Chandra ACIS Background Modeling

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Steps Toward ACIS Background Model Templates

The aim:
- templates for ACIS (TE-mode) detector background modeling

Detector background:
- particle-induced:
  - continuum (particle charge clouds)
  - fluorescent lines (structure in detector FOV)
  - framestore fluorescent lines (framestore cover: Al + Au)
- Four basic combinations:
  - FI vs. BI chip
  - VFAINT vs. FAINT mode
Background Features (ACIS “stowed”)

- particle-induced background (continuum)
- fluorescent lines (+ framestore lines)
Background Features (ACIS “stowed”)

- particle-induced background (continuum)
- fluorescent lines (+ framestore lines)

![Graph showing energy vs. rate for different periods and filters](image-url)
Background Spatial/Spectral Variation (ACIS “stowed”)

FI Chips – I0, I2, I3 (no VF cleaning)

ACIS–023

Energy [eV]

CHIPY [pix]

T. Gaetz (CXC/SAO)
Background Spatial/Spectral Variation (ACIS “stowed”)  
FI Chips – I0, I2, I3 (with VF cleaning)

ACIS–023

Energy [eV]

CHIPY [pix]

0.5 1

5000 10^4
Background Spatial/Spectral Variation (ACIS “stowed”)  
BI Chip – S3 (with VF cleaning)
Background Features (ACIS “stowed”)

Not processed by X-ray optics
  • particle-induced background (continuum)
    • not real X-rays
    • regular RMF? diagonal RMF?
      no ARF
  • fluorescent lines (detector FOV)
    • should be with RMF, detector-only ARF (QE, OBF)
  • fluorescent lines (framestore)
    • bypass OBF
    • with RMF, should be detector-only ARF (QE), no OBF
      • Currently: no way to “turn off” OBF in ARF
Background Features (ACIS “stowed”)

See also:
  “Chandra ACIS-I particle background: an analytical model”
- ACIS-I only, VFAINT filtered only

My approach:
- Aim for physics-based lines where possible.
- Extend to FAINT mode data
- Extend to S3 FAINT mode and VFAINT filtered data
### Physically Expected Line Complexes

<table>
<thead>
<tr>
<th>Element</th>
<th>Line</th>
<th>Wavelength (Å)</th>
<th>Additional Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>Al K$_\alpha$</td>
<td>1.48656</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Al</td>
<td>Al K$_\beta$</td>
<td>1.55745</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Si</td>
<td>Si K$_\alpha$</td>
<td>1.73978</td>
<td></td>
</tr>
<tr>
<td>Al</td>
<td>Au M$_\alpha_2$</td>
<td>2.118</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Al</td>
<td>Au M$_\alpha_1$</td>
<td>2.1229</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Al</td>
<td>Au M$_\beta$</td>
<td>2.205</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Al</td>
<td>Au M$_\gamma$</td>
<td>2.410</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Ni</td>
<td>Ni K$_\alpha_1$</td>
<td>7.4609</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>Ni K$_\alpha_2$</td>
<td>7.4782</td>
<td></td>
</tr>
<tr>
<td>Ni</td>
<td>Ni K$<em>\beta</em>{1,3}$</td>
<td>8.2647</td>
<td></td>
</tr>
<tr>
<td>Au</td>
<td>Au L$_1$</td>
<td>8.4939</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Au</td>
<td>Au L$_\alpha_1$</td>
<td>9.7133</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Au</td>
<td>Au L$_\alpha_2$</td>
<td>9.6280</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Au</td>
<td>Au L$_\beta_2$</td>
<td>11.5847</td>
<td>+ framestore line</td>
</tr>
<tr>
<td>Au</td>
<td>Au L$_\beta_2$</td>
<td>11.4423</td>
<td>+ framestore line</td>
</tr>
</tbody>
</table>
Group Physically Expected Lines

- Group the Au M lines; tie norms and widths to Au M$_{\alpha_2}$
- Group Au L$_{\alpha_1}$ and Au L$_{\alpha_1}$; tie norm and width to Au L$_{\alpha_1}$
- Au lines have direct and frame store components
  - CTI correction overcorrects
    (assumes event is actually in imaging array)
  - Frame store component depends on chipy (roughly linear)
- “framestore” version: group as above
  - grouping lines makes modeling framestore component easier
  - allow the Au M$_{\alpha_2}$ and Au L$_{\alpha_1}$ energy to vary
  - allow line width of Au M$_{\alpha_2}$ and Au L$_{\alpha_1}$ to vary
    compensates for variation with chipy
- In principle, Au L$_{\beta_2}$ and Au L$_{\beta_1}$; however, RMF energies don’t extend high enough to their framestore lines.
- Also group Al K$_{\alpha}$, Al K$_{\beta}$; framestore lines
Spectral extractions:
- spectra extracted in four broad regions:
  - chipx: 1:1024
  - chipy: 1:256, 247:512, 513:768, 769:1024
- merge I0+I2+I3 data
- periods D+E+F ACIS-stowed data; \( \sim 1 \text{Ms} \)
- For now, RMF only, no ARF
Beginnings of a model
Spectral modelling

Particle continuum:
- shallow powerlaw (index $\sim 0.08$)
- low-energy peak: $\exp$ model

Fluorescent lines:
- groups of FOV lines: gaussian lines
- groups of framestore lines:
  - single line of a group can vary
  - energies of the rest scaled as for the FOV line group
  - line widths tied to reference line width
  - width allowed to vary (large range of $\text{chipy}$)
Background Spatial/Spectral Variation (ACIS “stowed”)

VF cleaned

Period D,E,F: ACIS–023: ∆chipy 1–256
Background Spatial/Spectral Variation (ACIS “stowed”)
VF cleaned

Period D,E,F: ACIS–023: ∆chipy 257_512

Counts sec$^{-1}$ keV$^{-1}$

$
\begin{array}{c}
\text{Energy (keV)} \\
\hline
0.01 \\
5 \times 10^{-3} \\
0.02 \\
\end{array}
$

$\Delta C$

Energy (keV)
Background Spatial/Spectral Variation (ACIS “stowed”)

Period D,E,F: ACIS–023: Δchipy 513_768

Counts sec⁻¹ keV⁻¹

Energy (keV)
Background Spatial/Spectral Variation (ACIS “stowed”)
VF cleaned

Period D,E,F: ACIS-023: Δchipy 769_1024

Counts sec\(^{-1}\) keV\(^{-1}\)

Energy (keV)

Counts sec\(^{-1}\) keV\(^{-1}\)

ΔC

Energy (keV)
Summary
Background Spectral modelling

ACIS-stowed FI data, VF filtered
  - progress in modeling with physical line energies

More to do:
  - FI chips
    - no VF filtering case
    - $\Delta \text{chipy} = 256$, background vs. node
    - $\Delta \text{chipy} = 128$
    - as above, individual chips
  - ACIS-S3
    - VF filtered, and non-VF filtered