EPIC-pn Burst Mode X-ray loading and rate-dependent CTI calibration

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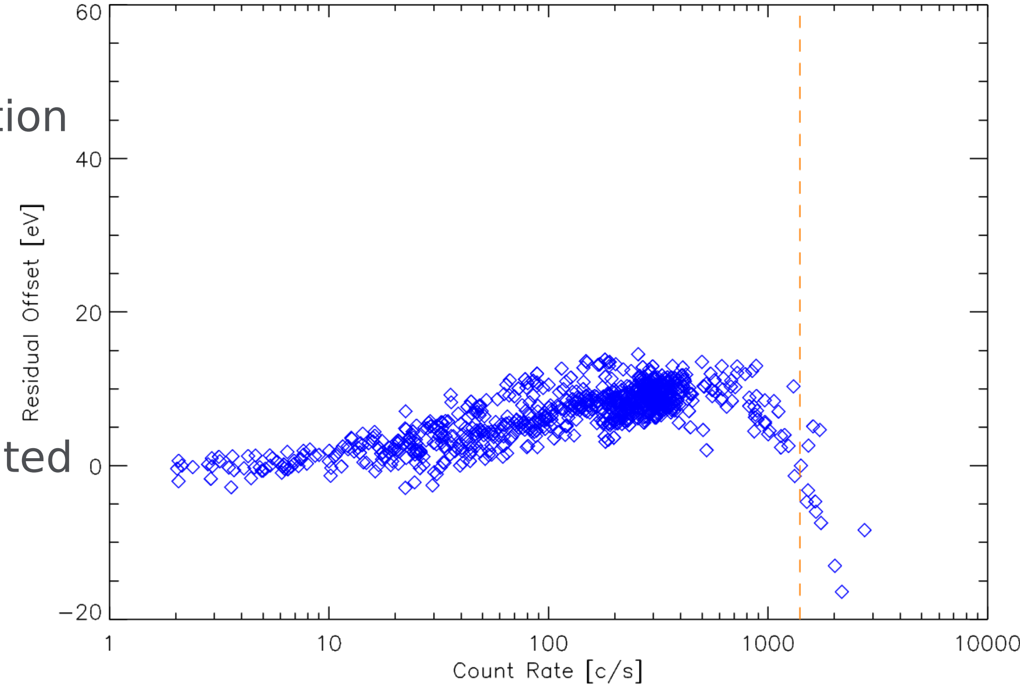
Energy offsets caused by X-ray loading

- In 2010, significant effects from X-ray loading (XRL) were discovered in the timing mode and burst mode offset maps (Guainazzi & Smith 2013, XMM-CAL-SRN-0302)

=> As of 23rd March 2012 offset maps with closed filter rather than science filter



- But pre-2012 observations need XRL correction

- Causes not understood

=> Empirical correction:

$$\Delta\mathbf{PHA} = \boldsymbol{a} + \boldsymbol{b} \times \mathbf{XRL}$$

- In Timing Mode a=0, b=1 already implemented
- Since in burst mode, no offset at low count rates: a=0. Further b=1 was chosen and subsequent Rate Dependent Charge Transfer Ineffecieny (RDCTI) calibration adjusted:

Rate Dependent CTI correction

Energy shifts caused by Charge Transfer Inefficiencies (CTI) are correced with

a parameterized function (hard-coded in the SAS) called Gain factor:

$$\mathbf{G=(\mathit{a0}\ C^{\mathit{a1}}) + \mathit{a2}}$$

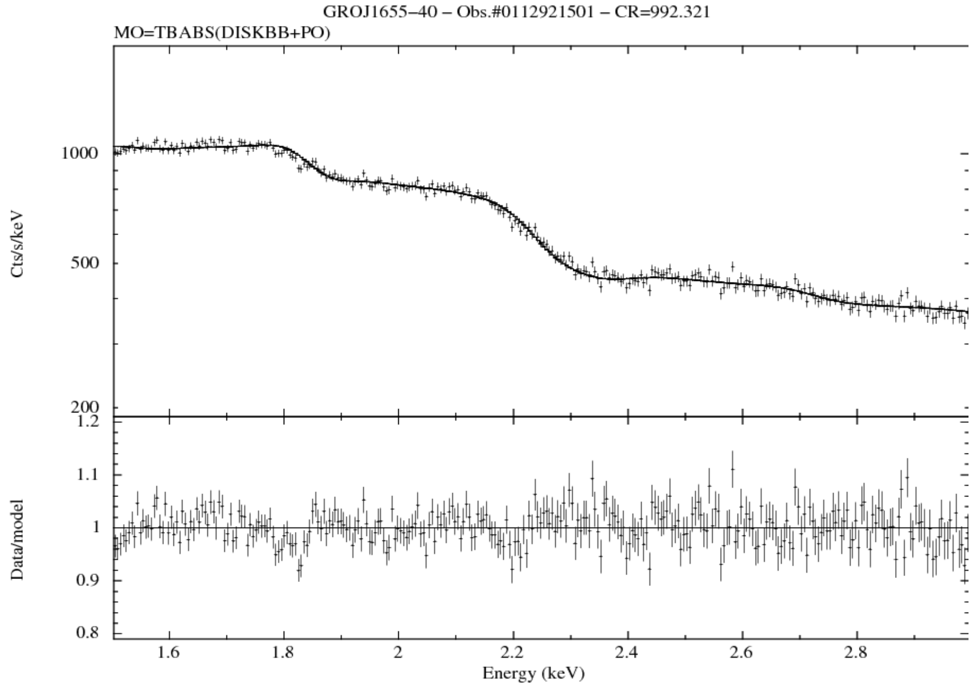
with C the average number of shifted electrons in the events file and *a0, a1, a2* adjustable parameters that are stored in the CCF component

EPN_CTI_0045.CCF

where 0045 is the current version number. Thus the values of *a0, a1, a2* control the rate dependent correction and are determined empirically.

Energy scale correction: Determine energy shifts

- To detect possible energy shifts in the final spectra, distinct features such as emission lines would be ideal, but most burst mode spectra only contain continuum with very weak emission/absorption lines which might even be shifted by high velocities
- Use instrumental edges of Si (CCD) and Au (mirror) that are included in the response
- Method: perform a spectral fit including a gain parameter that shifts the entire spectrum
- Ideal: gain parameter zero
- Use non-zero gain parameters to empirically determine calibration parameters



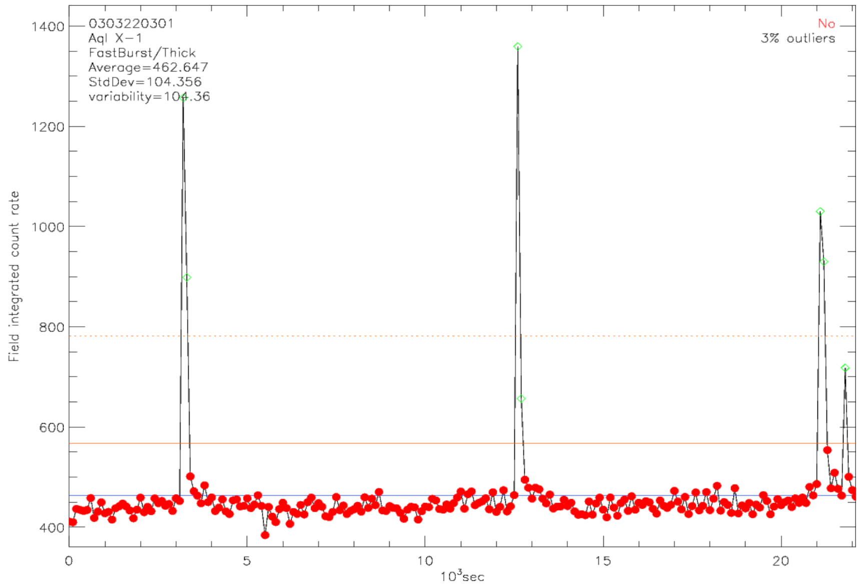
Energy scale correction: Sample

- XMM-Newton Science Archive (XSA) contains 123 burst mode exposures (small sample)
- Since we are calibrating rate dependent effects, only observations of non-variable sources can be used.

Only include sources with variations within 3 times the standard deviation

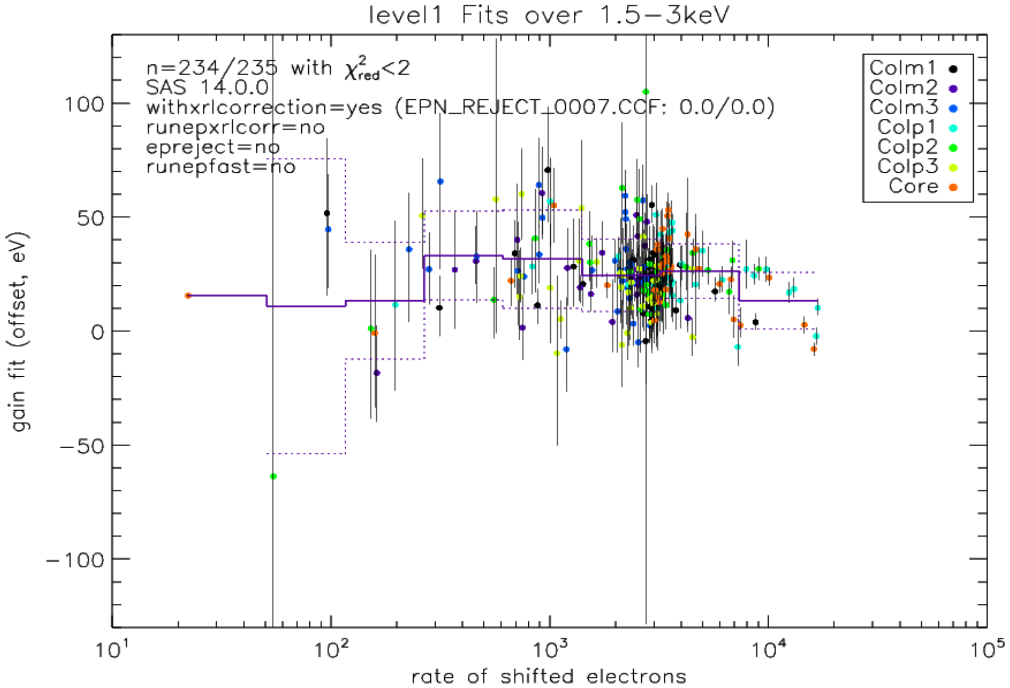
=> even smaller sample

- Sources with sharply-peaked variability patterns can be included when applying time filtering (gti)



Energy scale correction: Current status

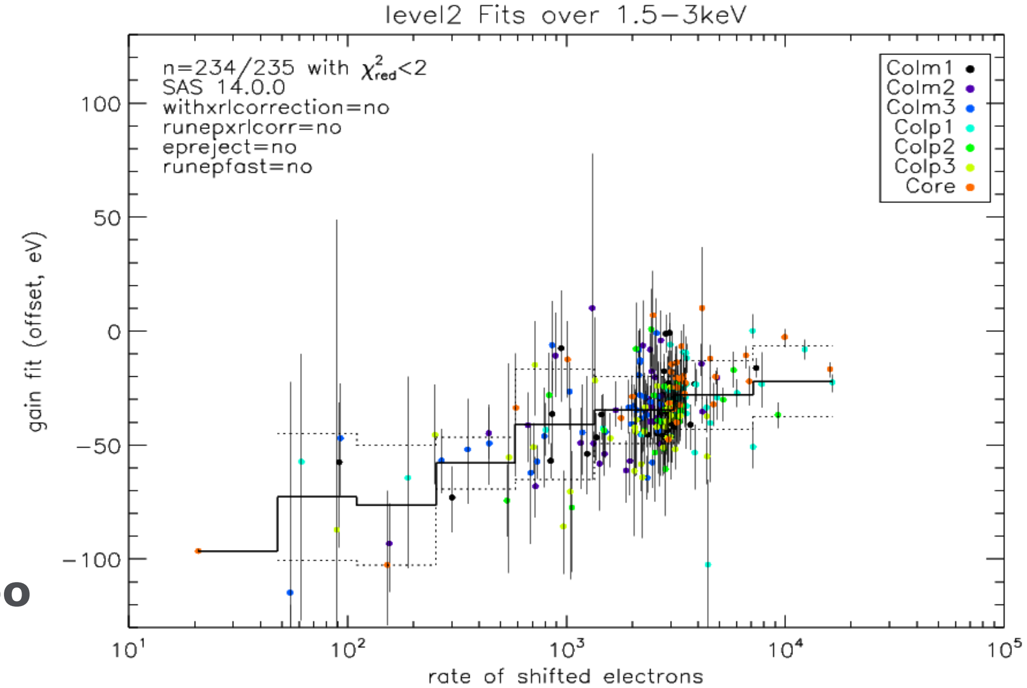
- The currently public CCF for burst mode contains energy scale corrections
  - XRL: *a*=0, *b*=0 EPN_REJECT_0007.CCF thus no correction
  - RDCTI: *a0*=0.003, *a1*=0.3050, *a2*=0.943



- withdefaultcal=yes

Energy scale correction: Without any corrections

- The currently public CCF for burst mode contains energy scale corrections
  - XRL: *a*=0, *b*=0 EPN_REJECT_0007.CCF thus no correction
  - RDCTI: *a0*=0.003, *a1*=0.3050, *a2*=0.943



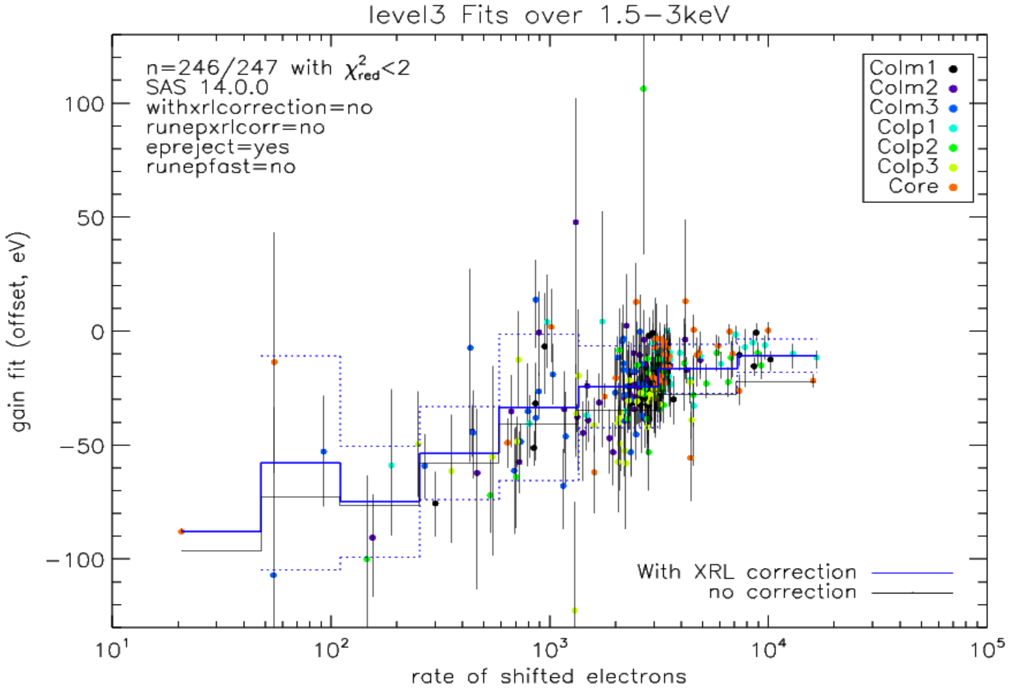
withdefaultcal=**NOoooooo**

no XRL: *a*=0, *b*=0

no RDCTI*: a0*=*a1*=0, *a2*=1 => *G*=1

Energy scale correction: Only XRL correction

- The currently public CCF for burst mode contains energy scale corrections
  - XRL: *a*=0, *b*=0 EPN_REJECT_0007.CCF thus no correction
  - RDCTI: *a0*=0.003, *a1*=0.3050, *a2*=0.943



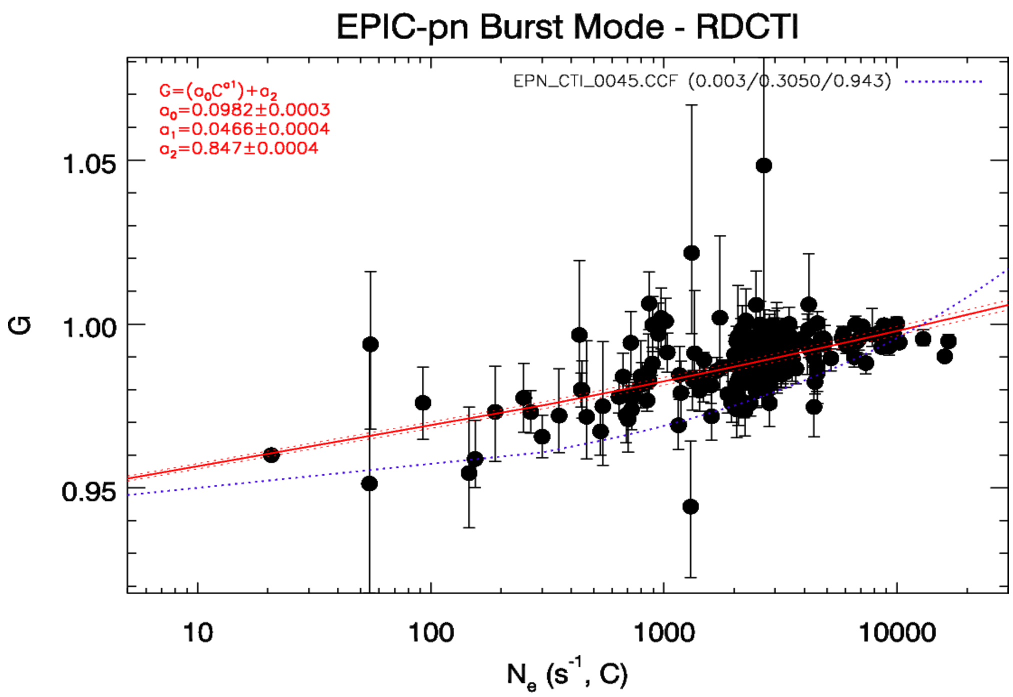
- New: XRL: *a*=0, *b*=1

=> recalibrate *a0, a1, a2* for RDCTI

Energy scale correction: Determine parameters for gain factor

- Normalise gain shifts from spectral fits to the energy of the gold edge:

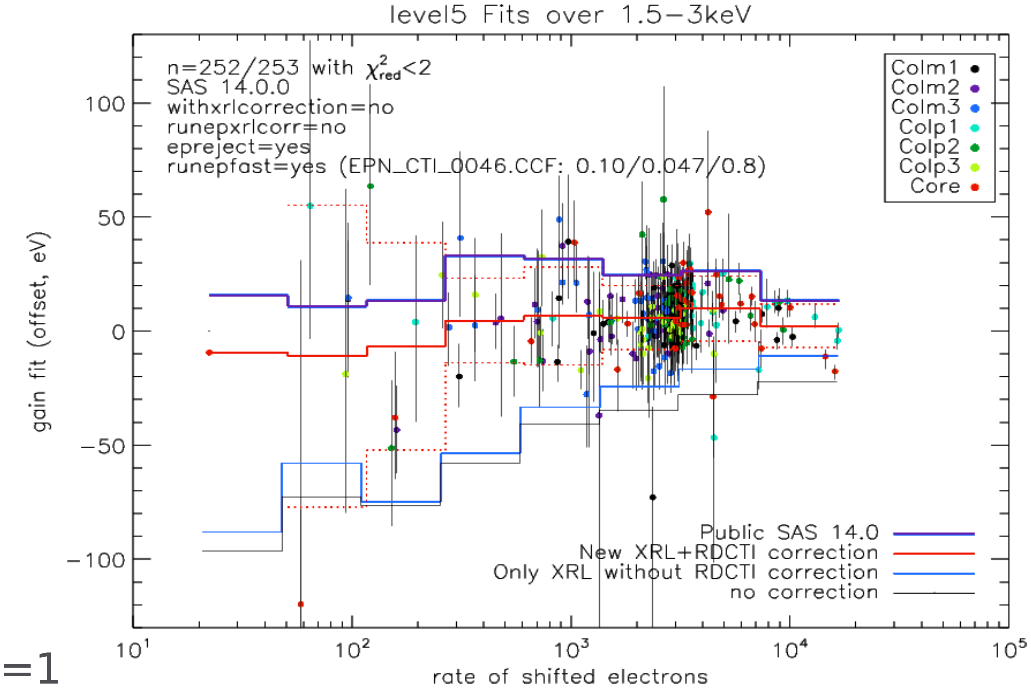
G=gain/2200eV+1



- Perform a fit to datapoints with *a0, a1, a2* as free parameters

Energy scale correction: Current status

- The currently public CCF for burst mode contains energy scale corrections
  - XRL: *a*=0, *b*=0 EPN_REJECT_0007.CCF thus no correction
  - RDCTI: *a0*=0.003, *a1*=0.3050, *a2*=0.943

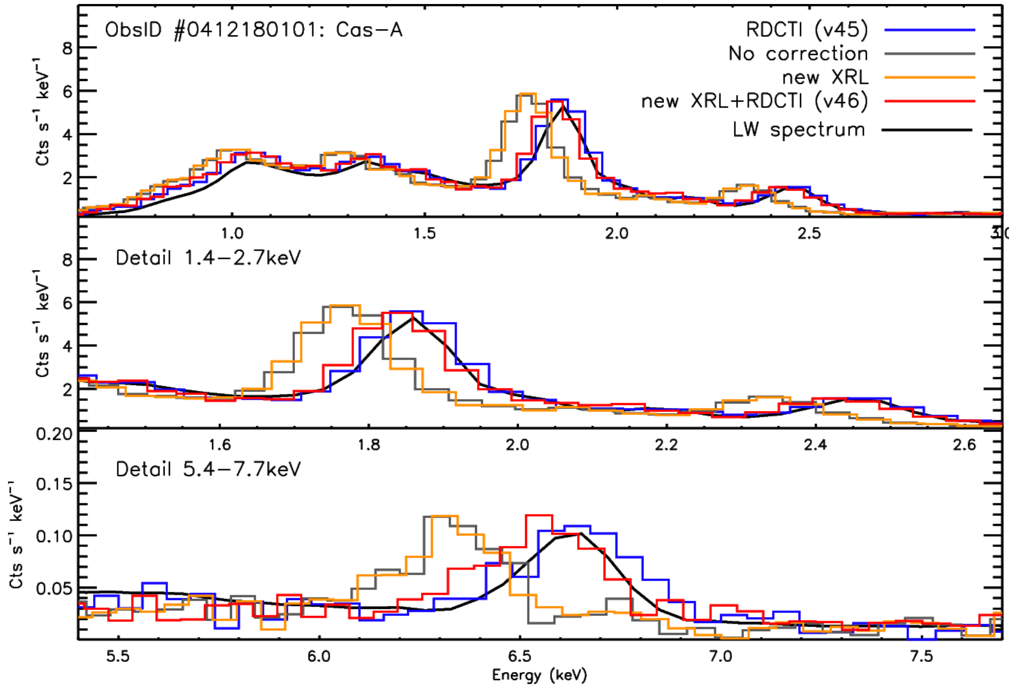


- New: XRL: *a*=0, *b*=1

RDCTI: *a0*=0.1, *a1*=0.047, *a2*=0.8

Energy scale correction: Validation

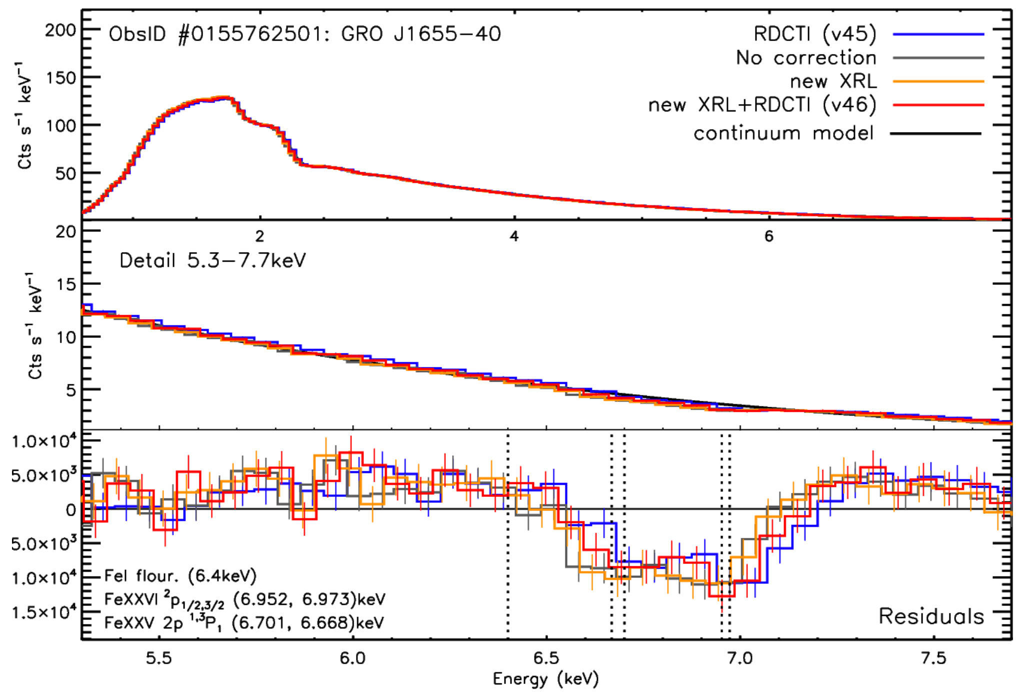
- One burst mode exposure contains emission lines, Cas A, and there is a Large Window exposure for direct (model-independent) comparison:



- The new calibration (red) is slightly worse than present one (blue)
- But: this is the faintest target in the sample and not representative for typical use of burst mode

Energy scale correction: Validation

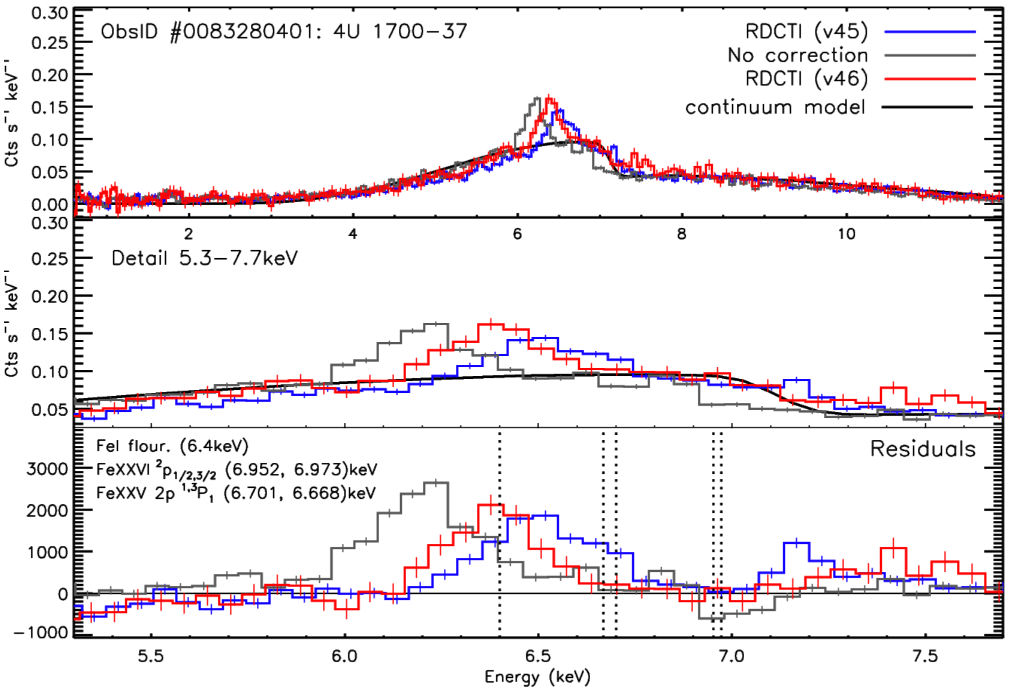
- GRO J 1655-50 has absorption lines of Fe XXV

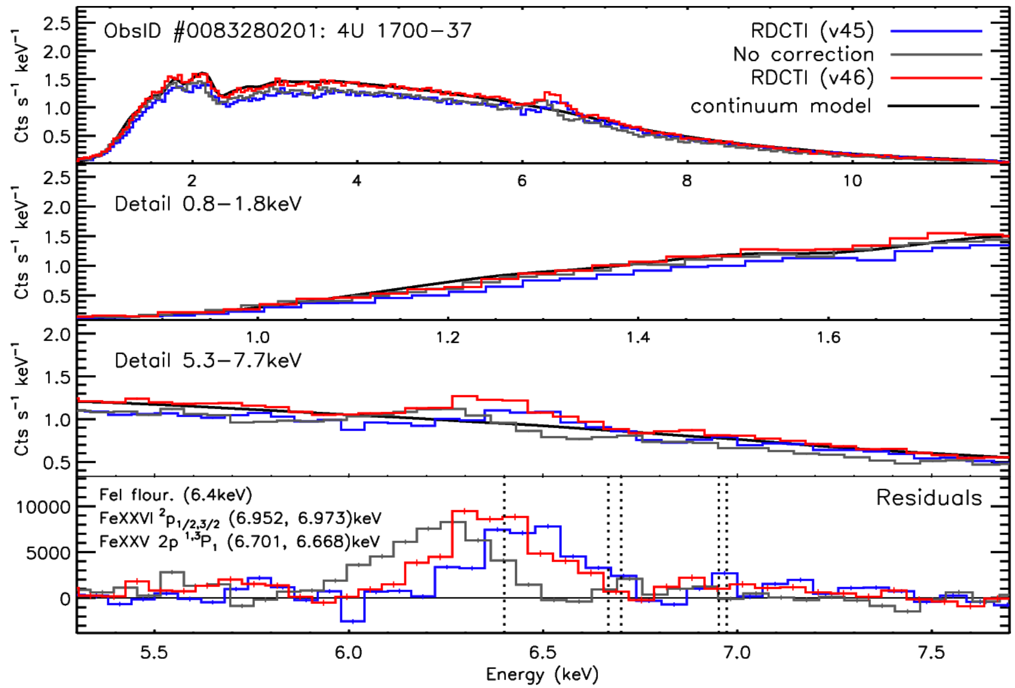


- The new calibration (red) is clearly better than present one (blue)

Energy scale correction: Validation

- 4U 1700-37 has Fe XXV/XXVI emission lines and a neutral Fe absorption edge:





- The new calibration (red) is much better than present one (blue)
- Note that these observations have no offset map, thus XRL correction not effective