Update of the time-dependent PN redistribution/resolution

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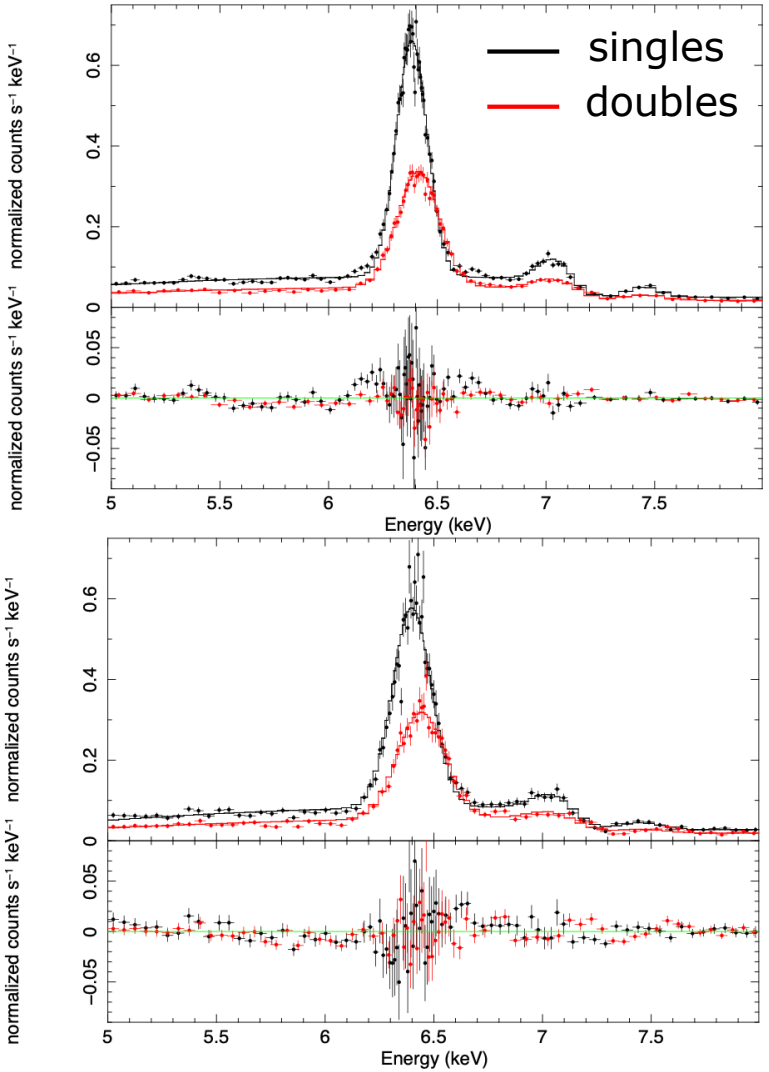
EPIC Cal meeting
3-4 June 2024

PN Redistribution/resolution - previously

- Previous update in 2014 (SRN 0322).
  - Analysis based on pn FF observations of Circinus Galaxy from revs 0304 (0111240101) and 2605 (0656580601)
  - Noise params (N4) was made time-dependent
  - Fit Iron lines (mainly 6.4 Fe-Kα keV line – assumed intrinsic narrow line (width=0 (< 60 eV 90% confidence) - Guainazzi – BeppoSAX)).
    - *Chandra HETG data (Andonie et al, 2022) measured a width of 13eV*
    Weaker lines around 7.05 and 7.4 keV
- New XMM observation made in rev 4423 (0932990101)

OBSID (epoch)	Rev	Date	Exp (ks) (fs)
0111240101 (1)	0304	2001-08-06	71
0656580601 (2)	2605	2014-03-01	15
0932990101 (3)	4423	2024-02-02	101

Previous observations with EPN REDIST_0012 (from SRN 322)

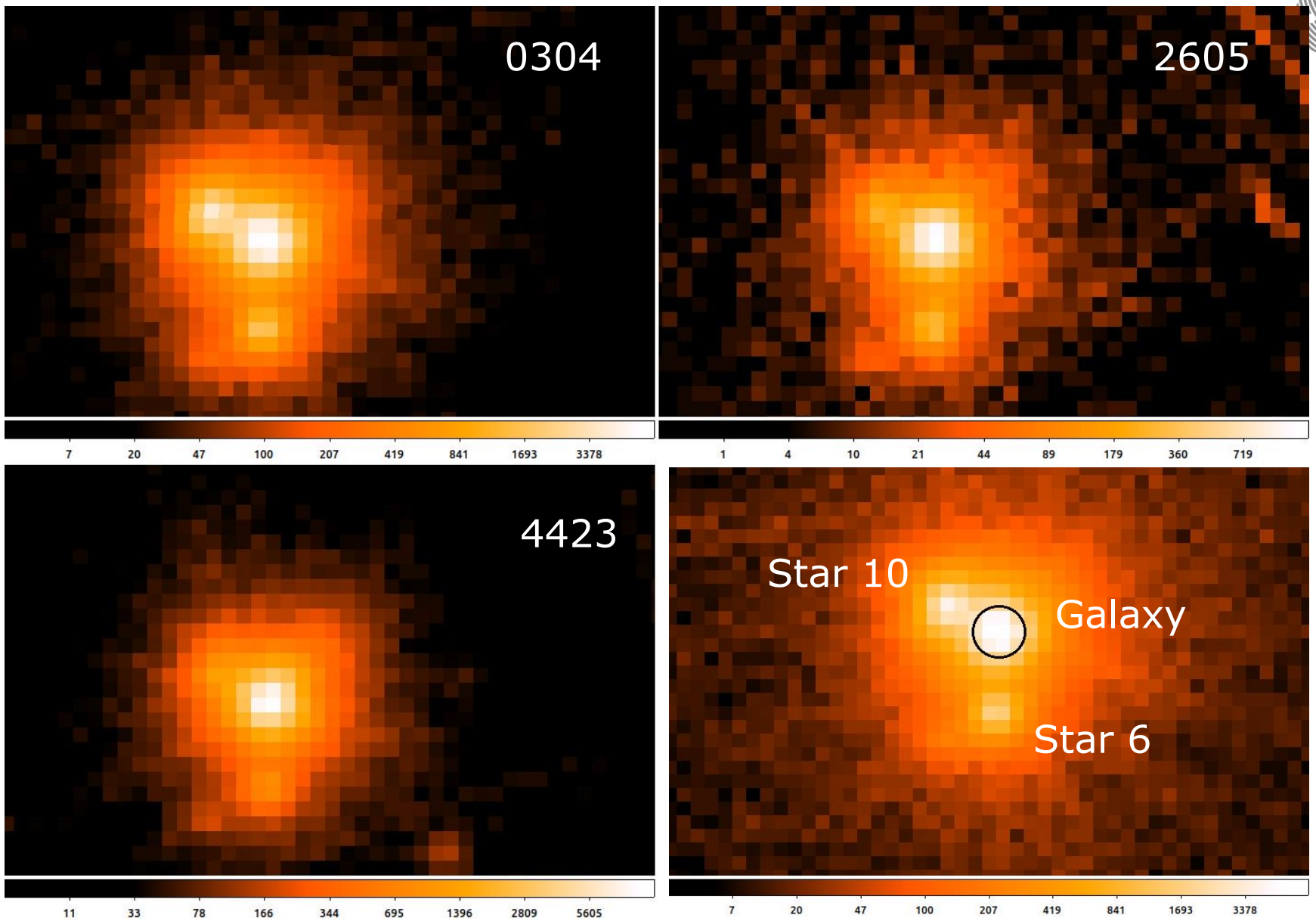


Rev 0304

Residual width = 24eV

Rev 2605

Residual width = 24eV

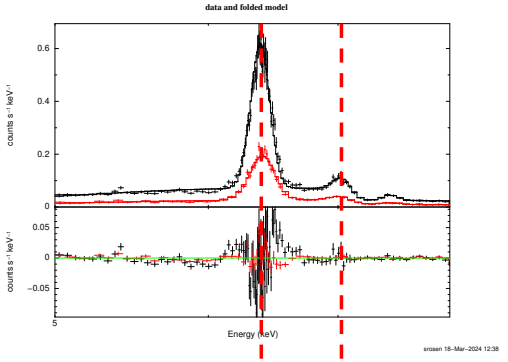


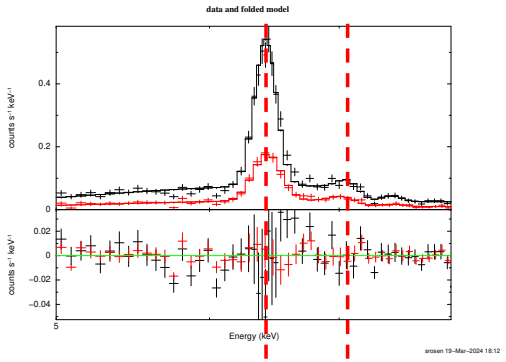
The contaminant sources

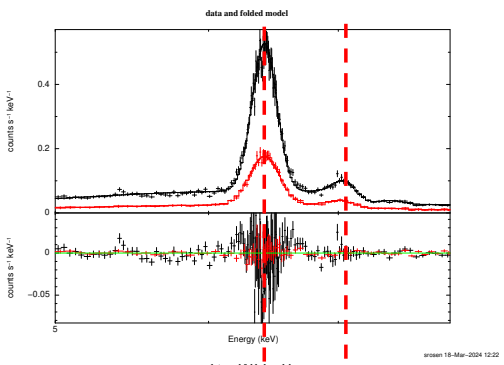
(r=150 pix but contaminated themselves by central galaxy)

Epoch 1 (w=0) | Epoch 2 (w=0) | Epoch 3 (w=0)

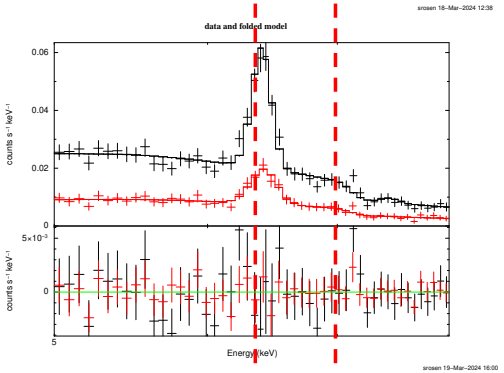
Galaxy

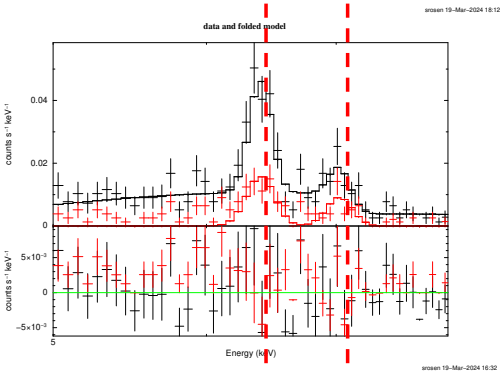


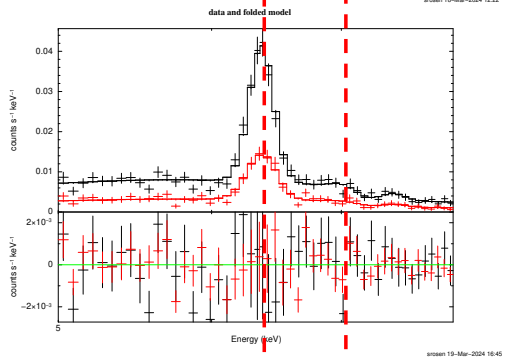




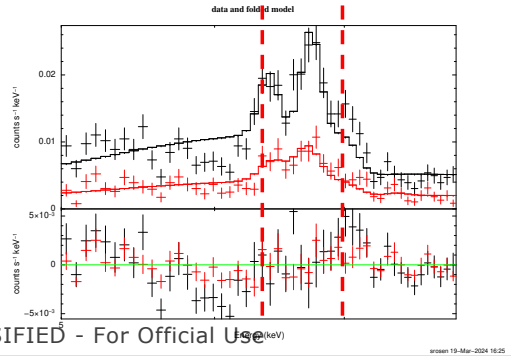
Star 10

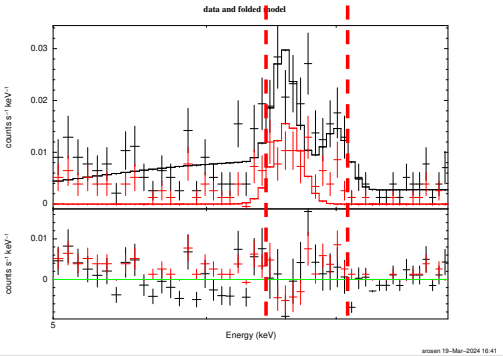


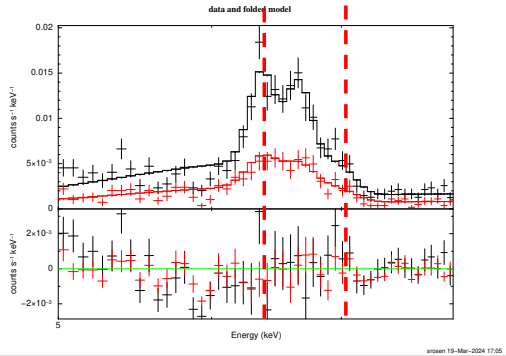




Star 6







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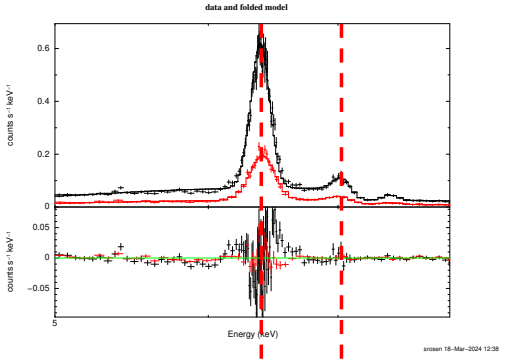
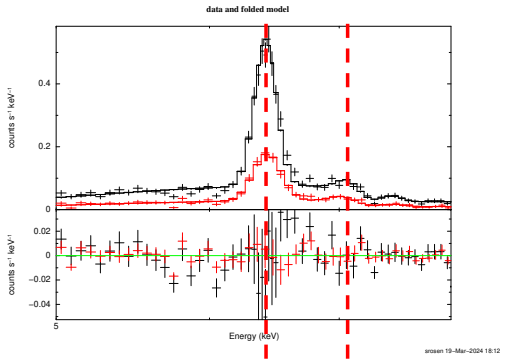
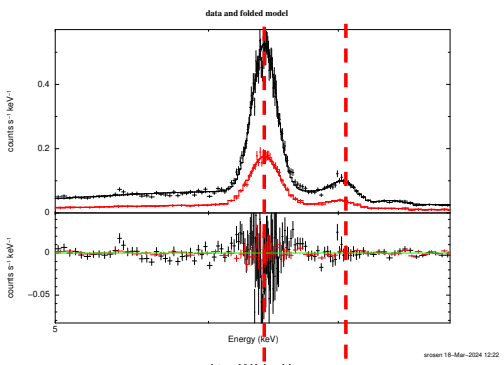
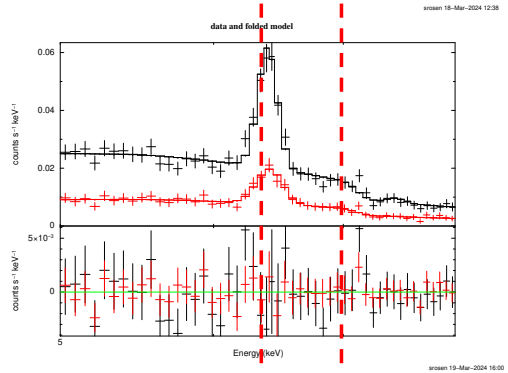
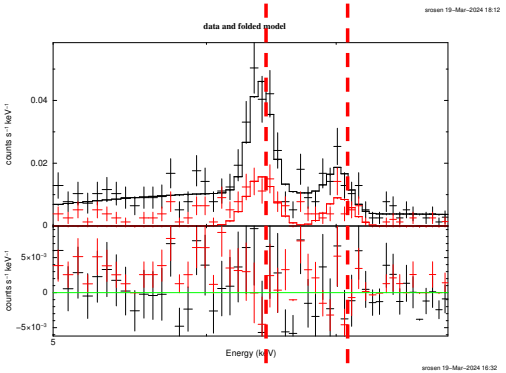


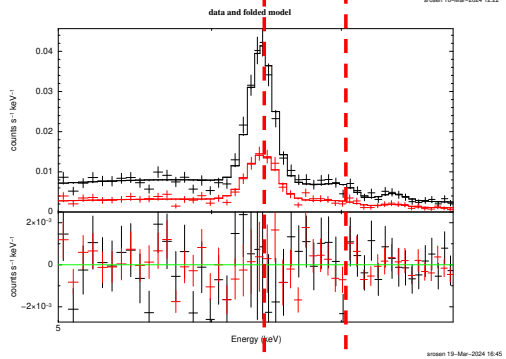




Star 10







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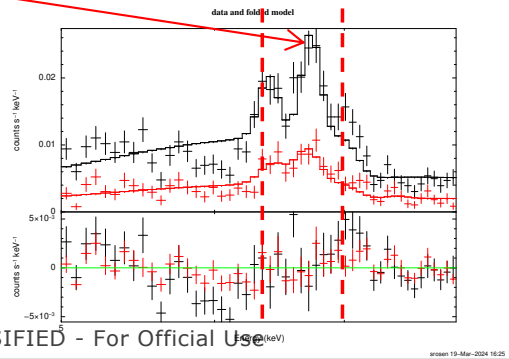
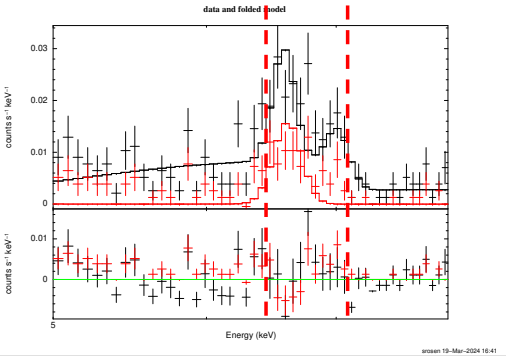
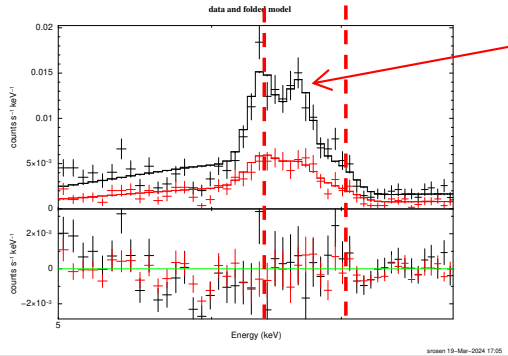
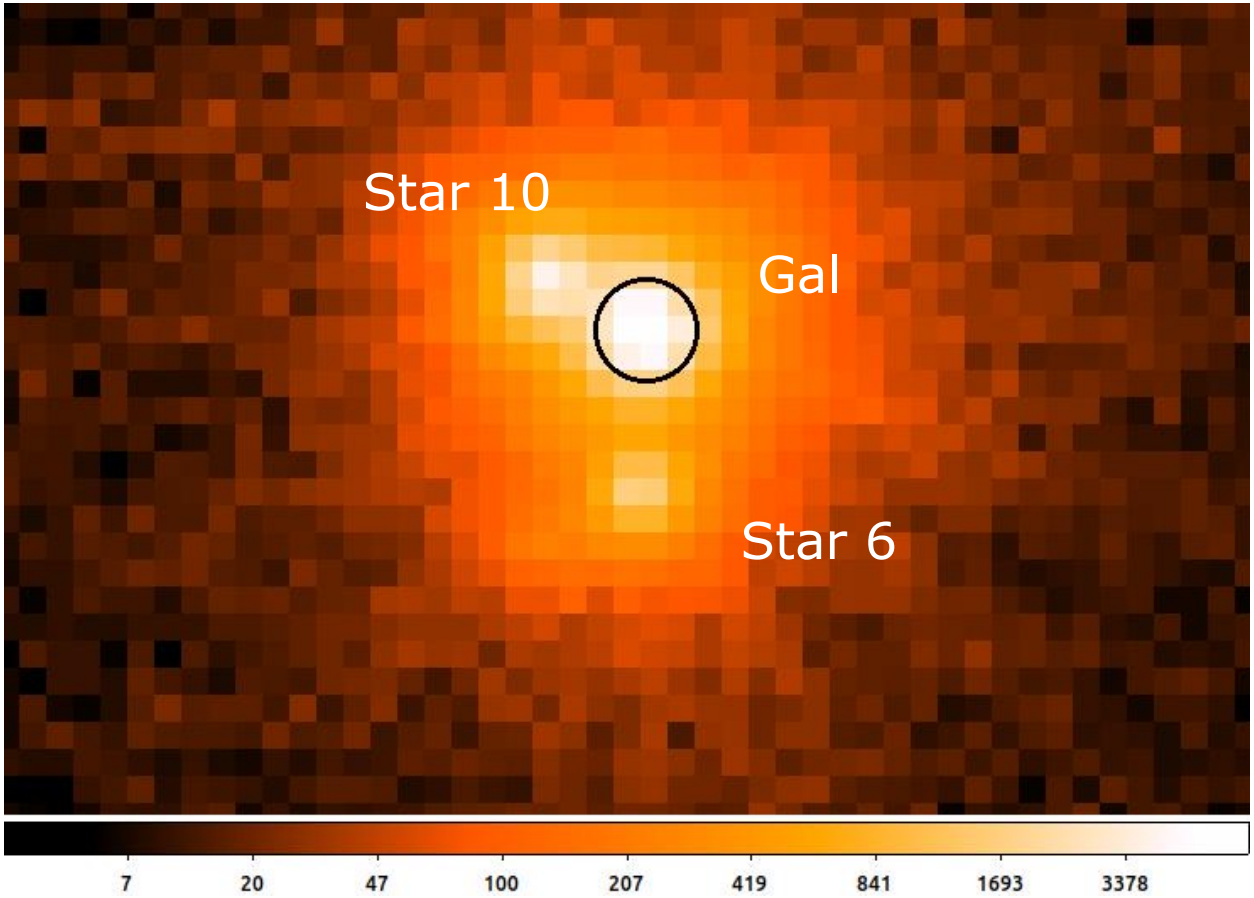








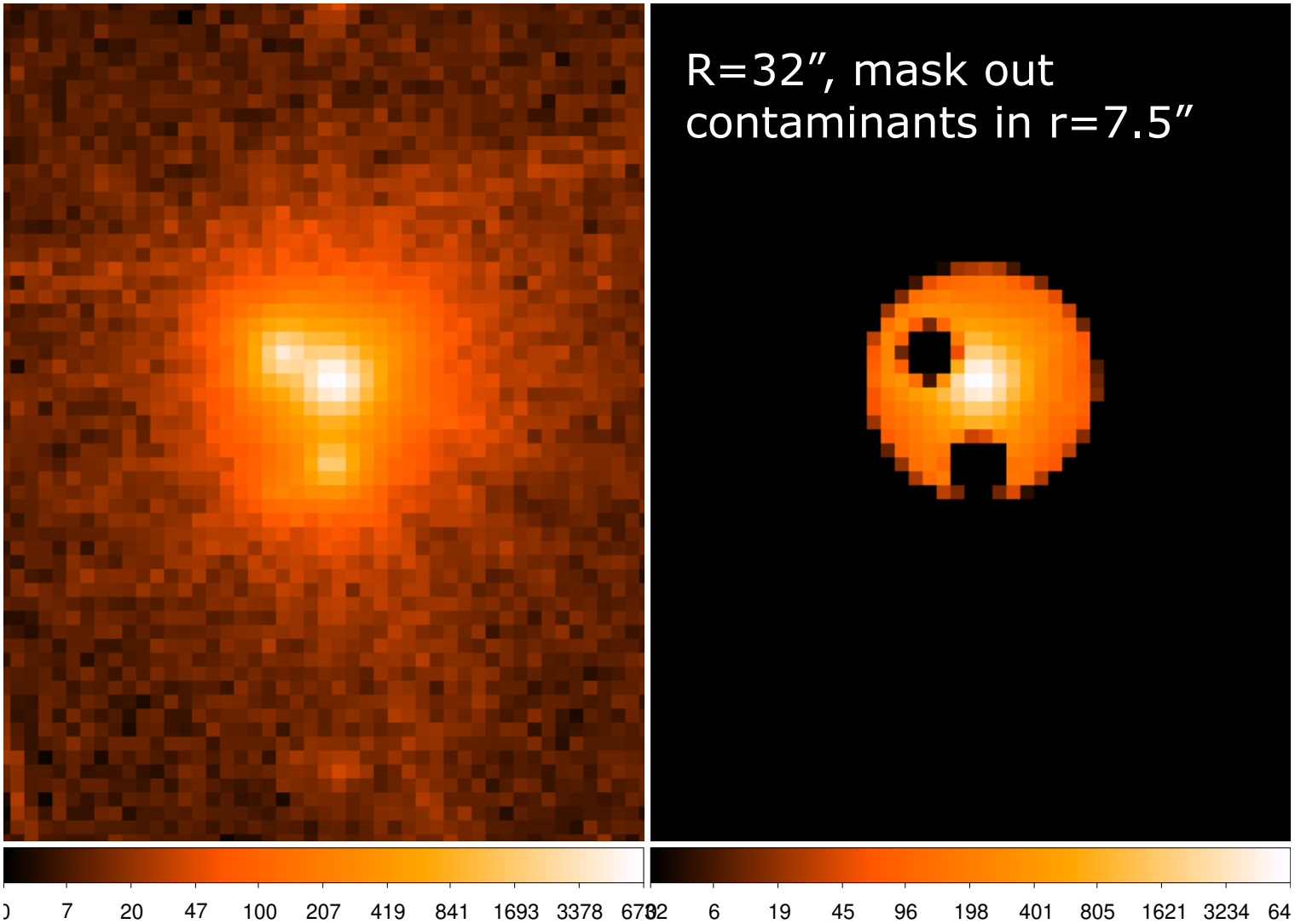
Initially extracted just target events in

R= 7.5” (150 pix)

Minimize contamination from 2 fainter (variable) srcs

Reduced statistics, less contamination.

Small aperture can distort relative numbers of double cf single events.


R=32”, mask out
contaminants in r=7.5”
0 7 20 47 100 207 419 841 1693 3378 6732
0 6 19 45 96 198 401 805 1621 3234 6467

Analysis

- Cleaned event lists created with epproc based on standard threads
- Separate spectra extracted from single events and from double events, e.g. epoch 3, e.g. for source region

singles:
```
evselect table=pnclean.fits withspectrumset=yes
spectrumset=pnsource_spectrum_singles_${tag}.fits energycolumn=PI spectralbinsize=5
withspecranges=yes specchannelmin=0 specchannelmax=20479  expression='(FLAG==0) &&
(PATTERN==0) && ((X,Y) IN circle(25366,23981,640.0)) && (!(X,Y) IN circle(253
70,23518,200)) && (!(X,Y) IN circle(25069,24118,200))'
```

doubles:
```
evselect table=pnclean.fits withspectrumset=yes
spectrumset=pnsource_spectrum_doubles_${tag}.fits energycolumn=PI spectralbinsize=5
withspecranges=yes specchannelmin=0 specchannelmax=20479  expression='(FLAG==0) &&
(PATTERN>=1 && PATTERN <=4) && ((X,Y) IN circle(25366,23981,640.0)) && (!(X,Y) IN
circle(25370,23518,200)) && (!(X,Y) IN circle(25069,24118,200))'
```

- Background offset, at similar Y position to target, r=20”

Analysis

- Fit only 5-8 keV range: phabs*pow + 3 gaussian lines
- Fit singles(S)/doubles(D) simultaneously, unbinned. Cash statistic
- N_H and PL index tied
- Line width tied for S/D for a given line (also tested, untied) but lines not linked.
- 6.4 and 7.05 keV line energies fitted, 7.4 keV line energy fixed. Normalisations fitted

Rev 0304 (0111240101)

Existing CCF (0012): epoch 1 S/D N4 pars = (1.4, 3.1)x10^{-8}.

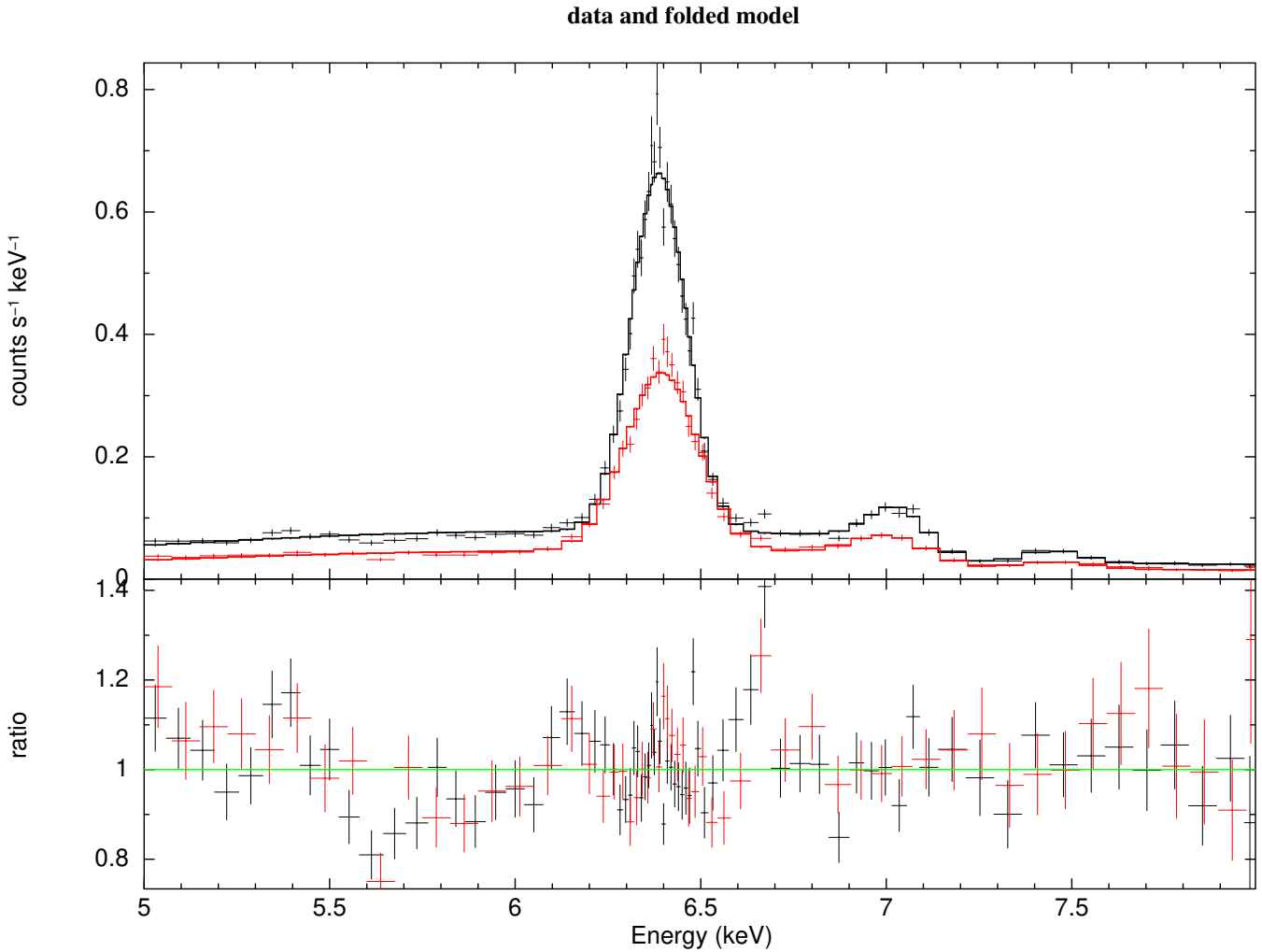
Explored params within +/- 0.2

No fit (S/D tied) gave width < 21 eV (i.e. closer to Chandra value 13eV)

Opted to retain epoch 1 values and adjust those of epochs 2 and 3 to achieve a consistent width ~21eV.

Provides temporal consistency for users

Rev 0304 (0111240101)



Retaining previous CCF params for epoch 1:

Fitted width(tied) ~21eV

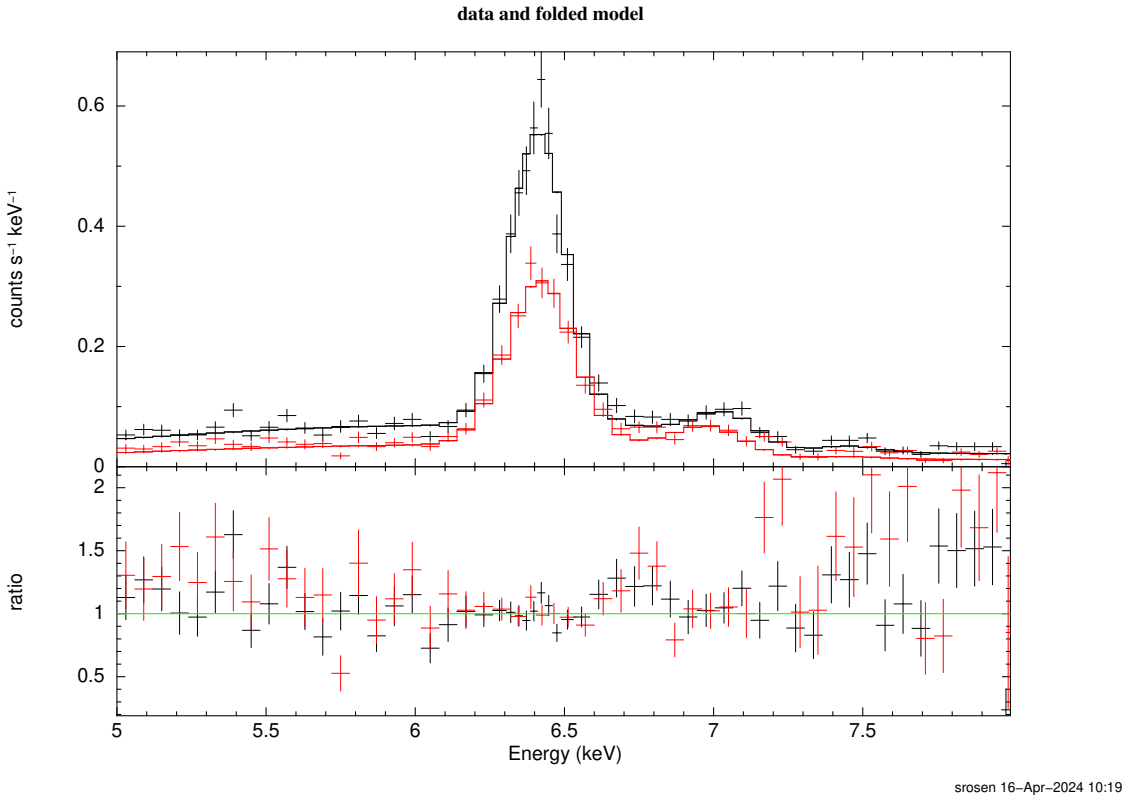
90% error range 14-26 eV

Untied, width for doubles is poorly constrained and tends to low values (< 5eV).

Rev 2605 (0656580601)

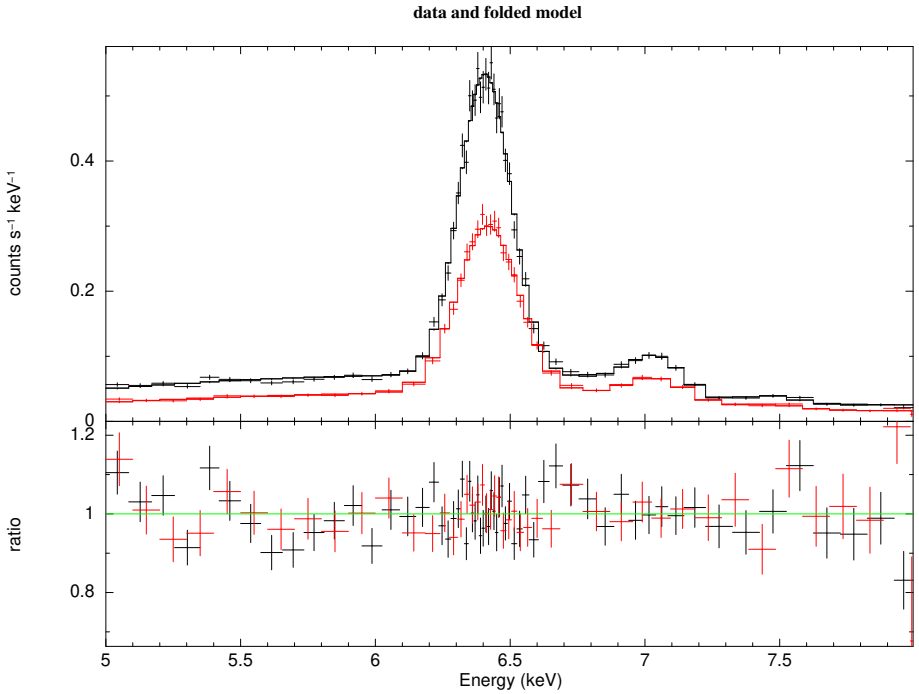
Fit to epoch 2 required modest adjustment of N4(singles) from -4.7 → -5.6 x10^{-8}, to achieve tied width ~ 24eV.

Short exposure → poor statistics → poorly constrained width
90% uncertainty range 2-38eV.

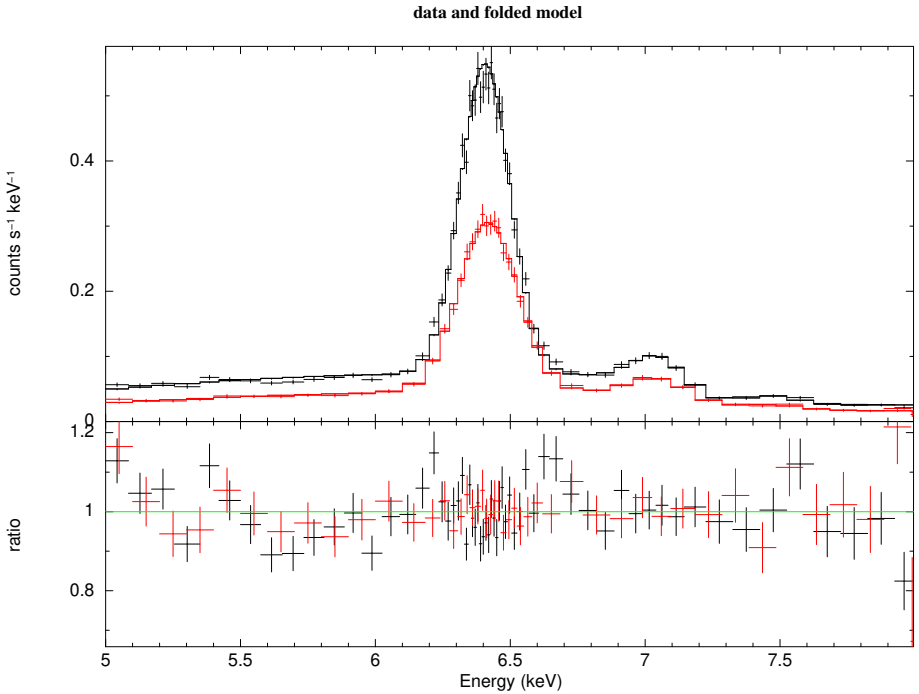


Rev 4423 (0932990101) – existing CCF (0012)

For epochs > rev 2605, rmfgen assumes N4 parameters with epoch 2 values when using CCF0012 in SAS.

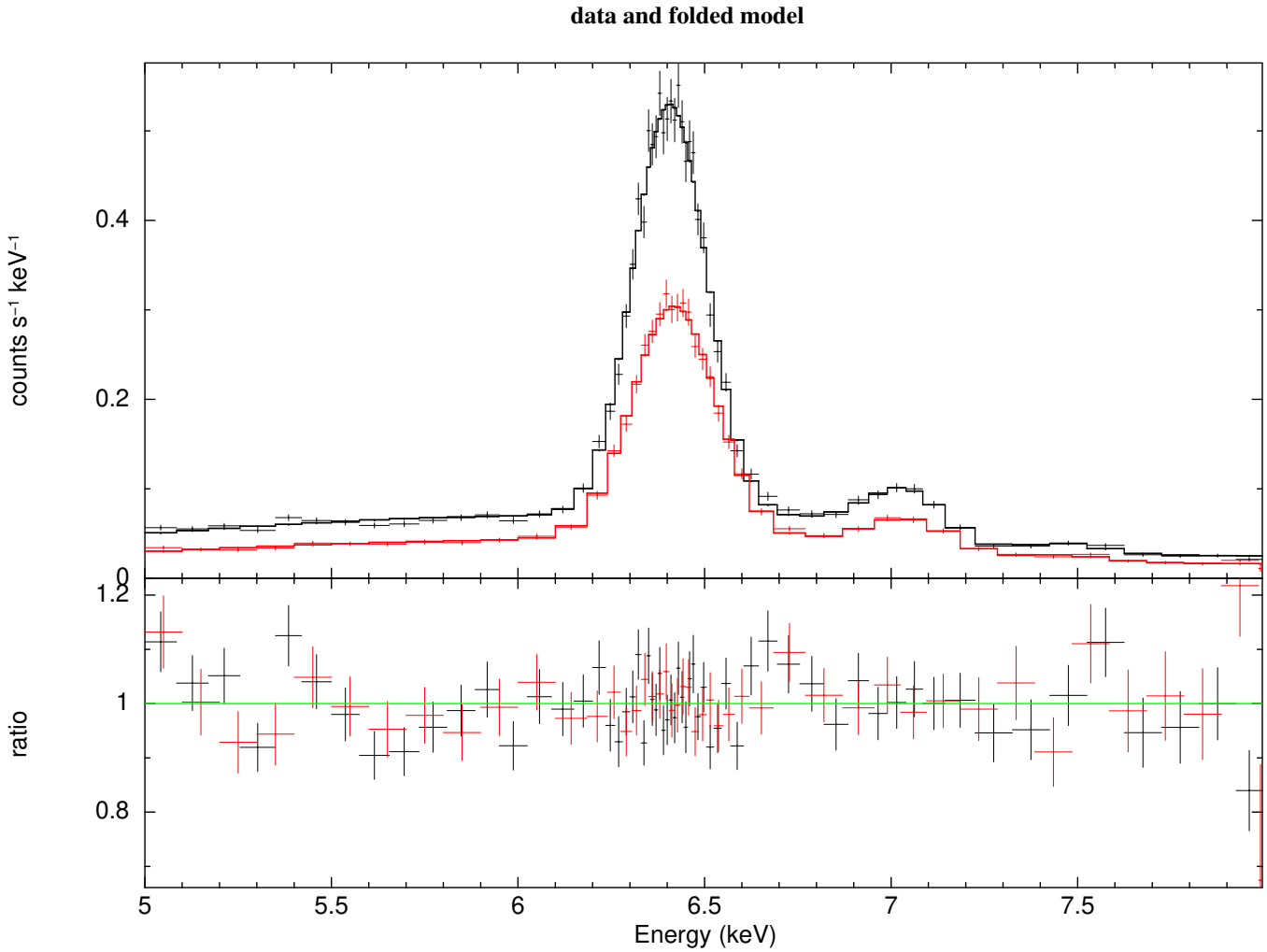


Fitted tied width = 37eV
(C=1338.0, dof=1182)



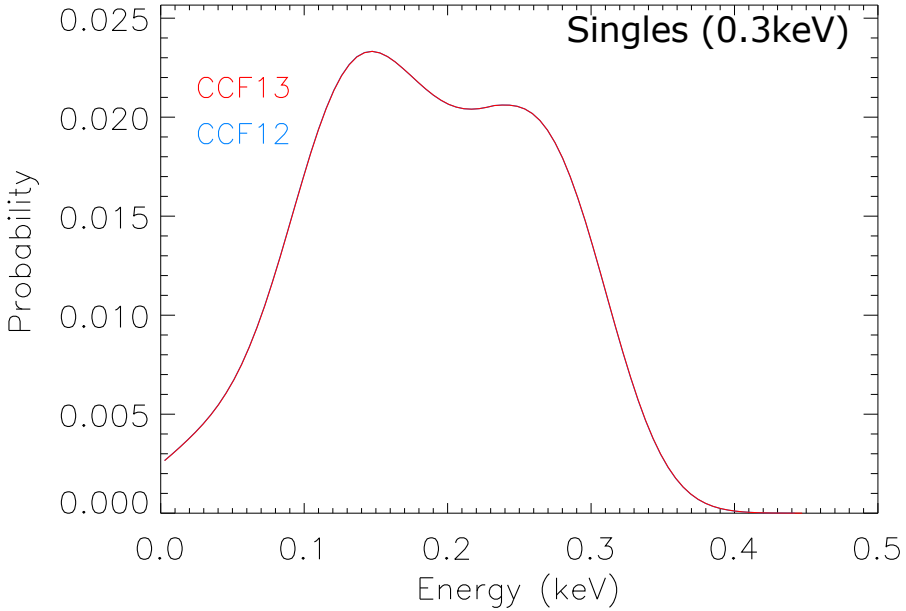
Fixed tied width = 21eV
(C=1356.1, dof=1184)

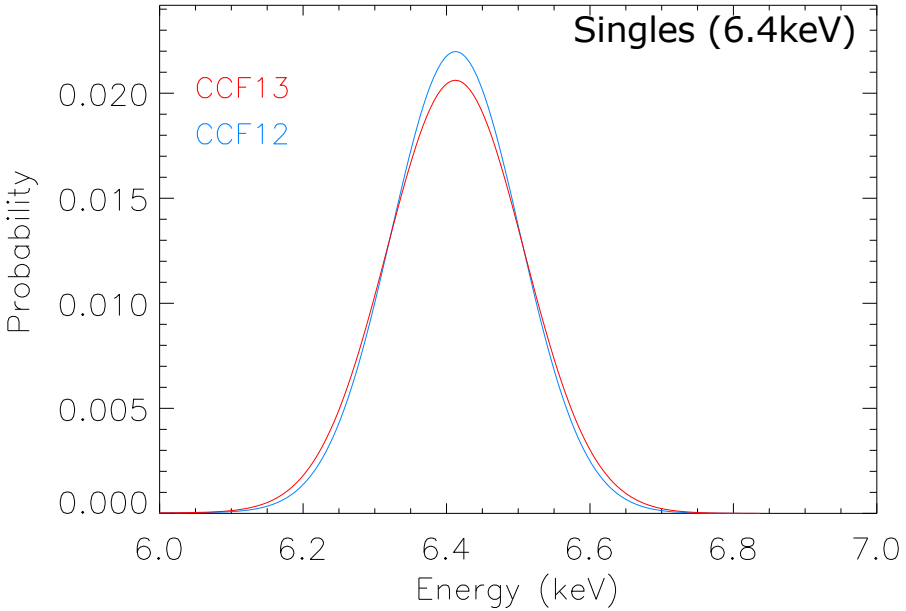
Rev 4423 (0932990101) – new CCF (0013)

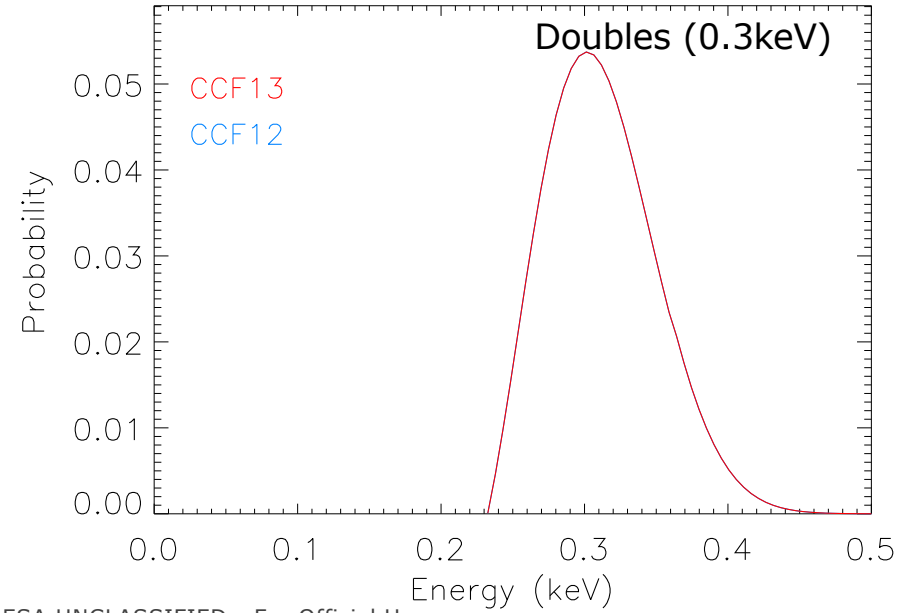


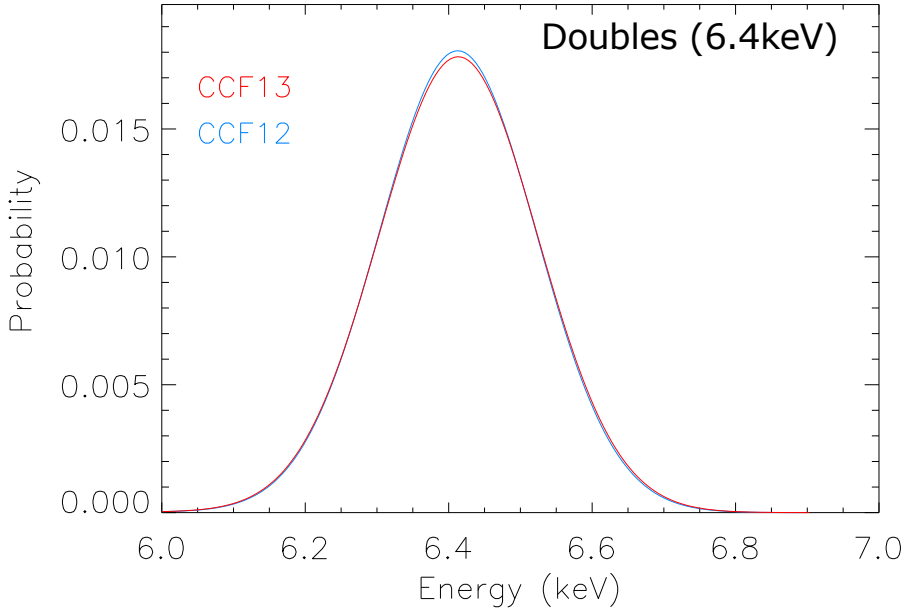
N4 parameters adjusted to achieve a fitted (S+D tied) width ~21eV (90% range 8-28 eV) (C=1335.09, dof=1182).

Epoch 3 (rev 4423): CCF 0012 cf CCF 0013 redistribution









Outcomes

- Adjustments of N4 parameters (only)
- Epoch 1 values unchanged
- Modest change to epoch 2 (singles).
- First values derived for epoch 3 – added (assumed same for all 6 modes)
- No position dependence included (as before)

Pattern	Time (MJD)	N4 ($x10^{-8}$)
1	52127	1.4
1	56717	-5.6
1	60342	-6.6
2	52127	3.1
2	56717	2.2
2	60342	2.1

Outcomes

- S+D tied fits yield 6.4keV line width ~21-24 eV for all 3 epochs

- Width for doubles (when fitted independently) are poorly constrained and tend to smaller values (a few eV) – width for independent singles increases slightly.
- Tying width of weak Fe Kβ (7.05 keV) line to Fe Kα (6.4 keV), barely changes the width (20.6 eV)

Epoch (rev)	W_{S+D} (eV)	W_S (eV)
1 (0304)	21 (14-26)	23 (16-29)
2 (2605)	24 (2-38)	25 (0-44)
3 (4423)	21 (8-28)	22 (7-30)

- Offaxis obs (rev 0824450301, rev 3438) in CCD7 at Y=146 gave width=38.9eV (CCF0012) cf 32.4eV when using CCF0013.

Summary

- Weaker sources near central galaxy are variable and/or appear to contain lines not apparent in the galaxy emission – can affect residual fit widths.
- Fitted width for epoch 1 ~21 eV with existing params (did not identify parameter region where width approaches 13 eV of Chandra HETG)
- Opted to adjust N4 params to achieve ~ same residual width (~21 eV) for each of the 3 epochs
- Achieved 21-24 eV by modest adjustment of epoch 2 values and new values for epoch 3
- CCF 0013 updated/released
- Positional (off axis) variations are apparent but no effort applied to address this
- Significant effects at lower energies not expected but not verified by data.