X-IFU bright source studies with SIXTE

Philippe Peille
on behalf of the X-IFU E2E simulations team
CHARACTERIZING THE X-IFU PIXELS COUNT RATE CAPABILITY

- TESSIM allows the generation of representative data streams from the future X-IFU pixels

- The degradation of energy resolution as a function of count rate can be assessed by SIRENA
  - Generation of pulses separated by variable time intervals
  - Energy reconstruction using the optimal filtering technique (Szymkowiak et al., 1993)

\[
\min \left( \sum \frac{|D(f) - E \times T(f)|^2}{|N(f)|^2} \right) \Rightarrow E \propto \sum \frac{D(f) \times S^*(f)}{|N(f)|^2}
\]

![Diagram showing energy resolution and time intervals](image)
EVENT GRADING AND TES ARRAY OPTIMIZATION

- Different TES array configuration studied during a TES array optimization exercise
- Corresponding TES parameters provided by the GSFC team

- Event grades determined using the observed energy resolution degradation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>LPA (a)</th>
<th>LPA (b)</th>
<th>LPA (c)</th>
<th>SPA (b-c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valid event criterium</td>
<td>$T_1 \geq 2.6$ ms</td>
<td>$T_1 \geq 5.1$ ms</td>
<td>$T_1 \geq 9$ ms</td>
<td>$T_1 \geq 820 \mu$s</td>
</tr>
<tr>
<td>High res event criterium / $\Delta E$</td>
<td>$T_2 \geq 6.6$ ms / 2.5 eV</td>
<td>$T_2 \geq 105$ ms / 2.5 eV</td>
<td>$T_2 \geq 105$ ms / 2.5 eV</td>
<td>$T_2 \geq 3.3$ ms / 2.5 eV</td>
</tr>
<tr>
<td>Medium res event criterium / $\Delta E$</td>
<td>$T_2 \geq 1.6$ ms / 3.0 eV</td>
<td>$T_2 \geq 3.3$ ms / 3.0 eV</td>
<td>$T_2 \geq 6.6$ ms / 3.0 eV</td>
<td>$T_2 \geq 820 \mu$s / 3.0 eV</td>
</tr>
<tr>
<td>Low res event criterium / $\Delta E$</td>
<td>N/A / 15 eV</td>
<td>N/A / 30 eV</td>
<td>N/A / 90 eV</td>
<td>N/A / 15 eV</td>
</tr>
</tbody>
</table>
TRANSLATING TO OVERALL X-IFU COUNT RATE CAPABILITY

- Crab spectrum defined by an absorbed powerlaw
  \( \text{tbabs} \times \text{powerlaw} \)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( n_H )</th>
<th>( \Gamma )</th>
<th>norm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>0.4 (10^{22}) cm(^{-2})</td>
<td>2.1</td>
<td>9.5 ph/keV/cm(^2)/s</td>
</tr>
</tbody>
</table>

- 1 mCrab corresponds to \( \sim 92\) cts/s taking gaps into account

- ATHENA PSF used to translate into individual count rates

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PSF spread on the baseline X-IFU pixels
- The event grades scheme allows to estimate the X-IFU count rate capability for different configurations

Introducing an SPA improves the CR capability by an order of magnitude
X-IFU SPECTRAL STABILITY

- Verification of the End-to-End count rate capability of the X-IFU through SIXTE simulations
- Study of spinning black hole spectra with different intensities

Introducing an SPA improves the spectral stability by an order of magnitude
DEFOCUSING

- PSFs sent to the E2E team by Dick Willingale for different defocussing offsets
- Count rate capability study redone with defocused PSFs

On focus

10 mm

20 mm

Configuration (a)

Configuration (b)

Configuration (c)
NEXT STEP: CROSSTALK

- At high count rates, a significant fraction of events will be influenced by crosstalk events from neighbor pixels
  - Thermal crosstalk through TES array substrate
  - Electrical crosstalk through FDM multiplexing and non-linearity of the readout chain

- Crosstalk may be a limiting factor for bright source observations requiring the nominal energy resolution
  - WHIM absorption lines detection through gamma-ray afterglows

- First implementation in SIXTE using 1- and N-dimensional coupling matrices
  - Parametrization already implemented in SIXTE
NEXT STEP: CROSSTALK

- Crosstalk implementation in the advanced detector XML

```xml
<?xml version="1.0"?>
<pixdetector type="x-ifu" npix="324" xoff="0" yoff="0">
  <readout_freq value="156.25e3">
    <grading num="1" name="high" pre="128" post="512" rmf="athena_xifu_rmf_highres_v20150609.rmf"/>
    <grading num="2" name="mid" pre="128" post="128" rmf="athena_xifu_rmf_midres_v20150609.rmf"/>
    <grading num="3" name="low" pre="128" post="0" rmf="athena_xifu_rmf_lowres_v20150609.rmf"/>
  </readout_freq>
  <threshold_event_lo_keV value="5.e-2"/>
  <channel_freq_list filename="roland_chan.dat"/>
  <crosstalk>
    <thermalcrosstalk distance="4.01e-6" weight="1e-3"/>
    <thermalcrosstalk distance="5.66e-6" weight="4e-4"/>
    <electricalcrosstalk R0="1.1e-3" Lfprim="120e-9" Lcommon="2.5e-9" Lfsec="2e-6"/>
    <timedependence filename="SPA_timedep_crossweights_6keV.dat" pixelttype="SPA"/>
    <intermodulation filename="nlxtlk-lut-v5.fits"/>
  </crosstalk>
</pixdetector>
```
# Next step: Crosstalk

- Read-out channels on a small pixel array

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</tr>
</tbody>
</table>

**Philippe Peille**
**NEXT STEP: CROSSTALK**

- First implementation of the crosstalk mechanism already available in SIXTE
- Currently being tested

- First assessment of the crosstalk impact to the X-IFU bright source science will be presented at the next SPIE meeting
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with SIXTE

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on behalf of the X-IFU E2E simulations team

SXTE workshop, IRAP, April 21 2016