X-ray Observations of Jet Sources Using Astrosat

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Plan

- Astrosat – a brief overview
  Polarimetry ?
- Key science topics
- Micro-quasars:
  - Wide band X-ray spectroscopy
  - Hard X-ray components
  - Monitoring
  - Observing strategy
- Gamma ray bursts
- Conclusions
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 24** 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: Second quarter of 2014
- Operational life > 5 years

Slide courtesy: K S Sarma
ASTROSAT: Observation Phases and Data Policy

<table>
<thead>
<tr>
<th>Instruments</th>
<th>PV Phase (6 months)</th>
<th>Guaranteed Time (next 6 months)</th>
<th>First Year Regular observations</th>
<th>Second year Regular observations</th>
<th>Third year Regular observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray Inst. Teams</td>
<td>67%</td>
<td>4 months</td>
<td>32.5%</td>
<td>20%</td>
<td>-</td>
</tr>
<tr>
<td>UVIT Teams</td>
<td>33%</td>
<td>2 months</td>
<td>17.5%</td>
<td>10%</td>
<td>-</td>
</tr>
<tr>
<td>Indian proposals</td>
<td>-</td>
<td>-</td>
<td>35%</td>
<td>45%</td>
<td>65%</td>
</tr>
<tr>
<td>International proposals</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>10%</td>
<td>20%</td>
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<tr>
<td>CSA Team'</td>
<td>-</td>
<td>-</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>LU Team'</td>
<td>-</td>
<td>-</td>
<td>3%</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>TOO</td>
<td>-</td>
<td>-</td>
<td>5%</td>
<td>5%</td>
<td>5%</td>
</tr>
<tr>
<td>Calibration time</td>
<td>-</td>
<td>-</td>
<td>2%</td>
<td>2%</td>
<td>2%</td>
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</table>

Slide courtesy: K S Sarma
Astrosat Instruments

1. **LAXPC**: Large Area X-ray Proportional Counters; $A_{\text{eff}} \approx 6000 \text{ cm}^2$; FOV $= 1^0 \times 1^0$; 3-80 keV;

2. **CZTI**: Cadmium-Zinc-Telluride Imager with Coded Aperture Mask (CAM); $A_{\text{eff}} = 500 \text{ cm}^2$; FOV $= 6^0 \times 6^0$; 10 – 100 keV; $E/\Delta E \approx 20$ to 30.

3. **SXT**: Soft X-ray Telescope using conical-foil mirrors $A_{\text{eff}} \approx 200 \text{ cm}^2$; FOV $= 0.5^0$; (~3' res); 0.3-8 keV; $E/\Delta E \approx 30$

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

5. **UVIT**: Ultraviolet Imaging Telescope two telescopes each with 38 cm aperture; near-uv, far-uv and visible bands.
LAXPC: Large area Xenon-filled Proportional Counters

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

E /ΔE ~ 3 - 7

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: Ravi Manchanda
See Paul et al. 2013 (arXiv: 1307.5637)

J.S. Yadav (Poster – this conference)
**CZT-Imager...**

Size: 482 x 458 x 603 mm

Weight - 50 kg

Power – 60 Watts

Collimator: 6 x 6 Degree

17 x 17 Degree

- Heat pipes
- CFRP support
- Handling brackets
- CAM
- Collimator
- Side joining plates
- Radiator
- Optical cube
- Alpha tag source
- CZT bottom hsg.
# CZT-Imager characteristics

<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
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</thead>
<tbody>
<tr>
<td>Area</td>
<td>$1024 \text{ cm}^2$</td>
</tr>
<tr>
<td>Pixels</td>
<td>16384</td>
</tr>
<tr>
<td>Pixel size</td>
<td>$2.4 \text{ mm} \times 2.4 \text{ mm}$ (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 deg$^2$ (uncollimated)</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 - Up to 1 MeV (Photometric)</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>0.5 mCrab (5 sigma; $10^4$ s)</td>
</tr>
</tbody>
</table>
Polarization in CZT-I

- Photo-electric effect. GEMS
- Thomson scattering – Polix 4 – 30 keV
- Compton scattering – Integral Cyg X-1
- CZT-I has Polarization Sensitivity in 100 – 200 keV
Polarization

Crab 3 sigma detection in < 1 day

<table>
<thead>
<tr>
<th></th>
<th>Next (%)</th>
<th>1:2</th>
<th>3:4</th>
<th>4:5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs</td>
<td>2.4+0.1</td>
<td>4.3+0.2</td>
<td>0.8+0.1</td>
<td>8.0+2.0</td>
</tr>
<tr>
<td>Monte Carlo</td>
<td>2.43</td>
<td>4.9</td>
<td>1.0</td>
<td>10.0</td>
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</tbody>
</table>
Modulation Curve at 0 degree

10.78 % edge modulation factor
4.8 % corner modulation factor

Modulation Curve at 90 degree

-7.802 % edge modulation factor
2.57 % corner modulation factor
Polarization measurement capability of CZTI

Arrows represent incident polarization direction

Slide courtesy: Santosh Vadawale
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
Reflector 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
Door Mech

Thermal Baffle

Optics

Heat Pipe + Radiator Plate

Slide courtesy: K P Singh
Mn $K_{\alpha}, K_{\beta}$
145 eV resn.
Scanning Sky Monitor (SSM)

- 3 PSPC
- Area 60 cm$^2$ (5 keV)
- Ang res. : 2.5° & 12'
- Res 20% @ 6 keV
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

<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></td>
<td></td>
</tr>
<tr>
<td>Near-UV=NUV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></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></td>
</tr>
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</table>

Slide courtesy: Swarna Ghosh
<table>
<thead>
<tr>
<th>parameter</th>
<th>GALEX</th>
<th>UVIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slitless Spectroscopy with</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>VIS : 50 cm(^2)</td>
<td></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
UVIT: Vibration Tests
Astrosat: Special Features

- Low Inclination
- Continuous time-tagged individual photon data (LAXPC & CZTI) – a few tens of micro-second accuracy
- Bright source observing capability of SXT
- Facility to change/ adjust observation time of SSM pointing.
- Hard X-ray (above ~ 80 keV) monitoring capability.
AGN & XRBs: Key Science Topics

Wideband X-ray spectroscopy

Spectral-timing analysis

Disk-Jet connection

Long term soft/hard variability

Quasi Periodic Oscillations
Wide Band X-ray Spectroscopy with Astrosat

- Overlapping energy ranges
- Low background and simultaneous measurement
- Wide dynamic range

Zdziarski et al. 2005
Monitoring…

Soft X-ray transients:
- ~ 50 transients (~2 new per year)
- About 80% > 100 mCrab; 90% |b| < 5 degree

Extragalactic sources:
- About two dozen bright extragalactic objects
- Flux 2 – 15 mCrab.

Hard and Soft X-ray measurements possible
Observation Strategy

- Continuous monitoring of new transients
  - State transitions
  - HF QPOs
- TOO driven long monitoring of persistent sources during state transitions
- Bright AGNs (about a dozen) monitoring and wide band spectral observations.
Gamma-ray bursts

- 1000 cm$^2$ detectors (CZT as well as CsI Veto detectors) above 100 keV
- Flexible pointing by SSM
- Spectral measurements above 100 keV
- Polarization measurements
Conclusions

- Wide band X-ray spectroscopy is the strength of Astrosat.
- Useful to pin down the spectral components and have a definitive geometrical paradigm for the emission.
- New features (individual photon counting and possibly polarization) will enhance the observation capabilities.