

AstroSat Calibration Meeting
(AstroSat Science Support Cell, IUCAA, Pune)

Cross spectral calibration of LAXPC, CZTI, and NuSTAR with Crab

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Analysis:

3 epochs of Crab observations with AstroSat are analysed from 2017, 2018, and 2020. Quasi-contemporaneous NuSTAR observations are considered.

LAXPC:

- Data reduced using Format (A) pipeline.
- Only LAXPC20 spectra are used for cross-calibration fitting.

CZTI:

- Spectra produced using pipeline v3 and associated CALDB

NuSTAR:

- nupipeline v0.4.9 (2021-03-21)
- For bright sources, post-processing filters can veto some good source counts. Can underestimate source flux and lead to mismatch between FPMs.

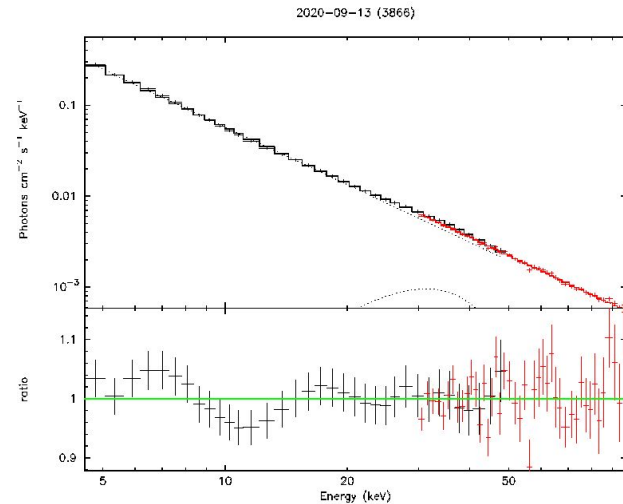
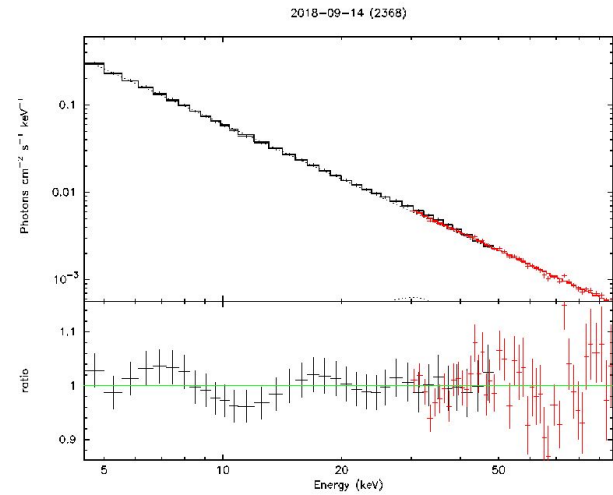
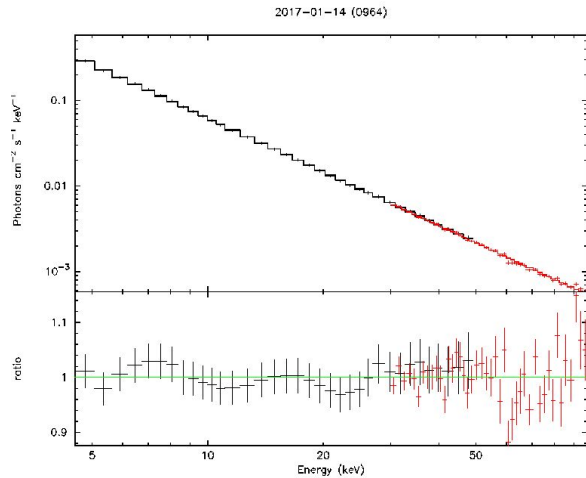
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SXT:

- Pipeline v1.4b

LAXPC-CZTI

- LAXPC20 and CZTI_Q0 were jointly fitted.
- LAXPC (4 - 50 keV). CZTI (30 - 100 keV)
- Model: TBabs*powerlaw
- nH fixed at $2.2 \times 10^{21} \text{ cm}^{-2}$ (Madsen et al 2015)
- The photon index and its norm were tied across the instruments



- The cross-normalization constant has increased from 1% to 15% from 2017 to 2020
- The gaussian at 30 keV was not required for 0964.
- Photon index and normalization have remained consistent
- Total (4 - 100 keV) flux is $3 \times 10^{-8} \text{ erg s}^{-1} \text{ cm}^{-2}$

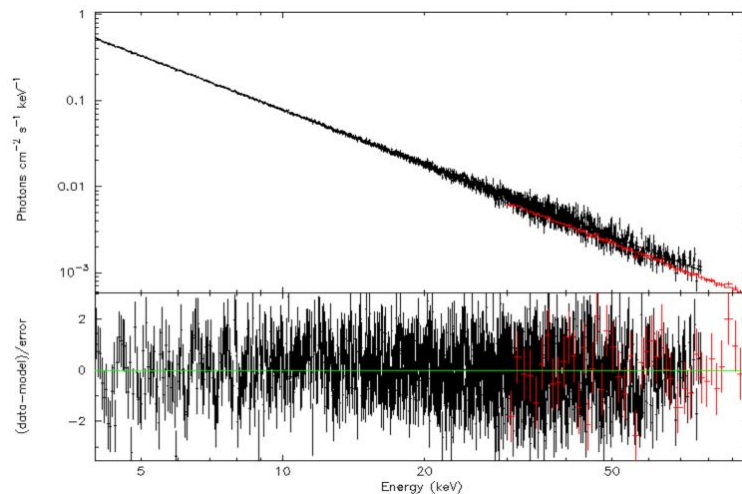
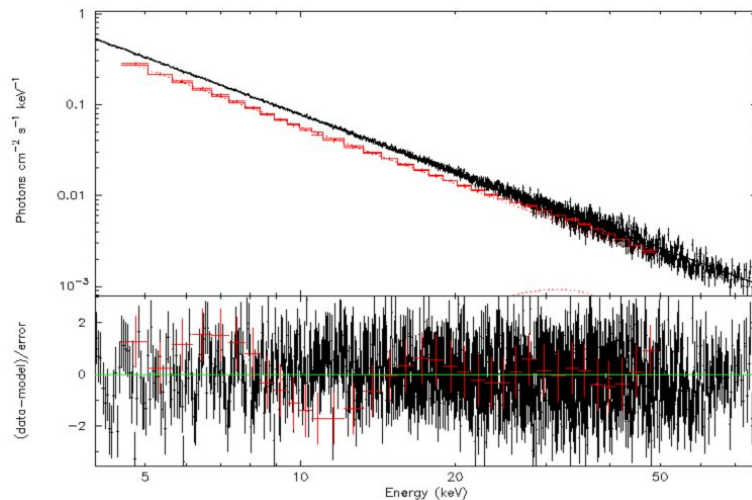
Date	OBSID	Constant	Γ	PL norm	LineE	Sigma	norm	χ^2_ν
20170114	0964	0.99 ± 0.01	2.08 ± 0.01	7.39 ± 0.15	-	-	-	1.01
20180914	2638	1.05 ± 0.03	2.10 ± 0.01	7.57 ± 0.24	30.1 ± 2.4	$7.6^{+3.5}_{-2.6}$	0.012 ± 0.006	1.04
20200913	3866	1.14 ± 0.03	2.10 ± 0.01	7.29 ± 0.22	31.3 ± 1.7	$10.0^{+3.0}_{2.0}$	0.025 ± 0.006	1.04

LAXPC-NuSTAR / CZTI-NuSTAR

- No exact simultaneous data. Joint fitting with nearest NuSTAR observations
- The fitting results are dominated by NuSTAR due to better statistics
- The cross-normalization constant for CZTI remains stable at $\sim 17\%$. For LAXPC it changes from 19% to 26%.

Cross-normalization constant of LAXPC and CZTI with NuSTAR

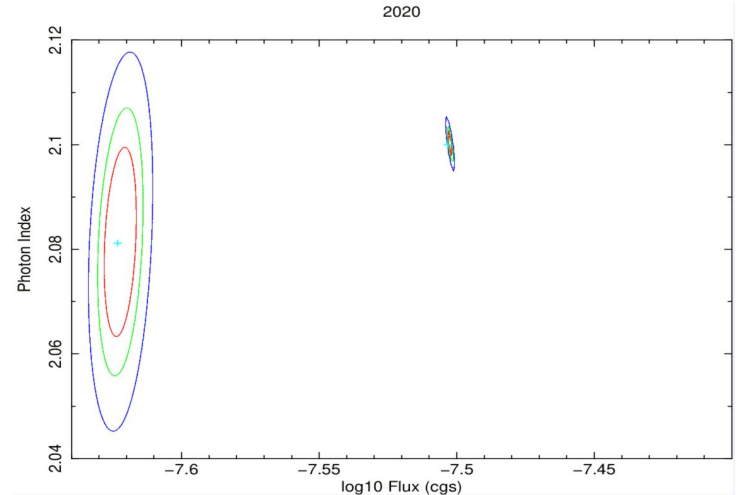
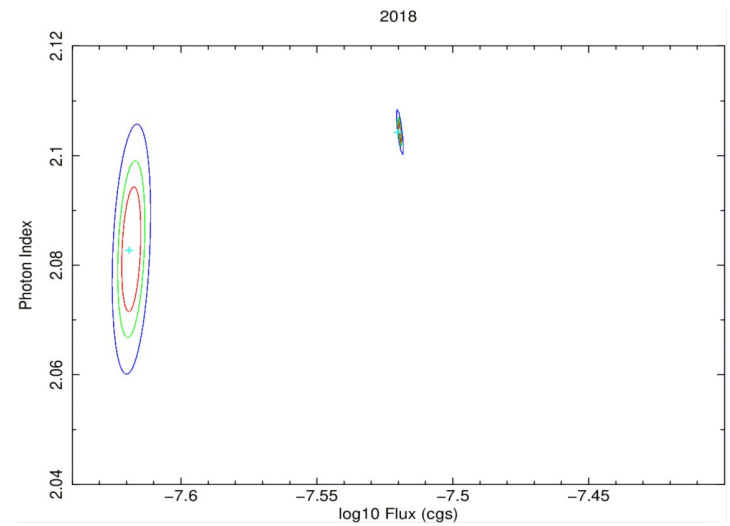
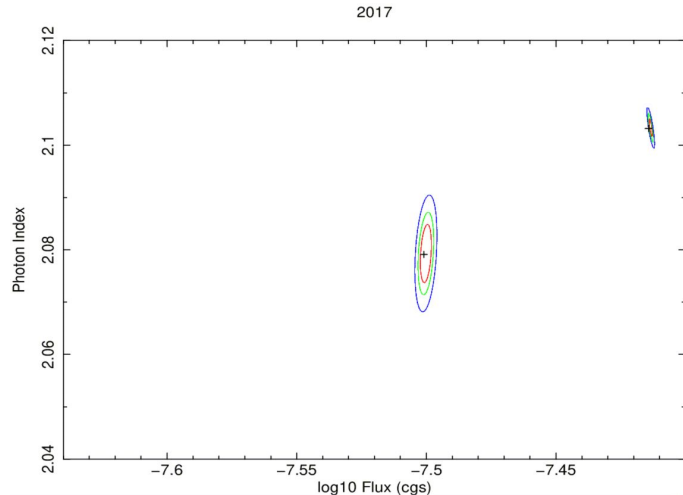
Instrument	2017	2018	2020
LAXPC	0.813 ± 0.005	0.784 ± 0.006	0.741 ± 0.006
CZTI	0.834 ± 0.004	0.831 ± 0.005	0.838 ± 0.005



LAXPC - NuSTAR

Separately fitted in the common range of 4-55 keV.

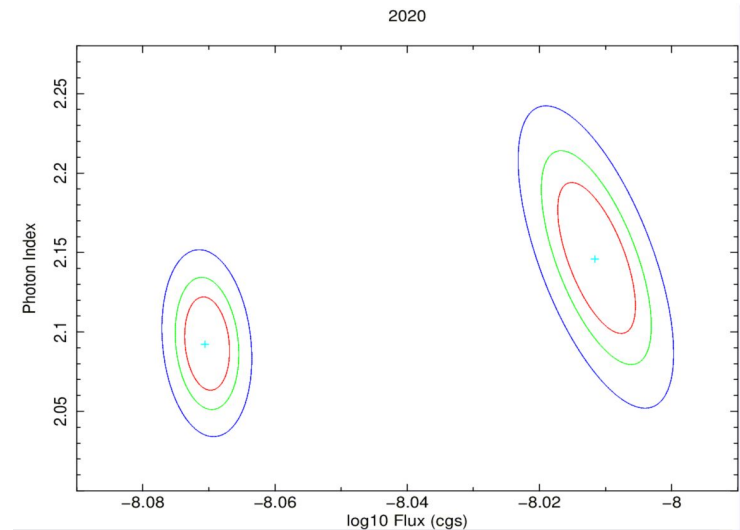
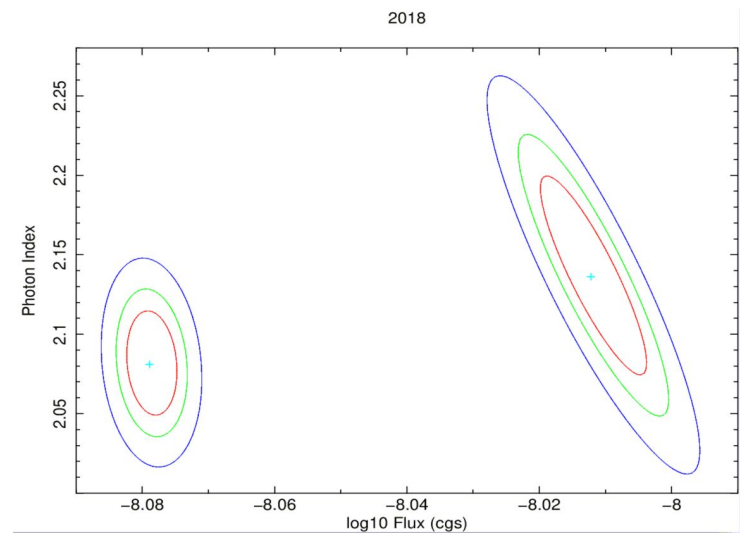
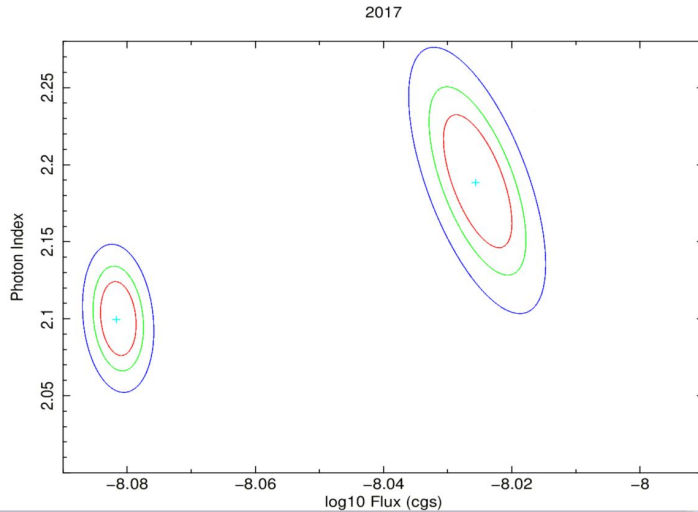
- Difference in flux is about 20%
- Fluxes in both LAXPC and NuSTAR decreased from 2017 to 2018/2020.
- Best fit photon index remains stable
- LAXPC contours continually increase in size.



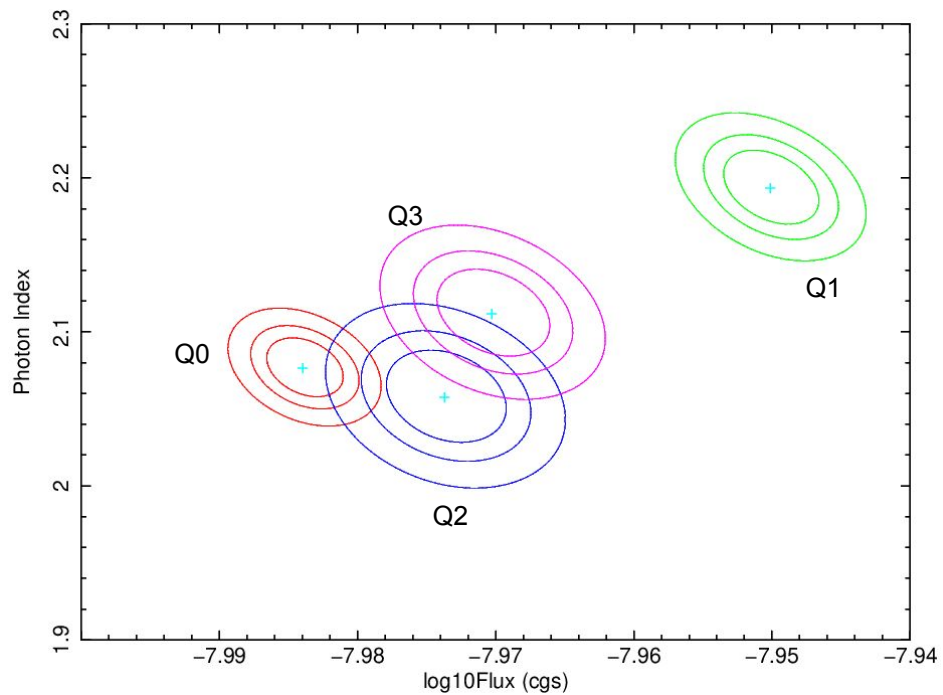
CZTI - NuSTAR

Separately fitted in the range of 30 -78 keV.

- Difference in photon index have reduced, due to decrease in NuSTAR estimates.
- Difference in flux remains at $\sim 15\%$



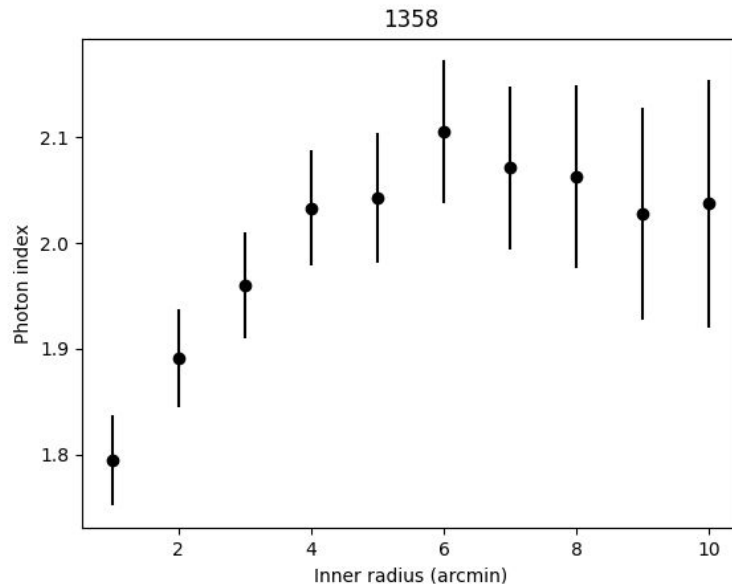
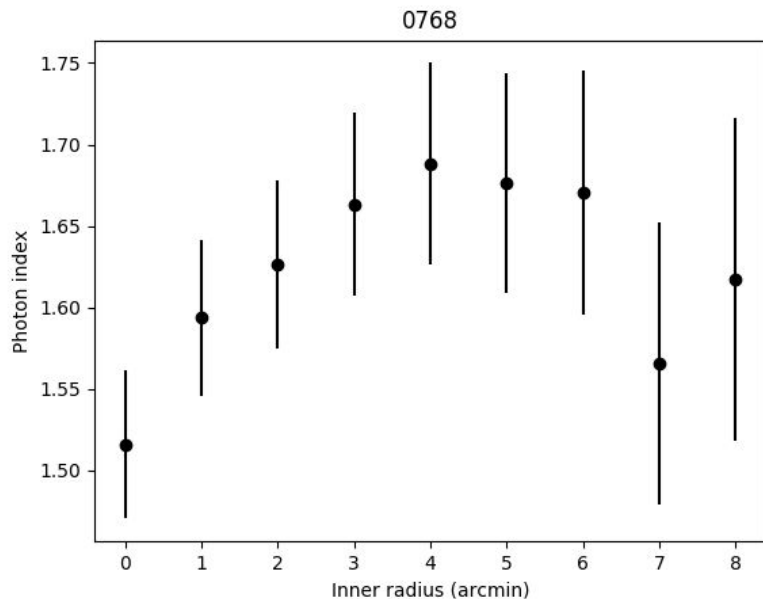
Cross-calibration of the four quadrants of CZTI.



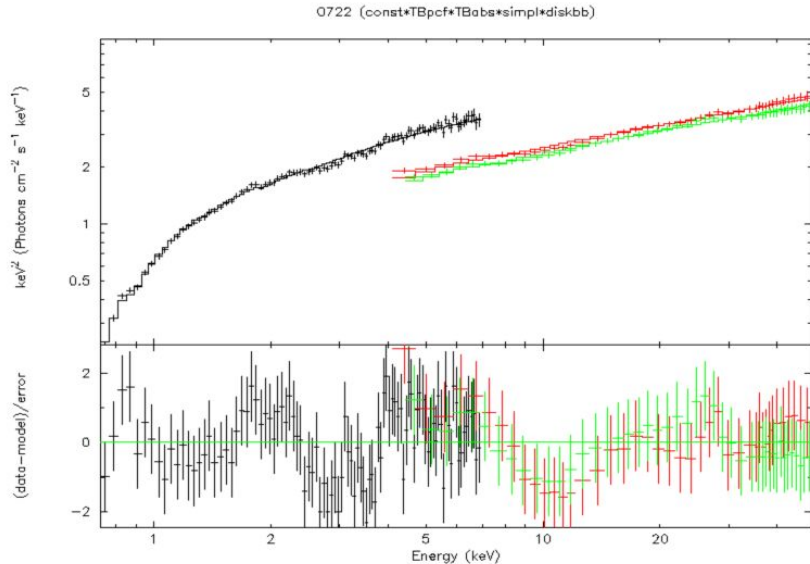
Spectral state dependence of cross-normalization factor between SXT and LAXPC

A test with Cygnus X-1

- SXT analysis using pipeline v1.4b
- Pileup correction done by using annular region selection.
- Hard state requires 2' - 3' inner radius. Softer states require bigger inner radius (~6').

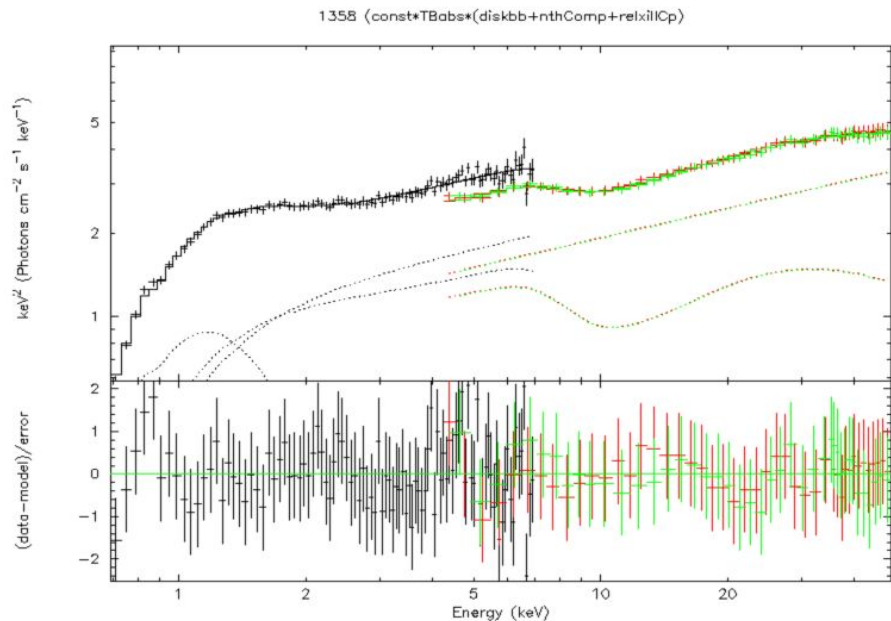


- During hard state the constant factor is about 60%.
It is independent of the model and spectral binning.



Data group: 1			
1	constant	factor	1.62788
2	TBpcf	nH	10^{22} 2.52480
2	TBpcf	pcf	0.500000
2	TBpcf	redshift	0.0
3	TBabs	nH	10^{22} 0.413357
4	simpl	Gamma	1.63246
4	simpl	FracSctr	0.350431
4	simpl	UpScOnly	1.00000
5	diskbb	Tin	keV 0.336923
5	diskbb	norm	2.47178E+04
Data group: 2			
1	constant	factor	1.00000
2	TBpcf	nH	10^{22} 2.52480
2	TBpcf	pcf	0.500000
2	TBpcf	redshift	0.0
3	TBabs	nH	10^{22} 0.413357
4	simpl	Gamma	1.63246
4	simpl	FracSctr	0.350431
4	simpl	UpScOnly	1.00000
5	diskbb	Tin	keV 0.336923
5	diskbb	norm	2.47178E+04

- For intermediate and soft states (where disk emission is strong), the cross-normalization factor is 10% - 20%
- Gain offset lied between 35-45 eV for all observations.



				Data group: 1
1	constant	factor		1.15575
2	TBabs	nH	10 ²²	0.489270
3	diskbb	Tin	keV	0.284617
3	diskbb	norm		4.33404E+04
4	nthComp	Gamma		1.67609
4	nthComp	kT_e	keV	1000.00
4	nthComp	kT_bb	keV	0.284617
4	nthComp	inp_type	0/1	1.00000
4	nthComp	Redshift		0.0
4	nthComp	norm		0.828516
5	relxillCp	Index1		3.00000
5	relxillCp	Index2		3.00000
5	relxillCp	Rbr		100.000
5	relxillCp	a		0.990000
5	relxillCp	Incl	deg	30.0000
5	relxillCp	Rin		-2.10216
5	relxillCp	Rout		400.000
5	relxillCp	z		0.0
5	relxillCp	gamma		1.67609
5	relxillCp	logxi		4.03481
5	relxillCp	Afe		10.0000
5	relxillCp	kTe	keV	1000.00
5	relxillCp	refl_frac		-1.00000
5	relxillCp	norm		1.38312E-02
				Data group: 2
1	constant	factor		1.00000
2	TBabs	nH	10 ²²	0.489270
3	diskbb	Tin	keV	0.284617
3	diskbb	norm		4.33404E+04
4	nthComp	Gamma		1.67609
4	nthComp	kT_e	keV	1000.00
4	nthComp	kT_bb	keV	0.284617