CALISTE 64
A new CdTe micro-camera for hard X-ray spectro-imaging

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Caliste 64, prototype of CdTe micro-camera for Simbol-X mission

Caliste 64 with a 2mm-thick detector (1 × 1 × 2 cm³)
SIMBOL-X MISSION

- CNES-ASI (France/Italy) project in phase B to be flown in 2014
- A 20 m focal length observatory to detect hard X-rays (0.5 keV-80 keV) by focusing technique.
- Sensitivity and angular resolution improved of two orders of magnitude compared to telescopes with indirect imaging.

- Two satellites flying in formation
  - Mirror spacecraft
  - Detector spacecraft

Observation of high energy phenomena (matter accretion near black holes, matter ejection in quasars...)

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SIMBOL-X FOCAL PLANE

Active anticoincidence (APC)

Low Energy Detector (MPE)
Si DEPFET Macropixel, 0.5-20 keV

High Energy Detector (CEA/Irfu)
CdTe, 4-100 keV

CALISTE, elementary detection unit with 256 pixels
## INSTRUMENT REQUIREMENTS

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Simbol-X Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mission</td>
<td>HED Instrument</td>
</tr>
<tr>
<td>Energy band</td>
<td>0.5 – 80 keV</td>
</tr>
<tr>
<td>Field of view</td>
<td>12 arcmin</td>
</tr>
<tr>
<td>PSF Sampling</td>
<td>~3 mm diameter HEW point spread function</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>Observation of 68 and 78 keV lines (Abundance of $^{44}$Ti in supernovae)</td>
</tr>
<tr>
<td>Time resolution</td>
<td>50 µs for science (pulsars) 300 ns anticoincidence window (background rejection)</td>
</tr>
<tr>
<td></td>
<td>Efficiency &gt; 90 % at 80 keV Effective Threshold $\sim 4$ keV</td>
</tr>
<tr>
<td></td>
<td>Array of 64 cm$^2$</td>
</tr>
<tr>
<td></td>
<td>Pixel size of 625 µm</td>
</tr>
<tr>
<td></td>
<td>$\Delta E &lt; 1.2$ keV FWHM at 60 keV</td>
</tr>
<tr>
<td></td>
<td>Time-tagging $&lt; 100$ ns rms</td>
</tr>
</tbody>
</table>
CANDIDATE DETECTOR FOR SIMBOL-X

- **Current measurement**
- **Spectroscopy measurement**

- 64-pixel detector on substrate
- Al-Ti-Au Schottky CdTe
- 1mm, 400V, -35°C

< 2 pA for most pixels

0.58 keV @ 13.94 keV
0.77 keV @ 59.54 keV

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Caliste 64: design and performance

Caliste 64 in the set-up for electric and spectroscopic measurement
CALISTE 64 DESIGN AND FABRICATION

IDeF-X V1.1 ASIC
16 analog channels

CdTe 64-pixel detector
(1mm pitch, 1 or 2 mm thick)

Mounting on PCB

Caliste 64 camera

4 ASIC Stacking

Electrical body
with a 7 x 7 PGA
SPECTRO-IMAGER WITH TIME-TAGGING CAPABILITY

- **Set-up**
  - CALISTE 64 in thermal enclosure with Americium 241 source
    - Detects photons from the source
    - Sends trigger
  - Circuit with FPGA outside the enclosure
    - Configures ASICs
    - Performs reading sequences
    - Sends data packets to the computer
  - Each event is defined by
    - A position (pixel number)
    - An energy (amplitude of the pulse)
    - A time (trigger)

- **High time-tagging accuracy requires** time-walk correction.
TIME-TAGGING ACCURACY

- Electronic noise
- Technological dispersal

-mean noise on time-walk

-front-end electronics contribute to an error on time-walk

\[ \Delta t < 60 \text{ ns rms for } E > 100 \text{ keV} \] (9.6 µs peaking time, 3 keV low threshold)
NOISE PERFORMANCE

- Fast voltage step through test entry to simulate detector response.
- Tunable current source to simulate dark current $i_d$ of the detector.
- ENC = 65 el. rms over the 64 pixels when $i_d \approx 7$ pA ($\tau_p = 7.2$ µs)
SPECTROSCOPY (1/2)

- **Individual spectrum**
  - -10°C, -400V, 241 Am
  - Low threshold ~1.5 keV
  - Ex. Pixel 1:
    - 650 eV @ 13.94 keV
    - 796 eV @ 59.54 keV

- **Statistics on 64 pixels**
  - Uniformity
  - Mean FWHM
    - 705 eV @ 13.94 keV
    - 858 eV @ 59.54 keV

M X-ray fluorescence line Np (3.3 keV)
Low threshold

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SPECTROSCOPY (2/2)

- Tests with 3 cameras SN3, SN4, SN5 at -10°C
- Best sum spectra from calibrated individual spectra

<table>
<thead>
<tr>
<th>Sample</th>
<th>Thickness</th>
<th>Bias voltage</th>
<th>$\Delta E @14$ keV</th>
<th>$\Delta E @60$ keV</th>
<th>Peak to valley ratio (59.54 / 57 keV)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN3</td>
<td>1 mm</td>
<td>400 V</td>
<td>694 eV</td>
<td>851 eV</td>
<td>44</td>
</tr>
<tr>
<td>SN4</td>
<td>1 mm</td>
<td>500 V</td>
<td>664 eV</td>
<td>841 eV</td>
<td>55</td>
</tr>
<tr>
<td>SN5</td>
<td>2 mm</td>
<td>800 V</td>
<td>735 eV</td>
<td>905 eV</td>
<td>34</td>
</tr>
</tbody>
</table>
Correlation between the energies of the hit neighbor pixels

- See Poster « Charge sharing in CdTe pixilated detectors » Meuris et al. (Session II)

Spectrum with the summed energies

- 1.23 keV FWHM @ 59.54 keV

Detector sensitive in pixel and interpixel zones
## CONCLUSION

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<th>Criteria</th>
<th>Simbol-X requirements</th>
<th>CALISTE 64</th>
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<tr>
<td>Spectroscopy</td>
<td>1.3 keV @60keV</td>
<td>0.85 eV @ 60 keV</td>
</tr>
<tr>
<td>Time resolution</td>
<td>100 ns rms</td>
<td>60 ns rms @100 keV</td>
</tr>
<tr>
<td>Pixel pitch</td>
<td>625 µm</td>
<td>1000 µm</td>
</tr>
</tbody>
</table>

- **Next step for Simbol-X: Caliste 256**
  - Same volume as Caliste 64
  - 256 pixels of 625 µm pitch (Simbol-X geometry)
Thank you for your attention

6 Images with Caliste 64
in energy range around 60 keV, with Cu mark, -100V, +30°C, 1min
CALISTE 64 DESIGN

- A hybrid component based on a 3D Plus space proof technology.
- CdTe detector
  (64 pixels, 1mm pitch, 1mm thick, guard ring)
- Front-end electronics
  (4 IDeF-X 1.1 ASIC of 16 analogue channels)
- Rear interface
  (7x7 pin grid array, 1.27 mm pitch)
- X radiography

- Four micro PCB perpendicular to detection plan.
- Four ASICs to read out 2 rows of eight pixels each.
- Lateral routing to share signals between ASICs.