Spectral and spatial deformations on piled-up sources

“a one case study, of MOS data”
Motivations:

- A number of sources are with high flux, generating pile-up
- Standard spectral and spatial analysis is no more valid,
- Large corrections to get absolute flux, spectral shape, spatial distribution...

Plan for this study:

- Step 1: measure pile-up effects on spectra and spatial distribution … done
- Step 2: check against theoretical predictions… started
- Step 3: provide “standard analysis” route for piled-up sources... future
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The source

GRS 1758-258

MOS 1 & 2 in small window
PN in large window

Count rate ~ 20 c/s
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Central CCDs

MOS 1

21.87 ± 0.03 c/s (stable)
(~ 6.6 counts/frame)

MOS 2

21.65 ± 0.03 c/s (stable)
(~ 6.6 counts/frame)
• Spectra and counts studied in concentric rings with following characteristics, with counts being for pattern 0 events:

<table>
<thead>
<tr>
<th>R_in arcsec</th>
<th>R_out arcsec</th>
<th>Physical pixels</th>
<th>counts /frame</th>
<th>c/frame /pixel</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>3</td>
<td>23</td>
<td>0.73</td>
<td>3.12e-2</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>70</td>
<td>1.04</td>
<td>1.48e-2</td>
</tr>
<tr>
<td>6</td>
<td>12</td>
<td>280</td>
<td>1.42</td>
<td>5.07e-3</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>1122</td>
<td>1.03</td>
<td>9.15e-4</td>
</tr>
<tr>
<td>24</td>
<td>44</td>
<td>3531</td>
<td>0.64</td>
<td>1.80e-4</td>
</tr>
</tbody>
</table>

• Look for spectral differences in different rings

• All study performed with pattern 0 events only, since pattern 0 the less sensitive to pile-up, especially regarding spectral effects
Results will be compared to encircled energy data from file XRT1_XENCIREN_0000.CCF (merci Jean)

This file show a strong energy dependence in the encircled energy
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Background

Source 24–44 arcsec and background spectra

spec_m1_p0_r24–44 grp10.PHA spectrum_m1_annulus_p0–noflare_rsc24–44

normalized counts/sec/keV

1

0.1

0.01

10^{-3}

10^{-4}

channel energy (keV)

10

ferrando 7-May–2001 17:02
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Raw spectra comparison
Spectral and spatial deformations on piled-up sources

Simple fit inner core

nH = 2.69  index = 4.83

Normalized counts/sec/keV vs channel energy (keV)

Normalized counts/sec/keV vs channel energy (keV)
Spectral and spatial deformations on piled-up sources

Simple fit outer ring

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Spectral and spatial deformations on piled-up sources

Ratio spectrum inner core to reference

![Graph showing spectral and spatial deformations](image-url)
Spectral and spatial deformations on piled-up sources

Ratio spectrum 3-6 arcsec to reference

Ratio of spectrum spec_m1_p0_r3-6.PHA to spec_m1_p0_r24-44.PHA

Counts ratio vs. eV
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Ratio spectrum 6-12 arcsec to reference
• Flux loss and pile-up was modelled using Jean Ballet pile-up program, together with the 1-D PSF calculated from the encircled energy CCF file and the pattern distribution at 1.5 keV
• Incoming flux was adjusted so that modelled observed rate equals the actual value of ~ 6 / frame
Numerical results from model are:

- Incident flux of 8.0 cts/frame needed to get 6.2 cts/frame detected, i.e. that the average flux loss is ~ 22 % for all patterns

- Pile-up and flux loss dependence for mono-pixels can be large:

<table>
<thead>
<tr>
<th>Ring (arcsec)</th>
<th>piled-up fraction</th>
<th>flux-loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>central pixel</td>
<td>16.9 %</td>
<td>98.8 %</td>
</tr>
<tr>
<td>0.0 - 3.3</td>
<td>3.4 %</td>
<td>65.2 %</td>
</tr>
<tr>
<td>3.3 - 5.5</td>
<td>1.7 %</td>
<td>34.4 %</td>
</tr>
<tr>
<td>5.5 - 12.1</td>
<td>0.39 %</td>
<td>9.2 %</td>
</tr>
<tr>
<td>12.1 - 24.2</td>
<td>0.067 %</td>
<td>1.6 %</td>
</tr>
<tr>
<td>24.2 - 44.0</td>
<td>0.0074 %</td>
<td>0.2 %</td>
</tr>
</tbody>
</table>
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Flux loss correction and data

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Conclusions

- Spectral distortion strong even when pattern 0 selected

- The energy dependence of the encircled energy CCF function does not seem to fit these data - A flatter energy dependence in the wings would do better…

- The first rough attempt to use Jean’s model looks promising, at least for flux loss corrections.

- Pile-up is essentially a local effect, and a good 2-D PSF description is needed to go further in modelling.

- Work need to be redone on more sources...