Chandra HRMA Effective Area

Terrance J. Gaetz
and
Richard J. Edgar, Diab Jerius, Brad Wargelin, Ping Zhao

Smithsonian Astrophysical Observatory

IACHEC 2010

Introduction

- The *Chandra* mirror A_{eff} is a semi-analytical model
- Detailed raytrace model with everything we know:
  - figure, geometry, misalignments
  - shape (deformations) and microroughness (scattering)
  - measured reflectivity properties (Ir optical constants)
  - as-measured as-built where possible
  - per-shell – add up four shells to get full HRMA
- Calibrate raytrace model with ground data

Introduction

- Ground calibrations measured A_{eff} with two detectors
  - FPC: flow proportional counter
    - line sources
    - various pinholes up to 35mm diameter
  - SSD: solid state detector,
    - line and continuum sources
    - mainly 2mm diameter pinhole
- Did not reproduce the detailed shape of raytrace A_{eff}.
  - discrepancies between detectors; not well understood
  - generated energy dependent polynomial correction factor for raytrace, shell-by-shell (full HRMA: add up shells) applied to on-orbit models only
- Further Developments (on-orbit)
  - Ir edge discrepancies: added ∼20Å hydrocarbon contamination layer on-orbit model only (version N0007)

Introduction

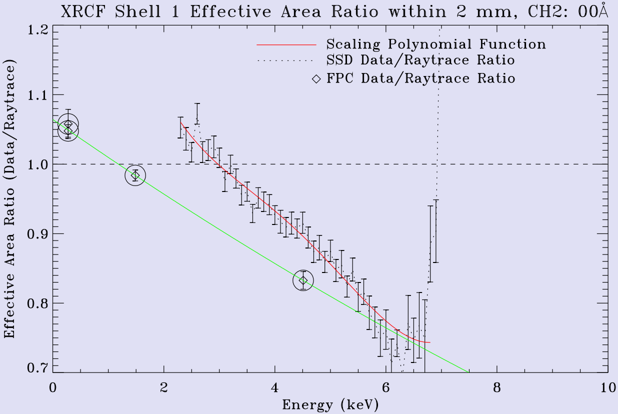
Generation of A_{eff} version N0008

- Fits for high-T clusters: *Chandra* and *XMM-Newton* discrepant
- Internal *Chandra* fit discrepancies for the same clusters
- This prompted reexamination of on-axis A_{eff}:
    - contamination already existed on the ground
        - HETG evidence, C, Cu continuum measurements; H. Marshall
    - stability ground to orbit within $\sim$ 10Å
        - FCM measurements, Elsner et al., SPIE 4138, 2000
    - stable once on-orbit
        - analysis of HZ 43 data (11/1999 - 01/2002), J. Drake memo
- Implication: optics had similar contamination on the ground
- Refit ground data, varying the contamination thickness

Vary contamination thickness - shell by shell

Example: (Data/Raytrace) for Shell 1 0 Å

N0007 Contamination level – none

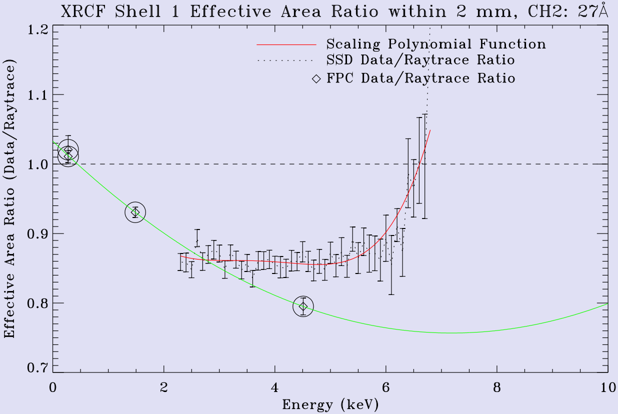


[turnup at high E: residual pileup effect]

Vary contamination thickness - shell by shell

Example: (Data/Raytrace) for Shell 1 27 Å

Pretty good, approximately the right level

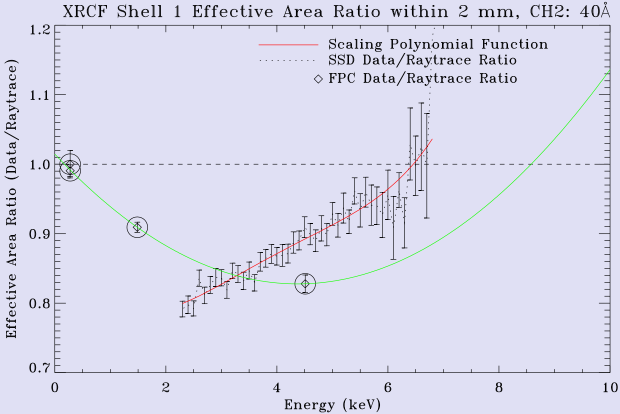


[turnup at high E: residual pileup effect]

Vary contamination thickness - shell by shell

Example: (Data/Raytrace) for Shell 1 40 Å

Woops – far too much contamination

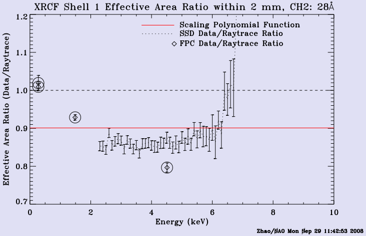


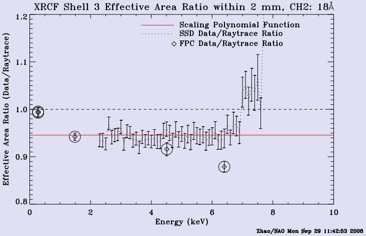
[turnup at high E: residual pileup effect]

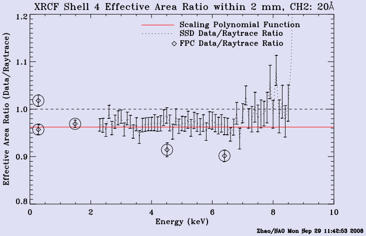
Contamination layer thicknesses: Final N0008 Results

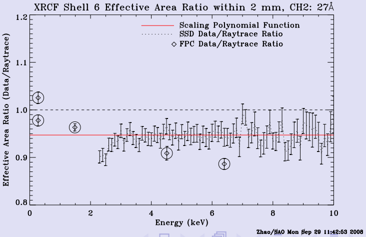
Shell 1: 28Å, Shell 3: 18Å, Shell 4: 20Å, Shell 6: 27Å; model F – red lines

- Model F: Average FPC, average SSD, average the averages
- Grey offsets unexplained; largest for shell 1







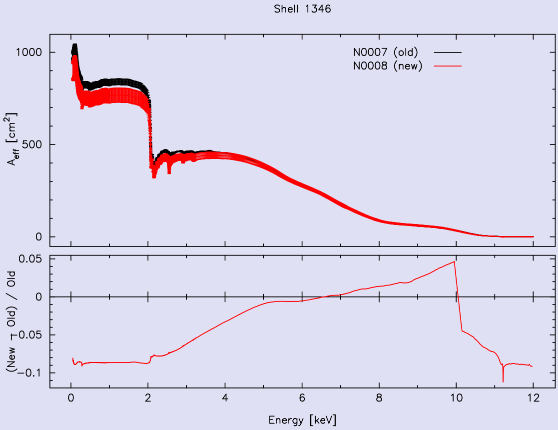


New HRMA axial effective area (N0008)

Released 2009-01-21 as part of CALDB 4.1.1

Model **f** $\Longrightarrow$ HRMA effective area N0008.

Comparison: N0007 vs N0008



New HRMA axial effective area (N0008)

Tests

Numerous tests, including:

galaxy clusters	(L. David)
AGNs	(V. Kashyap)
thermal SNR (E0102)	(J. DePasquale)
synchrotron-dominated SNR (G21.5-0.9)	(J. Posson-Brown)

Differences between N0008 and N0007:

- Derived spectral parameters (e.g., kT, Γ) typically differ less than $\sim$ 3%
- However...
  - kT can be up to $\sim$ 10% less for hot galaxy clusters
  - soft sources (0.5-2 keV band): derived fluxes can be up to $\sim$ 8% higher

Since Then

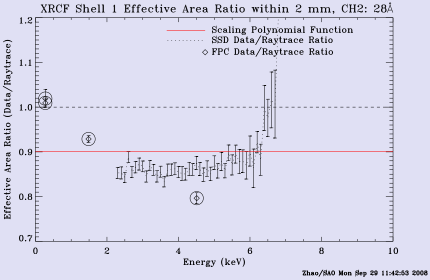
SINCE the release of the latest *Chandra* A_{eff} last year, the CXC Optics group has been working on further refinements to the HRMA A_{eff}.

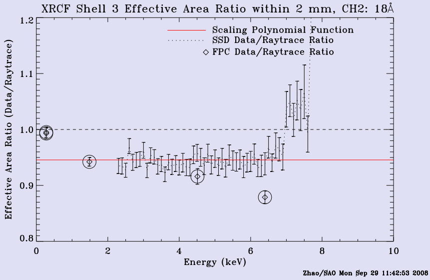
We have concentrated on the following areas:

- Re-analysis of the XRCF Emission Line measurements (see R. Edgar talk, this session)
- Improved corrections for Pileup in the SSD Detectors (D. Jerius, B. Wargelin)
- Determining an empirical correction for scattering deficiencies in our model. (T. Gaetz)

Improved corrections for Pileup in the SSD Detectors

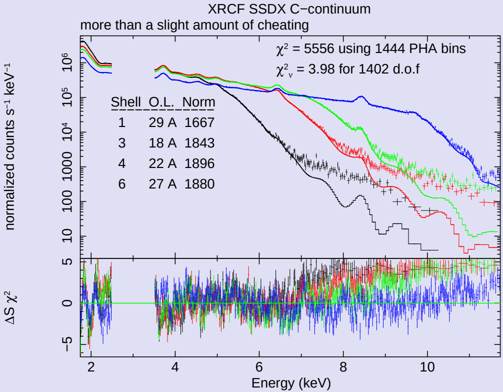
For some time we have had suspicions that our original analysis of XRCF continuum measurements made with the SSD detectors suffered from incomplete correction for detector pileup.





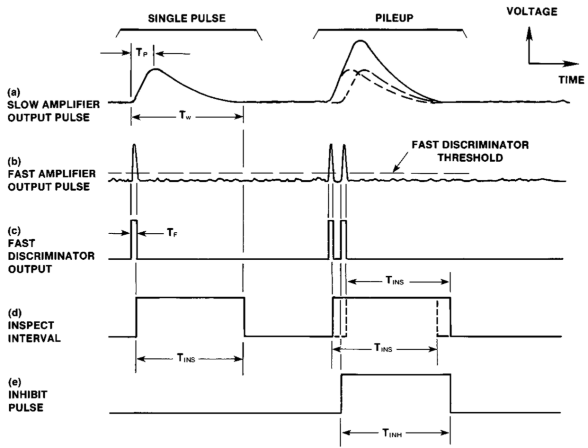
Improved corrections for Pileup in the SSD Detectors

For some time we have had suspicions that our original analysis of XRCF continuum measurements made with the SSD detectors suffered from incomplete correction for detector pileup.



Improved corrections for Pileup in the SSD Detectors

Pileup and Deadtime in SSD spectra:



Improved Pileup correction for the SSD Continuum data

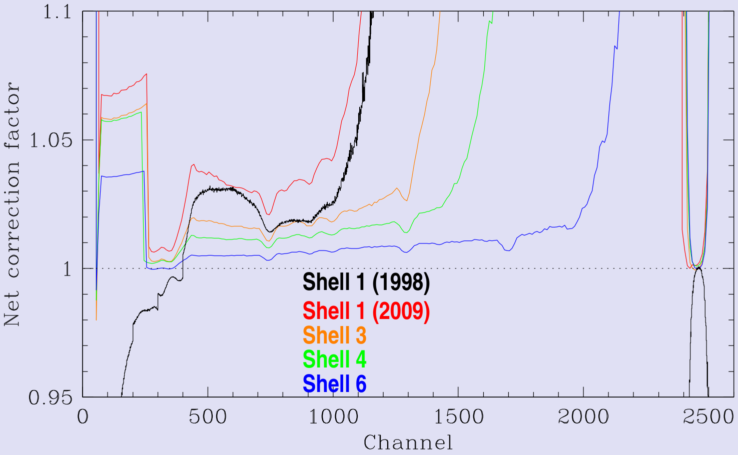
We modeled the effect of pileup using two orthogonal approaches:

	Monte Carlo	Probabilistic
What:	An event based model of the detector pileup rejection electronics was created. Multiple realizations of the input spectrum were run through the model and the output spectra were combined.	The probability of no-, two-, and three-event interactions was calculated for each possible temporal superposition of input events and energy permutations for the input. An output spectrum was generated based upon the summed probabilities.
Pro:	All possible interactions are automatically sampled Can model full detector resolution.	Exact calculations of the probabilities.
Con:	Inexact. Requires multiple realizations to build up statistics.	Calculations of higher order interactions or full detector resolution prohibitively expensive.

The Monte Carlo approach validates the Probabilistic approach.

Improved corrections for Pileup in the SSD Detectors

Representative Pileup Correction Factors

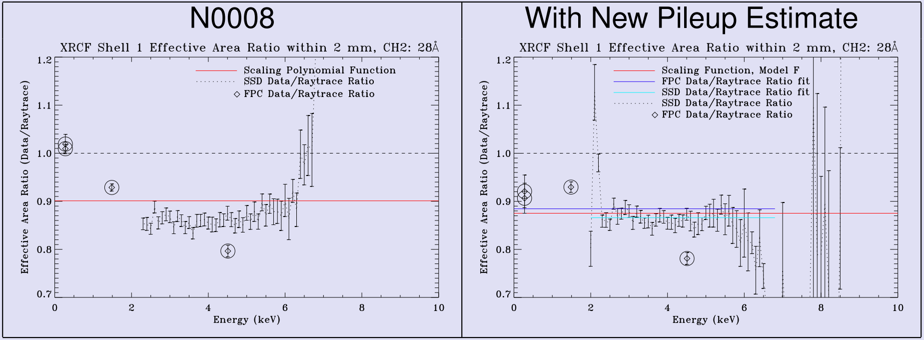


Ignore channels below 300 (1.5keV) – not used in our analysis.

Revised A_{eff}, Shell 1 (preliminary)

Compare to improved XRCF line and continuum measurements.

Please Note! *In progress work – not an official A_{eff}.*

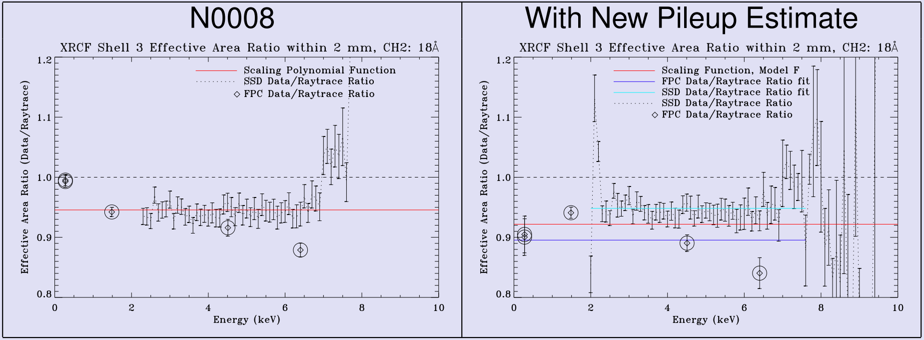


Note: only applied revised pileup; *no* refit yet for contaminant

Revised A_{eff}, Shell 3 (preliminary)

Compare to improved XRCF line and continuum measurements.

Please Note! *In progress work – not an official A_{eff}.*

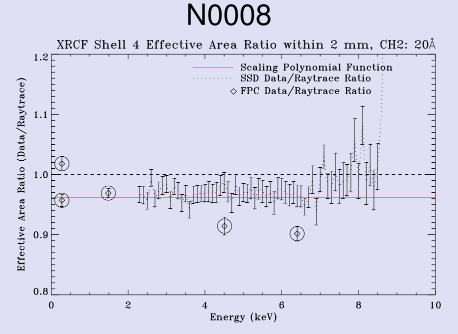


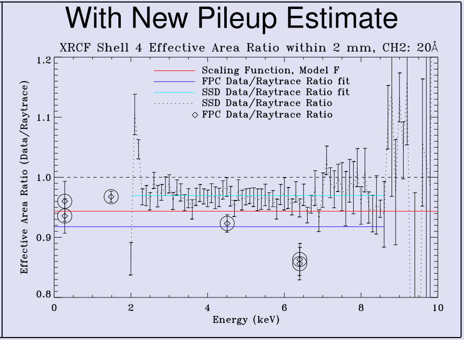
Note: only applied revised pileup; *no* refit yet for contaminant

Revised A_{eff}, Shell 4 (preliminary)

Compare to improved XRCF line and continuum measurements.

Please Note! *In progress work – not an official* A_{eff}.



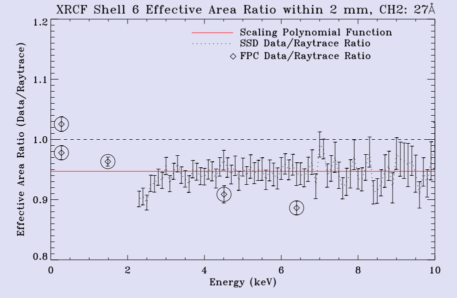


Note: only applied revised pileup; *no* refit yet for contaminant

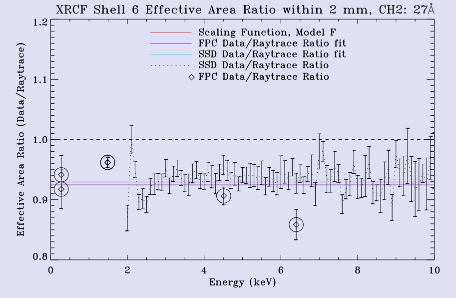
Compare to improved XRCF line and continuum measurements.

Please Note! *In progress work – not an official A_{eff}.*

N0008



New Pileup Estimate



Note: only applied revised pileup; *no* refit yet for contaminant

Additional Corrections (not yet applied)

- The raytrace model underpredicts the amount of light scattered in the PSF wings, affecting the A_{eff} measurement.
  - compare the difference in FPC flux between the 2mm pinholes (as used by SSD) and the larger 35mm FPC pinhole; compare to raytrace predictions
  - energy-dependent few% effect; should trade off against contaminant thickness
- The quadrant shutters used to isolate individual mirror shells could produce some vignetting (strut shadows).
  - compare full HRMA and individual shell out-of-focus (“ring focus”) images to measure widths strut shadows
  - small effect ($\lesssim$1%, mostly grey)

Summary

- Searched for systematic effects which would modify A_{eff}:
  - No big surprises found!
- A number of corrections identified
  - improved line A_{eff} values (Edgar)
  - improved pileup correction (Wargelin & Jerius)
  - empirical scattering correction (Gaetz)
  - quadrant shutter correction: small, mostly grey (Gaetz)

  - check and verify corrections
  - one more iteration fitting raytrace to data
  - revise A_{eff} (even if the change is small, we want to provide the best estimate available)