

Cross-Calibration between XMM-Newton and Chandra

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Overview

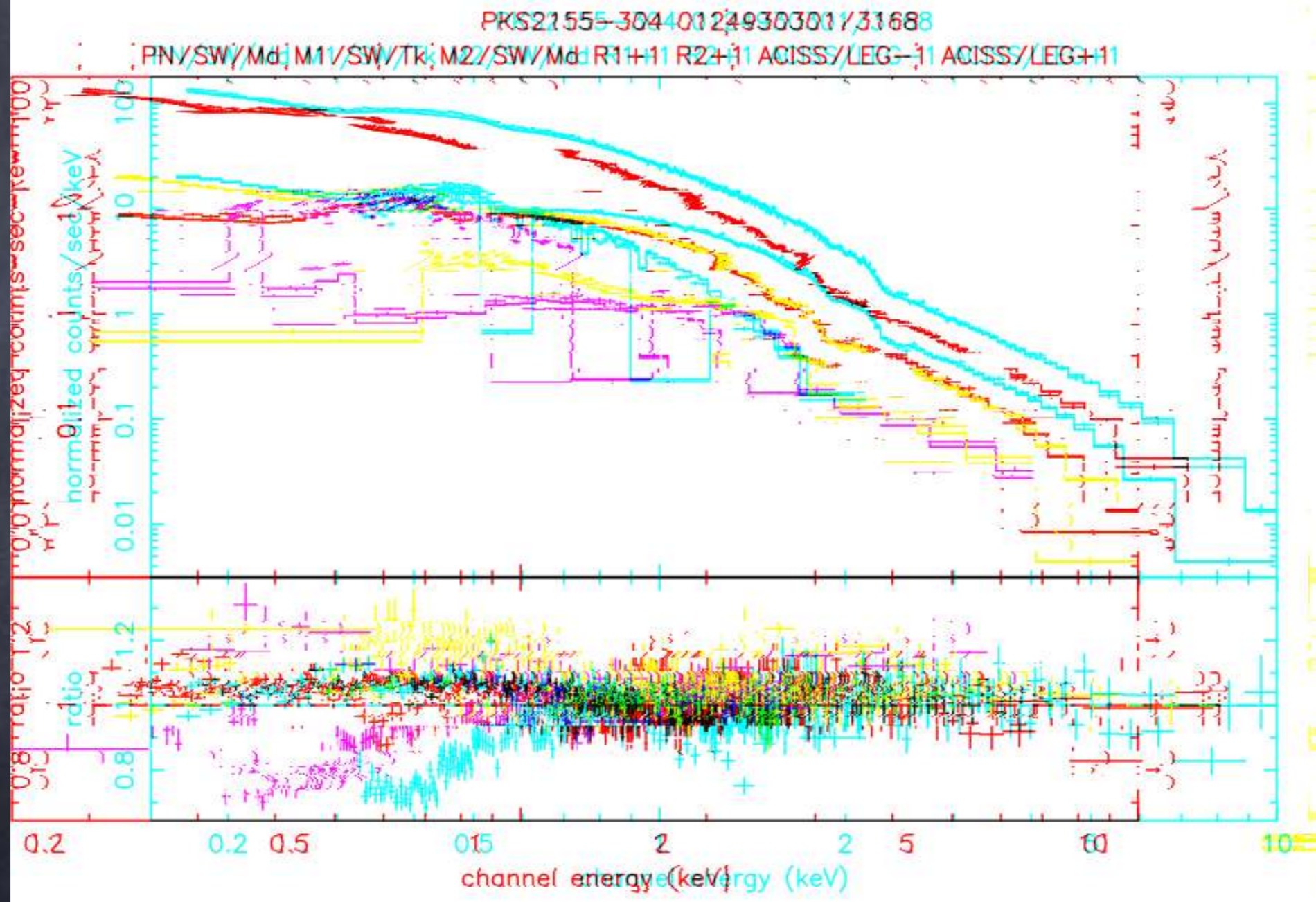
- XMM/Chandra Cross-calibration telecons:
 - continuing monthly meetings
 - formed web pages comparing fits
- Began effort to cross-cal formally
 - Goal: achieve $\chi^2 = 1$ for all cal sources
 - prototyping methodology continues
- Attending meetings for joint cal discussions
 - this EPIC cal meeting
 - multi-observatory cross-cal meeting in June (Reykjavik)
- Implementing cross-cal with Suzaku in May

XMM/Chandra Blazar Observations to Date

XMM-Chandra Cross-Calibration Observations of AGN												
Target	XMM						Chandra					
	Rev	Seq #	Start Date	exp (ks)	A	Γ	Config	ObsID	Start Date	exp (ks)	A	Γ
PKS 2155-304	87	124930101	2000-05-30:0530	61			HETGS	1705	2000-05-31:1740	30	4e-2	2.507
		124930201	2000-05-31:0030	72			LETG/ACIS	1703	2000-05-31:0220	30	0.051 1e-1	2.66 1.72
							LETG/HRC	1704	2000-05-31:0950	30		
3C 273	94	126700301	2000-06-13:2340	73			ACIS-S	1711	2000-06-14:0550	30		
	96	126700801	2000-06-17:2320	73	0.0024 0.0176	3.17 1.63	ACIS-S	1712	2000-06-14:1420	30		
	277	136550101	2001-06-13:0710	90	6.48e-3 0.0187	3 1.57	HETG	2463	2001-06-13:0700	30	2e-2	1.74
							LETG/ACIS	2464	2001-06-13:1610	30	7e-3 1e-2	2.577 1.47
						LETG/HRC	2462	2001-06-14:1250	30			
						LETG/ACIS	2471	2001-06-15:2030	30	8e-3 1e-2	2.72 2.72	
PKS 2155-304	362	89210101	2001-12-01:0600	15	0.063 0.068 Eb=1.22	2.5 2.86	HETGS	3167	2001-11-30:2010	30	6e-2	2.738
							LETG/ACIS	3168	2001-11-30:1120	30	9e-2 0.171	2.995 1.71
							LETG/HRC	3166	2001-11-30:0230	30		
	545	124930601	2002-11-29:2330	115	0.0272 0.0269 Eb = 0.98	2.28 2.81	HETGS	3706	2002-11-29:2230	30	0.02	2.72
							LETG/ACIS	3707	2002-11-30:0700	30	2e-2 0.052	2.91 1.67
						HETGS	3708	2002-11-29:1430	30	3e-2	2.759	
						LETG/HRC	4406	2002-11-30:0210	15			
						LETG/HRC	3709	2002-11-30:1450	15			
3C 273	655	159960101	2003-07-07:1740	58	2.15e-3 0.0278	3.14 1.81	HETGS	4430	2003-07-07:1230	30	3e-2	1.837
							LETG/ACIS	4431	2003-07-07:2050	30	7e-3 0.021	2.16 1.675
	835	136550801	2004-06-30:1300	63	7.6e-4 0.0178	3.91 1.77	HETGS	5169	2004-06-30:1300	30	2e-2	1.737
							LETG/ACIS	5170	2004-06-30:2150	30	7e-3 9e-3	2.18 1.47
PKS 2155-304	908	158960901	2004-11-22:2130	29			LETG/HRC	5172	2004-11-22:2330	30		
		158961001	2004-11-23:1950	40			HETGS	5173	2004-11-23:2330	30	2e-2	2.8
1H1426+428	1015	310190201	2005-06-25:0603	45	0.015 0.0153	1.9 2.16	HETGS	6088	2005-06-25:0555	45	2e-2	2.03
										LETG/ACIS	6089	2005-08-04:0436

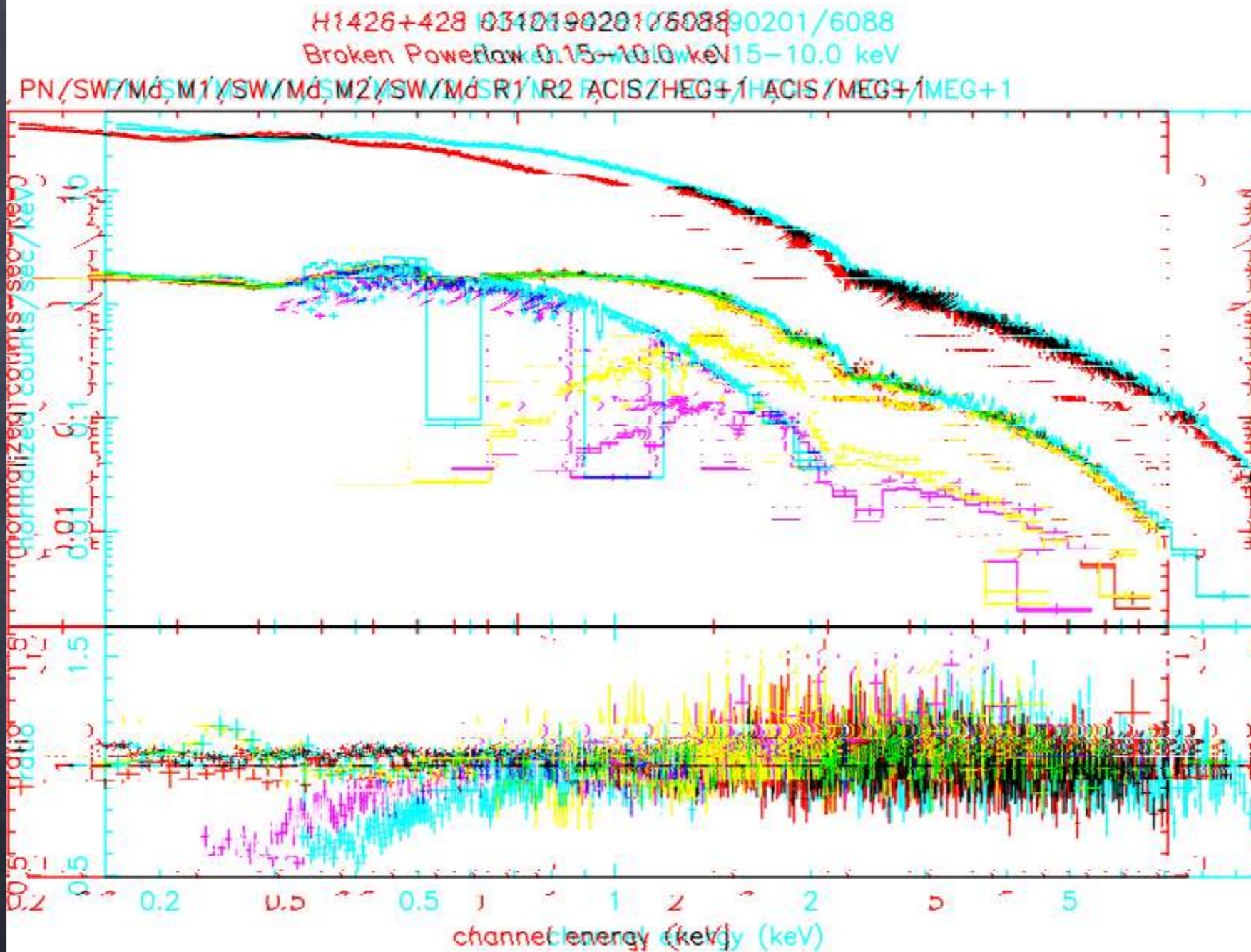
From <http://space.mit.edu/ASC/calib/crosscal/>

Chandra Instr.	Instr.	N_H [cm^{-2}]	Model	phabs*	broken power law	pl.ind.1	inE break [keV]	pl.ind.2	ind.2	norm.	norm.	
ACIS/LEG/LEG	1.24	$1.24 \cdot 10^{20}$	(fixed)	fixed	2.50	2.50	1.22	1.22	2.86	2.86	$3.0 \cdot 10^{-2}$	10^{-2}



From XMM team: XMM-SOC-CAL-TN-0052 (Stuhlinger et al. 2006)

Chandra Instr.	$N_{\text{HH}} [\text{cm}^{-2}]$	phind1	EEbreak [keV]	phind2	norm.
ACIS/MEG/HEG	$1.366 \cdot 10^{20}$ (fixed)	11866	11277	22166	$1.500 \cdot 10^{-22}$



From XMM team: XMM-SOC-CAL-TN-0052 (Stuhlinger et al. 2006)

Comparing XMM and Chandra

- XMM web pages
 - Fit results internal for now
 - data page:
http://xmm.esac.esa.int/~xmmdoc/EPIC_CR
- XMM report: XMM-SOC-CAL-TN-0052 (Stuhlinger et al. 2006)
- CXC web page:
<http://space.mit.edu/ASC/calib/crosscal/>
- XMM whiteboard used for some reports
- Results agree generally but not within errors

Sample XMM-Chandra Comparison (XMM side)

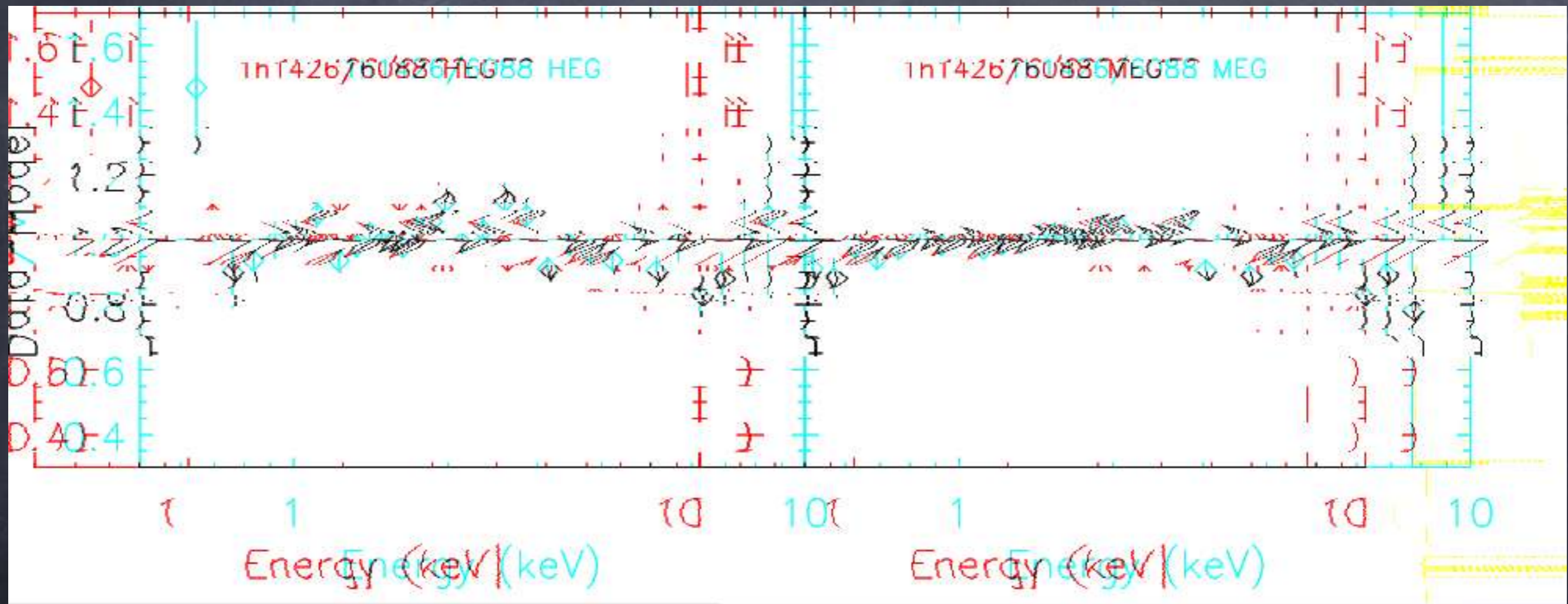
Comparing indices is difficult

Object: **1E 0205-428**
 Date: **2005-10-28 05:00**
 Obs ID: **XMM-0310190301**
 Chandra: **4099**
 Association: **1E 0205-428**
 Model: **TBabs * bknpower**
 Fit ranges: **EPIC 0.2-10.0 keV**
RGS 0.55-2.0 keV
SUSPEC 0.5-5.0 keV
ACIS-IFU 0.5-5.0 keV

Instrument	Index	Phindex1	BreakE	Phindex2	norm
XMM-EPIC	1.56E+20 (fixed)	1.99 (+0.00/-0.00)	1.23 (+0.00/-0.00)	2.16 (+0.00/-0.00)	1.52E+02
pn	1.36E+20 (fixed)	1.90±0.01	1.08±0.04	2.16±0.01	1.55±0.01 E-02
MOS1	1.36E+20 (fixed)	1.72±0.02	1.42±0.00	2.16±0.02	1.72±0.01 E-02
MOS2	1.36E+20 (fixed)	1.77±0.02	1.36±0.08	2.16±0.02	1.56±0.01 E-02
RGS1	1.36E+20 (fixed)	1.93 (+0.09/-0.13)	1.31 (+0.14/-0.13)	1.81 (+0.10/-0.15)	3.65 (+0.17/-0.10) E-02
RGS2	1.36E+20 (fixed)	1.93 (+0.26/-0.04)	0.87 (+0.28/-0.13)	1.71 (+0.08/-0.07)	4.17 (+0.03/-0.04) E-02
ACIS-REG	1.36E+20 (fixed)	1.74 (+0.09/-0.09)	1.09 (+0.23/-0.16)	2.04 (+0.03/-0.04)	1.00 (+0.19/-0.06) E-02
SUSPEC	1.36E+20 (fixed)	2.35 (+0.10/-0.09)	1.86±0.04	1.96±0.03	1.44 (+0.03/-0.05) E-02

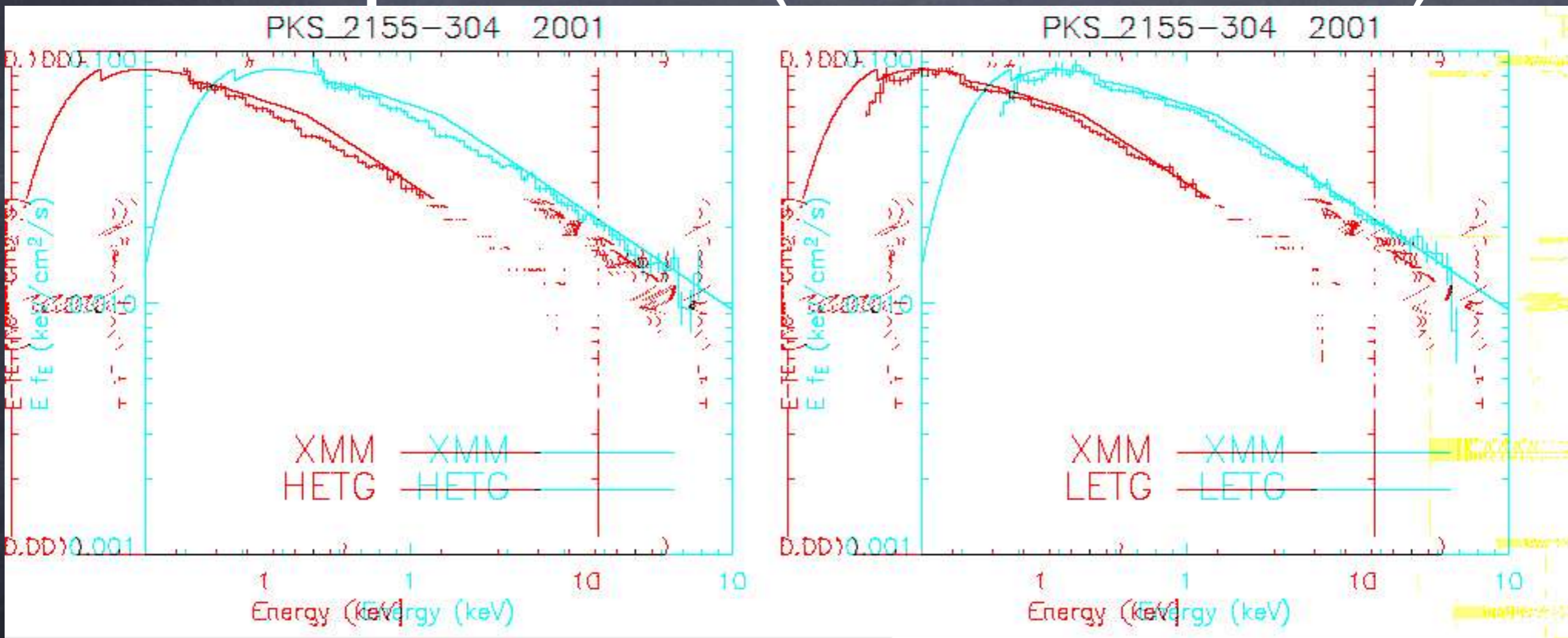
From http://xmm.esac.esa.int/~xmmdoc/EPIC_CROSSCAL/cross_cal_data.php

Sample XMM-Chandra Comparison (HETGS side)



From <http://space.mit.edu/ASC/calib/crosscal/>

Sample XMM-Chandra Comparison (HETGS side)



From <http://space.mit.edu/ASC/calib/crosscal/>

Caveats: XMM-Chandra Comparison (HETGS side)

- Variability: affects one observation of PKS 2155-304 (but not 1H 1426+428 and 3C 273)
- Different models used by ESAC and CXC
 - broken PL vs. smooth PL
 - HETGS fits without 2PL
- Residuals: compare for complete story
- Bow-tie: models extrapolated to low SNR
- Have not achieved $\chi^2 = 1$ for bright sources

Formalizing Cross-Calibration

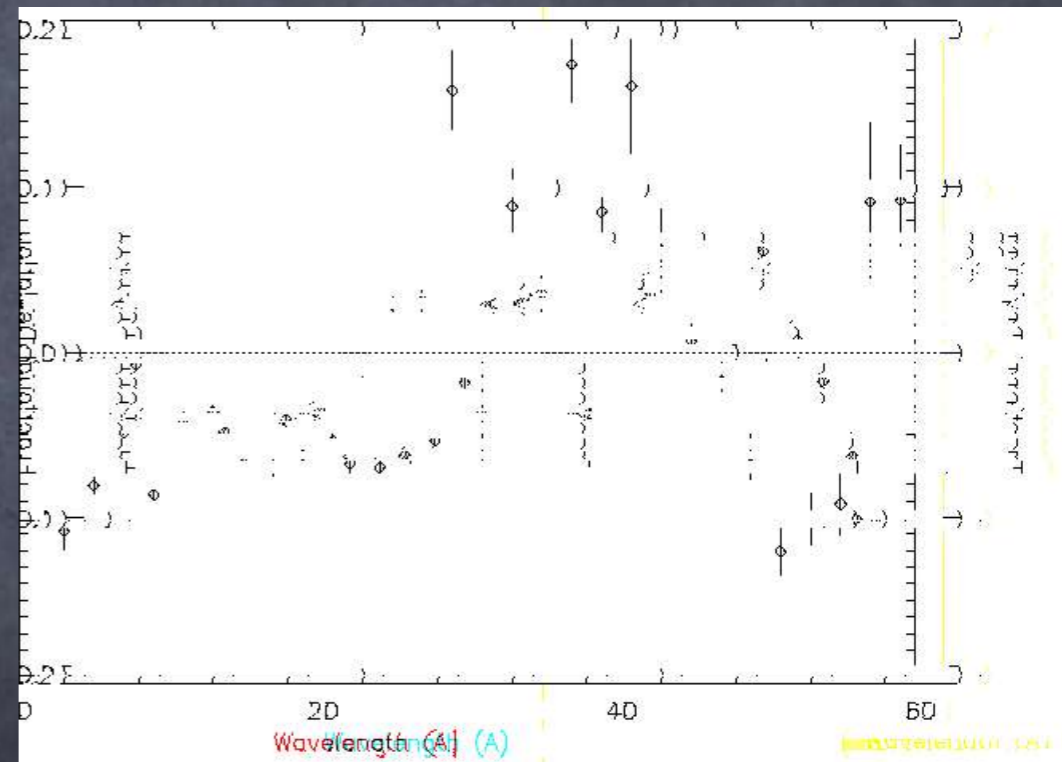
- Goal: achieve $\chi^2/\nu = 1$ for all cal sources
- Premise: Users want $\chi^2/\nu = 1$ if model fits
- Local adjustments, $A_{jn} g(x; \beta_j)$ -- overdetermined system, reducing χ^2 ---->
- A_{jn} depend on instrument n , β_j fixed
- Compare instruments by comparing A_{jn}
- Method proposed: Use penalty function

- Minimize $\Lambda = \sum_j A_j^2 + \exp\left(\frac{(\chi_{\nu j}^2 - 1)^2}{\nu_j}\right)$

- where $\chi_{n\nu}^2 = \frac{1}{\nu_n} \sum_{i=1}^{I_n} \frac{[y_{in} - f(x_{in}; \vec{\alpha})(1 + \sum_j A_{nj} g(x_{in}; \vec{\beta}_j))]^2}{s_{in}^2}$

Formalizing Cross-Calibration

- Test cases
 - Mk 421: bright, 100 ks
 - XTE J1118+480: bright 24 ks
- $g(x) = \text{Gaussian}$, $\sigma = 2\text{\AA}$, 2\AA apart, starting at 1\AA
- Results
 - OK amplitudes (figure)
 - $\min \chi^2$
 - separately: 2.20, 1.14
 - jointly: 2.62, 1.48
- Conclusions
 - Need more Gaussians
 - or different basis functions
 - or adaptive functions ...



Work in Progress

- Joint web page population
 - Coordinate modeling between projects
 - Process all Chandra cal data uniformly
 - Will add analysis of 1E 0102-72
- Developing joint analysis methodology
 - Primary goals may not be achievable soon
 - Must define secondary goals
- Setting up cross-cal with XMM and Suzaku
 - Target: PKS 2155-304
 - This week
 - Will use LETG/HRC
- Chandra grating observations of PKS 2155
 - Aug '06 — independent of XMM, Suzaku
 - To be used for Chandra internal cross-cal

Overview

- Formed web pages comparing fits
 - General but not statistical agreement
 - Results need revision and analysis
- Prototyping formal cross-cal methodology
- Attending meetings for joint cal discussions
 - Improves approach to data handling
 - Refines analysis and methodology
- Implementing cross-cal with Suzaku in May