X-ray burst science with Astrosat

A R Rao
Tata Institute of Fundamental Research, India
(arrao@tifr.res.in)

40 years of X-ray bursts: Extreme explosions in dense environments
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Astrosat

1. **LAXPC**: Large Area X-ray Proportional Counters; 
   \( A_{\text{eff}} \approx 6000 \text{ cm}^2 \); FOV = 1\(^{\circ}\) X 1\(^{\circ}\); 3-80 keV;

2. **CZTI**: Cadmium-Zinc-Telluride Imager with Coded Aperture Mask (CAM); 
   \( A_{\text{eff}} = 500 \text{ cm}^2 \); FOV = 6\(^{\circ}\) X 6\(^{\circ}\); 10 – 100 keV; E/\(\Delta E \) \approx 20 to 30.

3. **SSM**: Scanning Sky Monitor with 3 PSPCs and CAM; 
   \( A_{\text{eff}} \approx 30 \text{ cm}^2 \) (each); 2-20 keV.

4. **SXT**: Soft X-ray Telescope using conical-foil mirrors 
   \( A_{\text{eff}} \approx 200 \text{ cm}^2 \); FOV = 0.5\(^{\circ}\); (~3\(^{'}\) res); 0.3-8 keV; E/\(\Delta E \) \approx 30

5. **UVIT**: Ultraviolet Imaging Telescope; two telescopes each with 38 cm aperture; near-uv, far-uv and visible bands.

*PI: S. Seetha (ISRO); LAXPC: J S Yadav (TIFR); SXT: K P Singh (TIFR); UVIT: S N Tandon (IIA); CZTI: A R Rao (TIFR); SSM: M.C. Ramadevi (ISRO)*

*Singh et al. 2014*
Participating Institutes...

- **ISRO Centers**
  Satellite, rocket, T&E, Launch, Orbit, SSM, Level 1&2 software + overall management

- **Research Institutes**
  Tata Institute of Fundamental Research
  LAXPC, CZTI, SXT
  Indian Institute of Astrophysics UVIT
  IUCAA SSM, CZTI
  RRI LAXPC
  PRL, Universities,

- Leicester Uty (SXT), Canadian Space Agency (UVIT)
ASTROSAT

- IRS (Indian Remote Sensing) Class
- Launch PSLV C30 from SHAR
- Altitude: 650 km; Inclination: 6 deg.
- Mass: 1550 kg. (780 kg. Payloads)
- Power: 2200 watts
- 200 Gb (210 Mb/sec)
- Satellite Positioning System for orbit and time data
- Payload pointing (3σ): 0.05 degree
- Slew rate: 0.6 deg/sec
- Launch: 3rd quarter of 2015
- Operational life > 5 years

Slide courtesy: K S Sarma
**LAXPC:**
Large area Xenon-filled Proportional Counters

Energy range : 3 – 80 keV
Time Resolution: 10 µsec
Dead time : 50 µsec
Area : 6000 cm²

\[ \frac{E}{\Delta E} \sim 3 - 7 \]

**Event Analysis Mode:** Time Tagged events (10 µsec), pulse height and layer ID.

**Broad Band Counting Mode:** Rate in various energy bands with selectable periods (8 ms to 1024 ms)

**Fast Counter Mode:** Event rate in top layer of detector in 4 different energy bands in 160 µsec (3.0-6.0 keV, 6.0-8.0 keV, 8.0-12.0 keV, 12.0-20.0 keV)

Three identical xenon filled proportional counters. Multi layer and multi cell geometry with 60 anode cells and 28 anti cells

Xenon + methane mixture at a pressure 1500 mm of Hg.

50 micron thick aluminized Mylar window with a FOV of 1°x1°

Slide courtesy: R K Manchanda
LAXPC Effective Area

Slide courtesy: J S Yadav/ M Pahari
## CZT-Imager

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>1024 cm²</td>
</tr>
<tr>
<td>Pixels</td>
<td>16384</td>
</tr>
<tr>
<td>Pixel size</td>
<td>2.4 mm X 2.4 mm (5 mm thick)</td>
</tr>
<tr>
<td>Read-out</td>
<td>ASIC based (128 chips of 128 channels)</td>
</tr>
<tr>
<td>Imaging method</td>
<td>Coded Aperture Mask (CAM)</td>
</tr>
<tr>
<td>Field of View</td>
<td>17 X 17 deg² (100 – 300 keV)</td>
</tr>
<tr>
<td></td>
<td>Polarization measurement</td>
</tr>
<tr>
<td></td>
<td>6 X 6 (10 – 100 keV) – CAM</td>
</tr>
<tr>
<td>Angular resolution</td>
<td>8 arcmin</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>5% @ 100 keV</td>
</tr>
<tr>
<td>Energy range</td>
<td>10 – 100 keV (100 – 300 keV; uncollimated)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.5 mCrab (5 sigma; 10⁴ s)</td>
</tr>
</tbody>
</table>
Scanning Sky Monitor (SSM)

- 3 PSPC
- Area 60 cm² (5 keV)
- Ang res. : 2.5° & 12’
- Res 20%@ 6 keV
Soft X-ray Telescope (SXT)

Telescope Length: 2465 mm (Telescope + camera + baffle + door)
Top Envelope Diameter: 386 mm
Focal Length: 2000 mm

Epoxy Replicated Gold Mirrors on Al substrates in conical Approximation to Wolter I geometry.
Radii of mirrors: 65 - 130 mm; Reflector Length: 100 mm
Reflectors thickness: 0.2 mm (Al) + Epoxy (~50 microns) + gold (1400 Angstroms)
No. of nested shells: 40
No. of reflectors: 320 (40 per quadrant)
Detector: E2V CCD-22 (Frame-Store) 600 x 600

Field of view: 41.3 x 41.3 arcmin
PSF: ~ 2 arcmins
Sensitivity (expected): 15 µCrab (0.5 cps/mCrab)

Slide courtesy: K P Singh
CCD: X-ray illumination

CCD: Optical illumination

Mn K$_{\alpha}$, K$_{\beta}$
145 eV resn.

Slide courtesy: K P Singh
Ultraviolet Imaging Telescope (UVIT)

- Doors
- Main-baffles
- Secondary Mirror
- Sec. Baffle
- Primary Baffle
- TiCone (interface With S/C)
- Primary mirror (375 mm)
- Thermal cover (this encloses Detectors and filter-wheels)

~3100 mm

Slide courtesy: Swarna Ghosh
## Comparison of UVIT with GALEX (#1 of 2)

<table>
<thead>
<tr>
<th>parameter</th>
<th>GALEX</th>
<th>UVIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of telescopes</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Telescope optics</td>
<td>RC, f/6</td>
<td>RC, f/12; RC, f/12</td>
</tr>
<tr>
<td>Primary Mirror size (dia)</td>
<td>50 cm</td>
<td>38 cm, 38 cm</td>
</tr>
<tr>
<td>FoV (Circular dia)</td>
<td>75 arc-min</td>
<td>28 arc-min</td>
</tr>
<tr>
<td>No. of bands</td>
<td>2</td>
<td>3 channels</td>
</tr>
<tr>
<td>(Far-UV = FUV)</td>
<td>FUV (125-180 nm)</td>
<td></td>
</tr>
<tr>
<td>(Near-UV = NUV)</td>
<td>NUV (180-300 nm)</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>Visible = VIS (320-550 nm)</td>
<td></td>
</tr>
<tr>
<td>Filters in FUV</td>
<td>1 fixed band</td>
<td>4 filters</td>
</tr>
<tr>
<td>Filters in NUV</td>
<td>1 fixed band</td>
<td>5 filters</td>
</tr>
<tr>
<td>Filters in VIS</td>
<td>----------------------</td>
<td>5 filters</td>
</tr>
</tbody>
</table>

Slide courtesy: Swarna Ghosh
# Comparison of UVIT with GALEX

<table>
<thead>
<tr>
<th>Parameter</th>
<th>GALEX</th>
<th>UVIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slitless Spectroscopy with Grism</td>
<td>Grism</td>
<td>Grating</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>R ~ 100-200</td>
<td>R ~ 100-200</td>
</tr>
<tr>
<td>No. of grism/grating</td>
<td>1 per band</td>
<td>2 per band (orthogonal pair)</td>
</tr>
<tr>
<td>Angular resolution (FWHM)</td>
<td>4.5-6.0 arc-sec</td>
<td>&lt; 1.8 arc-sec</td>
</tr>
<tr>
<td>Peak Effective area</td>
<td>FUV : 37 cm$^2$</td>
<td>FUV : ~15 cm$^2$</td>
</tr>
<tr>
<td></td>
<td>NUV : 62 cm$^2$</td>
<td>NUV : ~50 cm$^2$</td>
</tr>
<tr>
<td></td>
<td>-------------------------</td>
<td>VIS : 50 cm$^2$</td>
</tr>
<tr>
<td>Saturation ($m_{AB}$)</td>
<td>&lt; 10 mag</td>
<td>&lt; 8.0 mag (with ND filter)</td>
</tr>
<tr>
<td>Time resolution</td>
<td>~ 10 milli-sec</td>
<td>&lt; 5 milli-sec</td>
</tr>
</tbody>
</table>

Slide courtesy: Swarna Ghosh
**X-ray burst science with Astrosat**

- Low Inclination
- Continuous time-tagged individual photon data (LAXPC, CZTI & SSM) - micro-seconds accuracy
- Bright source observing capability of SXT
- Facility to adjust SSM observation time
- Hard X-ray (above ~ 80 keV) monitoring capability.
- Significant time devoted for 'timing science'

**Spectral capability:** Wide band high resolution spectrum

**ASM capability:** Burst statistics

**X-ray/ UV-optical association:** Simultaneous multi-filter UV/ optical observations simultaneously with X-ray spectroscopy.
Rapid burster: XRT (Sala+2012)

- $M = 1.1 \pm 0.3 \, M_\odot$
- $R = 9.6 \pm 1.5 \, \text{km}$
Astrosat spectra (1 s)

- Accurate temperature
- Dead time/ pile-up correction
- Other spectral components (in ‘t Zand+ 2013)
X-ray/ UV-optical association

- EXO 0748-676 (Paul+2012)
- A few seconds delay, no association with binary orbit:
  - accretion disk, companion?
- X-ray spectroscopy along with simultaneous 3-band (FUV, NUV, opt) observations can be used to measure precise transfer function and binary parameters.
Conclusions

- Astrosat is an observatory class satellite, scheduled to be launched this year.
- X-ray timing measurement is the major thrust of the satellite.
- It will continue the legacy of RXTE for X-ray burst observations.
- Wide band X-ray spectroscopy and multi-wavelength observations from a single platform will add to our understanding of X-ray bursts.