Correcting for the temperature dependence of ACIS CTI

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Summary

- ACIS CTI and the correction algorithm
- Temperature-dependent performance
- Focal plane temperature excursions
- Adjusting the correction model
- Performance of the adjusted algorithm
Charge transfer inefficiency: a reminder

- CTI, fractional charge loss per pixel transfer
- Linear fit to pulseheight vs row; CTI = (slope/intercept)
ACIS CTI correction

- Incorporated into Chandra data processing pipeline and CIAO tool `acis_process_events`
- Post-facto 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 drop 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

- \( \frac{d\text{CTI}}{dT} \sim +2\% / \text{deg (FI)}, \ -1\% / \text{deg (BI)} \)
- Roughly linear for small temperature deviations
- Causes temperature dependent performance
- More important for FI than BI
Focal plane temperature excursions

- ACIS cooling is less efficient in some Chandra orientations
  - Other spacecraft constraints not always favorable for ACIS
- Some aging of radiator surfaces, less efficient
- In 2000, 99% of observations < -119°C; in 2006, 86%
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>
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</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
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 CTI-temperature dependence to adjust trapmap
• Tested two versions
  – Average observation temperature
  – Dynamic frame-by-frame temperature
Performance of adjusted corrector

- Reduces temperature dependence of pulseheight
- >99% of observations now within 0.3% pulseheight calibration goal
- Using mean temperature seems adequate

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Standard</td>
<td>−0.7%</td>
<td>−0.4%</td>
</tr>
<tr>
<td>Average T</td>
<td>−0.04%</td>
<td>+0.1%</td>
</tr>
<tr>
<td>Dynamic T</td>
<td>−0.05%</td>
<td>+0.1%</td>
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</table>
Performance of adjusted corrector

Temperature-dependent FWHM change (eV / deg)

<table>
<thead>
<tr>
<th></th>
<th>1.5 keV</th>
<th>6 keV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>+3.8 eV</td>
<td>+11.2 eV</td>
</tr>
<tr>
<td>Average T</td>
<td>+3.2 eV</td>
<td>+11.4 eV</td>
</tr>
<tr>
<td>Dynamic T</td>
<td>+3.1 eV</td>
<td>+10.7 eV</td>
</tr>
</tbody>
</table>

- Very small reduction in temperature dependence of line width
- At 6 keV, dynamic temperature is better than average
Status of adjusted corrector

- New algorithm removes pulseheight dependence
  - Need to verify at energies < 1.5 keV
- New algorithm provides minimal improvement to line width
  - Magnitude of width change may be acceptable as is
- Not likely to be implemented in a_p_e soon
- Further work needed
  - Why is the FWHM improvement so small?
  - Do we need to follow the temperature variation? Is the mean good enough?
  - Can this be implemented as a gain tweak like t_gain?
ACIS temperature and you

• How to find the mean temperature of your observations?
  – Header of event list file *_evt2.fits
  – Keyword: FP_TEMP, in Kelvin

• How to view the temperature profile during your observations?
  – Mission timeline file *_mtl1.fits in secondary directory
  – Plot TIME vs FP_TEMP in your favorite plotting program

• Nominal calibrated temperature is –119.7°C