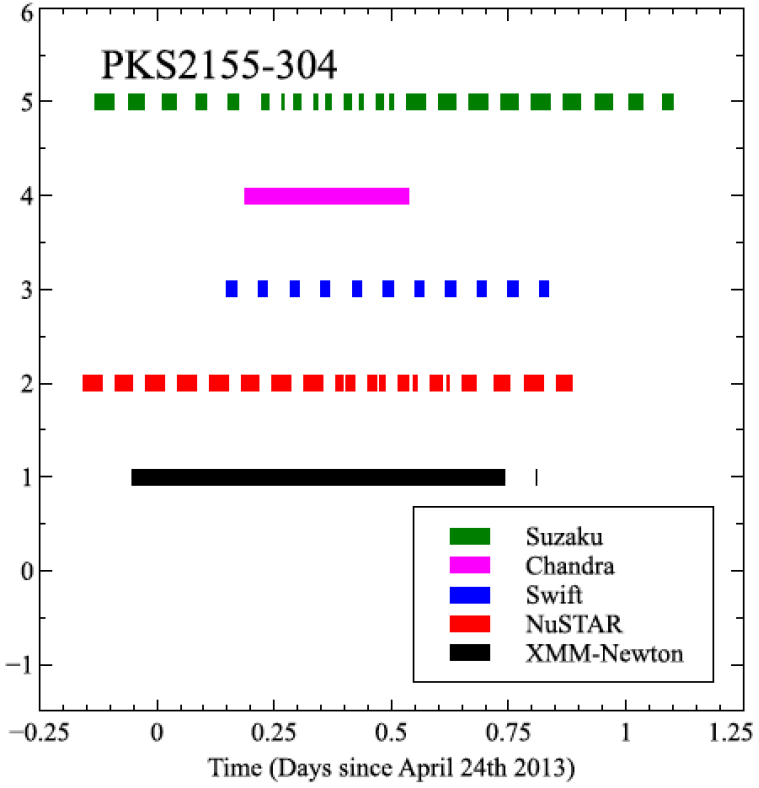
Cross Calibration Status 3c273 & PKS 2155

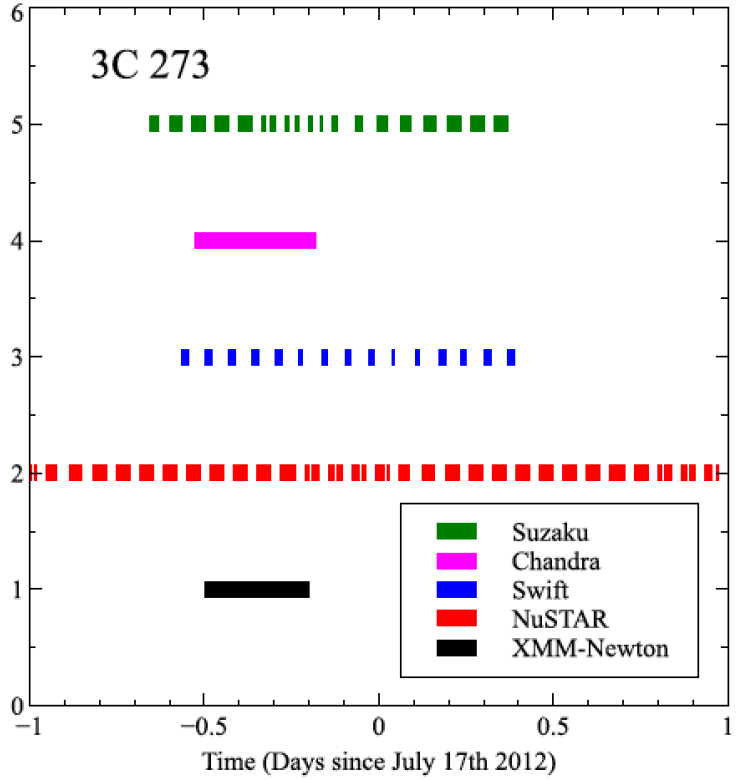
Kristin Kruse Madsen

Paper status

- All data analysis, plots and tables are done and automated for future data sets and/or re-extracted data sets.
- About 30-50% done with the text, pending review of plots and analysis.

Campaigns


PKS2155-304
Suzaku
Chandra
Swift
NuSTAR
XMM-Newton
Time (Days since April 24th 2013)


3C 273
Suzaku
Chandra
Swift
NuSTAR
XMM-Newton
Time (Days since July 17th 2012)

GTI cuts

TABLE 1
CROSS CALIBRATION CAMPAIGN

Instrument	OBSID	Exposure	OBSID	Exposure
	PKS2155-304		3c273	
NuSTAR	60002022002	45.	10002020001	244.
Chandra	15475	30.	14455	30.
XMM	0411782101	76.	0414191001	38.9
Swift	00030795108	17.7	00050900019	13.
Swift			00050900020	6.9
Suzaku	108010010	53.3	107013010	39.8

1. We analyze 10 observatory pairs as defined in Table 2.
2. We match up START and STOP times to the limiting observation ignoring SAA and occultation periods
3. Parameters from different observatory pairs should not be compared against each other.

TABLE 2
INSTRUMENT PAIRS

GTI Start (MJD)	GTI Stop (MJD)	Concatenated observation	Limiting observation	Exposure (ks)
		PKS 2155-304		
56406.184	56406.532	Suzaku	Chandra	8.3/30.1
56405.840	56406.883	Suzaku	NuSTAR	48.3/38.4
56406.146	56406.831	Suzaku	Swift	25.8/17.8
56405.944	56406.808	Suzaku	XMM	30.7/68.6
56406.184	56406.532	NuSTAR	Chandra	30.1/16.0
56405.840	56406.883	NuSTAR	Swift	29.0/17.8
56405.944	56406.808	NuSTAR	XMM	31.9/68.6
56406.184	56406.532	XMM	Chandra	
56406.146	56406.808	XMM	Swift	
56406.184	56406.532	Swift	Chandra	8.1/30.1
		3C 273		
56124.346	56125.369	NuSTAR	Suzaku	/40.2
56124.475	56124.822	NuSTAR	Chandra	/30.0
56124.438	56125.389	NuSTAR	Swift	/20.1
56124.504	56124.801	NuSTAR	XMM	/25.3
56124.475	56124.822	Suzaku	Chandra	/30.0
56124.438	56125.389	Suzaku	Swift	/20.1
56124.504	56124.801	Suzaku	XMM	/25.3
56124.475	56124.822	Swift	Chandra	/30.0
56124.504	56124.801	Swift	XMM	/25.3
56124.504	56124.801	Chandra	XMM	/25.3

Individual fits PKS 2155

TABLE 3
CROSS-CALIBRATION *tbabs* × *pegpwrlw*

Instrument	Γ	Flux 3–7 keV 10^{-12} erg/cm^2/s	Energy fit Range (keV)
PKS2155-304			
FPMA	2.73 ±0.13	5.90 ±0.23	3–8
FPMB	2.79 ±0.15	5.75 ±0.24	3–8
ACIS LETGS	2.92 ±0.08	6.45 ±0.27	2–8
FPMA	2.81 ±0.07	5.49 ±0.12	3–9
FPMB	2.77 ±0.07	5.45 ±0.13	3–9
XIS0	2.80 ±0.08	5.17 ±0.11	3–9
XIS1	2.84 ±0.09	5.12 ±0.11	3–9
XIS3	2.87 ±0.08	5.18 ±0.11	3–9
FPMA	2.82 ±0.09	5.45 ±0.16	3–9
FPMB	2.78 ±0.10	5.32 ±0.17	3–9
XRT	2.91 ±0.11	5.16 ±0.29	2–8
FPMA	2.80 ±0.07	5.64 ±0.14	3–10
FPMB	2.80 ±0.07	5.56 ±0.15	3–10
XMM MOS1	2.70 ±0.03	5.80 ±0.11	2–9
XMM MOS2	2.75 ±0.03	5.62 ±0.10	2–9
XMM pn	2.78 ±0.03	5.52 ±0.09	2–9

Instrument	Γ	Flux 1–5 keV 10^{-12} erg/cm^2/s	Energy fit Range (keV)
XRT	2.60 ±0.05	19.7 ±0.47	1–7
ACIS LETGS	2.65 ±0.03	22.0 ±0.30	1–7
XIS0	2.85 ±0.03	19.7 ±0.33	1–8
XIS1	2.79 ±0.03	21.0 ±0.31	1–8
XIS3	2.76 ±0.03	20.0 ±0.32	1–8
ACIS LETGS	2.65 ±0.03	22.0 ±0.30	1–8
XIS0	2.79 ±0.02	18.0 ±0.17	1–8
XIS1	2.81 ±0.02	19.0 ±0.17	1–8
XIS3	2.79 ±0.02	18.2 ±0.17	1–8
XRT	2.69 ±0.03	18.1 ±0.30	1–8
XIS0	2.79 ±0.01	18.4 ±0.16	1–9
XIS1	2.79 ±0.01	19.6 ±0.15	1–9
XIS3	2.77 ±0.01	18.9 ±0.16	1–9
XMM MOS1	2.77 ±0.01	19.8 ±0.12	1–9
XMM MOS2	2.81 ±0.01	19.9 ±0.12	1–9
XMM pn	2.73 ±0.01	18.8 ±0.10	1–9
ACIS LETGS	2.65 ±0.03	22.0 ±0.30	1–8
MOS1	2.79 ±0.02	20.6 ±0.22	1–9
MOS2	2.82 ±0.02	20.4 ±0.22	1–9
pn	2.74 ±0.01	19.5 ±0.15	1–9
XRT	2.69 ±0.03	18.1 ±0.30	1–8
MOS1	2.79 ±0.02	20.6 ±0.22	1–9
MOS2	2.82 ±0.02	20.4 ±0.22	1–9
pn	2.74 ±0.01	19.5 ±0.15	1–9

Individual fits 3C273

TABLE 4
CROSS-CALIBRATION *tbabs* × *pegpwrlw*

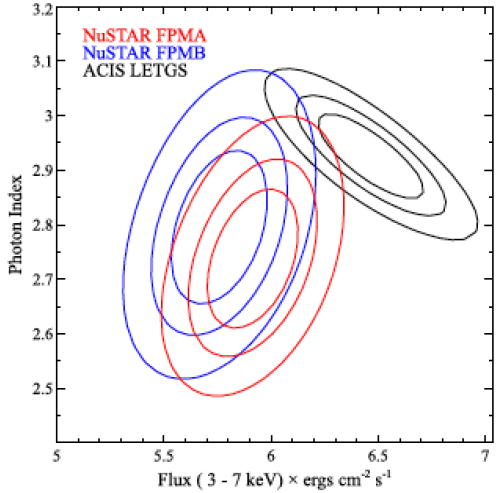
Instrument	Γ	Flux 3–7 keV 10^{-12} erg/cm^2/s	Energy fit Range (keV)
3C273			
FPMA	1.59 ±0.04	39.9 ±0.55	3–8
FPMB	1.69 ±0.04	41.3 ±0.59	3–8
ACIS METGS	1.62 ±0.05	44.9 ±1.30	2–8
ACIS HETGS	1.53 ±0.05	44.2 ±1.00	2–8
FPMA	1.65 ±0.02	40.9 ±0.33	3–9
FPMB	1.66 ±0.02	42.5 ±0.36	3–9
XIS0	1.63 ±0.02	40.6 ±0.31	3–9
XIS1	1.69 ±0.02	40.4 ±0.31	3–9
XIS3	1.66 ±0.02	41.5 ±0.32	3–9
FPMA	1.64 ±0.02	40.9 ±0.36	3–9
FPMB	1.66 ±0.02	42.2 ±0.38	3–9
XRT	1.55 ±0.06	42.4 ±1.24	2–8
FPMA	1.63 ±0.03	39.7 ±0.60	3–10
FPMB	1.67 ±0.03	41.3 ±0.64	3–10
XMM MOS1	1.51 ±0.02	40.6 ±0.44	2–9
XMM MOS2	1.52 ±0.02	39.0 ±0.42	2–9
XMM pn	1.58 ±0.01	37.0 ±0.25	2–9

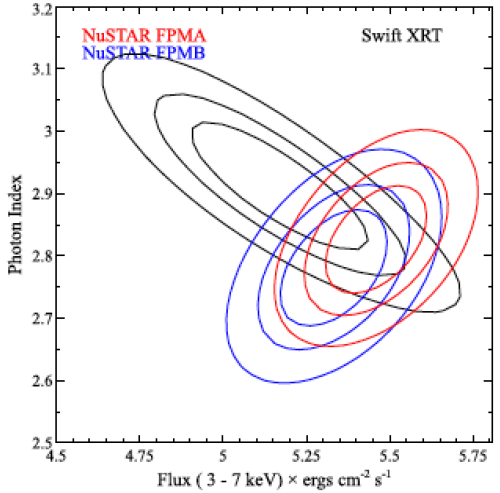
Instrument	Γ	Flux 1–5 keV 10^{-12} erg/cm^2/s	Energy fit Range (keV)
XRT	1.41 ±0.04	61.6 ±1.58	1–7
ACIS METGS	1.57 ±0.02	64.5 ±0.72	1–7
ACIS HETGS	1.58 ±0.02	62.8 ±0.82	1–7
XIS0	1.61 ±0.01	58.4 ±0.48	1–8
XIS1	1.69 ±0.01	58.7 ±0.43	1–8
XIS3	1.65 ±0.01	59.6 ±0.47	1–8
ACIS METGS	1.57 ±0.02	64.5 ±0.72	1–7
ACIS HETGS	1.58 ±0.02	62.8 ±0.81	1–7
XIS0	1.62 ±0.00	40.5 ±0.33	1–8
XIS1	1.67 ±0.00	39.1 ±0.34	1–8
XIS3	1.64 ±0.00	41.2 ±0.33	1–8
XRT	1.55 ±0.06	42.4 ±1.24	2–8
XIS0	1.62 ±0.01	39.4 ±0.57	1–9
XIS1	1.69 ±0.01	38.1 ±0.56	1–9
XIS3	1.65 ±0.01	39.8 ±0.56	1–9
XMM MOS1	1.51 ±0.02	40.6 ±0.44	2–9
XMM MOS2	1.52 ±0.02	39.0 ±0.42	2–9
XMM pn	1.58 ±0.01	37.0 ±0.25	2–9
ACIS METGS	1.58 ±0.02	44.8 ±1.13	1–8
ACIS HETGS	1.59 ±0.02	43.7 ±1.02	1–8
XMM MOS1	1.51 ±0.02	40.6 ±0.44	2–9
XMM MOS2	1.52 ±0.02	39.0 ±0.42	2–9
XMM pn	1.58 ±0.01	37.0 ±0.25	2–9
XRT	1.41 ±0.04	48.1 ±2.16	1–7
XMM MOS1	1.51 ±0.02	40.6 ±0.44	2–9
XMM MOS2	1.52 ±0.02	39.0 ±0.42	2–9
XMM pn	1.58 ±0.01	37.0 ±0.25	2–9
Instrument	Γ	Flux 20–40 keV 10^{-12} erg/cm^2/s	Energy fit Range (keV)
FPMA	1.73 ±0.05	60.4 ±1.41	15–45
FPMB	1.83 ±0.06	60.5 ±1.50	15–45
HXD	1.75 ±0.12	68.3 ±3.45	15–45

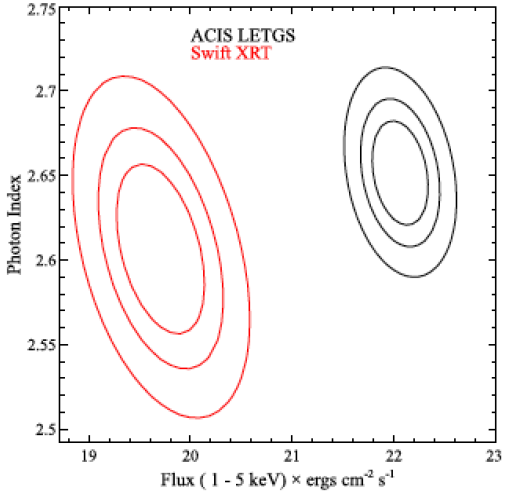
Plots

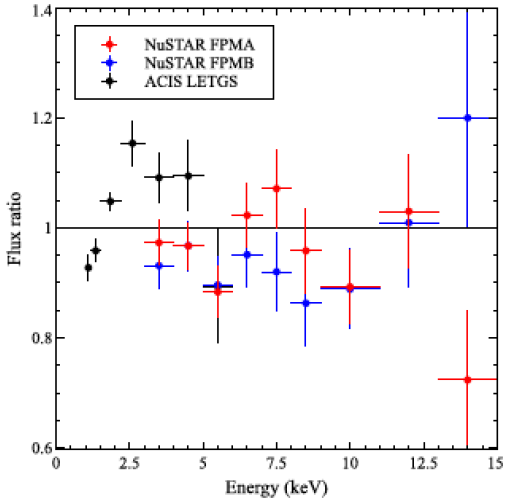
- Next couple of slides
  - Top panel is the confidence contours of the individual fits.
  - Bottom panel is the flux ratios to a combined power-law fit.

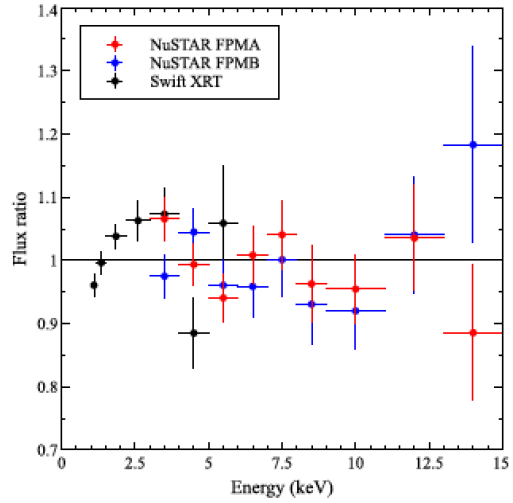
PKS 2155

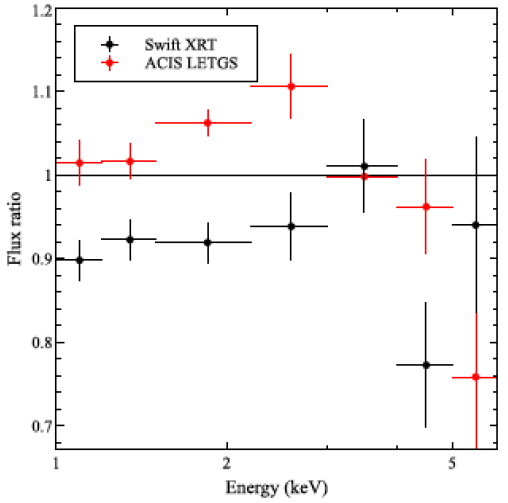

NuSTAR FPMA
NuSTAR FPMB
ACIS LETGS
Photon Index
Flux (3 - 7 keV) × ergs cm^{-2} s^{-1}


NuSTAR FPMA
NuSTAR FPMB
Swift XRT
Photon Index
Flux (3 - 7 keV) × ergs cm^{-2} s^{-1}

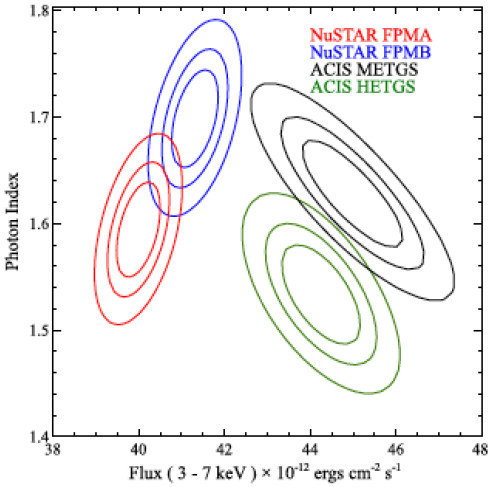

ACIS LETGS
Swift XRT
Photon Index
Flux (1 - 5 keV) × ergs cm^{-2} s^{-1}

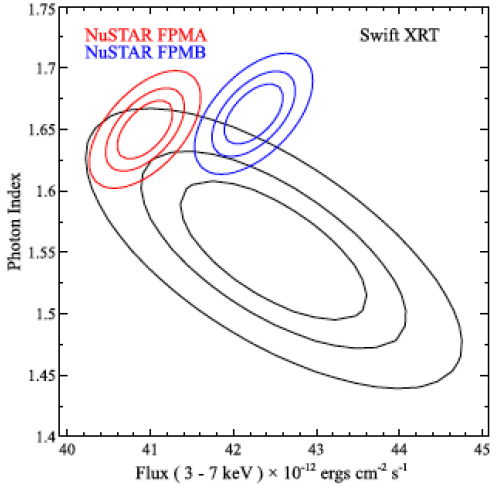

NuSTAR FPMA
NuSTAR FPMB
ACIS LETGS
Flux ratio
Energy (keV)

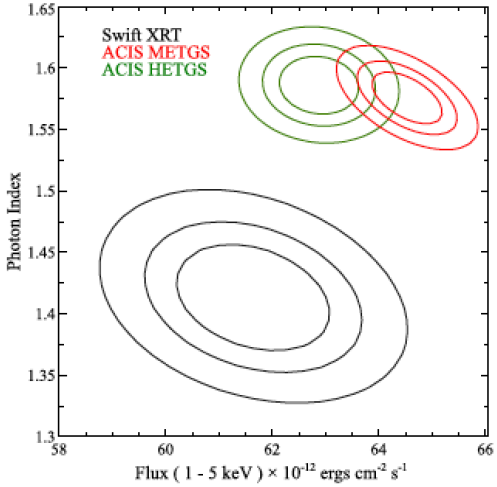

NuSTAR FPMA
NuSTAR FPMB
Swift XRT
Flux ratio
Energy (keV)

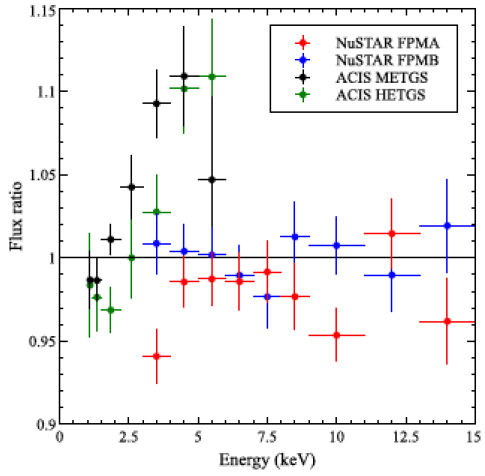

Swift XRT
ACIS LETGS
Flux ratio
Energy (keV)

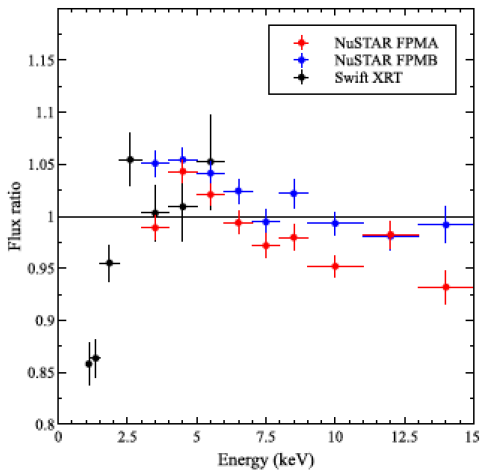
3C273

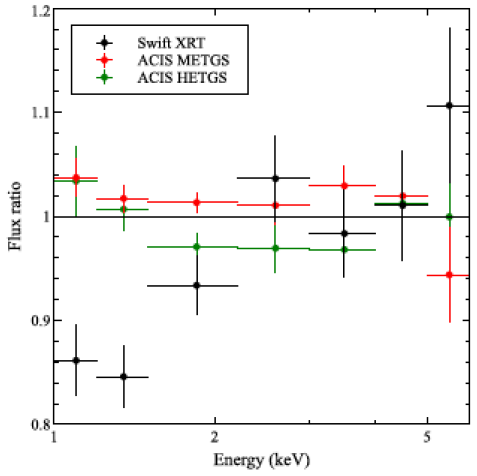

NuSTAR FPMA
NuSTAR FPMB
ACIS METGS
ACIS HETGS
Photon Index
Flux (3 - 7 keV) × 10^-12 ergs cm^-2 s^-1


NuSTAR FPMA
NuSTAR FPMB
Swift XRT
Photon Index
Flux (3 - 7 keV) × 10^-12 ergs cm^-2 s^-1

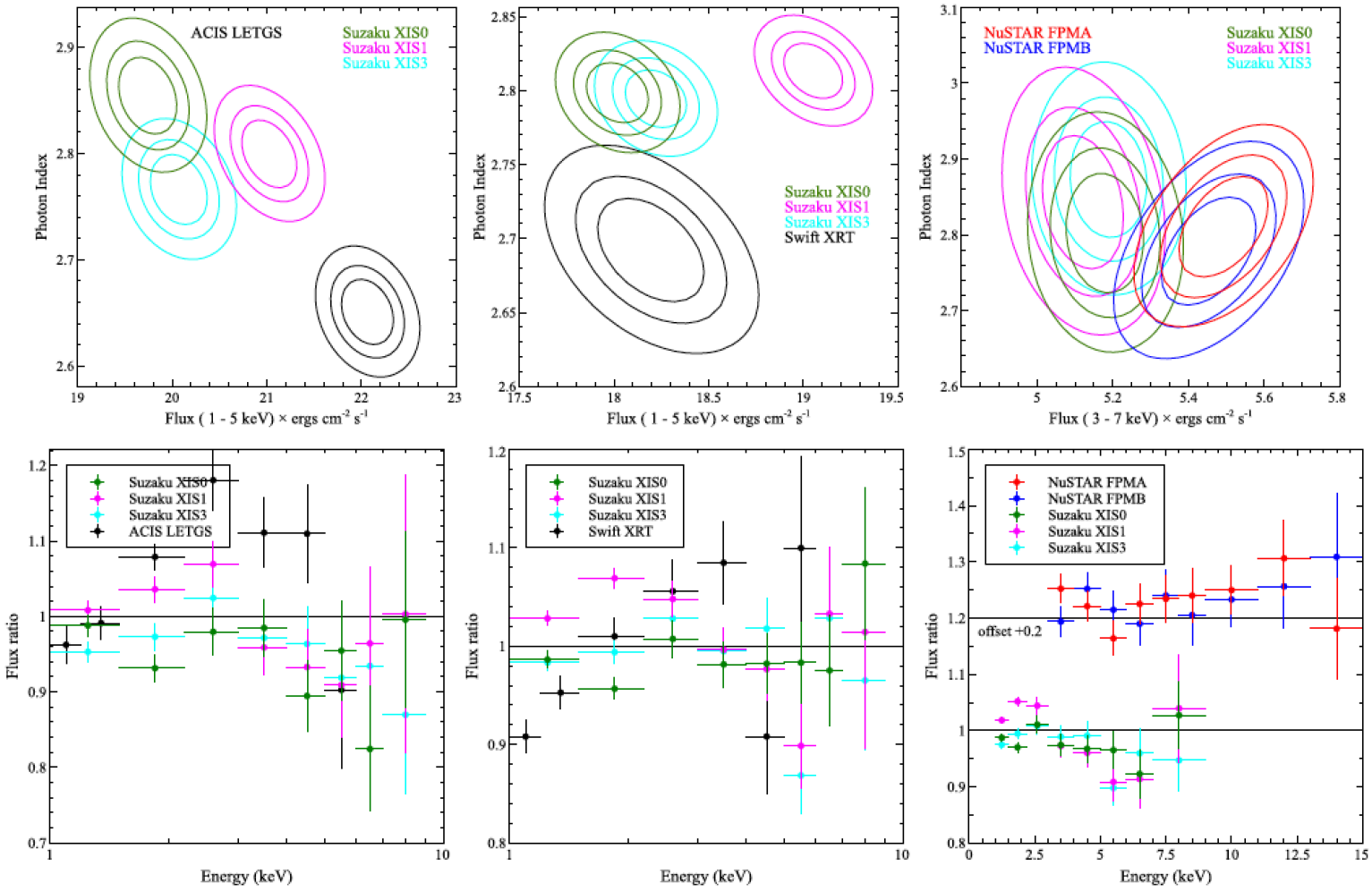

Swift XRT
ACIS METGS
ACIS HETGS
Photon Index
Flux (1 - 5 keV) × 10^-12 ergs cm^-2 s^-1


NuSTAR FPMA
NuSTAR FPMB
ACIS METGS
ACIS HETGS
Flux ratio
Energy (keV)

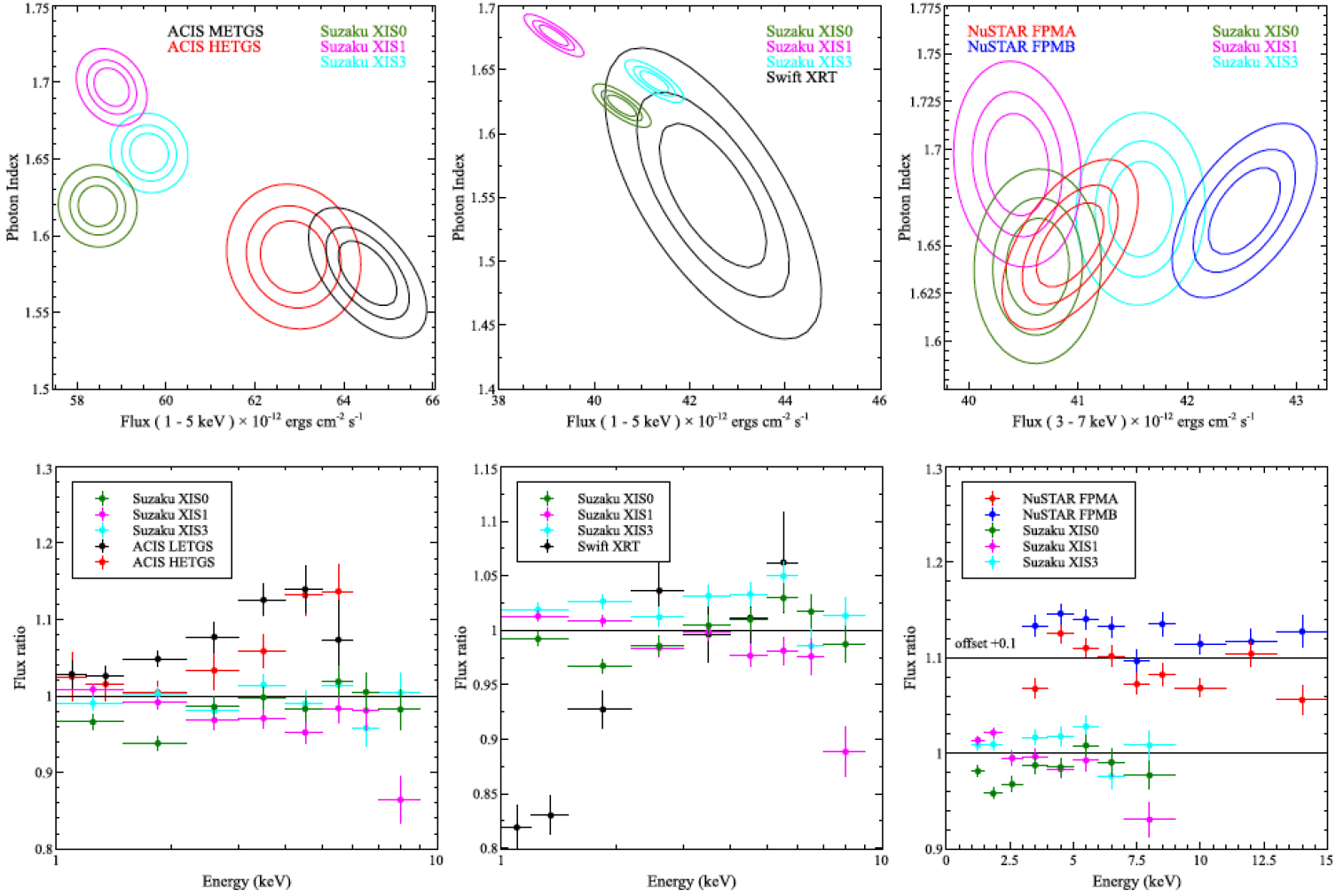

NuSTAR FPMA
NuSTAR FPMB
Swift XRT
Flux ratio
Energy (keV)


Swift XRT
ACIS METGS
ACIS HETGS
Flux ratio
Energy (keV)

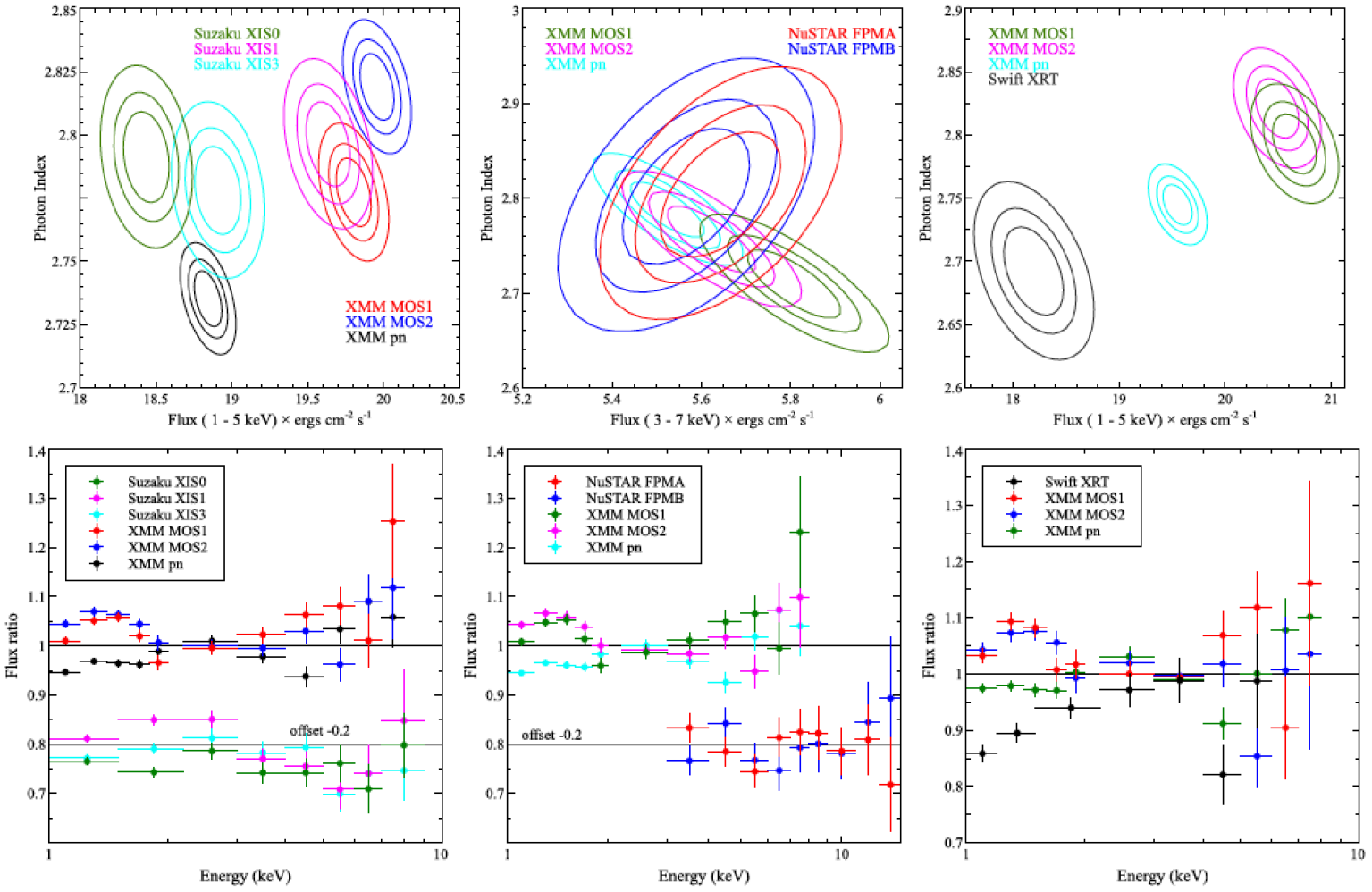
PKS 2155


ACIS LETGS
Suzaku XIS0
Suzaku XIS1
Suzaku XIS3
Photon Index
Flux (1 - 5 keV) × ergs cm^{-2} s^{-1}
Swift XRT
NuSTAR FPMA
NuSTAR FPMB
Flux (3 - 7 keV) × ergs cm^{-2} s^{-1}
ACIS LETGS
Flux ratio
Energy (keV)
offset +0.2

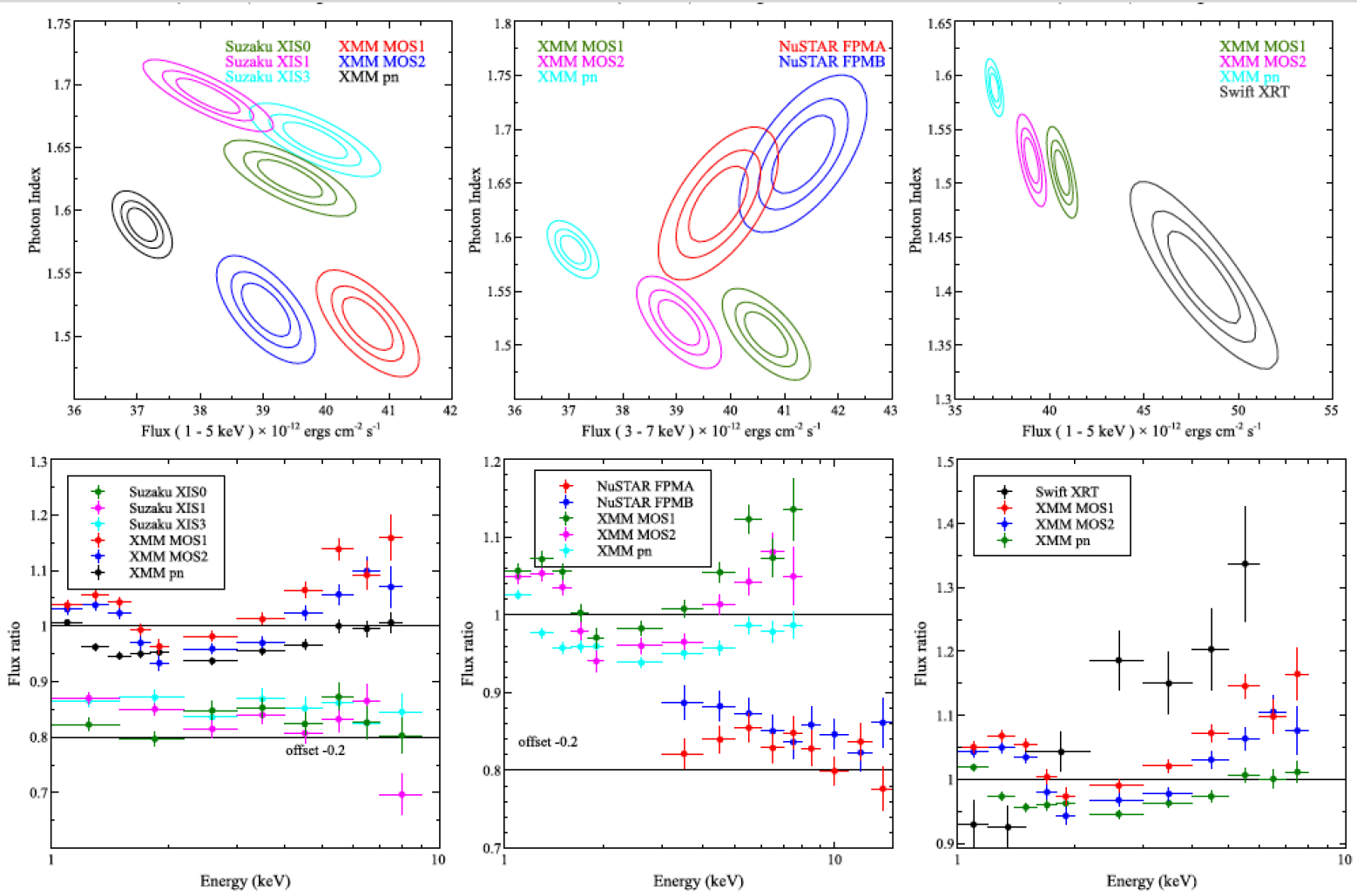
3C273


ACIS METGS
ACIS HETGS
Suzaku XIS0
Suzaku XIS1
Suzaku XIS3
Photon Index
Flux (1 - 5 keV) × 10^-12 ergs cm^-2 s^-1
Swift XRT
NuSTAR FPMA
NuSTAR FPMB
Flux (3 - 7 keV) × 10^-12 ergs cm^-2 s^-1
ACIS LETGS
Flux ratio
Energy (keV)
offset +0.1

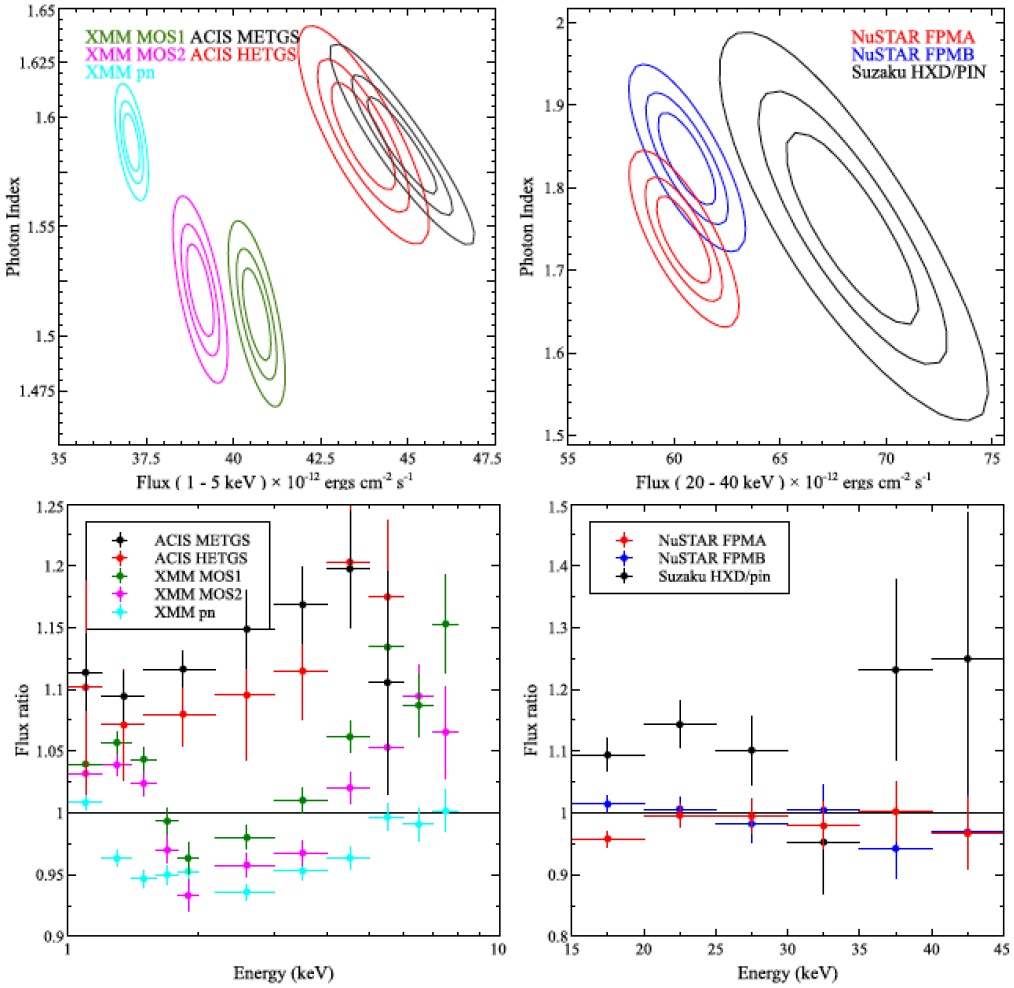
PKS 2155


Suzaku XIS0
Suzaku XIS1
Suzaku XIS3
XMM MOS1
XMM MOS2
XMM pn
Photon Index
Flux (1 - 5 keV) × ergs cm^{-2} s^{-1}
XMM MOS1
XMM MOS2
XMM pn
NuSTAR FPMA
NuSTAR FPMB
Photon Index
Flux (3 - 7 keV) × ergs cm^{-2} s^{-1}
XMM MOS1
XMM MOS2
XMM pn
Swift XRT
Photon Index
Flux (1 - 5 keV) × ergs cm^{-2} s^{-1}
Suzaku XIS0
Suzaku XIS1
Suzaku XIS3
XMM MOS1
XMM MOS2
XMM pn
offset -0.2
Flux ratio
Energy (keV)
NuSTAR FPMA
NuSTAR FPMB
XMM MOS1
XMM MOS2
XMM pn
offset -0.2
Flux ratio
Energy (keV)
Swift XRT
XMM MOS1
XMM MOS2
XMM pn
Flux ratio
Energy (keV)

3C273


Suzaku XIS0
Suzaku XIS1
Suzaku XIS3
XMM MOS1
XMM MOS2
XMM pn
Photon Index
Flux (1 - 5 keV) × 10^-12 ergs cm^-2 s^-1
XMM MOS1
XMM MOS2
XMM pn
NuSTAR FPMA
NuSTAR FPMB
Photon Index
Flux (3 - 7 keV) × 10^-12 ergs cm^-2 s^-1
XMM MOS1
XMM MOS2
XMM pn
Swift XRT
Photon Index
Flux (1 - 5 keV) × 10^-12 ergs cm^-2 s^-1
Suzaku XIS0
Suzaku XIS1
Suzaku XIS3
XMM MOS1
XMM MOS2
XMM pn
offset -0.2
Flux ratio
Energy (keV)
NuSTAR FPMA
NuSTAR FPMB
XMM MOS1
XMM MOS2
XMM pn
offset -0.2
Flux ratio
Energy (keV)
Swift XRT
XMM MOS1
XMM MOS2
XMM pn
Flux ratio
Energy (keV)

3C273


XMM MOS1 ACIS METGS
XMM MOS2 ACIS HETGS
XMM pn
Photon Index
Flux (1 - 5 keV) × 10^-12 ergs cm^-2 s^-1
NuSTAR FPMA
NuSTAR FPMB
Suzaku HXD/PIN
Photon Index
Flux (20 - 40 keV) × 10^-12 ergs cm^-2 s^-1
ACIS METGS
ACIS HETGS
XMM MOS1
XMM MOS2
XMM pn
Flux ratio
Energy (keV)
NuSTAR FPMA
NuSTAR FPMB
Suzaku HXD/pin
Flux ratio
Energy (keV)

Action Items

- Review of draft and plots by observatory/instrument responsible representative
  - In particular XMM/pn for 3C273
- If necessary it is easy to rerun analysis if I am given replacement spectra and responses.
- Time line:
  a. Draft is ready for review for plots and tables
  b. Text is not ready for review – but will be as soon as a) is agreed upon.