Large Area X-ray Proportional Counter (LAXPC) Instrument onboard ASTROSAT

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ASTROSAT –

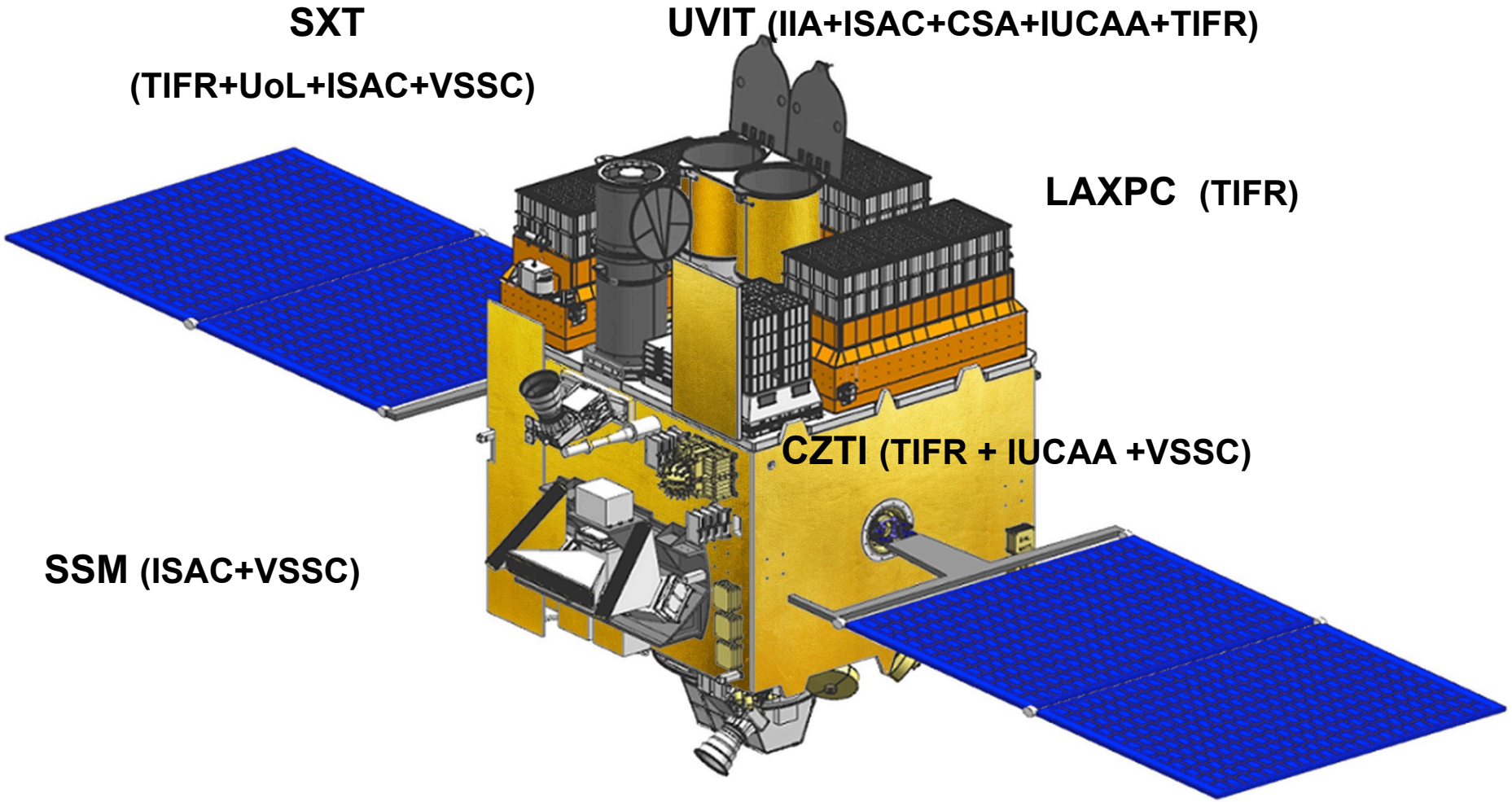
India's First Astronomy Satellite

simultaneous observations in multi-wave bands (UV to hard X-ray)

Five science payloads

***PSLV-XL C-30 carrying ASTROSAT*: 28th Sep 2015**

ASTROSAT: *Co-aligned multi-wave instruments*



Mass of 1513 kg. (750 kg. Payloads) + 6 more small satellites

Power = 2200 watts by solar panels + 2 x 36AH Li-ion batteries

ASTROSAT

Expected Performance Parameters of the scientific Instruments

ASTROSAT Payload Characteristics

	UVIT	SXT	LAXPC	CZTI	SSM
Detector	Intensified CMOS	X-ray CCD	Proportional Counter	CdZnTe Detector Array	Position Sensitive Proportional Counter
Type	Imaging	Imaging	Non-Imaging	Imaging	Imaging
Bandwidth	1300 - 5500 Ang.	0.3 - 8 keV	3 - 80 keV	10 - 100 keV	2 - 10 keV
Effective Area (Cm^2)	8 - 50 (Depends on Filter)	128 @ 1.5 keV, 11 @ 6 keV	8000 @5 - 20 keV	1000 @ E > 10 keV	~60 @ 5 keV
Field of View (FWHM)	28' Dia	~40' Dia	47' x 47'	4.6° x 4.6°	22° x 100°
Energy Resolution	< 1000 A	~ 5 - 6 % @ 1.5 keV	12% @ 60 keV	8% @ 100 keV	20% @ 6 keV
Time Resolution	1.7 ms	278 ms	10 µs	1 ms	1 ms
Total Mass (Kg)	230	65	414	50	48
Prime Responsibility	IIA	TIFR	TIFR	TIFR	ISAC

ASTROSAT

Launched into a nearly circular orbit with Altitude: 640 - 650 km;
Inclination : 6 deg.

- Orbital period : ~98 minutes;
- Eclipse period : 35 minutes; Sunlit period : 62 minutes
- Heaters and sensors for thermal control of all the payloads and subsystems as specified.
- Three-axis stabilization.
- Orientation by 4 reaction wheels and 3 magnetic torquers (capacity: 60 A m^2) + inputs from 3 dual gimbal gyros, 2 star sensors and 2 magnetometers.
- Target acquisition capability of 0.05°
- Pointing accuracy of ~1 arcsec with star sensors.
- Drift rate is expected to be 0.2 arcsec/s.
- Maximum slew rate will be 0.6°/s.
- Operational life > 5 years

Main Science goals:

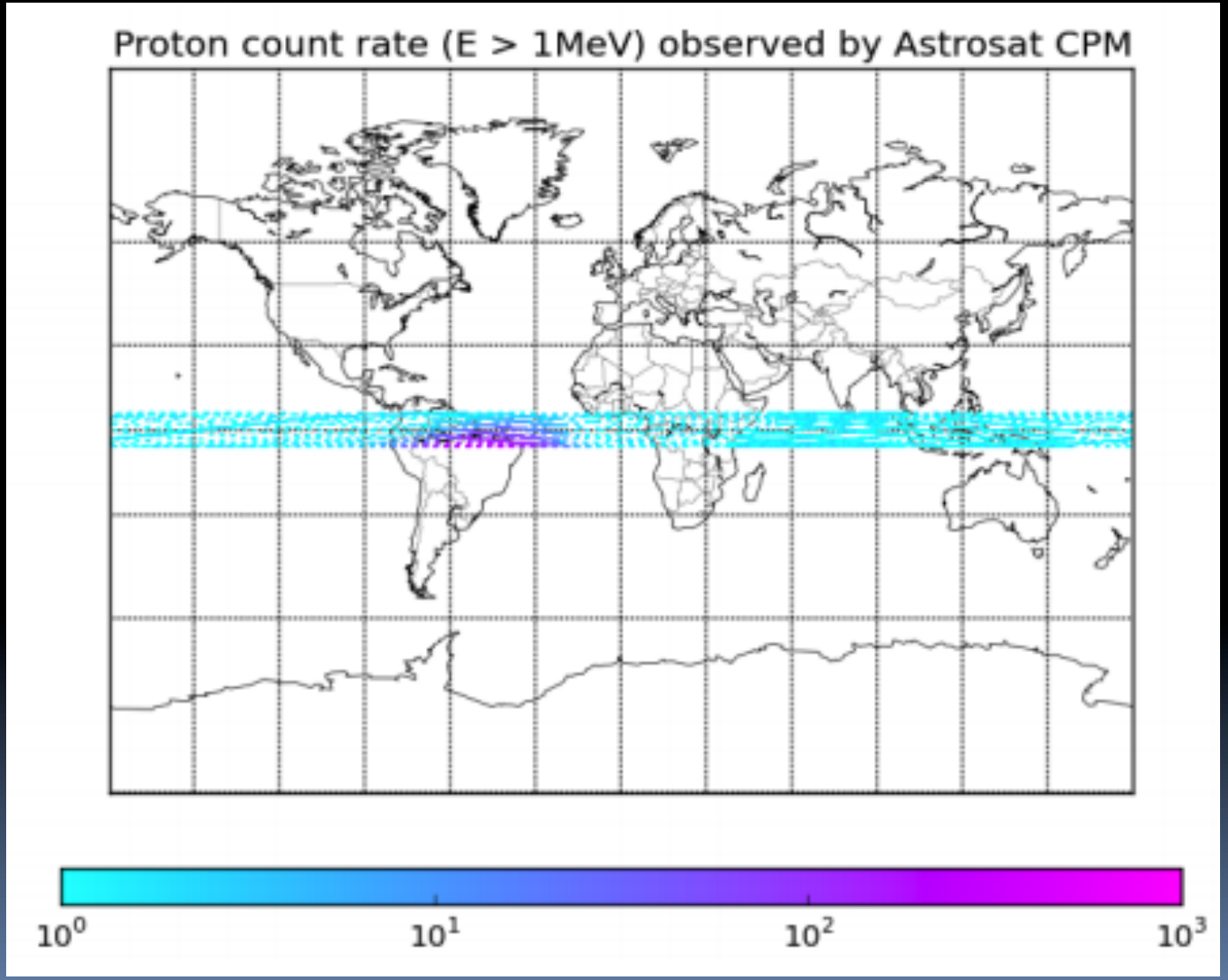
- Physics of regions with strong gravity

  →Accretion – White Dwarfs (CVs), Neutron Star Binaries and Black Holes (galactic, extragalactic – AGN).
- Physics of highly accelerated streams of particles

  →astronomical jets (Blazars)
- *Strong Magnetic fields (Cyclotron lines) etc.*
- *Physics of very hot coronal plasmas and their Hard X-ray components and flares*

Charge Particle Monitor samples SAA (Oct. 1, 2015)

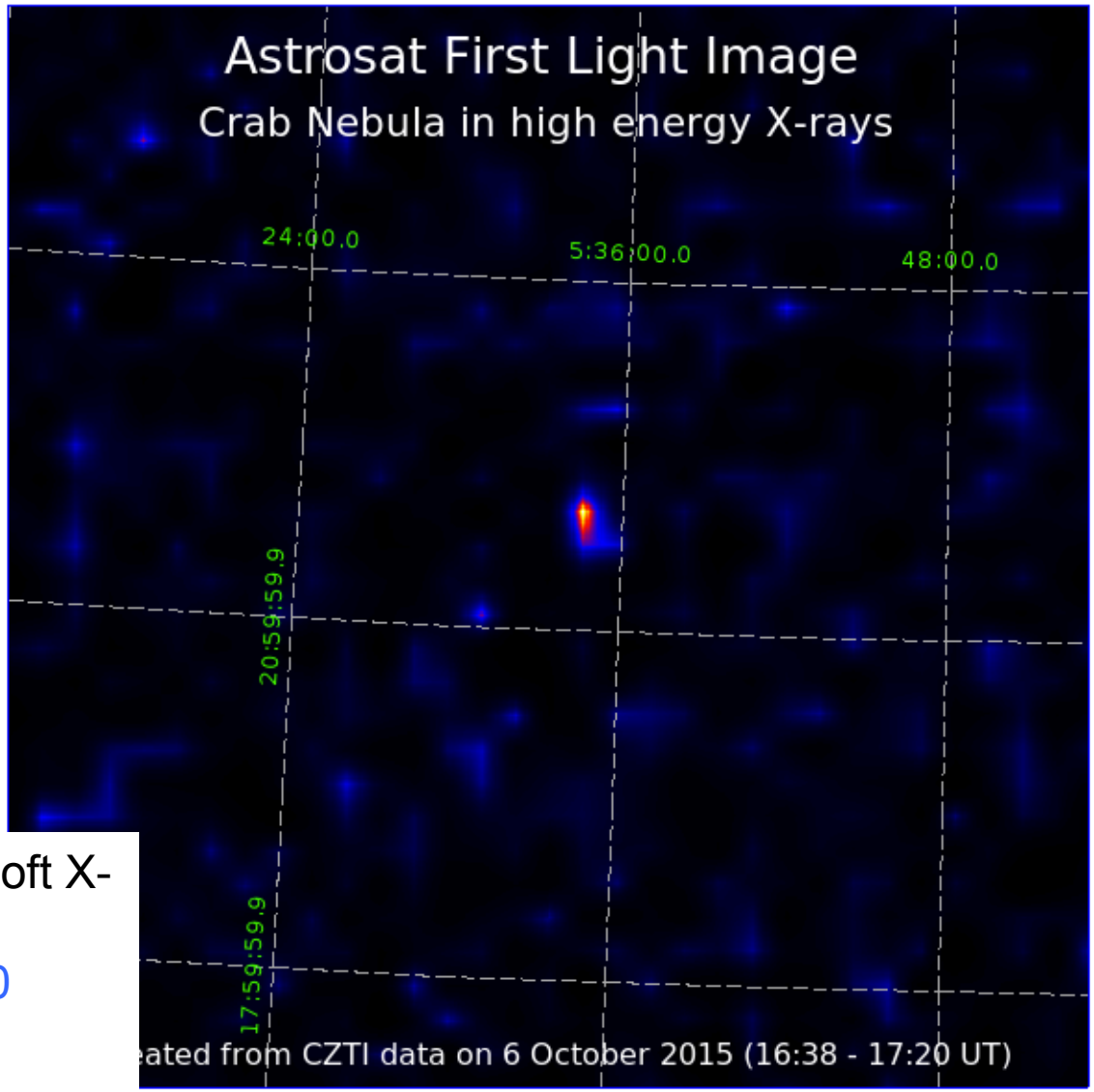
To monitor the SAA entry & exit to lower voltages of the LAXPC, CZTI, SSM



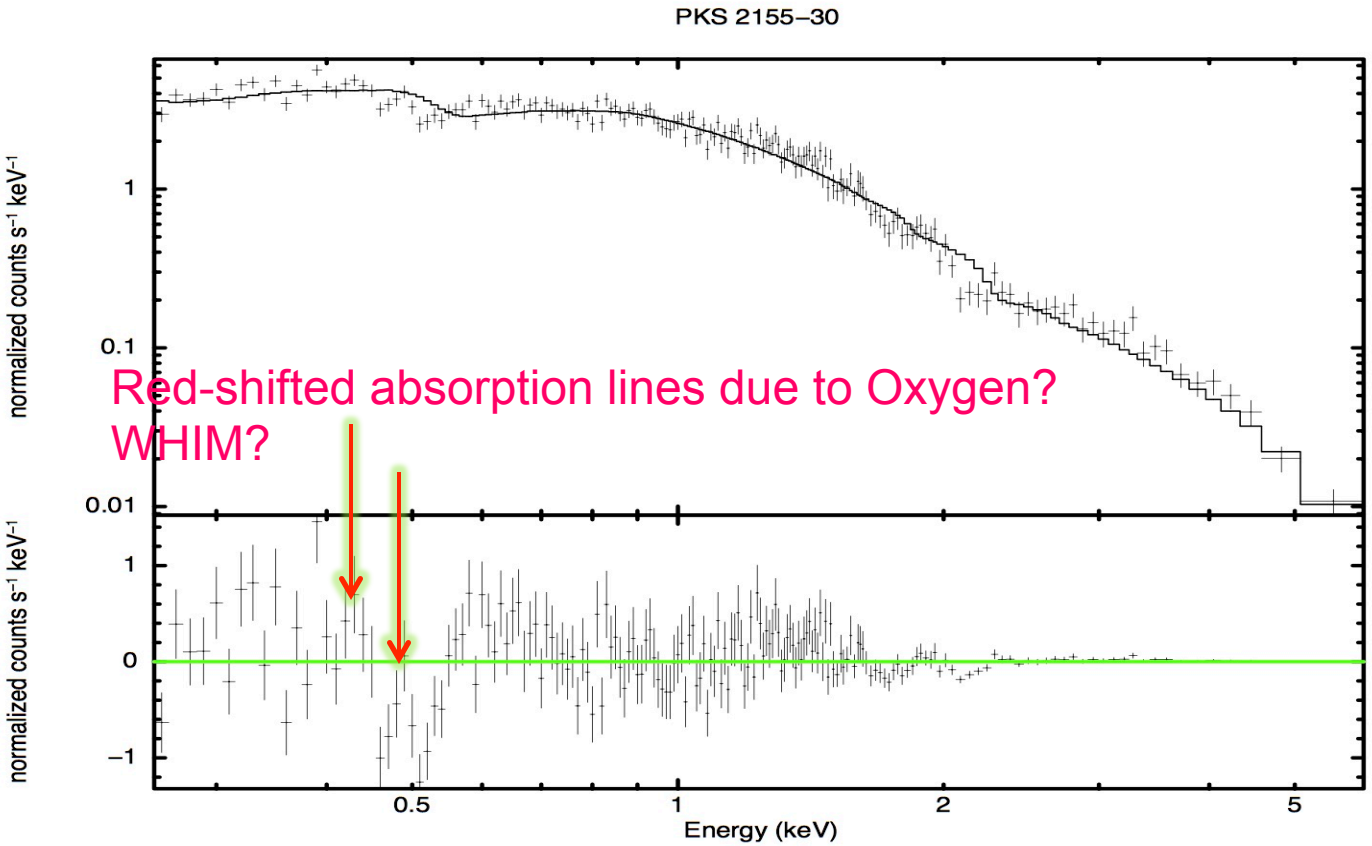
CZTI: Crab (6th October, 2015)

X-rays > 25 keV
Resolution: 10 arcmin
(Moon Dia: 30 arcmin)

Image (blue) in Soft X-rays: ~2 arcmin
Power of 100,000 suns.
33 ms Pulsar (29.65 Hz)



SXT ; PKS2155-304 (26th Oct., 2015)



UVIT (1st Dec., 2015)

Doors

Main-baffles

Secondary Mirror

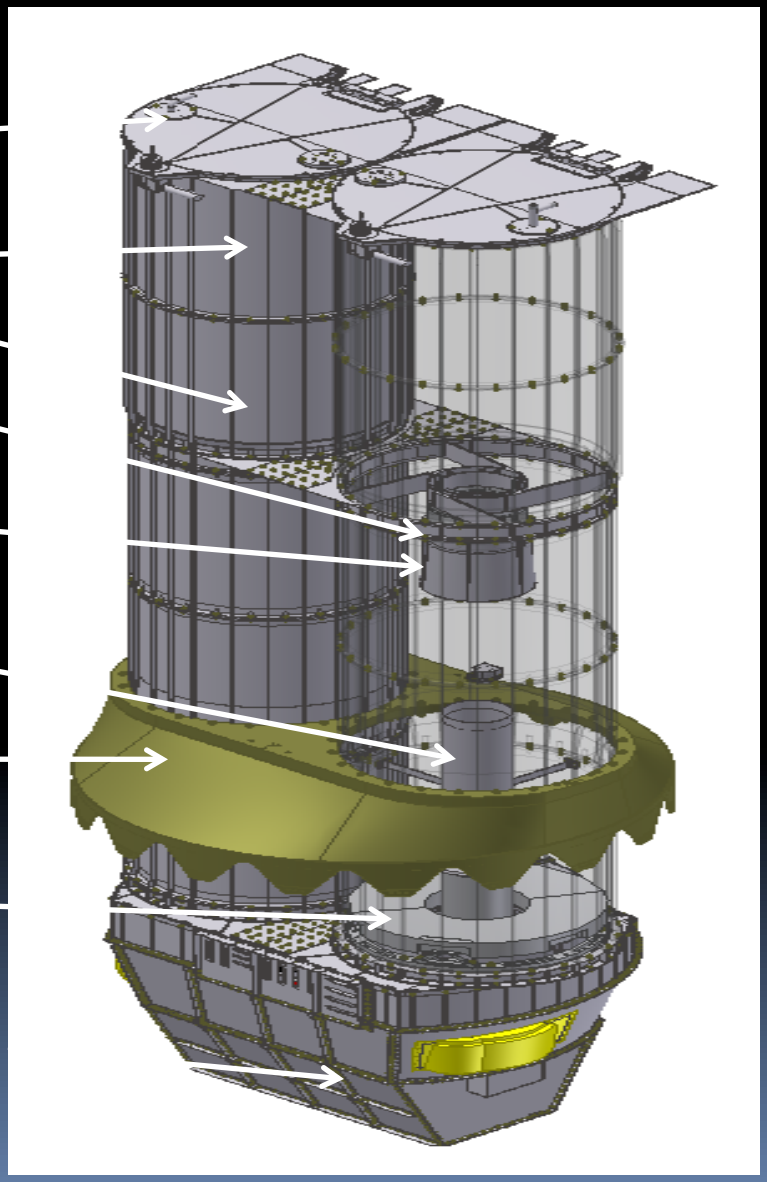
Sec. Baffle

Primary Baffle

TiCone (interface
With S/C)

Primary mirror (375 mm)

Thermal cover (this encloses
Detectors and filter-wheels)



~3100 mm

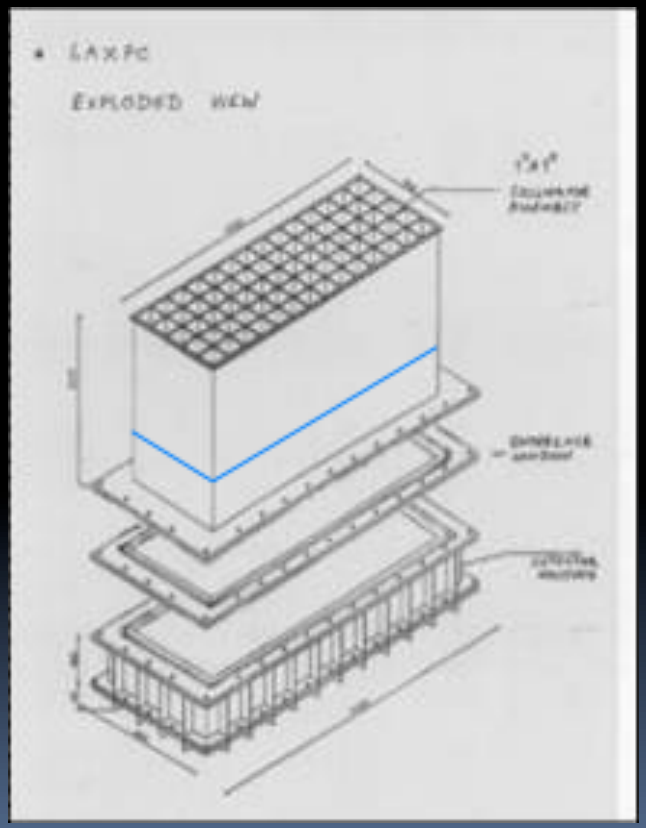
LAXPC: Large Area Xenon Proportional Counters (~419 Kg)

X-ray timing (10 μsec) low spectral resolution studies

A broad energy band (3 - 80 keV) with high detection efficiency

- Three co-aligned identical Counters
- Each with a multi-wire-multi-layer configuration filled with 90%Xe +10% Methane gas at 1520 torr. Energy resolution (12%@22 keV)
- A 50 micron thick aluminized Mylar window for X-ray entrance
- ***Mylar film support --*** by a honeycomb window support collimator
- A narrow field of view of .8x.8 degs provided by *mechanical collimators made of a sandwich of* 50μ Sn + 25μ Cu + 100μ Al co-aligned with the window support collimator and sitting above it.
- Blocking shield on sides and bottom : 1mm Sn + 0.2 mm Cu

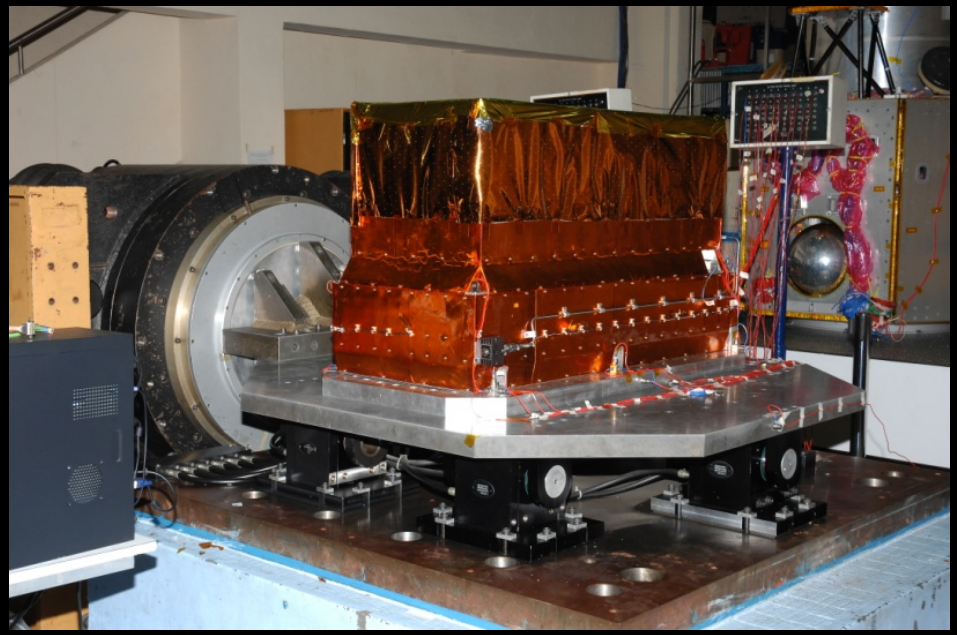
60 anode cells 3 cm x 3 cm x 100 cm in 5 layers each 3 cm deep (12 anodes/layer). Mutual & layer by layer anticoincidence + Veto layers of 46 anodes cells (1.5x1.5 cm)
1600 wires – tension 80 gm per wire

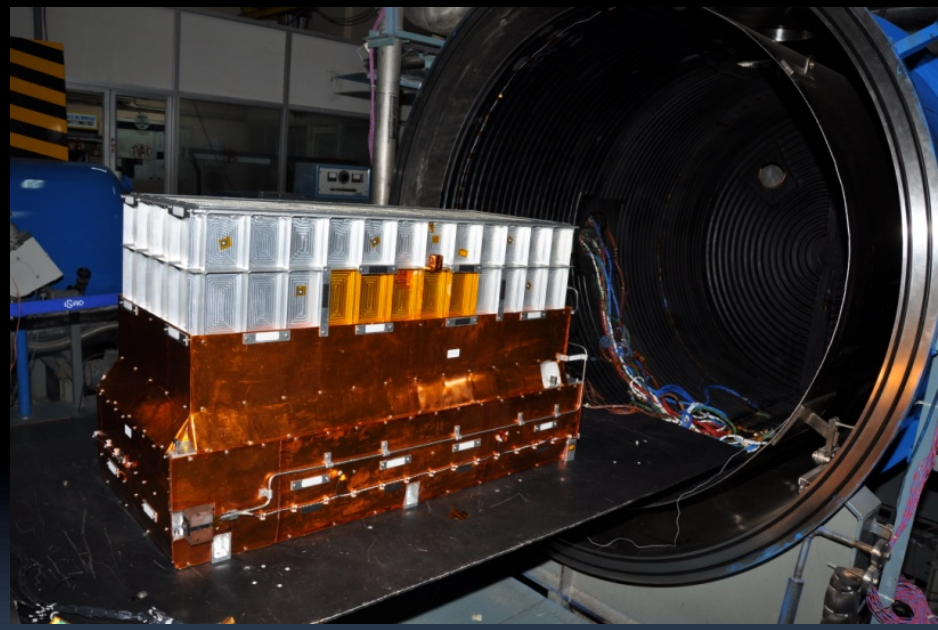


- **LAXPC Instrument consists of 3 identical detectors.**
- **Each LAXPC has the following major components :**
  - **Field of View Collimator (FOVC)**
  - **Window Support Collimator (WSC)**
  - **Collimator Housing**
  - **Anode Frames**
  - **Detector Housing**
  - **Back Plate**
  -

LAXPC-10 vibration test

LAXPC-20 thermovac test

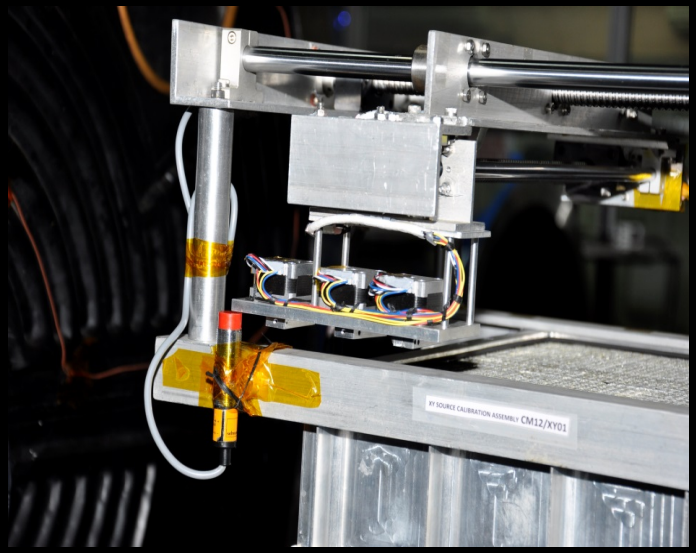


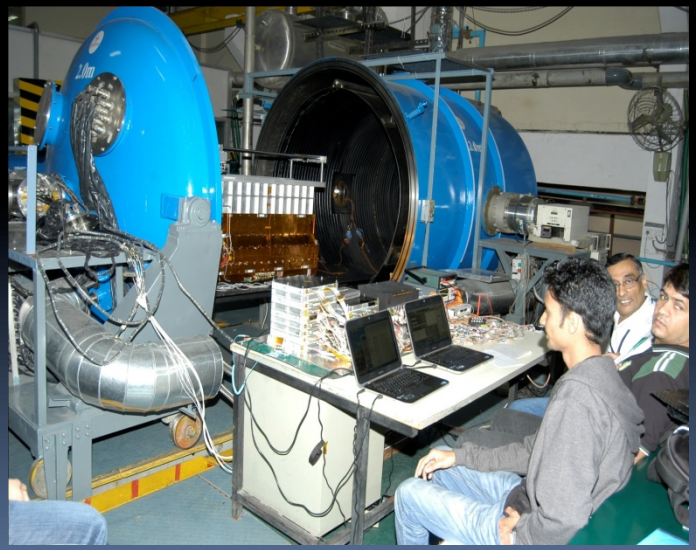


After completing all electronic & detector tests and final calibration, all three flight units of LAXPC instrument were handed over to ISRO for integration with satellite on 20th October, 2014.

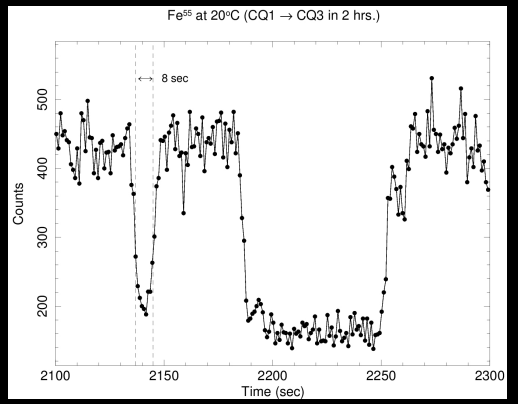
Test set-up

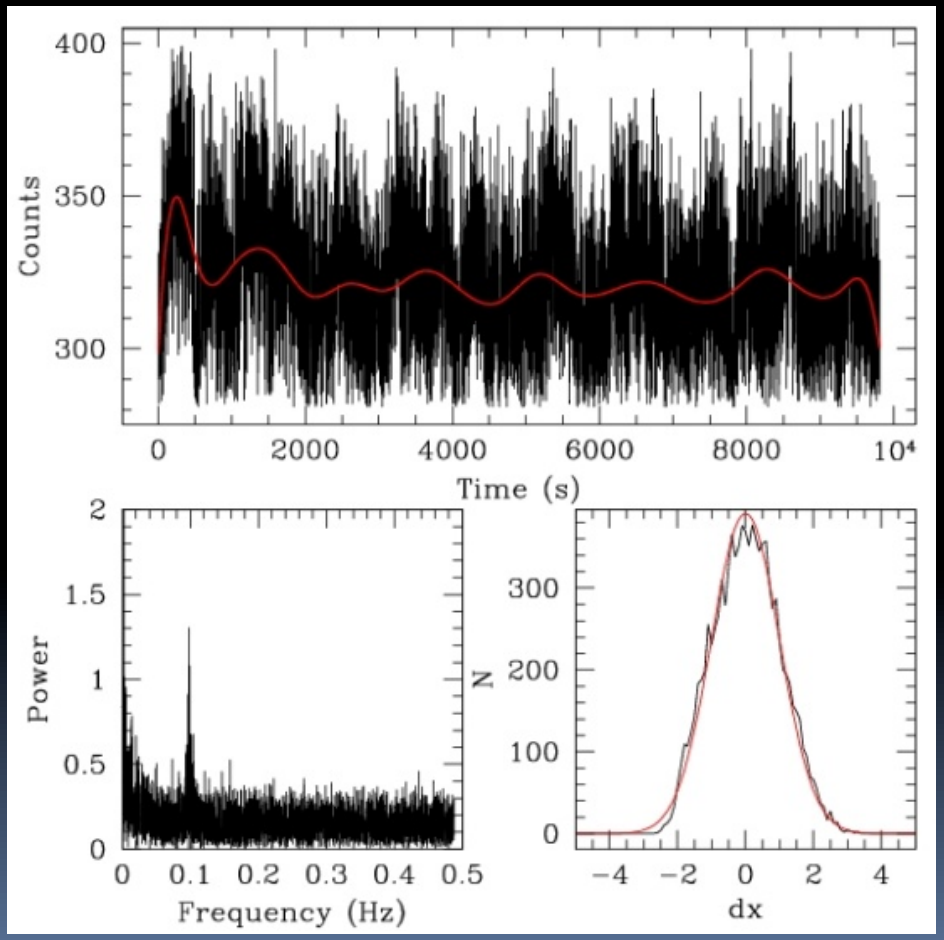
- Three radioactive sources, Iron (Fe^{55}), Cadmium (Cd^{109}) & Americium (Am^{241}), were used for the calibration of LAXPC flight detector.
- The thermovac chamber pressure were about ~$1x10^{-6}$ mbar at various temperature.
- The complete chain (Flight Detector + PE + STBG) was setup.



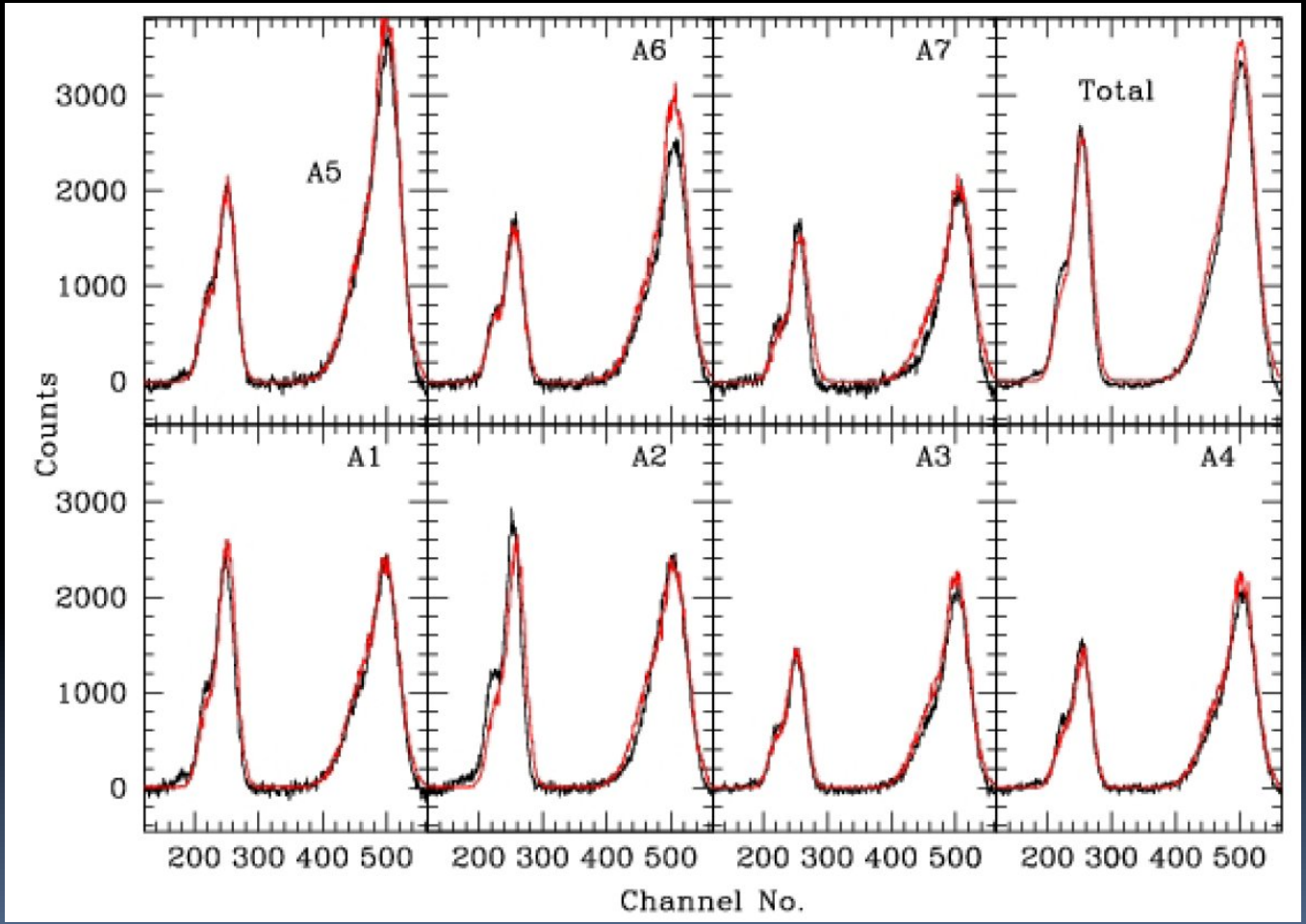


- Calibration by using remotely controlled x-y motion and on/off of radio active sources from out side the thermo vac chamber
- Study of Collimator characteristics
- GEANT4 simulation of LAXPC detector

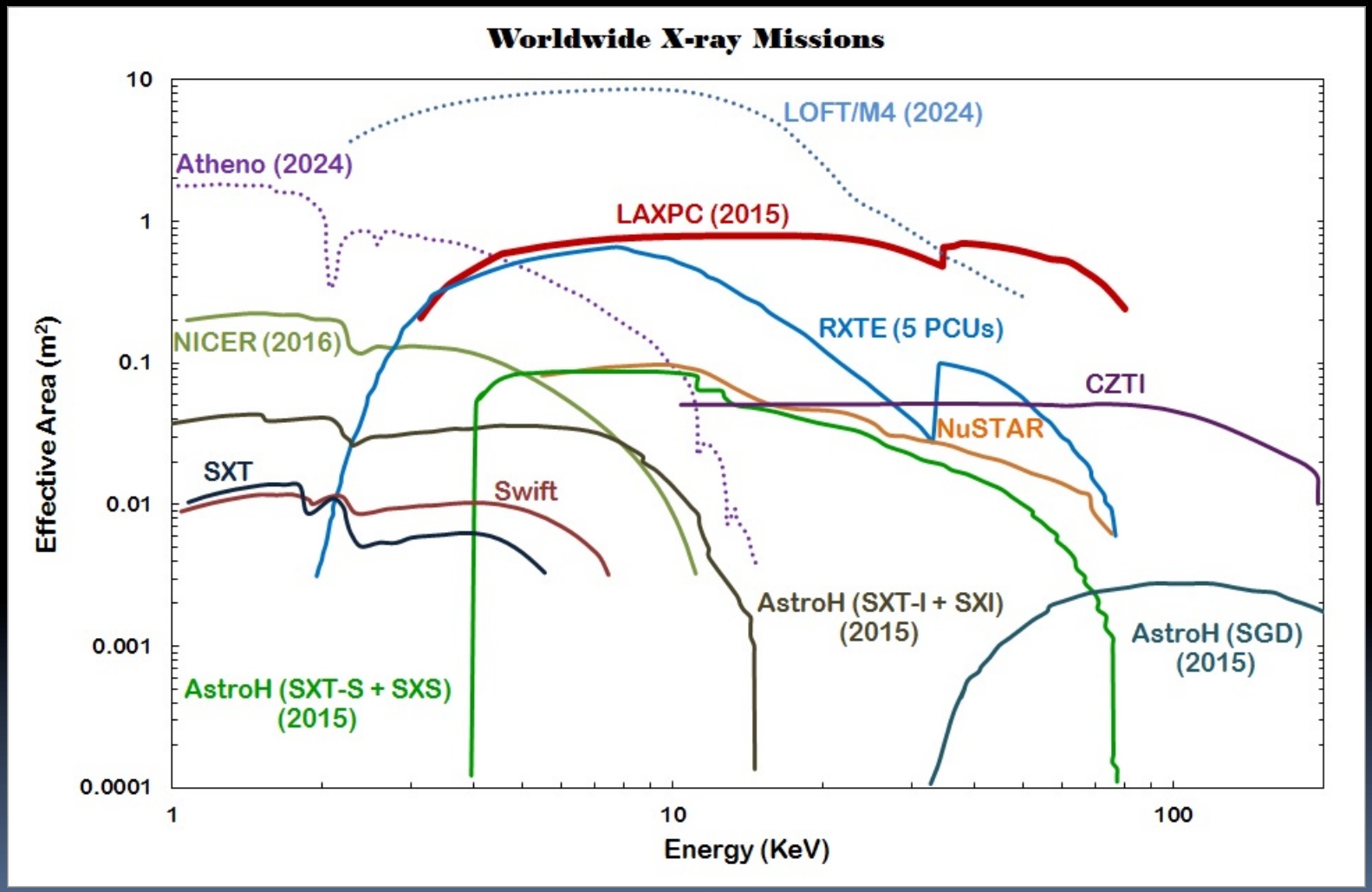




GEANT4 simulation for LAXPC30 unit & results for Am source (all 5 layers)



ASTROSAT: A comparison with other X-ray Satellites



Effect of purification on energy resolution

Each of the LAXPC detectors will have an onboard gas purification system. This system will be operated as and when required to purify the gas filled in the detector by command. It is expected that energy resolution of LAXPC detector will degrade as impurity increases. The impurity rate is expetected to be more in the lab than that in orbit. We have tested purification system in the laboratory and figure (bellow) shows the improment in detectror resolution after purification of LAXPC30.

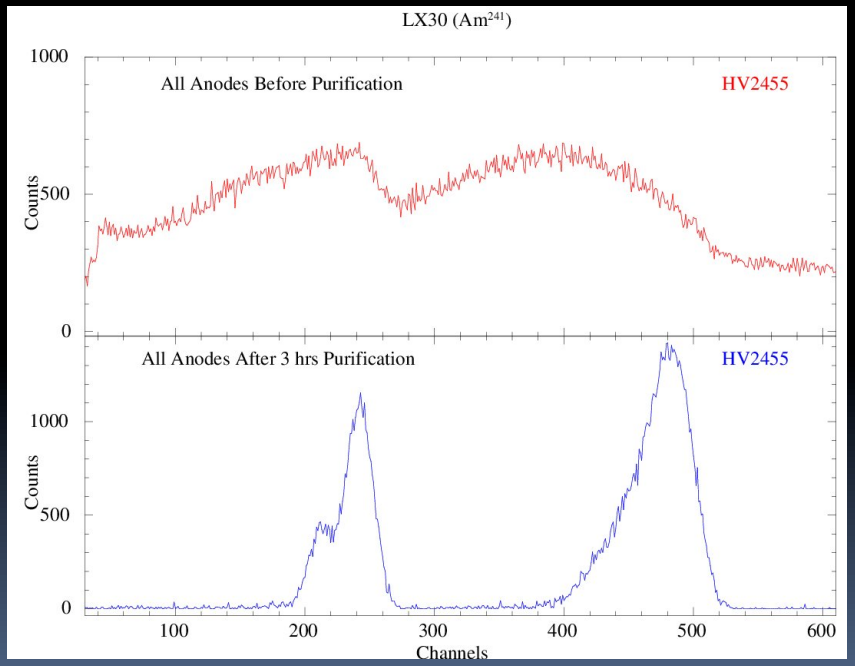
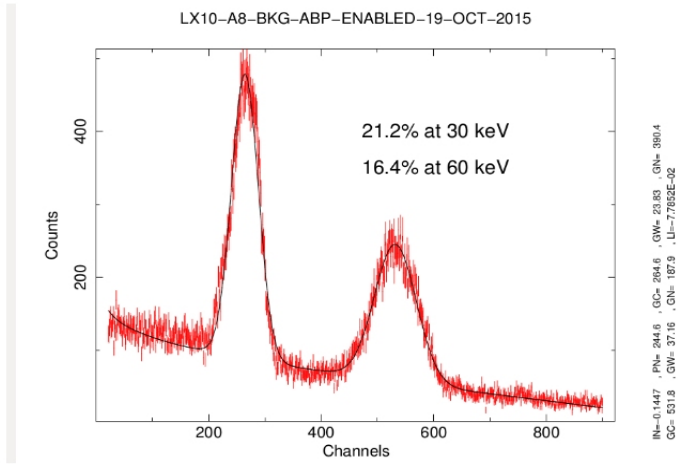
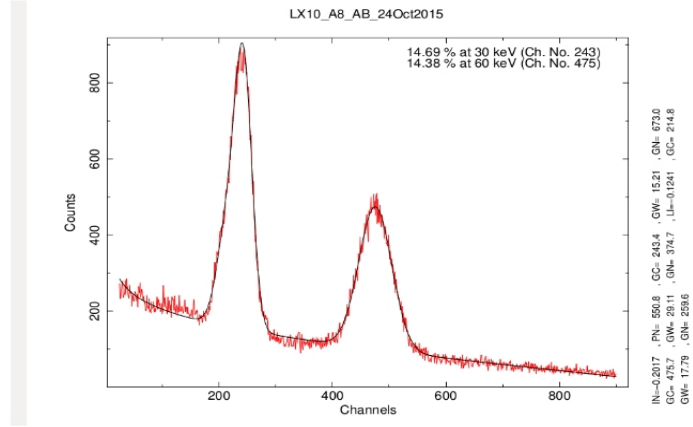
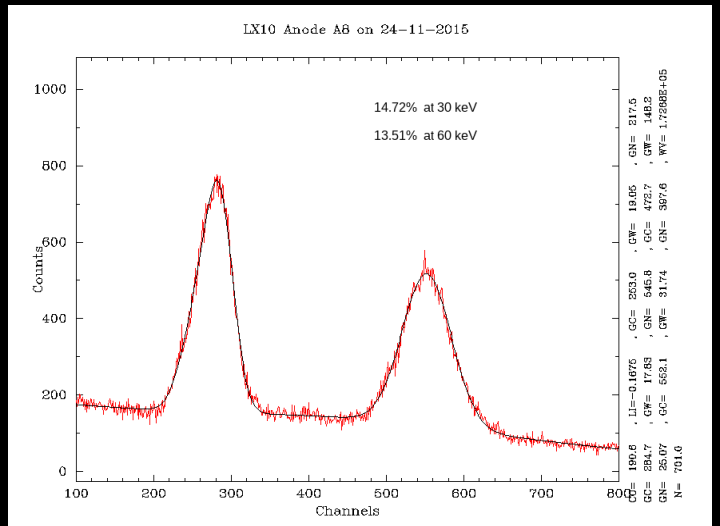


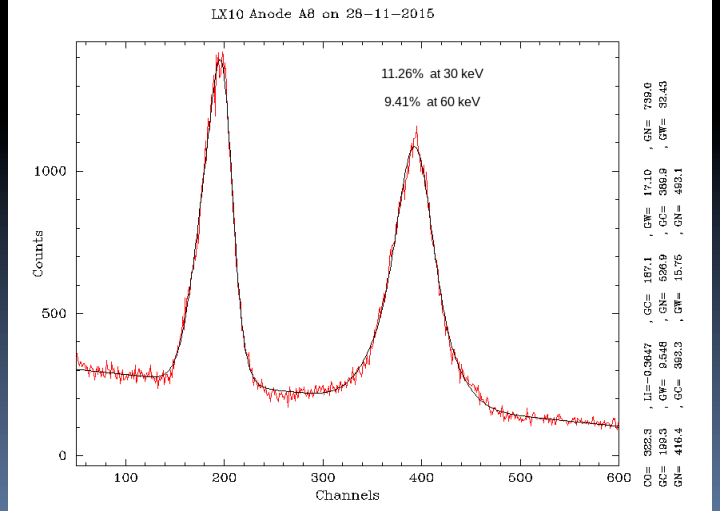
Figure : LAXPC30 detector energy resolution before (top) and after (bottom) purification.

Purification and improvement in energy resolution for LAXPC10 October & November 2015 (in orbit data)



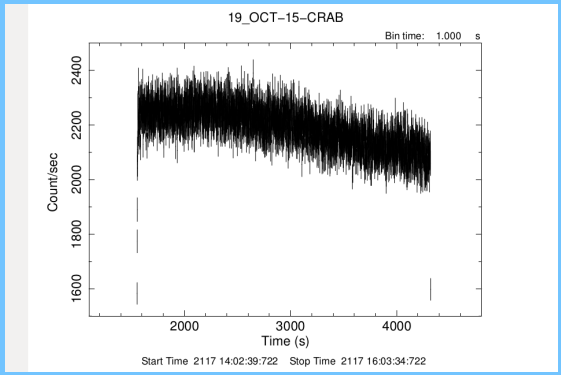


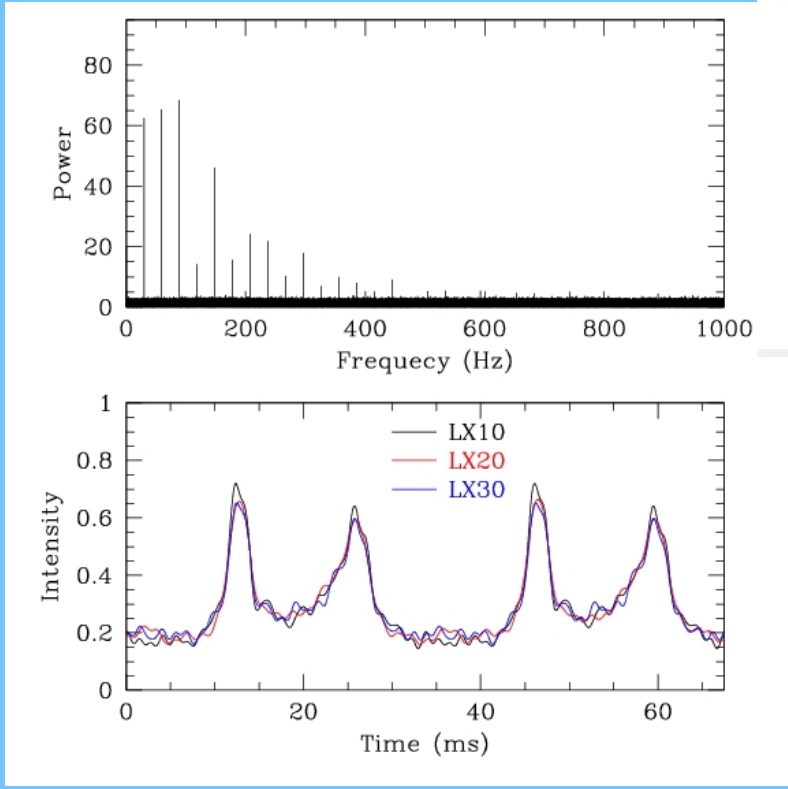




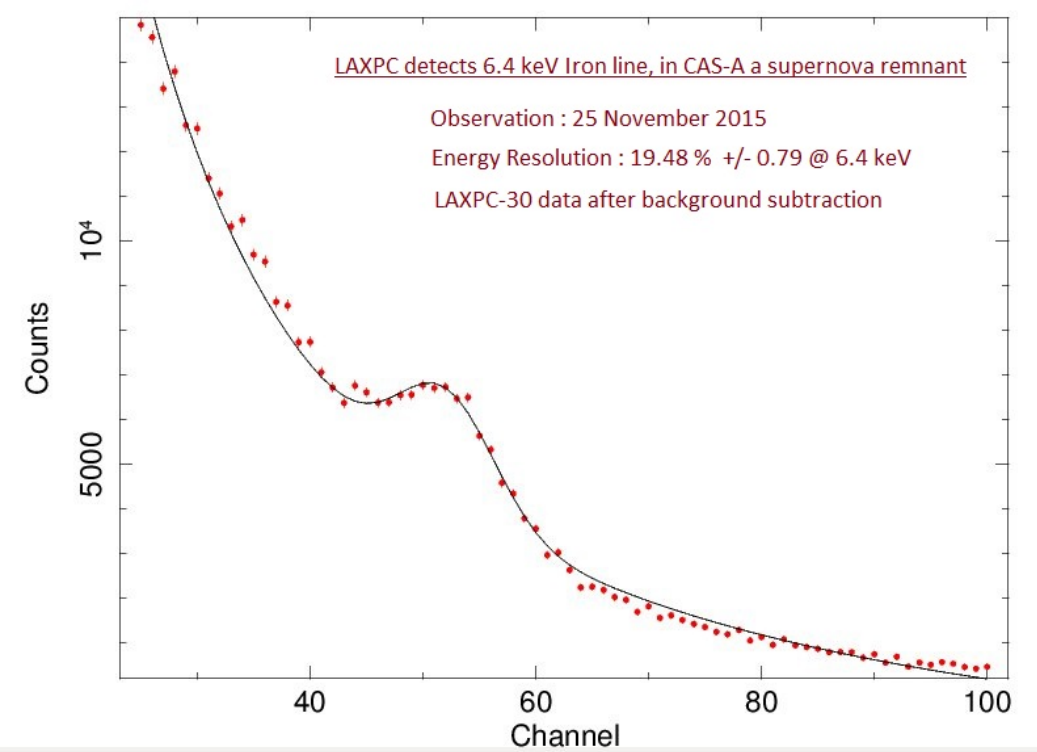
LAXPC first results :

Crab (a pulsar)



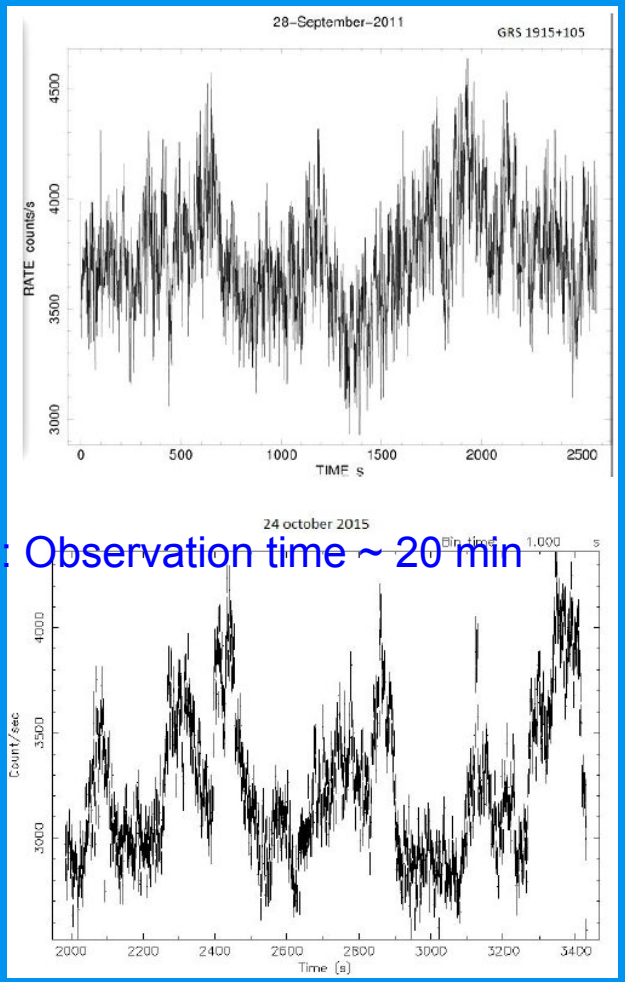


CAS –A (supernova remnant)

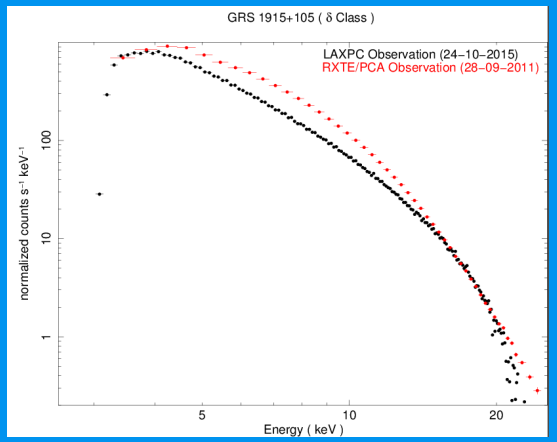


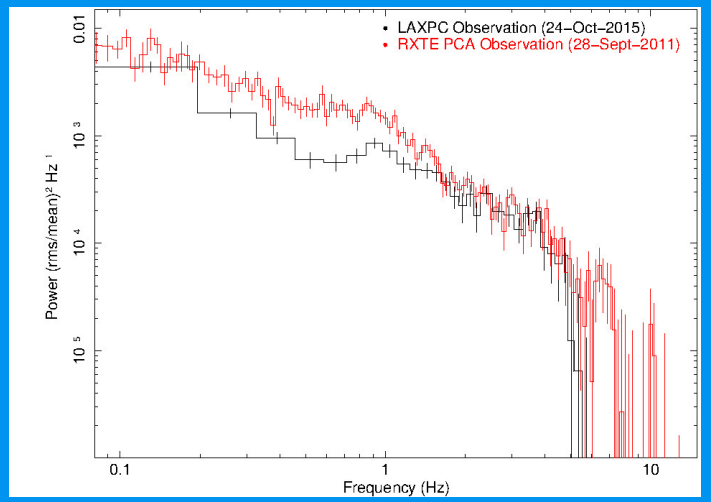
LAXPC first results:
Comparison with NASA RXTE/PCA for Black hole source; GRS 1915+105

RXTE/PCA: Observation time ~ 40 min



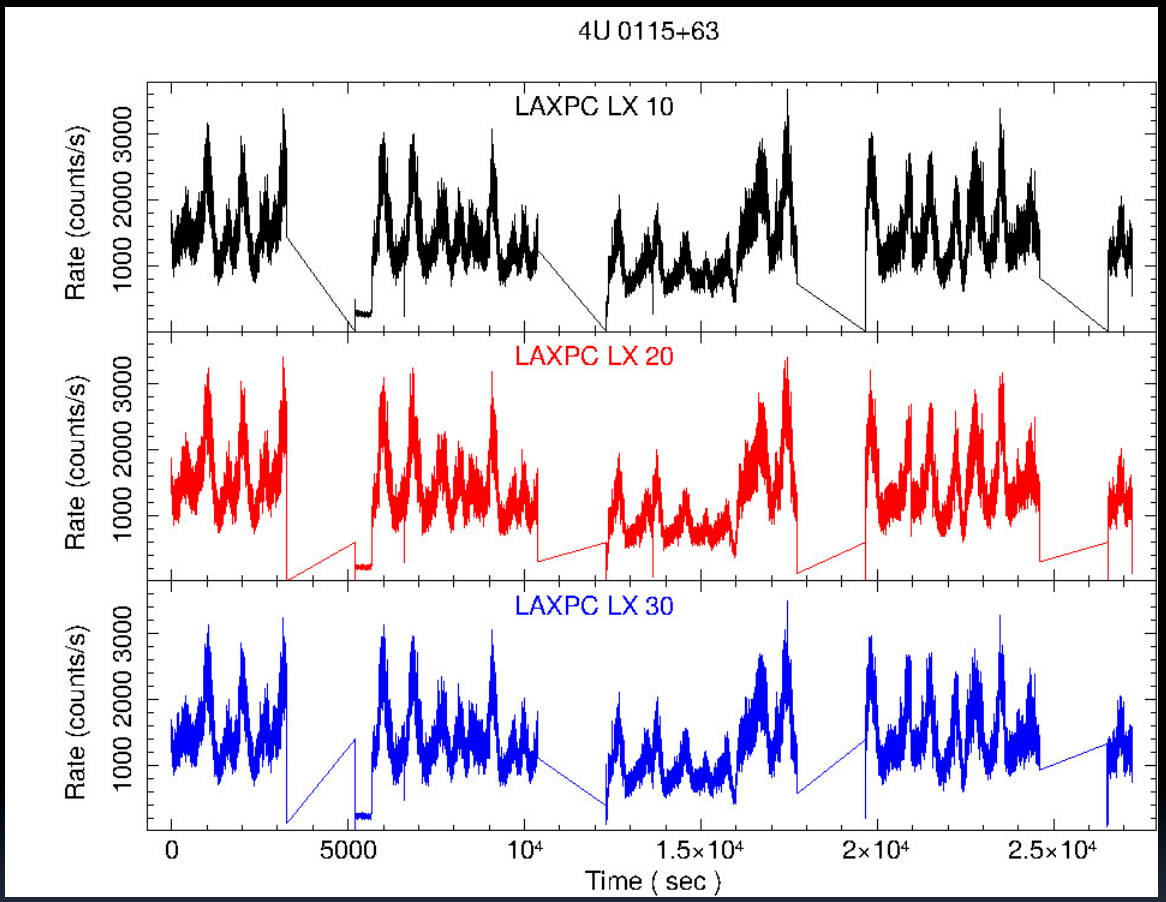
LAXPC : Observation time ~ 20 min

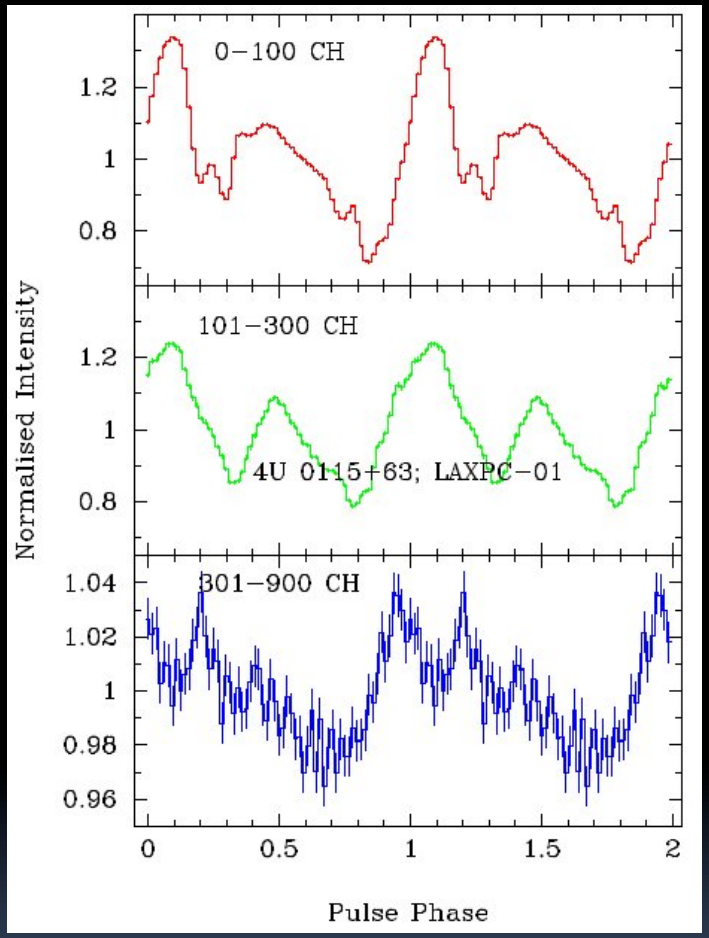




Detects δ X-ray class; a sub class of the high soft state (thermal state).

LAXPC first results: 4U 0115+63 (a pulsar in outburst)

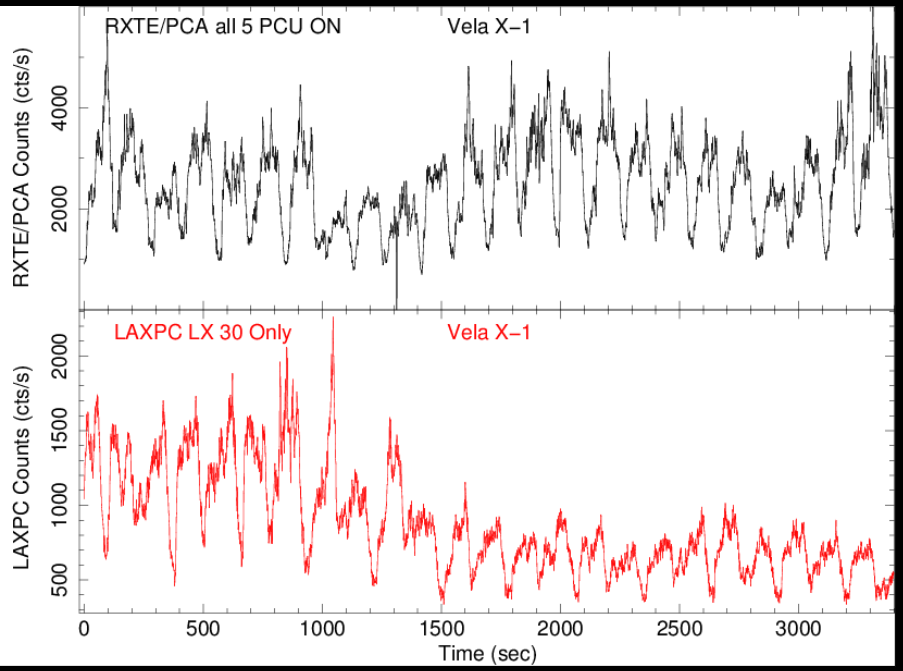


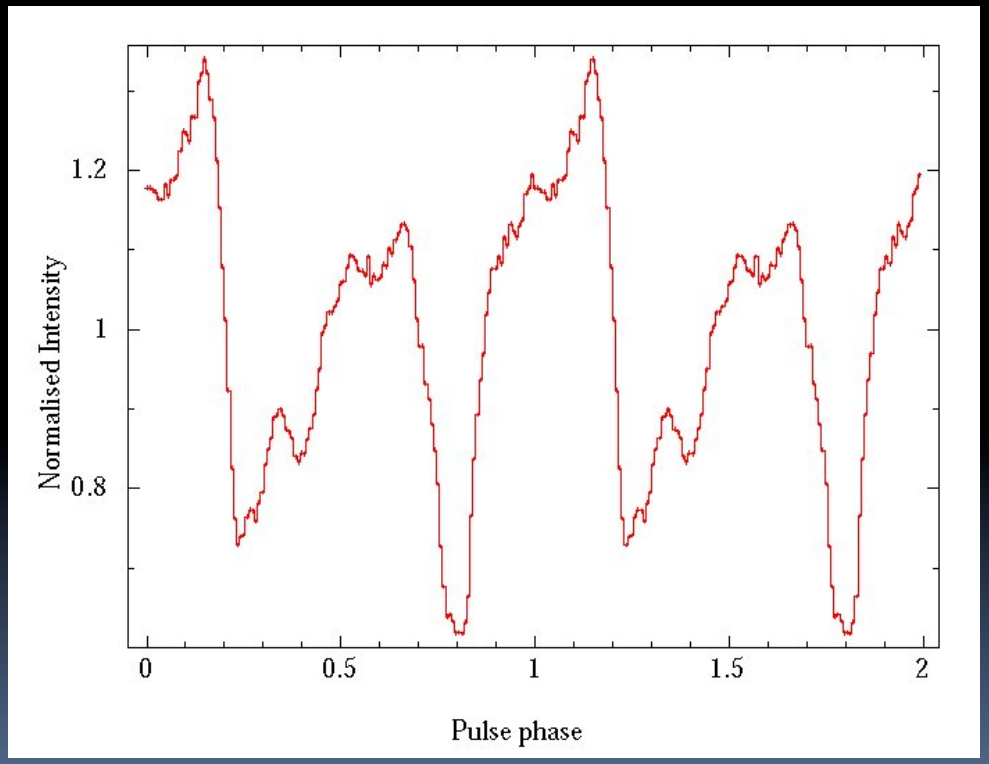


Transient X-ray pulsar (3.6 seconds) 4U0115+63.

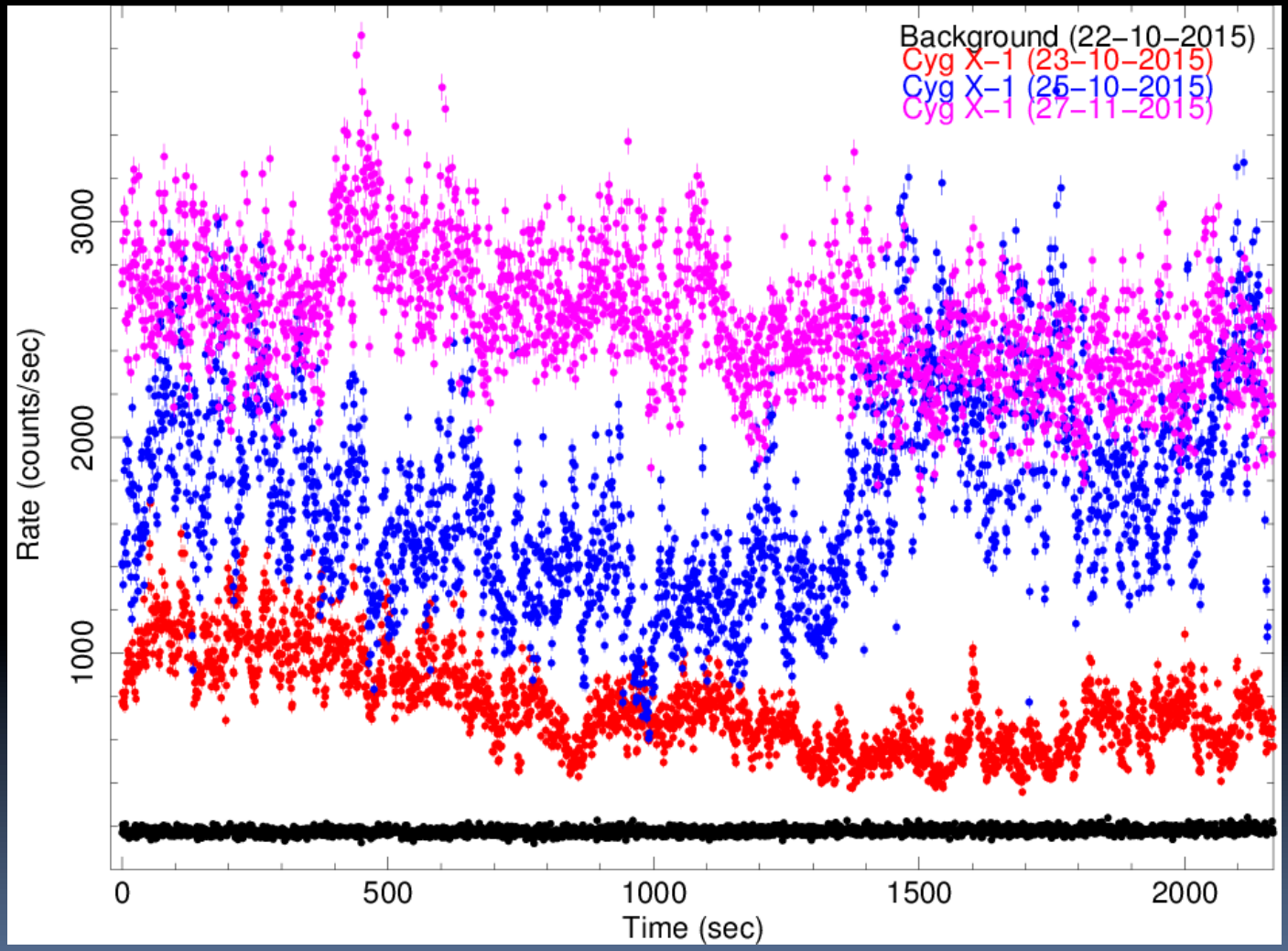
High Mass X-ray Binary with a neutron star (high magnetic field) companion that accretes mass

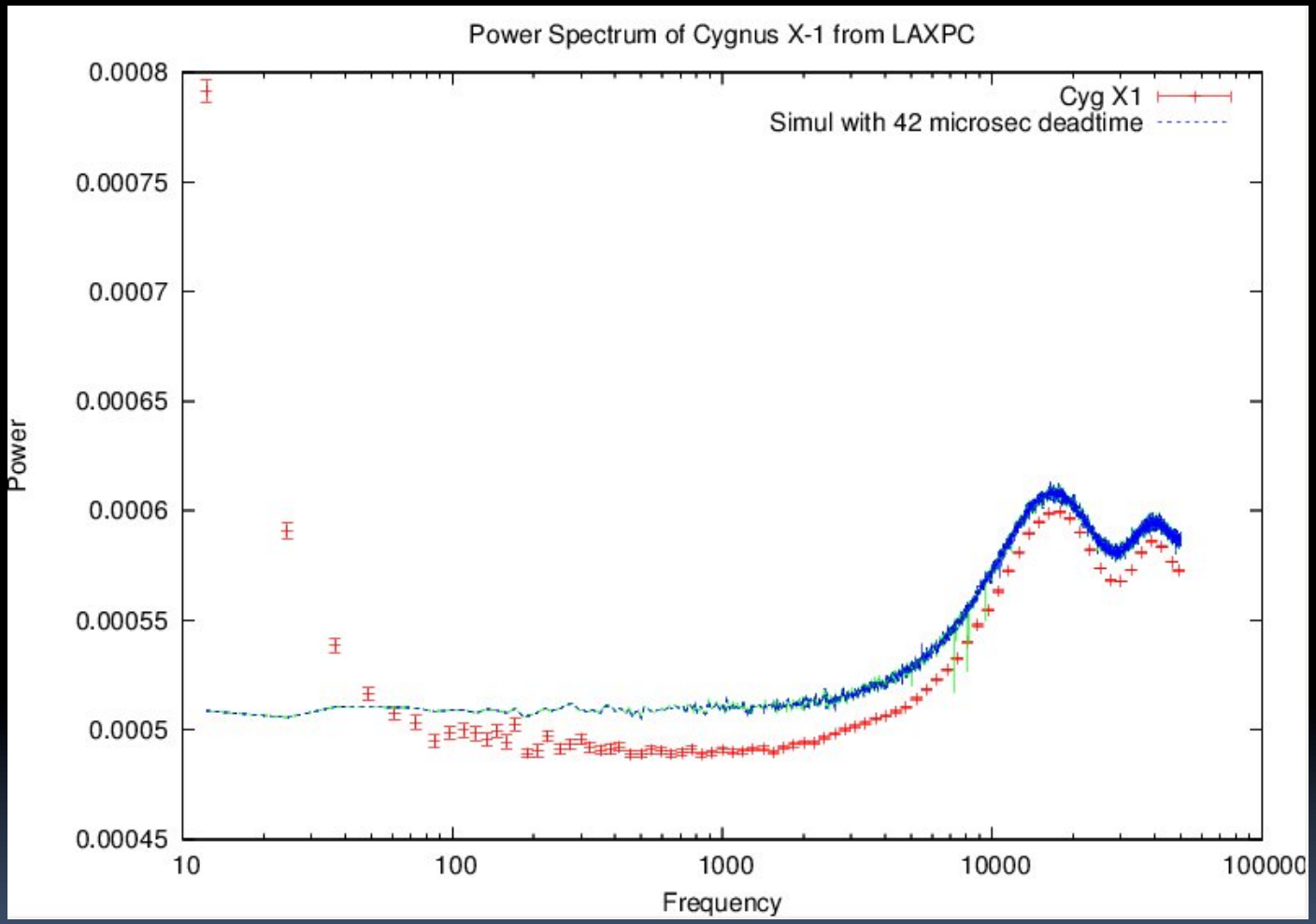
LACPC first results; Vela X-1



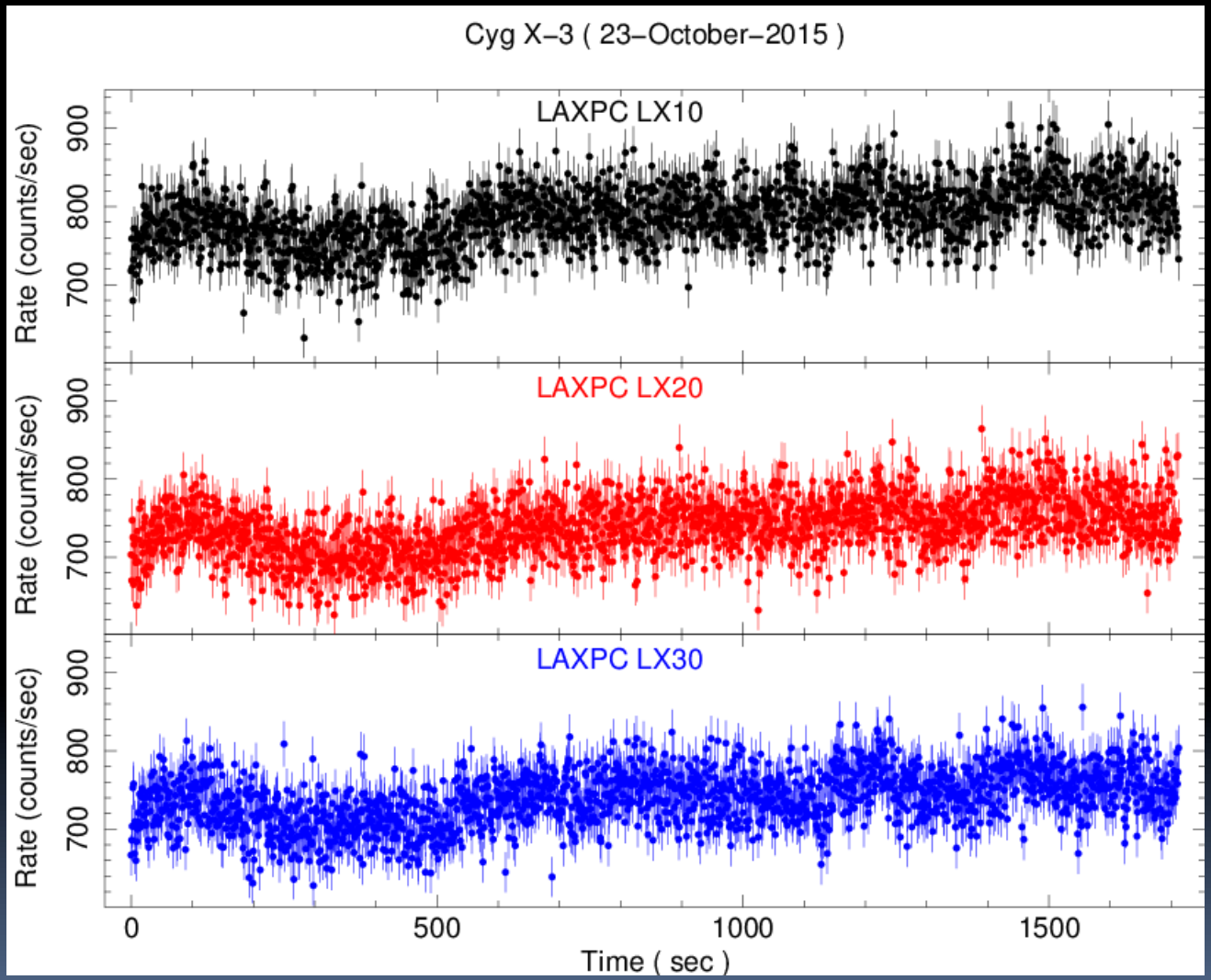


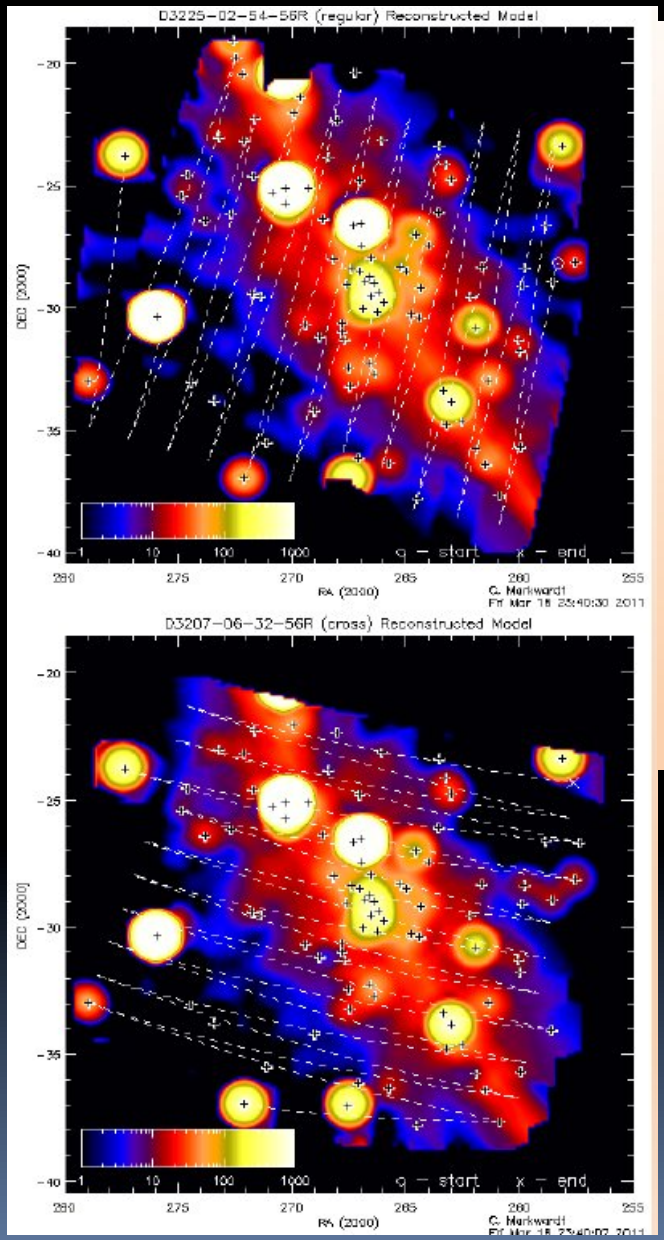
LACPC first results; Cyg X-1




Power Spectrum of Cygnus X-1 from LAXPC
Cyg X1
Simul with 42 microsec deadtime
Power
Frequency
0.0008
0.00075
0.0007
0.00065
0.0006
0.00055
0.0005
0.00045
10
100
1000
10000
100000

LACPC first results; Cyg X-3





RXTE/PCA Galactic bulge scan

- 22˚ x 22˚ Galactic bulge scan across Galactic longitude (slew rate 6 degrees per min)
- ~Single scan of 480 sq degree covers appx. in 70 minutes
- Twice a week considering sun elevation angle restriction – cross scan confirms assigned flux to a point source
- Total ~8500 sec < 2 RXTE orbits (10800 sec)
- Image reconstructed based on fits to scan of different sources (sensitive to 0.5 - 1 mCrab)
- Bursts (> 2 mCrab) was be identified clearly

Similar scan program for LAXPC instrument (sensitivity around 0.1 mCrab). LAXPC instrument is likely to discover many new transient sources.

ASTROSAT – Post launch Mission Plan

- 1st year
  - First 6 months – PV Phase (4 X-ray; 2 UV)
  - Next 6 months – GT Phase (4 X-ray; 2 UV)
- 2nd year
  - 5% Canada, 3% UK, 5% TOO, 2% Cal, 35% Open for GO (India), 50% Instruments' GT
- 3rd year
  - 5% Canada, 3% UK, 5% TOO, 2% Cal, 45% Open for GO (India), 30% Instruments' GT, 10% Open for International GO
- 4th year
  - 5% Canada, 3% UK, 5% TOO, 2% Cal, 65% India (GO), 20% International GO

Conclusions

LAXPC instrument has achieved all the spectral and timing goals as proposed initially. Background is stable. We are doing calibration and verification of payloads which will end by March 2016. LAXPC instrument (and other ASTROSAT Instruments) will be open to national/ international astronomers by end of first year (~October, 2016). We expect exciting science ahead.

Exciting Science to come …

Thanks !

On behalf of LAXPC Instrument team

Several colleagues at TIFR, Mumbai, ; , IUCAA), Pune

ISRO Satellite Centre (ISAC), Bangalore,

Raman Research Institute, Bangalore

Vikram Sarabhai Space Centre, Trivandrum,

Space Applications Centre, Ahmedabad & Physical Research Laboratory, Ahmedabad

have helped in development of LAXPC payload at various stages of its development

ASTROSAT: Its Main Strengths

- Simultaneous Opt- NUV –FUV- soft X-ray - hard X-ray measurements
- Large X-ray bandwidth, *better hard X-ray sensitivity than RXTE*
- Low background X-ray detectors : near Equatorial Launch
- Fine time resolution capability
- UV imaging capability better than GALEX