

Chandra Internal Cross-Calibration

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Scope

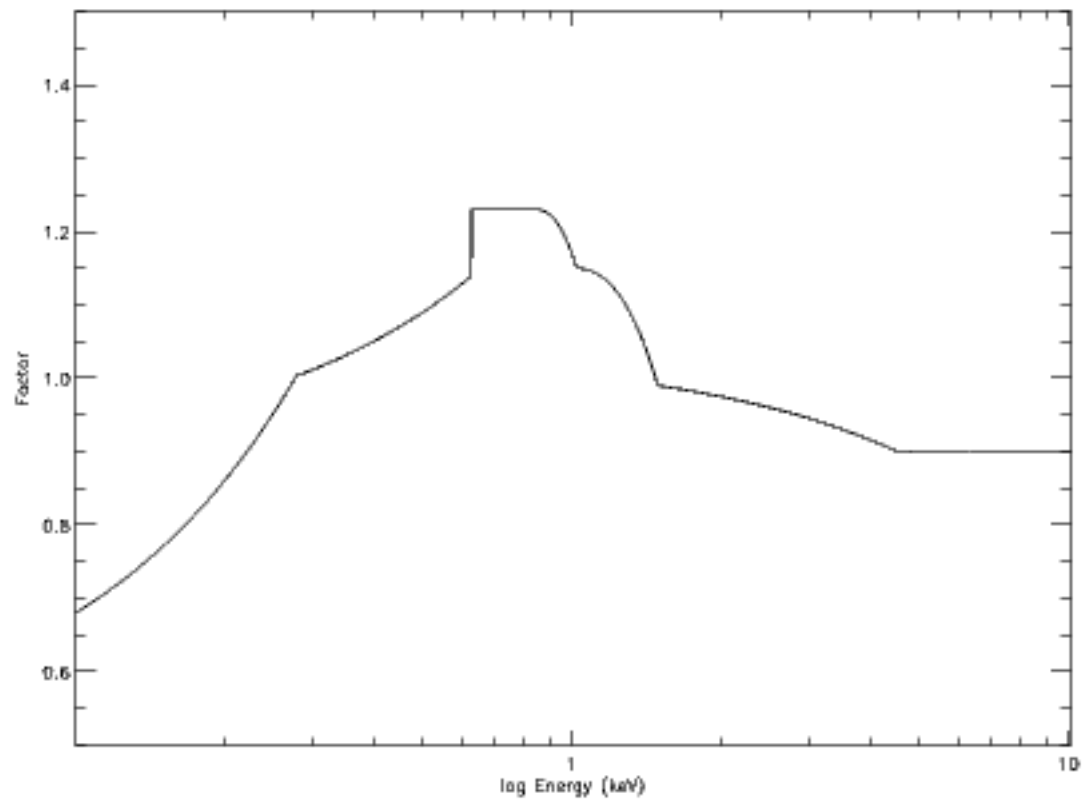
- Response to request from CUC:
 - “There has been very little discussion about cross-calibration across the Chandra instruments, e.g., between the bare ACIS-S, bare ACIS-I, ACIS-S/HETG and HRC/LETG. It remains unclear to what extent this internal cross-calibration is naturally achieved through the regular calibration efforts. The CUC requests an explicit update about internal Chandra cross-calibration. While the CUC acknowledges that it is challenging to find potential sources, it also recommends examining the cross-calibration of ACIS grating spectra with the spectrum of the zero-th order image.”
- Preliminary response: make web page and presentation to CUC
 - URL: http://space.mit.edu/ASC/calib/crosscal/internal_crosscal.html
- Concentrating on effective area comparisons

Cases for Cross-Cal

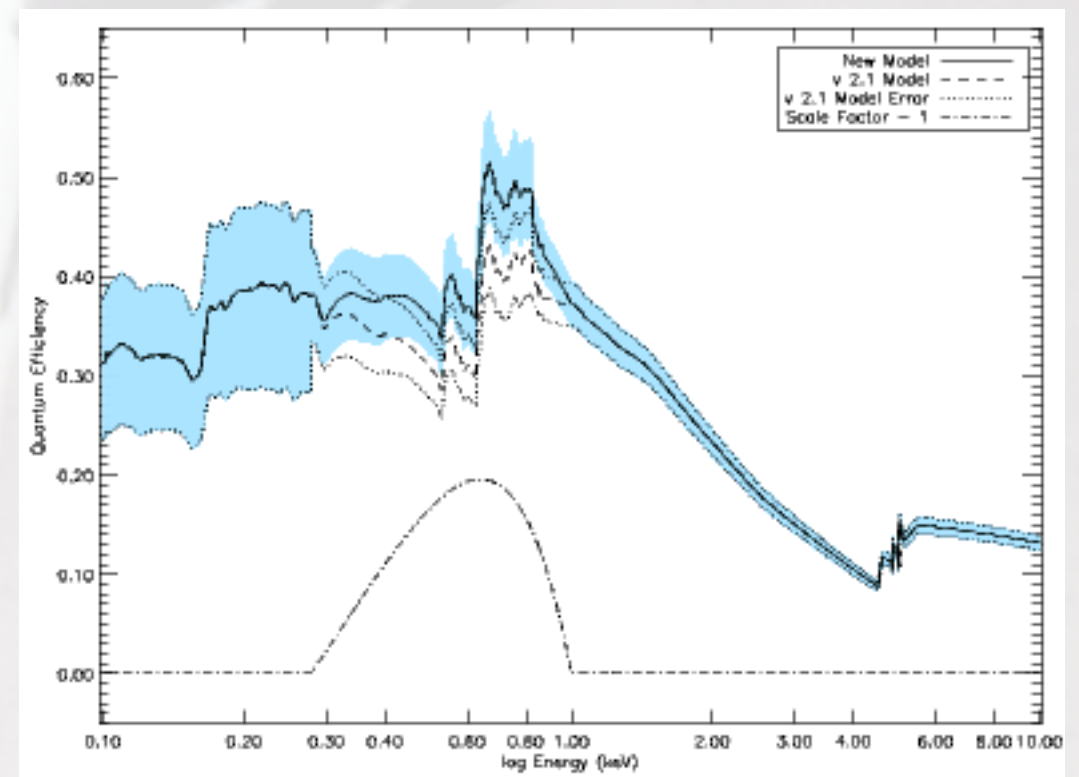
- HRC-I v. HRC-S
- LETG/HRC-S v. HETGS
- ACIS-S v. HRC-S: Discovery of ACIS contaminant
- ACIS-I v. ACIS-S
- HETGS: MEG v. HEG
 - HRMA Ir-M edge
 - Assumption of simple blazar spectra
- Gratings v. ACIS
- LETG/ACIS-S v. HETGS
- Joint Chandra and Suzaku or XMM observations

HRC-I v. HRC-S

- Compare rates of several sources
 - Assume HRC-S QE is good
 - Adjust HRC-I QE using piecewise quadratics
 - Sources: PKS 2155-304, G21.5-0.9, HZ 43, Cas A
 - Changes give count rates within 2-5% of observations
 - http://cxc.harvard.edu/cal/Hrc/Documents/mcp_qe_i.v2.1.ps
 - http://cxc.harvard.edu/cal/Hrc/Documents/mcp_qe_i.v2.2.ps
- Twiki: <http://cxc.harvard.edu/twiki/bin/view.cgi/HrcCal/CrossCal/>



HLM— Chandra Internal Cal

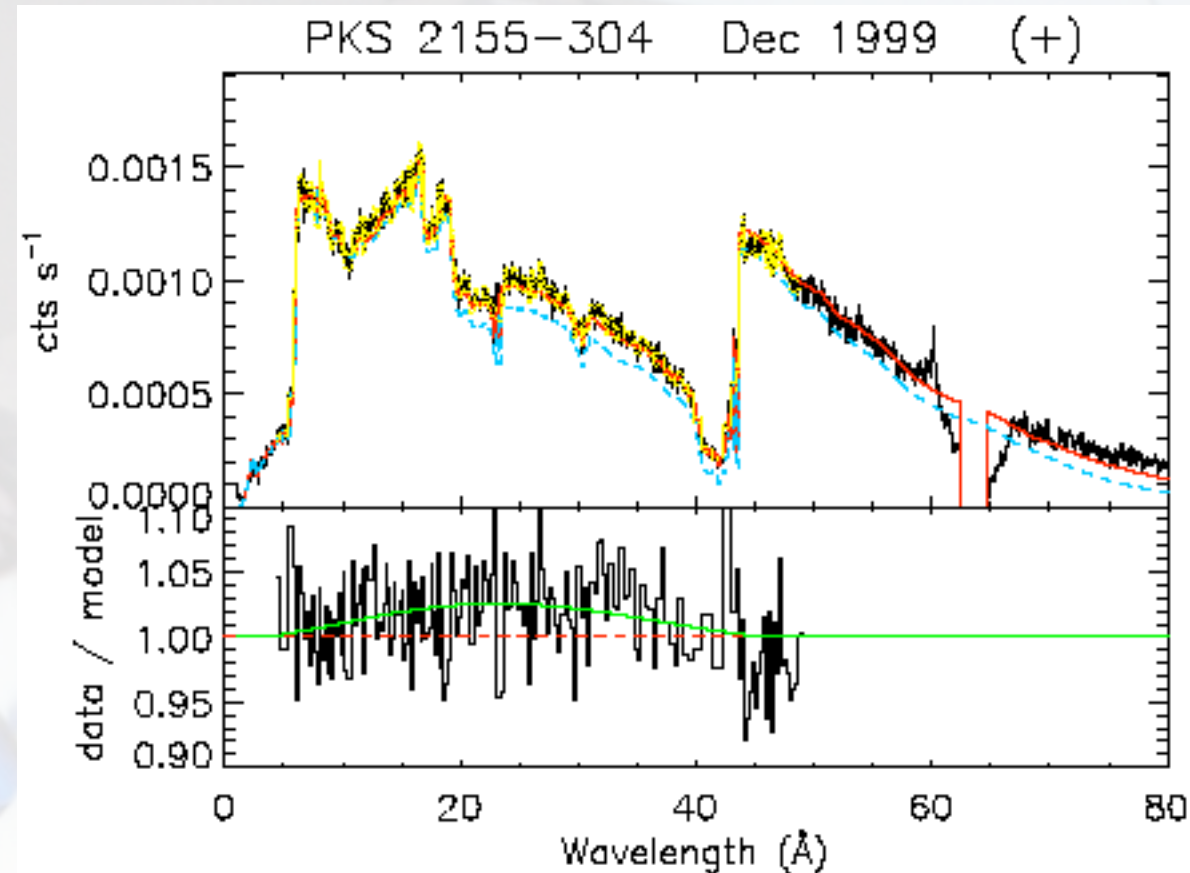


LETG/HRC-S v. HETGS

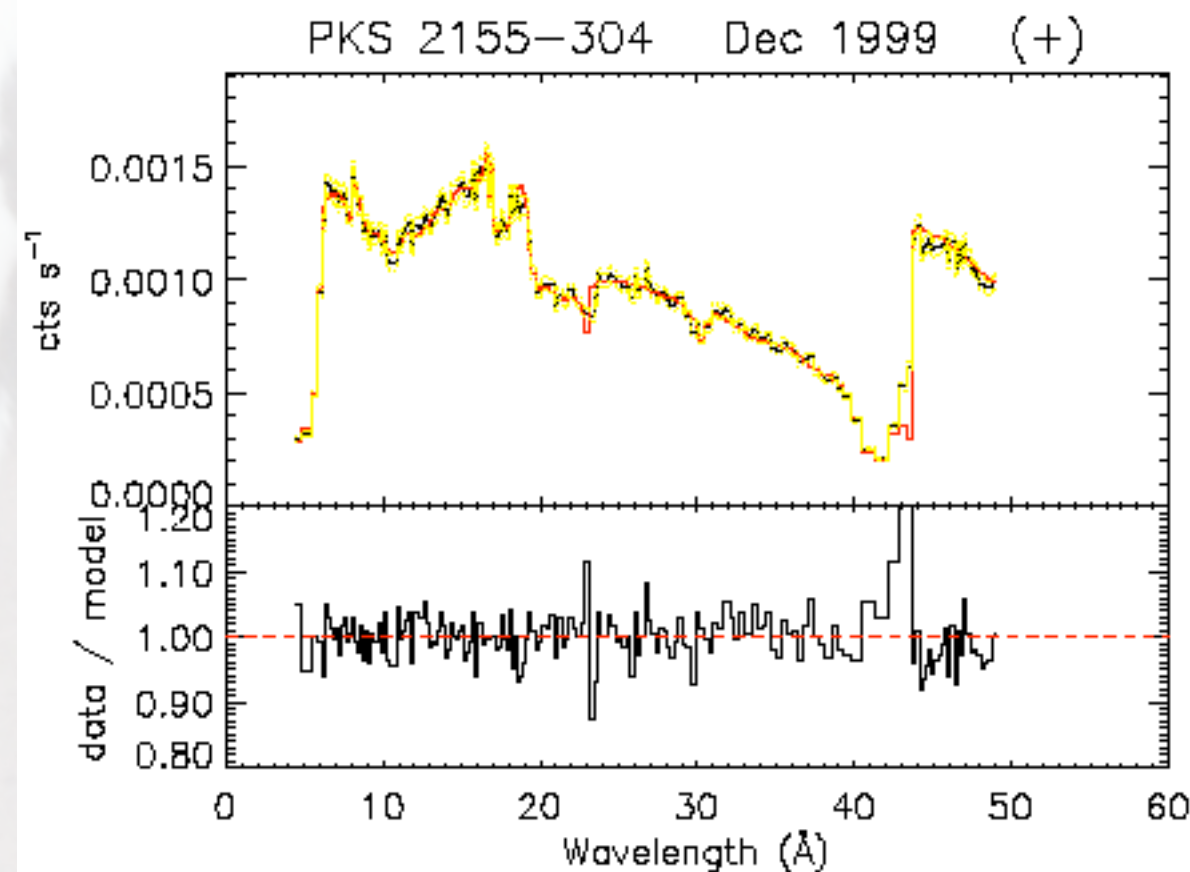
- Fix C-K edge in UVIS
 - Some discrepancies between component calibrations
 - http://space.mit.edu/CXC/calib/letg_acis/compare_poly.ps
 - Adopt ACIS-S filter model (same composition)
 - http://cxc.harvard.edu/cal/spie/letg_eff_area.ps
- Gentle HRC-S QE adjustment
 - Use fit to HETGS observation of PKS 2155-304
 - Adjustments are mild (<5%) --> agree to $< \pm 5\%$
 - http://cxc.harvard.edu/cal/spie/letg_eff_area.ps
- LETG high orders revised
 - used LETG/ACIS data
 - Relies on uniform QE and BI/Fl corrections
 - <http://cxc.harvard.edu/cal/Letg/HO2004/>
- Other in-flight observation analysis in progress

HRC-S QE fix using HETGS fit

Before

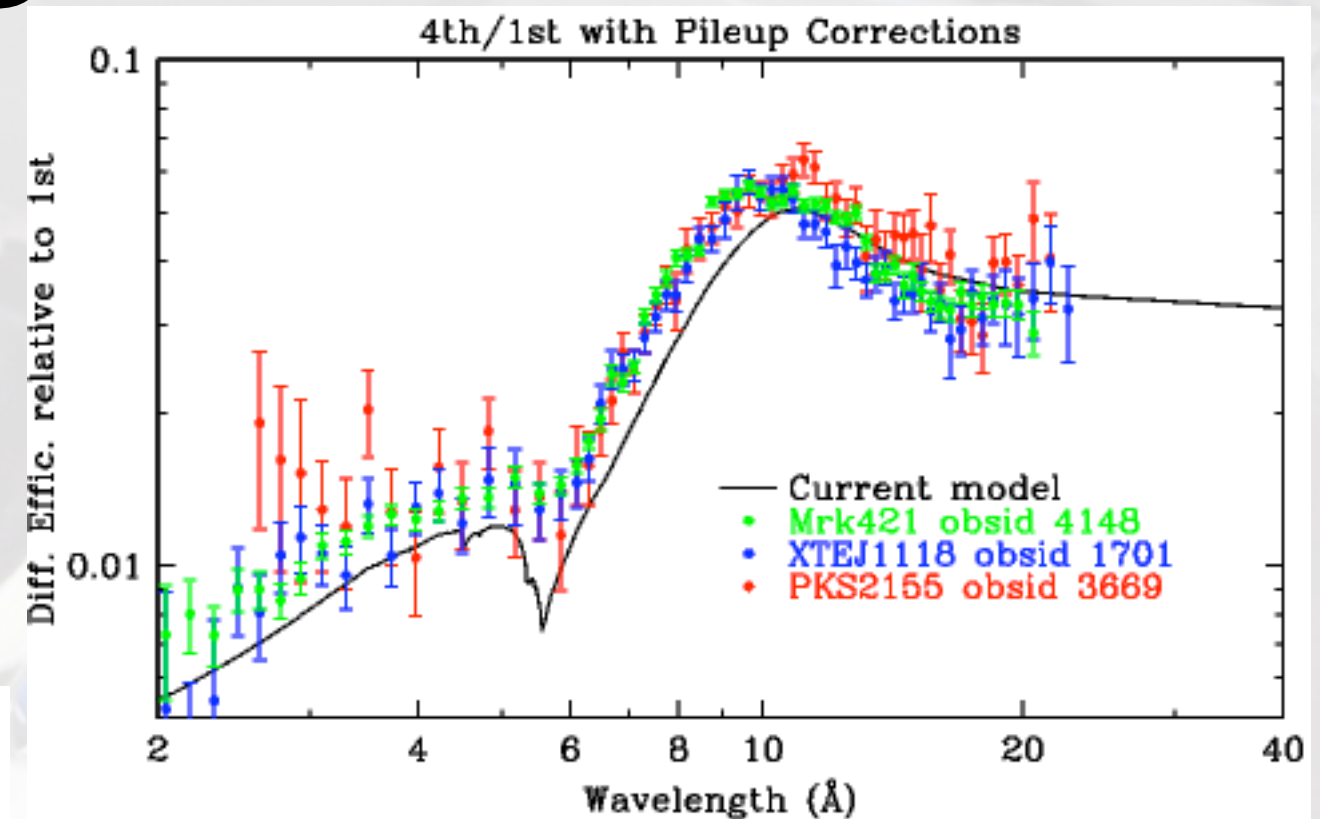
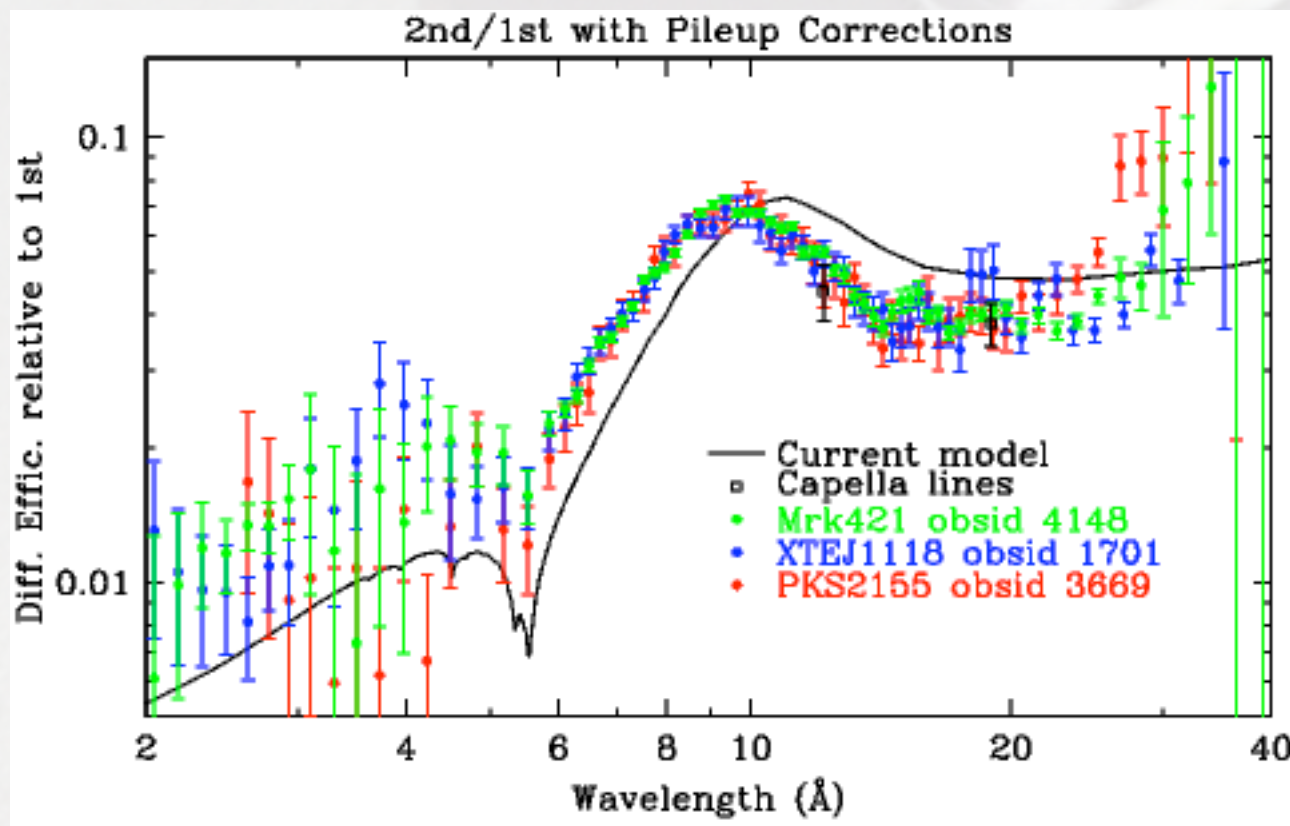


After



LETG High Orders

Odd orders were OK
Even orders were adjusted
using LETG/ACIS data



Orders should now be
good to better than $\pm 10\%$

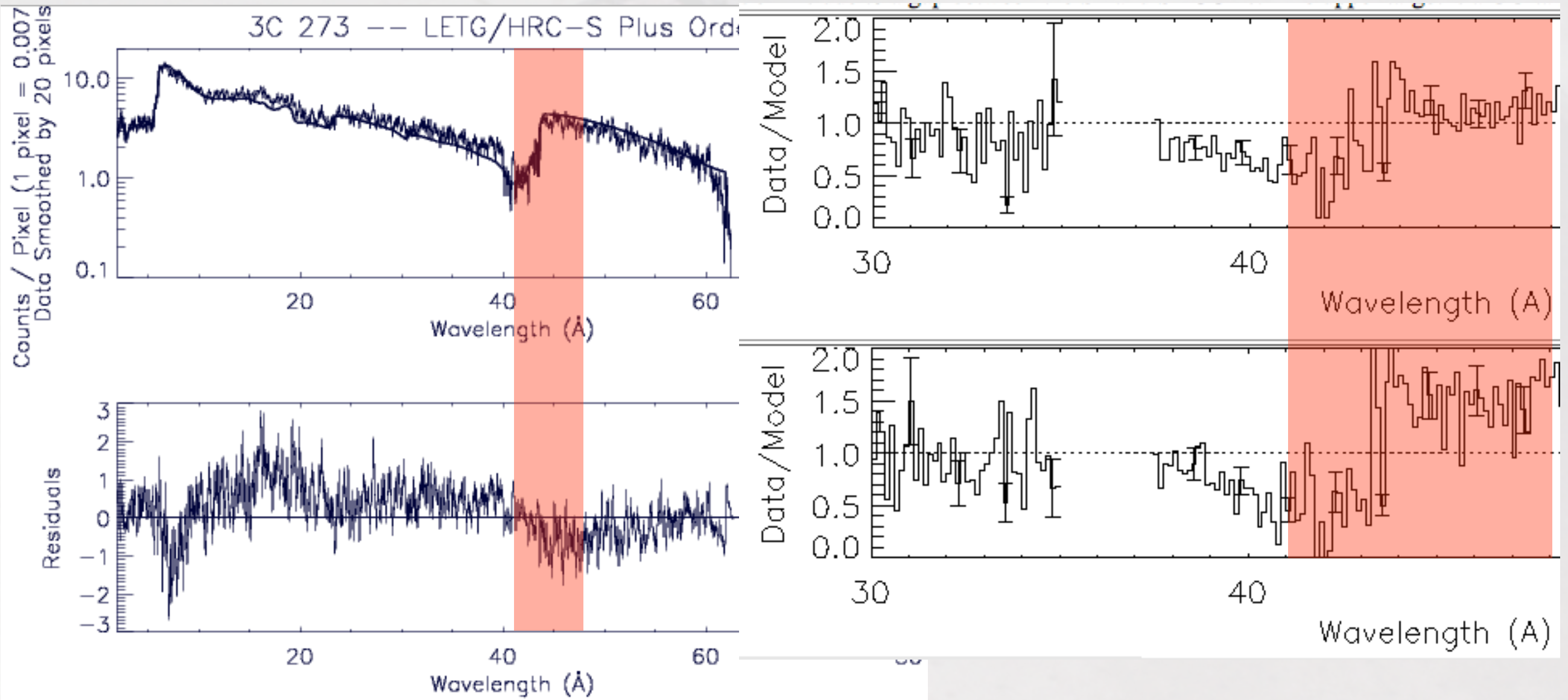
<http://cxc.harvard.edu/cal/Letg/HO2004/>

ACIS Contaminant

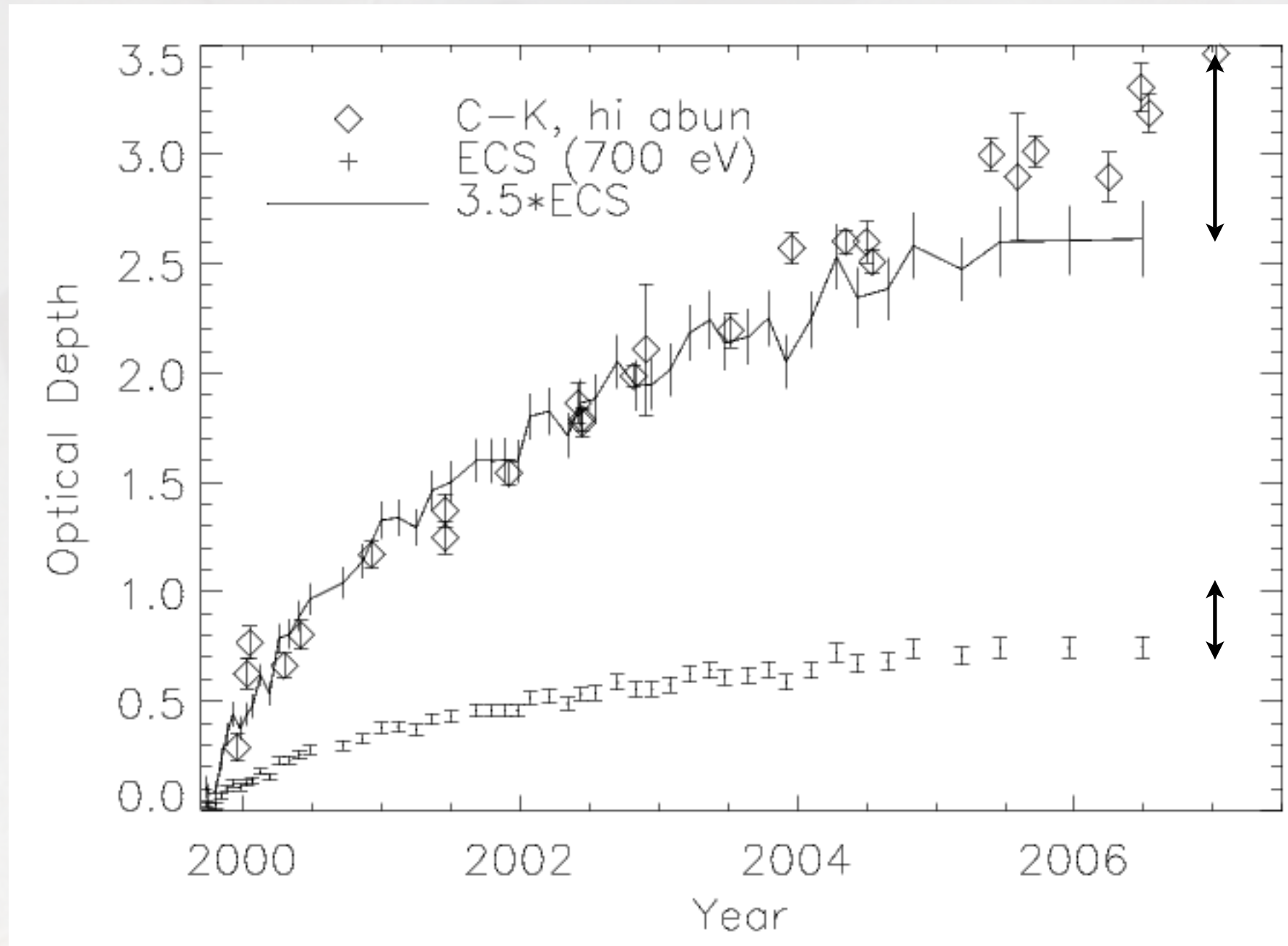
- LETG/HRC v. LETG/ACIS
 - proved that contaminant was on ACIS, not HRMA
 - http://space.mit.edu/ASC/calib/letg_acis/ck_cal_old.html
 - <http://xxx.arxiv.org/abs/astro-ph/0308332>
- ECS v. LETG/ACIS, Clusters v. time
 - used to check spectral, temporal model
 - http://cxc.harvard.edu/cal/Acis/Cal_prods/qeDeg/index.html
- ACIS observations v. time
 - Contamination correction good to $< \pm 5\%$
 - http://hea-www.harvard.edu/~depasq/e0102_CAL6G/E0102_analysis.html
- Issues remain between ECS and LETG/ACIS
 - Subject of further work
 - Tracked by ACIS “response” team

HRC-S v. ACIS-S

Both using LETG in Jan. 2000



ECS v. LETG/ACIS

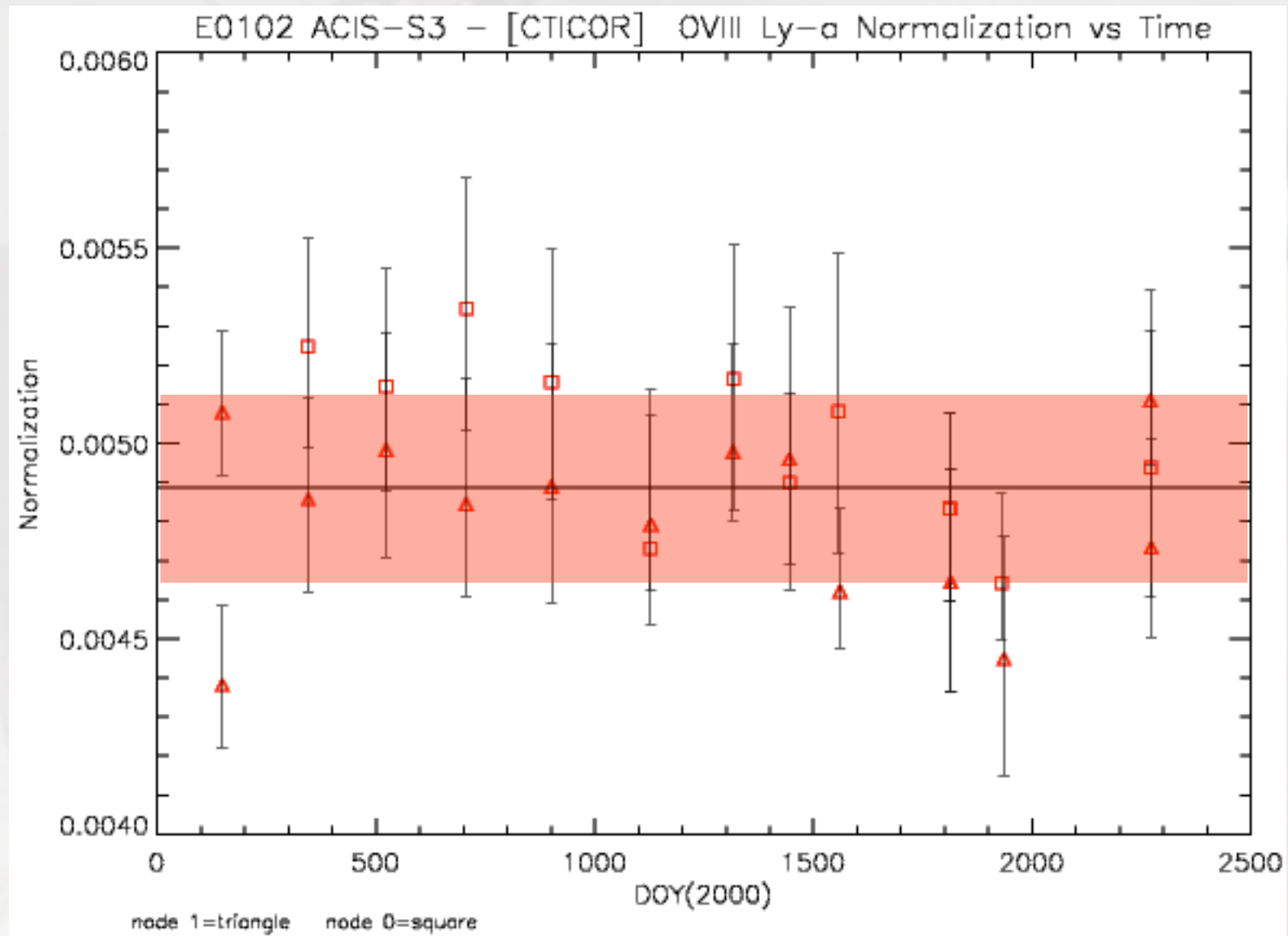


0.80 O.D.
here

implies
0.23 O.D.
here

http://space.mit.edu/ASC/calib/letg_acis/ck_cal_old.html

Contamination Correction



Good to
 $\pm 5\%$

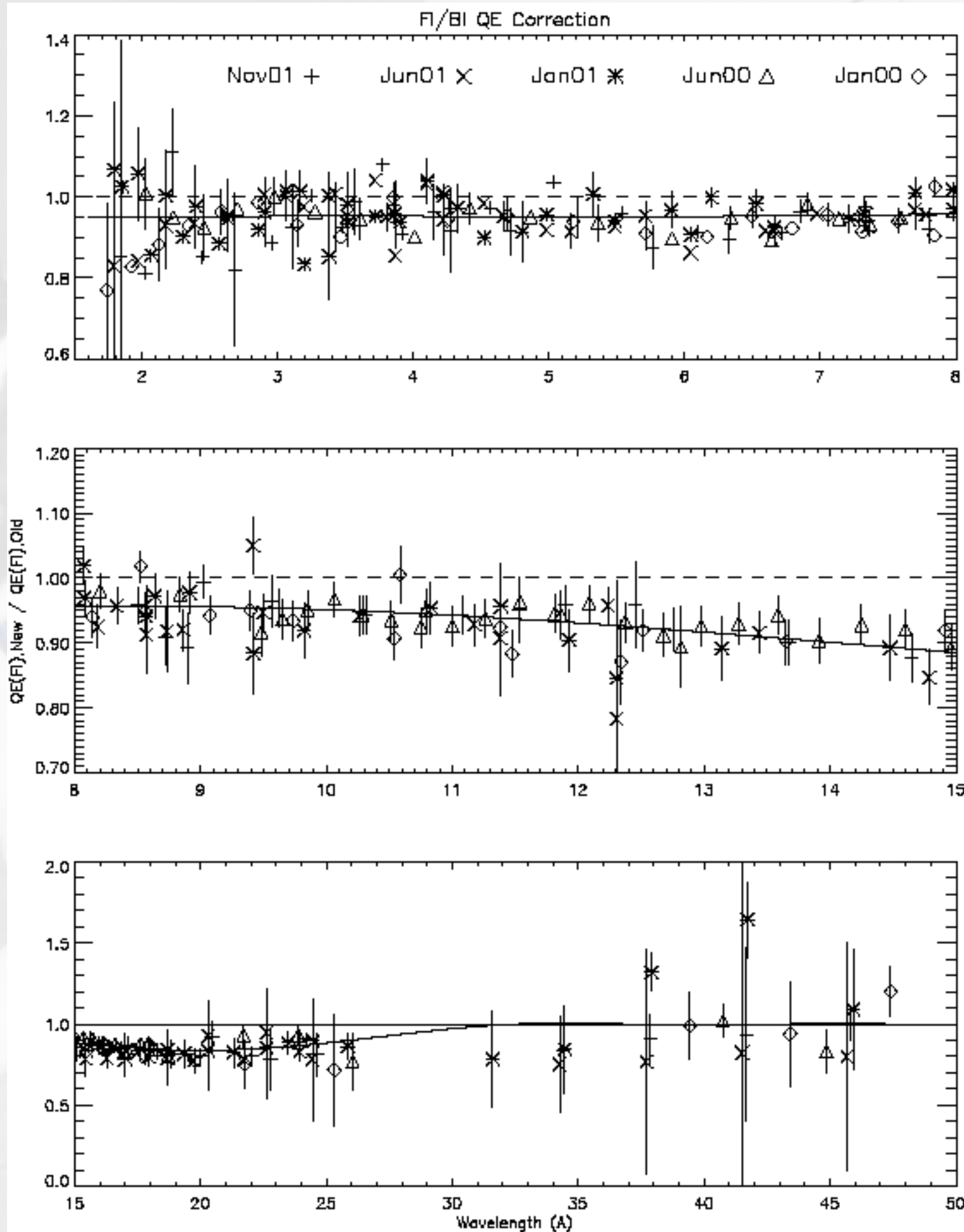
http://hea-www.harvard.edu/~depasq/e0102_CAL6G/E0102_analysis.html

ACIS-S v. ACIS-I

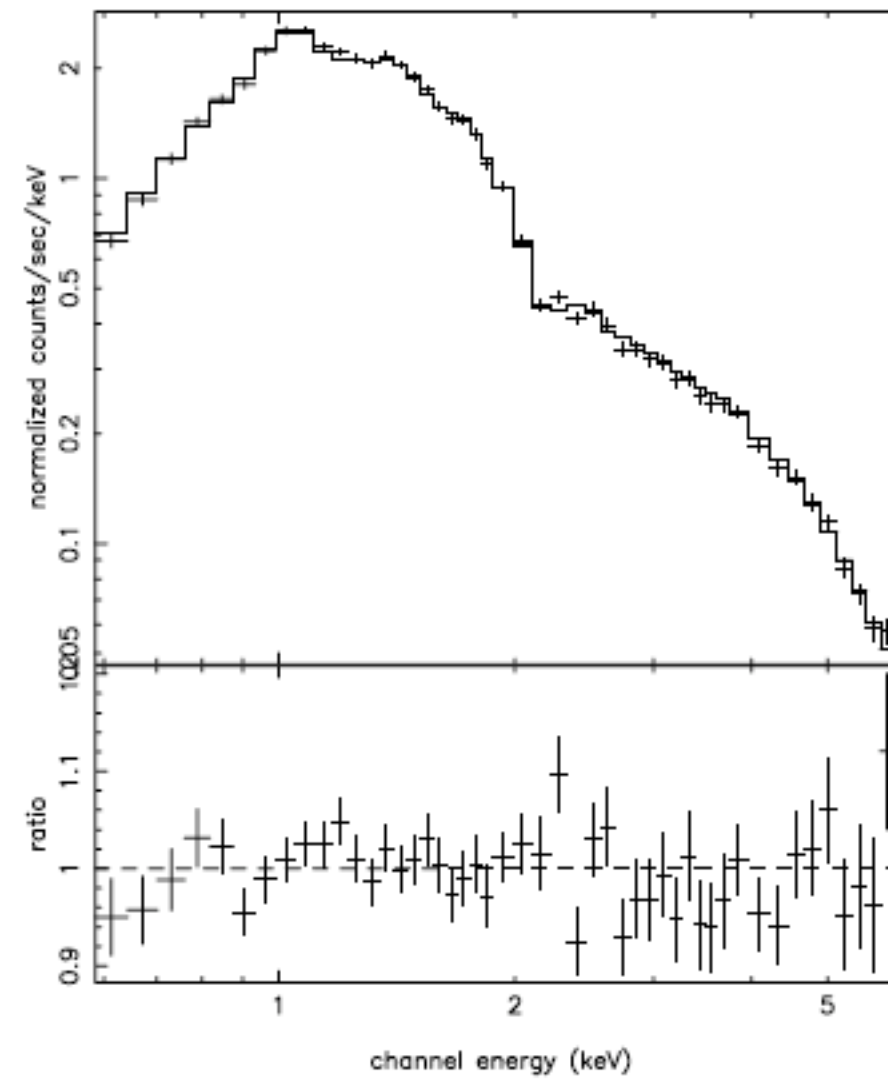
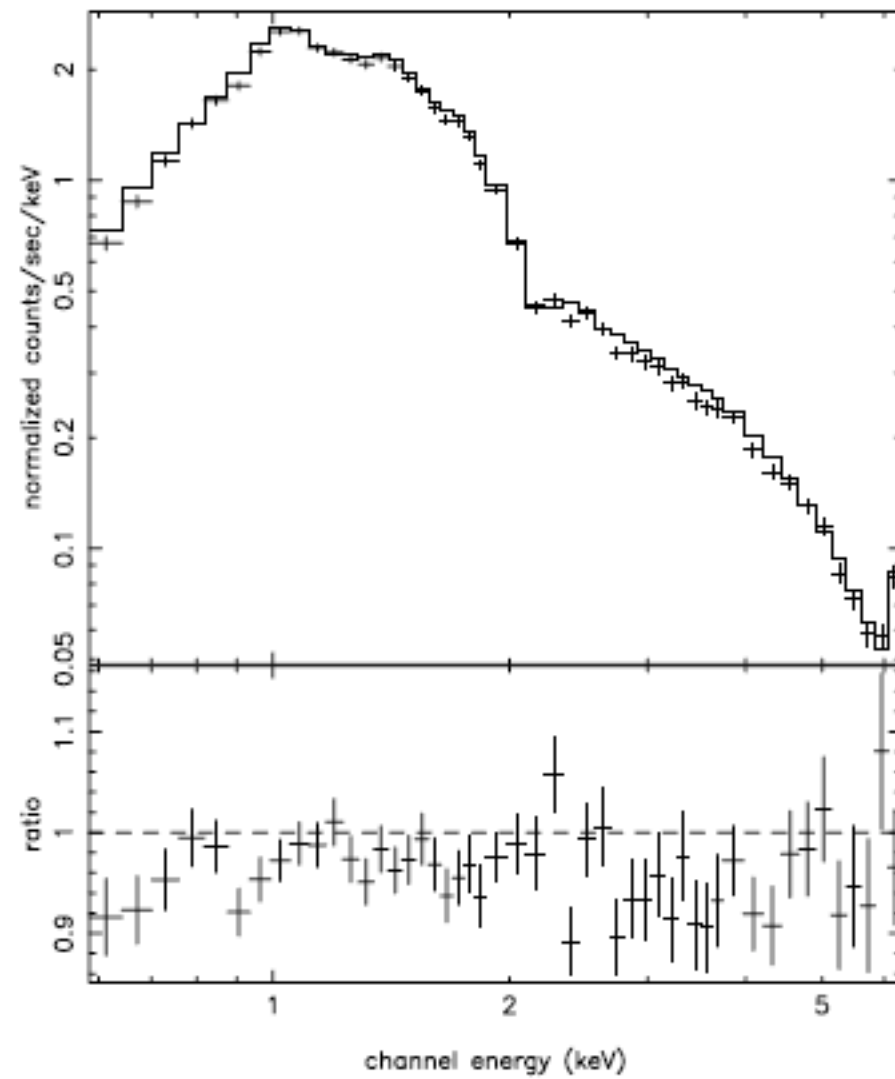
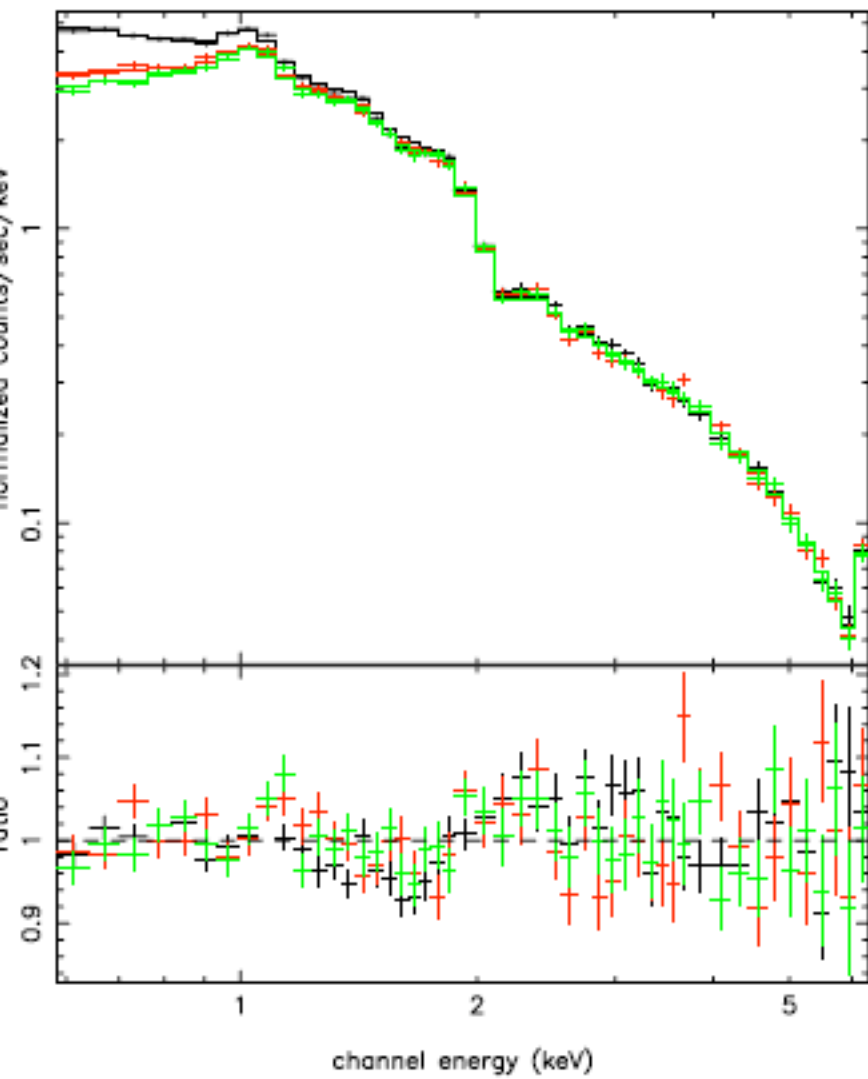
- BI v. FI QE
 - Using (L,H)ETGS +I v. -I
 - http://space.mit.edu/ASC/calib/letg_acis/letg_acis_cal.ps.gz
 - <http://xxx.arxiv.org/abs/astro-ph/0308332>
 - Fix derived from ground-cal data
 - http://cxc.harvard.edu/cal/Acis/Cal_prods/qe/qe_memo.ps
 - Verified using Abell 1795, HETGS data
 - http://hea-www.harvard.edu/~alexey/acis/memos/cont_spat.pdf
 - http://space.mit.edu/ASC/calib/heg_meg/
- QEU maps
 - Verified with modeling of Abell 1795
 - Can fit model from ACIS-S to data from ACIS-I
 - http://hea-www.harvard.edu/~alexey/acis/memos/cont_spat.pdf
- Agree to better than $\pm 5\%$ from 0.3 to 6 keV

FI/BI QE check using LETGS and HETGS + | v. - | (in 2003)

<http://xxx.arxiv.org/abs/astro-ph/0309114>

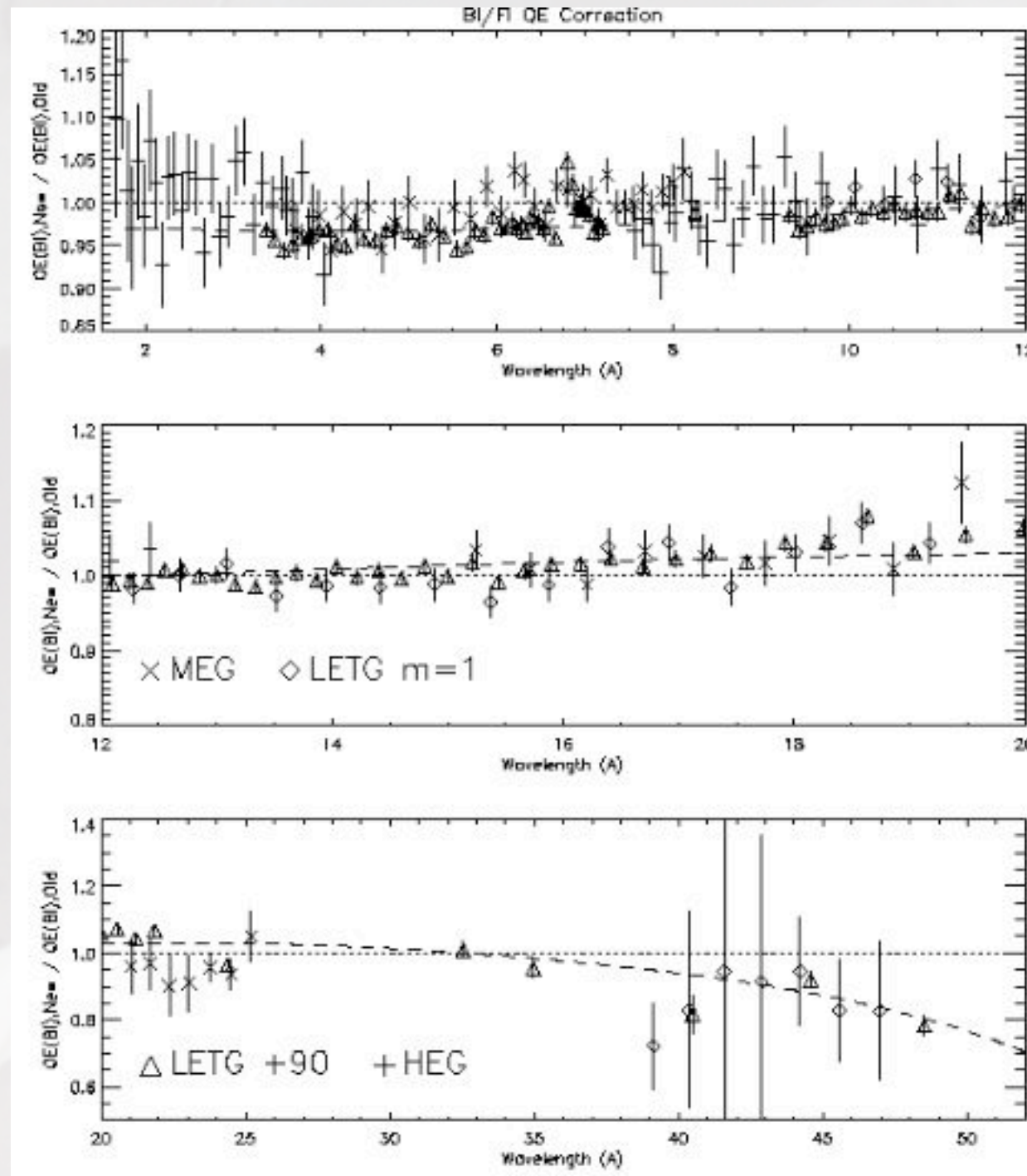


A1795 ACIS-I v. ACIS-S



http://hea-www.harvard.edu/~alexey/acis/memos/cont_spat.pdf

Gratings: compare +1 to -1



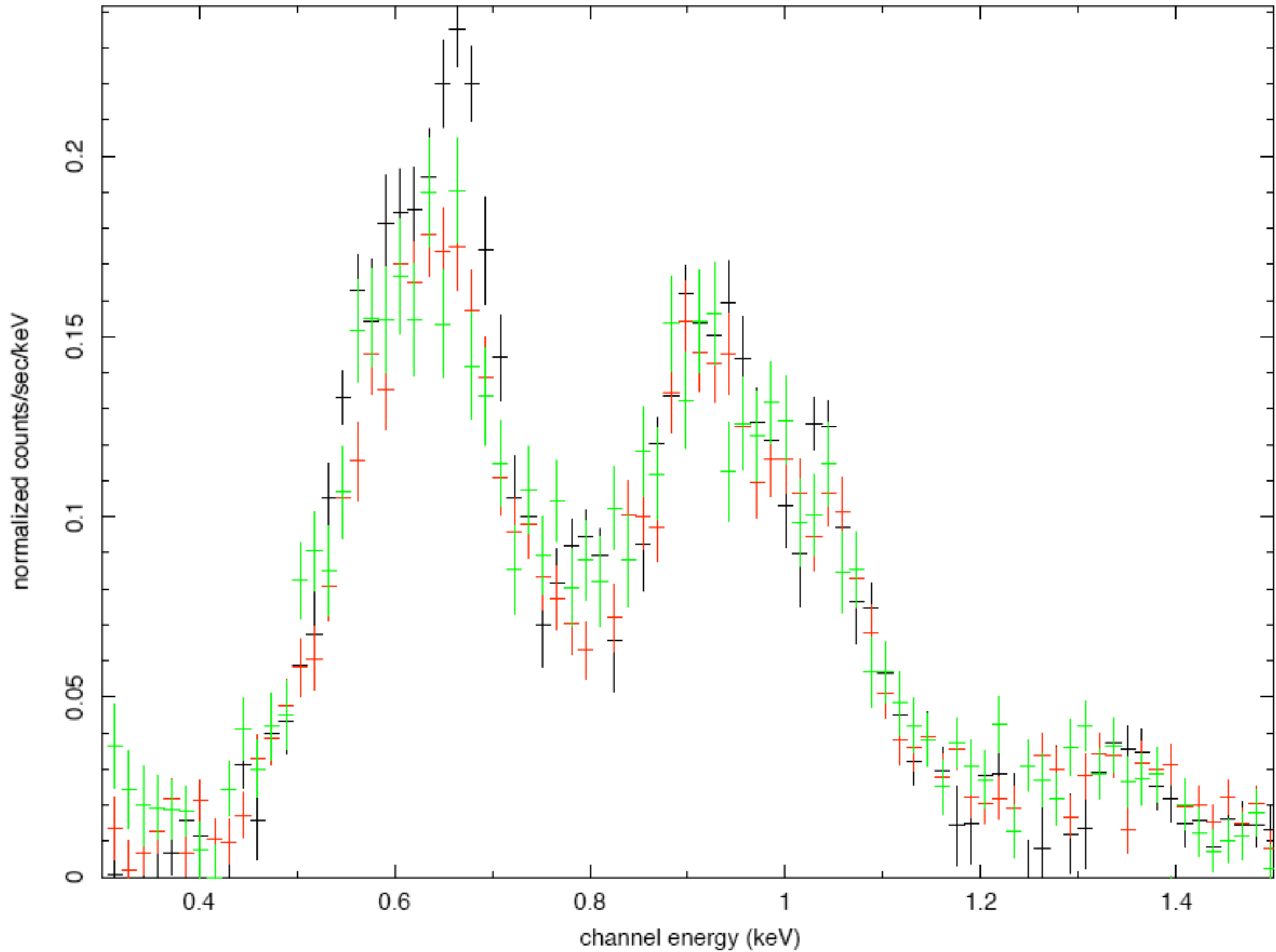
After BI QE
update
(April 2005)

http://space.mit.edu/ASC/calib/heg_meg/

Complications

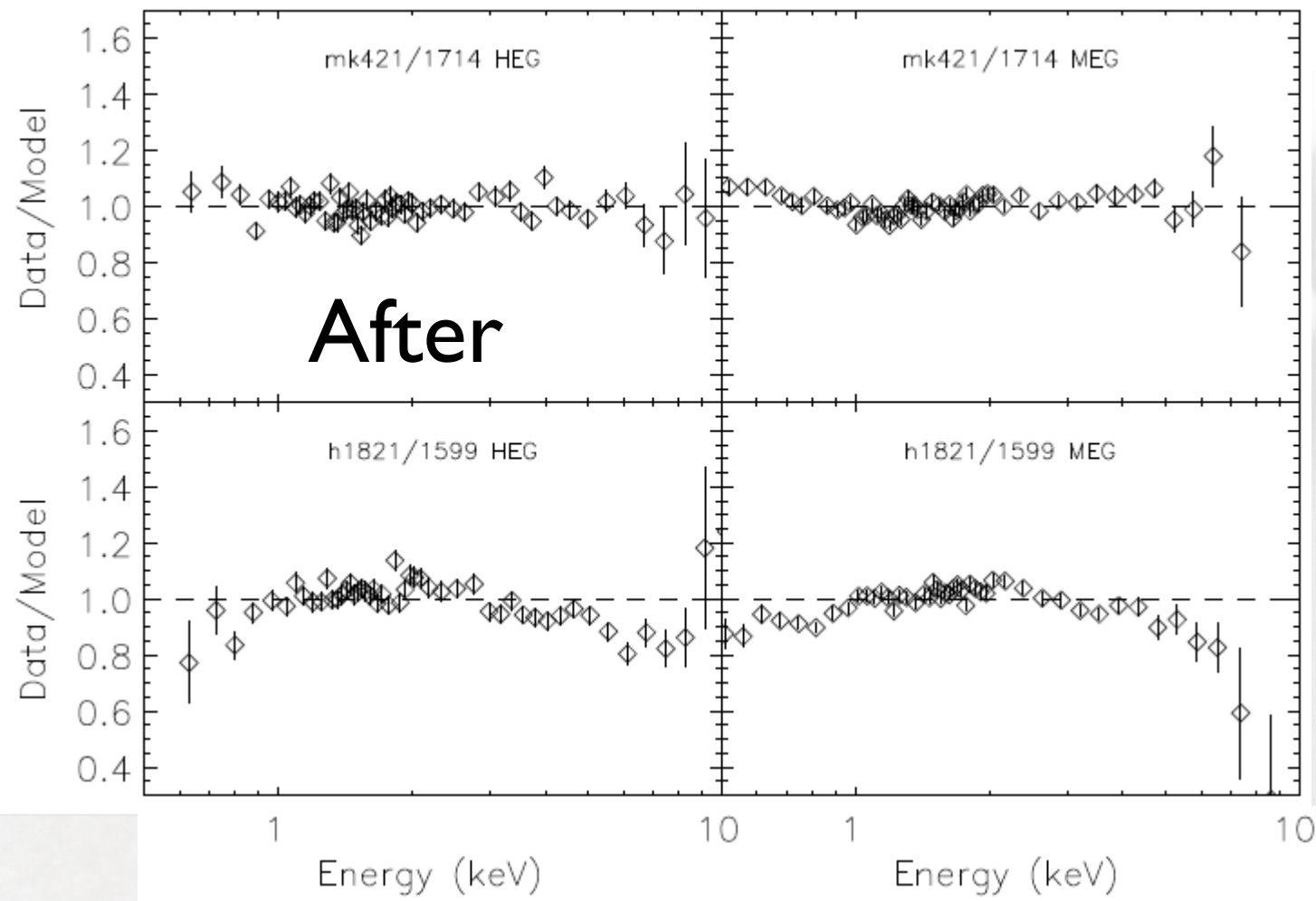
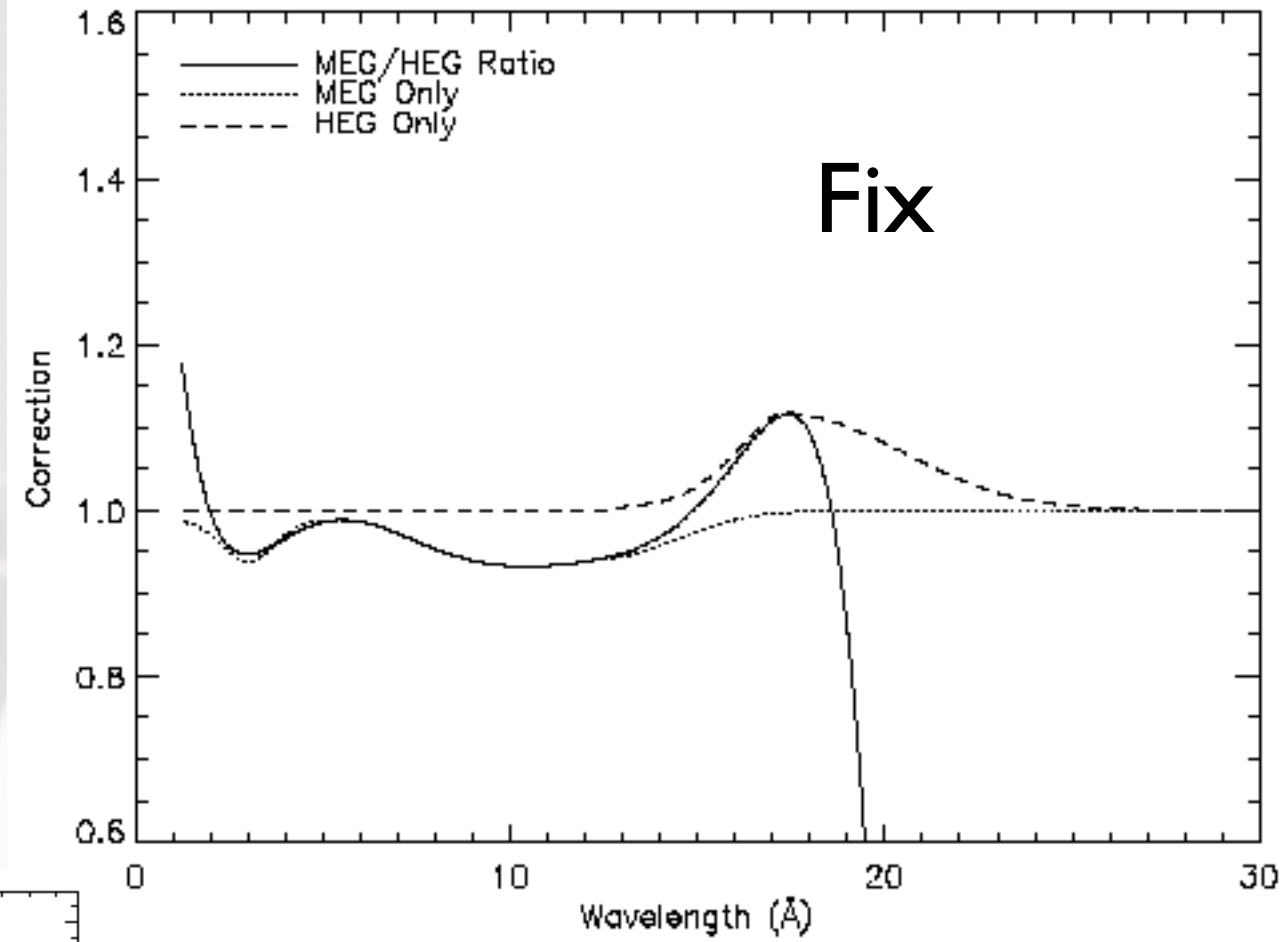
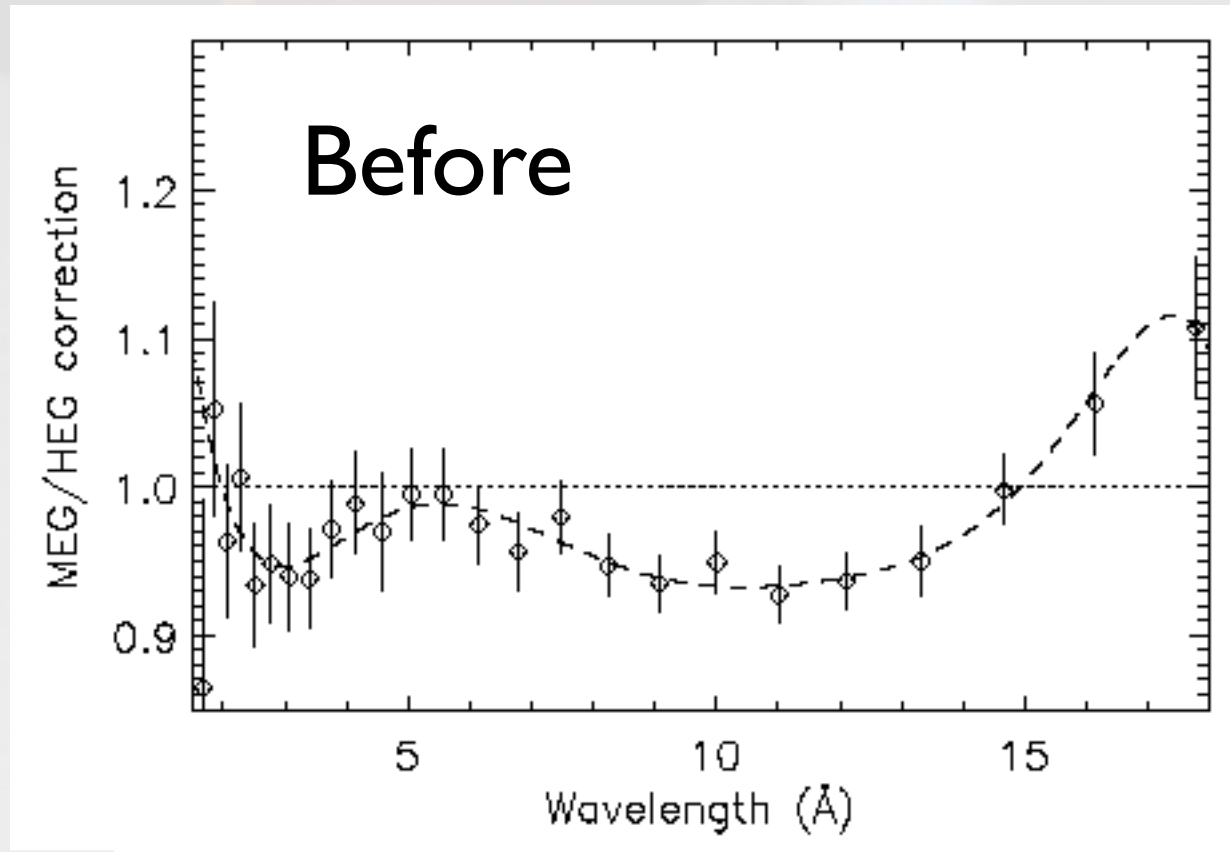
- ACIS RMF and CTI affects EA
 - RMF “tails” extend to low E
 - CTI causes grade migration
 - Charge traps have different time scales, so losses depend on readout mode
- Pileup redistributes energy to high E
 - Pileup models are somewhat uncertain
 - Avoided using:
 - faint sources — poor statistics
 - distributed sources — PSF issues (XMM), spatial nonuniformities (CTI, QE)
 - gratings — extra component, some flux reduction
 - CC mode — not separately calibrated, CTI is different
 - Streak spectrum is OK

E0102 S3 Streak Analysis
black=obs1311(scaled), red=s3n0 streak, green=s3n1 streak



HETGS: HEG v. MEG

- Requires BI,FI QE updates
- Requires fix to HRMA Ir-M edge
 - Consistent between MEG and HEG, different depths
 - http://space.mit.edu/ASC/calib/heg_meg/meg_heg_report.pdf
 - Modeled with 22 Å hydrocarbon HRMA overlayer
 - http://asc.harvard.edu/ccw/proceedings/05_proc/presentations/jerius/
- Efficiency fix in two stages
 - MEG v. HEG ratio determined
 - <http://xxx.arxiv.org/abs/astro-ph/0309114>
 - Allocation between MEG and HEG from AGN fits
 - For $E > 0.8$ keV, fix MEG, otherwise, HEG
 - http://space.mit.edu/ASC/calib/heg_meg/meg_heg_report.pdf



Residual relative errors $< \pm 2\%$

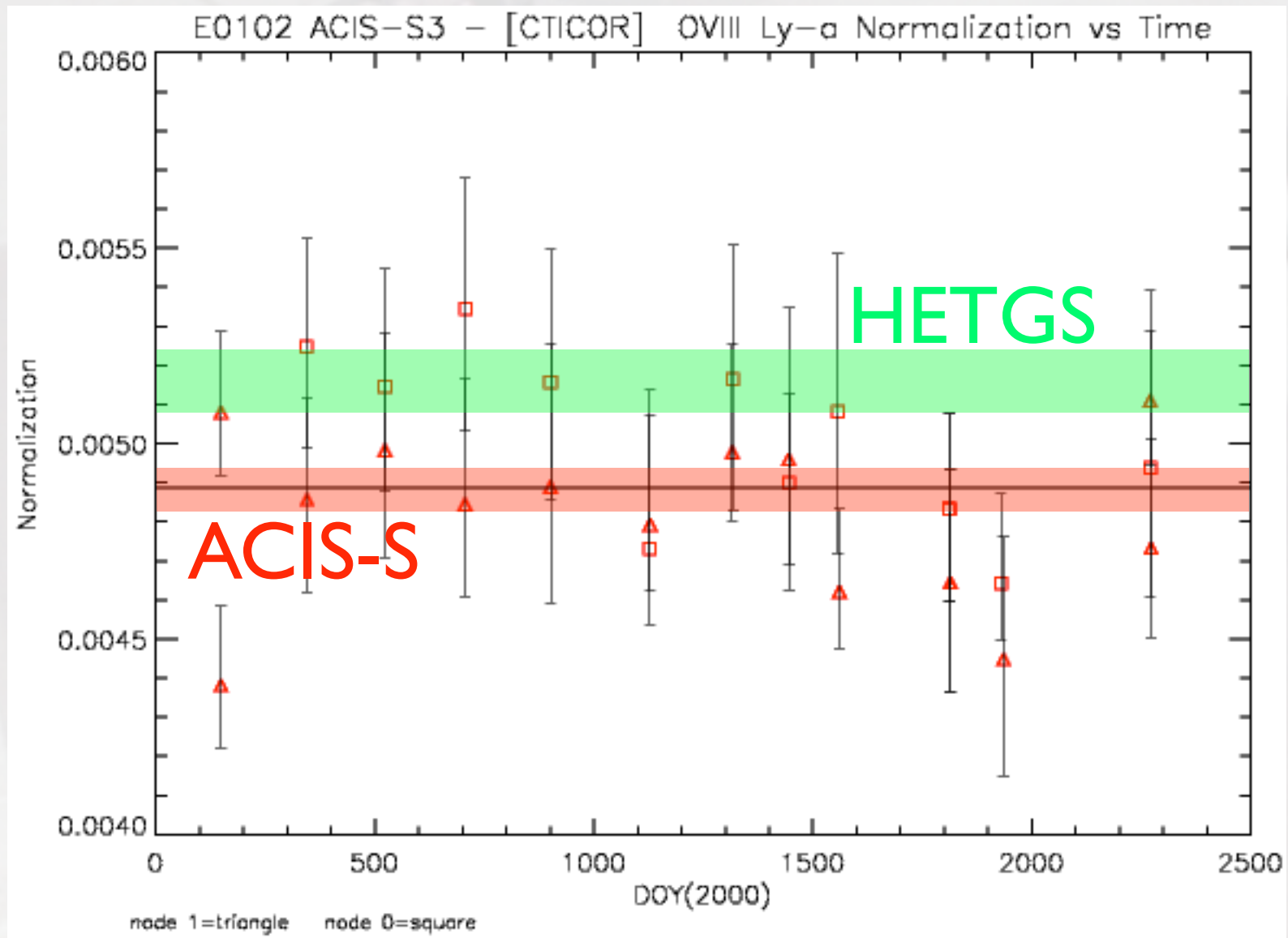
Residual absolute errors $< \pm 5\%$

http://space.mit.edu/ASC/calib/heg_meg/meg_heg_report.pdf

Gratings vs. ACIS

- Blazar observations
 - HETGS spectra fit simple models
 - Edges checked: O-K, Si-K
 - http://space.mit.edu/ASC/calib/heg_meg/meg_heg_report.pdf
- Observations of 1E0102
 - HETGS line fluxes used in ACIS analysis
 - Recomputed HETGS line fluxes using QE updates
 - O VIII: 0.00516(8) ph/cm²/s agrees to 5%
 - http://hea-www.harvard.edu/~depasq/e0102_CAL6G/E0102_analysis.html
 - 0th order streak matches ACIS direct
- High signal observations (Mk 421, XTE J1118)
 - Systematic residuals remain at < 5% level
 - Analysis in progress, looking for common residuals

Gratings vs. ACIS



Good to
 $\pm 5\%$

http://hea-www.harvard.edu/~depasq/e0102_CAL6G/E0102_analysis.html

LETG/ACIS v. HETGS

- Observations: PKS 2155-304, 3C 273 campaigns
- Usually had other telescope coverage (XMM)
 - Analyzed with joint GTI files (from XMM cal group)
 - Can cross-cal via XMM PN to take out variations
- Interesting case: “alternating” grating observation
 - Used in 2006
 - Alternating case can be analyzed independently of XMM
 - Analysis in progress

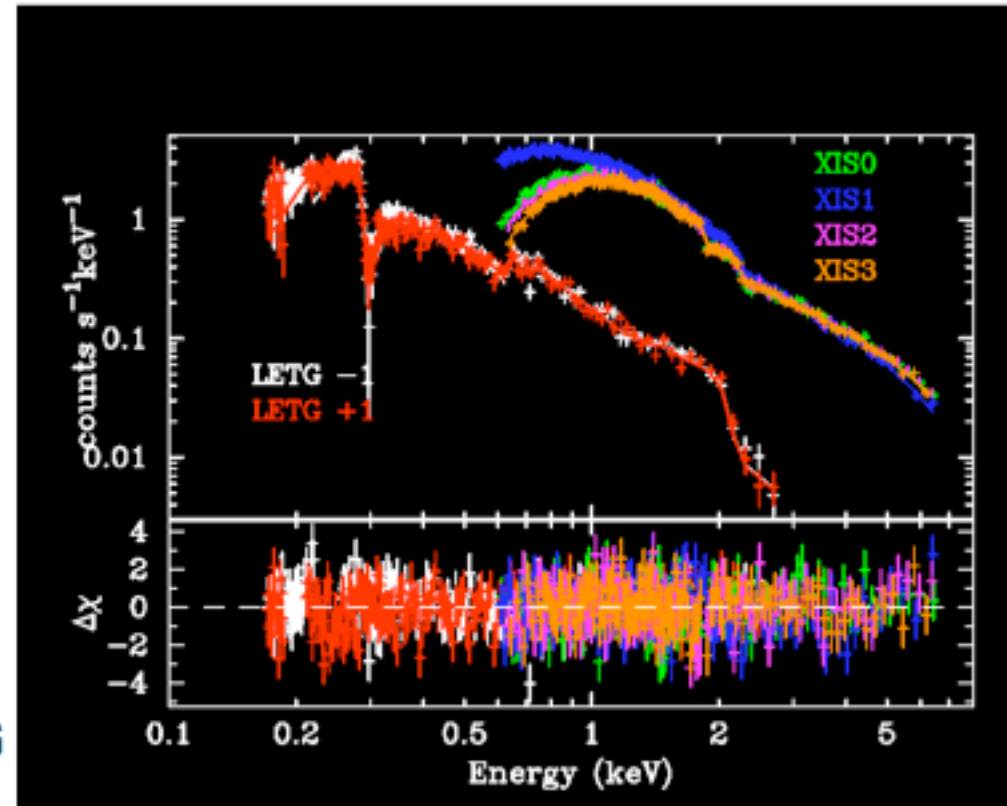
Cross-cal with XMM, Suzaku

- Joint observation with ASCA & SAX in 2000
 - slope and norm agreed within 10%
 - <http://space.mit.edu/ASC/calib/crosscal/index.html>
- XMM cross-cal is a major on-going effort
 - Preliminary results indicated $\pm 10\%$ agreement
 - <http://space.mit.edu/ASC/calib/crosscal/index.html>
 - <http://xmm.esac.esa.int/docs/documents/CAL-TN-0052-4-0.ps.gz>
 - Recent flux comparisons (work in progress)
 - Chandra TGs agree with PN to $< \pm 5\%$ in 1.5-4.0 keV band
 - Systematic differences remain in other bands at 5-15% level
- XMM, Suzaku cross-cal in May 2006
 - Spectral norms agree to 5% (uncert. $\pm 1\%$ in LETGS)
 - Slopes agree to .07 (± 0.042)
 - http://xmm.esac.esa.int/external/xmm_sw_cal/icwg/presentations/PKS2155-304.pdf

Cross-cal with Suzaku

2006 May: Spectral Fit

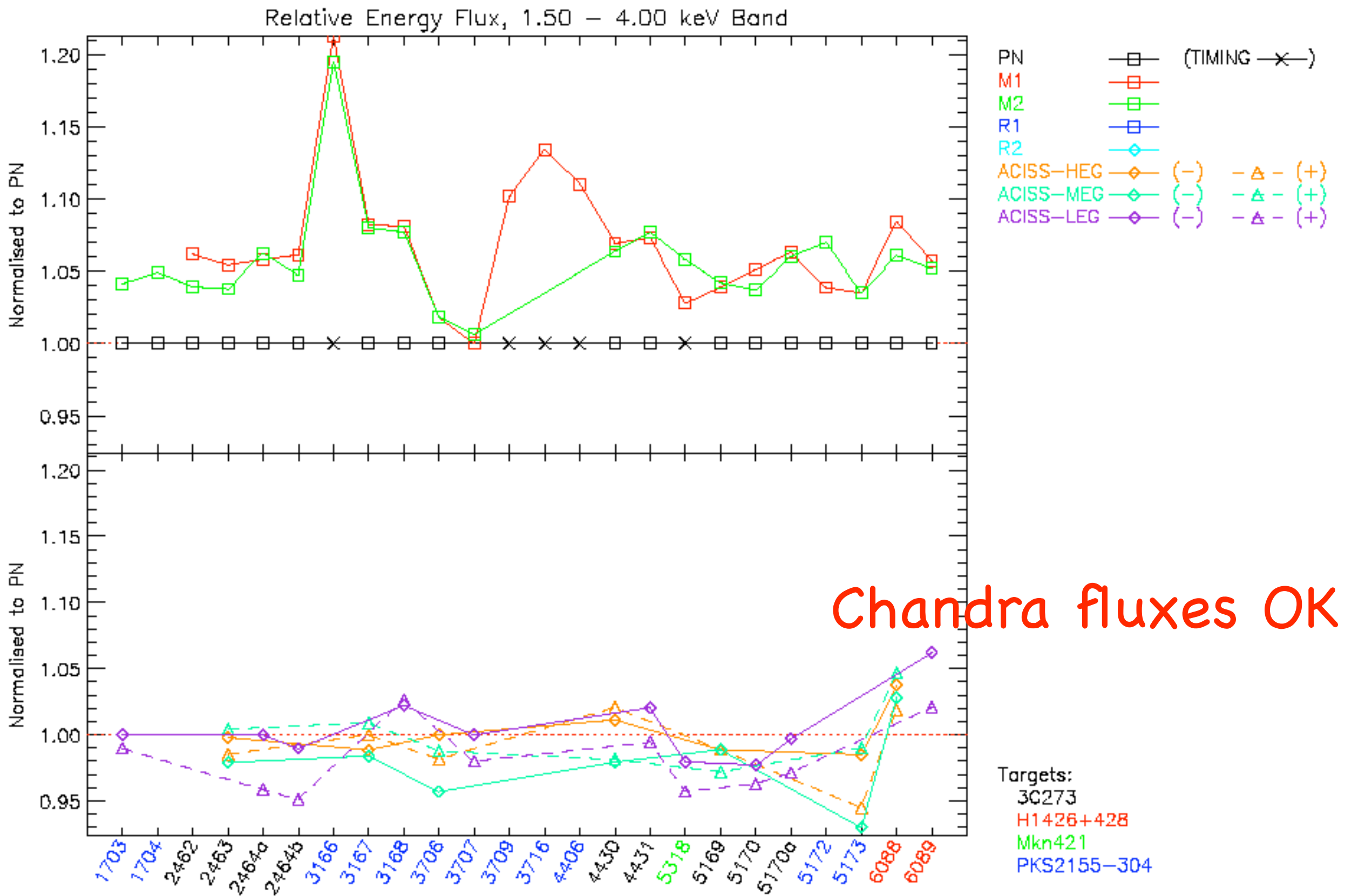
- Independent Fit
 - ★ Γ : 2.49-2.53 (XIS0,2,3:FI)
2.49 (LETG)
 - ★ Const: 0.97-1.0 (FI)
1.0 (LETG:fix)
- Constrained Fit (but N_H)
 - ★ $\Gamma = 2.523 \pm 0.011$
 - ★ Normalization =
1.006/0.950/1.003/1.001 for
XIS0/1/2/3 with respect to LETG



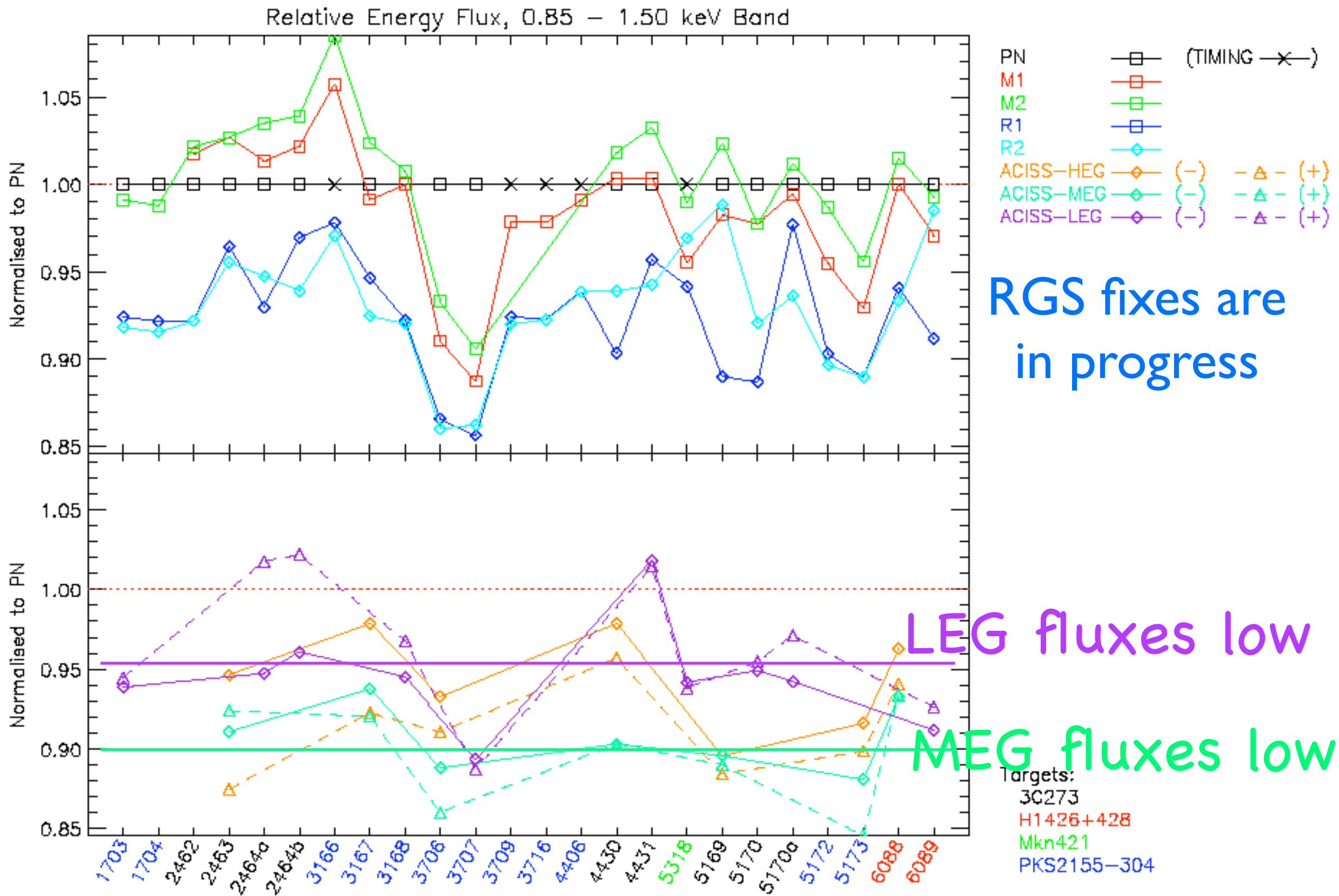
	Normalization	$N_H (10^{20} \text{cm}^{-2})$	Γ
XIS0	0.967(0.025)	< 7.8	2.487(0.022)
XIS1	0.961(0.024)	< 3.4	2.557(0.022)
XIS2	0.976(0.026)	< 8.1	2.504(0.023)
XIS3	0.996(0.027)	< 8.8	2.533(0.024)
LETG	1.000	1.314(0.089)	2.485(0.035)

(M. Ishida, IACHEC meeting, 2006)

http://xmm.esac.esa.int/external/xmm_sw_cal/icwg/presentations/PKS2155-304.pdf

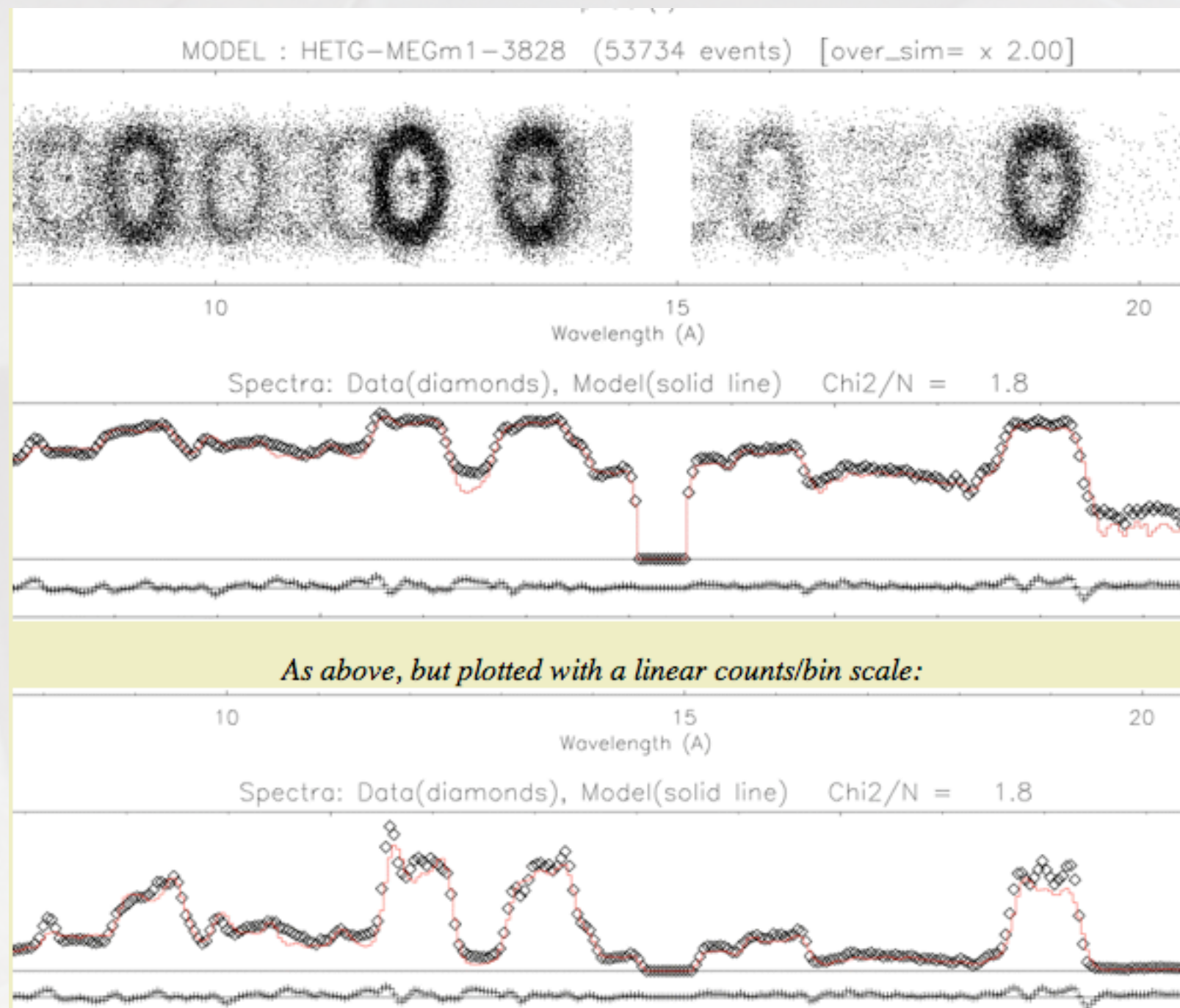


From Michael Smith's analysis



From Michael Smith's analysis

I E0102: HETGS v. RGS model



http://space.mit.edu/home/dd/Hydra/E0102_Cal/pollock_hetg.html

Summary

- Cross-calibrations agree to better than 5%
 - Exception: (H,L)ETGS fluxes in some bands v. XMM/PN
 - ACIS contaminant may now be an issue for $E < 0.5$ keV
- Remaining work
 - LETGS v. HETGS: analysis of 2006 internal cross-cal data
 - ACIS contaminant: reconcile ECS and LETG/ACIS
 - Not getting $\chi^2 = 1$ for high signal observations
 - Complete analysis of 2006 and 2007 LETGS-Suzaku data
 - Continue analysis of joint XMM-Chandra data
 - Fixes to MOS QE and RGS are “in the works”
 - Residual Chandra-XMM differences may remain
 - Few components of Chandra left to adjust
 - Complete analysis of 1E0102 data (HETGS, ACIS, XMM)