Updates to the *Chandra* HRMA Calibration

T. Gaetz

Smithsonian Astrophysical Observatory

4^{th} IACHEC meeting

Introduction

The *Chandra* mirror A_{eff} is a semi-analytic model:

- detailed raytrace model
  - figure, figure errors
  - geometry, misalignments
  - obscurations (apertures)
  - reflectivity (Ir-Cr-Zerodur); scattering from microroughness
- Ground Calibraton: Sparse datasets (energies, off-axis angles, pinhole sizes) did not constrain A_{eff}; used to verify raytrace models.
- Ground calibrations measured A_{eff} with two detectors
  - FPC: flow proportional counter; various pinholes up to 35mm diameter.
  - SSD: solid state detector, 2mm diameter pinhole
  - line and continuum sources

Introduction (cont.)

Ground calibration models did not reproduce the detailed shape of the measured A_{eff}.

- The discrepancies were not well understood.
- The discrepancies were encoded into an energy dependent correction factor which was applied in the on-orbit models

A_{eff} Discrepency at the Ir edge

- On-orbit HETG data showed a discrepancy at the Ir edge
- This was consistent with a 22Å hydrocarbon contamination layer
- Contamination added only to on-orbit models
- Fits for high-T clusters: *Chandra* and *XMM-Newton* discrepant
- *Chandra* fits showed internal discrepencies for the same clusters

More History

Initial analysis:

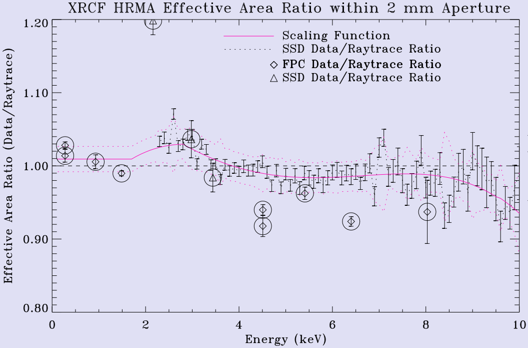
- "XRCF Correction" doesn't account for Ir edges; adding a $\sim$ 20Å contamination layer made the Ir edge look better,
- "XRCF Correction" qualitatively has same effect as contamination. Did "correction" partially account for contamination already existing on ground?

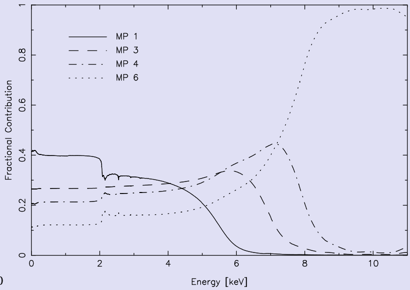
But... now contamination layer effect is doubled away from the edges.

- Removing the "XRCF Correction" while retaining an $\sim$ 20Å contamination layer *seemed* to address the inconsistencies within the *Chandra* fits.
- Does *not* completely resolve differences between observatories.

XRCF Model Underlying the Previous CALDB Version

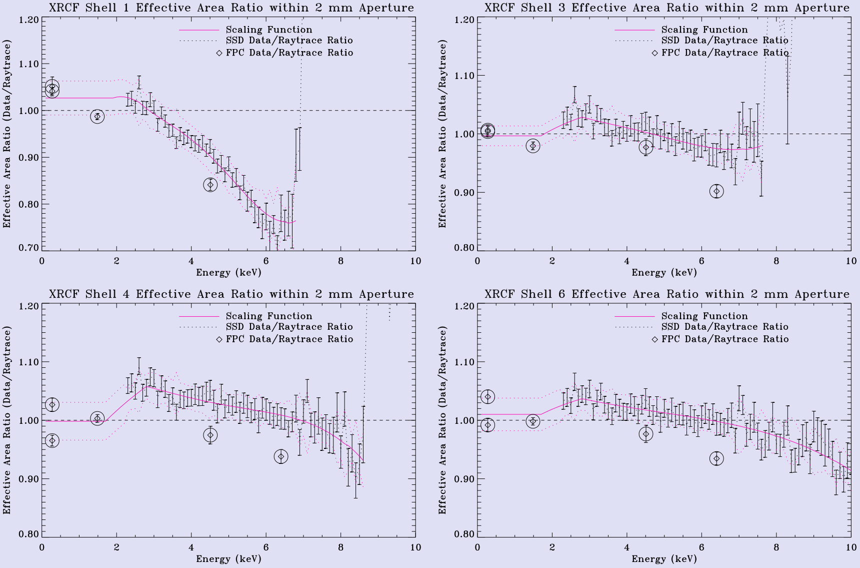
Full HRMA (synthetic model - add up the shells





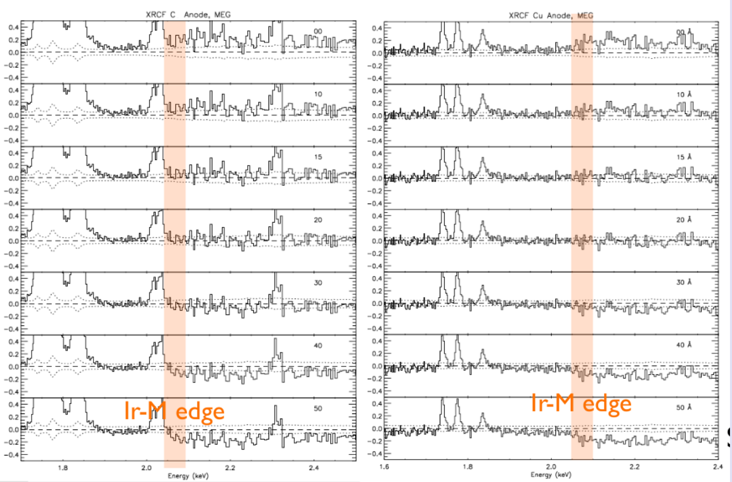
XRCF Model Underlying the Previous CALDB Version

Individual shells



Evidence for Contamination on the ground - HETG

HETG continuum measurements; C Anode, Cu Anode (MEG) (H. Marshall talk)



Consistent with ∼ 20Å overlayer (shells 1 and 3).

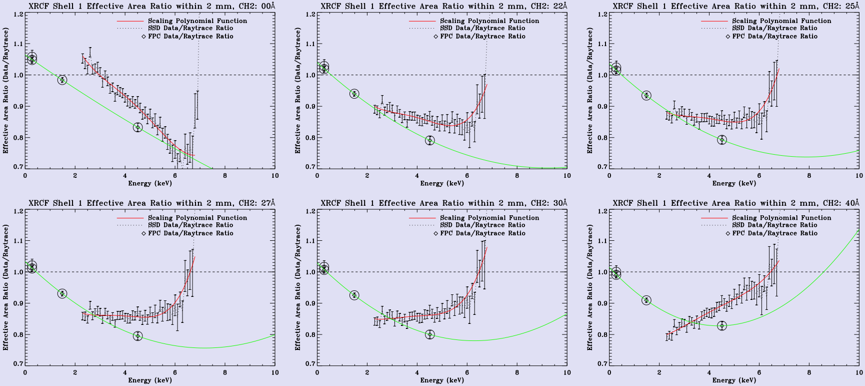
Stability, ground to orbit

- Flux Contamination Monitor (contamination cover at front of HRMA). ACIS+FCM measurements:
  - just before leaving XRCF
  - before opening contamination cover on-orbit
  - change in effective thickness of hydrocarbon layer $\leq$ 10Å (Elsner et al., SPIE 4138, 2000)
- analysis of HZ 43 data (Nov 1999 – Jan 2002); upper limit on C contamination thickness is 50Å (normal incidence) $\Rightarrow\sim$ 1Å (grazing incidence); no significant change since shortly after launch. (J. Drake memo).

Hypothesis: can the data be explained by a contamination layer present during ground calibration and persisting on-orbit?

Vary contamination thickness - shell by shell

Example: (Data/Raytrace) for Shell 1

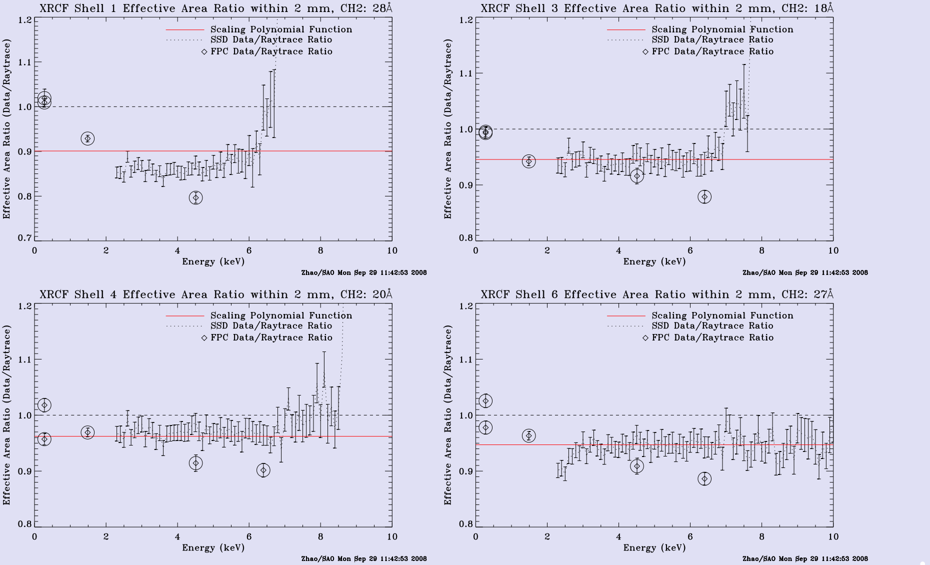


Final Thicknesses

Shell	1	3	4	6
Thickness	28Å	18Å	20Å	27Å

Final contamination layer thicknesses

Shell 1: 28Å, Shell 3: 18Å, Shell 4: 20Å, Shell 6: 27Å



Combining SSD and FPC data

A new correction factor

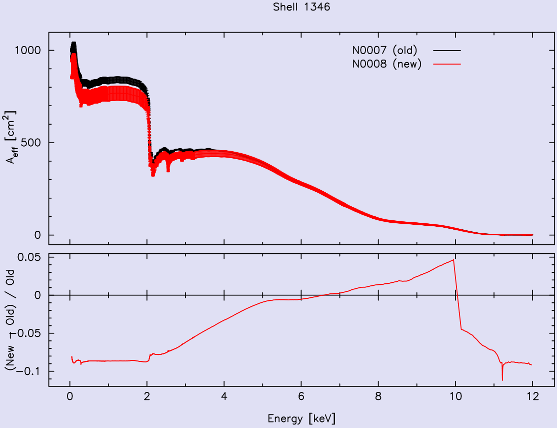
- Considered 10 algorithms for combining the data:
  - none truly horrible
  - a few worse than the rest
  - most pretty comparable
- many tests and long debate.
  Picked algorithm **f**. For each *shell*:
  - average the FPC data
  - average the SSD data
  - average the averages
- these grey correction factors were applied shell by shell to the on-orbit raytrace model.
- grey corrections similar for shells 2, 3, 4; larger for shell 1
- HRMA model $= \sum$ single shell models
  $\Rightarrow$ overall HRMA correction is not grey

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:

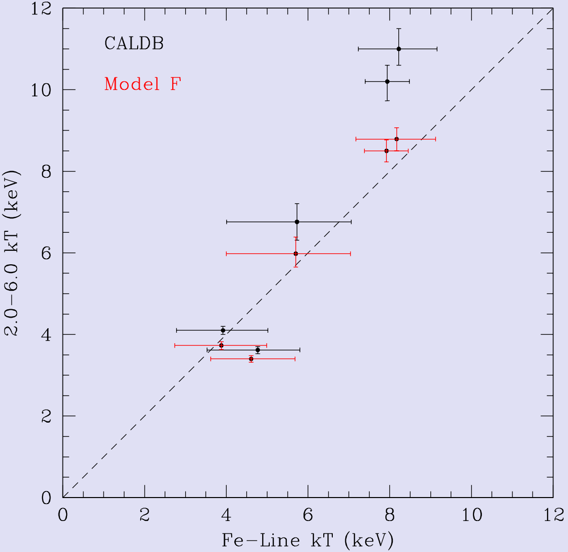
- galaxy clusters
- AGNs
- thermal SNR (E0102)
- synchrotron-dominated SNR (G21.5-0.9)
- soft thermal sources

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.

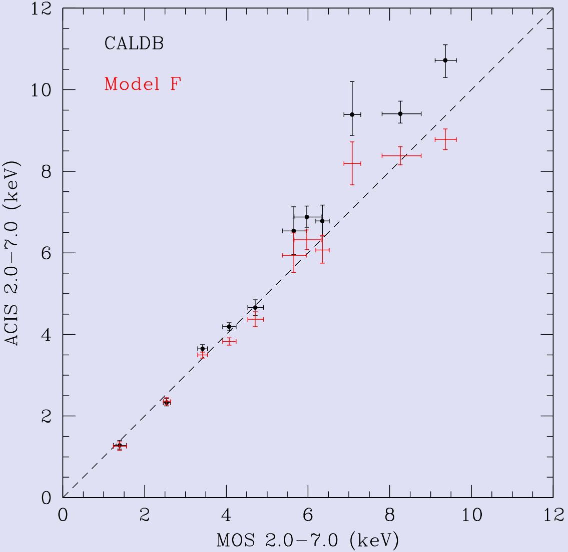
New HRMA axial effective area (N0008)

Galaxy Clusters



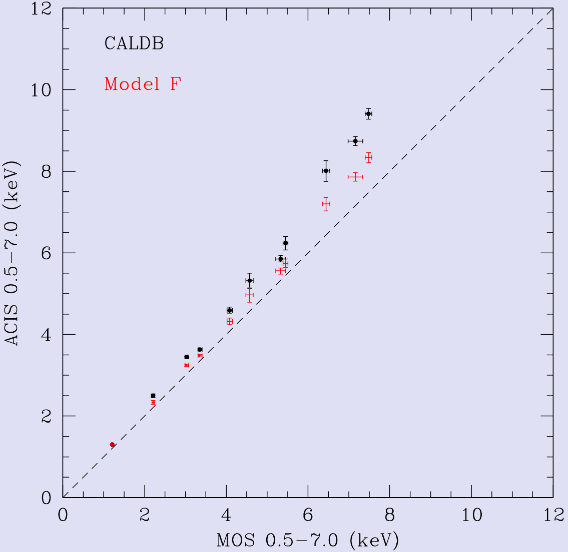
New HRMA axial effective area (N0008)

Galaxy Clusters



New HRMA axial effective area (N0008)

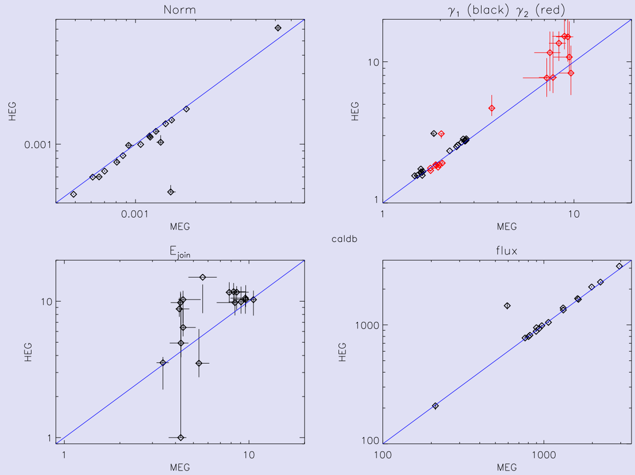
Galaxy Clusters



New HRMA axial effective area (N0008)

AGN spectra; Powerlaw sources (fit 0.7-7.5 keV) N0007

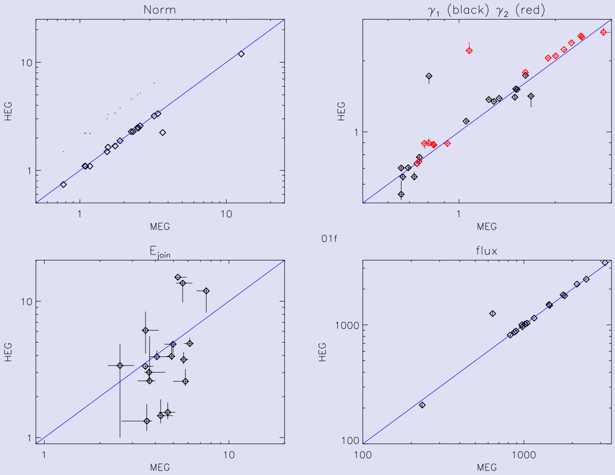
(2nd order MEG/HEG correction not applied)



New HRMA axial effective area (N0008)

AGN spectra; Powerlaw sources (fit 0.7-7.5 keV) N0008

(2nd order MEG/HEG correction not applied)



In-progress/Future work

Reanalysis of the ground data

- SSD - much improved treatment of pileup/deadtime corrections based on detailed modeling of the detector
  - analytic approach (B. Wargelin)
  - Monte-Carlo simulation of the detector pileup algorithms (D. Jerius)
- examine database to see if any useful measurements were missed; reanalysis of the data
- analysis of the single short full-HRMA SSD spectrum (phase C)
- reanalysis of the FPC data
- apply all known corrections, including a couple not in N0008
  - scattering correction; 2mm/35mm ratios, raytrace vs FPC, $\Rightarrow$ raytrace model puts too much of the flux
  - slight vignetting by the bottom shutter struts (shells 1, 3, 4; $< 0.5\%$ effect)

Summary

- New HRMA effective area (N0008) released
- Many tests, derived spectral parameters comparable ($\sim$ 3%) except for hot galaxy clusters (kT $\lesssim$10% lower) and derived fluxes for soft source ($\sim$ 8% higher).
- Systematic reanalysis of SSD and FPC data to see if the detector inconsistencies can be removed (or explained)