Instrumental limits to our knowledge in X-ray Astronomy

Matteo Guainazzi (XMM-Newton Science Operations Centre)

Neural correlates of interspecies perspective taking in the post-mortem Atlantic Salmon: An argument for multiple comparisons correction

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INTRODUCTION

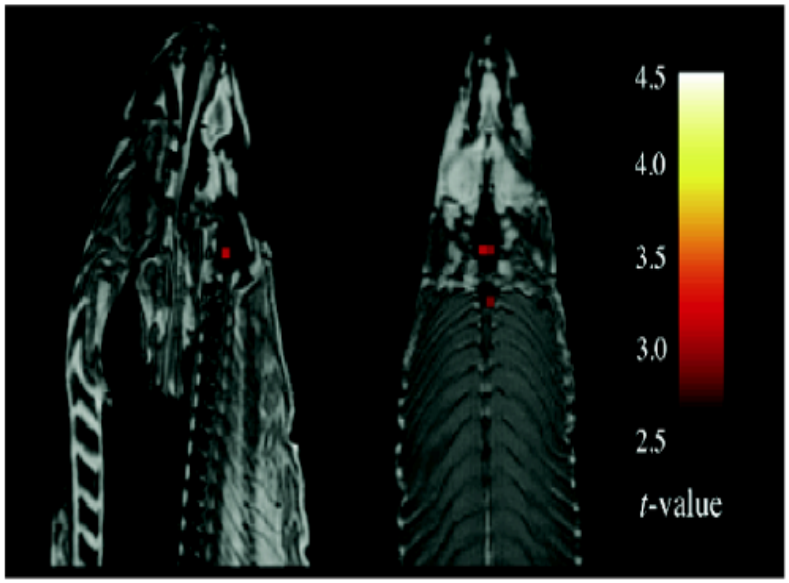
With the extreme dimensionality of functional neuroimaging data comes extreme risk for false positives. Across the 130,000 voxels in a typical fMRI volume the probability of a false positive is almost certain. Correction for multiple comparisons should be completed with these datasets, but is often ignored by investigators. To illustrate the magnitude of the problem we carried out a real experiment that demonstrates the danger of not correcting for chance properly.

METHODS

Subject. One mature Atlantic Salmon (Salmo salar) participated in the fMRI study. The salmon was approximately 18 inches long, weighed 3.8 lbs, and was not alive at the time of scanning.

Task. The task administered to the salmon involved completing an open-ended mentalizing task. The salmon was shown a series of photographs depicting human individuals in social situations with a specified emotional valence. The salmon was asked to determine what emotion the individual in the photo must have been experiencing.

GLM RESULTS



A *t*-contrast was used to test for regions with significant BOLD signal change during the photo condition compared to rest. The parameters for this comparison were $t(131) > 3.15$, p(uncorrected) < 0.001, 3 voxel extent threshold.

Several active voxels were discovered in a cluster located within the salmon's

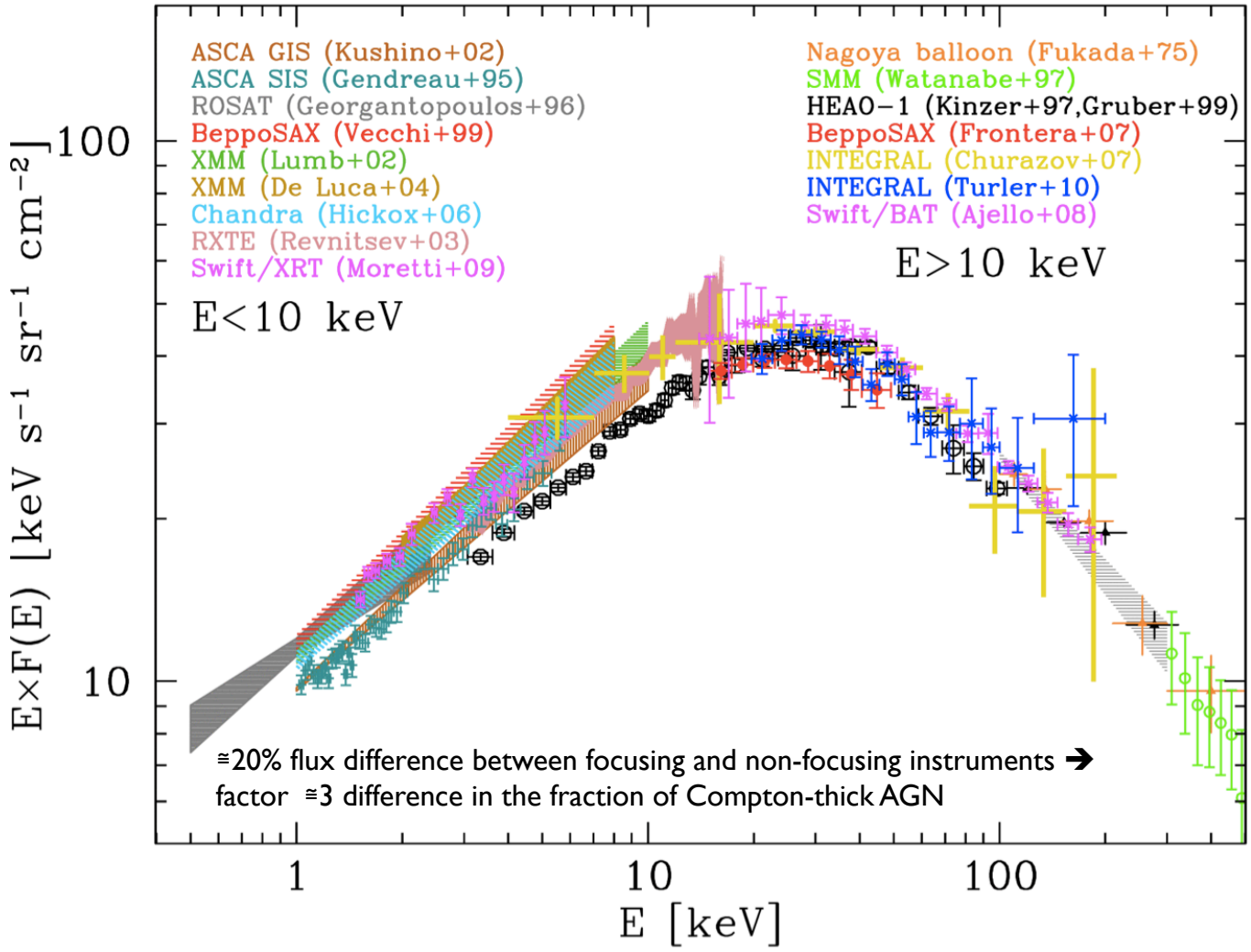
Outline

- Calibration uncertainties in X-ray astronomy (our "dead fish")
- Impact on accretion disk/BH science

Calibration (as any truly scientific endeavors) is a collective effort

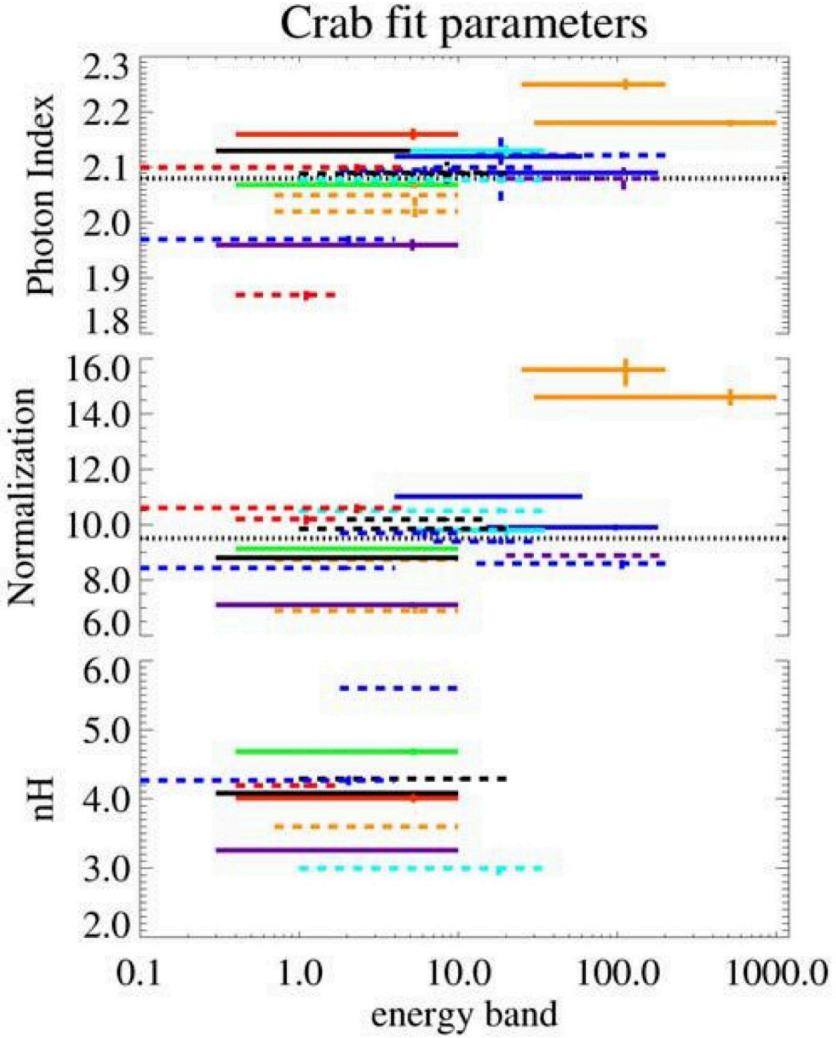
Discussions with and contributions by J.Nevalainen (Tartu University), G.Schnellenberger (Bonn University), and S.Sembay (Leicester University) are especially acknowledged

Synopsis of XRB measurements



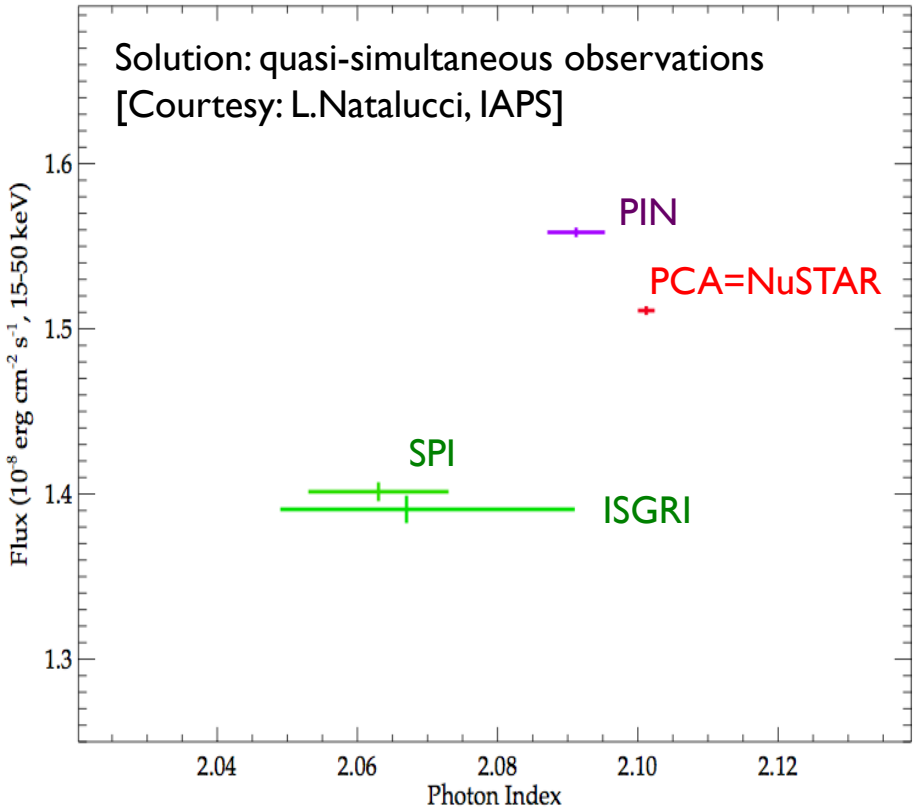
(Courtesy A.Comastri, Un. Bologna)

The instrumental view: hard X-rays



Problems:

- the Crab Nebula spectrum is not a power-law
- the Crab Nebula is not a constant source



(Kirsch et al., SPIE, 2005, 5898)

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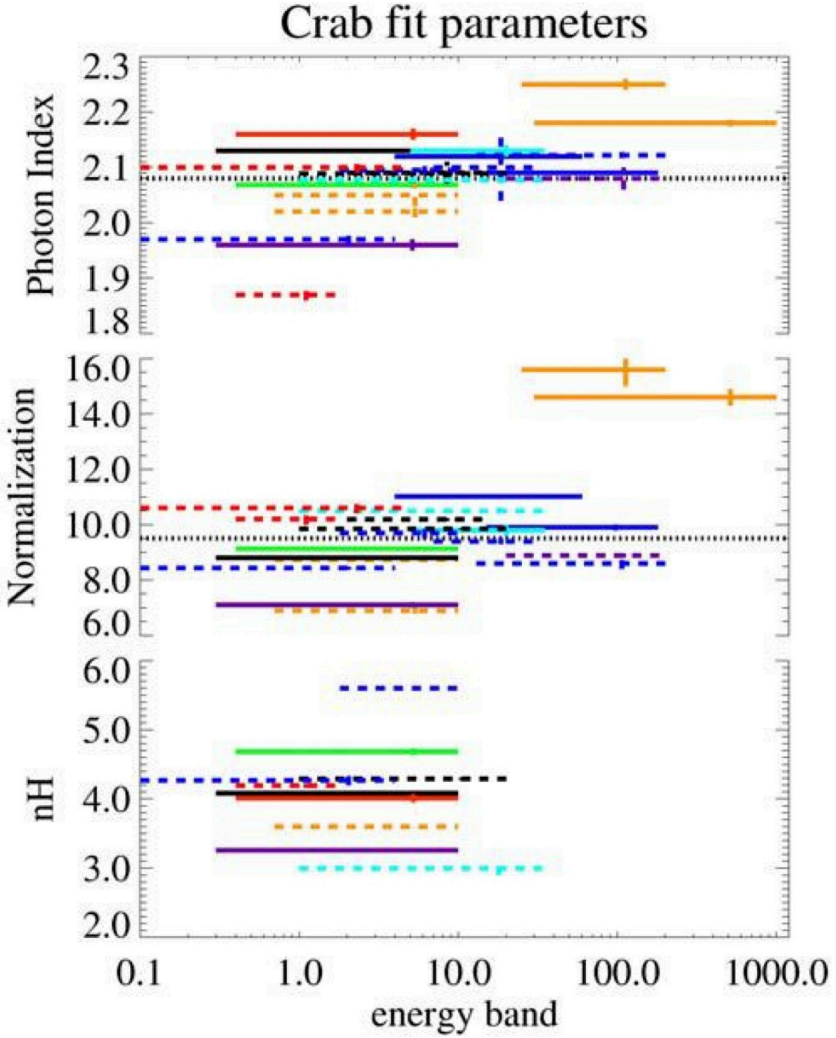

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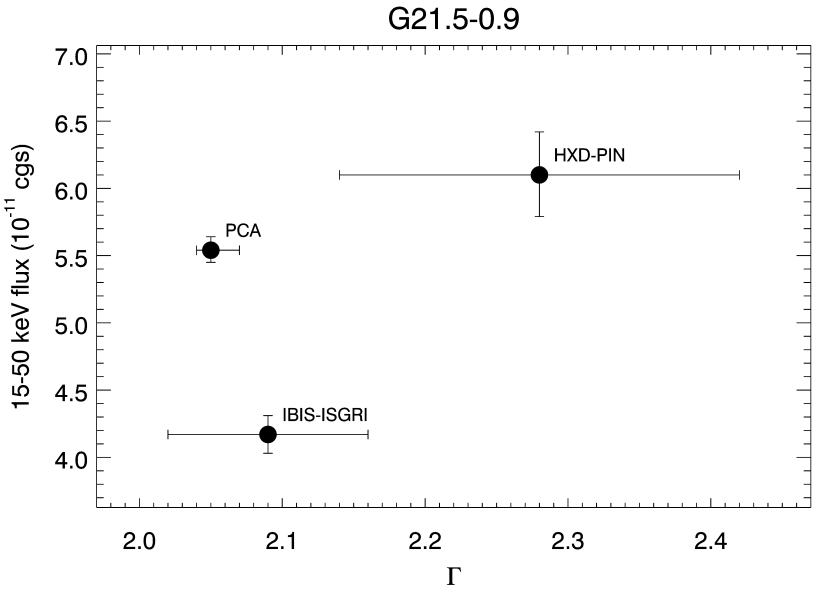

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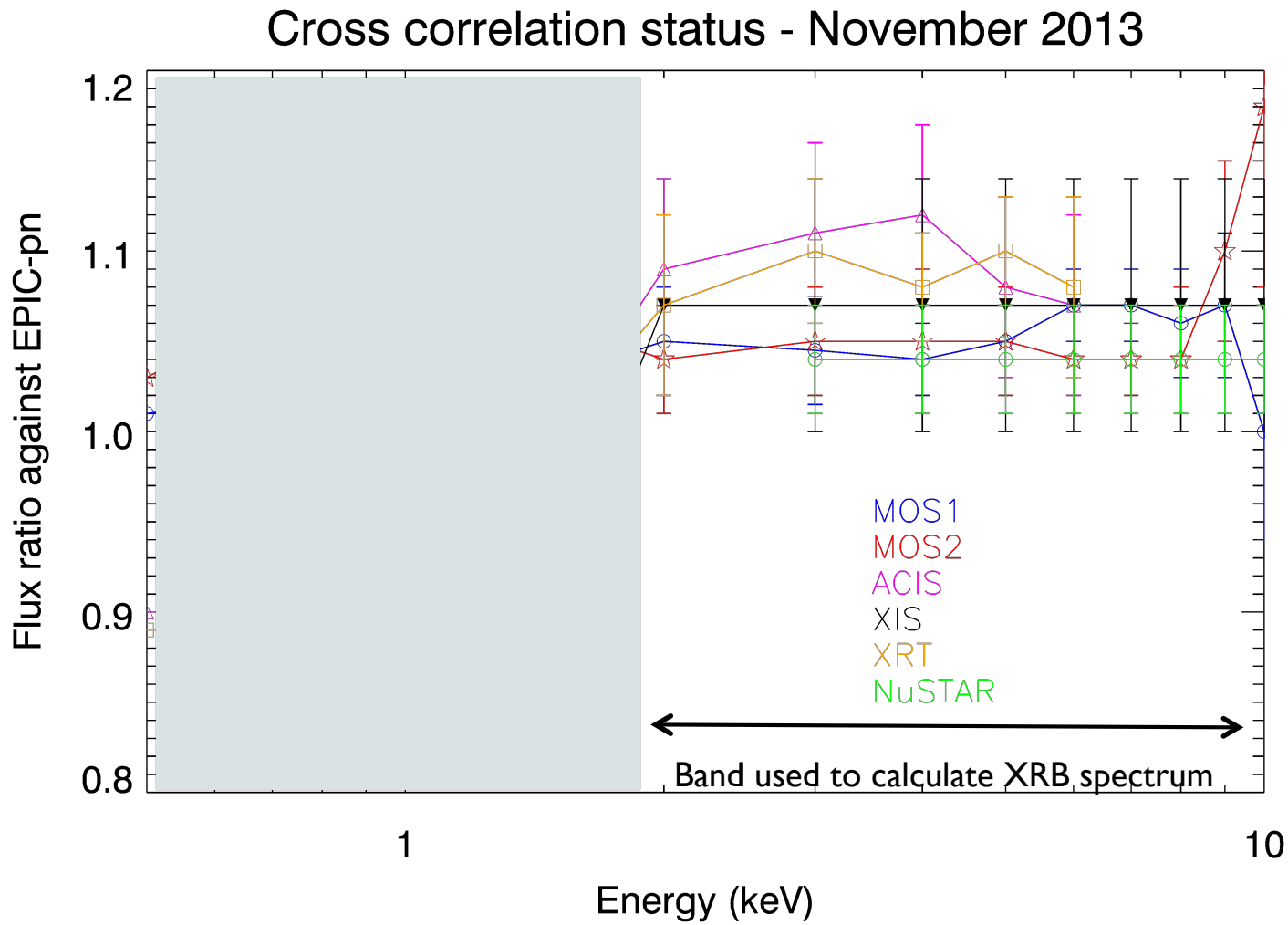
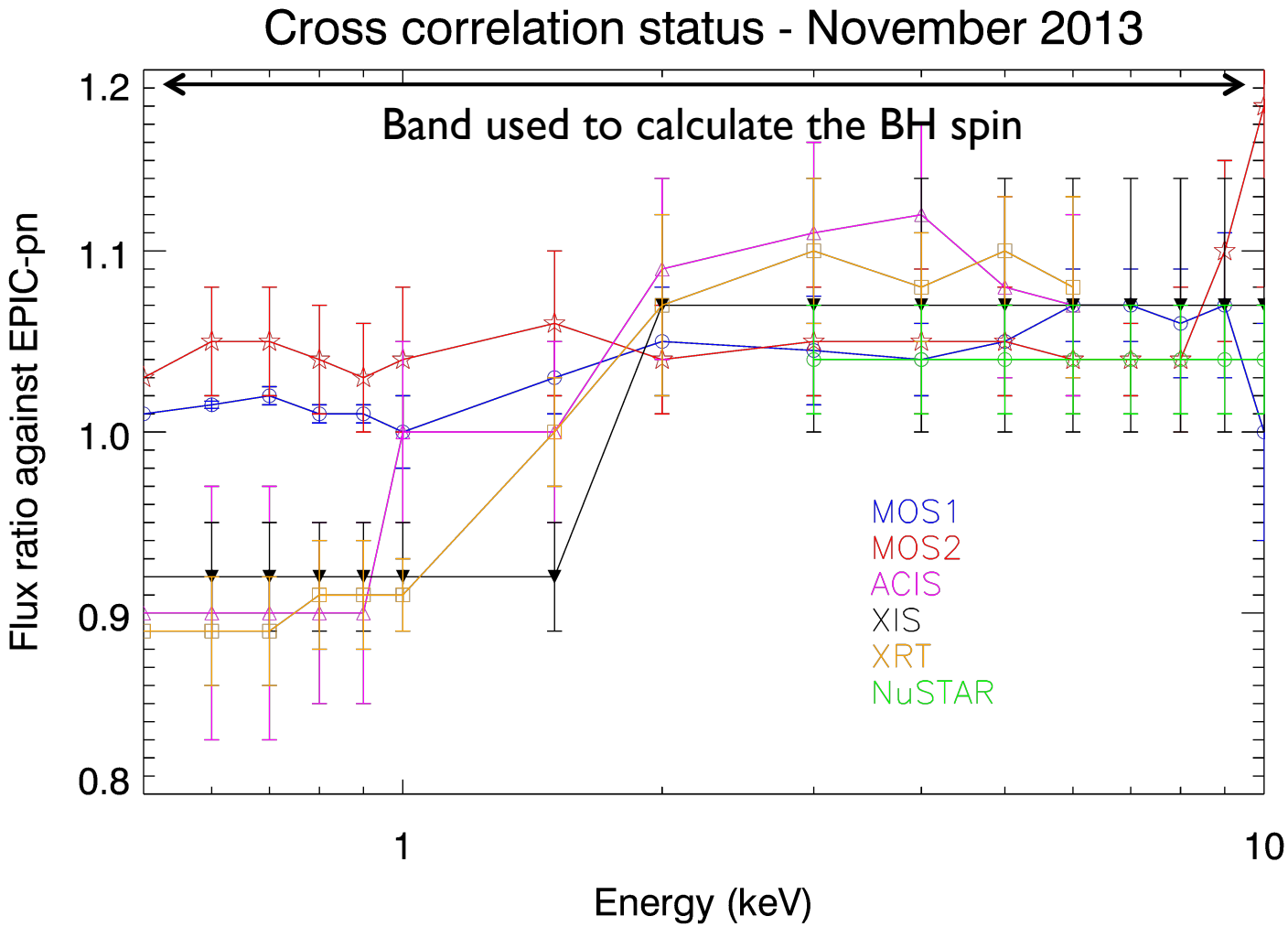
(Tsujimoto et al., 2011, A&A, 525, 25)

The instrumental view: soft X-rays (low. res.)



- ["Error bars" are the dispersion of existing measurement. Look at: `http://web.mit.edu/iachec/papers/index.html` for a list of papers discussing these results]

The instrumental view: soft X-rays (low. res.)



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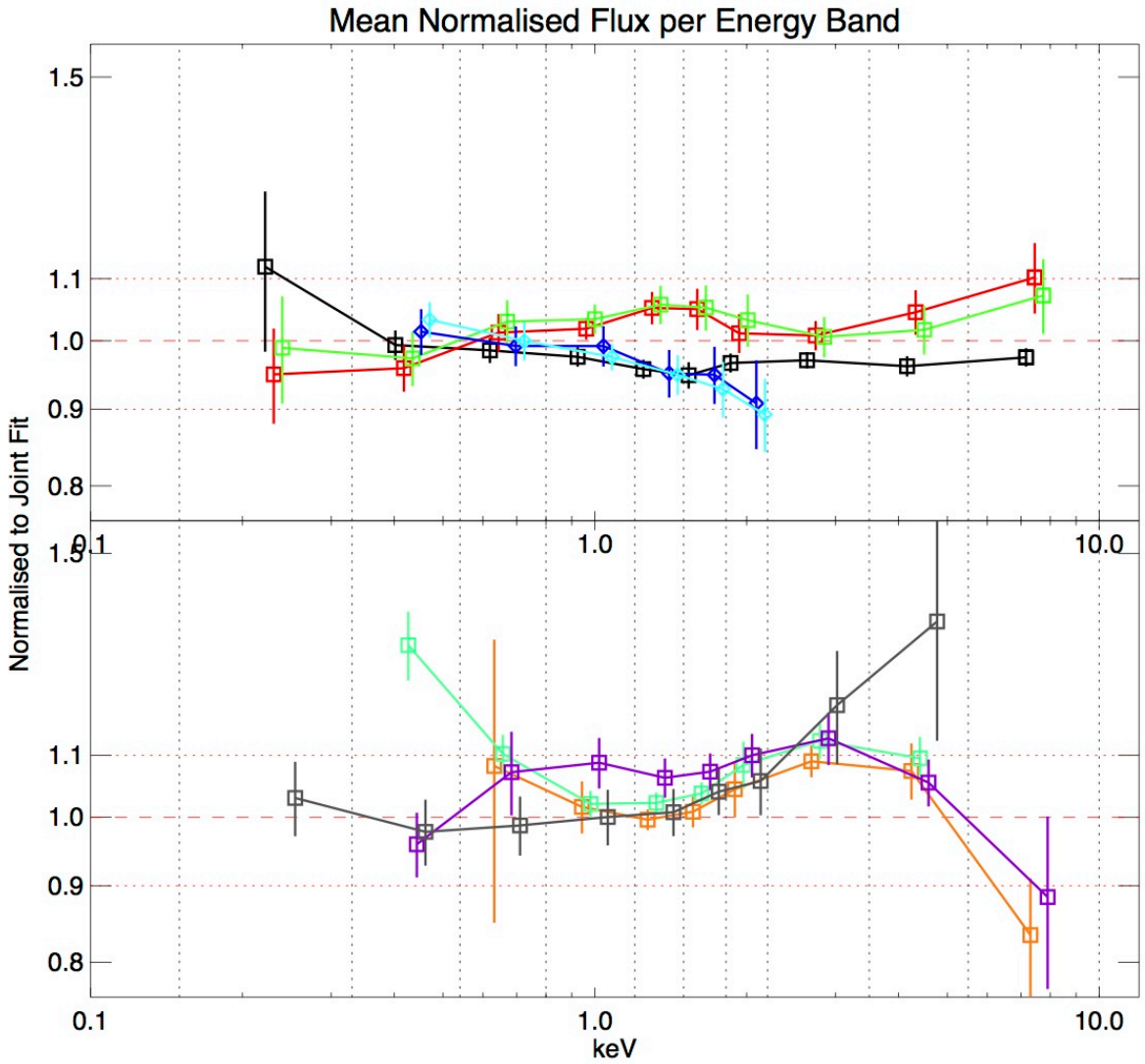
The instrumental view: soft X-rays (high. res.)



- (Smith et al., in prep.)

The brave fishermen

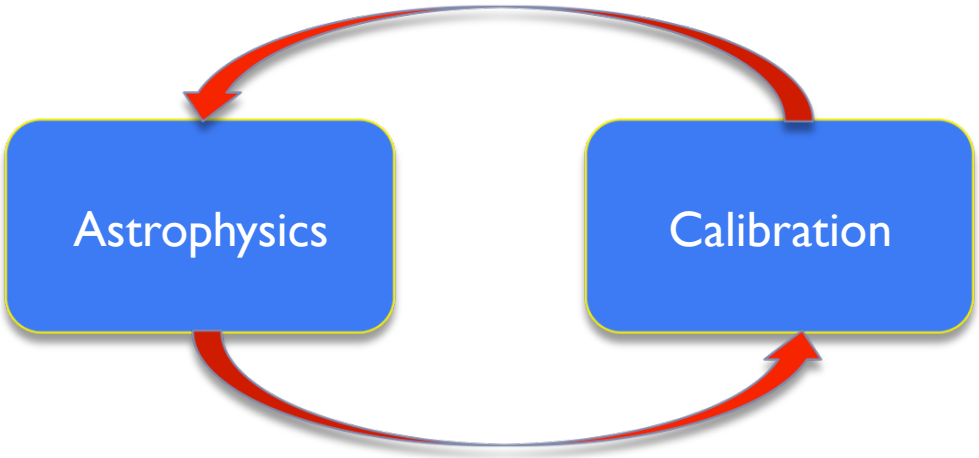
IACHEC = International Consortium for High-Energy Calibration

Our tasks: a) define calibration standards ("X-ray standard candles); b) publish the cross-calibration status (preferentially on refereed journals); c) improve the cross-calibration

- (http://web.mit.edu/iachec/)

Why so difficult?

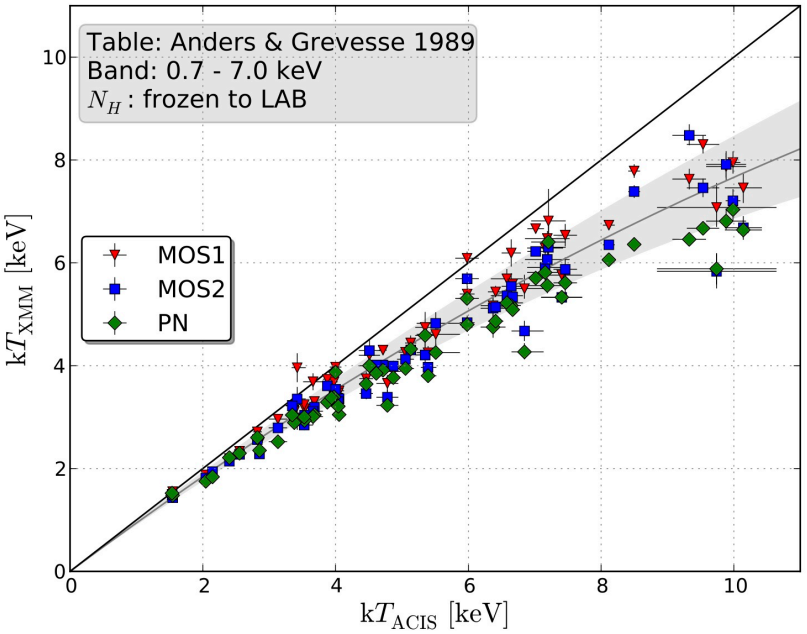
- Theory: full ground-calibration ➔ complete instrument physical model
- Practice: there is never enough time for ground-based calibrations
- Reality: instrument on-flight performances change
- X-ray astronomy cannot rely on standard candles *strictu sensu*

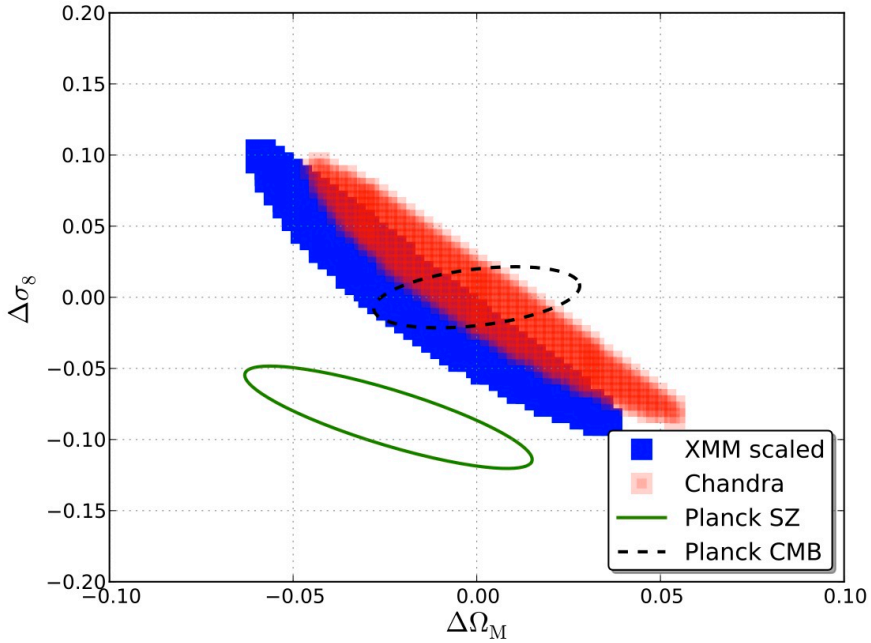


Calibration of X-ray instruments is always "with respect to ..."

Impact on cosmology

- The distribution of galaxy cluster masses depends on cosmological parameters
- Cluster masses can be derived assuming hydrostatic equilibrium
- X-ray measurements (yielding electron density and temperature) are required
- Determination of cosmological parameters depends on our ability to measure kT!





Not-negligible impact, although smaller than uncertainties of Planck measurements!

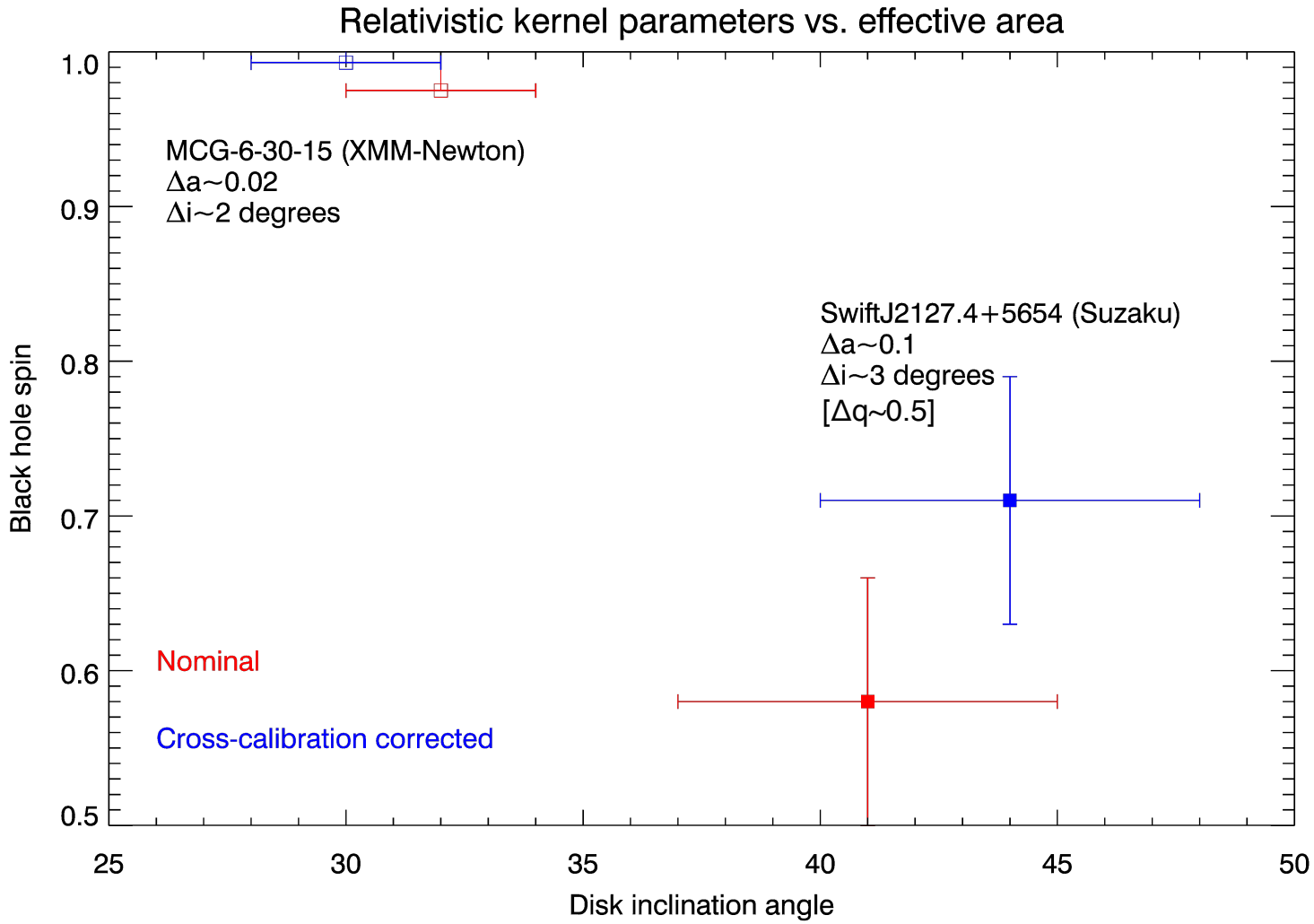
(Schnellenberger et al., submitted)

List of existing AGN BH spin masses

Object	Mass ($\times 10^6\ M_\odot$)	Spin	Mass/Spin references
Mrk335	14.2 ± 3.7	$0.83^{+0.09}_{-0.13}$	Pe04/Wa13
IRAS 00521–7054	–	>0.84	–/Ta12
Tons180	~8.1	$0.92^{+0.03}_{-0.11}$	ZW05/Wa13
Fairall 9	255 ± 56	$0.52^{+0.19}_{-0.15}$	Pe04/Lo12
Mrk359	~1.1	$0.66^{+0.30}_{-0.54}$	ZW05/Wa13
Mrk1018	~140	$0.58^{+0.36}_{-0.74}$	Be11/Wa13
1H0419-577	~340	>0.89	ZW05/Wa13
Ark120	150 ± 19	$0.64^{+0.19}_{-0.11}$	Pe04/Wa13
Swift J0501.9-3239	–	>0.99	–/Wa13
1H0707-495	~2.3	>0.97	ZW05/Zo10
Mrk79	52.4 ± 14.4	0.7 ± 0.1	Pe04/Ga11
Mrk110	25.1 ± 6.1	>0.89	Pe04/Wa13
NGC3783	29.8 ± 5.4	>0.88[a]	Pe04/Br11
NGC4051	1.91 ± 0.78	>0.99	Pe04/Pa12
RBS1124	–	>0.97	–/Wa13
IRAS13224–3809	~6.3	>0.987	Go12/Fa13
MCG–6-30-15	$2.9^{+1.8}_{-1.6}$	a>0.98	Mc05/BR06
Mrk841	~79	>0.52	ZW05/Wa13
Swift J2127.4+5654	~1.5	0.6 ± 0.2	Ma08/Mi09
Ark564	~1.1	$0.96^{+0.01}_{-0.11}$	ZW05/Wa13

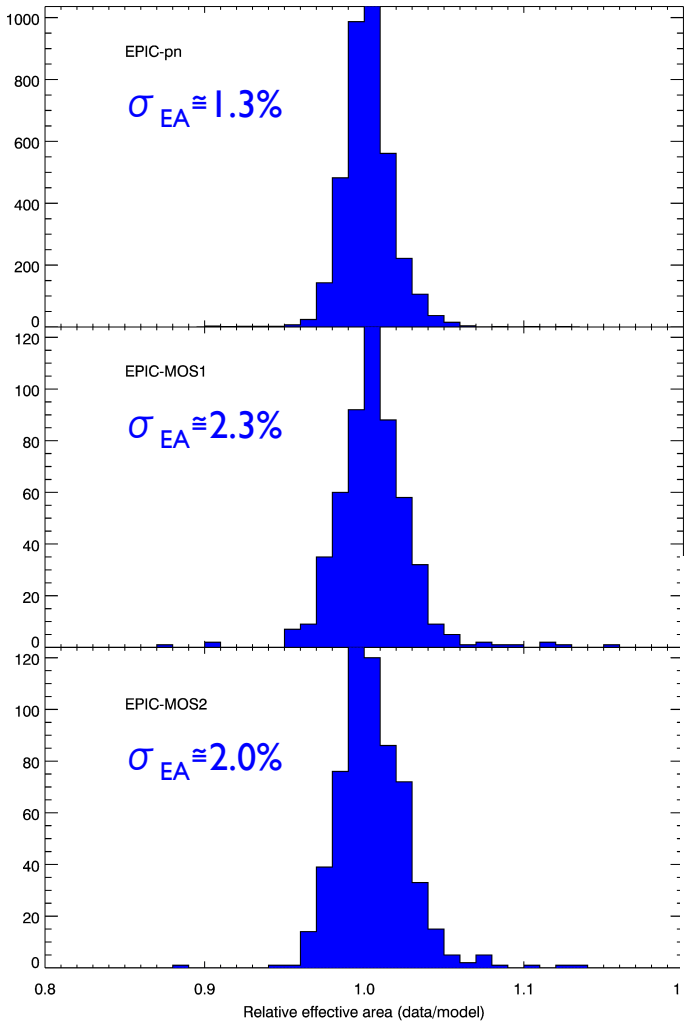
- (Reynolds et al., Sp.Sci.Rev., 2013)

Impact on accretion disk fits

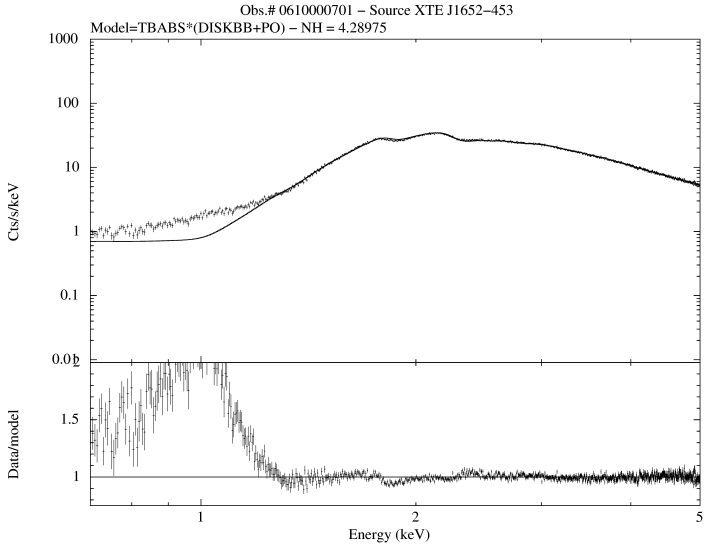


A digression (apparently on) on EPIC

EPIC effective area accuracy
Analysis of ~90 radio-loud AGN

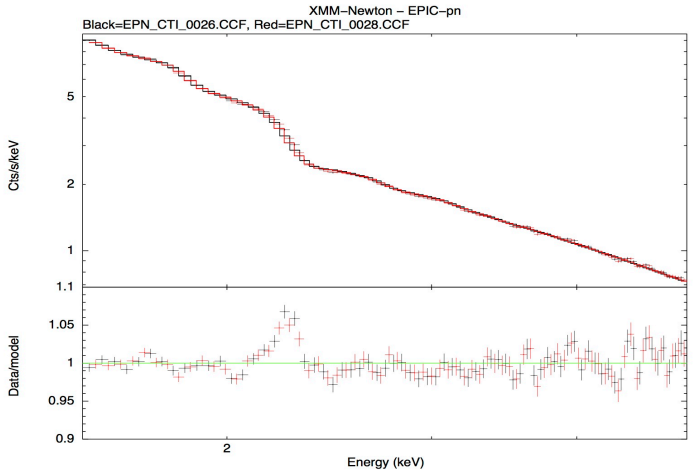


Why don't you get always residuals <2%?



"Soft excess" in obscured binaries with EPIC-pn Timing Mode (cf. Di Salvo's talk)

[Guainazzi et al., 2013, XMM-SOC-CAL-TN-0083]

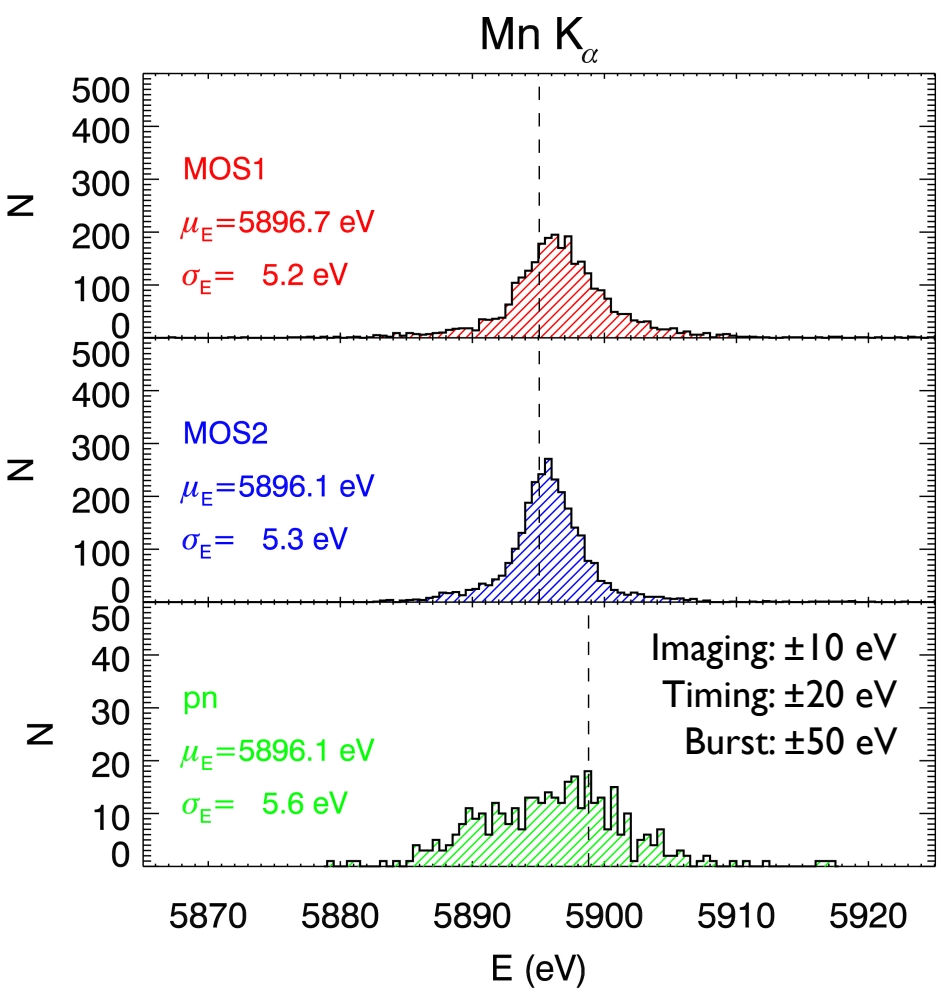


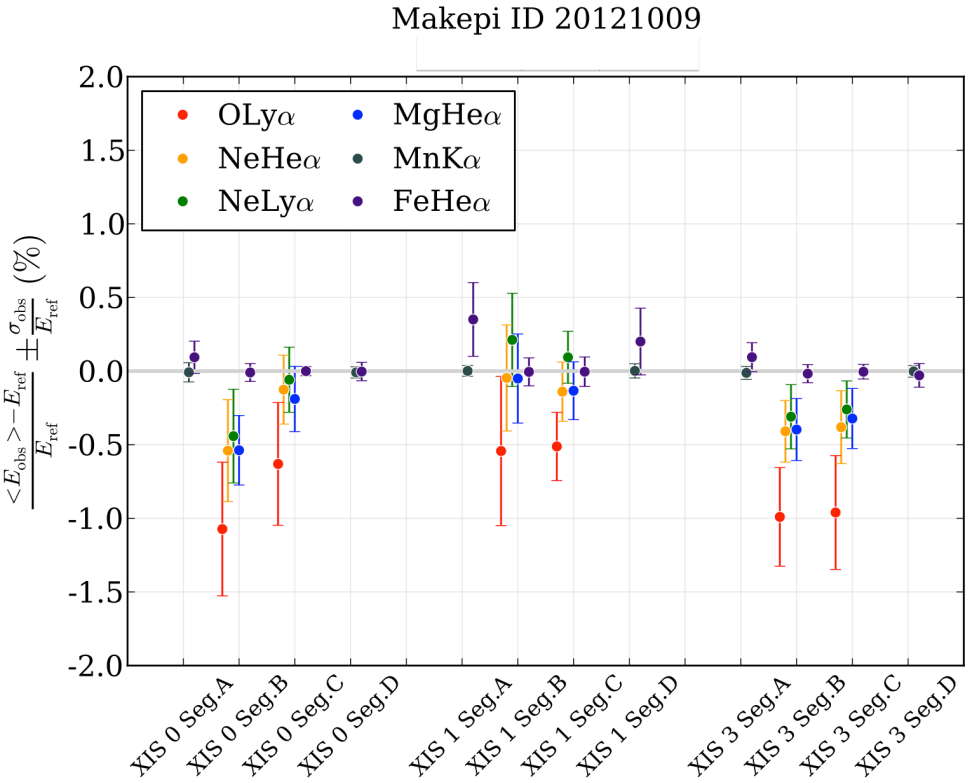
"2.3 keV feature" in recent EPIC-pn spectra ➔ inaccuracy of the energy scale

[Smith et al., 2013, XMM-SOC-REL-300]

Documents available at: `http://xmm2.esac.esa.int/external/xmm_sw_cal/calib/`

Energy scale accuracy

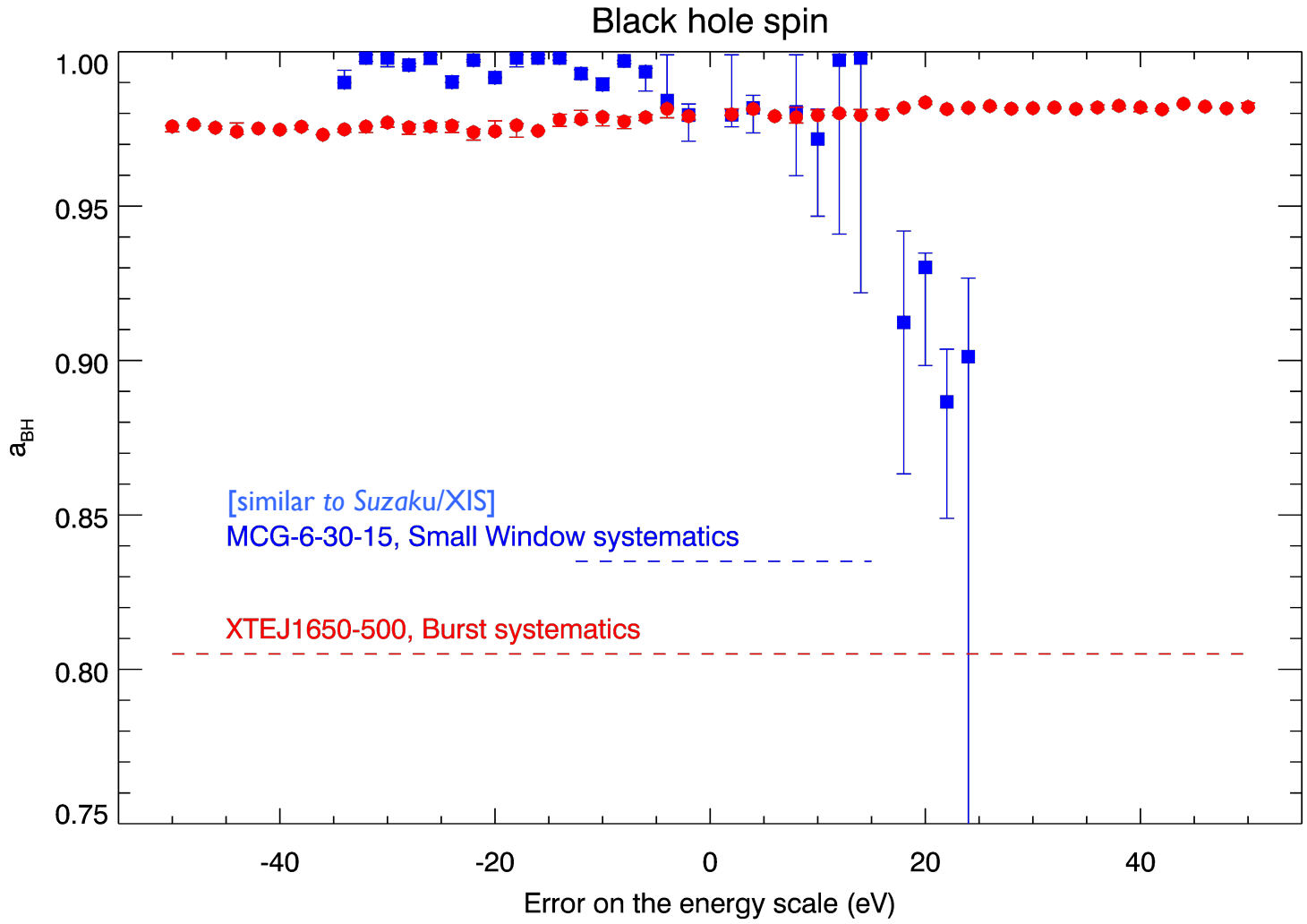




On-axis: XIS-FI: ±5 eV
XIS-BI: ±10 eV

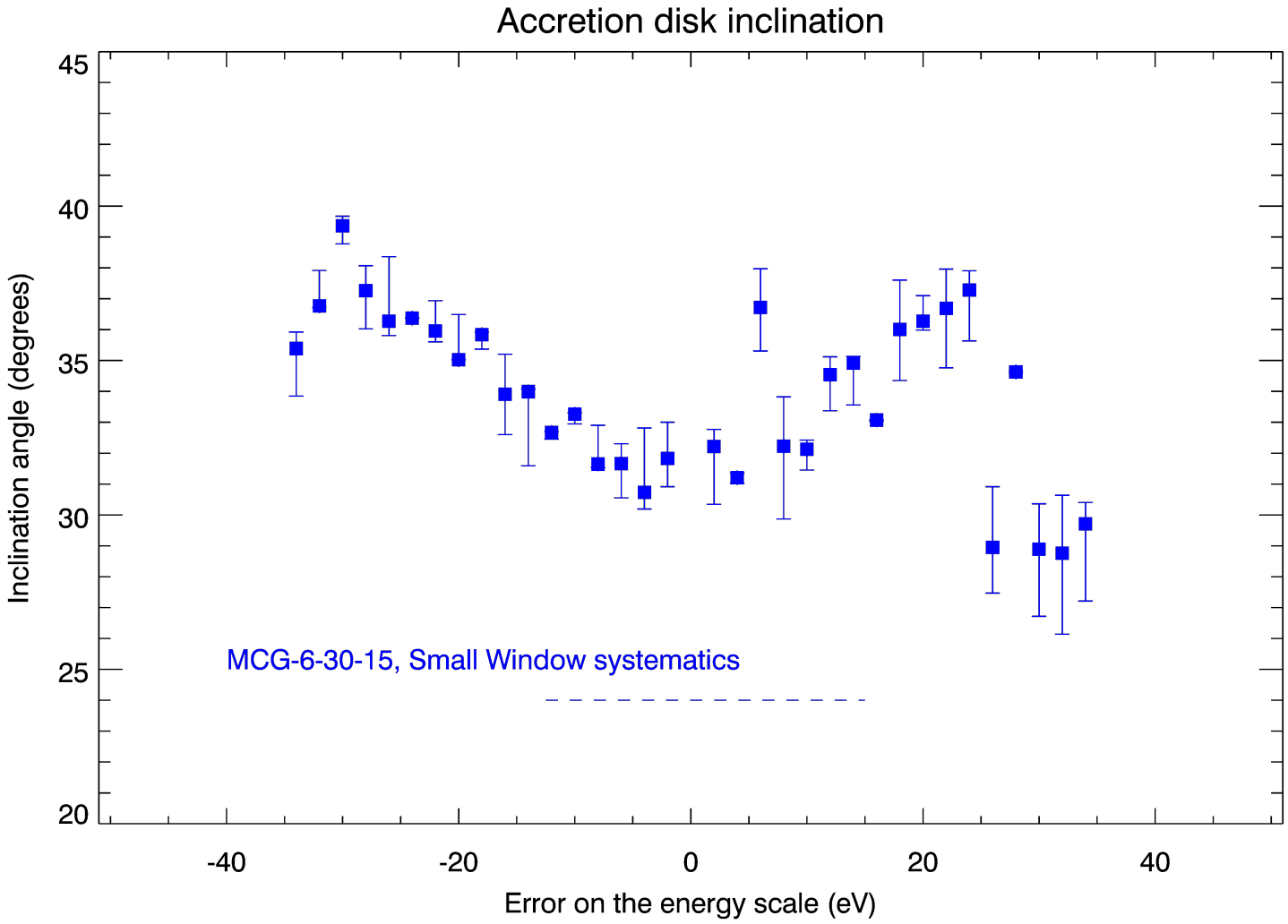
(data courtesy of M.Smith & M.Stuhlinger (courtesy M.Sawada, Ayoama Gakuin Un., and XIS Team)
For Fast Modes: Guainazzi et al., 2013, XMM-SOC-CAL-TN-0083)

Impact on BH spin



- (Guainazzi, in prep.)

Impact on accretion disk inclination



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Conclusions

- Any astrophysical problems, requiring a determination of the X-ray fluxes by better than ±10% is undecided
- At CCD resolution, any astrophysical problems, requiring measuring features weaker than 3% above the continuum require careful consideration of systematic effects
- The current calibration uncertainties *at nominal reconstruction of the energy scale* may have an impact of at least $\Delta a \leq 0.1$ and $\Delta i \leq 5°$ [$\Delta q \leq 0.5$] degrees on relativistic kernel fits
- Beware the dead fish, and teach your students do the same
- Get familiar with the IACHEC work.

  `http://web.mit.edu/iachec/`
- If everything else fails: `Matteo.Guainazzi@sciops.esa.int`