SPHiNX

Compton scattering polarimeter for GRBs

Fei, Xie (fxie@kth.se)
SPHiNX collaboration
1. What is SPHiNX?

2. What can SPHiNX do?
1. What is SPHiNX?

2. What can SPHiNX do?
SPHiNX

Satellite Polarimeter for High eNergy X-rays
• a proposal to Swedish Space Agency
• the second mission for InnoSat platform

<table>
<thead>
<tr>
<th>Available payload volume</th>
<th>525 x 700 x 480 mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Earth Orbit</td>
<td>Altitude: 550 km, Inclination: 53°</td>
</tr>
<tr>
<td>Mass budget</td>
<td>25 kg</td>
</tr>
<tr>
<td>Power budget</td>
<td>30 W</td>
</tr>
</tbody>
</table>
Payload
Detector

- Plastic scintillator
  - Low Z (C, H)
  - 42 units
  - Triangle: ~65 mm
  - Readout: PMT

- GAGG scintillator
  - High Z (Gd, Al, Ga, O)
  - 120 units
  - Rectangle: 13.5 mm x 5 mm
  - Readout: MPPC
Measure principle

- Compton scattering differential cross-section
  \[
  \frac{d\sigma}{d\Omega} = \frac{r_0^2 \varepsilon^2}{2} \left( \frac{1}{\varepsilon} + \varepsilon - 2\sin^2 \theta \cos^2 \psi \right)
  \]

- Modulation curve
  - amplitude -> fraction
  - phase -> angle

- Modulation factor $M_{100}$
  - 100% polarised photons
  - as large as possible
## Capabilities

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field of View</td>
<td>$\pm 60^\circ$</td>
</tr>
<tr>
<td>Energy range</td>
<td>50 – 500 keV</td>
</tr>
<tr>
<td>Effective area</td>
<td>$&gt; 125 \text{ cm}^2$</td>
</tr>
<tr>
<td>- one-hit</td>
<td></td>
</tr>
<tr>
<td>Effective area</td>
<td>$&gt; 100 \text{ cm}^2$</td>
</tr>
<tr>
<td>- two-hits</td>
<td></td>
</tr>
</tbody>
</table>

![Graph showing the energy range and effective area for one-hit and two-hit scenarios.](image)
1. What is SPHiNX?

2. What can SPHiNX do?
1. What is SPHiNX?

2. What can SPHiNX do?

Science goals

Improve the knowledge about the GRB
GRB prompt emission

- Fit with empirical models
  - Band function
  - a broken power-low with a peak

- Interpret with physics-based models
  - synchrotron
  - inverse Compton
  - photospheric

- Open questions
  - magnetic structure
  - jet composition
  - radiation mechanism
Models

- Synchrotron emission with ordered B-field
- Synchrotron emission with random B-field
- Inverse Compton process with random B-field

Distribution of the expected polarisation from three models which from Toma, et. al. (2009)
Background simulation

Geometric model
- Whole satellite

Space radiation environment
- Cosmic X-ray background
- Albedo gamma and neutron
- Primary Cosmic rays
  - Proton, Electron, Positron, Alpha
- Secondary particles
  - Proton, Electron, Positron

Physics model
- Shielding physics list by Geant4 collaboration
- G4EMLivermorePolarizedPhysics
<table>
<thead>
<tr>
<th>Component</th>
<th>One-hit rate (Hz)</th>
<th>Two-hit rate (Hz)</th>
<th>Higher multiplicity rate (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cosmic X-ray</td>
<td>1320.7</td>
<td>167.1</td>
<td>31.2</td>
</tr>
<tr>
<td>Albedo Gamma</td>
<td>388.3</td>
<td>93.5</td>
<td>25.7</td>
</tr>
<tr>
<td>Albedo Neutron</td>
<td>14.3</td>
<td>5.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Primary Particles</td>
<td>16.7</td>
<td>5.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Secondary Particles</td>
<td>10.4</td>
<td>4.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Total</td>
<td>1750</td>
<td>276</td>
<td>67</td>
</tr>
<tr>
<td>Component</td>
<td>One-hit rate (Hz)</td>
<td>Two-hit rate (Hz)</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>-------------------</td>
<td>-------------------</td>
<td></td>
</tr>
<tr>
<td>Cosmic X-ray</td>
<td>1320.7 -&gt; 75%</td>
<td>167.1 -&gt; 61%</td>
<td></td>
</tr>
<tr>
<td>Albedo Gamma</td>
<td>388.3 -&gt; 22%</td>
<td>93.5 -&gt; 34%</td>
<td></td>
</tr>
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<td>14.3</td>
<td>5.1</td>
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GRB simulation

- The same simulator with background simulation

- GRBs from Fermi GBM catalogue
  - 2136 GRBs by 16 August 2017
  - Average flux + duration + Band spectrum ($\alpha, \beta$ and $E_{\text{peak}}$)
  - Random position in FoV of SPHiNX ($\theta \leq 60^\circ$)
  - 100% polarised photons

- Calculate $M_{100}$ and MDP

- Estimate performance of SPHiNX
Modulation factor $M_{100}$

Stokes parameters

$$M_{100} = 2\sqrt{Q^2 + U^2}$$

Where,

$$Q = \frac{\sum_{i=1}^{N} \cos 2\psi_i}{N}$$

$$U = \frac{\sum_{i=1}^{N} \sin 2\psi_i}{N}$$
Minimum Detectable Polarisation

\[ MDP(99\%) = \frac{4.292}{SM_{100}} \sqrt{\frac{S + B}{T}} \]

Results

1. Trigger on ~200 GRBs in two years
2. 78 GRBs with MDP < 0.3
Model separation

- Synchrotron emission with ordered B-field
- Synchrotron emission with random B-field
- Inverse Compton process with random B-field
Outlook

- Polarisation measurement is a powerful discriminator for GRB prompt emission models

- GRB polarimeter proposed for the next Swedish small satellite mission

- Phase A/B1 report submitted at end of October

- Competition with 2 other missions

- Selection expected early in 2018