# First results from the *AstroSat* mission

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Tata Institute of Fundamental Research, India
2016 Oct 19

**6th Nepal meeting – Kathmandu**

# 2013 Kathmandu Meeting …

- Launch: Second quarter of 2014
- 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.

**Launch: 2015 September 28**
**All instruments working well**
**X-ray spectroscopy: work in progress**
**X-ray Polarization: definitely yes.**

# 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

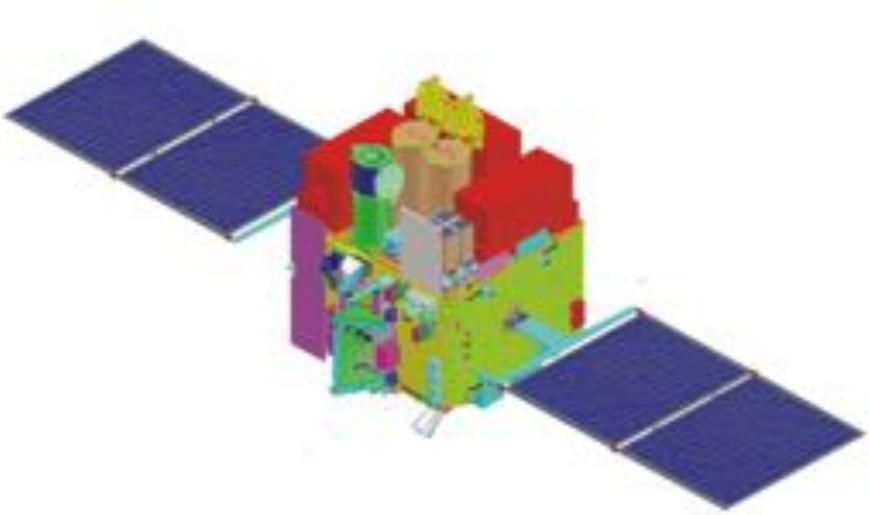
  RRI LAXPC

  PRL, Universities,

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

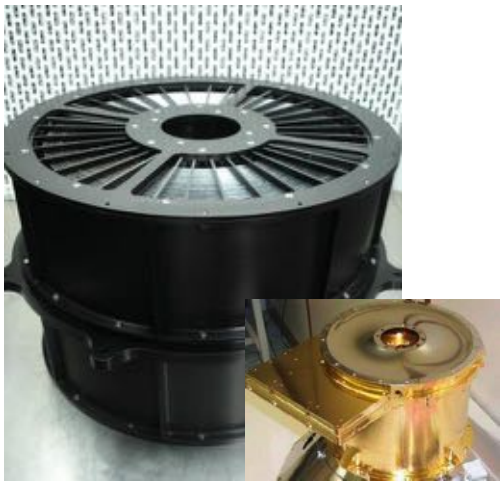
# AstroSat

- **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: 2015 September 28
- Operational life > 5 years

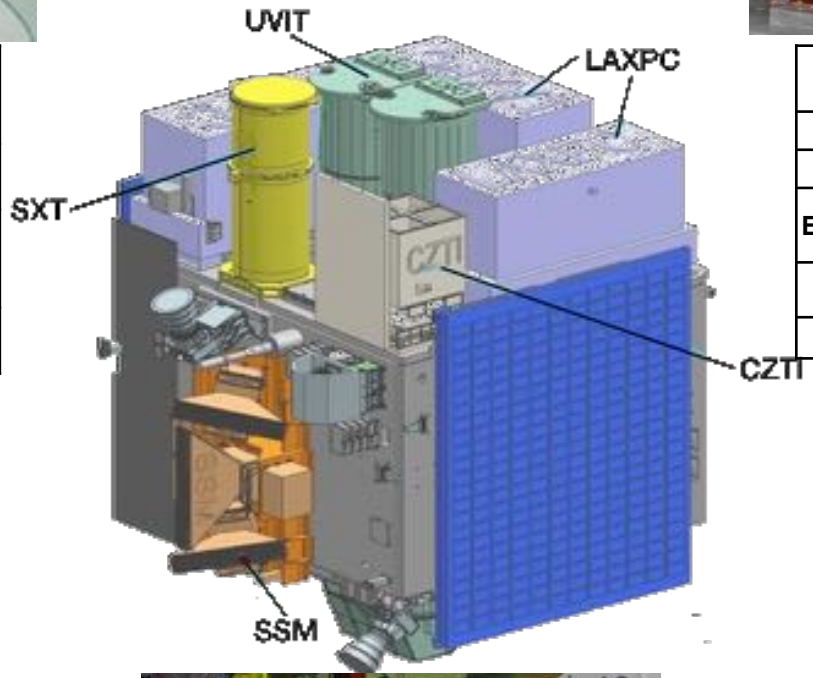


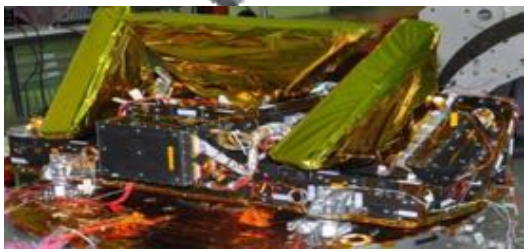

# AstroSat

| Detector | Photon-counting (Intensified) CMOS imagers |
|---|---|
| Optics | Twin Ritchie Chretian 2 mirror system |
| Bandwidth | 130-180 nm<br>200-300 nm<br>320-550 nm |
| Angular Resolution | 1.8 arc sec |

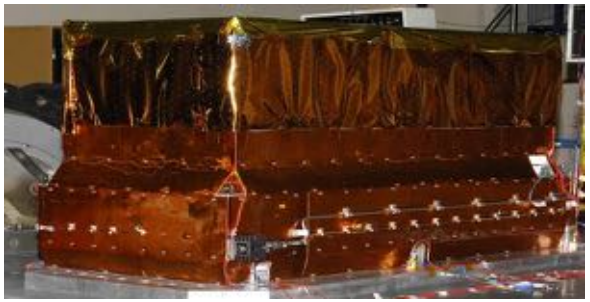


| Detector | X-Ray CCD at the focal plane |
|---|---|
| Optics | Conical foil ( Wolter-I) Mirrors |
| Bandwidth | 0.3 - 8 keV |
| Energy Resolution | 2.34% @ 5.9 keV |
| Angular Resolution | 2 arc min (HPD) |



| Detector | Position sensitive Proportional Counter(3) |
|---|---|
| Optics | 1-D coded Mask |
| Bandwidth | 2.5 - 10 keV |
| Energy Resolution | 25% @ 6 keV |



| Detector | Proportional counter |
|---|---|
| Optics | Collimator |
| Bandwidth | 3 - 80 keV |
| Energy Resolution | 12% @ 22 keV |
| Time resolution | 10 microsec |
| Effective area | 8000 cm2 |

| Detector | CdZnTe Detector |
|---|---|
| Optics | 2-D coded Mask |
| Bandwidth | 15 - 100 keV |
| Energy Resolution | 6% @100 keV |
| Time resolution | 20 microsec |

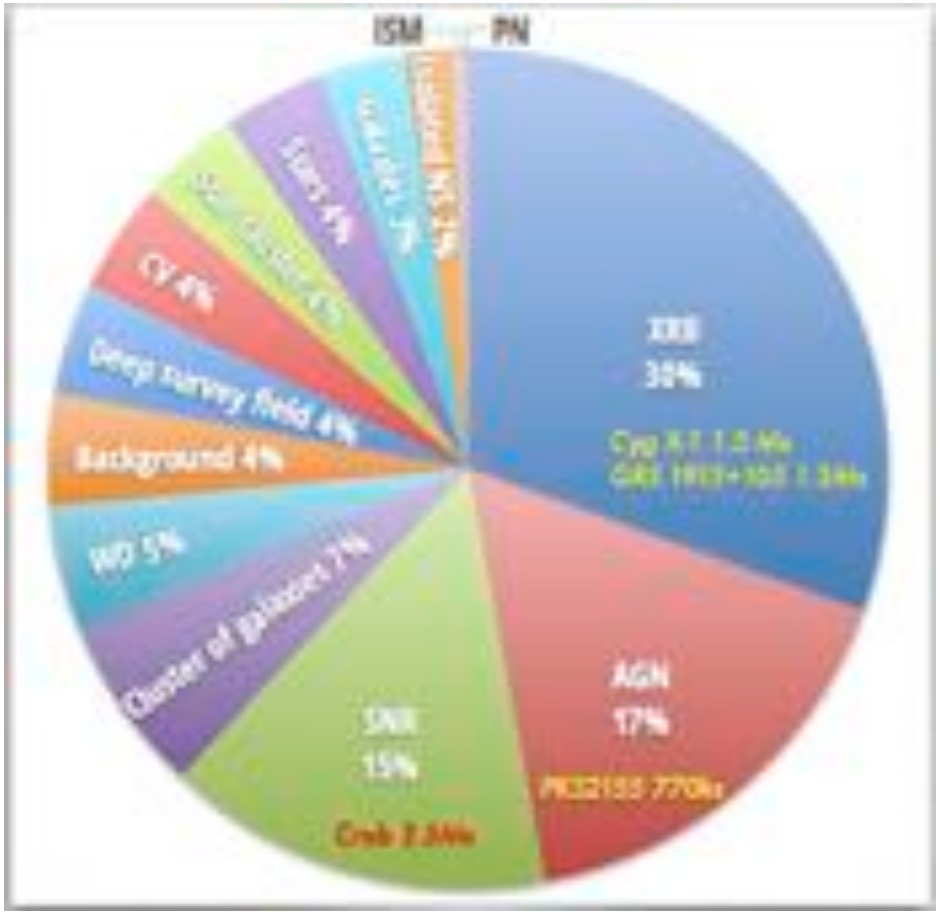
# The first year of *AstroSat*

- Six months PV phase
- Six months GT
- 30 Ms

  Efficiency :

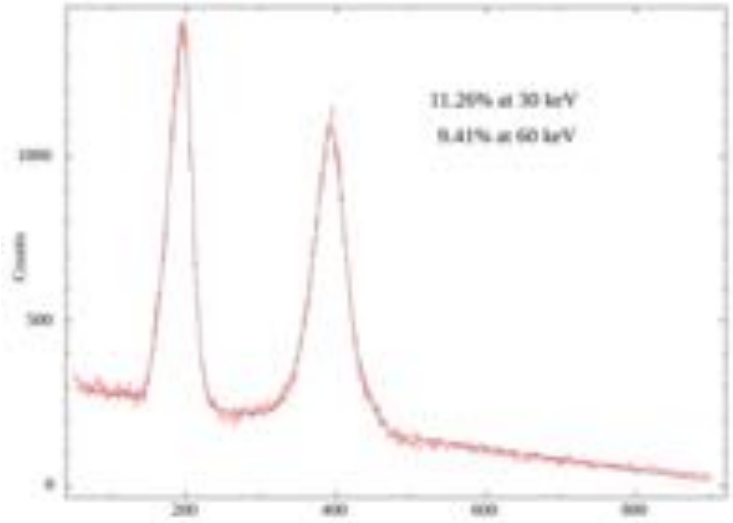
  ~10% (UVIT) to

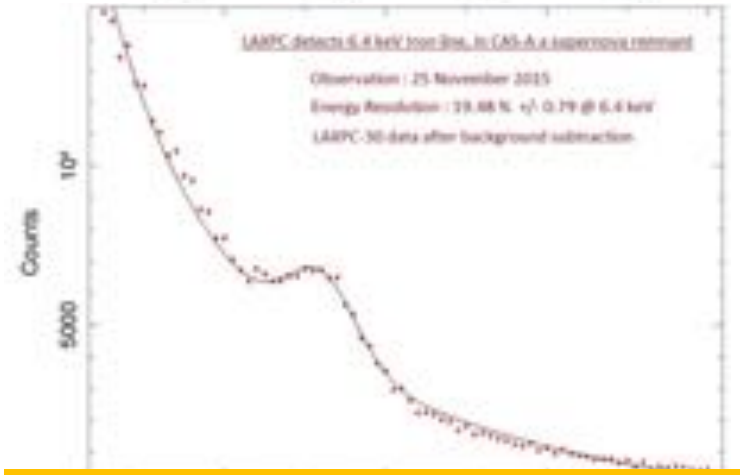
  ~ 55% (CZTI)
- 140 sources, 337 targets



# Instrument Performance: LAXPC

- All 3 LAXPC units performing as designed.



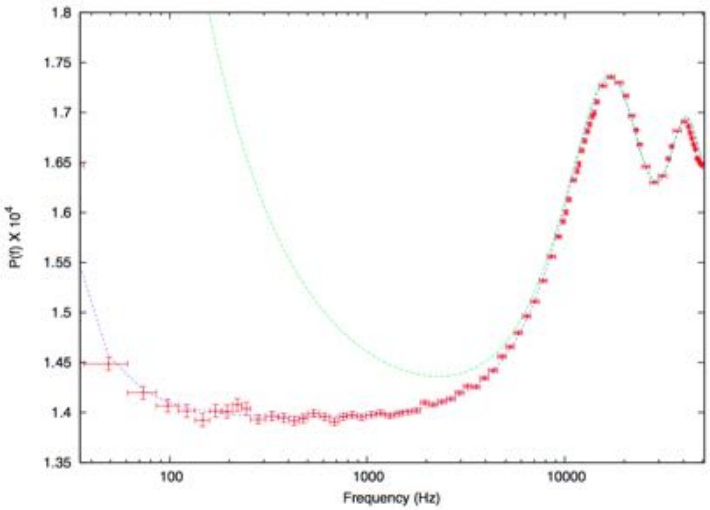

## Spectra:

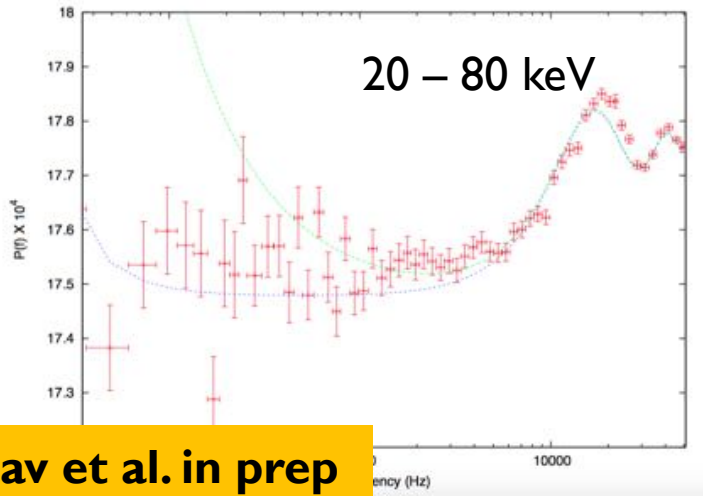
Resolution:
11% @ 30keV
9%@60 keV
19% @ 6.4 keV

## Timing:

Dead time: 42.3 $\mu$ s

QPO Q=4; rms=5%

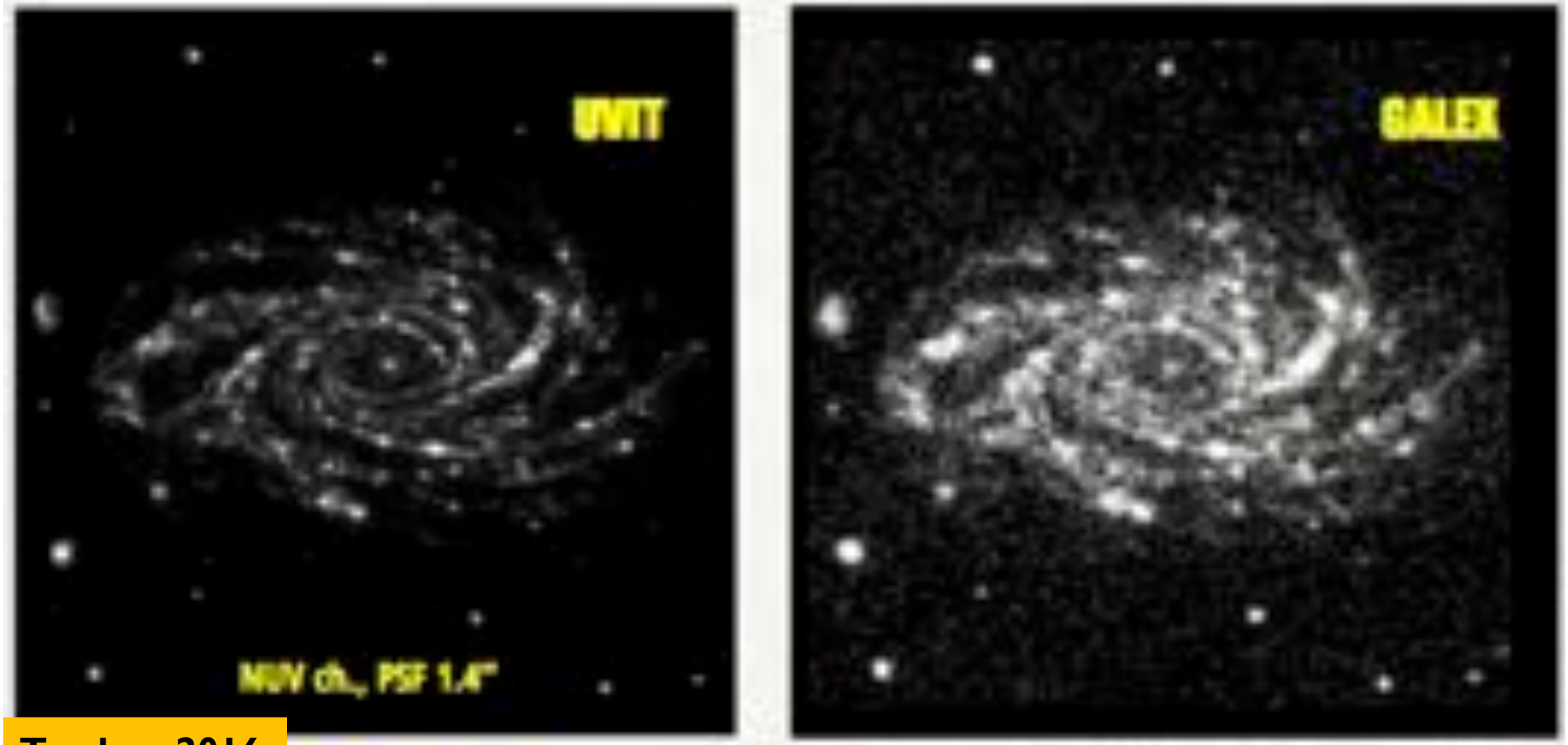



**Yadav et al. 2016 (ApJ in press; arXiv:1608.07023);Yadav et al. in prep**

# Instrument Performance: UVIT

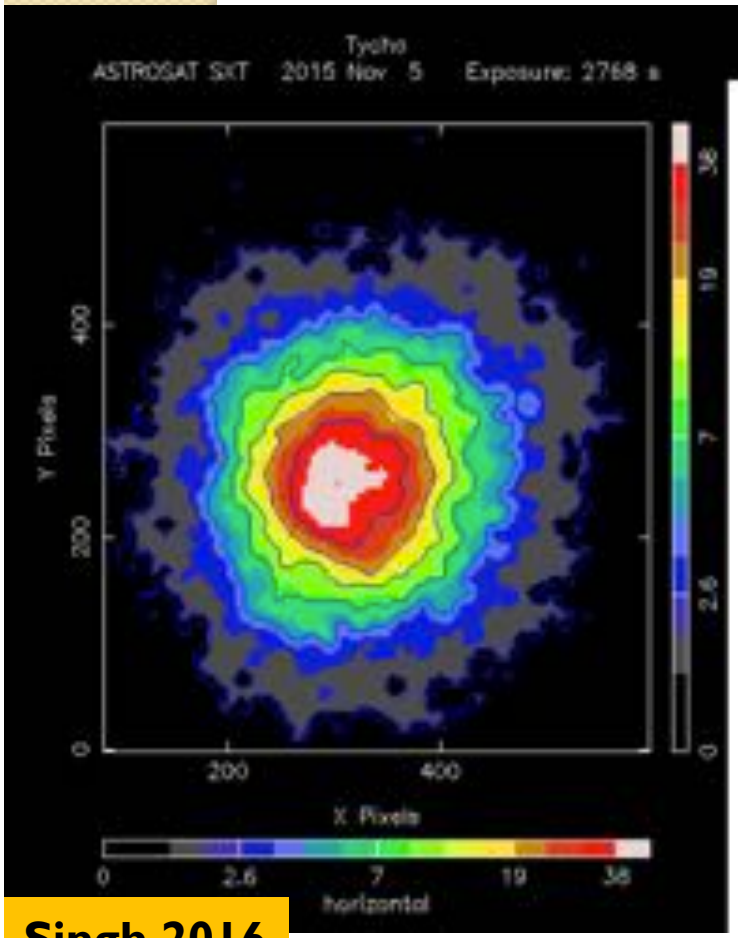
- NGC 2336

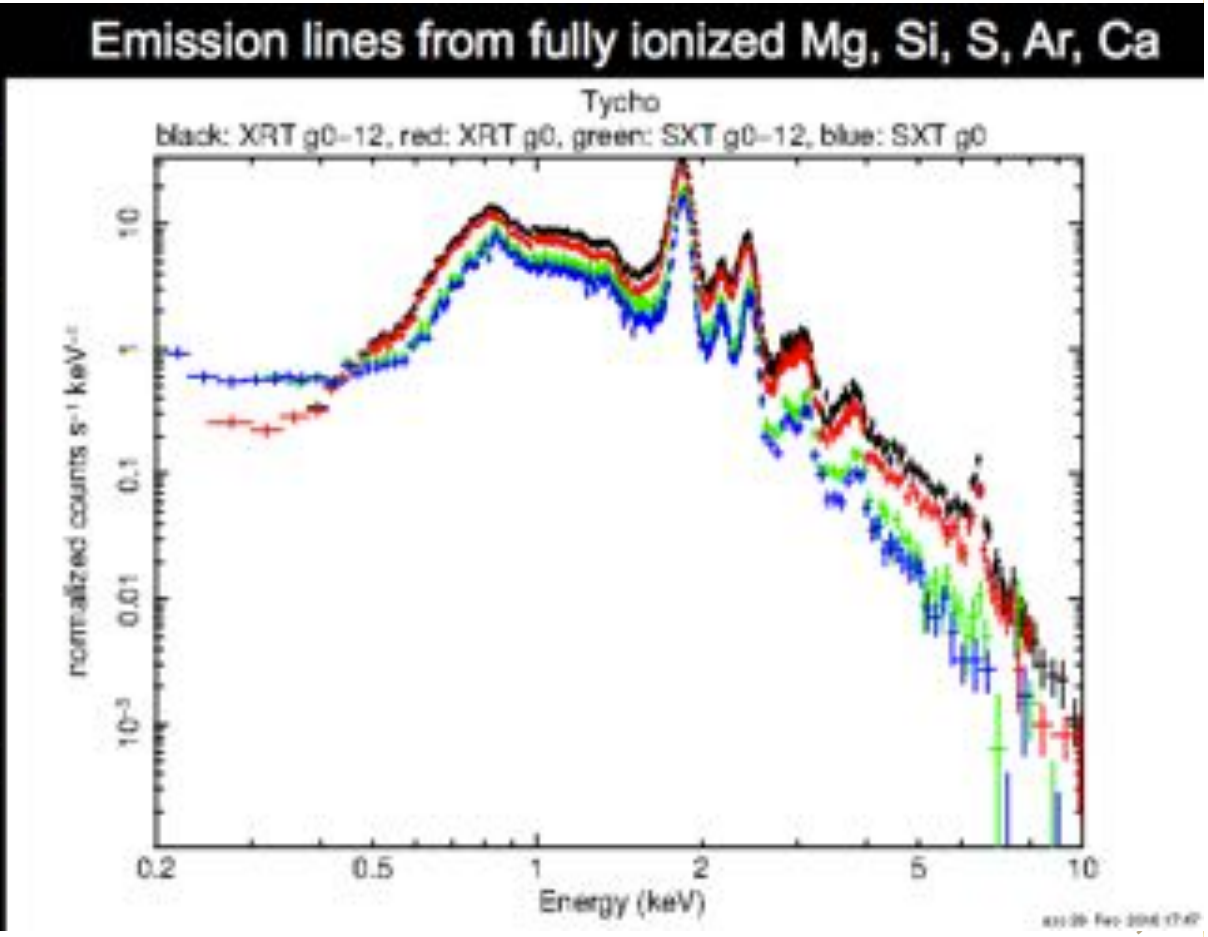



Tandon 2016

# Instrument Performance: SXT

- Tycho SNR




Singh 2016

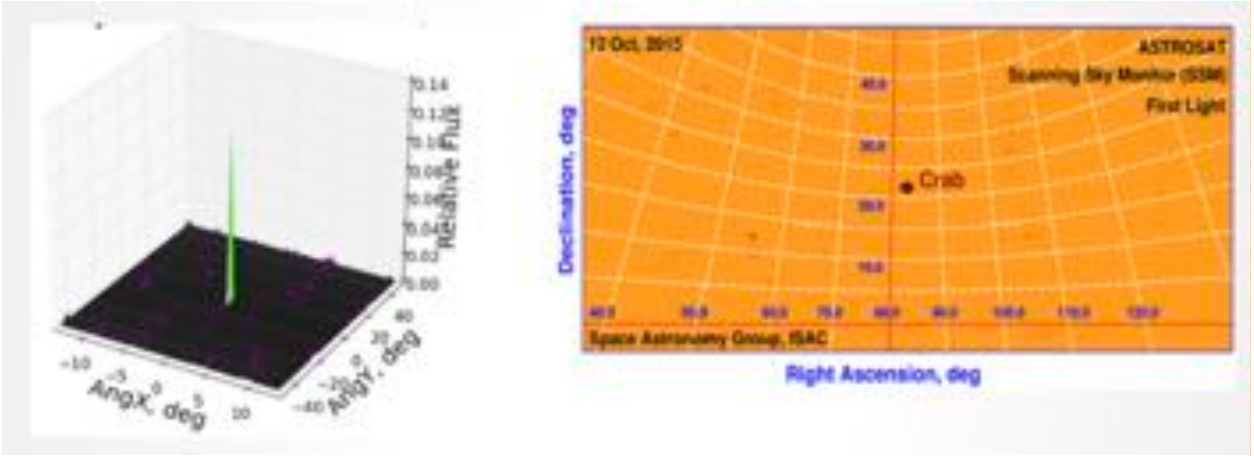
# Instrument Performance: SSM

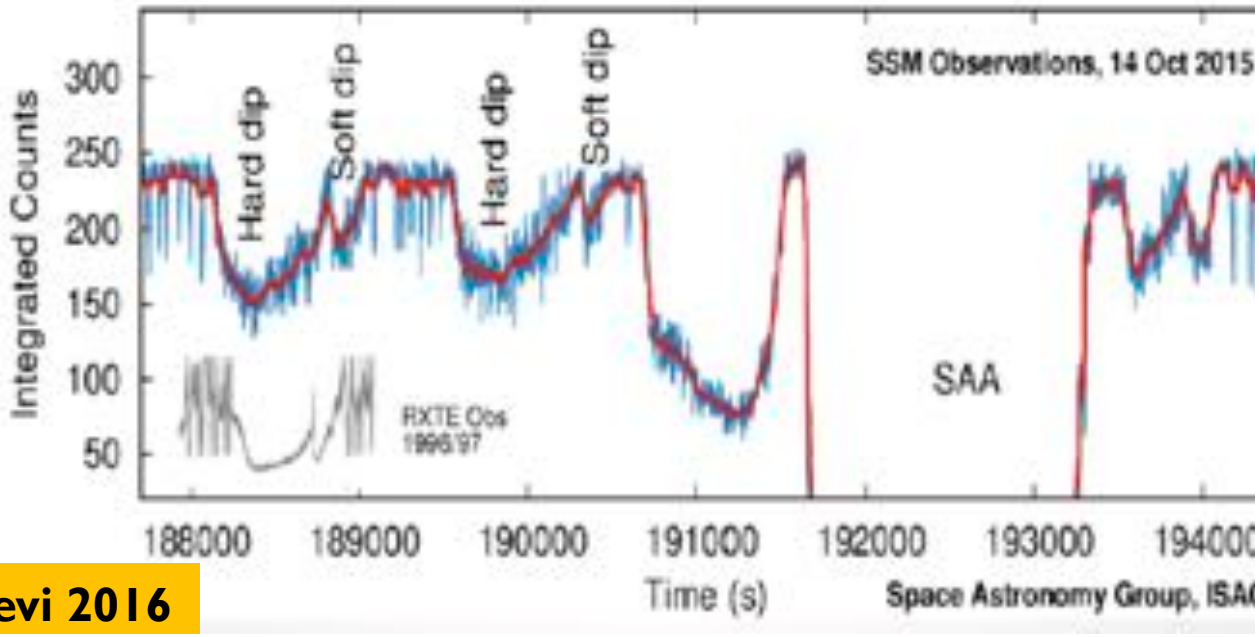
Crab

GRS 1915+105

Beta Class.

Ability to stare at a source for a long time.



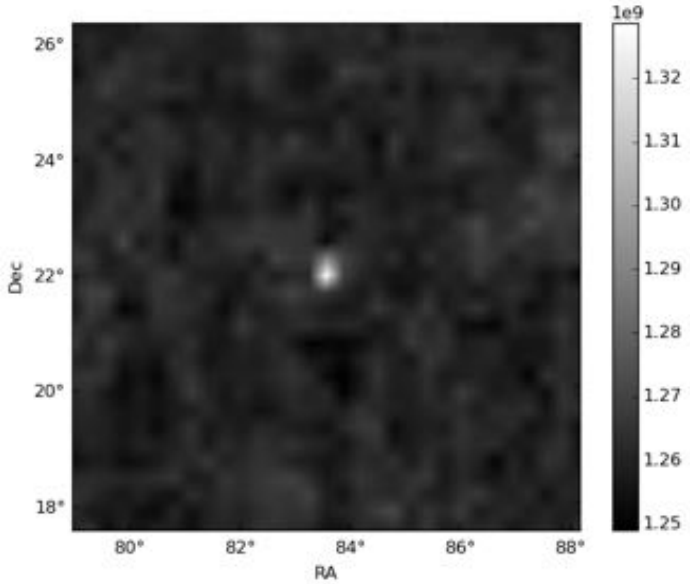




**Ramadevi et al. 2016; Ramadevi 2016**

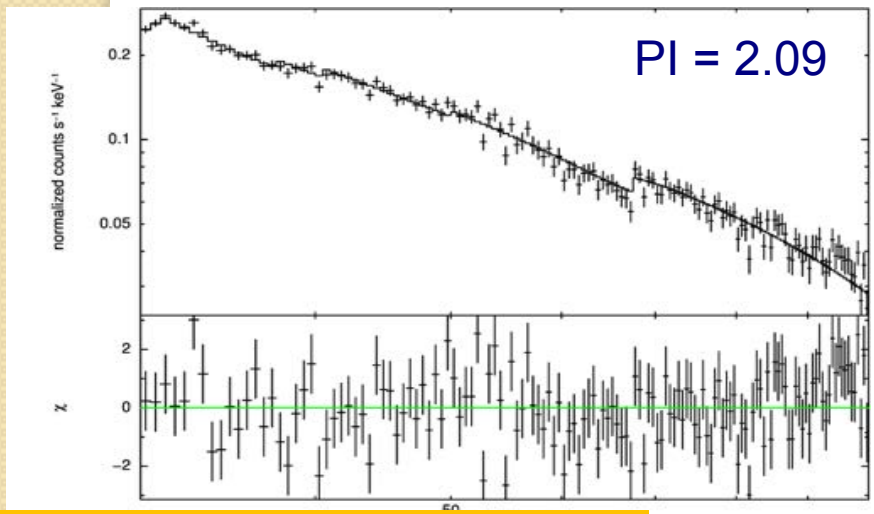
# Instrument Performance: CZTI

- Crab spin down (36 ns/day) detected clearly in one day observation
- X-ray pulse known to lead radio pulse by ~300 μs (Integral)
- CZTI pulse leads radio by ~490±150 μs
- Absolute time accuracy: ~200 μs

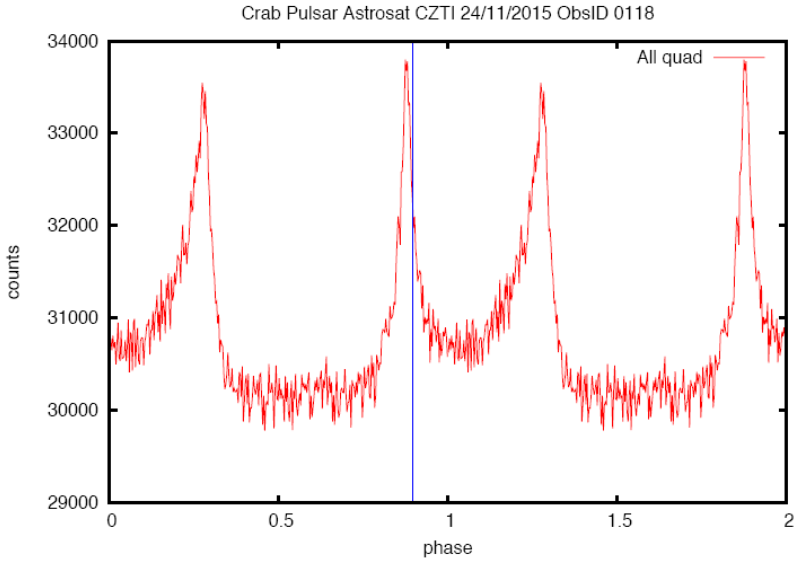
**Image**




**Spectrum**




**Pulse profile**

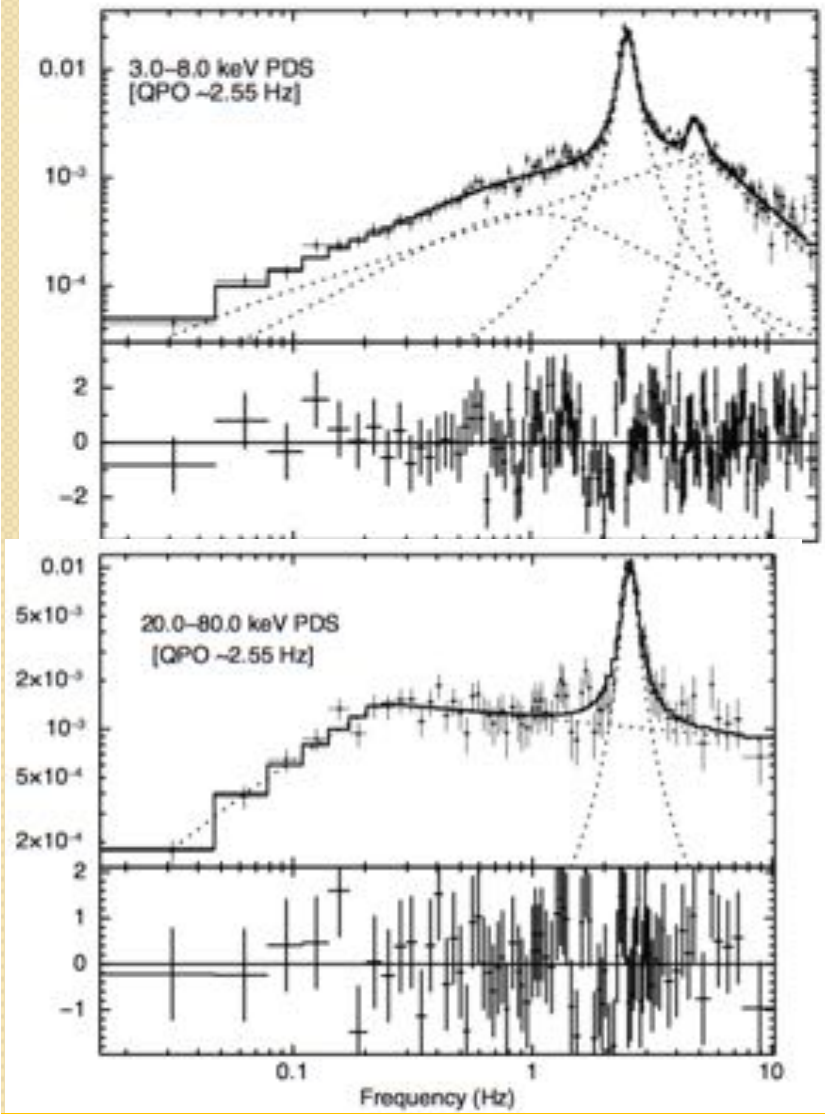


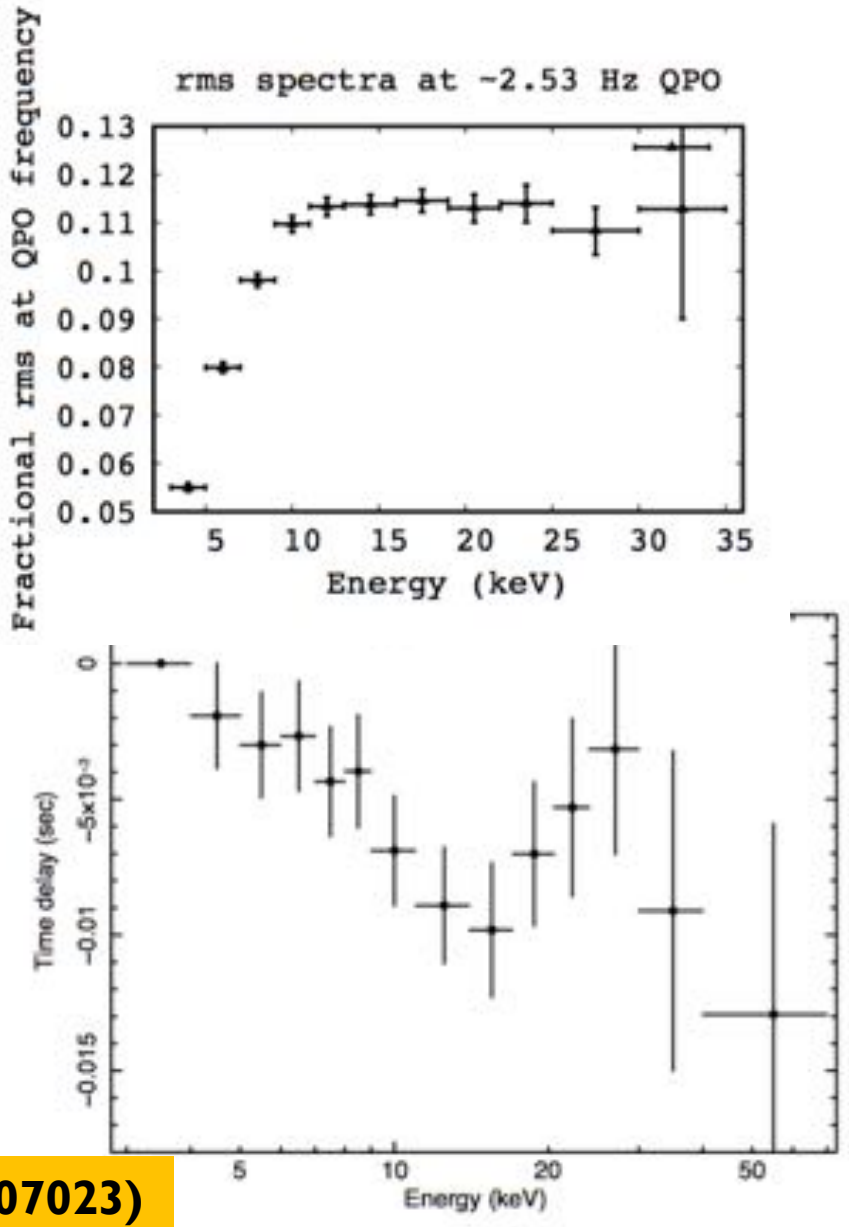

**Vadawale et al. 2016a; Rao 2016**

# *AstroSat* Results

- GRS 1915+105: Yadav et a. ApJ, in press 1608.07023
- GRB 151006A: Rao et al. . ApJ, in press 1608.07388
- *AstroSat*: Rao, Singh Bnhattacharya, SRT, 1608.06051
- In-Orbit Performance: SPIE 9905-45,46,47,48 (1609.00538)
- Instrument papers, JAA, sub., 1608.03408; 1608.06038
- Cyg X-3: Bhargava et al., ApJ, sub.
- Two ATels: Ramadevi et al (8185), . Yadav et al. (9515)
- Twelve GCNs
- Many ``in preparation"

# GRS 1915+105: $\chi$ Class

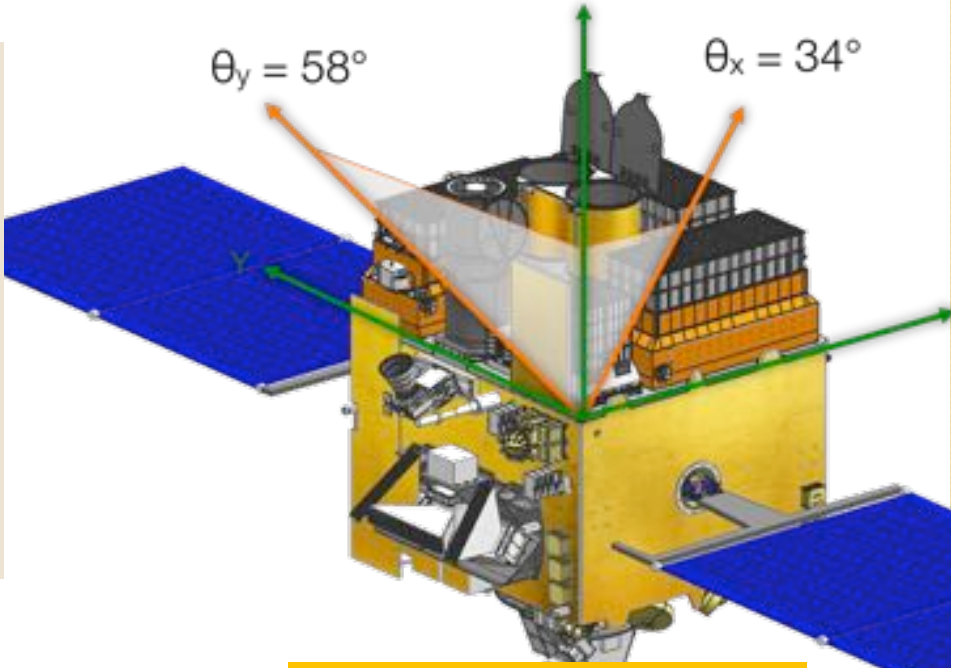


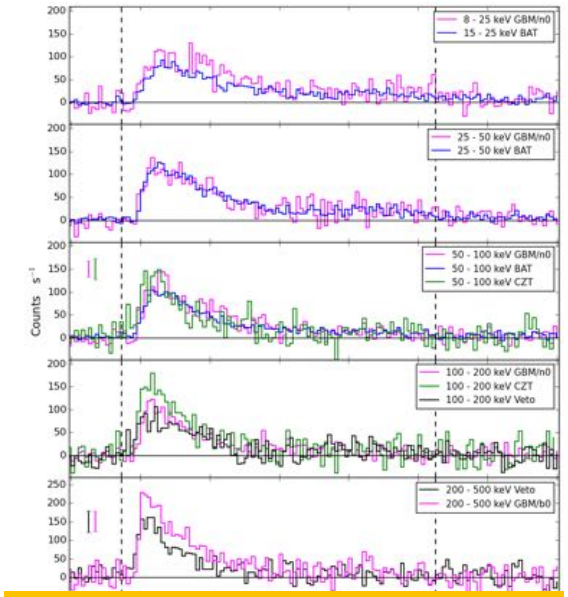



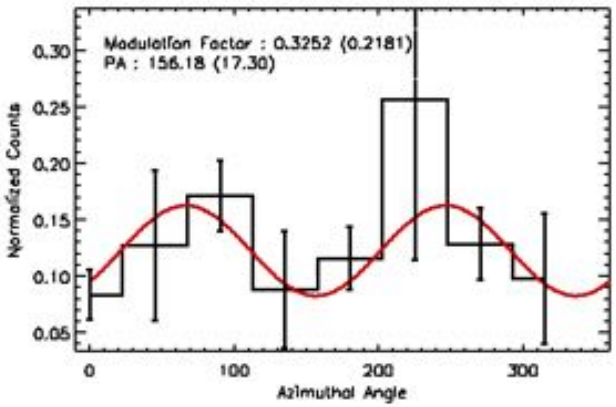

**Yadav et al. 2016 (ApJ in press; arXiv:1608.07023)**

# *AstroSat* CZT Imager detects GRB 151006A.

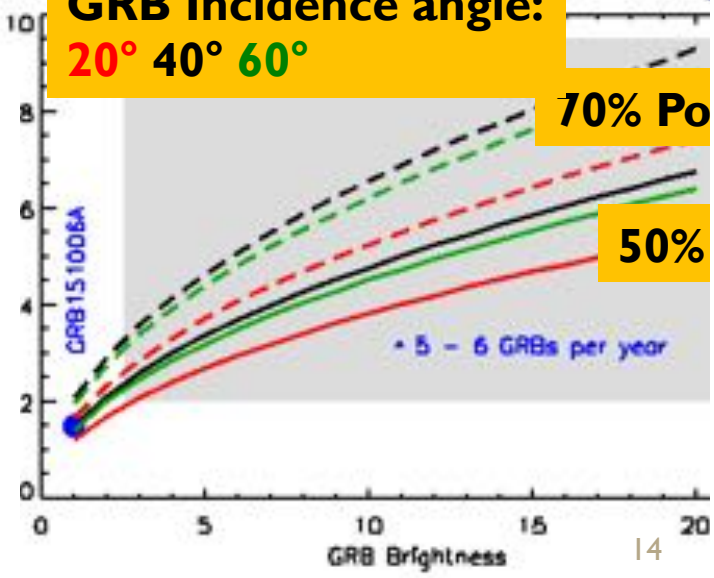
- On the first day of operation.
- Incident at 60°.7 from vertical ($\theta_x$ = 34°; $\theta_y$ = 58°)
- Material around CZT detectors are transparent to X-rays above 100 keV.
- Significant detection area for off-axis sources.



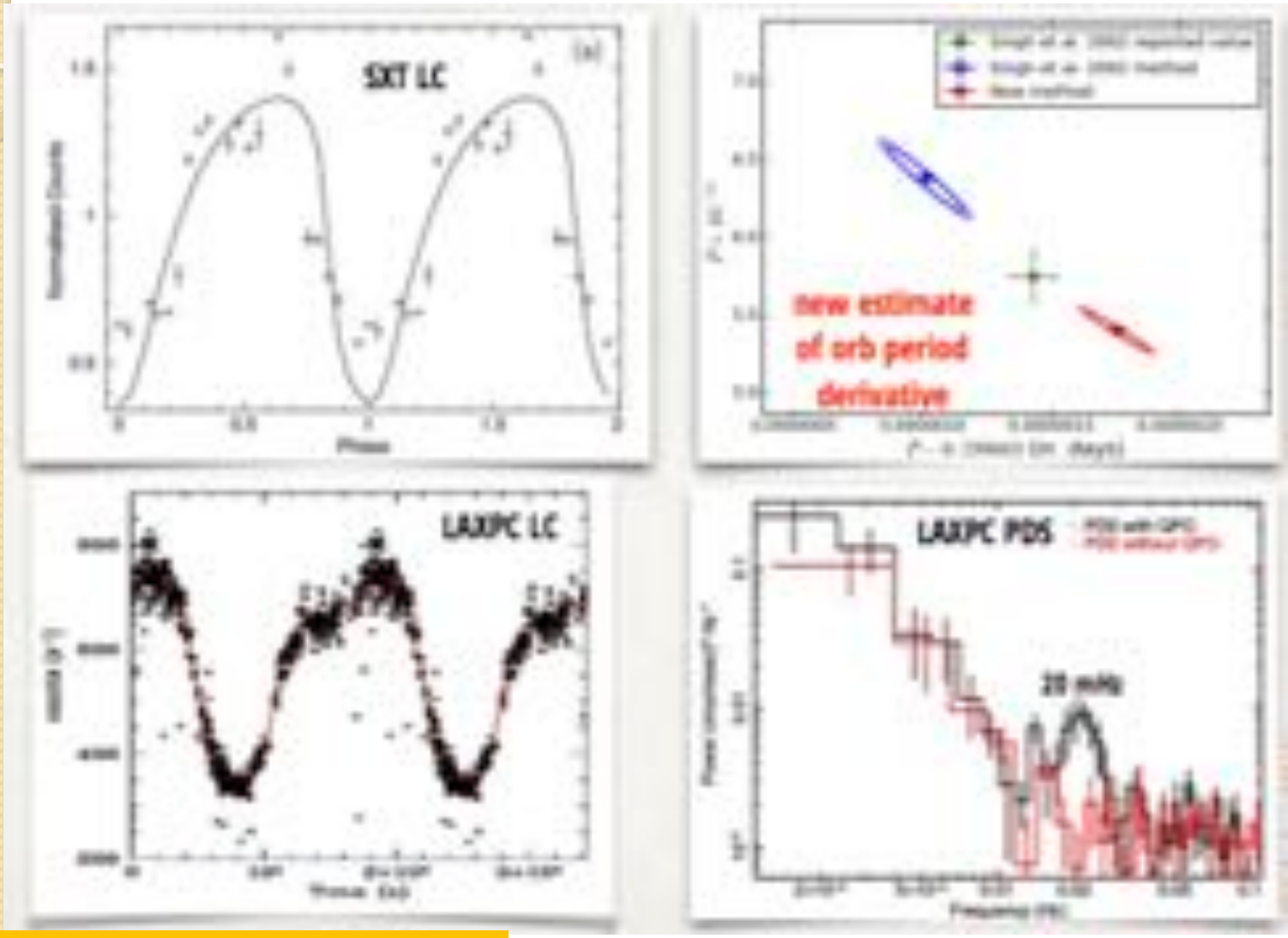




**GRB Incidence angle:**
**20° 40° 60°**



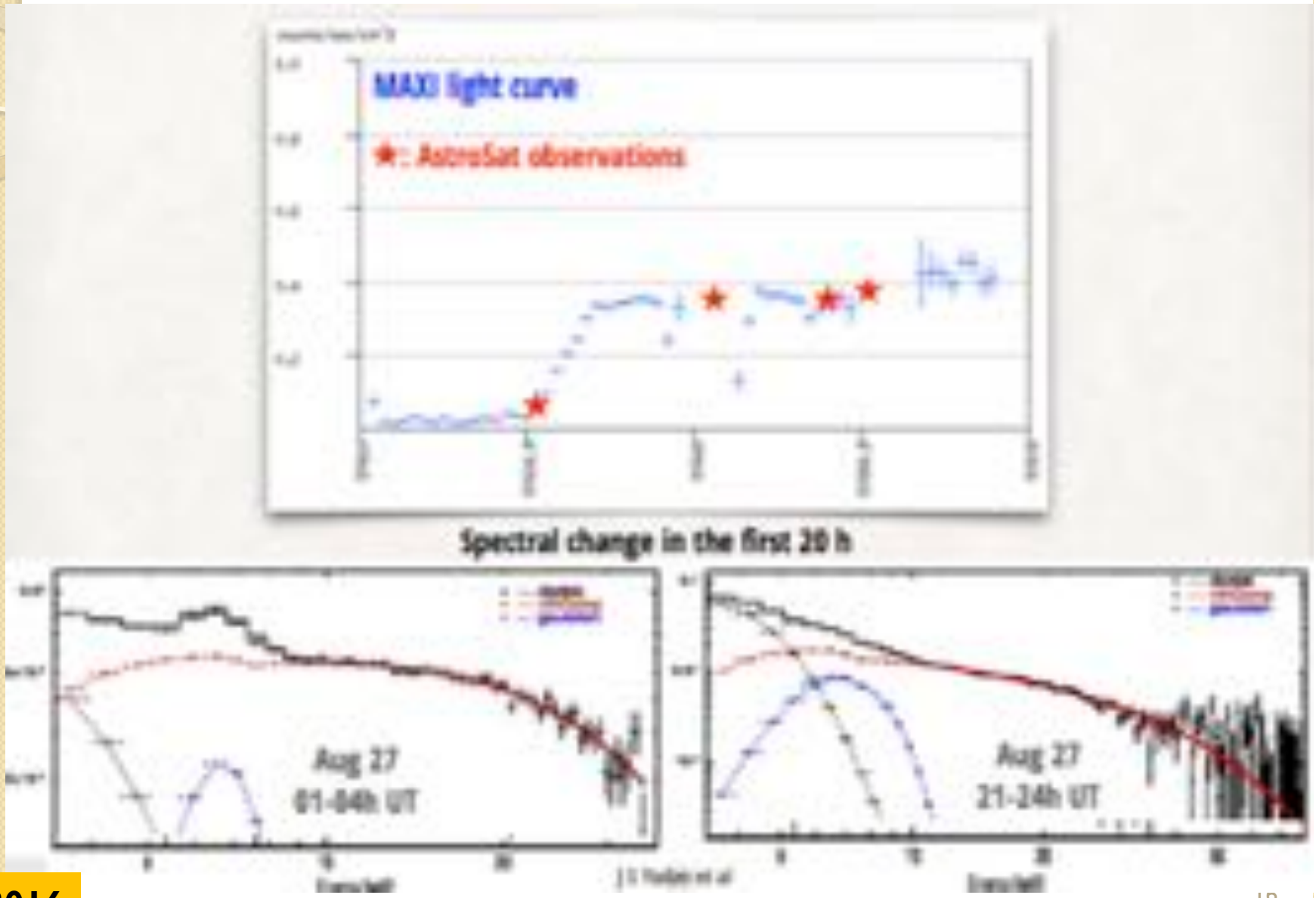

**Rao et al. 2016 (ApJ in press; arXiv:1608.07388)**

# Cygnus X-3

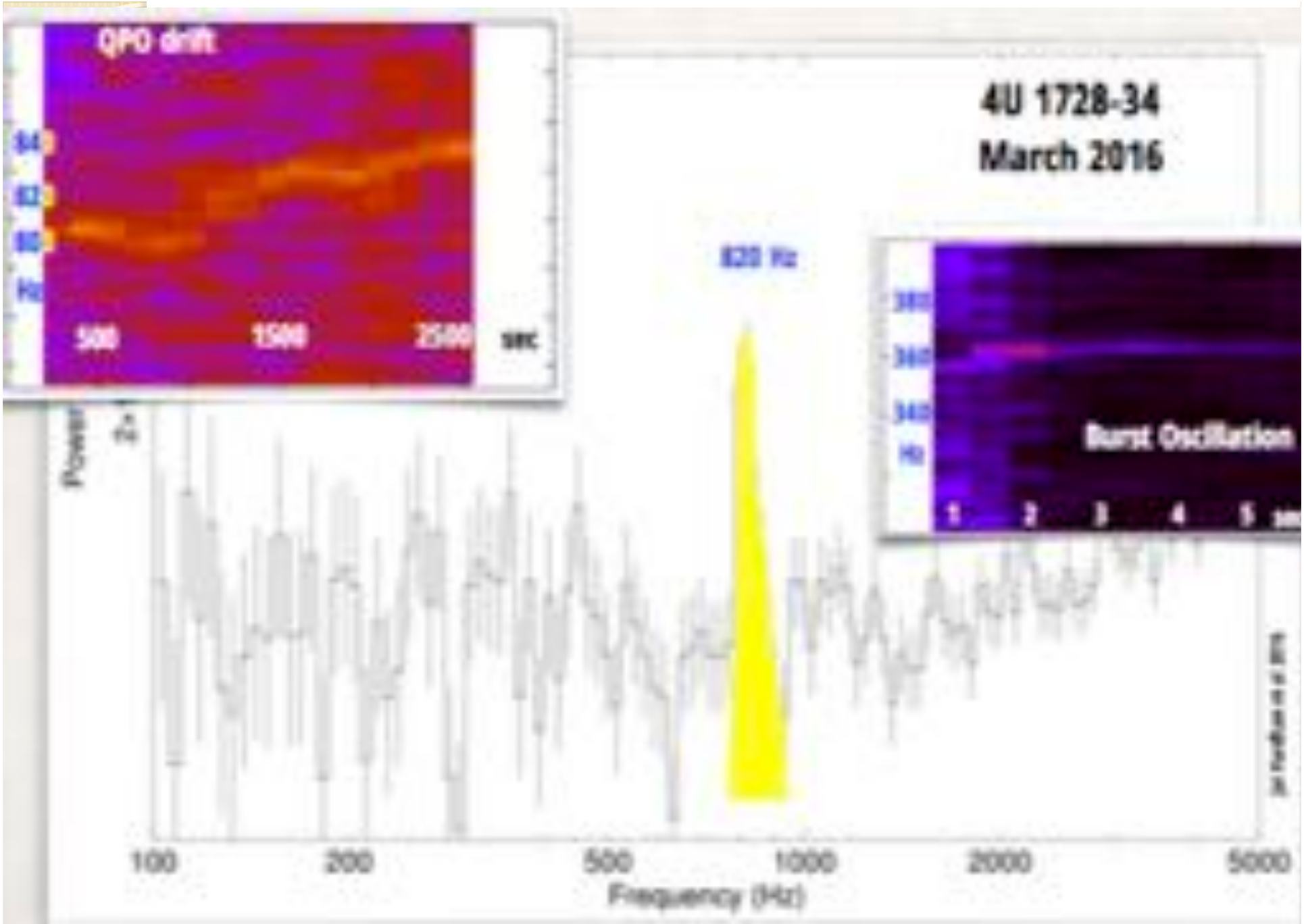



**Bhargava et al. 2016;Yadav (2016)**

# 4U 1630-472 : 2016 outburst

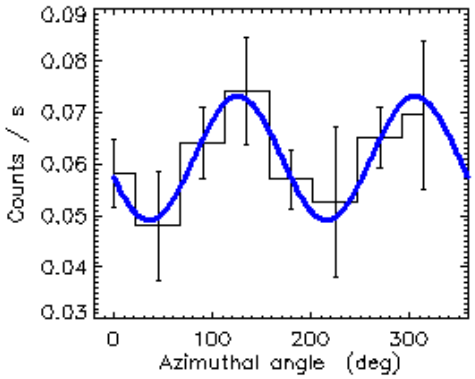


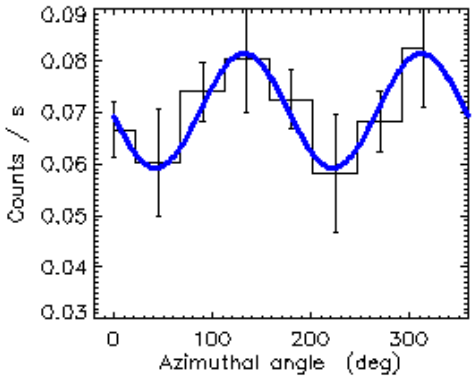

Yadav 2016

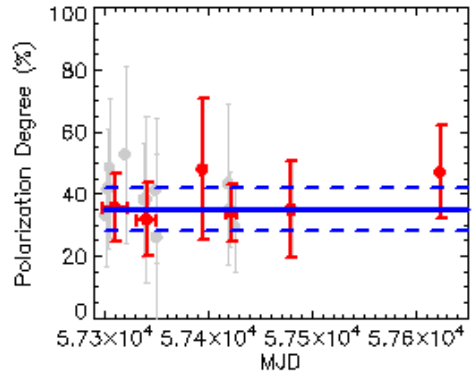

QPO drift
4U 1728-34
March 2016
Burst Oscillation
100
200
500
1000
2000
5000
Frequency (Hz)

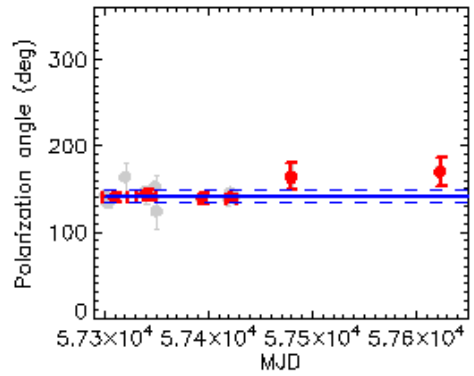
**Yadav 2016**

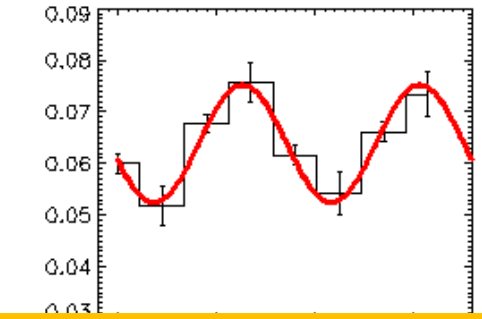
# Crab Polarization

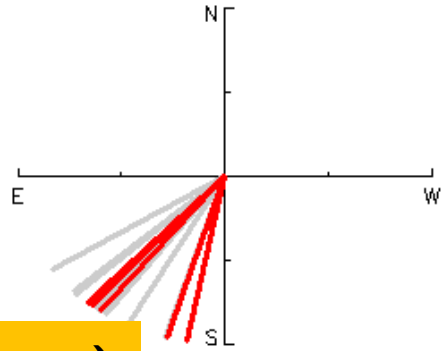


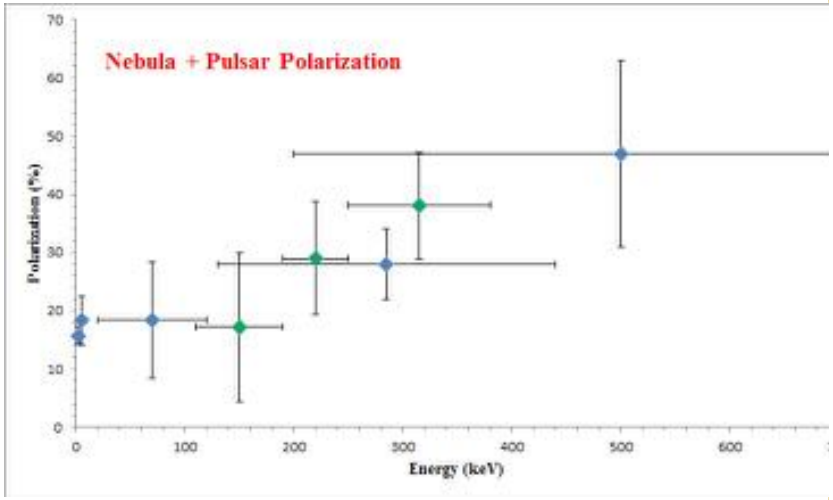



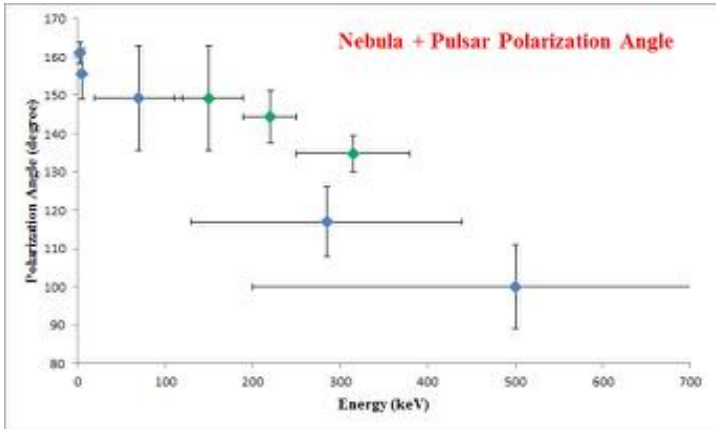





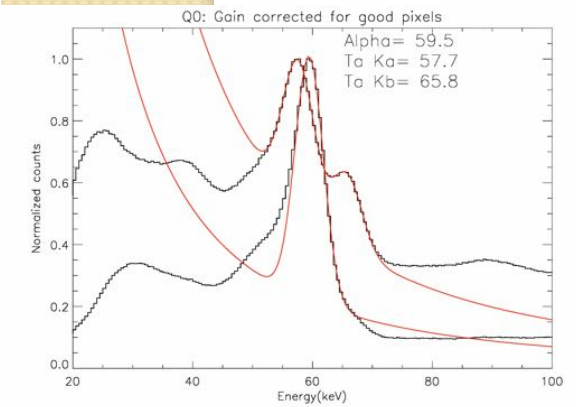




**Vadawale et al. 2016b (In prep.)**

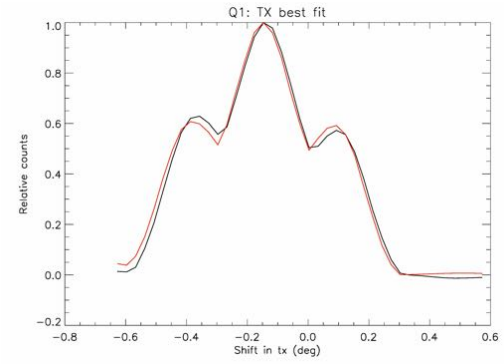
# A few key research areas …

- Cross-spectral calibration
- Millisecond ``events''
- Polarisation

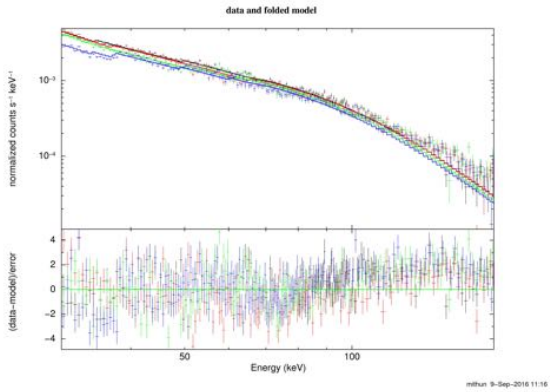
# Cross calibration and systematics



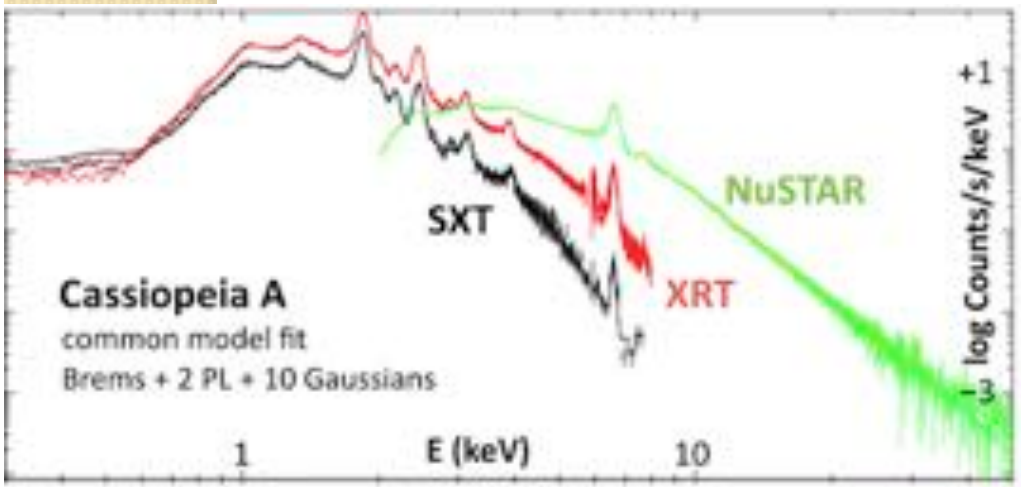

**Individual pixel gain**

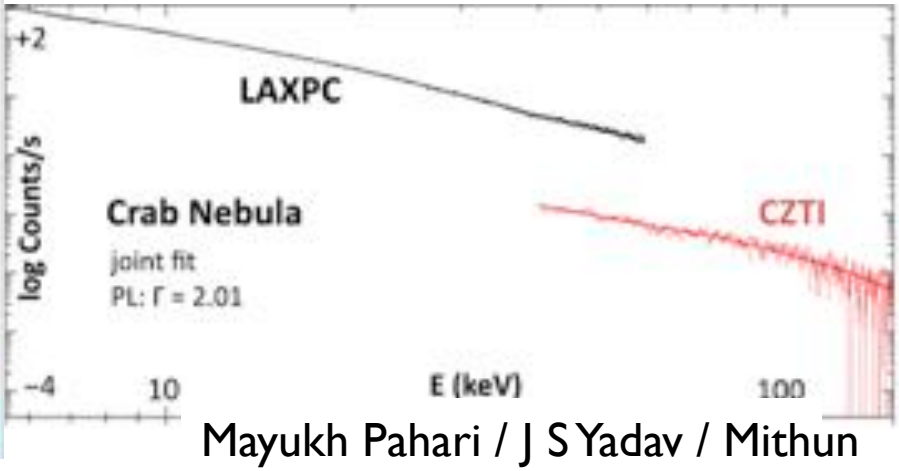



**Mask shift verification**




**Continuum spectrum**



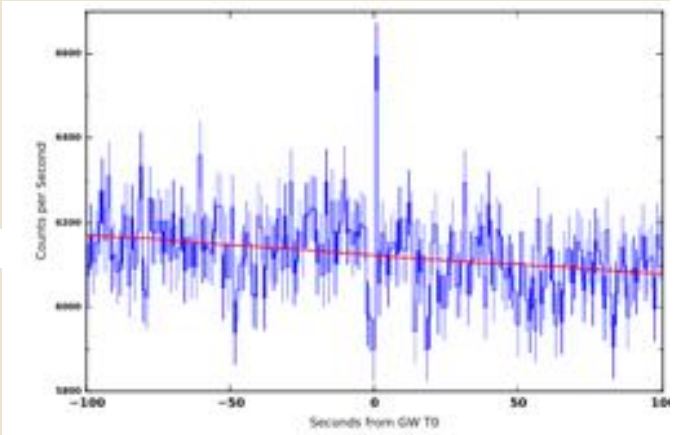

Mayukh Pahari / J S Yadav / Mithun

# Gamma-ray Bursts

*AstroSat*: 650 km; 6°

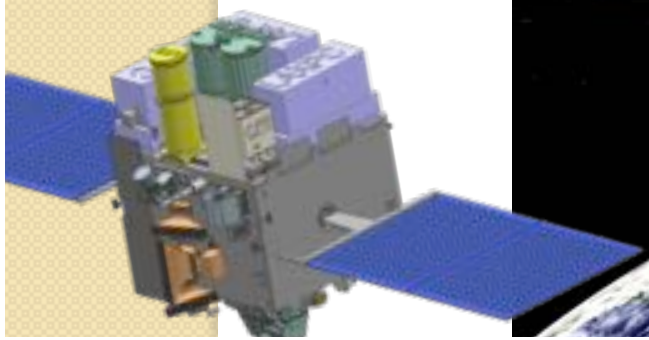
Fermi: 565 km 25°.6  Swift:  600 km 20°

- **First 10 months data. 214 total.**
- **~150 Fermi; ~60 Swift;  40 - 50 CZTI**
- **Full *AstroSat* mass model**
- **Possible GW counterparts.**



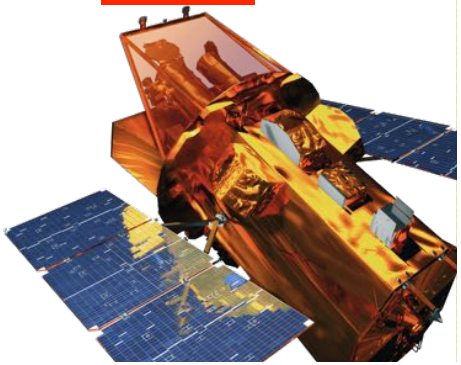

**Connaughton et al. 2016**
**See also Griener et al. 2016**

**Astrosat**

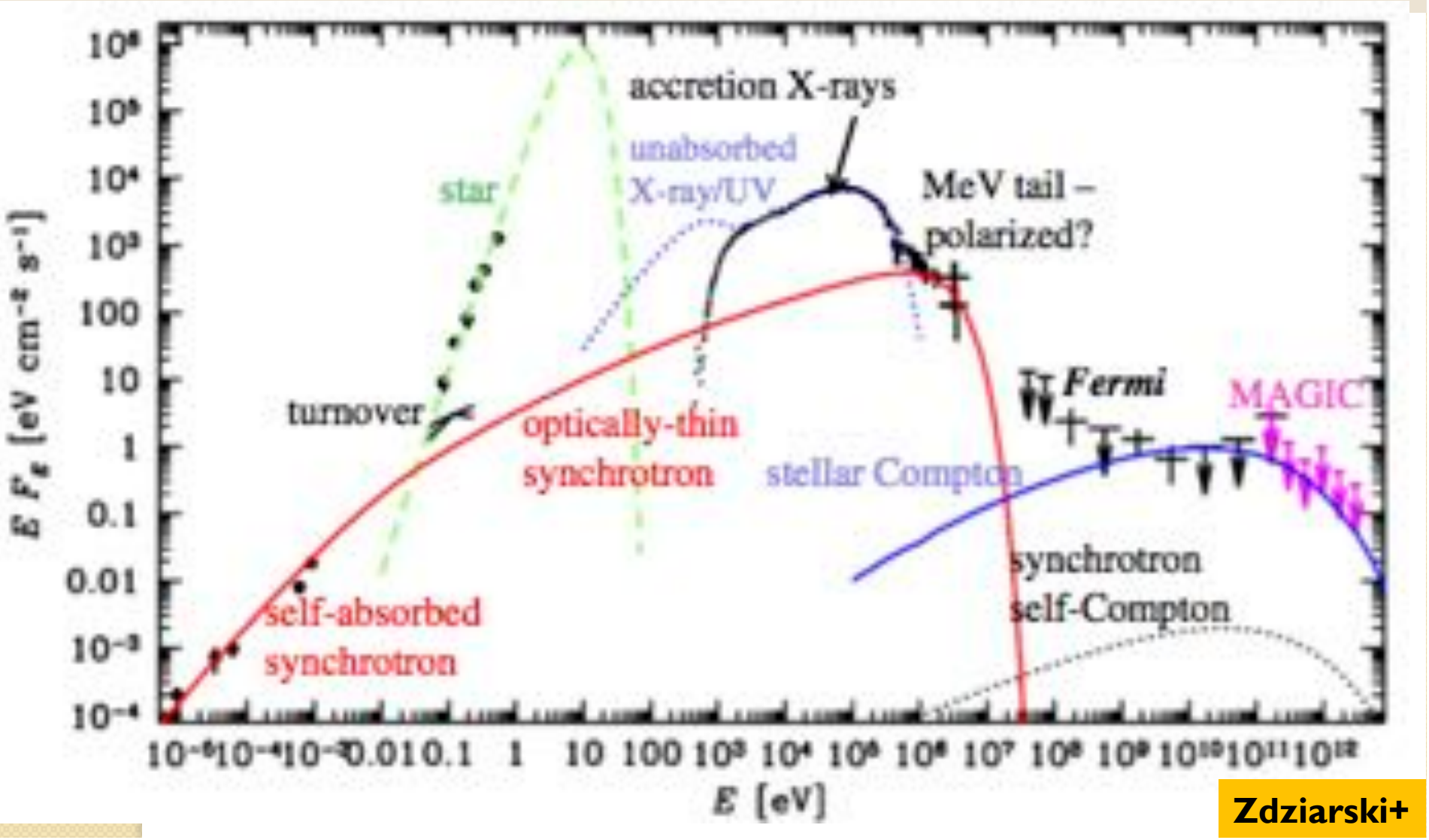


**Fermi**

**Swift**

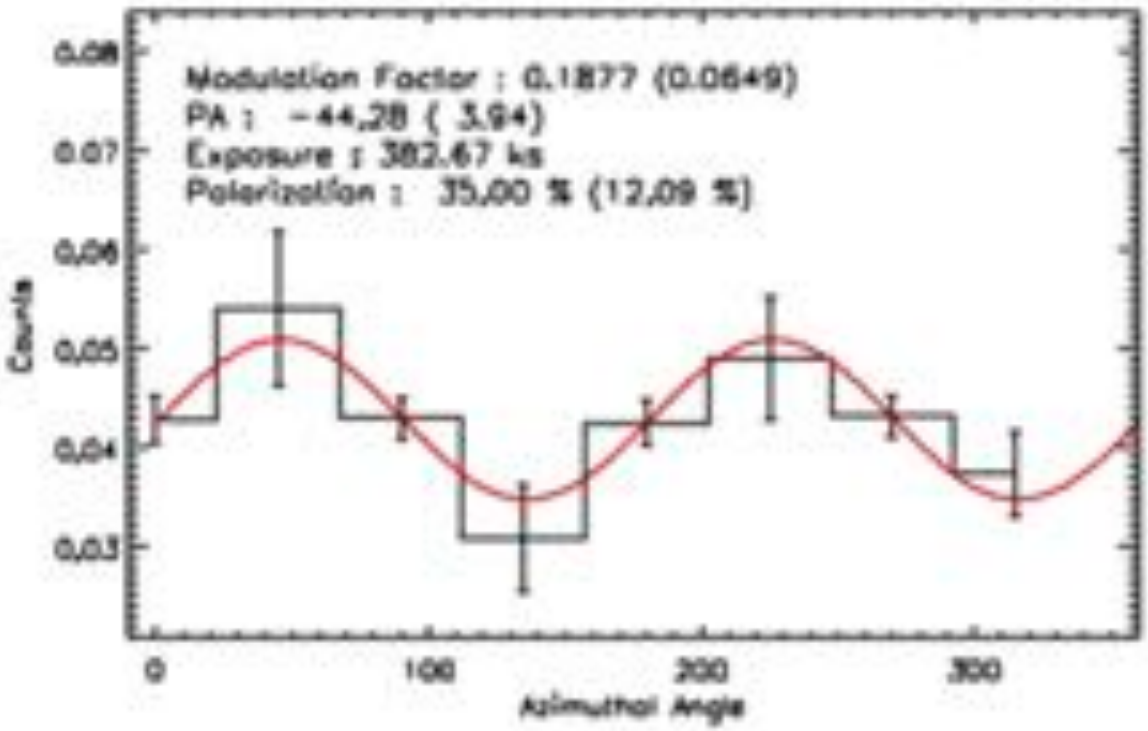


# Cygnus X-1: black hole binary




Zdziarski+

# Cygnus X-1: detection of Polarisation




**Vadawale et al. 2016c (In prep.)**

# Conclusions

- All instruments are performing as planned
- High energy timing response and hard X-ray polarization are the key features
- Regular observations are carried out
- Robust data analysis pipe line is being developed

- **Contacts:**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