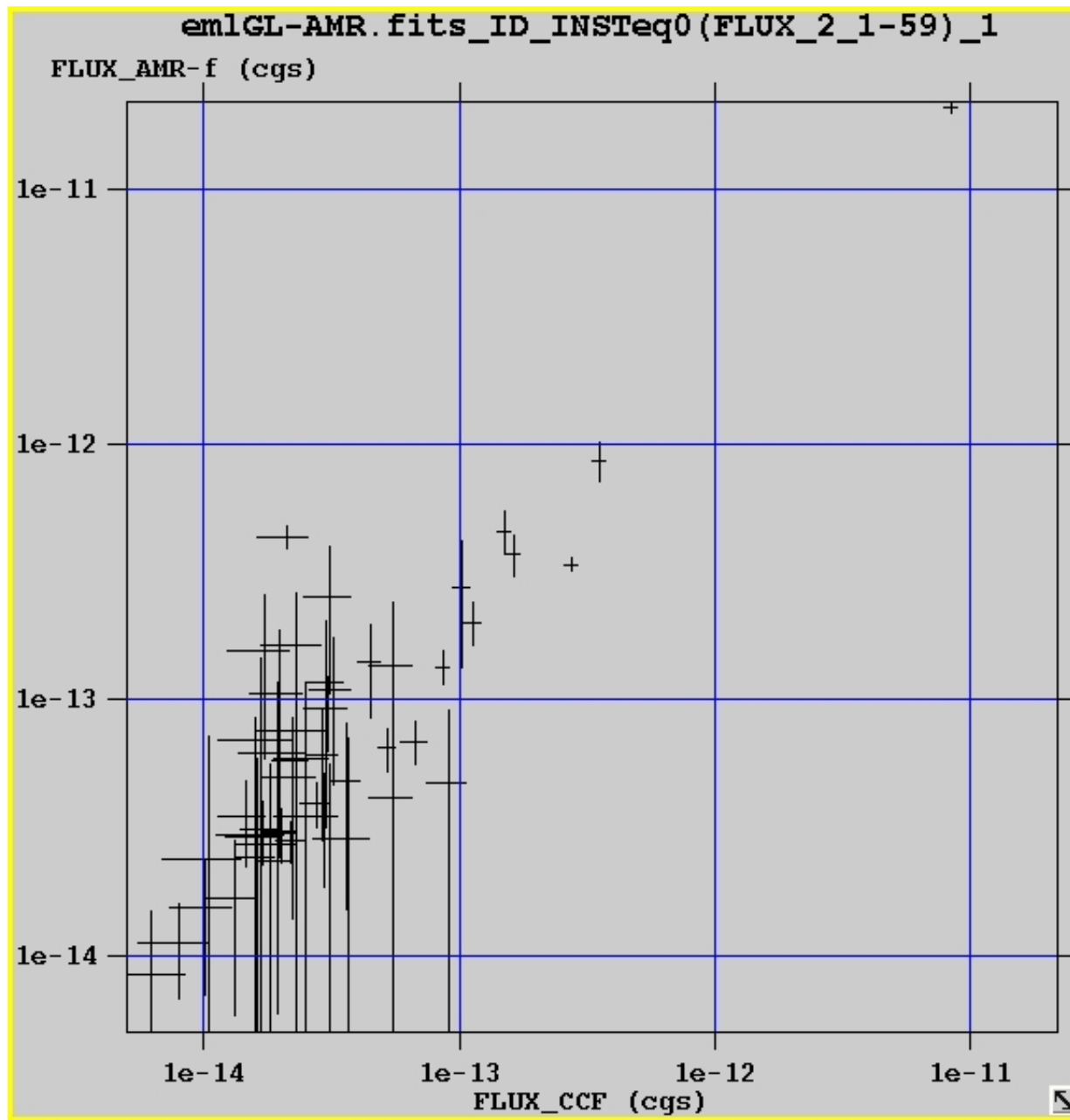


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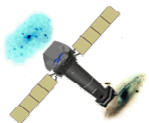


First source-search with AMR-
'F' CCFs:

0032141201

Estimated source flux

AMR-F v current

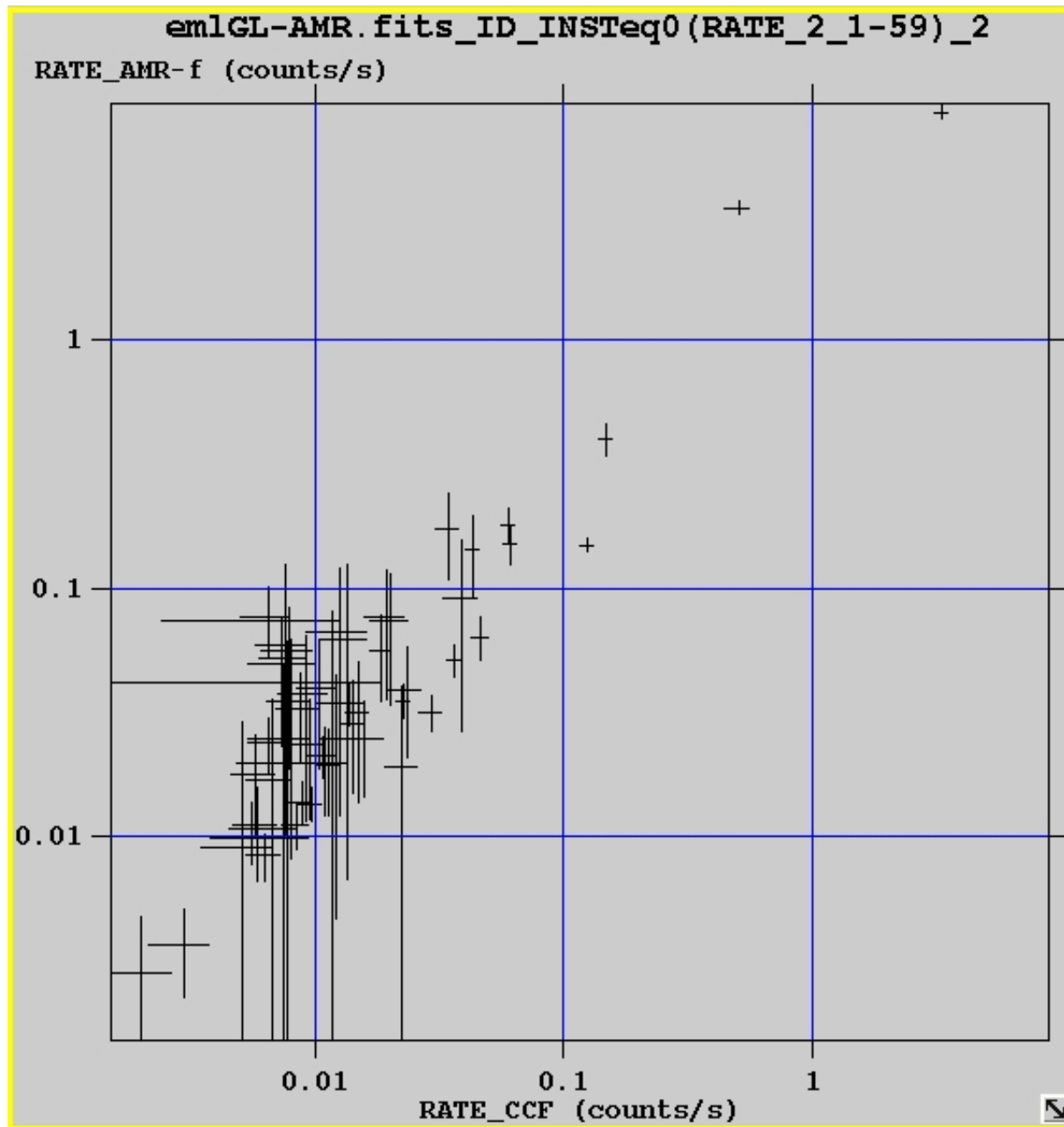


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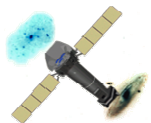


First source-search with AMR-
'F' CCFs:

0032141201

Estimated source count-rate

AMR-F v current

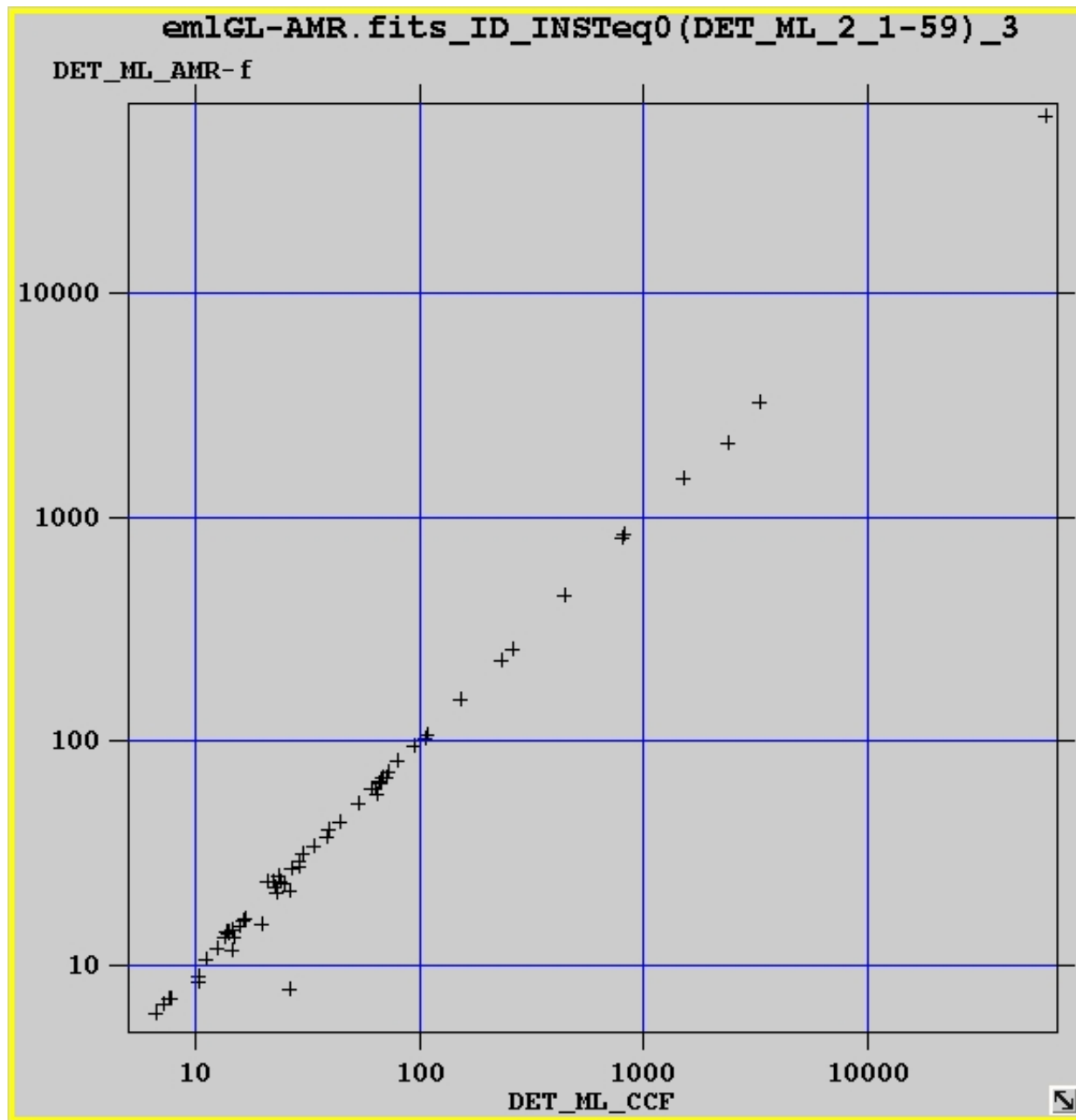


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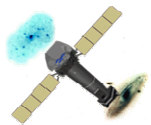


First source-search with AMR-
'F' CCFs:

0032141201

Detection likelihood

AMR-F v current

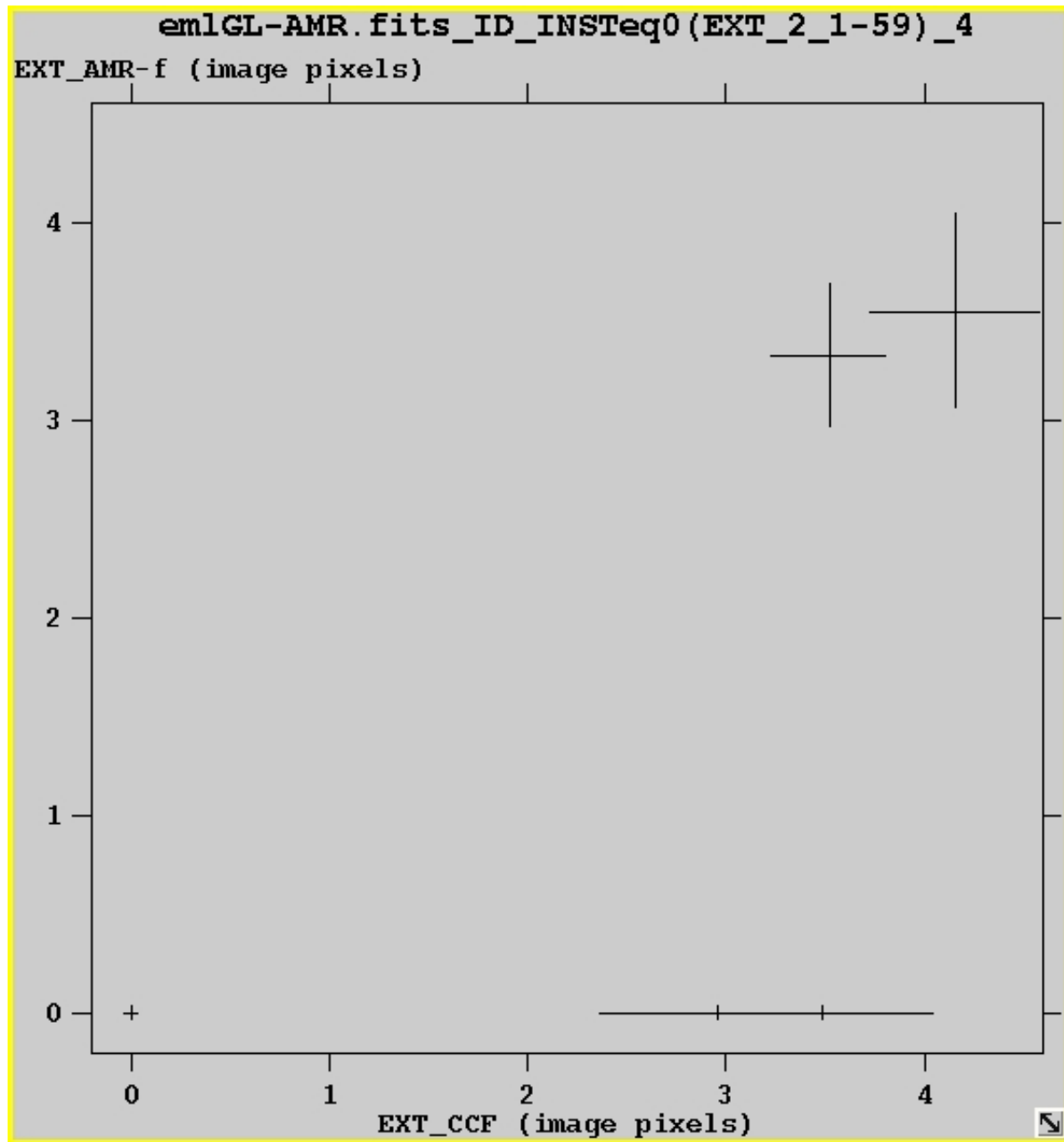


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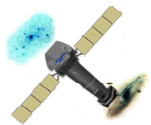


First source-search with AMR-
'F' CCFs:

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Estimated source extent

AMR-F v current



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Very bright off-axis source (problematic)

fv: Binary Table of emiGL.fits[1] in /home/work/amr30/EPIC/OffAxisPSF/GL/00321

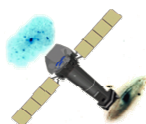
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☐ All	pixels	pixels		
Invert	Modify	Modify	Modify	Modify
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9	1.500000E+01	9.919962E-01	9.388936E-01	4.323293E-01
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15	1.500000E+01	9.919878E-01	9.388936E-01	3.988150E-01
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18	1.500000E+01	9.912072E-01	9.272270E-01	3.822750E-01
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fv: Binary Table of emiAMR.fits[1] in /home/work/amr30/EPIC/OffAxisPSF/GL/003

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☐ All	pixels	pixels		
Invert	Modify	Modify	Modify	Modify
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3	1.500000E+01	9.694373E-01	5.146723E-01	3.778920E-01
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18	1.500000E+01	9.513568E-01	4.308404E-01	4.197430E-01
19	1.500000E+01	7.727550E-01	9.334046E-02	2.510620E-01
20	1.500000E+01	NULL	NULL	NULL

Current CCF

AMR-F CCF



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Bright on-axis source

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File Edit Tools Help

☐ CUTRAD ☐ MASKFRAC ☐ EEf ☐ VIGNETTING

Select E E E E

☐ All pixels pixels pixels pixels

Invert Modify Modify Modify Modify

20	1.500000E+01	NULL	NULL	NULL
21	1.500000E+01	8.341774E-01	NULL	NULL
22	1.500000E+01	8.440030E-01	9.503056E-01	9.357589E-01
23	1.500000E+01	8.440030E-01	9.503056E-01	9.356865E-01
24	1.500000E+01	8.440030E-01	9.503056E-01	9.357242E-01
25	1.500000E+01	8.443074E-01	9.348180E-01	9.336932E-01
26	1.500000E+01	8.341774E-01	8.846723E-01	8.955373E-01
27	1.500000E+01	9.861470E-01	NULL	NULL
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30	1.500000E+01	9.934191E-01	9.503056E-01	9.497419E-01
31	1.500000E+01	9.922066E-01	9.348180E-01	9.473376E-01
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34	1.500000E+01	9.936877E-01	9.503056E-01	9.073297E-01
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36	1.500000E+01	9.936877E-01	9.503056E-01	9.072253E-01
37	1.500000E+01	9.922580E-01	9.348180E-01	9.033344E-01
38	1.500000E+01	9.861304E-01	8.846723E-01	8.254827E-01
39	1.500000E+01	NULL	NULL	NULL

Current CCF

fv: Binary Table of emiAMR.fits[1] in /home/work/amr30/EPIC/OffAxisPSF/GL/003

File Edit Tools Help

☐ CUTRAD ☐ MASKFRAC ☐ EEf ☐ VIGNETTING

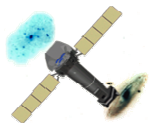
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☐ All pixels pixels pixels pixels

Invert Modify Modify Modify Modify

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24	1.500000E+01	8.205266E-01	8.583404E-01	9.166959E-01
25	1.500000E+01	8.288782E-01	6.486723E-01	9.139915E-01
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27	1.500000E+01	9.284839E-01	NULL	NULL
28	1.500000E+01	9.851902E-01	8.626723E-01	9.512050E-01
29	1.500000E+01	9.854367E-01	8.606724E-01	9.510654E-01
30	1.500000E+01	9.859065E-01	8.583404E-01	9.511408E-01
31	1.500000E+01	9.798025E-01	6.486723E-01	9.488619E-01
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35	1.500000E+01	9.854128E-01	8.606724E-01	9.531925E-01
36	1.500000E+01	9.860760E-01	8.583404E-01	9.532699E-01
37	1.500000E+01	9.798952E-01	6.486723E-01	9.510140E-01
38	1.500000E+01	9.240551E-01	2.166724E-01	9.043828E-01
39	1.500000E+01	NULL	NULL	NULL

AMR-F CCF

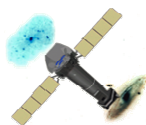
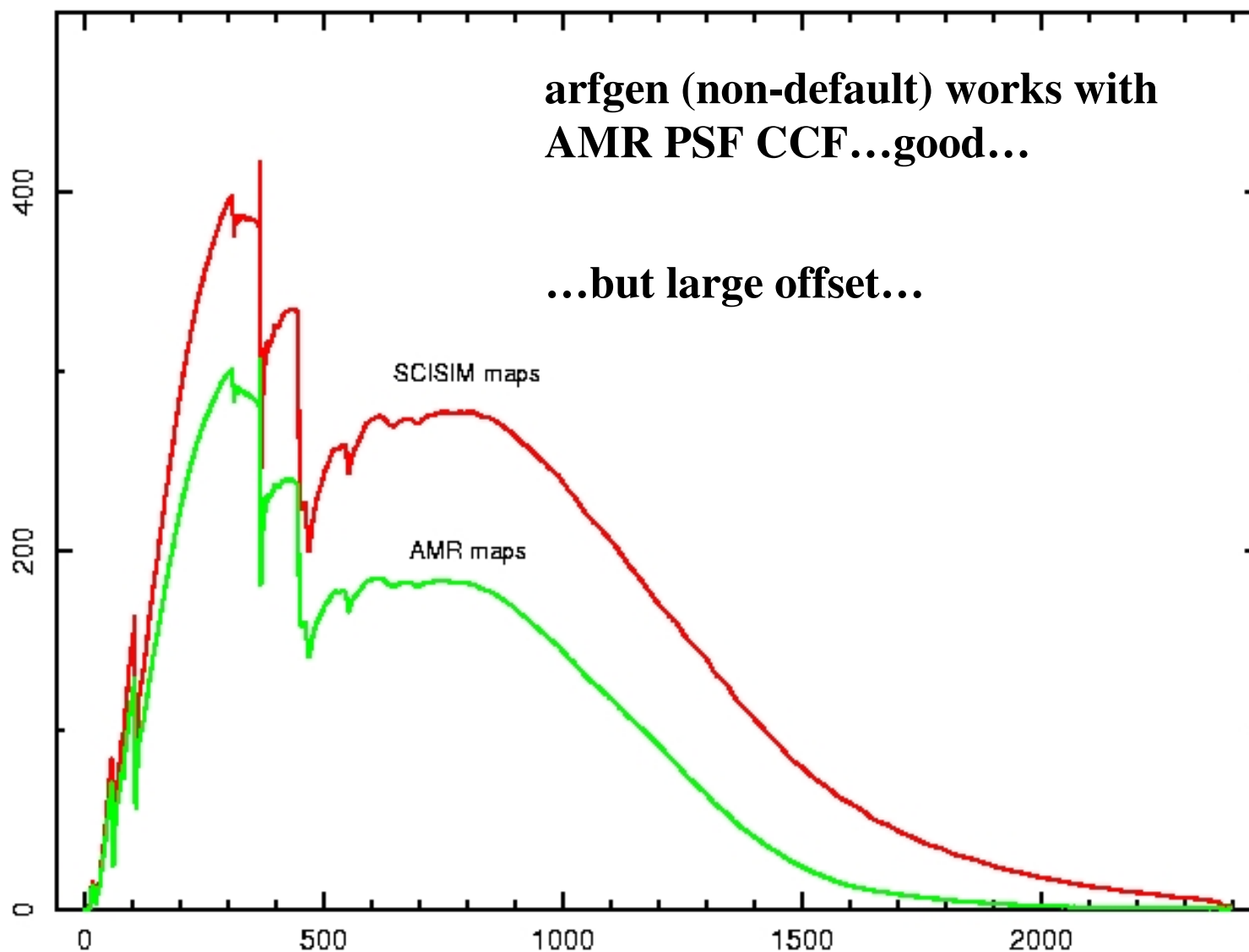


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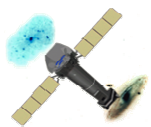
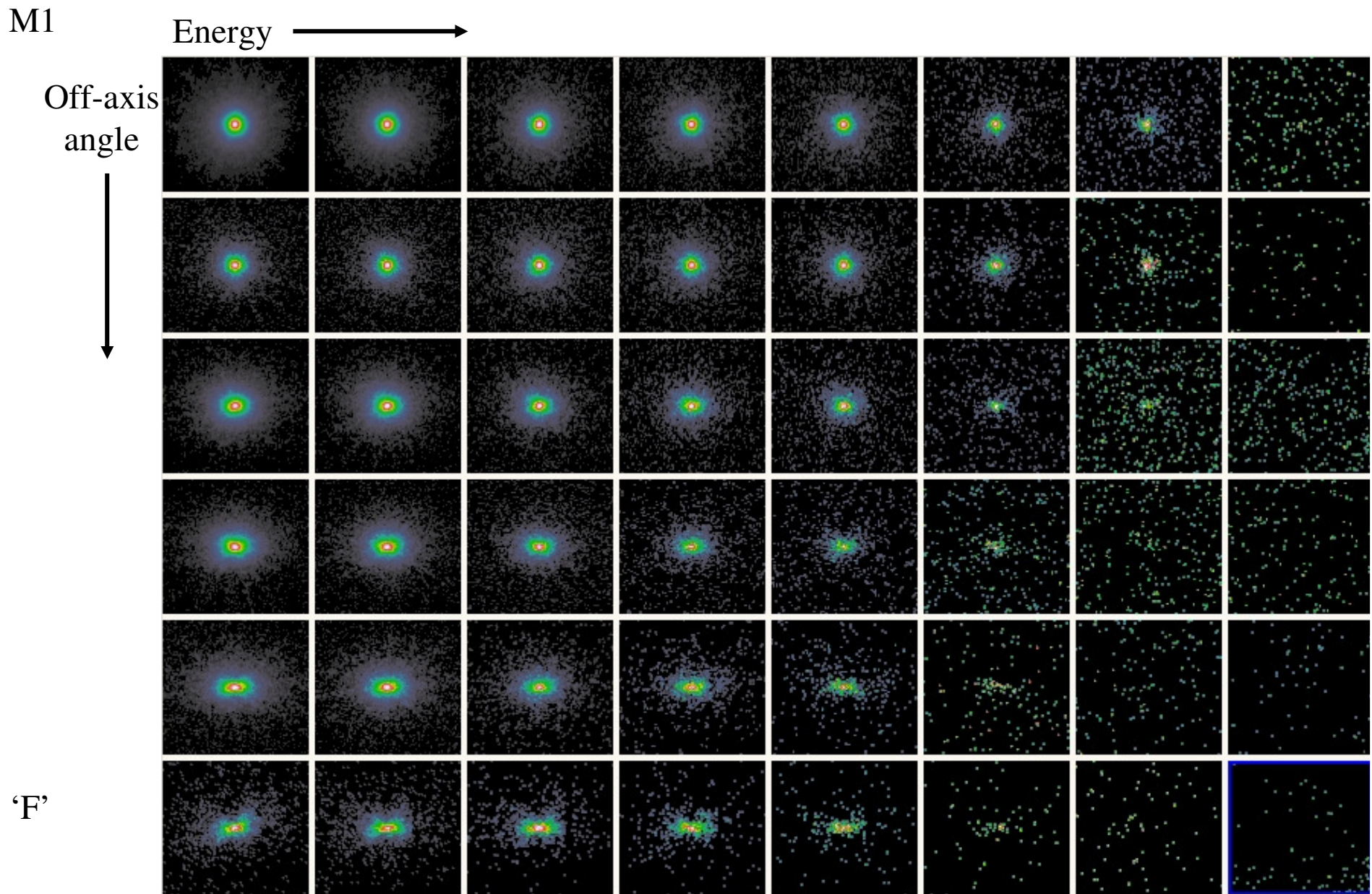


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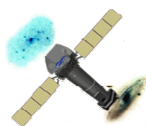
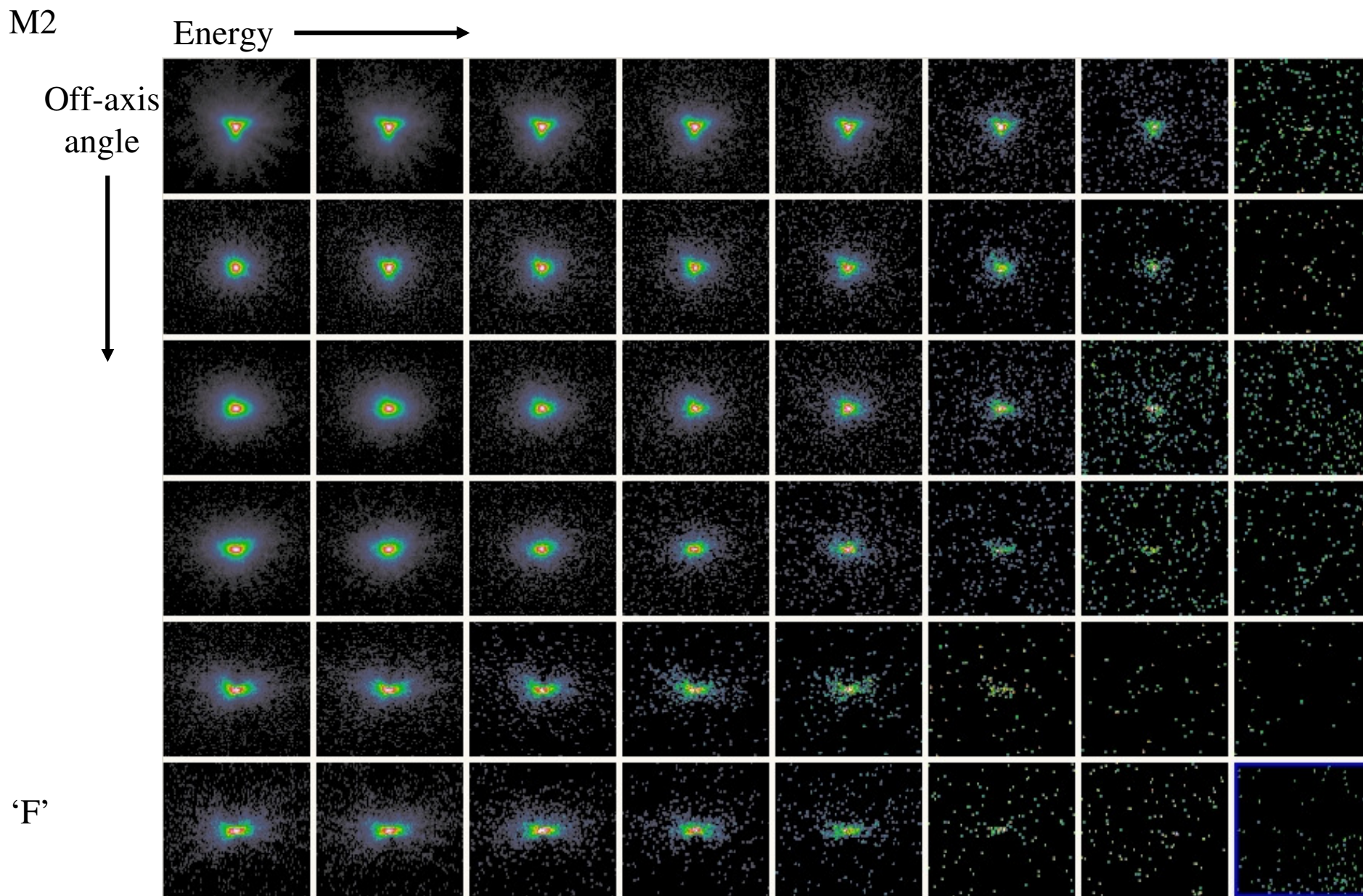


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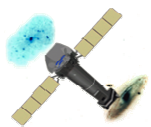
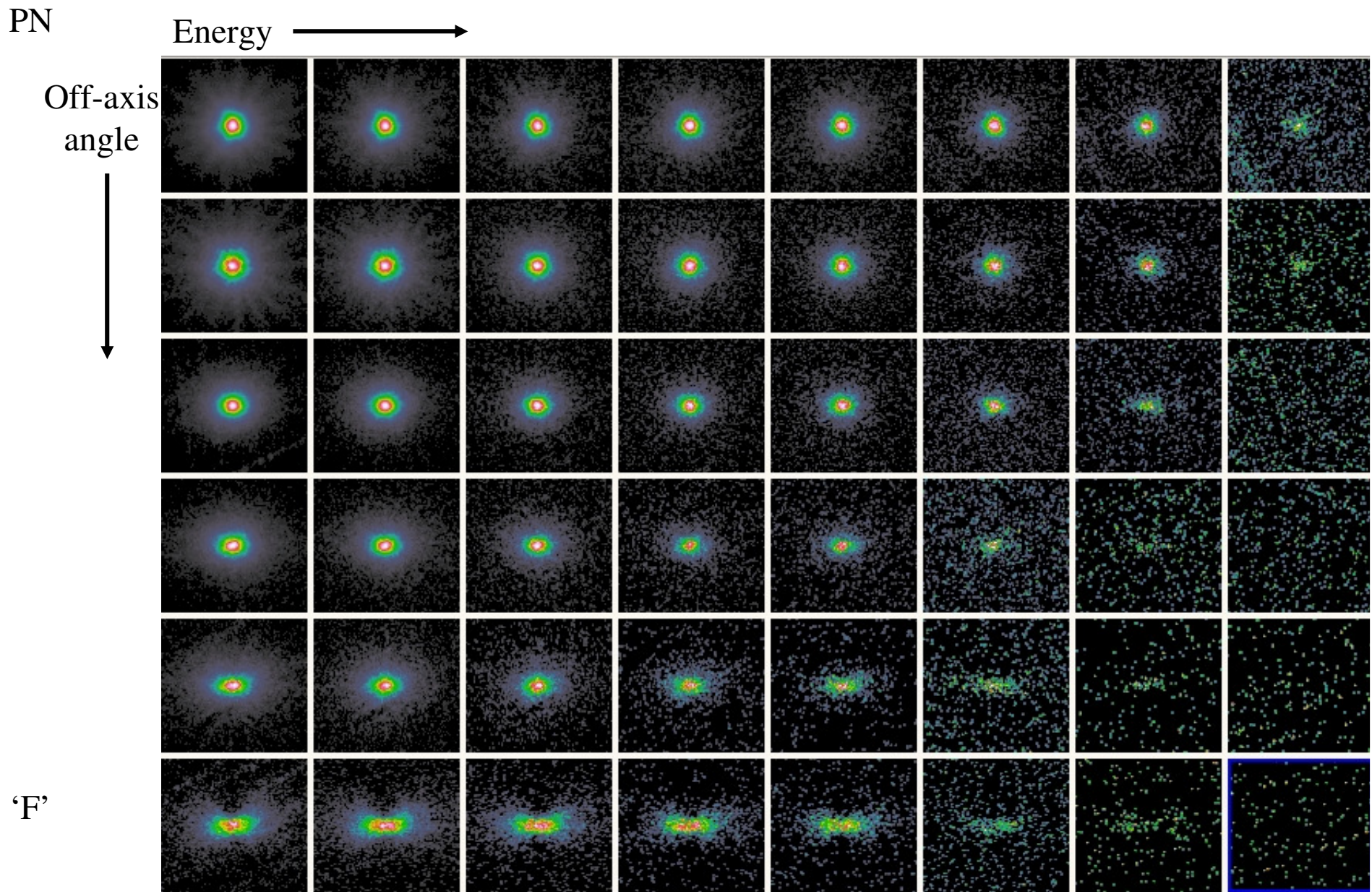


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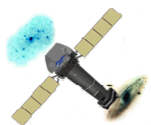
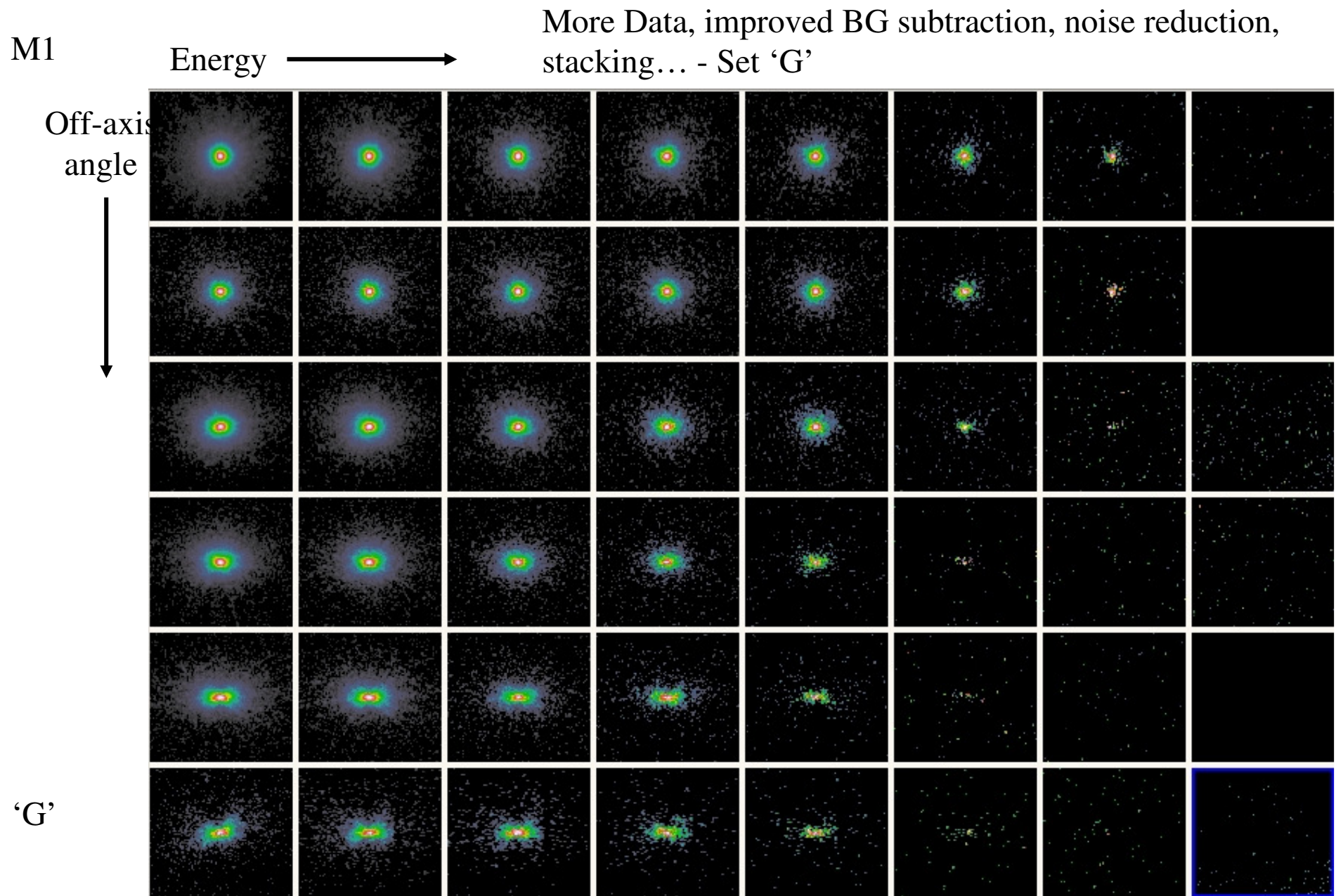


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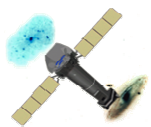
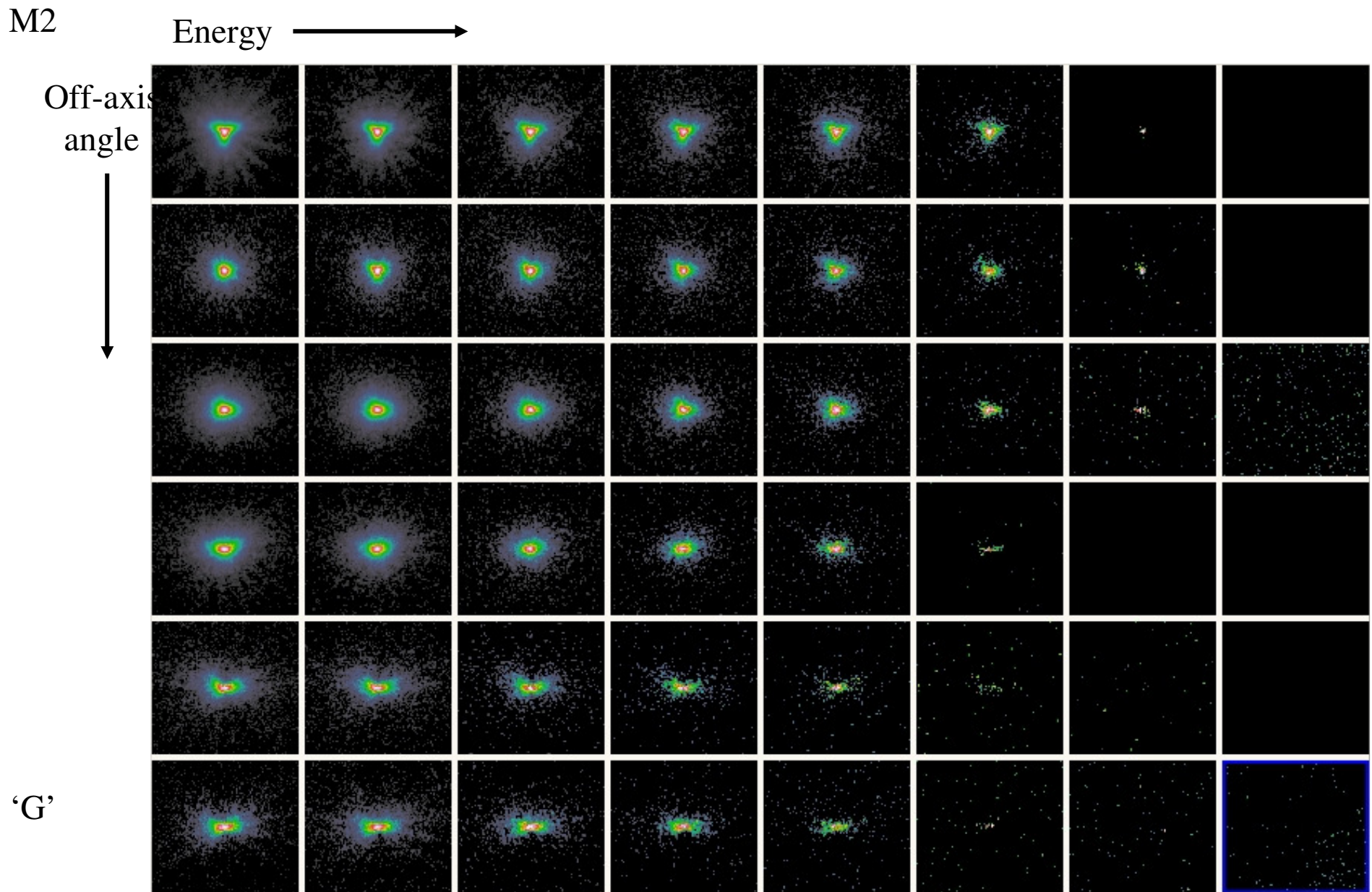


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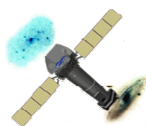
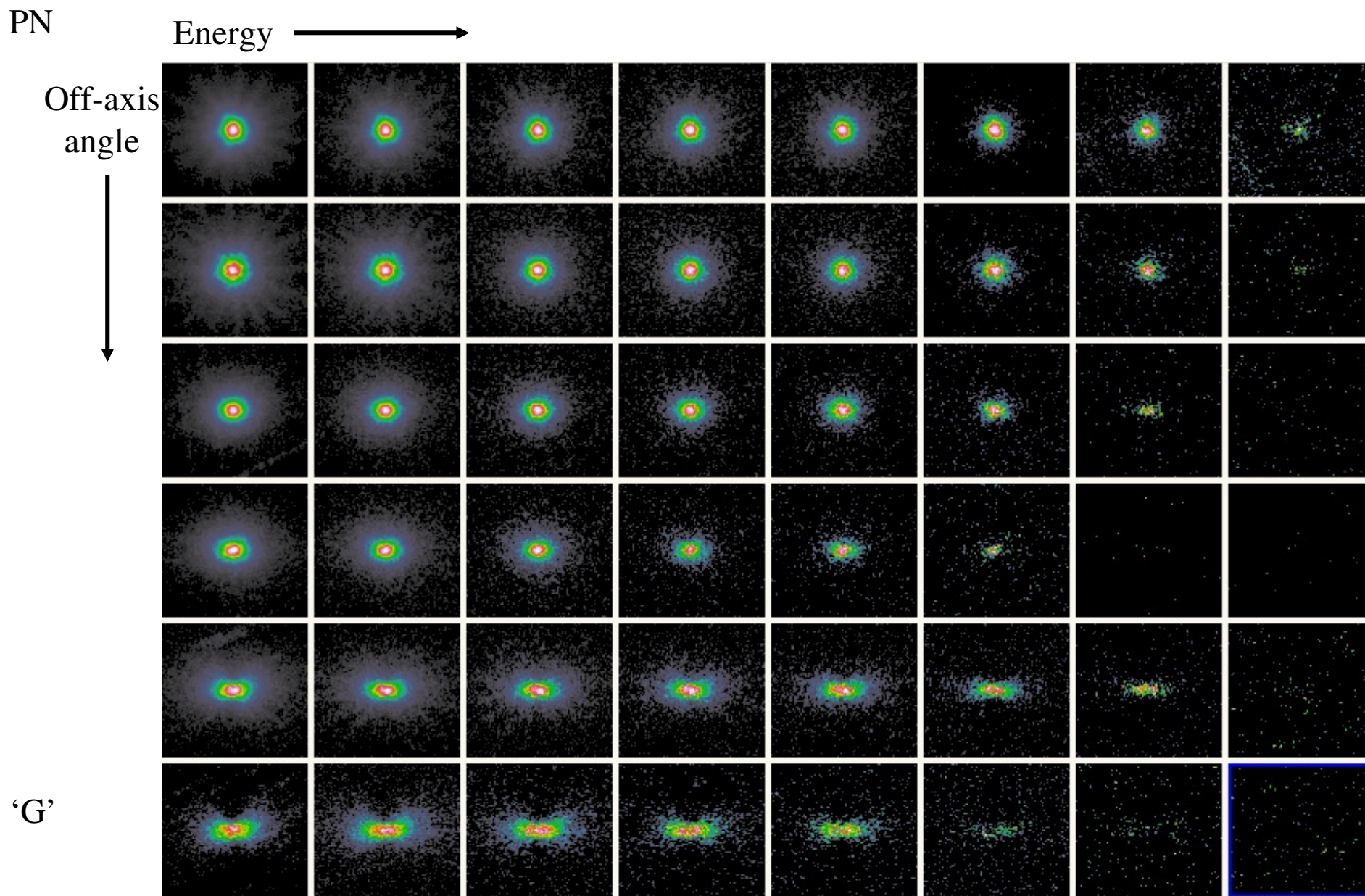


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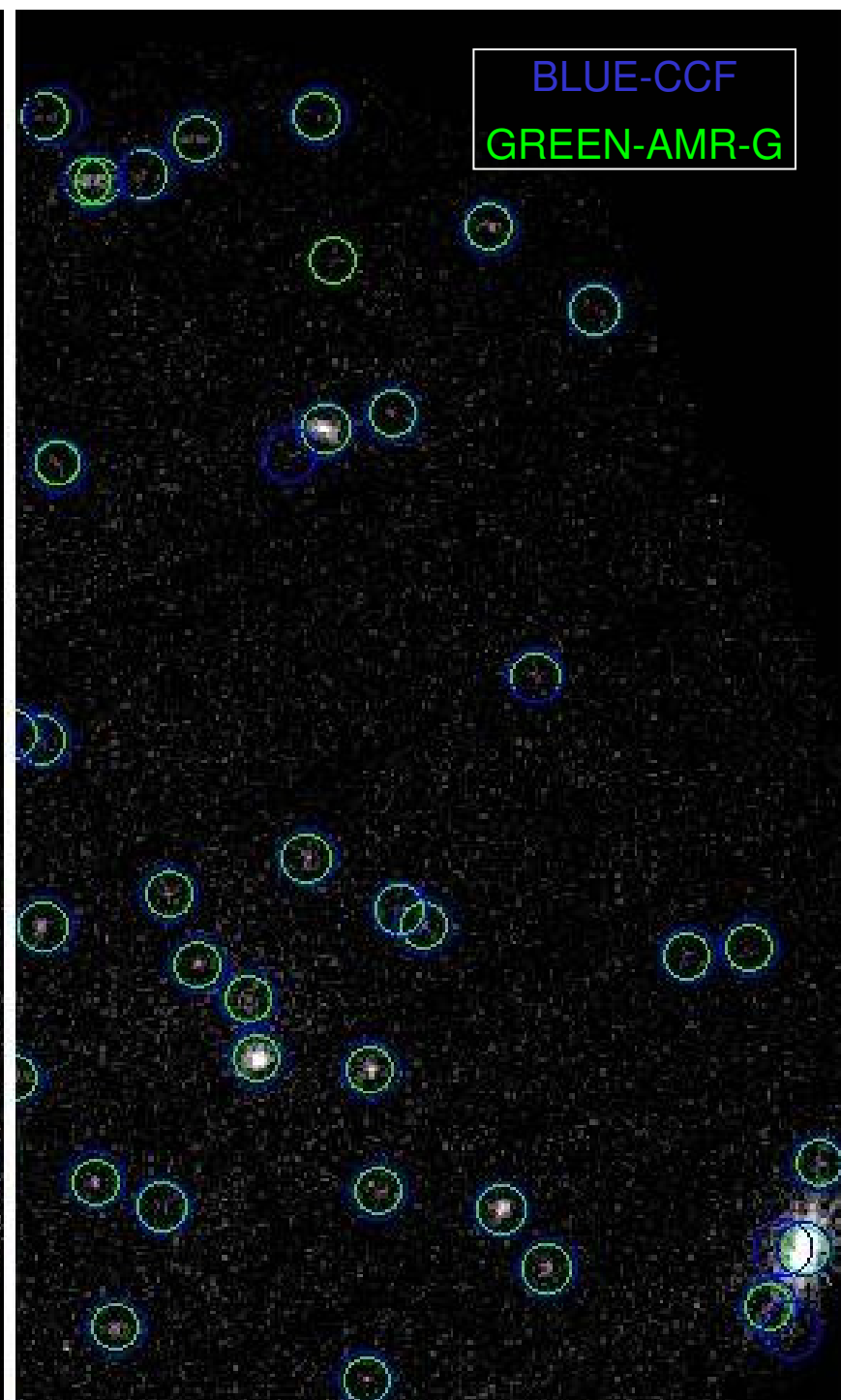
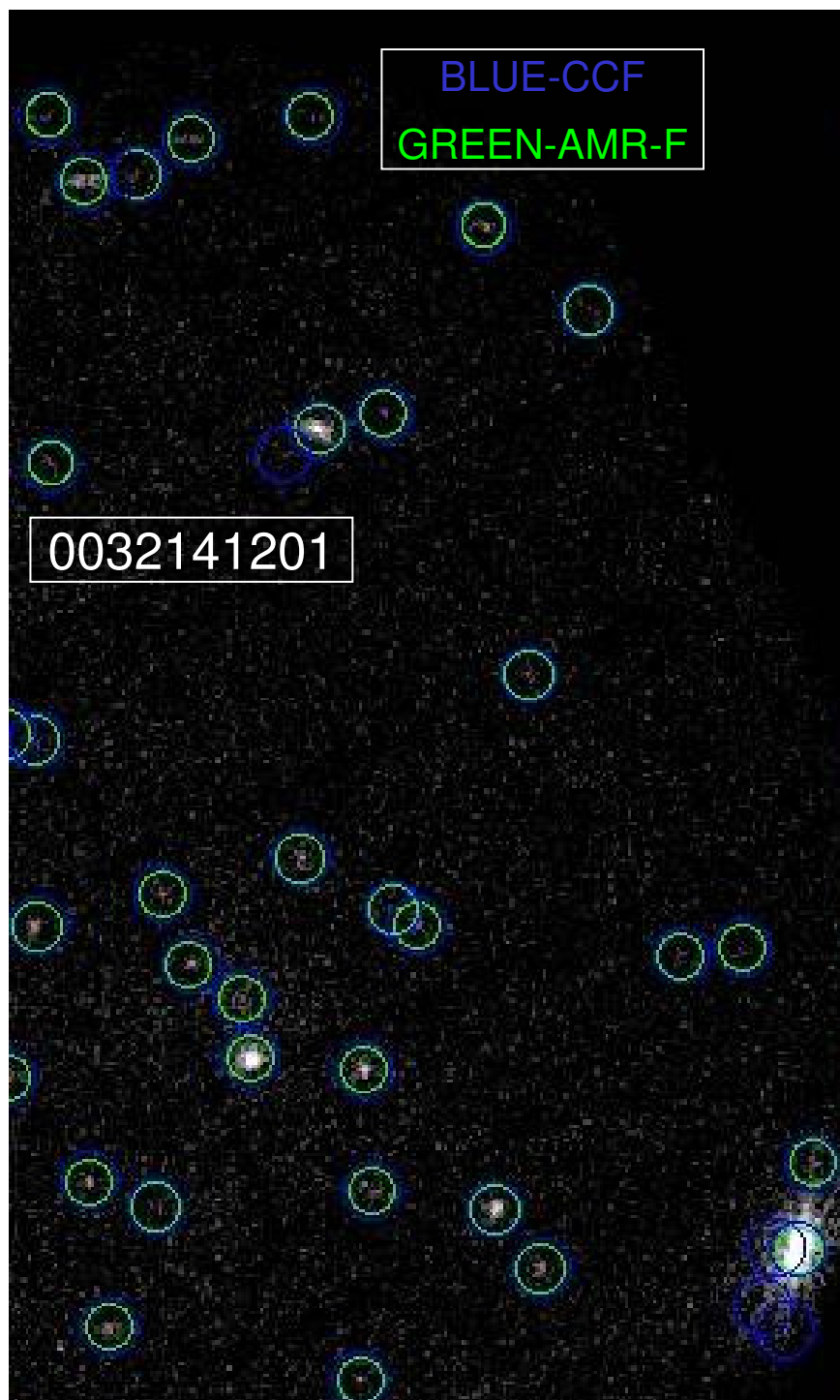


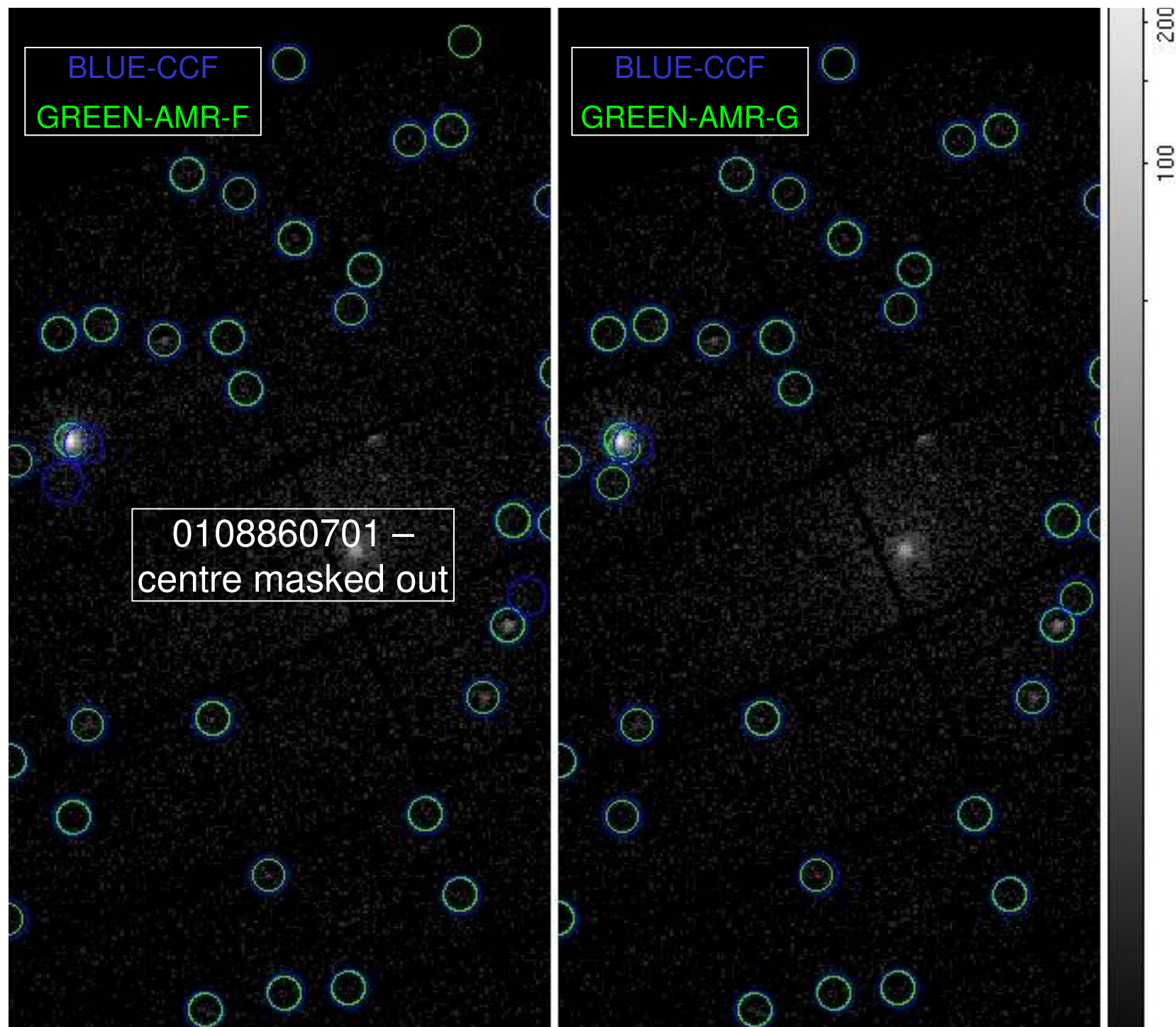
XMM
EPIC
MOS

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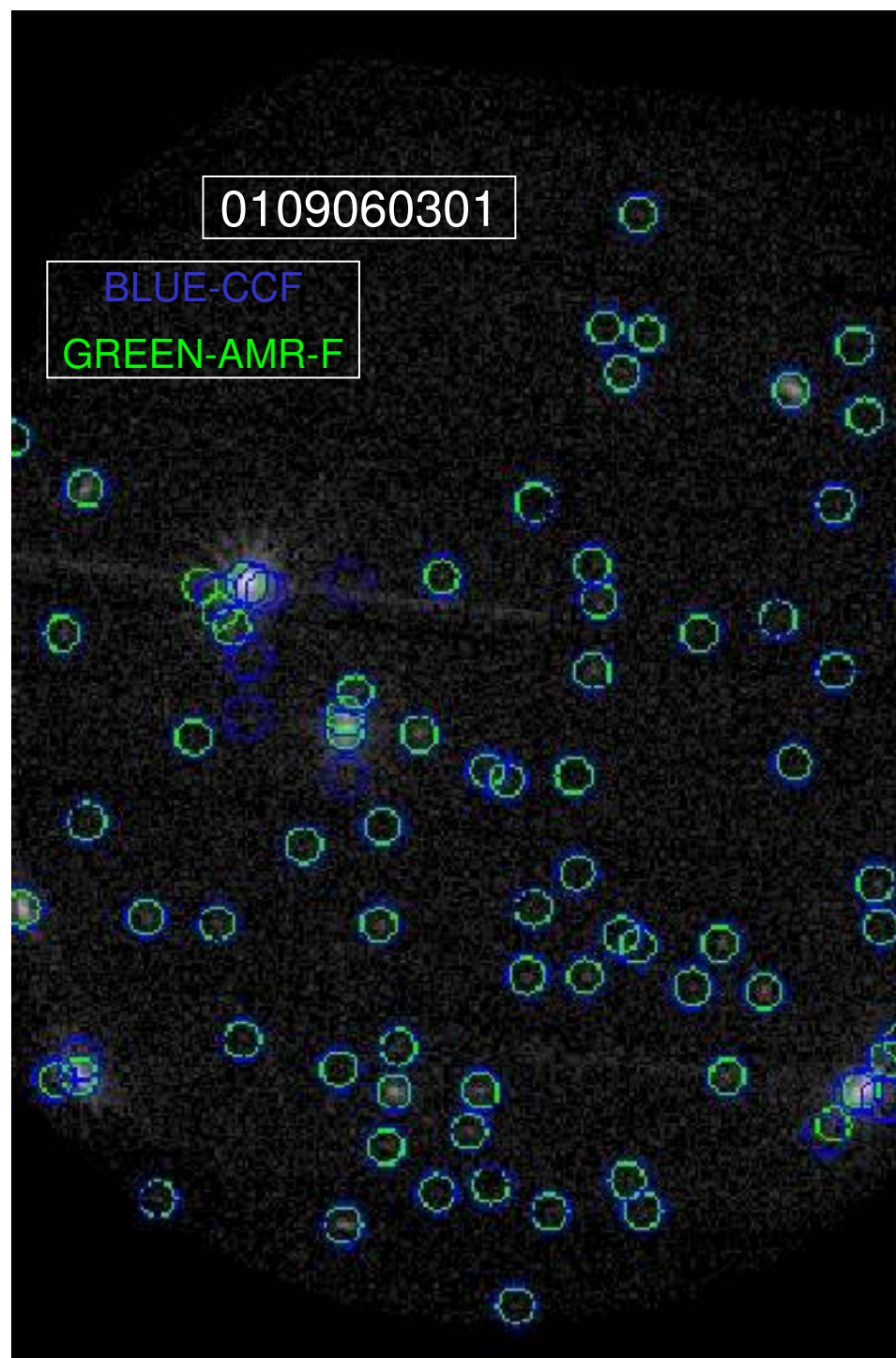




0109060301

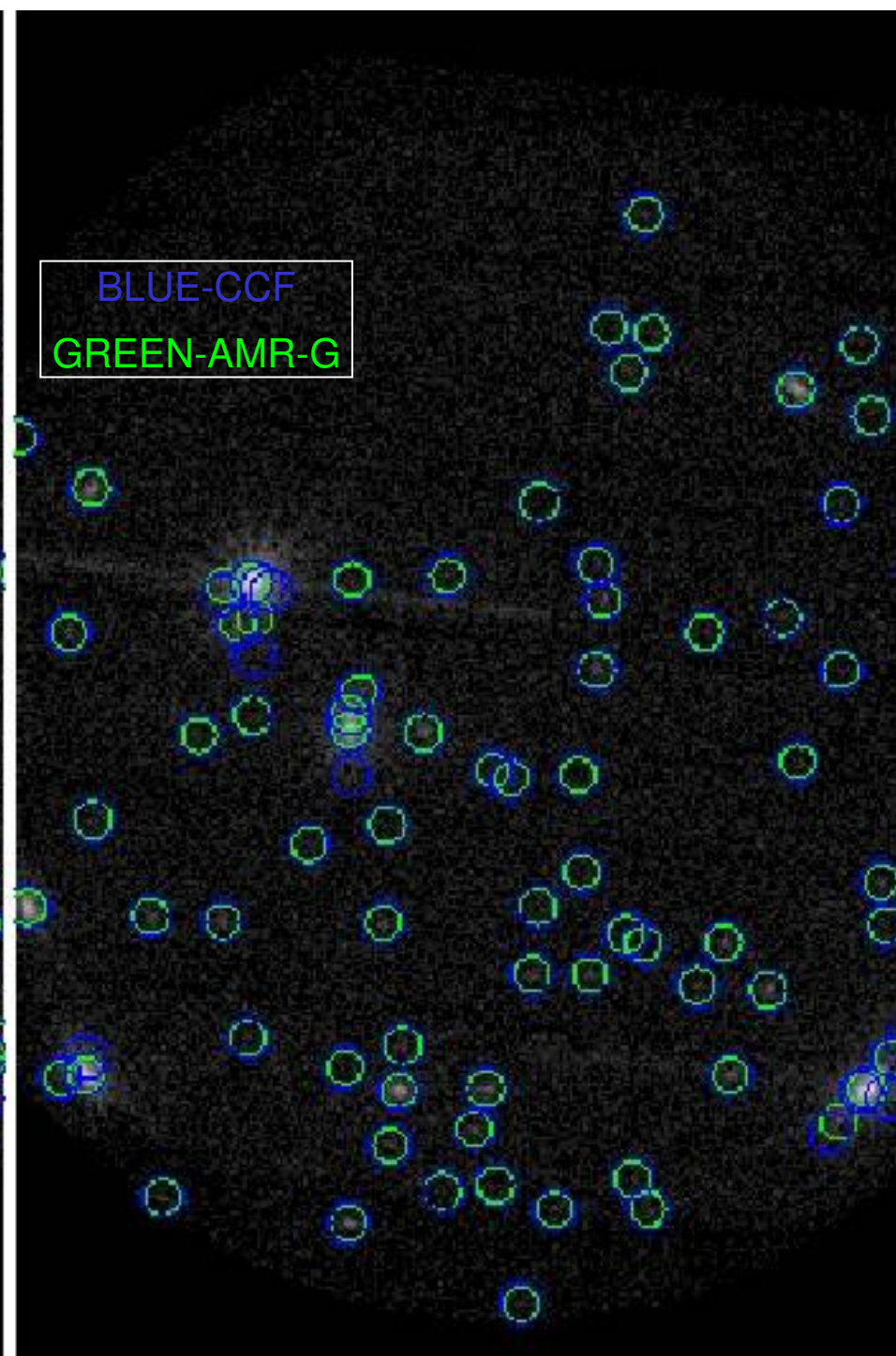
BLUE-CCF

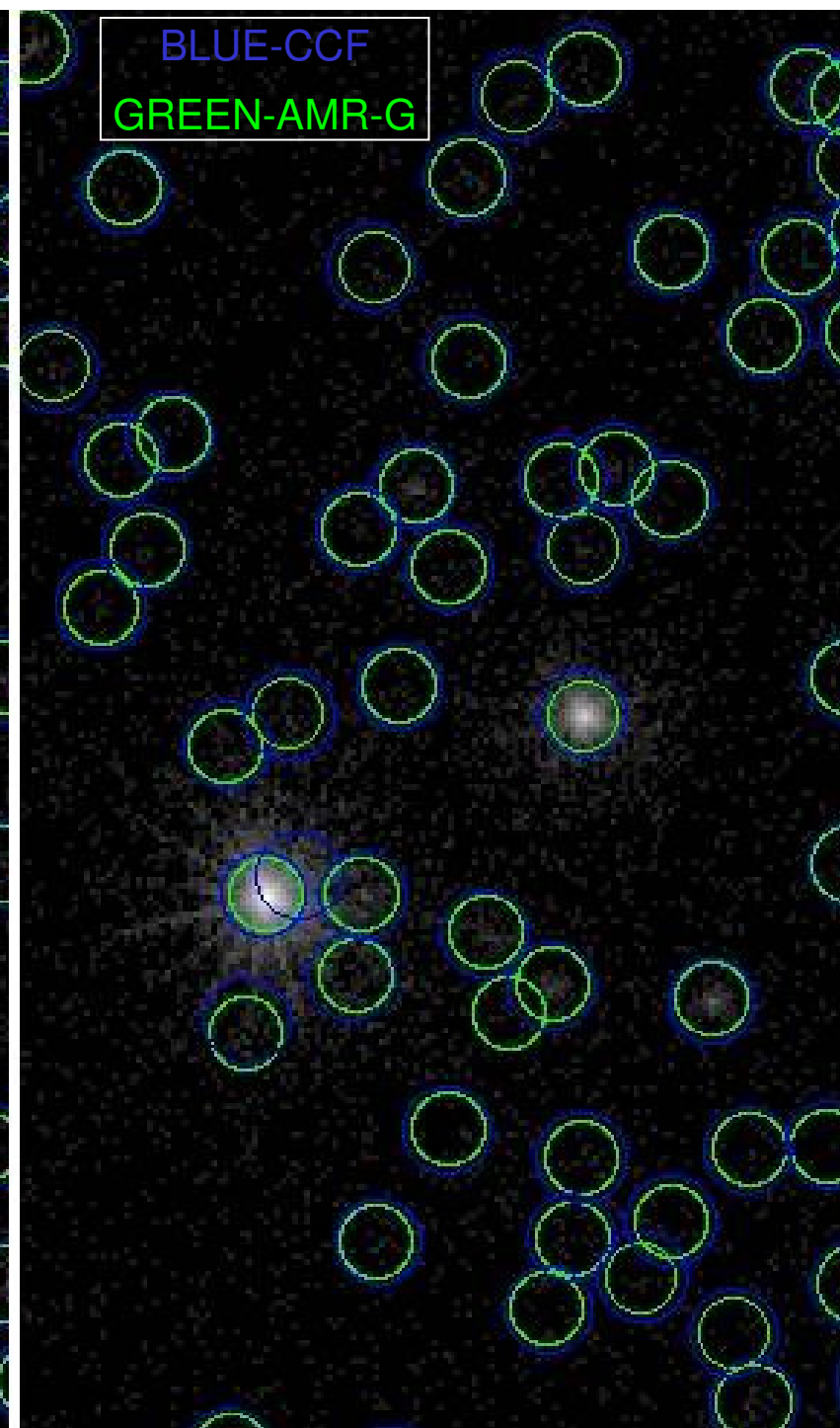
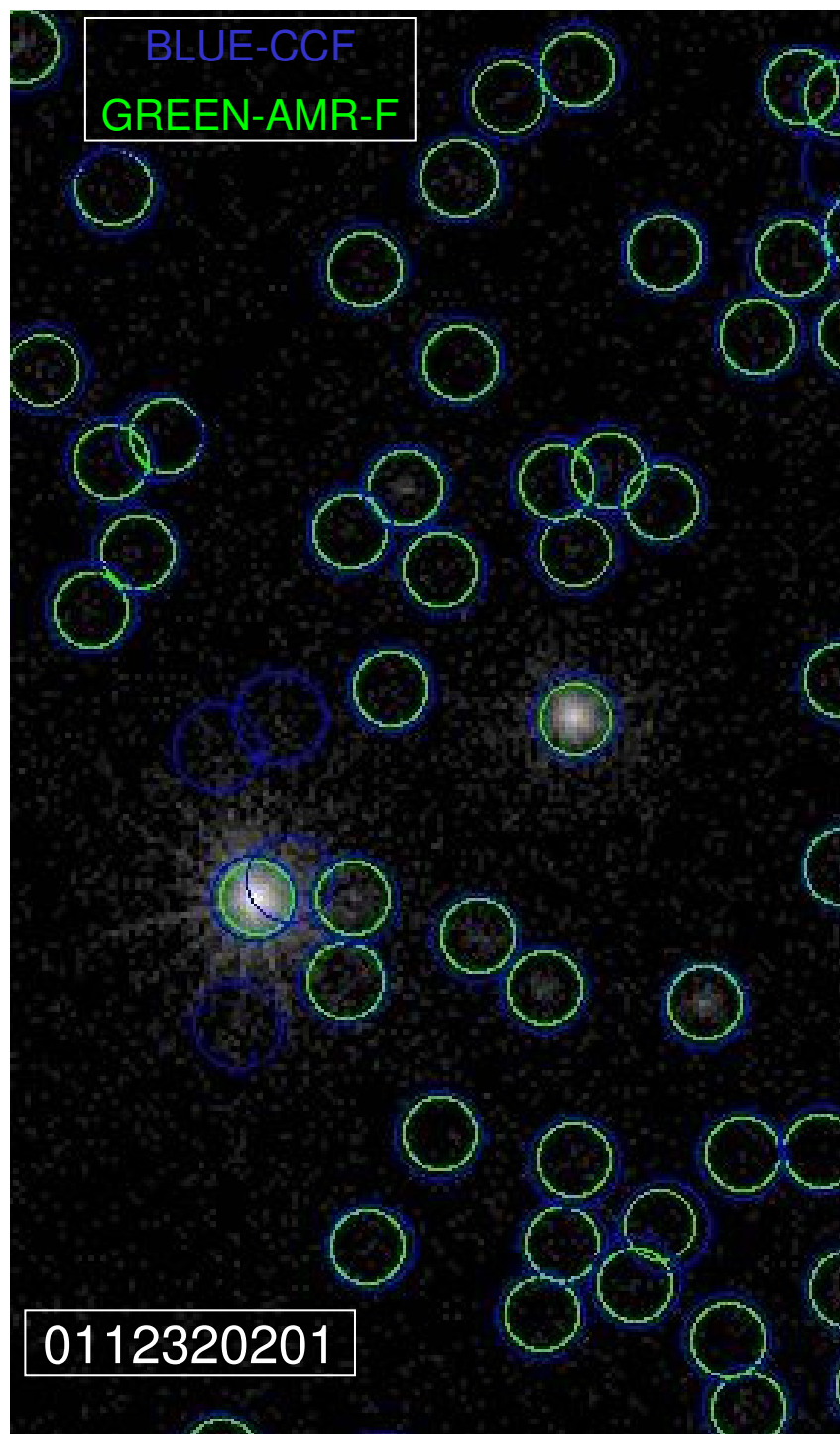
GREEN-AMR-F



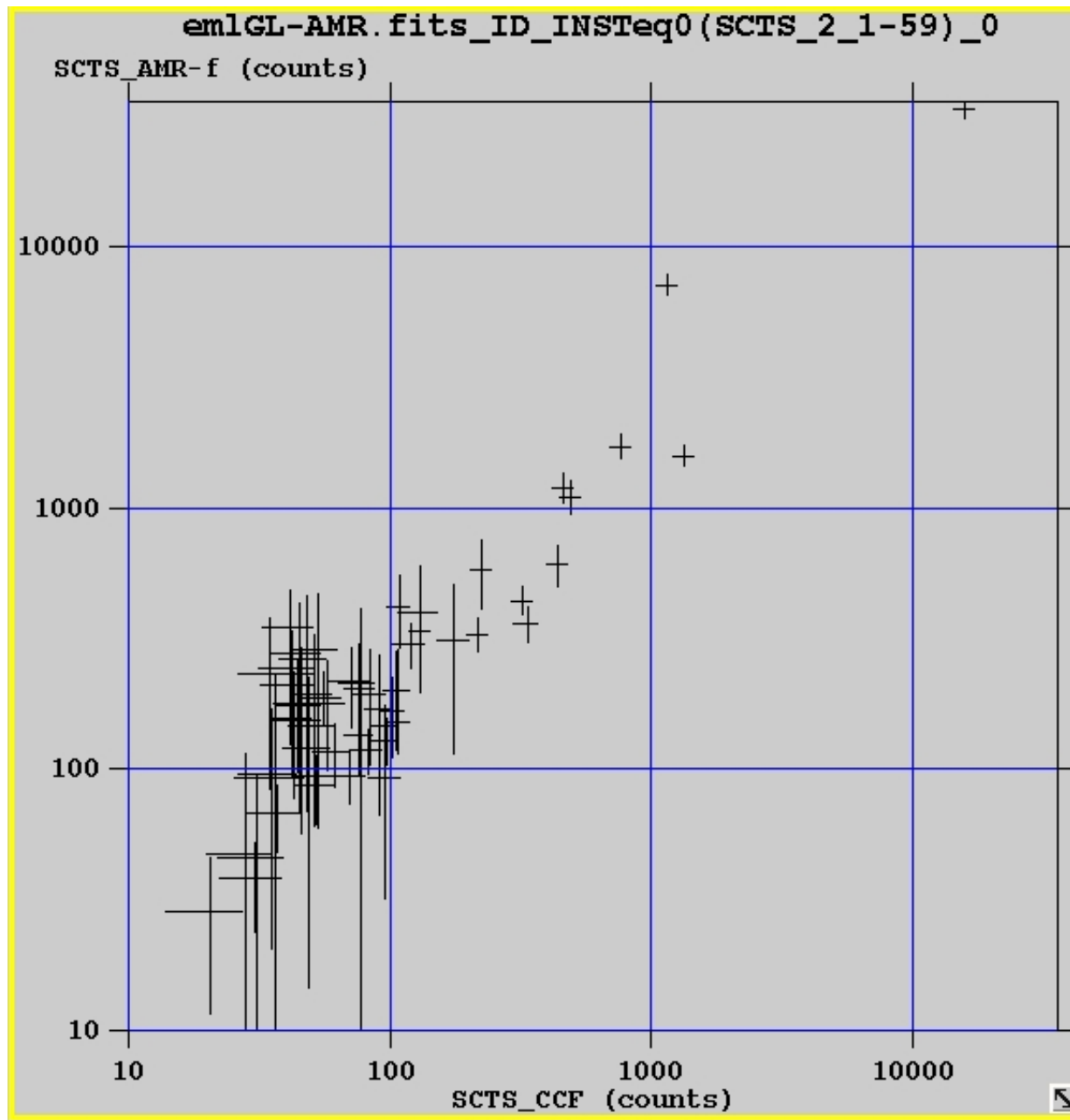
BLUE-CCF

GREEN-AMR-G





100

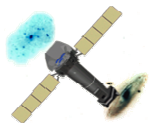


Source-search with AMR-‘F’
CCFs:

0032141201

Estimated source counts

AMR-F v current

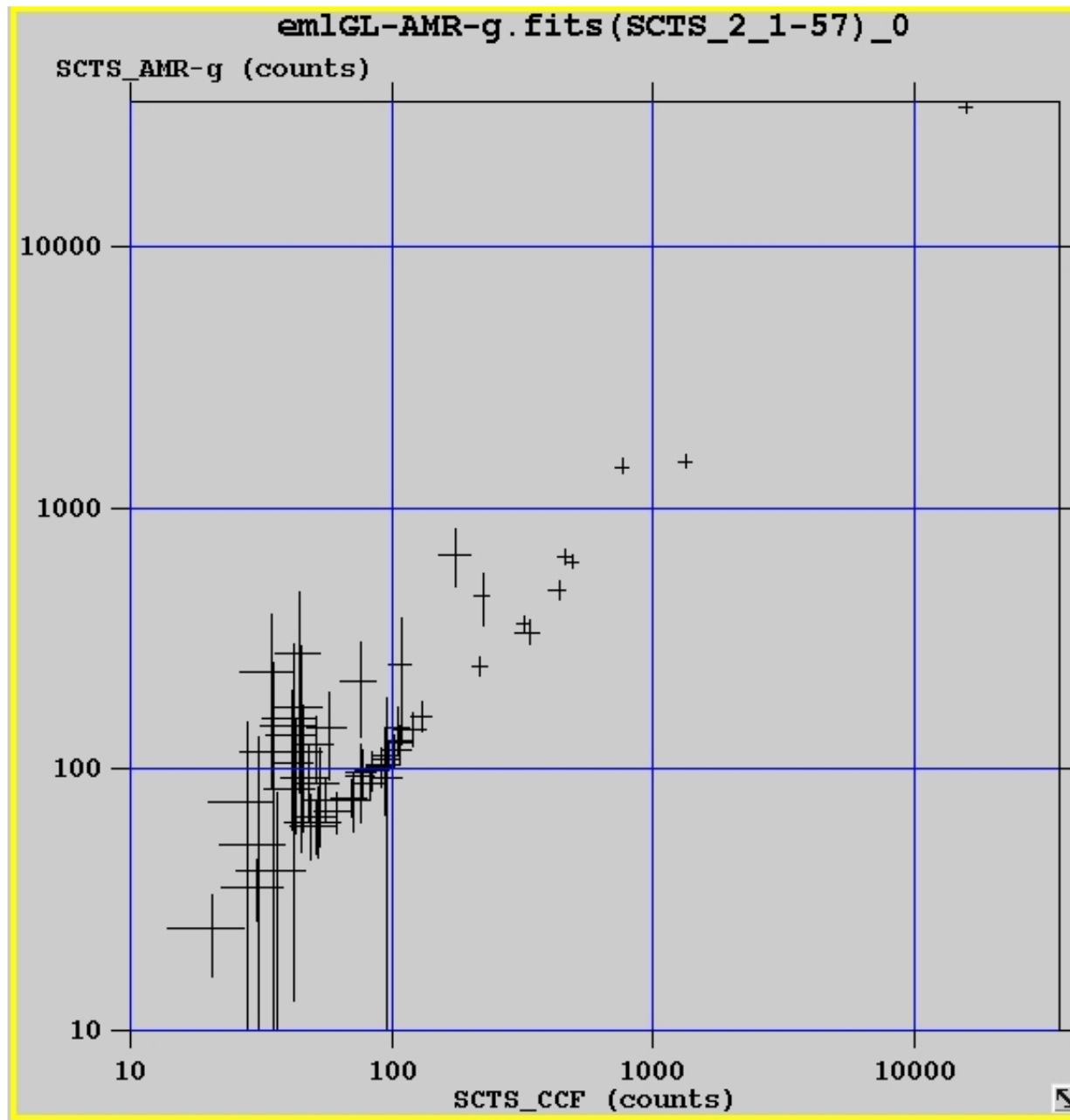


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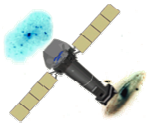


Source-search with AMR-‘G’
CCFs:

0032141201

Estimated source counts

AMR-G v current



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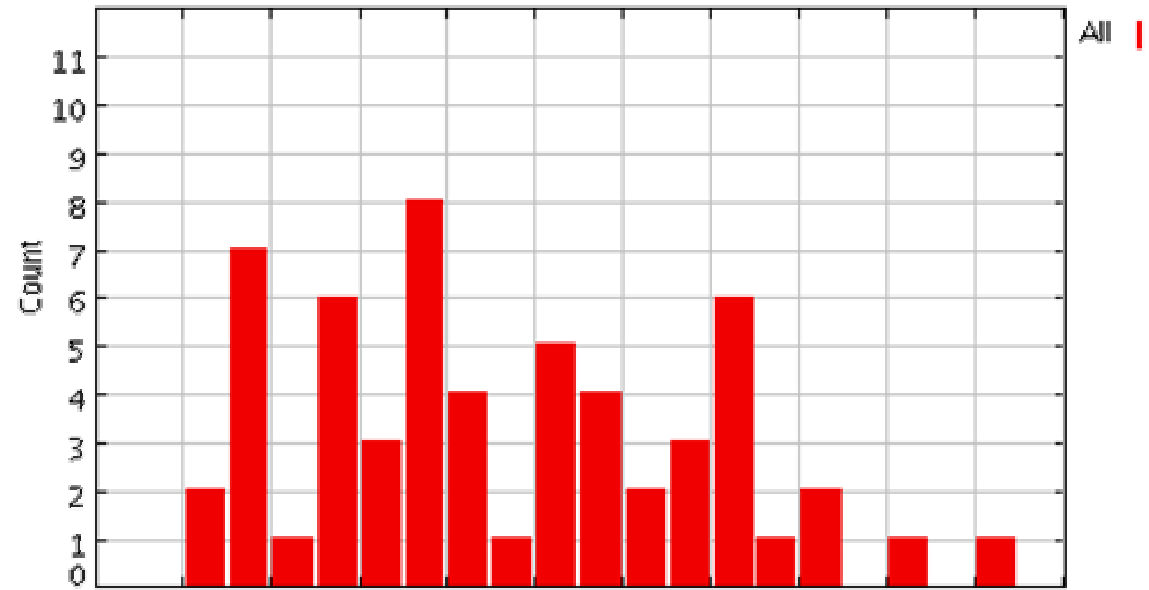
Histogram of Ratio of
Source counts

Current CCF/AMR CCF
(i.e. if CCF believed
should be ~ 1)

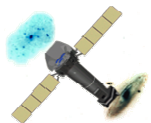
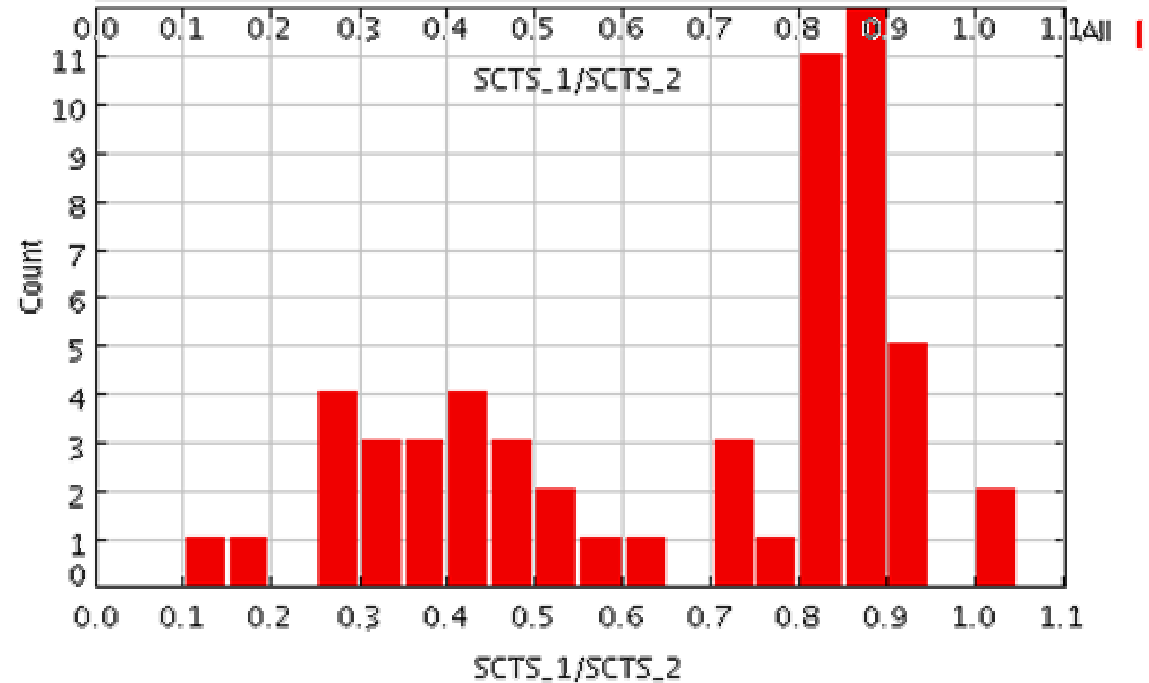
AMR values larger

But G-parameters closer
to current CCF

F



G



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Histogram of Ratio of
Source flux

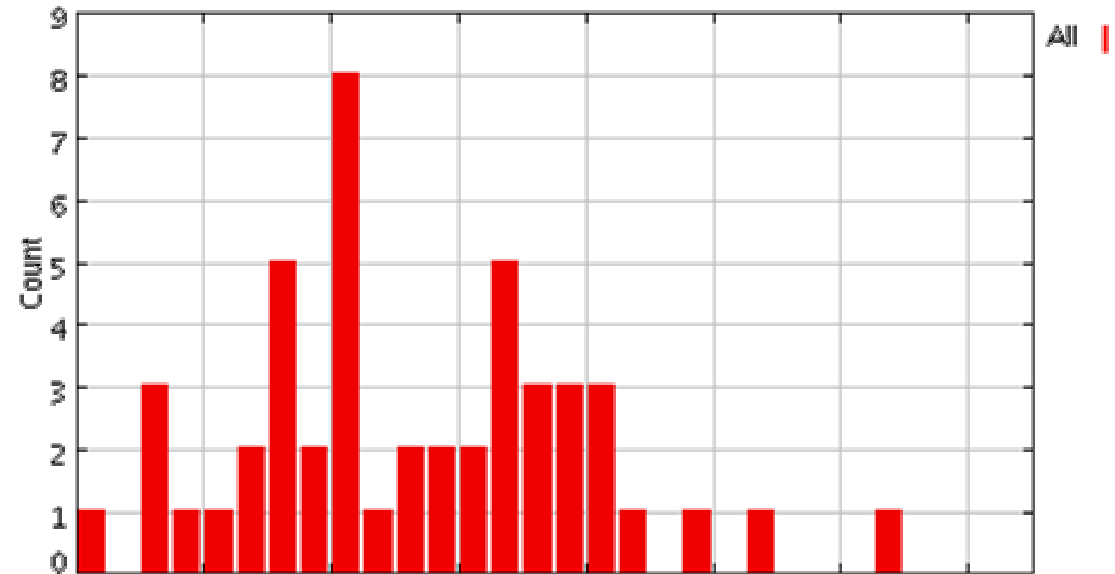
Current CCF/AMR CCF

(i.e. if CCF believed
should be ~ 1)

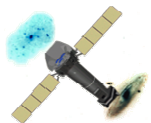
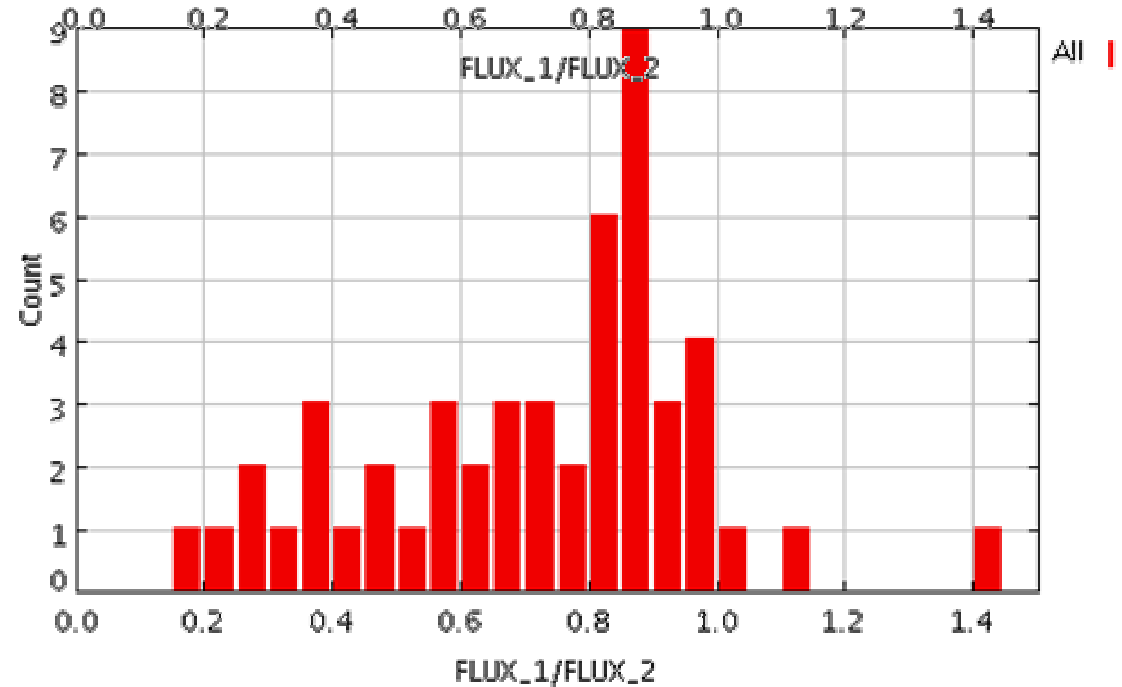
AMR values larger

But G-parameters closer
to current CCF

F



G



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Pause and take stock...

F (simpler) PSFs better at finding sources?

G (more data, less noisy) PSFs better at parameterizing sources?

Add more data... Improve G PSFs...

How about having 2 sets of images in CCF? AMR-F-like images to find the sources, and, once found, present CCF images or best AMR-‘z’ images to parameterize sources? Possible?

– Asked GL.

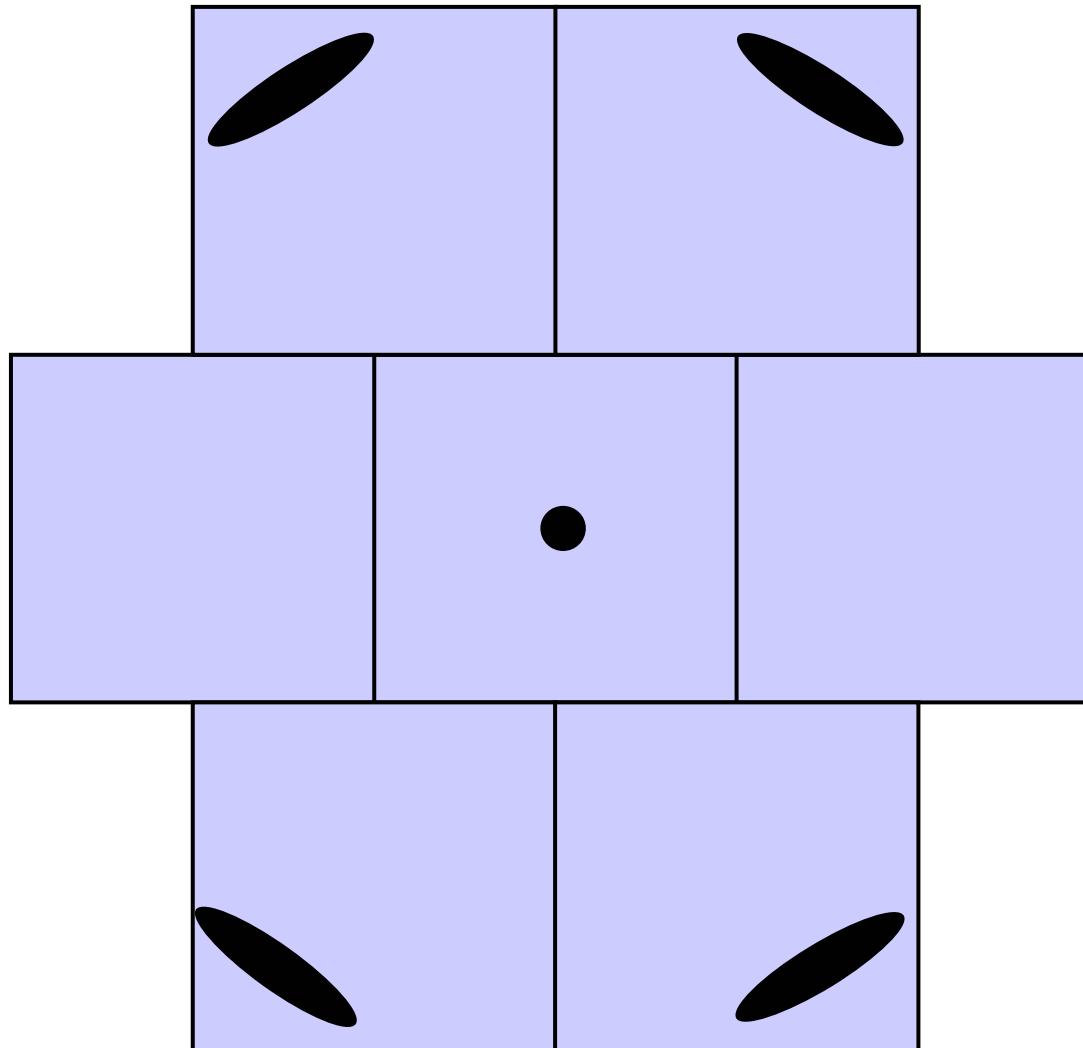
... first, an unusual problem...



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MOS1 (or pn)

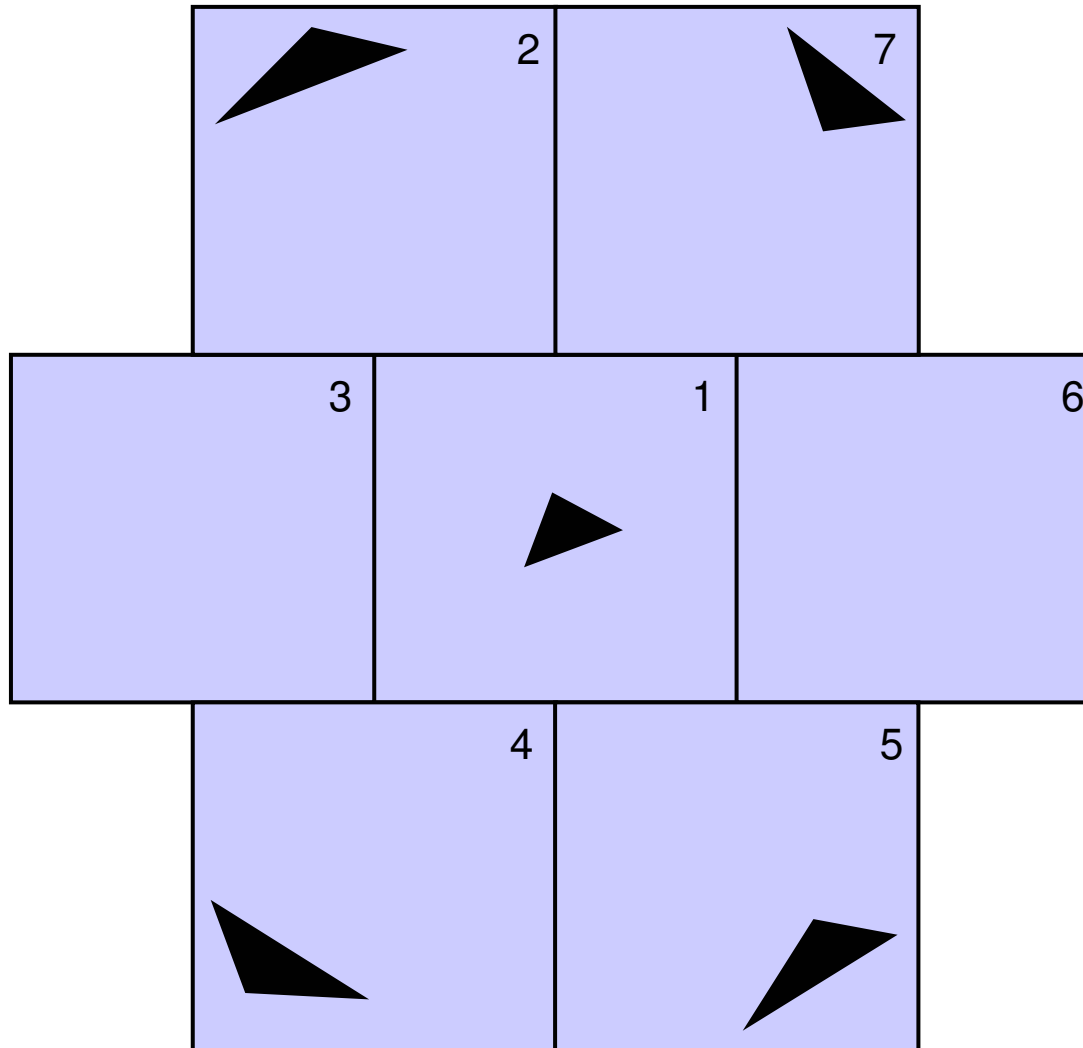


Point source has no obvious 'shape' – it is circularly symmetric

Off-axis versions are stretched tangentially

Off-axis PSFs (at a particular off-axis angle) are all the same shape – can be rotated and stacked

MOS2

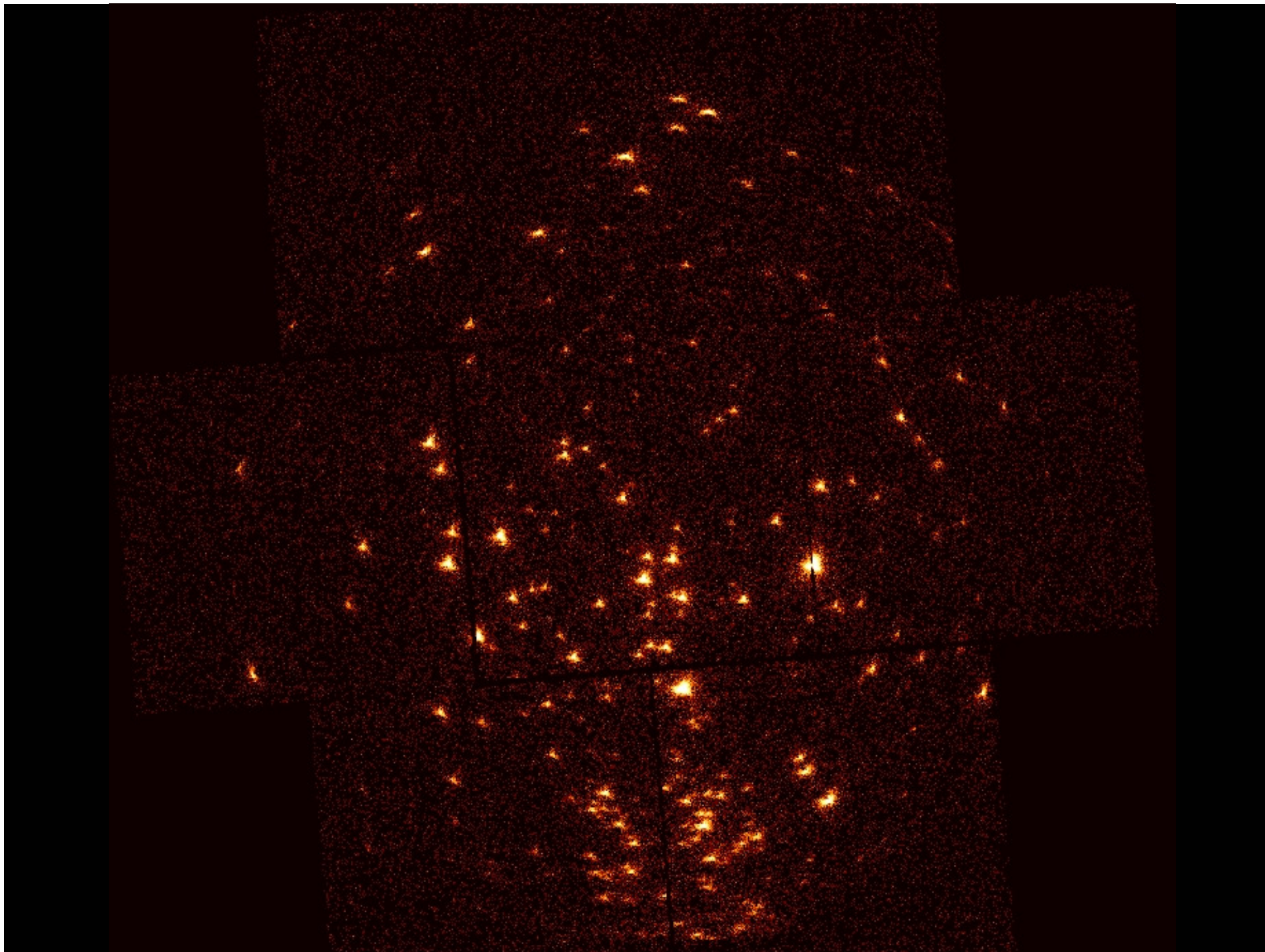


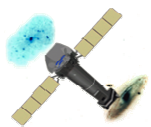
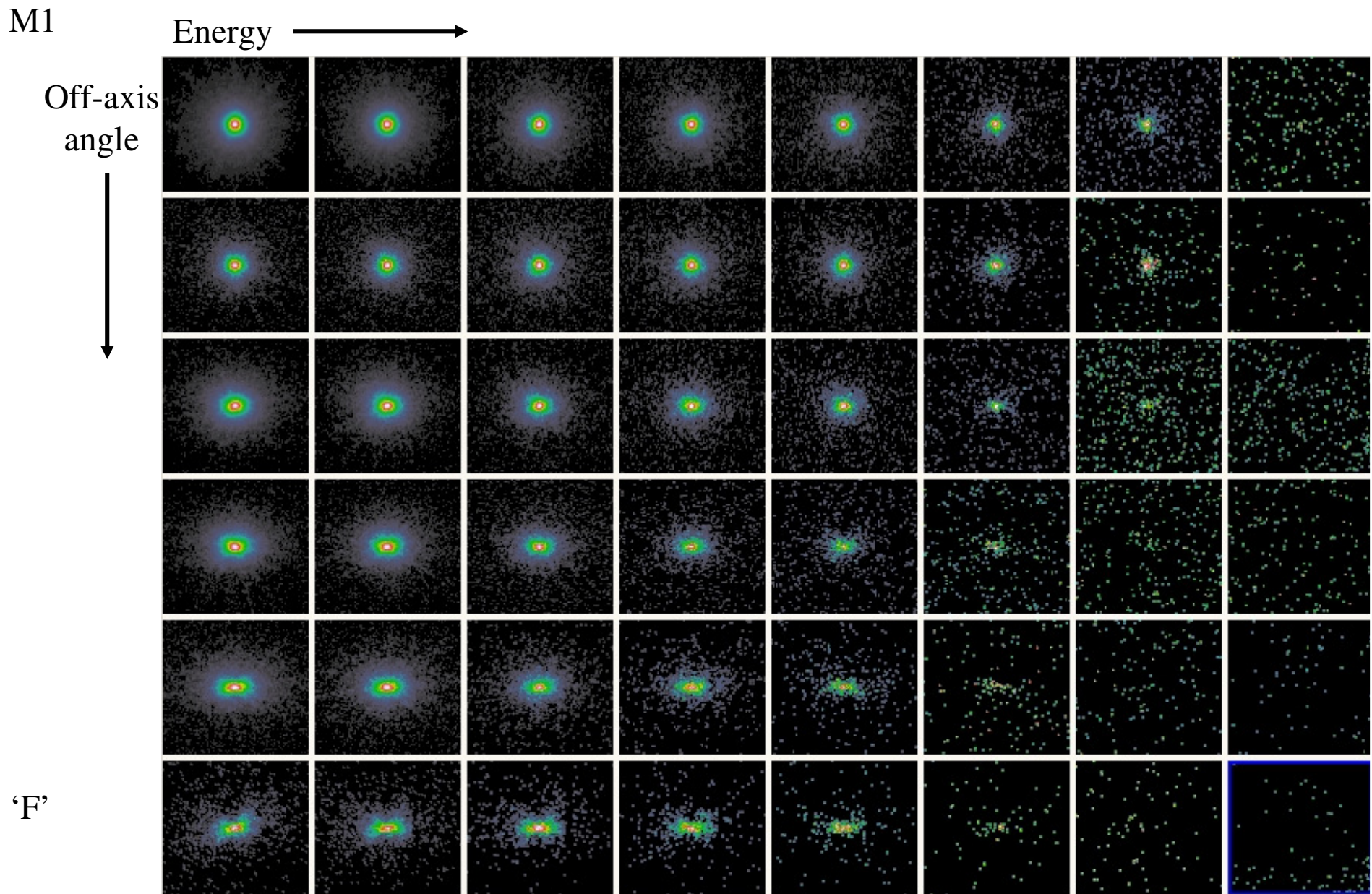
Point source has an obvious 'shape' – it is **not** circularly symmetric

Off-axis versions are stretched tangentially

Off-axis PSFs (at a particular off-axis angle) are all of **different** shape – **cannot** be rotated and stacked

Unless one has several bright sources at every point on the MOS2 detector, one must sacrifice either stretch or (orientation of) shape.



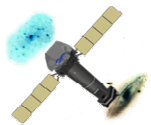
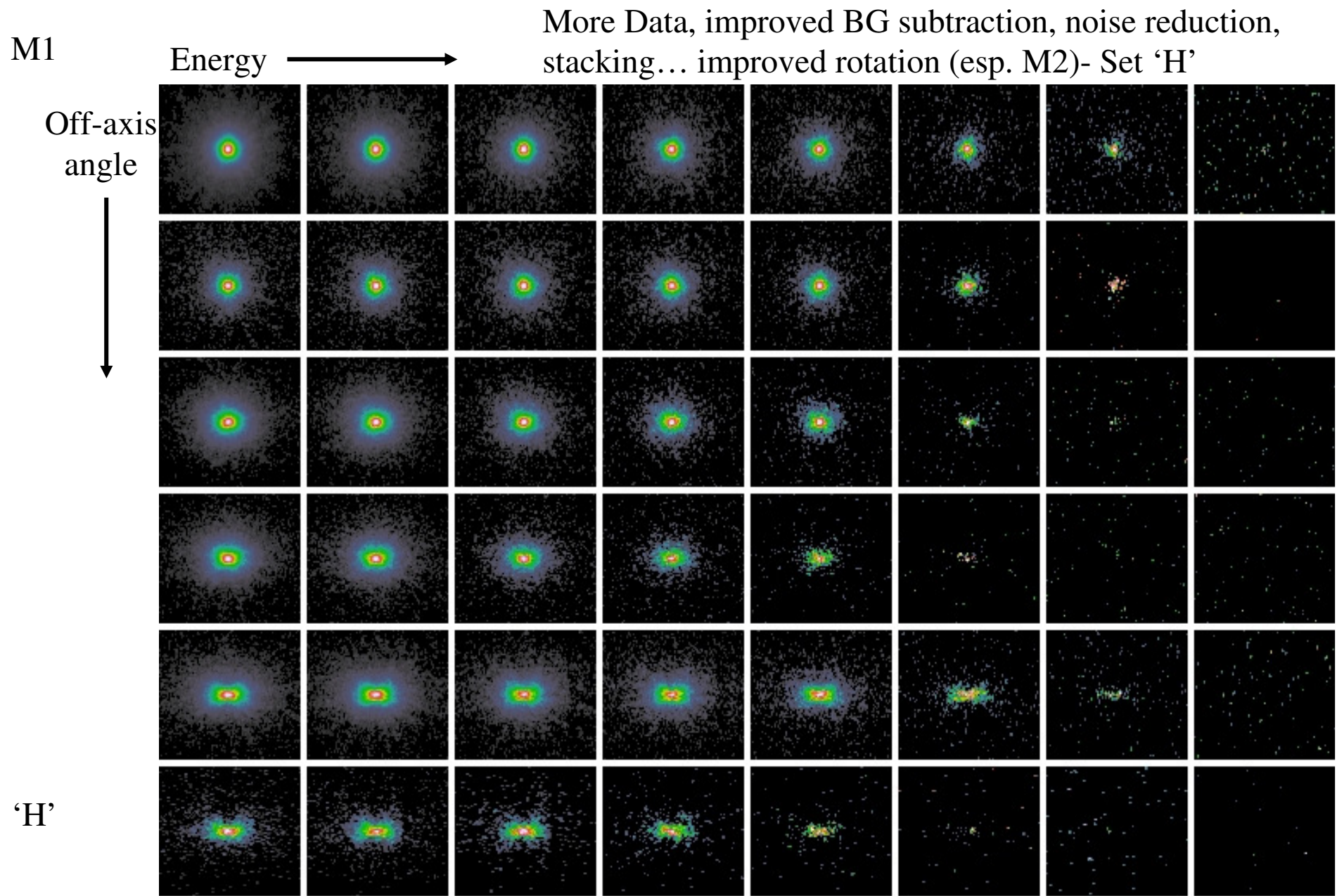


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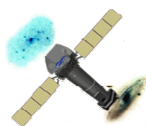
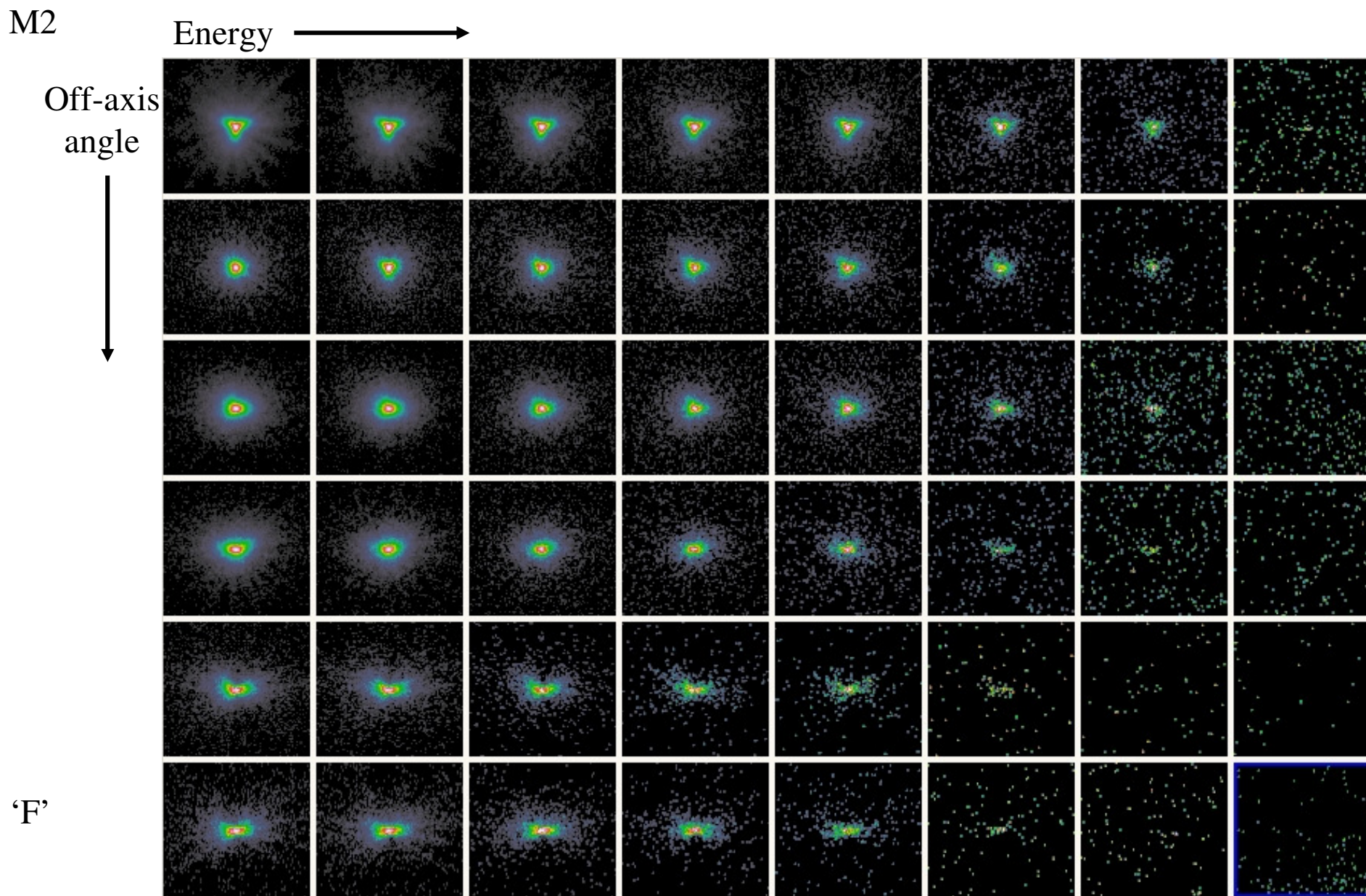


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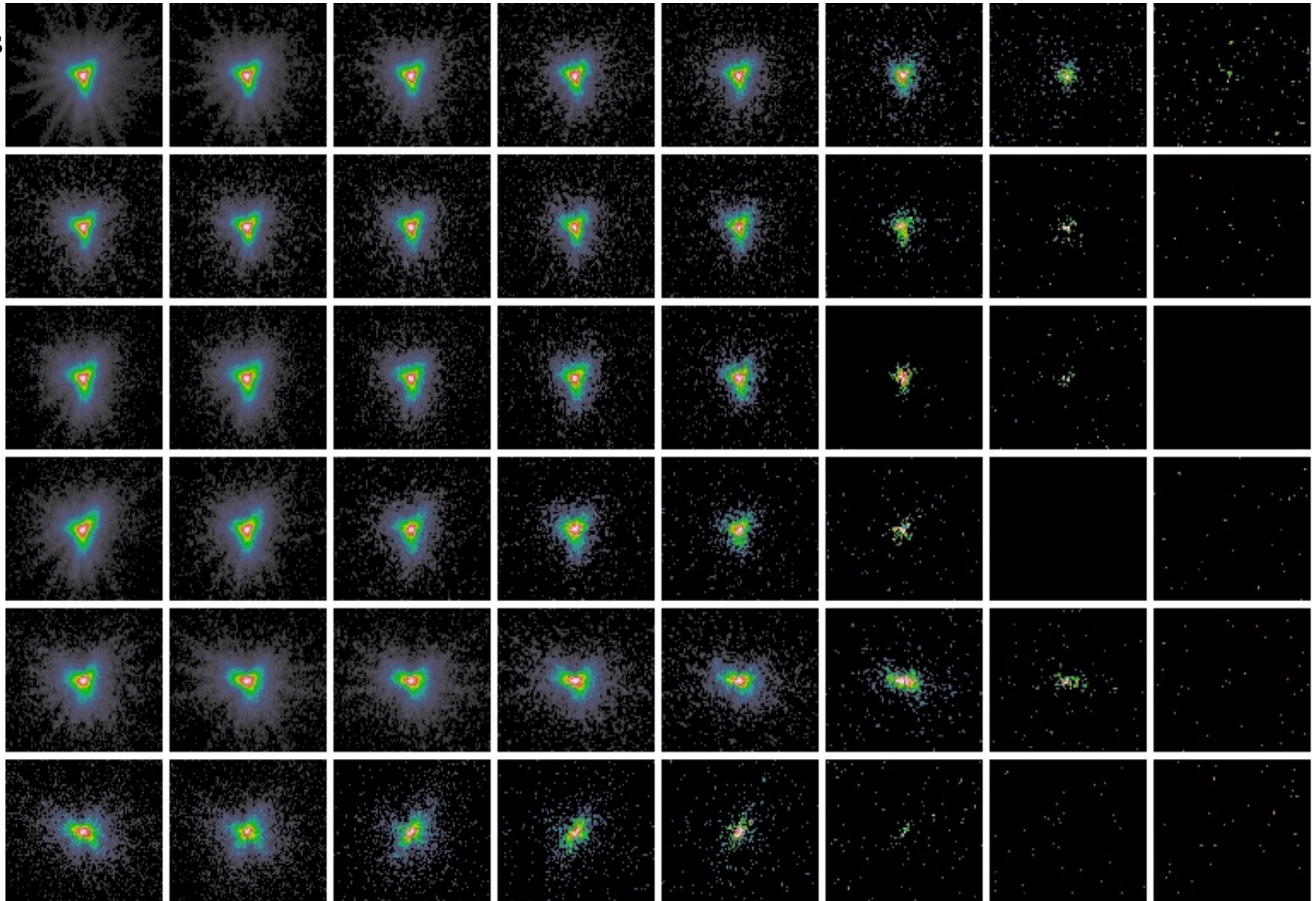
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M2

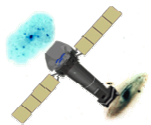
Energy →

n.b. M2 shape retained...

Off-axis
angle



‘H’

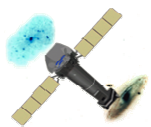
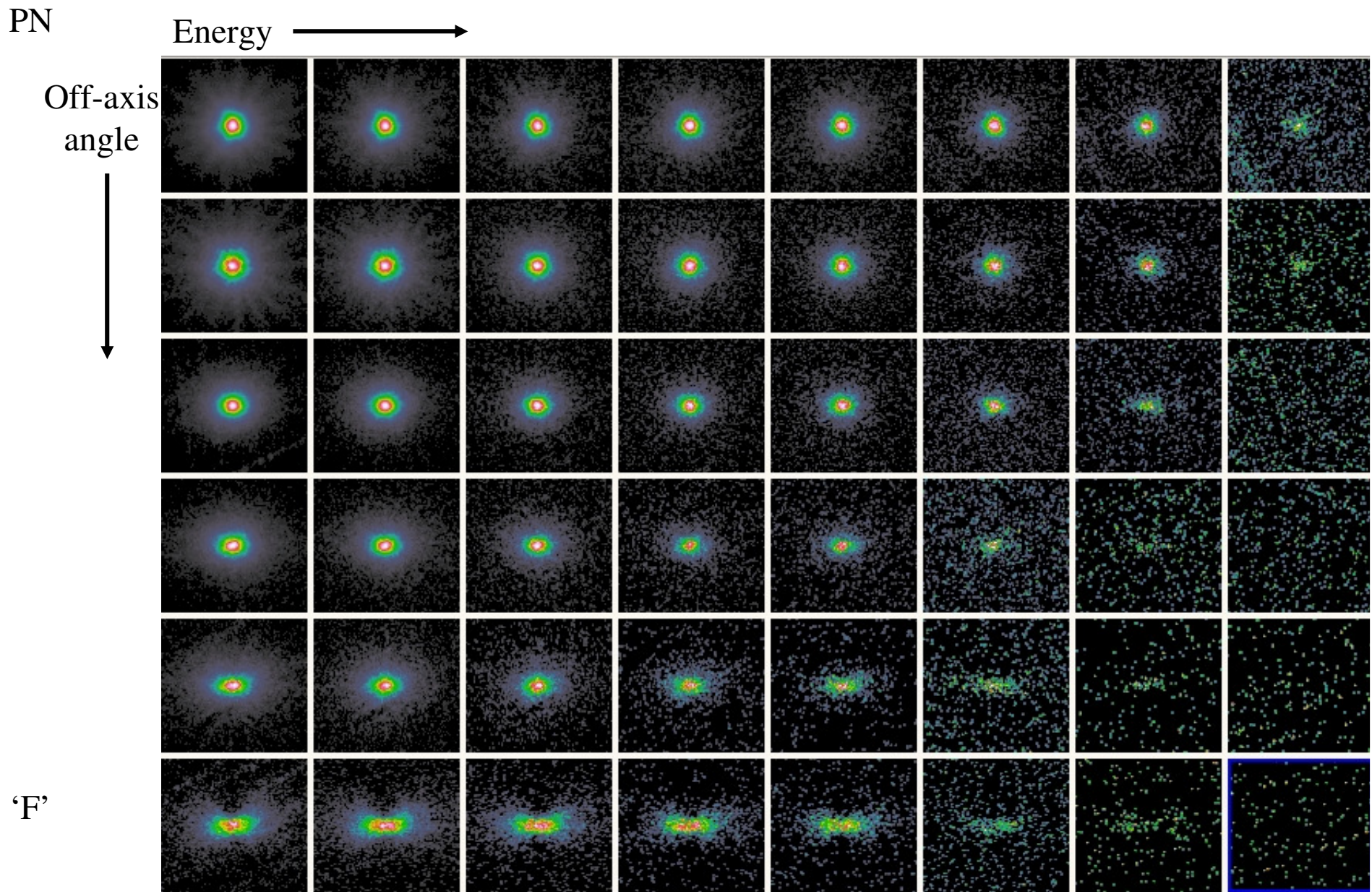


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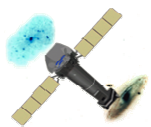
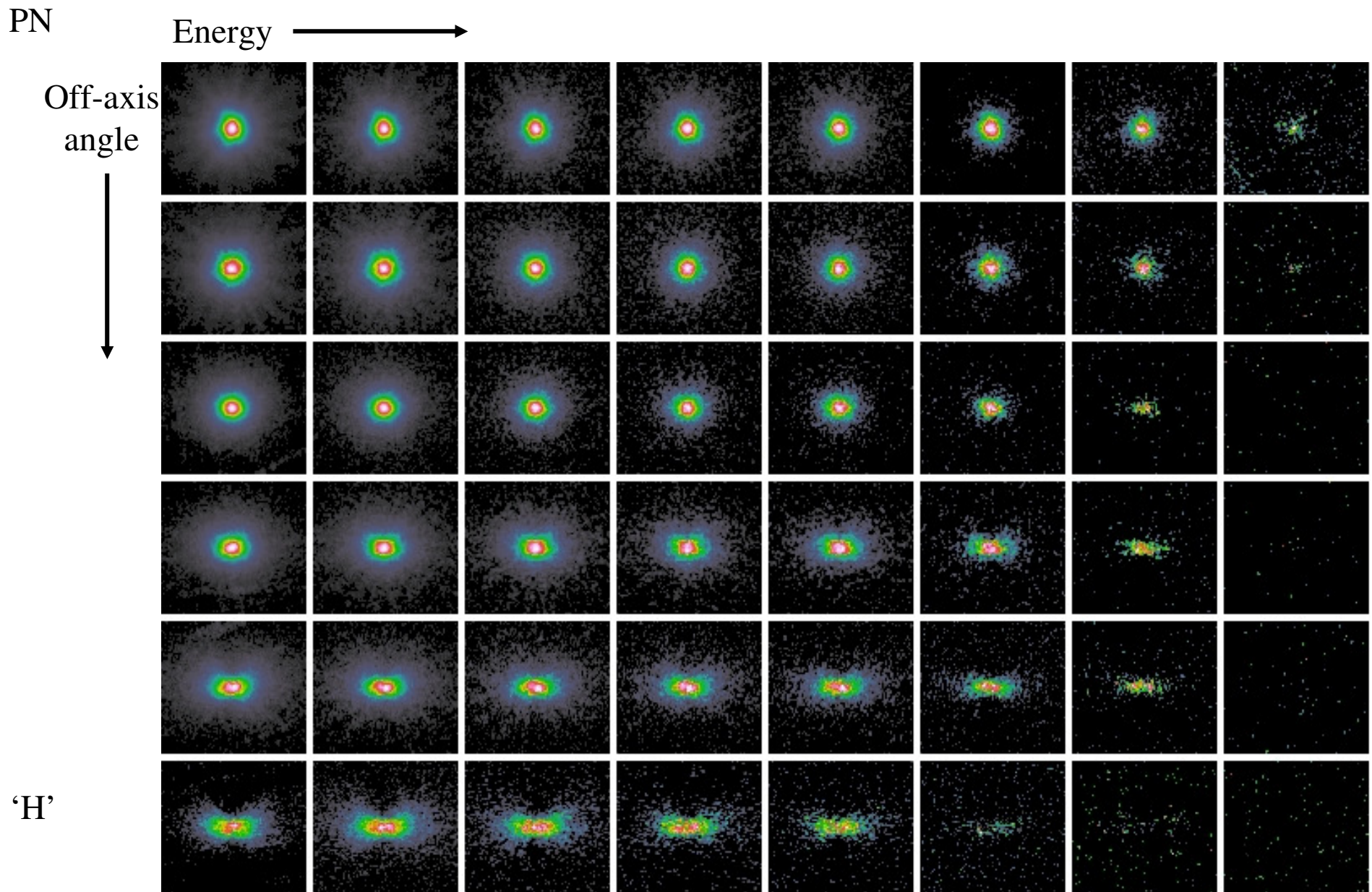


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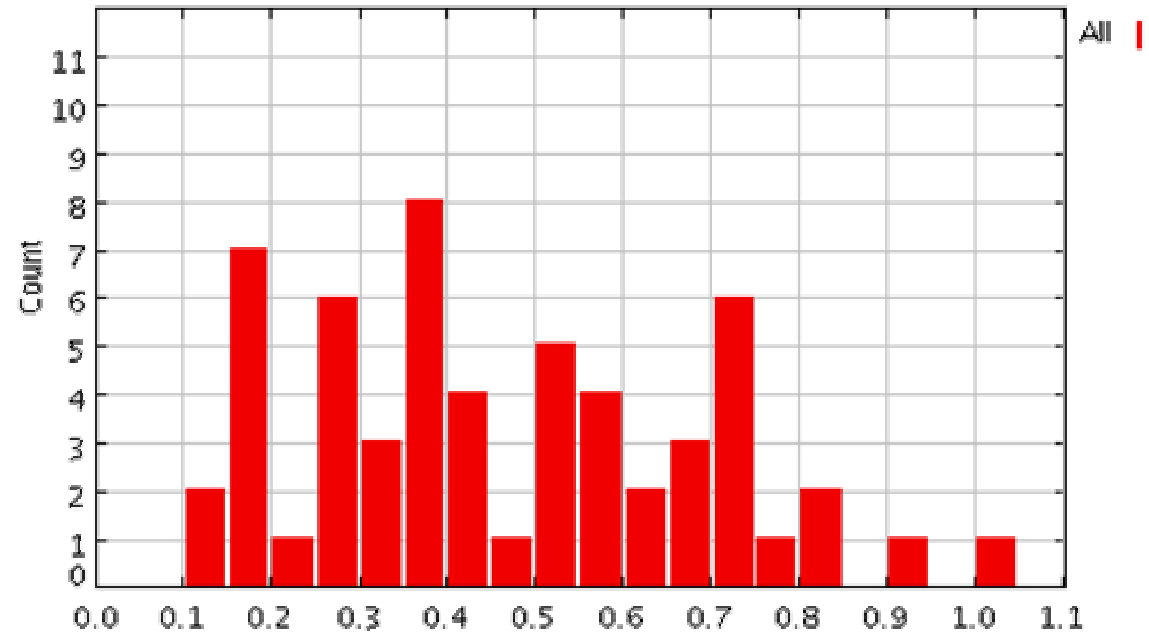
Histogram of Ratio of
Source counts

Current CCF/AMR CCF

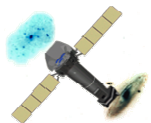
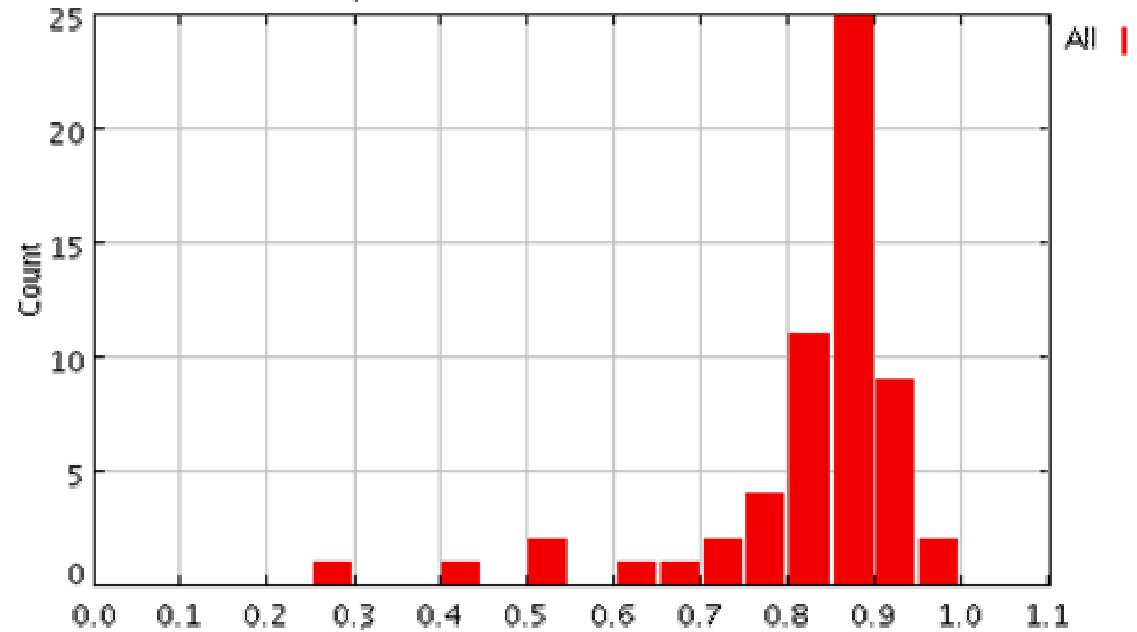
(i.e. if CCF believed
should be ~ 1)

AMR values larger

F



H



XMM
EPIC
MOS

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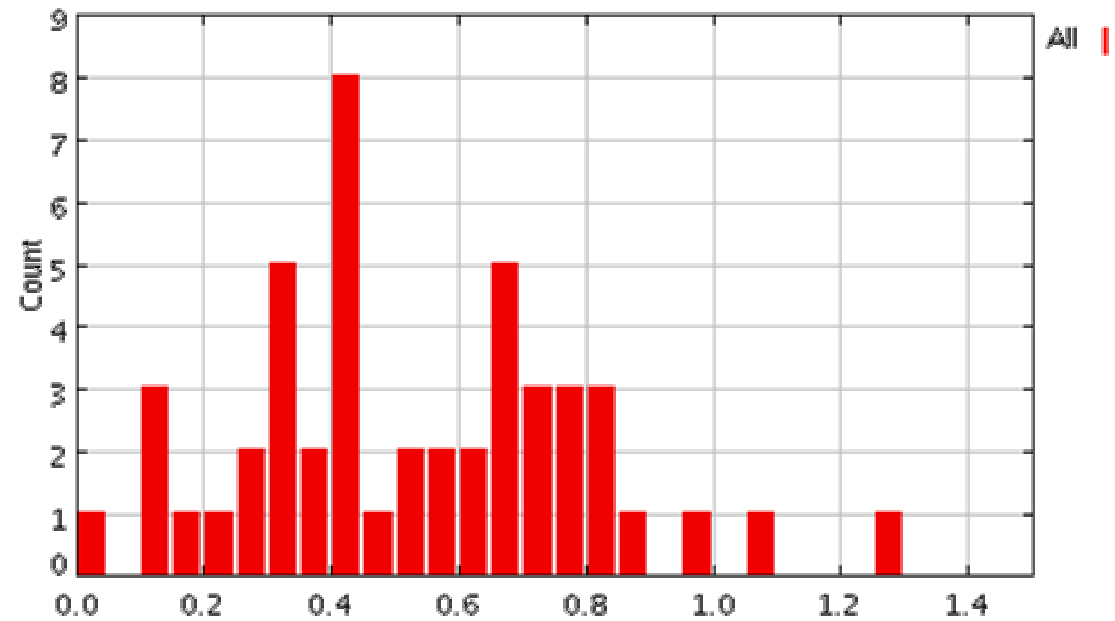
Histogram of Ratio of
Source flux

Current CCF/AMR CCF

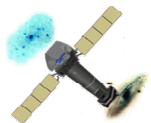
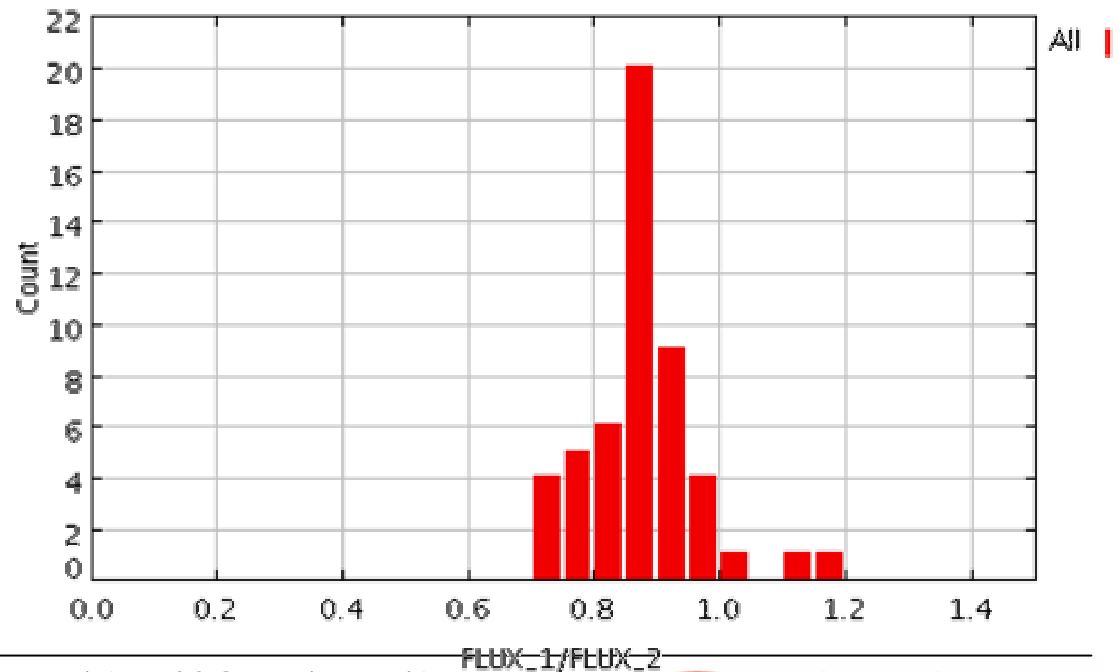
(i.e. if CCF believed
should be ~ 1)

AMR values larger

F



H

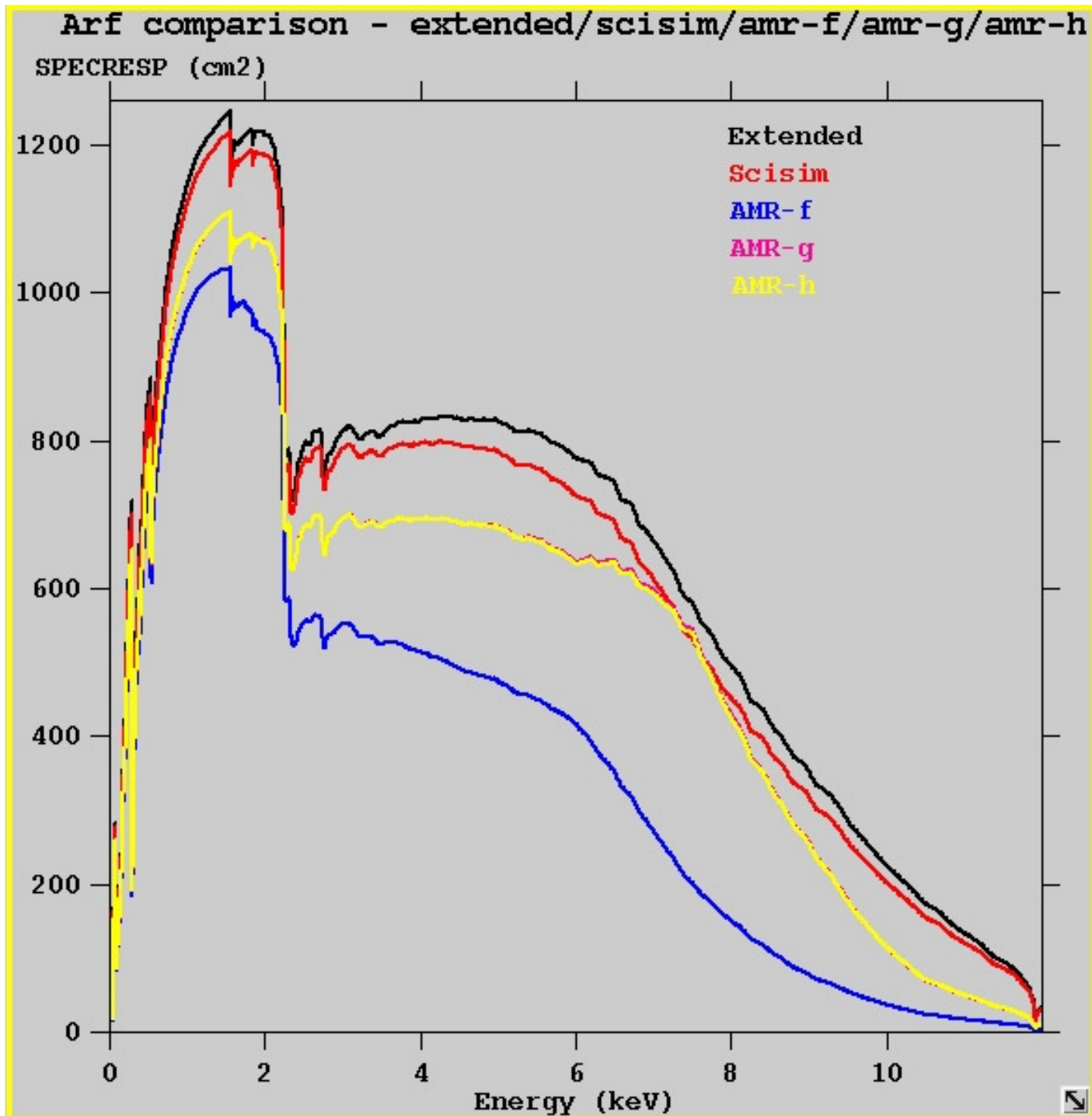


XMM
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MOS

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arfgen works with
AMR PSF CCF

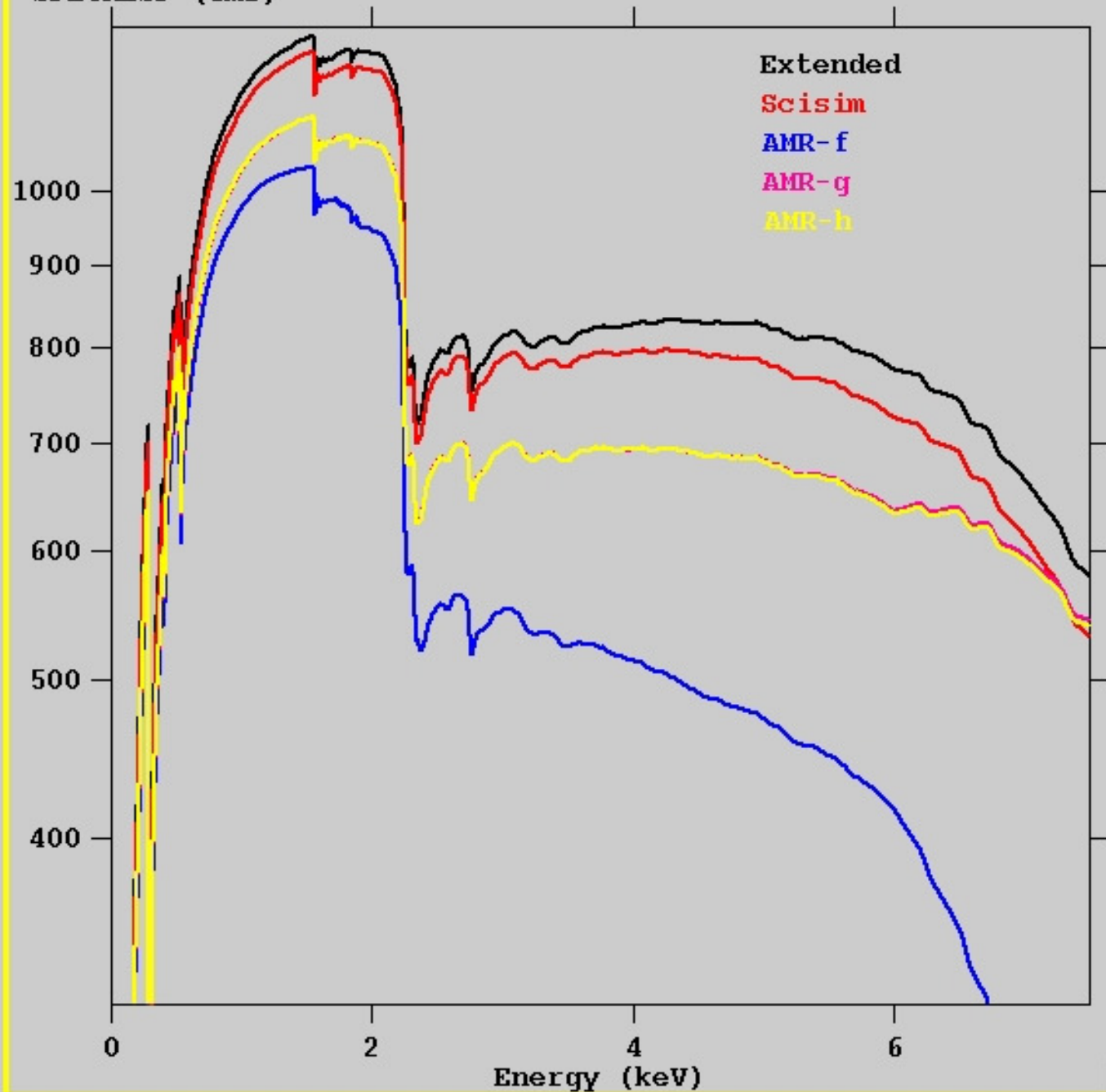
F, G, H PSFs
successively getting
closer to extended
ARF



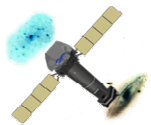
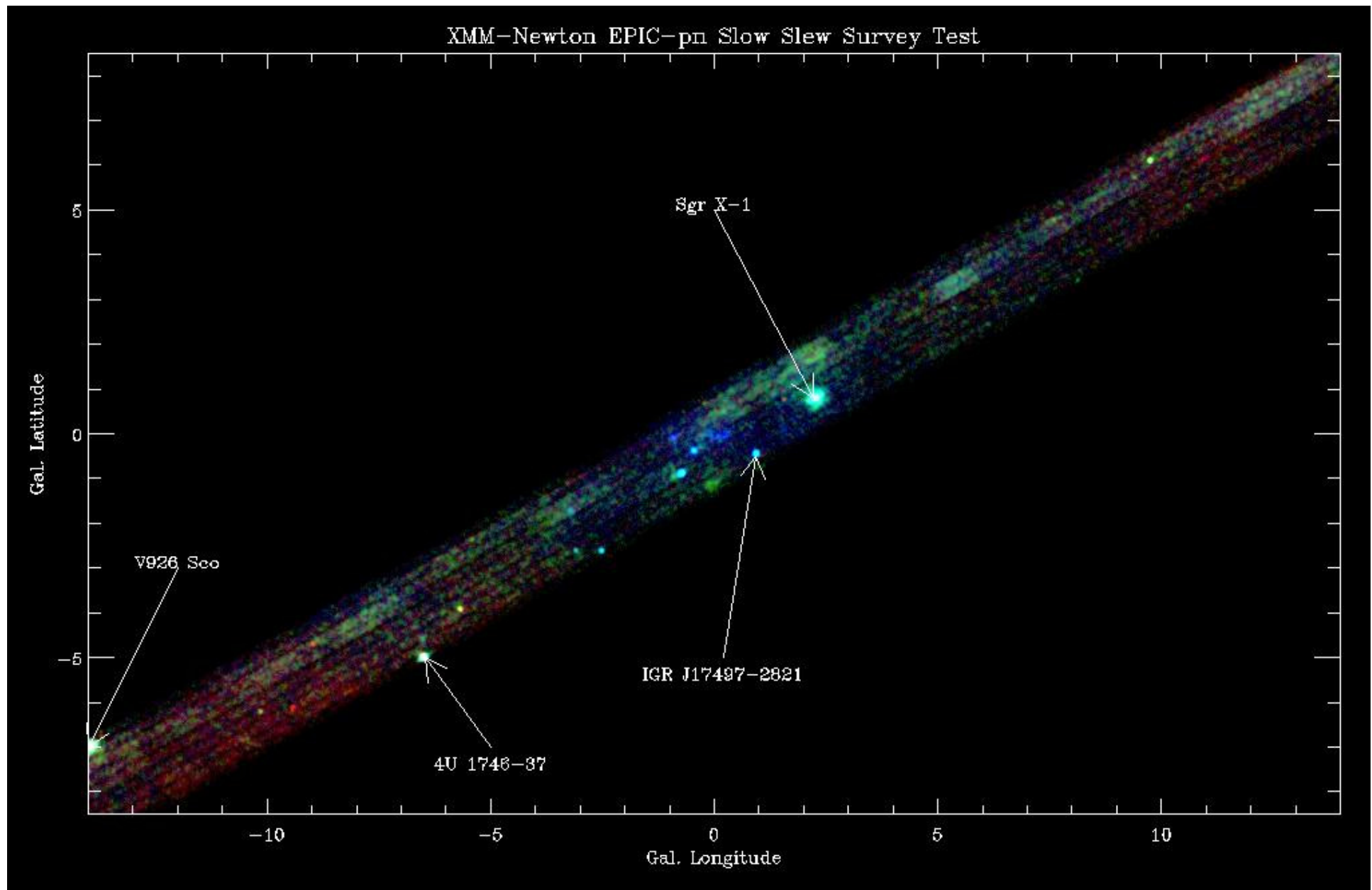
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Arf comparison - extended/scisim/amr-f/amr-g/amr-h

SPECRESP (cm²)



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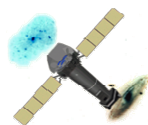
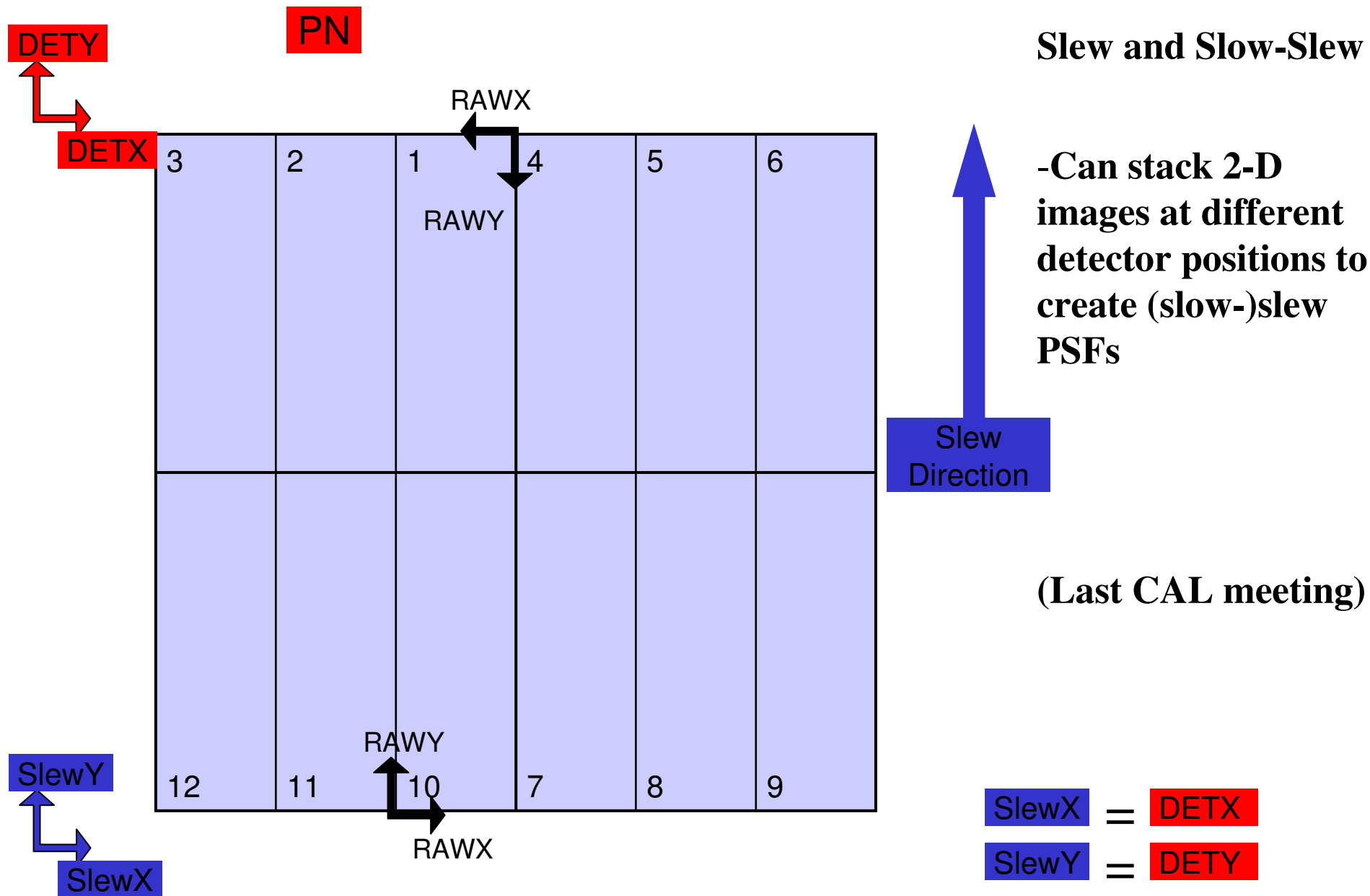


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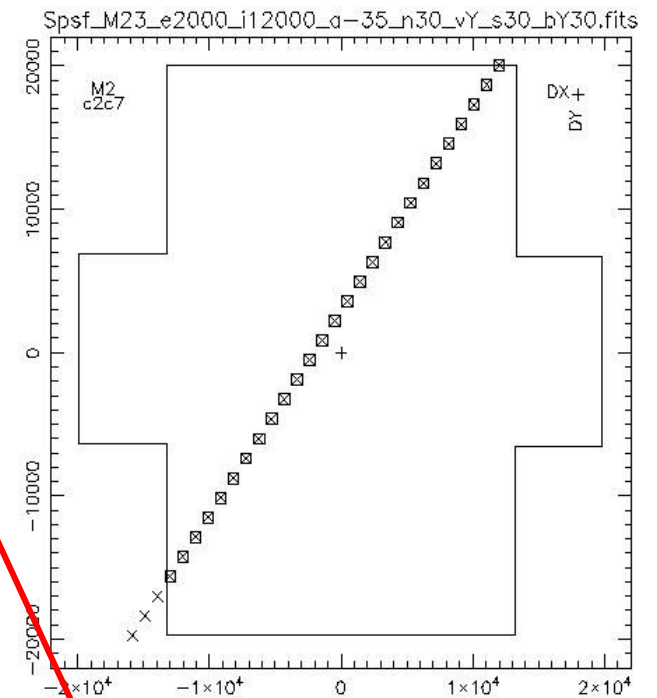
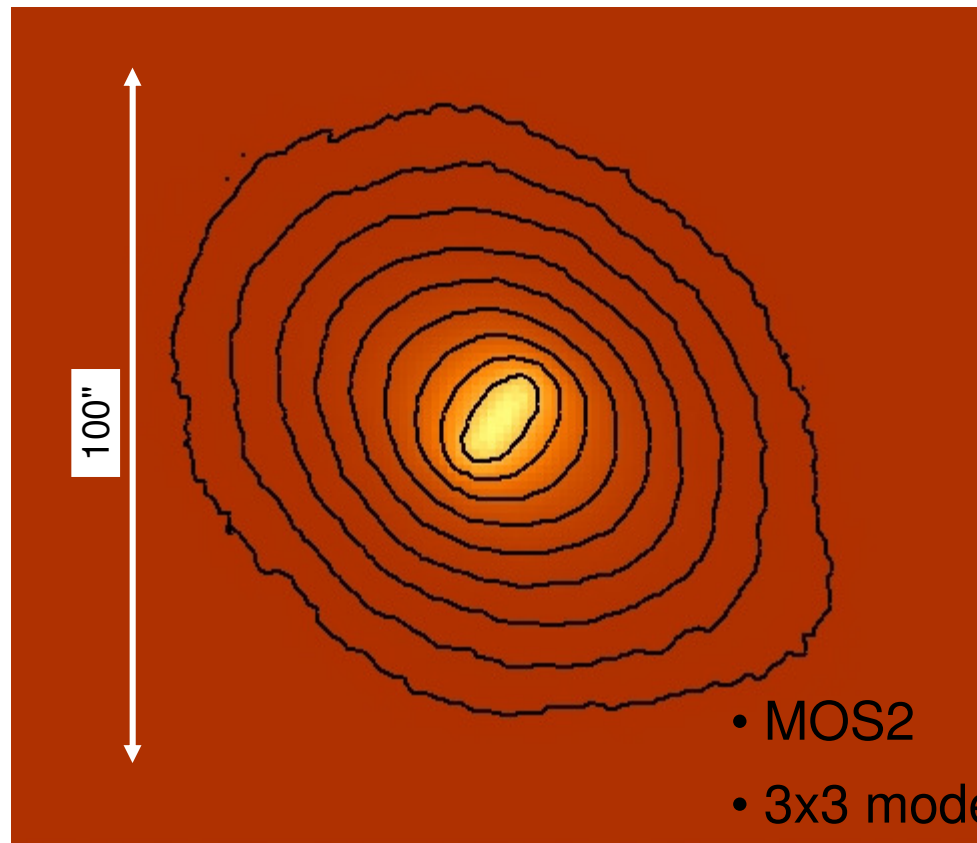


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MOS

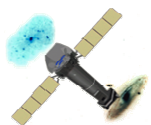
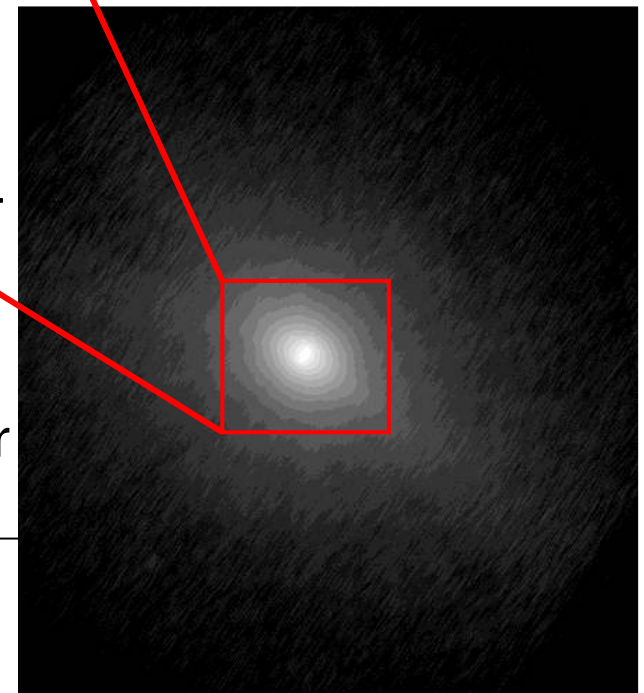
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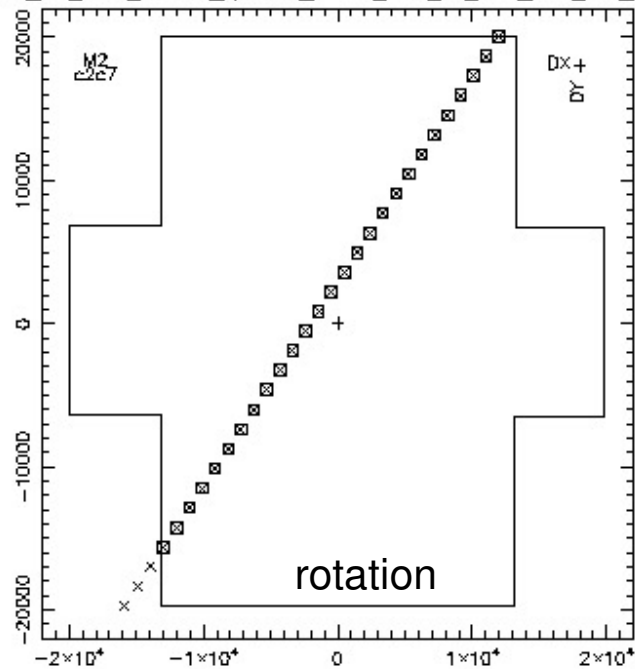
- MOS2
- 3x3 mode
- slew-speed=30%/hr
- 12" PSF blurring
- NB: easy to create equivalent 10 deg/hr CCF PSFs
- Outer parts of PSF due to off-axis PSFs
- Inner parts of PSF due to frameblurring (note frameblurring far less at 10 deg/hr)



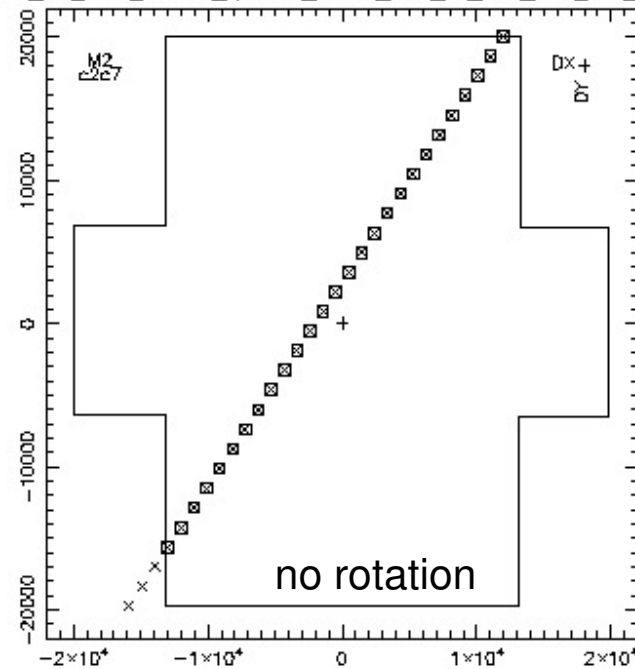
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Spsf_2D_M23_e2000_j12000_a-35_n30_vY_s30_bY0_m0_rY.1



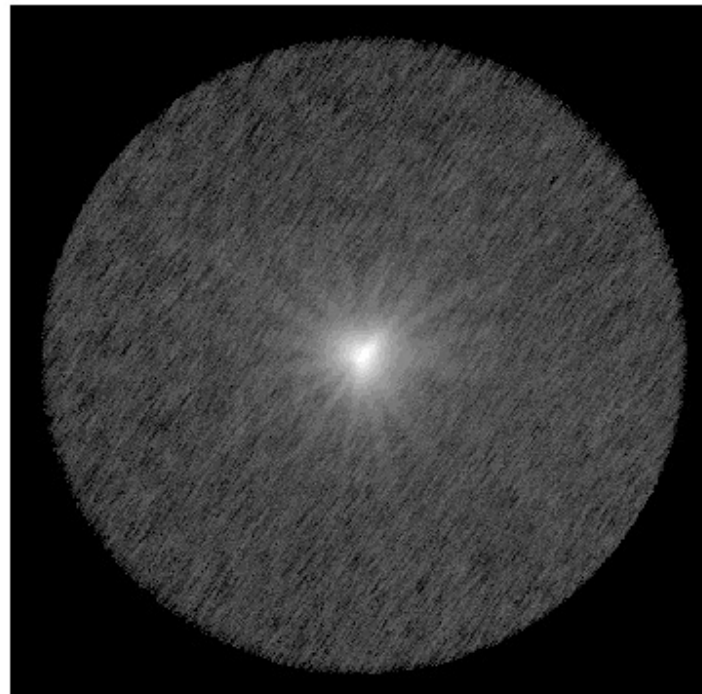
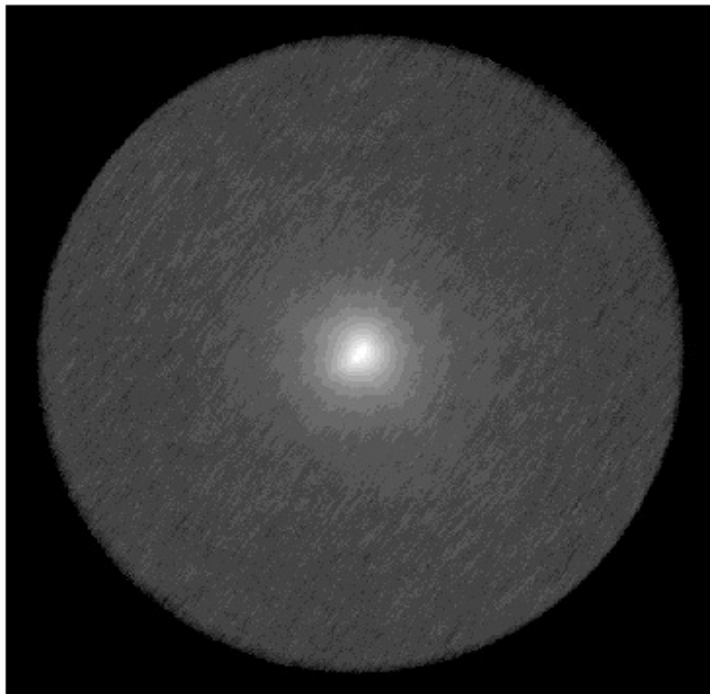
Spsf_2D_M23_e2000_j12000_a-35_n30_vY_s30_bY0_m0_rN.1



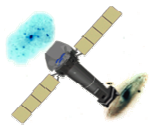
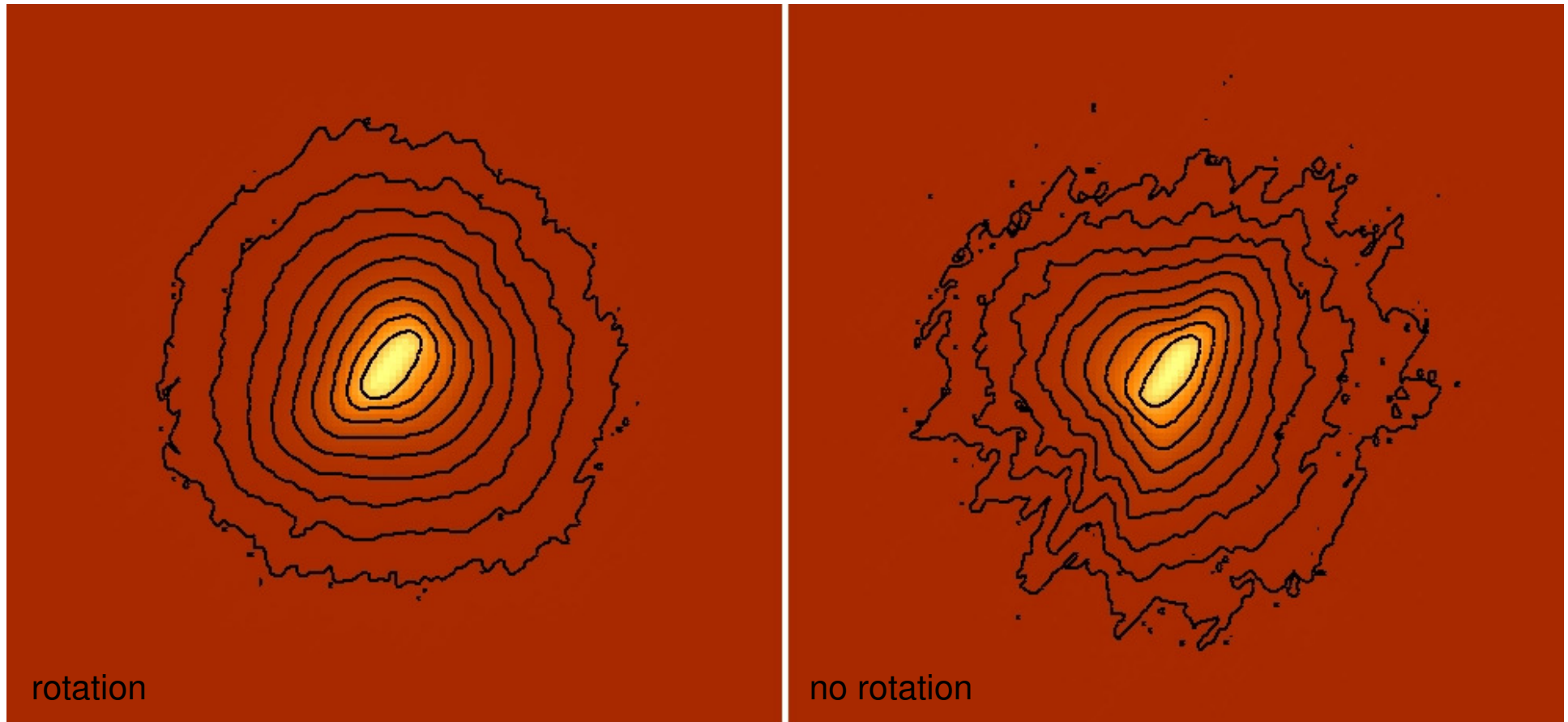
Similar rotation problem:

As source tracks across detector, stretch changes with off-axis angle and position on the detector.

However shape remains in same orientation.



MOS2



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EPIC
MOS

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Fluxes obtained from EPIC : pn/MOS flux ratios...

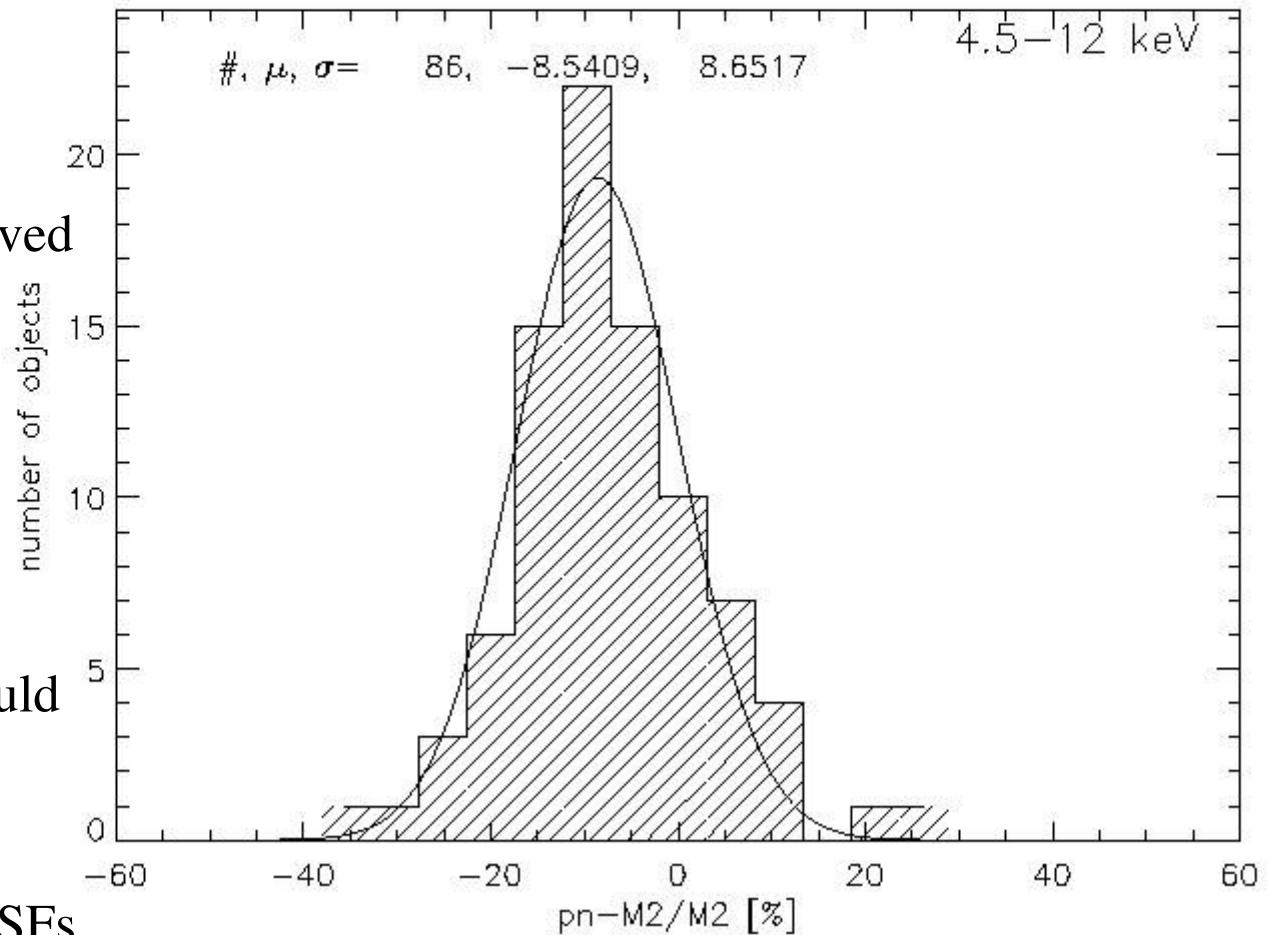
Seen for 2XMM, that derived pn fluxes are:

~ or > MOS at low-E

< or << MOS at mid- and high-E

(pn-MOS)/MOS ratio should be ~zero for all energies

What about when AMR PSFs are used?



(Silvia Mateos)

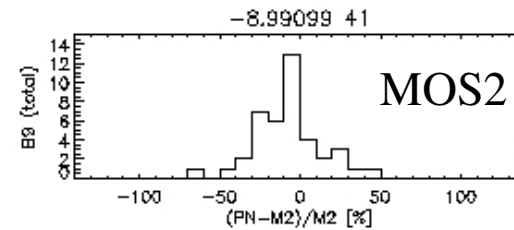
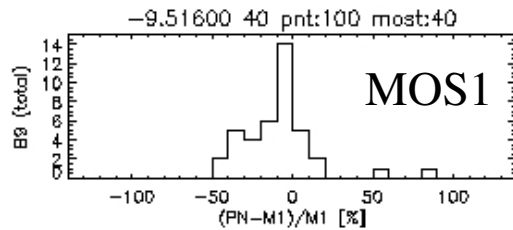


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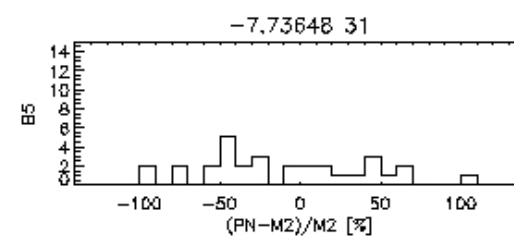
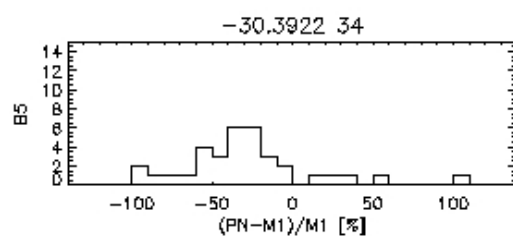
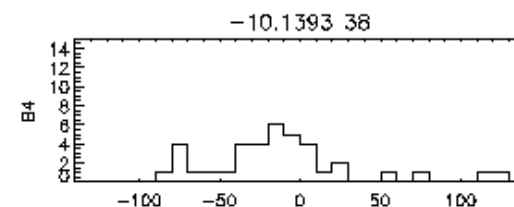
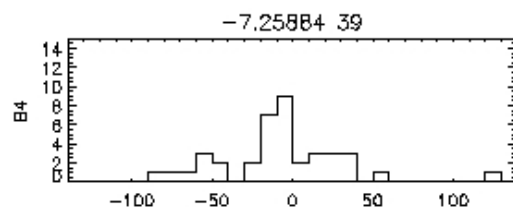
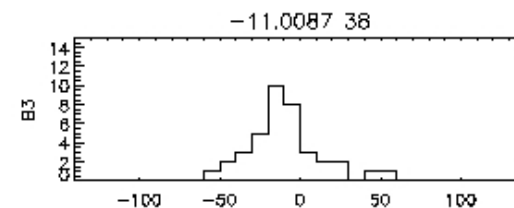
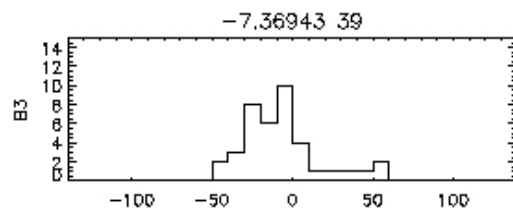
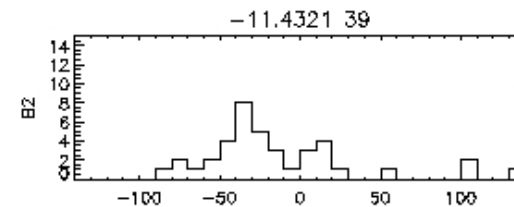
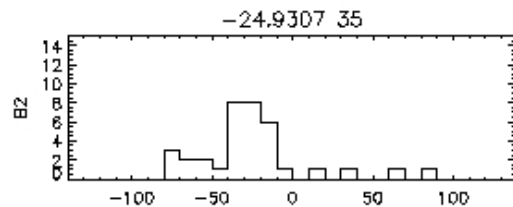
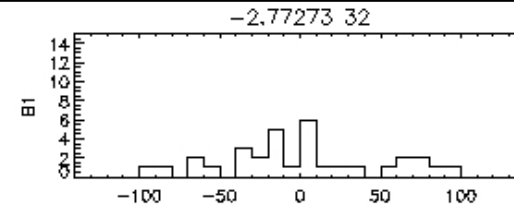
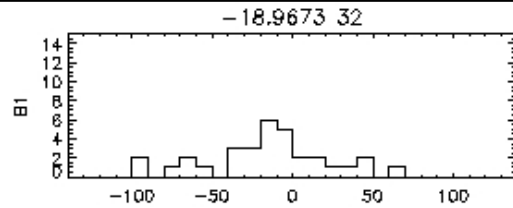


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Total band

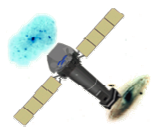


Energy



Using current CCFs on 5
'bad' observations

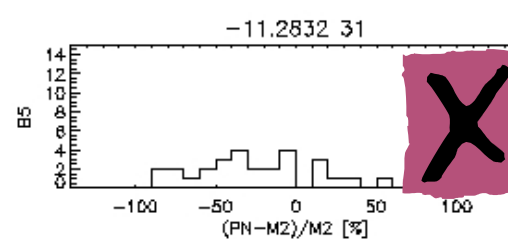
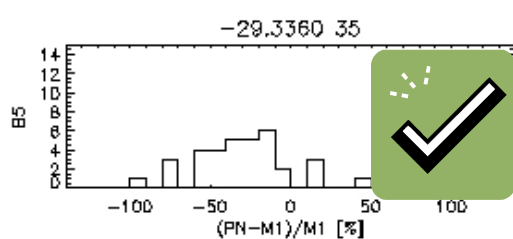
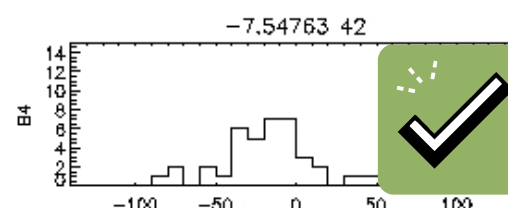
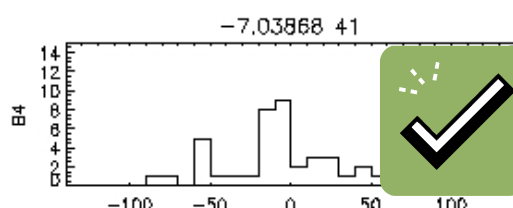
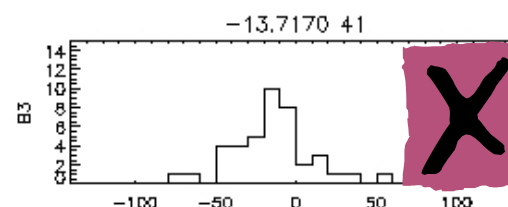
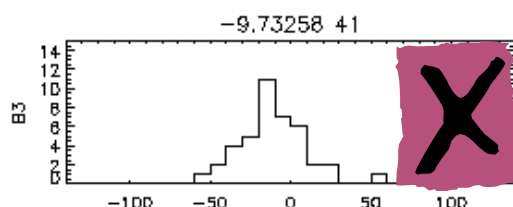
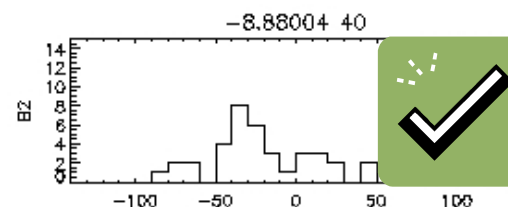
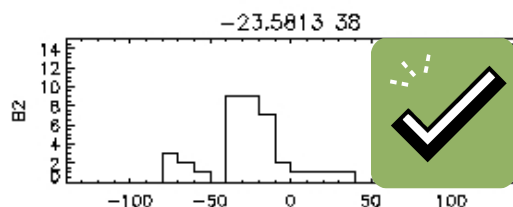
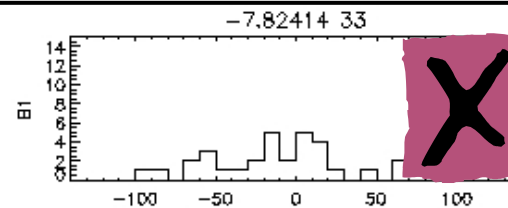
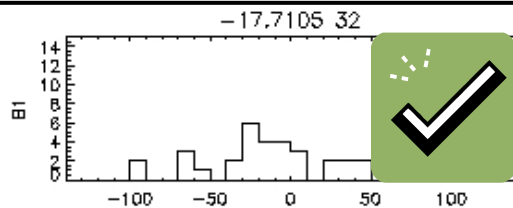
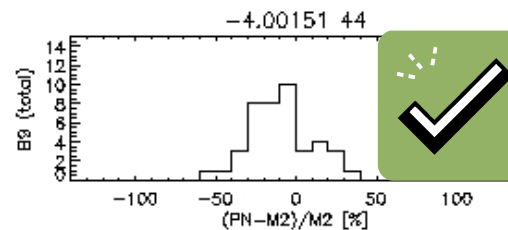
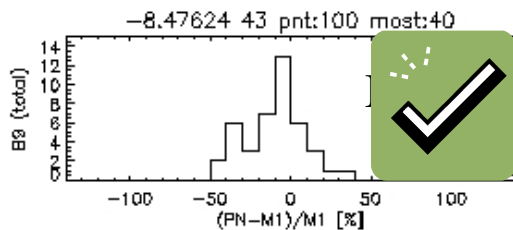
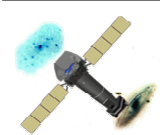
Analyzing sources with
pn counts >100 and
MOS1/MOS2 counts >40



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Total band

Energy



Using AMR-H CCFs on
5 'bad' observations

Analyzing sources with
pn counts >100 and
MOS1/MOS2 counts >40



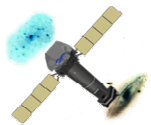
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Some (far-)future thoughts...

- 2-D PSFs (off- and on-axis)
 - Move from old, scisim, instrument-non-specific images to:
 - Real 2-D instrument-specific images (AMR-F, G, H, ...)
 - Analytical (noiseless) models of these 2-D instrument-specific images (e.g. 2-D King [beta] profiles)?
 - Issues to do with detecting and parameterizing sources (possible major SAS/CCF changes)
- 1-D PSFs (off- and on-axis)
 - 1-D profiles of above 2-D instrument-specific images (King fitting)
 - Changes to arfgen to work on 2-D images/analytical models[?] (major SAS/CCF changes)



end

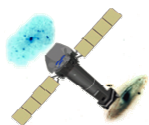


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slow slew plot using new 2d data psfs
Rotation and non-rotation probs – mos2
New psfs – h1

**Look at fluxes in bands/instruments – help
with silvias problem?**

Why m2 on-axis keep shape? ;-)

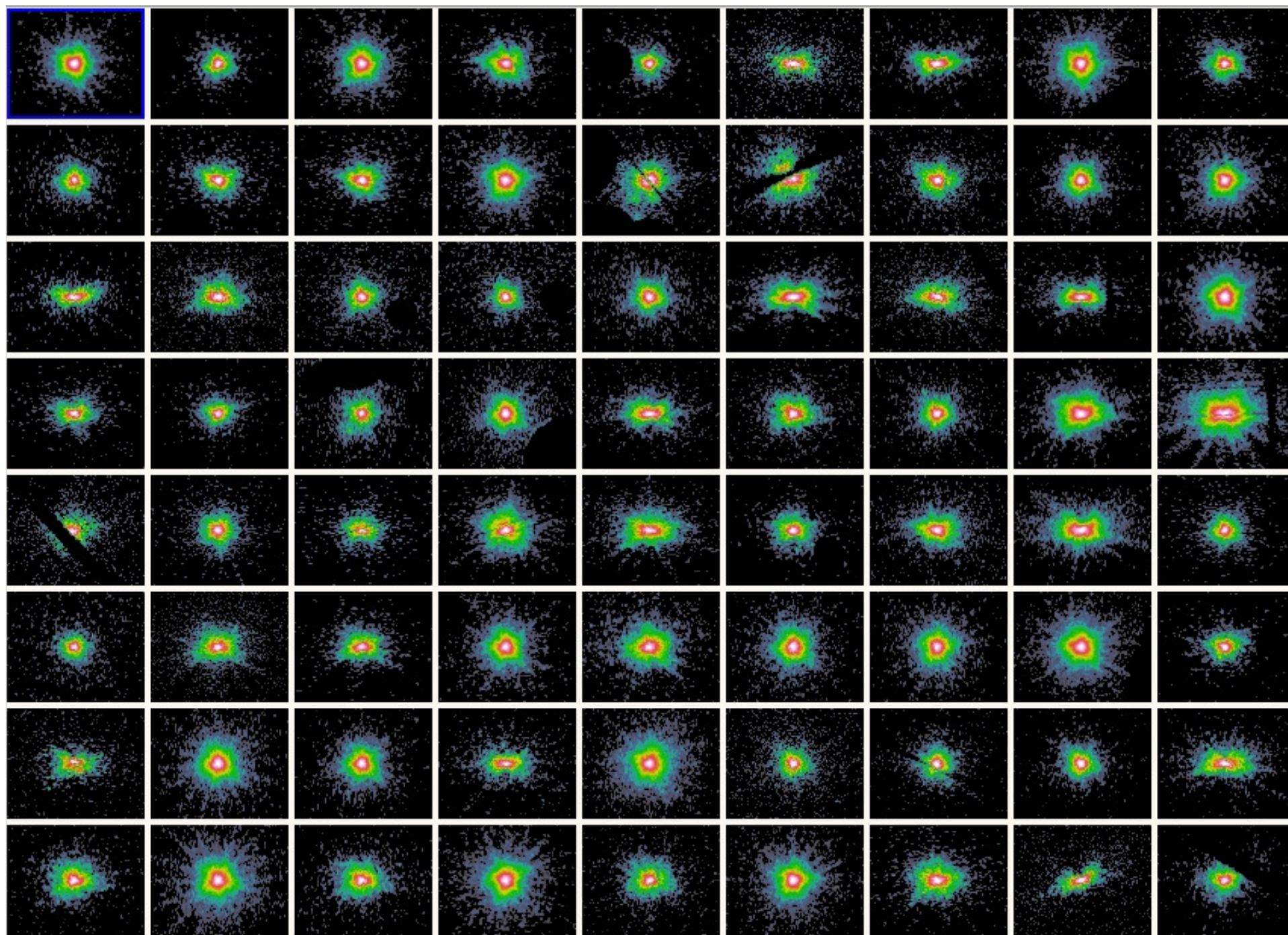
King profiles from ims?

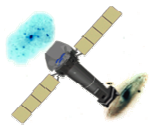
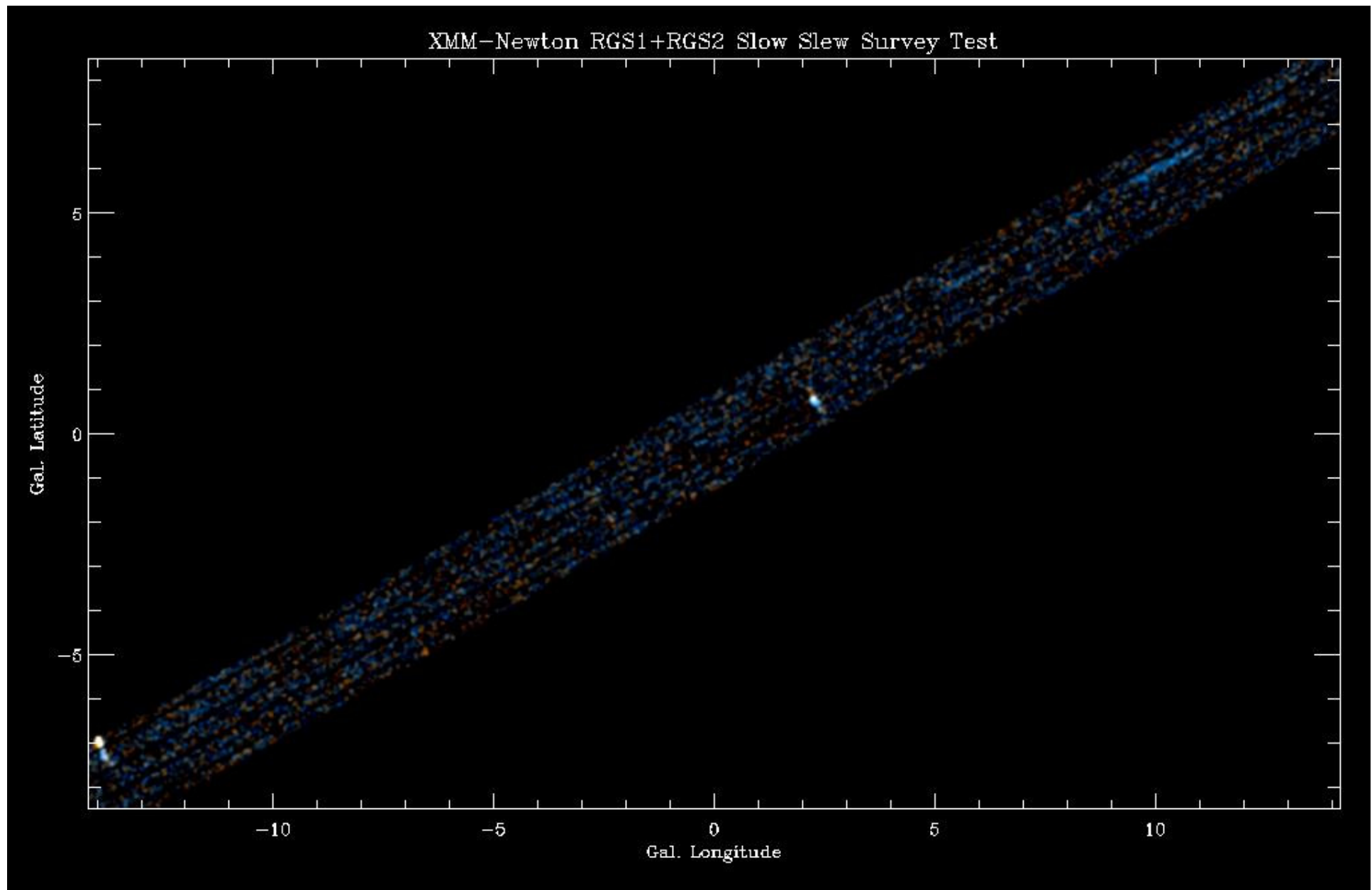


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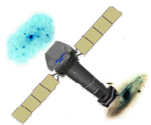
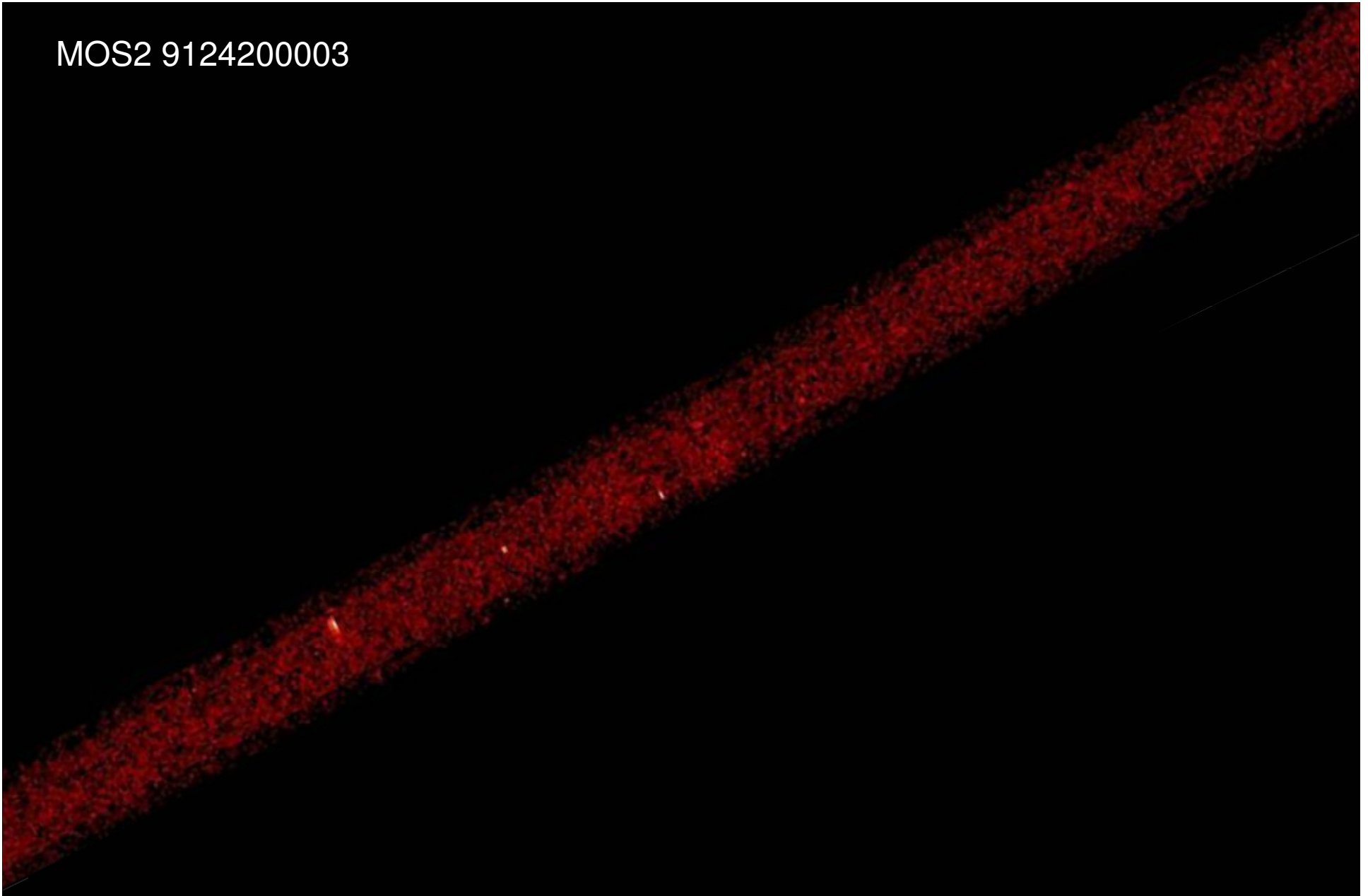
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MOS2 9124200003



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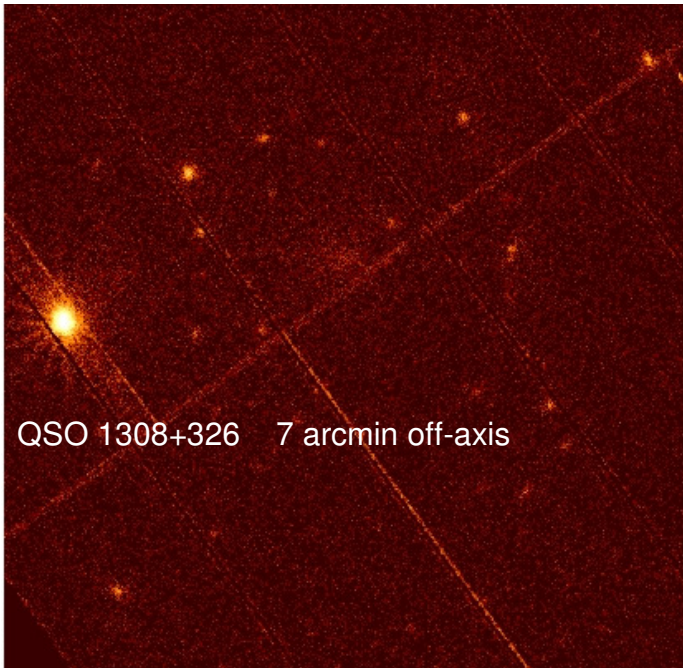
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Off-Axis PSF

A few suitable off-axis sources are now in the XMM archive...

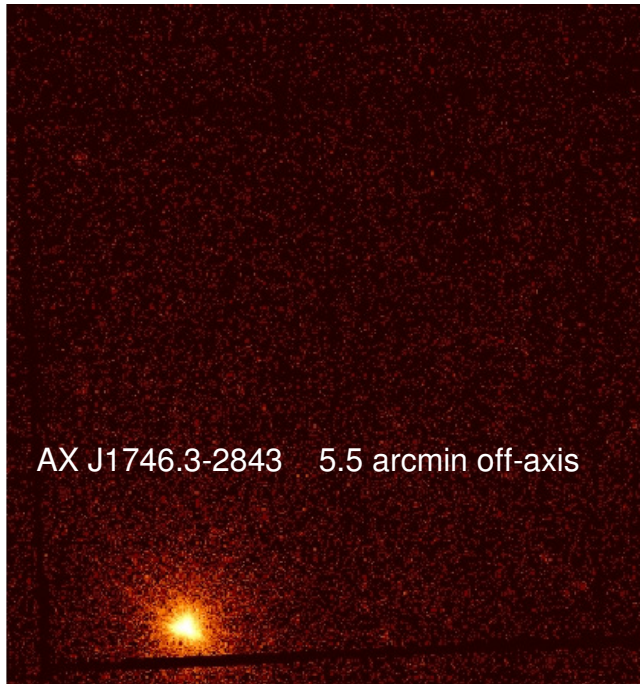
Work ongoing...

Sources both on- and off-axis...



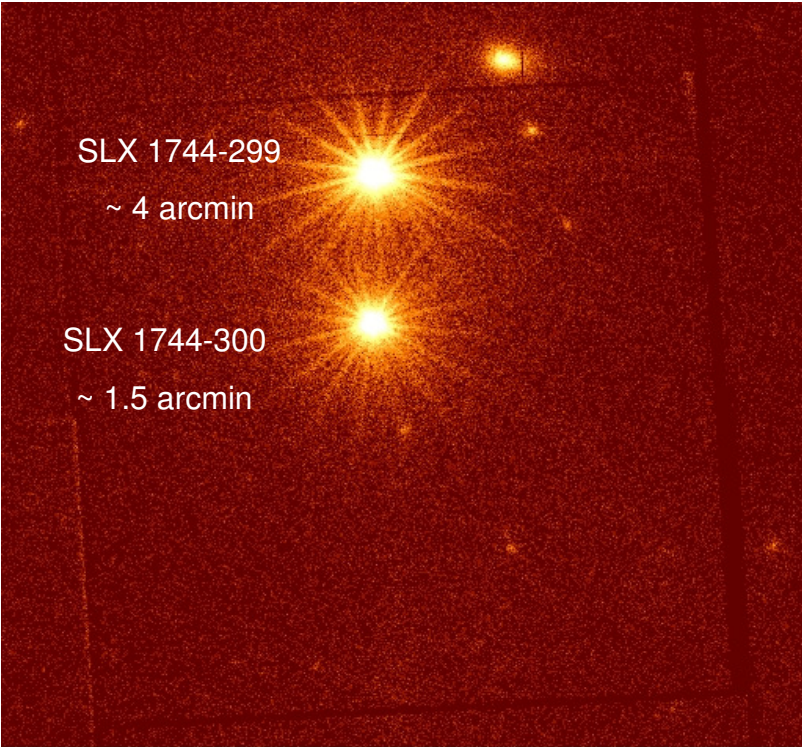
QSO 1308+326 7 arcmin off-axis

This image shows a deep-field X-ray observation of the quasar QSO 1308+326. The source is located 7 arcminutes off-axis from the center of the XMM-Newton detector. The image displays a complex pattern of bright, elongated features and numerous faint, diffuse sources, characteristic of off-axis observations.



AX J1746.3-2843 5.5 arcmin off-axis

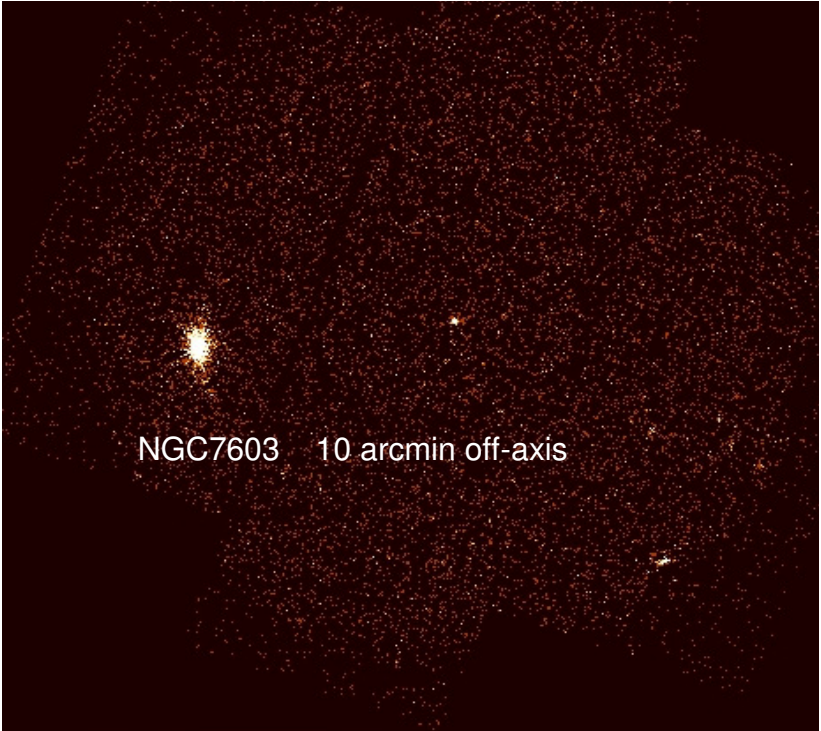
This image shows a deep-field X-ray observation of the active nucleus AX J1746.3-2843. The source is located 5.5 arcminutes off-axis from the center of the XMM-Newton detector. The image displays a complex pattern of bright, elongated features and numerous faint, diffuse sources, characteristic of off-axis observations.



SLX 1744-299
~ 4 arcmin

This image shows a deep-field X-ray observation of two sources, SLX 1744-299 and SLX 1744-300. The sources are located approximately 4 arcminutes off-axis from the center of the XMM-Newton detector. The image displays a complex pattern of bright, elongated features and numerous faint, diffuse sources, characteristic of off-axis observations.

SLX 1744-300
~ 1.5 arcmin



NGC 7603 10 arcmin off-axis

This image shows a deep-field X-ray observation of the galaxy NGC 7603. The source is located 10 arcminutes off-axis from the center of the XMM-Newton detector. The image displays a complex pattern of bright, elongated features and numerous faint, diffuse sources, characteristic of off-axis observations.