Composition of the Chandra ACIS Contaminant

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Early Findings

- Observations of AGN with ACIS/LETG led to discovery of contaminant C-K edge
- Early repair was a one-time fix, good for observations in early 2000

![Graphs showing fractional residuals over energy range](image-url)
C-K Edge is Unlike the Edge in the ACIS Filter

- Count spectrum from XTE J1118+480
- Filter dominates below 0.2867 keV, contaminant above
Modeling the C-K edge: EXAFS

- Data taken from June 2002 observation of PKS 2155-304
- Fit to power law without the 0.28-1.0 keV region
- Henke constants used above 0.4 keV
- Slight feature in 0.285-0.287 keV region added
- No N-K to <5%
Modeling the C-K edge: EXAFS

- Opacity due to C-K edge in contaminant is adjusted near the edge.
- Adjustment has “ripple” and exponential drop away from edge.
- Edge is at 0.2867 keV.
Modeling the O-K and F-K edges (Mk 421)

- TOO on Mk 421 gave a very good spectrum: over 4e6 counts
- Accounting for new C-K edge, O-K and F-K detected
  - F-K is not ID’ed with Fe-L in source frame
- O-K edge model derived from O in polyimide
- F-K edge constructed as in C-K, with NEXAFS & EXAFS
Checking the Model Fit

- Good fits obtained in F-K and O-K edge regions
- Features that remain are
  - intrinsic (ISM), or
  - due to uncorrected BI/FI relative errors
Abundances in the ACIS Contaminant

- Column densities, in atoms per sq. cm are
  - Carbon: $2 \times 10^{18}$
  - Nitrogen: $< 7 \times 10^{16}$
  - Oxygen: $1.75 \times 10^{17}$
  - Fluorine: $1.45 \times 10^{17}$

- Relative to Carbon:
  - $N/C < 30$
  - $O/C = 11.5 \pm 1$
  - $F/C = 14 \pm 1$

- Fluorinated compounds in Chandra (Braycote, Krytox) do not have so little F or O relative to C
  - Fluorocarbons must comprise only a small part of contaminant
  - Fluorocarbons can “crack” due to radiation into smaller compounds that may be hydrocarbons
• Lack of 0.285 keV absorption spike due to C=C double bonds indicates that contaminant is not aromatic (benzene rings)
• Contaminant does not have absorption like Teflon associated with C-F bonds
• Aliphatic hydrocarbons (like amine epoxy) with simple C-H bonds gives the best match
  • → Contaminant is mostly comprised of aliphatic hydrocarbons
Contamination Buildup

- C-K edge depth is easily measured in each LETG/ACIS data set
- Model is asymptotically linear, forced to go through zero at ACIS opening
- Model fits C-K edge data well but O-K edges are smaller than expected
Comparison to the External Cal Source

- The ACIS External Calibration Source (ECS) illuminates ACIS with Mn L & K lines for gain monitoring.

- Ratio of ECS Mn L to K varies and provides an optical depth.

- Optical depth in 2001-2003 is 20% higher than predicted from C-K (10-15% less throughput at 0.7 keV).

- No good explanation for difference yet ...

Extra absorbers like Si have undetected K or L edges

ECS may be too warm to have its own contamination

H opacity? H/C ~ 1000 required for odd material
Conclusions & Future Work

See: http://space.mit.edu/ASC/calib/letg_contamination.html

- Chandra ACIS contaminant consists mostly of carbon with some oxygen and fluorine
- Ratios do not match fluorinated compounds on Chandra
- C-K edge does not match fluorinated compounds
- We suggest that Braycote (or Krytox) cracks upon radiation damage and that mobile components are aliphatic hydrocarbons
- We are investigating spatial variations
- New X-ray transmissions of radiation-damaged Braycote are under analysis