Developing contributed software to correct for the temperature dependence of ACIS CTI

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Summary

• Part I: Motivation and CTI model
  – Temperature-dependent performance
  – Focal plane temperature excursions
  – Adjusting the correction model
  – Performance of the adjusted algorithm

• Part II: Developing the contributed software
ACIS CTI correction

- Incorporated into Chandra data processing pipeline and CIAO tool acis_process_events
- Reconstruction of original X-ray event
- Removes position dependence of pulseheight
- Significantly improves spectral resolution and detector uniformity
CTI is temperature dependent

- Charge traps have temperature-dependent re-emission time constants
- Time constants that shift below pixel-to-pixel transfer time (40 µs) or above CCD frame time are benign
- Distribution of trap species determines overall CTI-temperature profile
CTI dependence on temperature

- Roughly linear for small temperature deviations
- Causes temperature dependent performance
- More important for FI than BI CCDs
• ACIS cooling is less efficient in some Chandra orientations
  – Other spacecraft constraints not always favorable for ACIS
• In 2000, 99% of observations $<-119.2^\circ C$; in 2007, 68%
• For more on temperature history, see Poster by C. Grant
Implications for calibration: gain

Temperature-dependent pulseheight change (% / deg)

<table>
<thead>
<tr>
<th></th>
<th>1.5 keV</th>
<th>6 keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>I3 (FI)</td>
<td>-0.7%</td>
<td>-0.4%</td>
</tr>
<tr>
<td>S3 (BI)</td>
<td>+0.2%</td>
<td>+0.1%</td>
</tr>
</tbody>
</table>

- Top 64 rows of CCD (worst case)
- Smaller effect at lower rows
- Calibration accuracy goal is 0.3%
Implications for calibration: line width

Temperature-dependent line width change (eV / deg)

<table>
<thead>
<tr>
<th></th>
<th>1.5 keV</th>
<th>6 keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>I3 (FI)</td>
<td>4 eV</td>
<td>11 eV</td>
</tr>
<tr>
<td>S3 (BI)</td>
<td>&lt; 1 eV</td>
<td>&lt; 1 eV</td>
</tr>
</tbody>
</table>

- Top 64 rows of CCD (worst case)
- Smaller effect at lower rows
- Negligible for ACIS-S3

Catherine Grant (MIT)  Sep 21, 2009
Implication for calibration: summary

- Significant gain change for some CCDs/locations
- Line width change is less important
- Warmer temperatures are uncontrolled
  - Variation within a single observation as high as 3-4°C
- Scientific impact varies:
  - High: line-rich spectrum, ACIS-I, high S/N
  - Low: continuum spectrum, ACIS-S3, low S/N
Charge loss model

- Separates energy and position dependence
- Energy dependence is related to the volume of the charge cloud, should not be strongly temperature dependent
- Spatial dependence and magnitude of charge loss stored as “trapmaps”
- Trapmap $\propto$ CTI
  - Use linear fit to CTI-temperature dependence to adjust trapmap
Performance of adjusted corrector

• Reduces temperature dependence of pulseheight
• >99% of observations now within 0.3% pulseheight calibration goal

Temperature-dependent pulseheight change (% / deg)

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<thead>
<tr>
<th></th>
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<th>6 keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>−0.7%</td>
<td>−0.4%</td>
</tr>
<tr>
<td>T-dependent</td>
<td>+0.03%</td>
<td>−0.07%</td>
</tr>
</tbody>
</table>