Large Area X-ray Proportional Counter (LAXPC): Calibration and performance

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After completing all electronic & detector tests and final calibration, all three flight units of LAXPC instrument in AIT lab for integration with satellite on 20th October, 2014.

LAXPC: Large Area X-ray Proportional Counters (~419 Kg) (became fully operational on 19th Oct. 2015)

A broad energy band (3 - 80 keV) with high detection efficiency of X-ray above 20 keV and high timing resolution 10 μsec. .

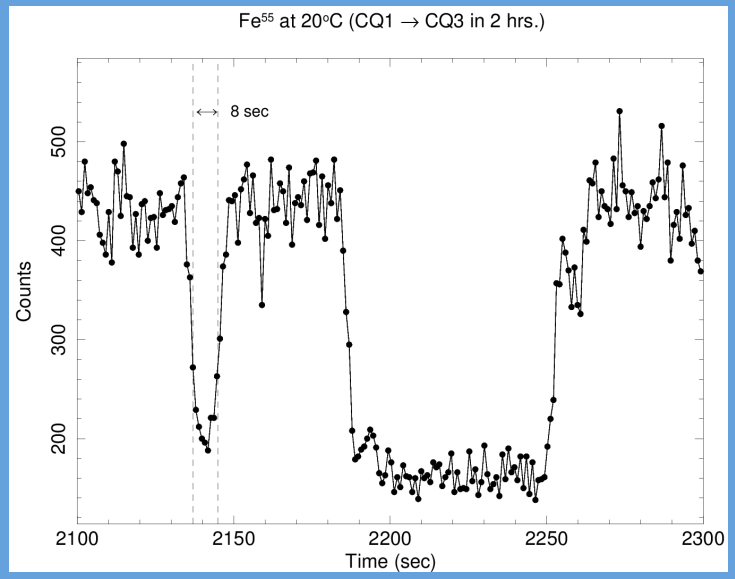
- Three co-aligned identical LAXPC detectors
- Each with a multi-wire-multi-layer configuration filled with 90%Xe +10% Methane gas at 1520 torr. Energy resolution (12%@22 keV)
- A 50 micron thick aluminized Mylar window for X-ray entrance
- ***Mylar film support*** -- by a honeycomb window support collimator
- 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

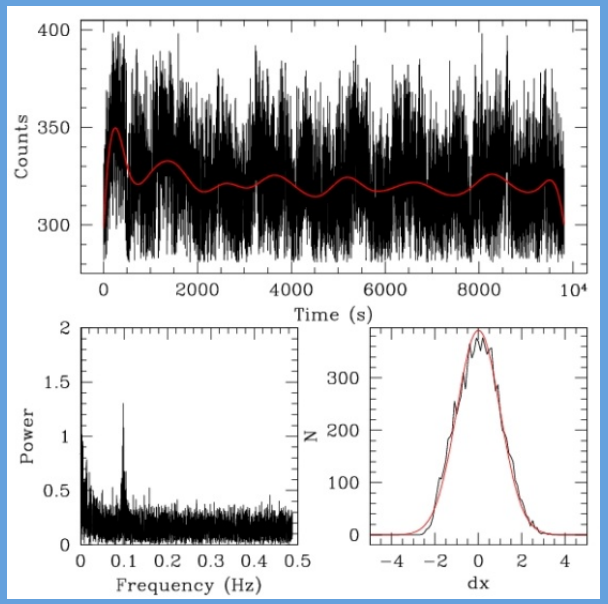
LAXPC Instrument Specification

No. of LAXPC Detectors (DT)	**Three (3) identical units**
Size of each LAXPC with collimator	**120 cm x 50 cm x 70 cm**
X-ray detection volume	**100 cm x 36 cm x 15 cm**
Collimator field of view	**47' x 47' for all the LAXPCs**
Detector Gas	**Xenon + Methane @ 1520 Torr**
Energy range	**3 - 80 keV**
Average detection efficiency	**100% Below 20 keV** **50 % in 20-80 keV**
Energy resolution	**12% FWHM at 60 keV**
Total Effective Area of 3 LAXPCs	**≈ 8000 cm^2 @ 5 - 20 keV**
Processing Electronic (PE)	**Three**
System Time Base Generator (STBG)	**10μsec time resolution**
Total weight of LAXPC Payload	**414 kg**

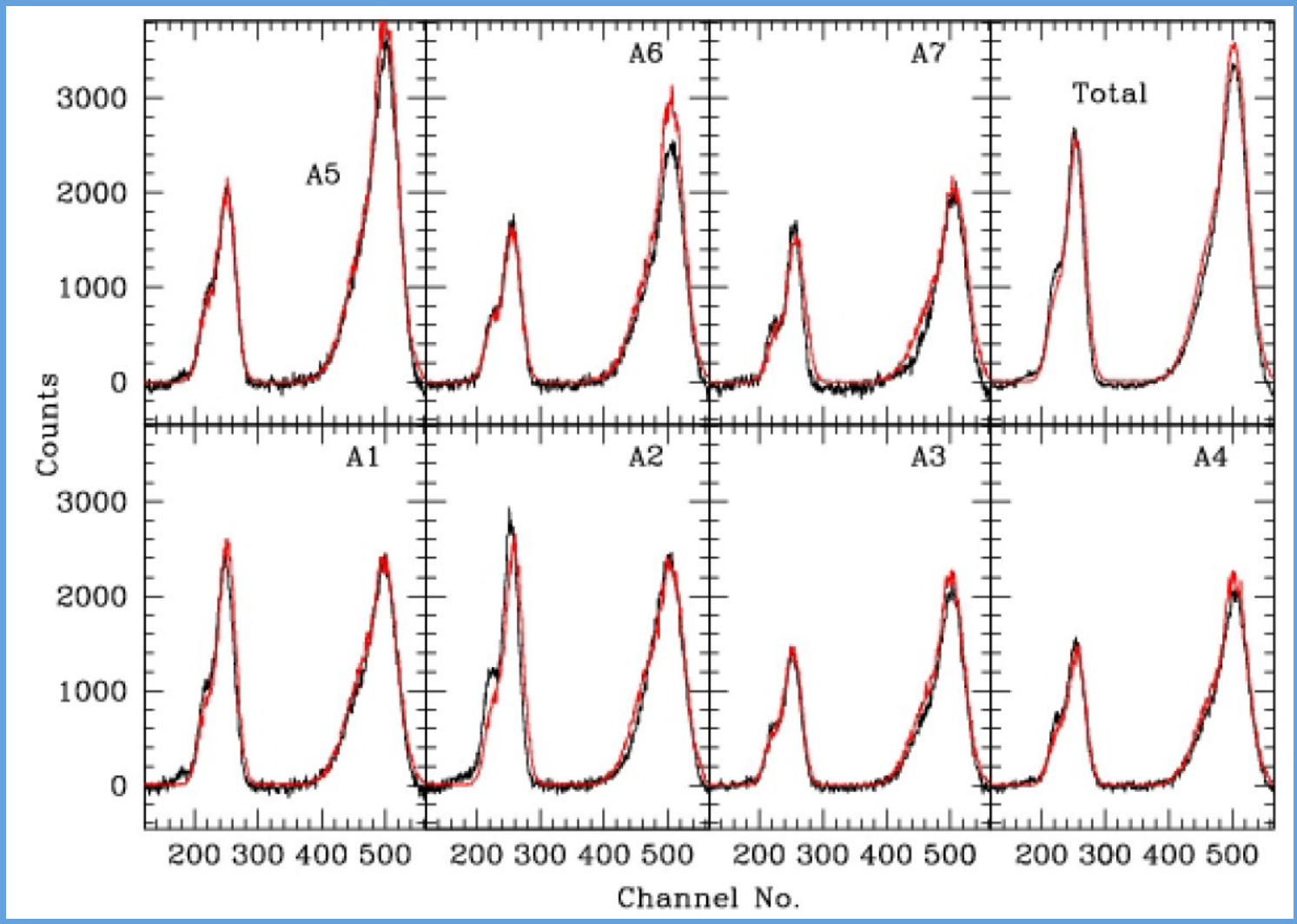
Calibration in lab (before launch}

- All calibration is done in scan mode using remotely controlled X-Y motion from out side the thermvac chamber.
- Study of Collimator characteristics
- GEANT4 simulation of LAXPC detector

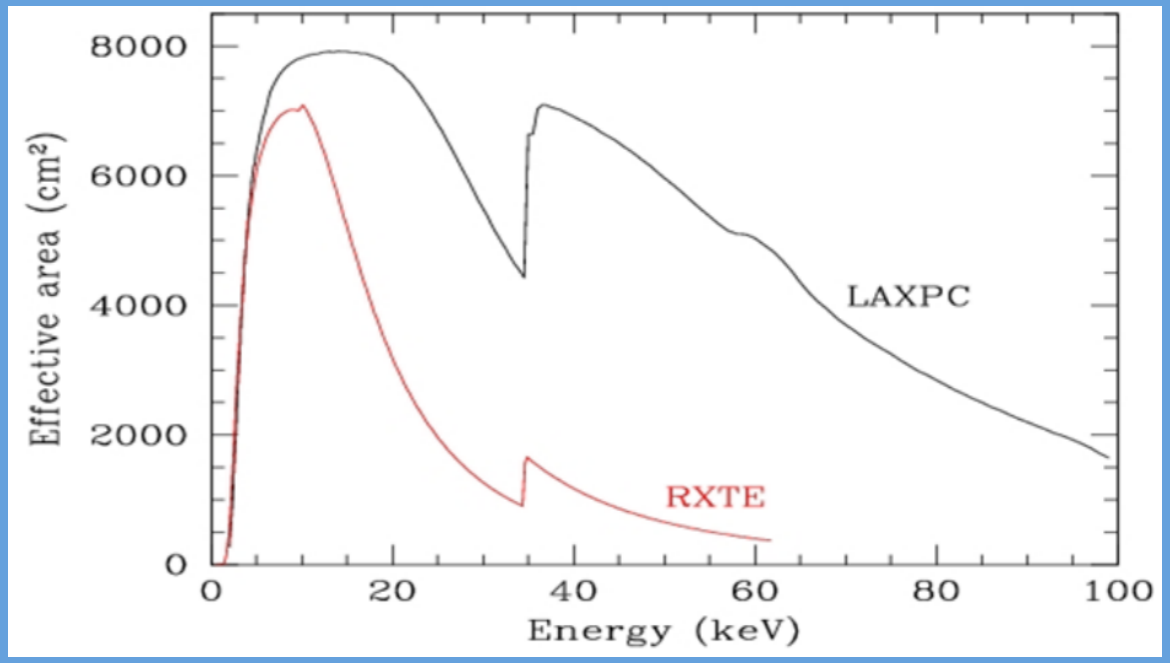


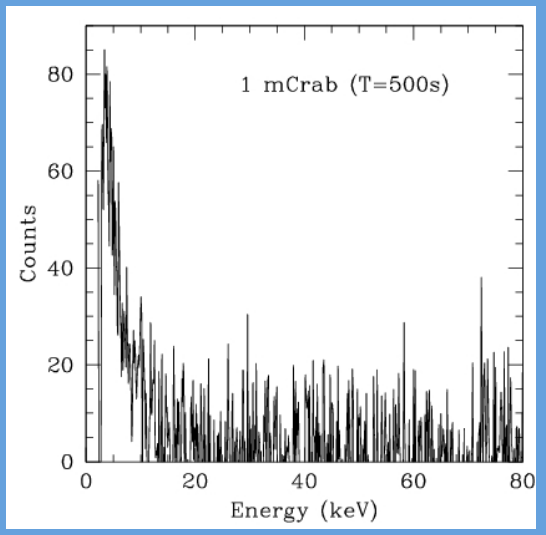


GEANT4 simulation for LAXPC30 unit & Am source (all 5 layers)



Comparison of LAXPC with RXTE/PCA



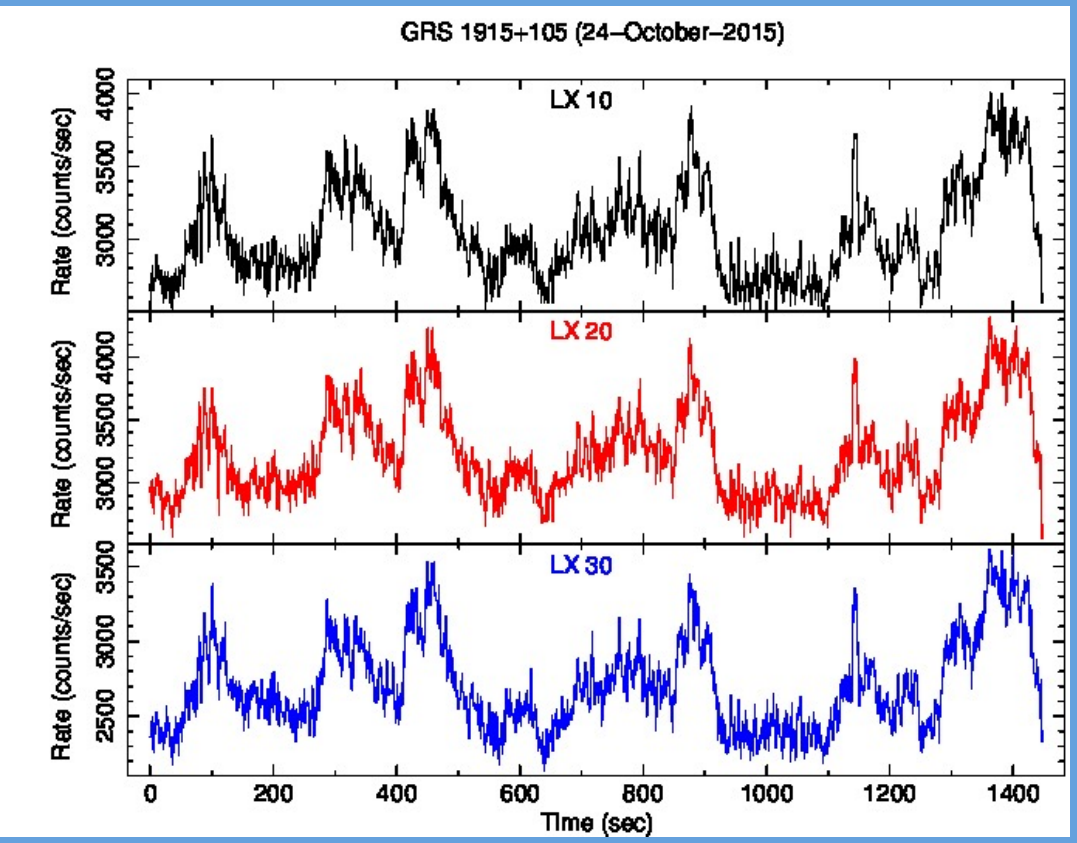


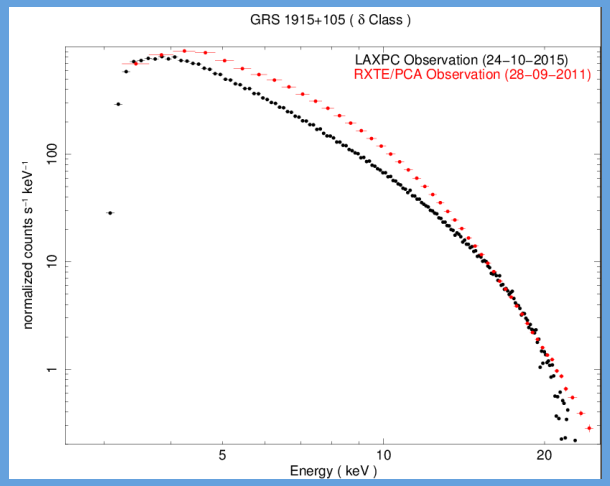
LAXPC instrument will have four times or more effective area above 20 keV as compared to RXTE/PCA. It can detect 0.1 mcrab sources in few thousand second.

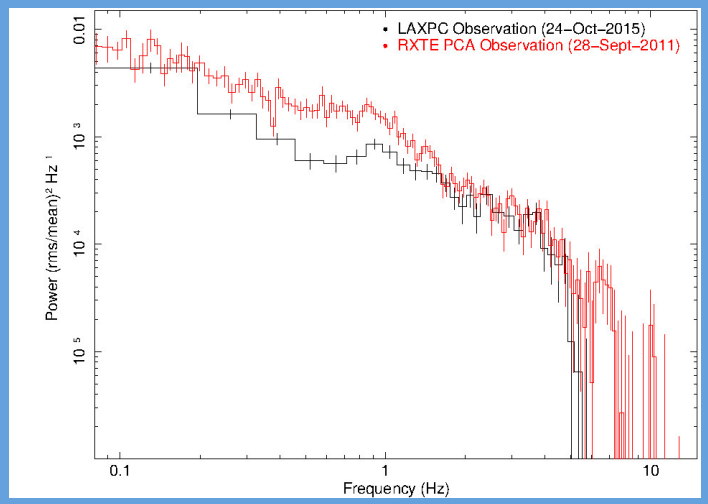
LAXPC initial results: Data quality

Comparison with NASA RXTE/PCA for Black hole source; GRS 1915+105

LAXPC : Observation time ~ 20 min

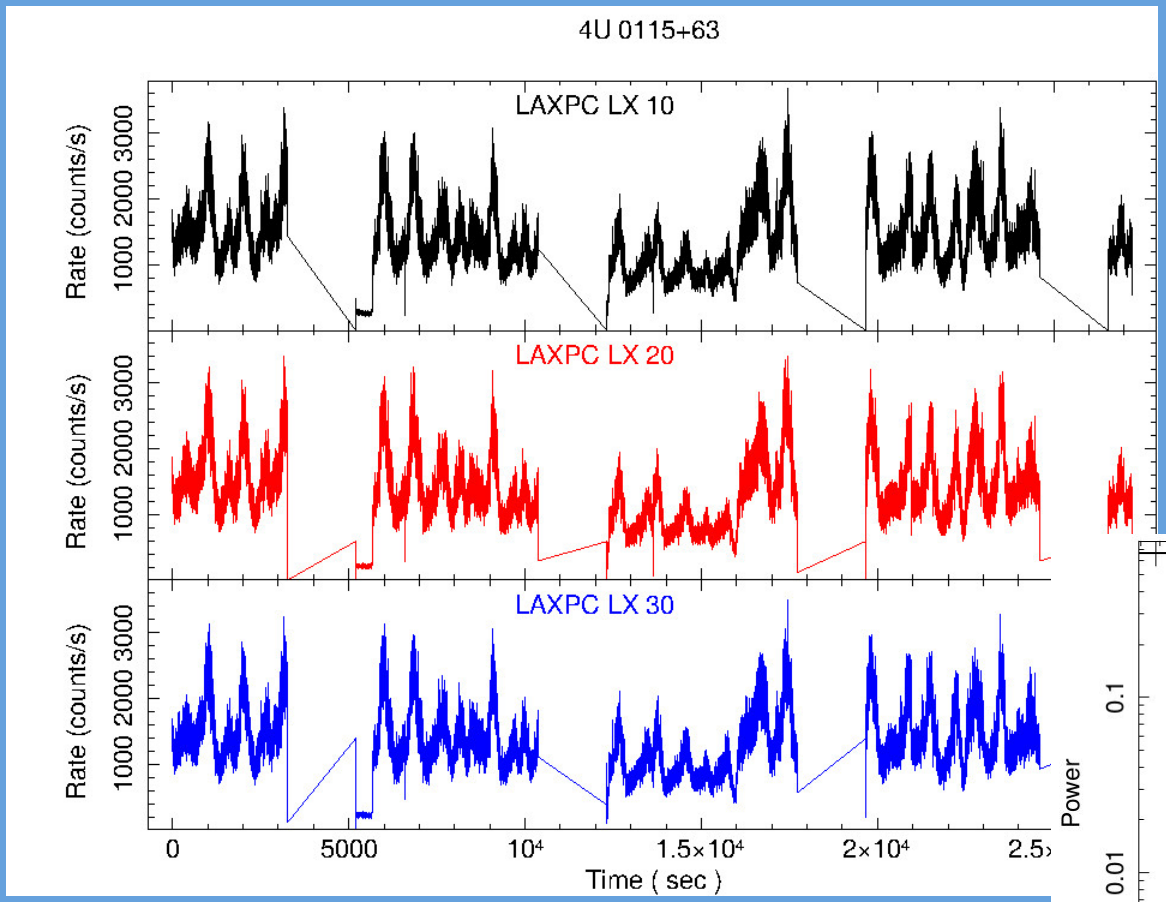






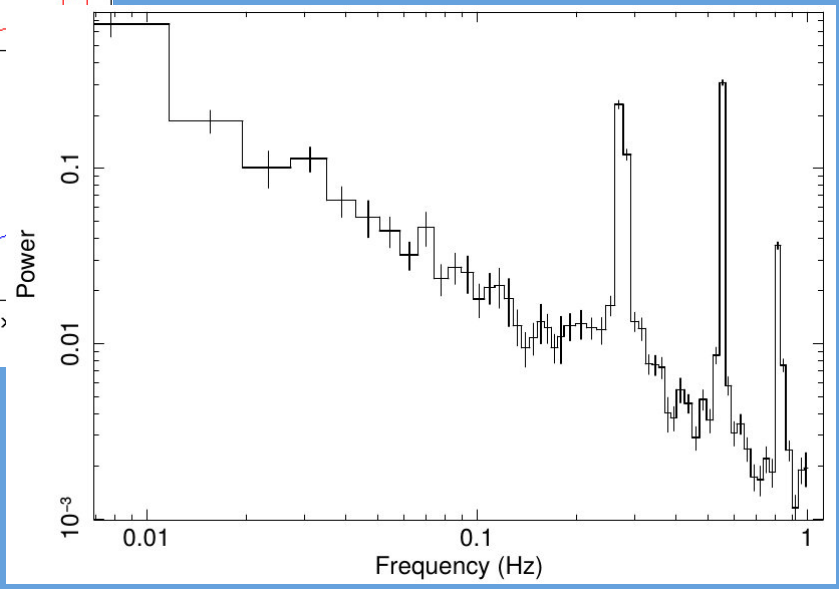
Detects δ X-ray class; a sub class of the high soft state (thermal state).

4U 0115+63 (a pulsar in outburst)

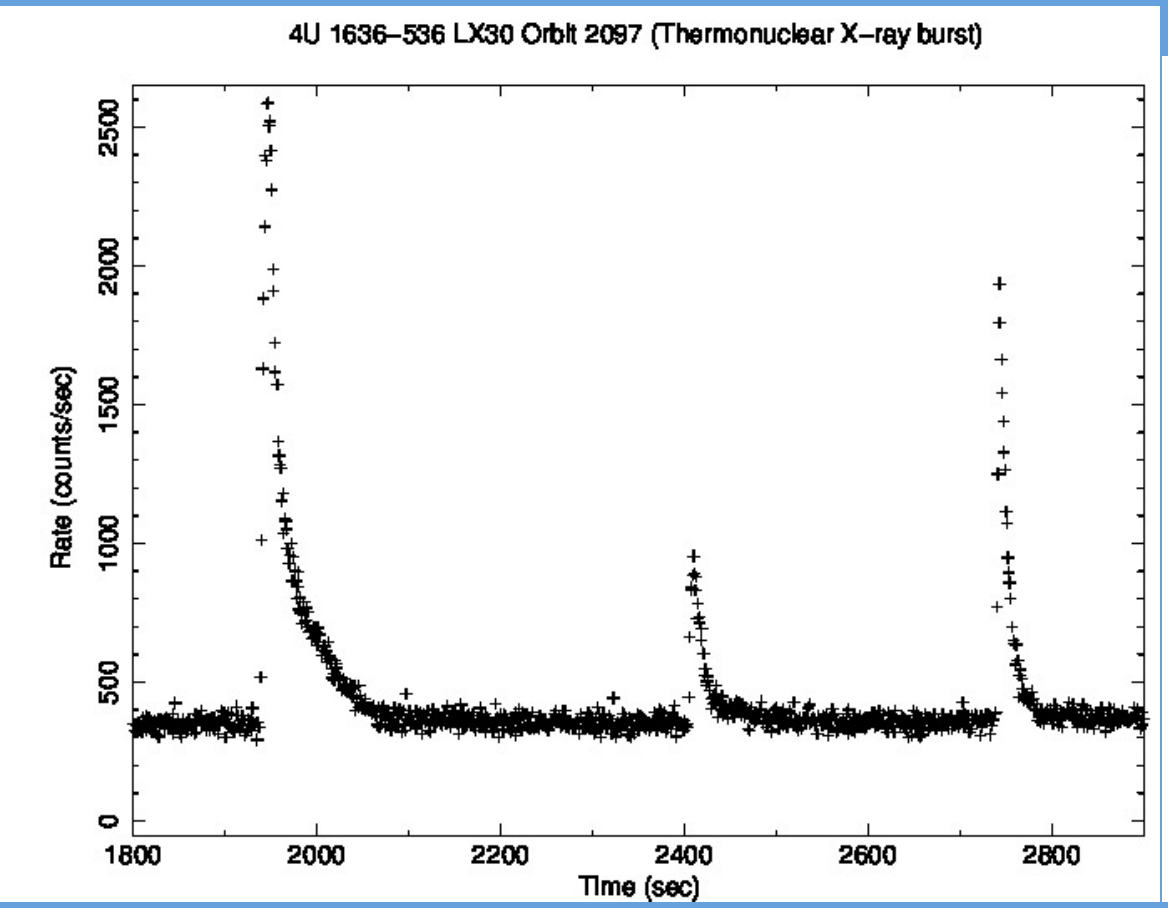


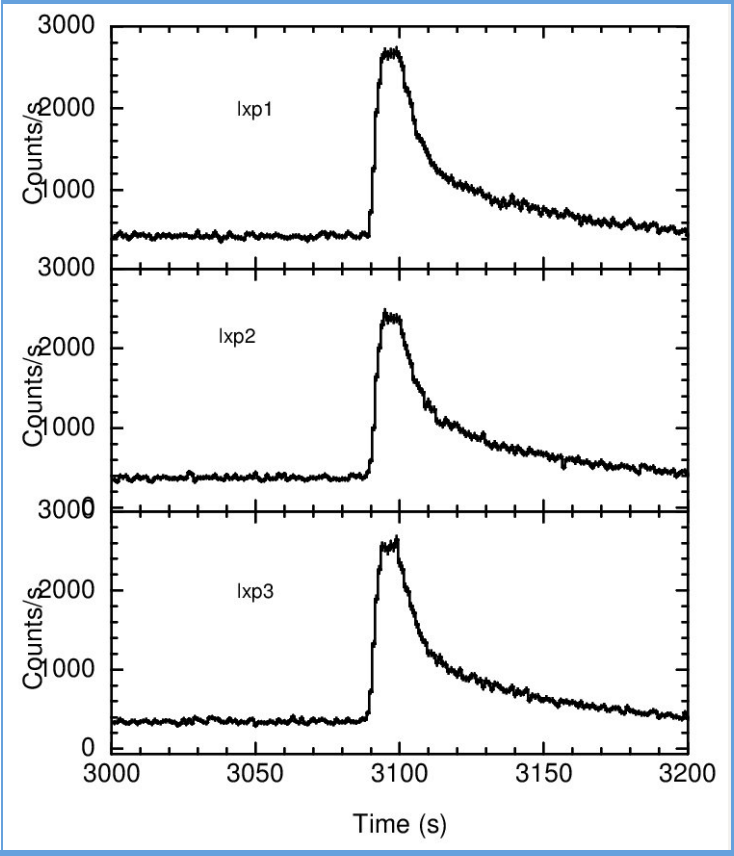
Transient X-ray pulsar (3.6 seconds) 4U0115+63.

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



Thermonuclear bursts in 4U 1636-536

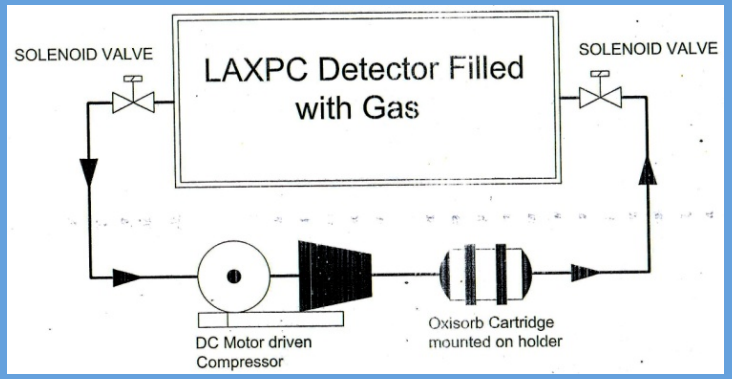


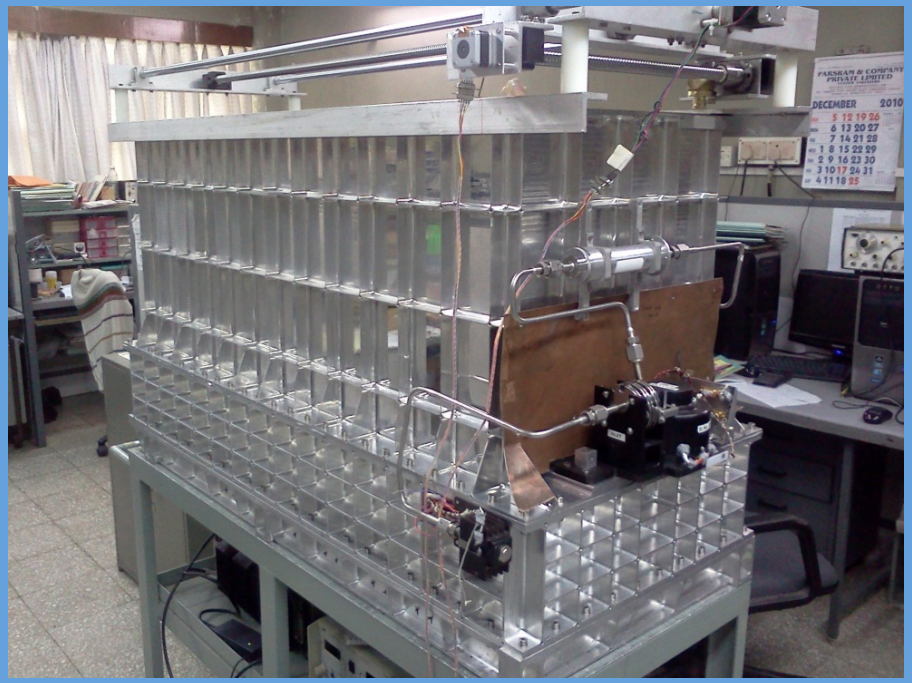


Detector performannce:

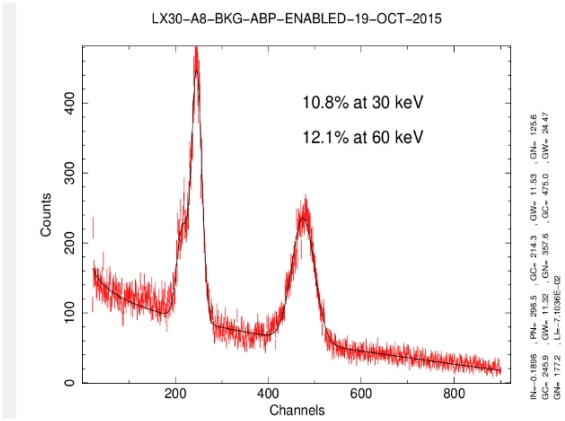
On-board Purification & Detector energy resolution

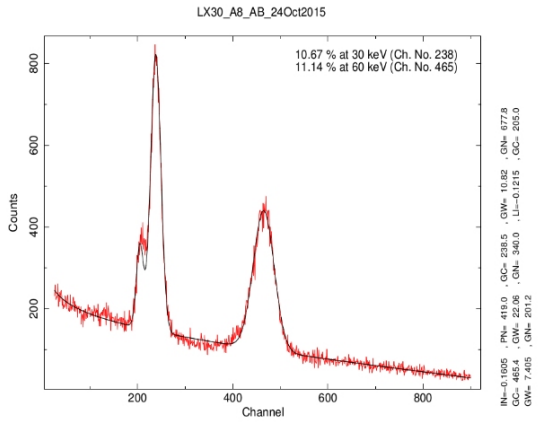
- On-Board Purification for Flight Detectors

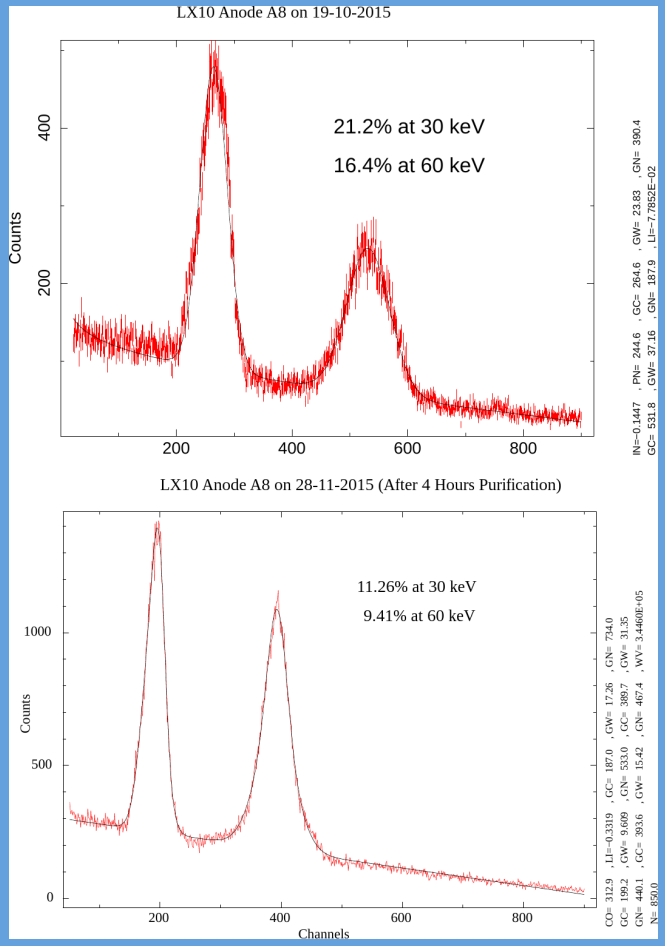




Each of the LAXPC detectors has an onboard gas purification system. This system will be operated as and when required to purify the gas filled in the detector by command. It is expected that energy resolution of LAXPC detector will degrade as impurity increases.

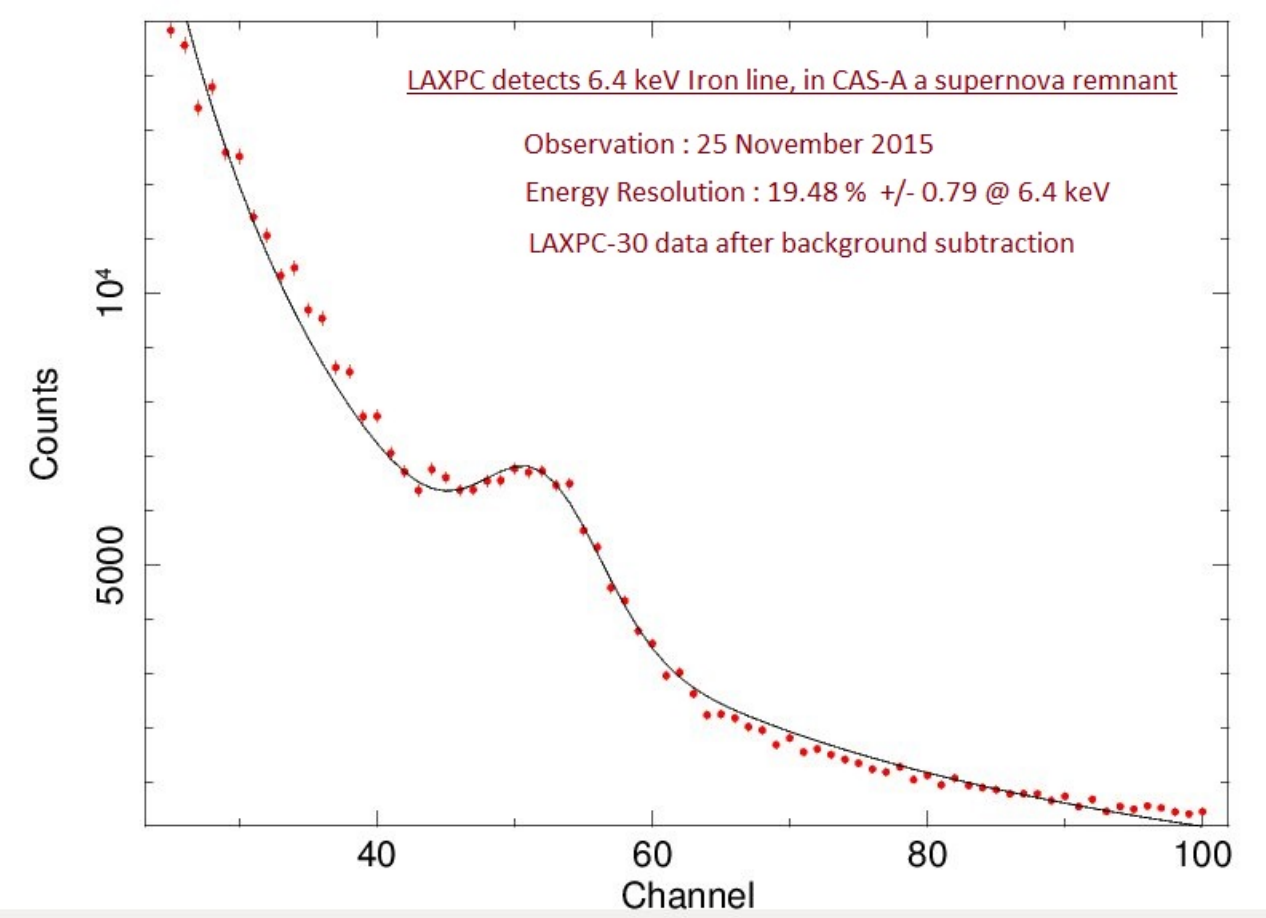






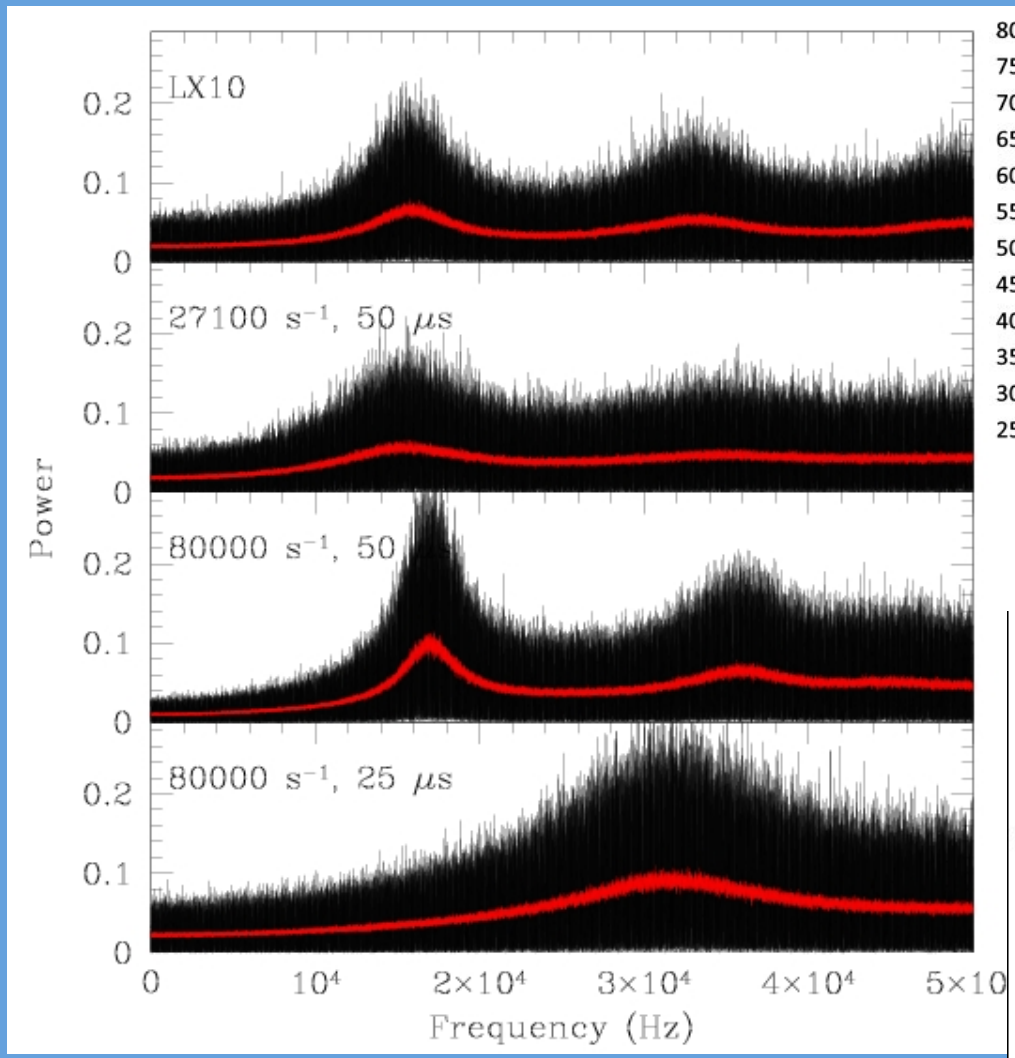
Energy resolution at 6.4 keV in orbit

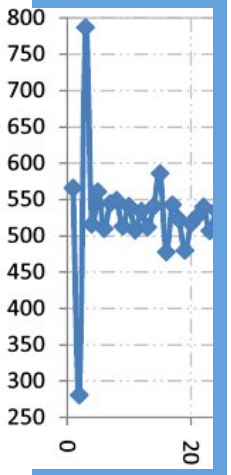
CAS –A (supernova remnant)

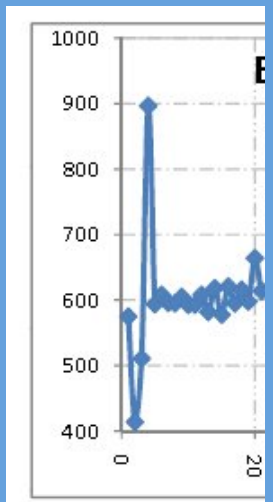


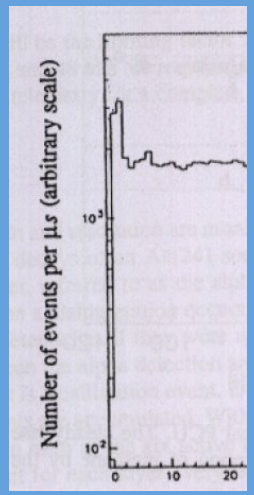
2. Timing characteristics: In event mode, there is no problem & 10 μs time resolution is achieved (in lab)

LAXPC 10 AND 30 RXTE/PCA



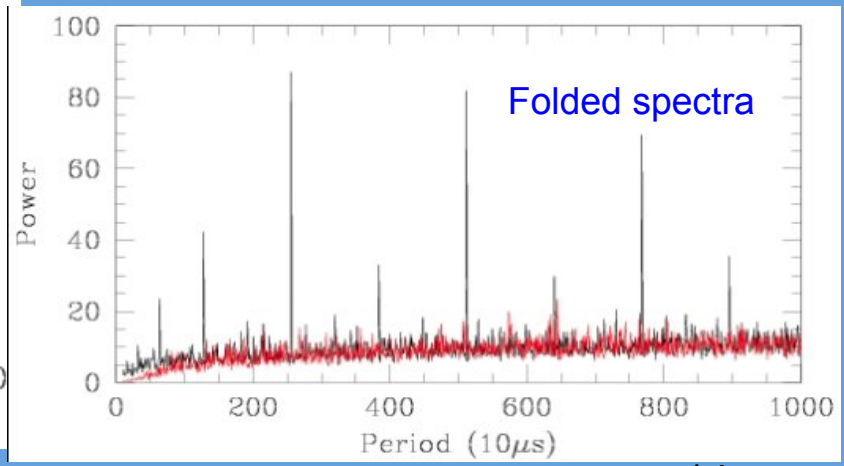


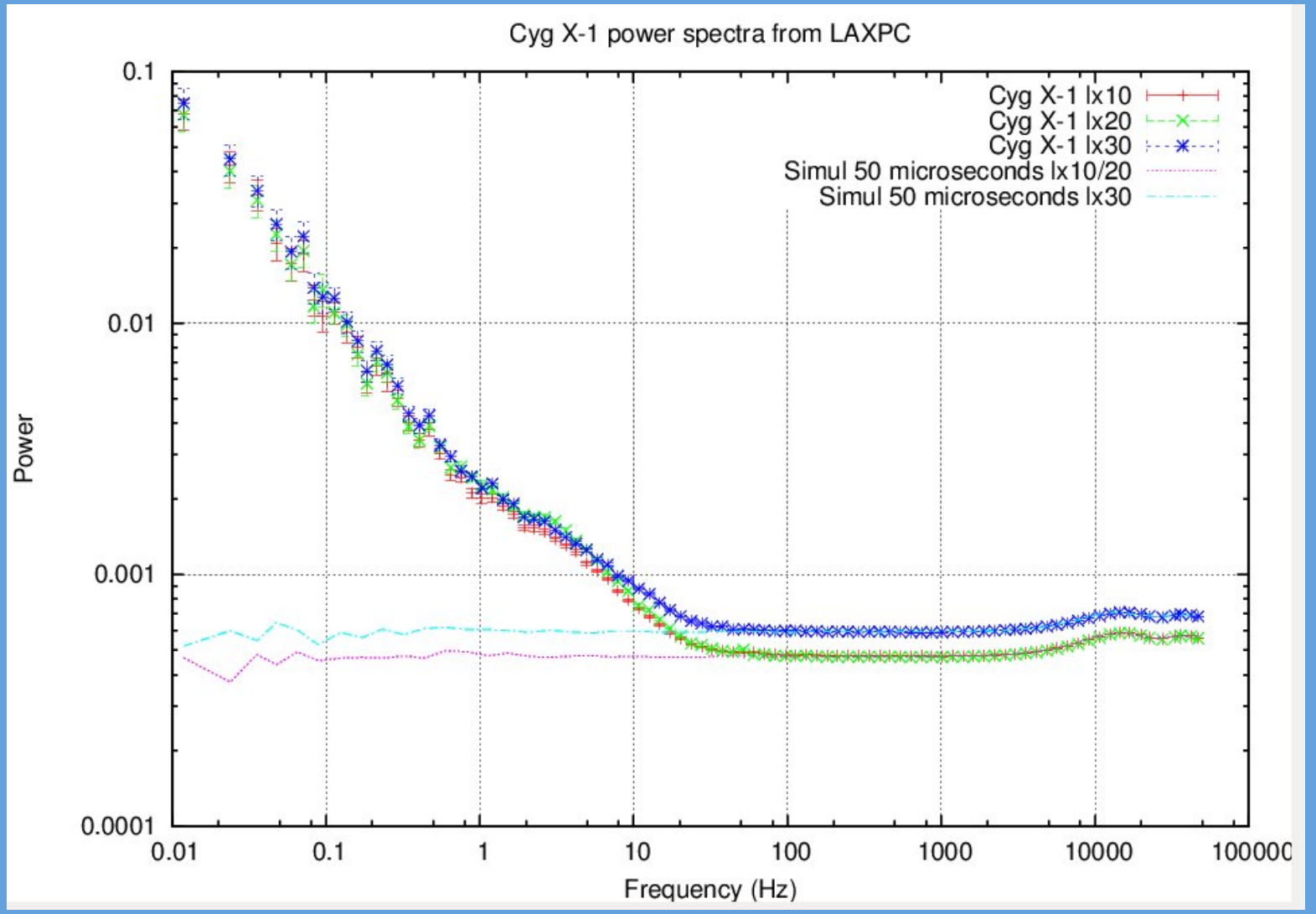


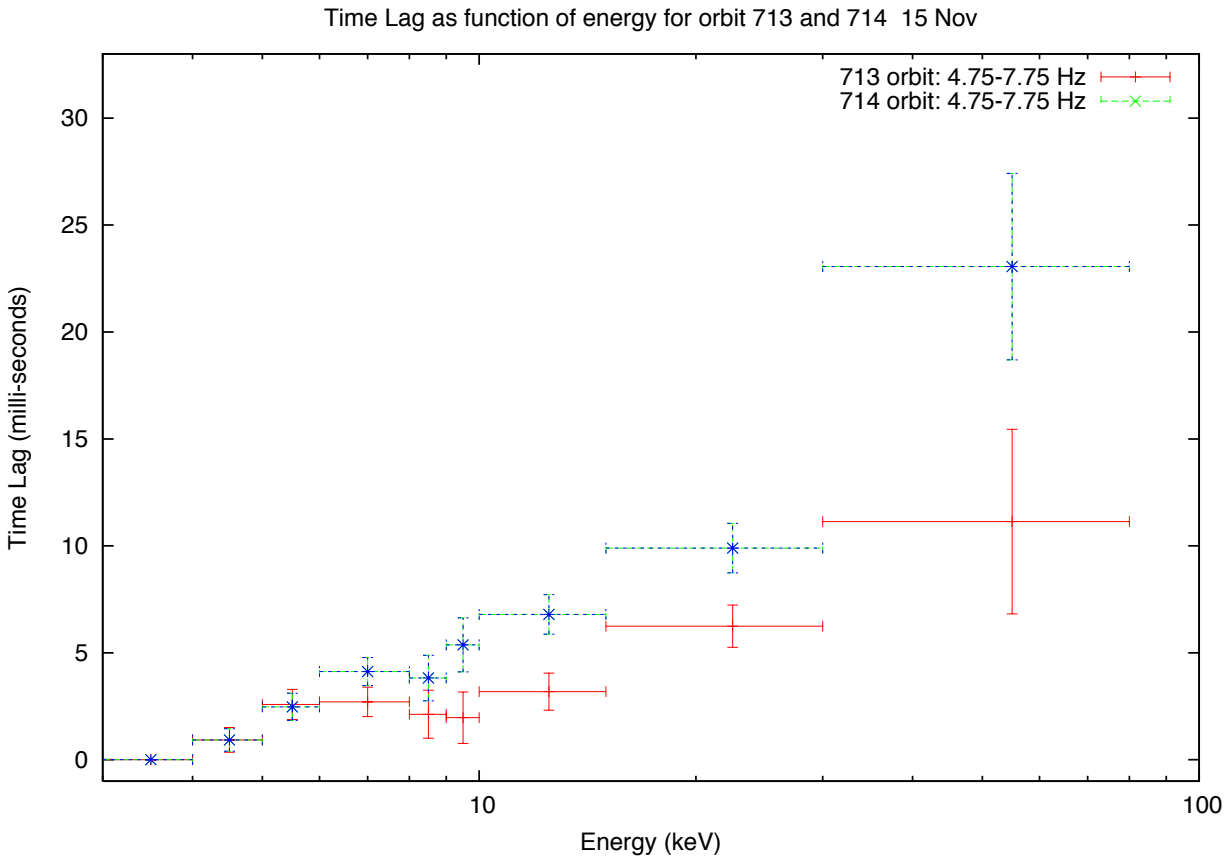


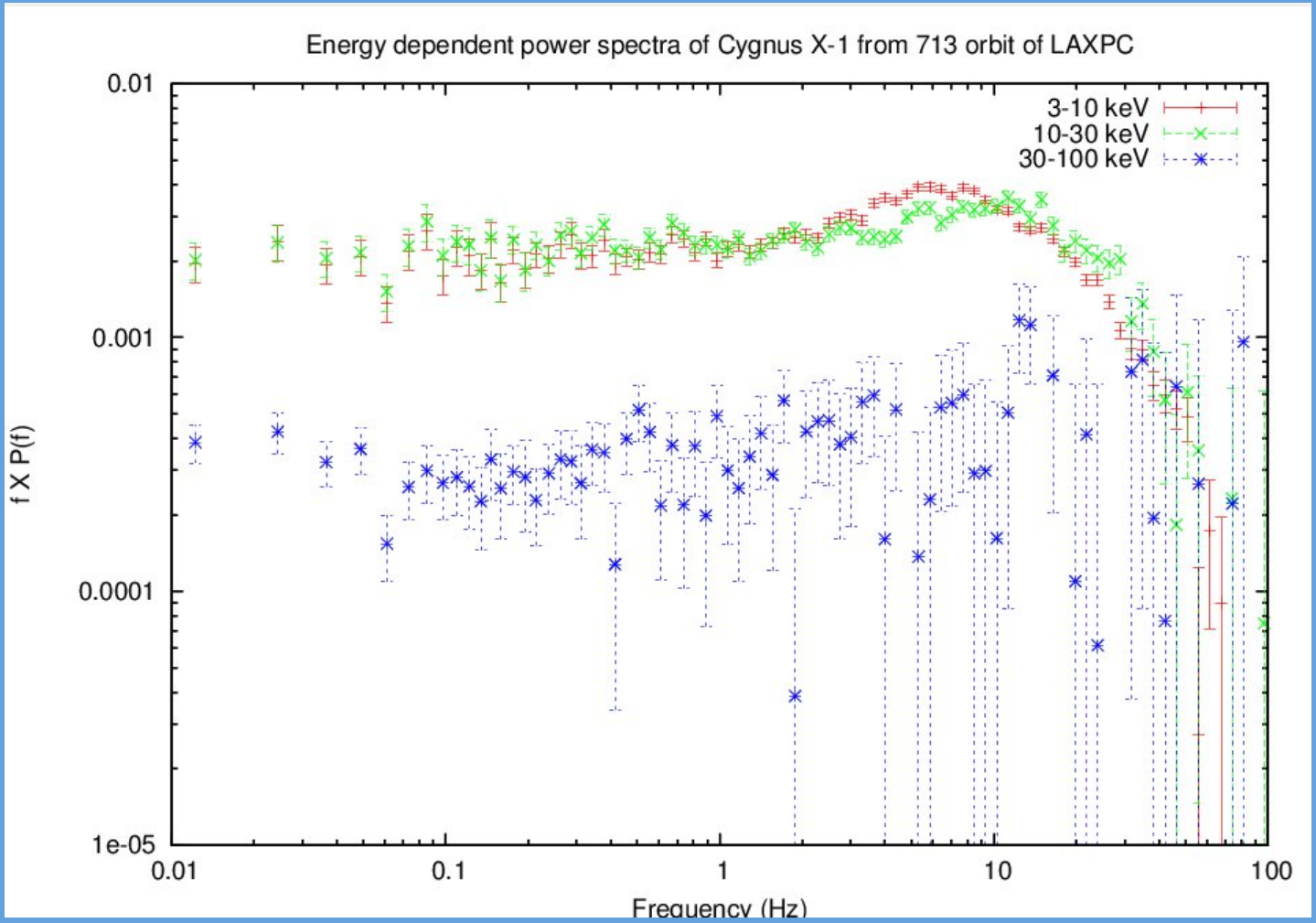
Black line when period is n*10 μs

Red line when period is (n+0.02)*10μs

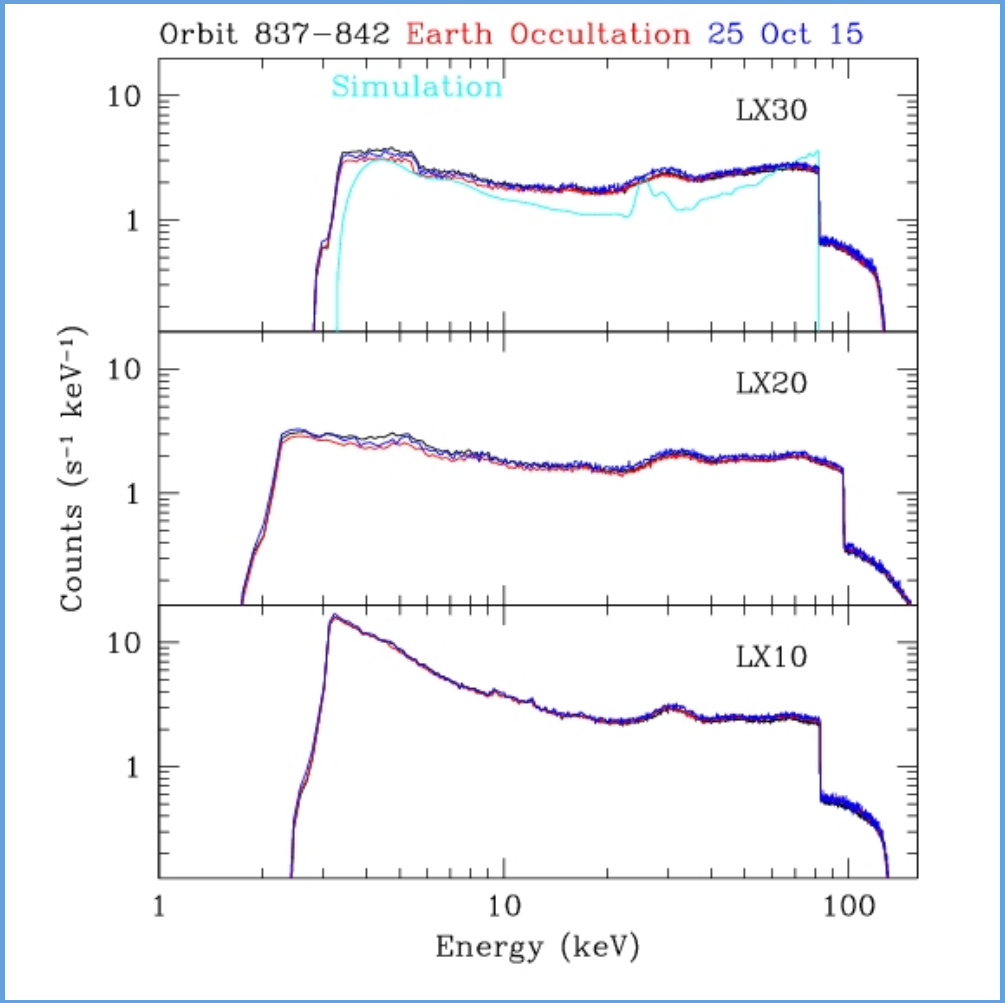


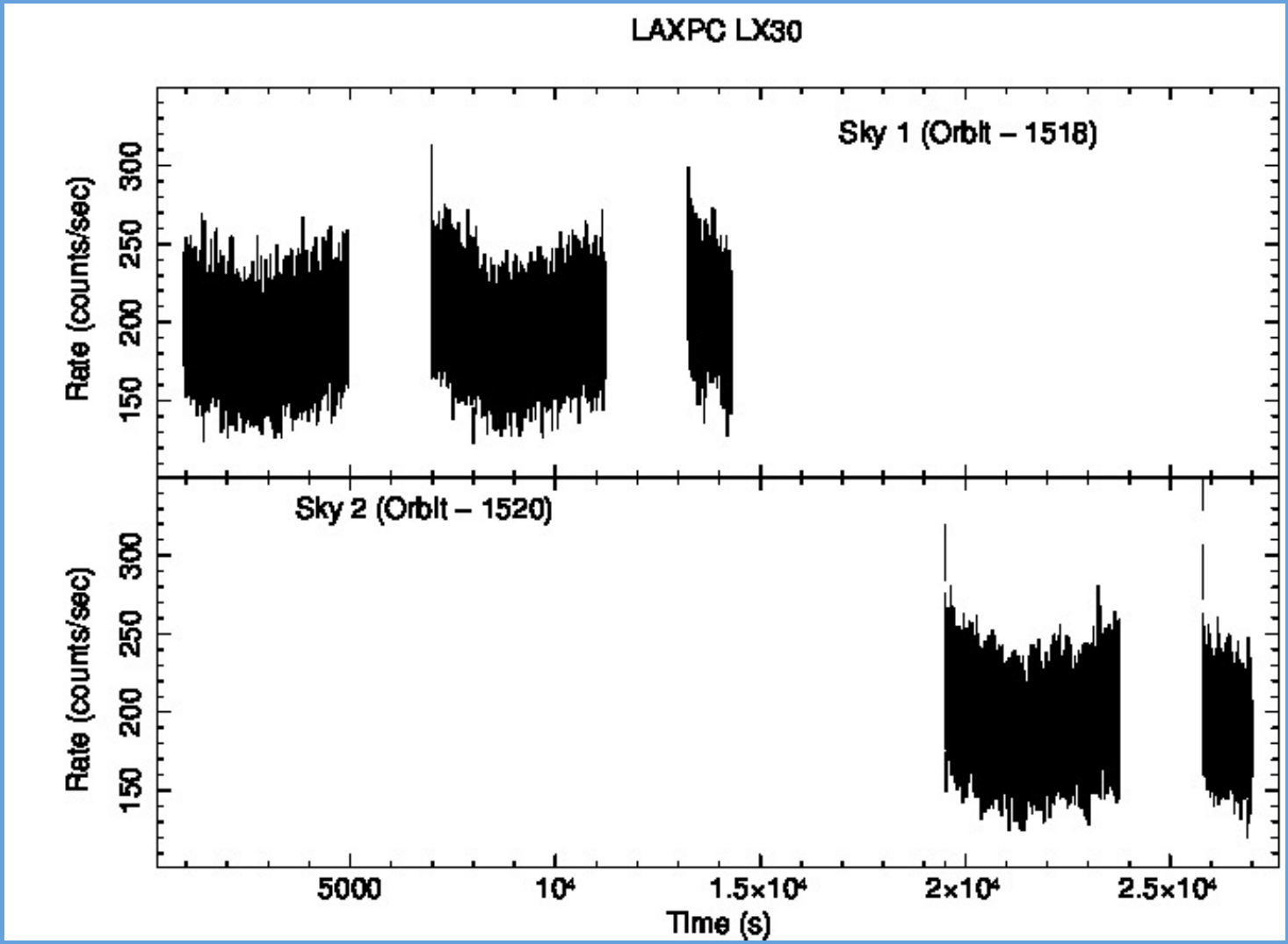

Cyg X-1 power spectra from LAXPC
Cyg X-1 lx10
Cyg X-1 lx20
Cyg X-1 lx30
Simul 50 microseconds lx10/20
Simul 50 microseconds lx30
Power
Frequency (Hz)
0.1
0.01
0.001
0.0001
0.01
0.1
1
10
100
1000
10000
100000

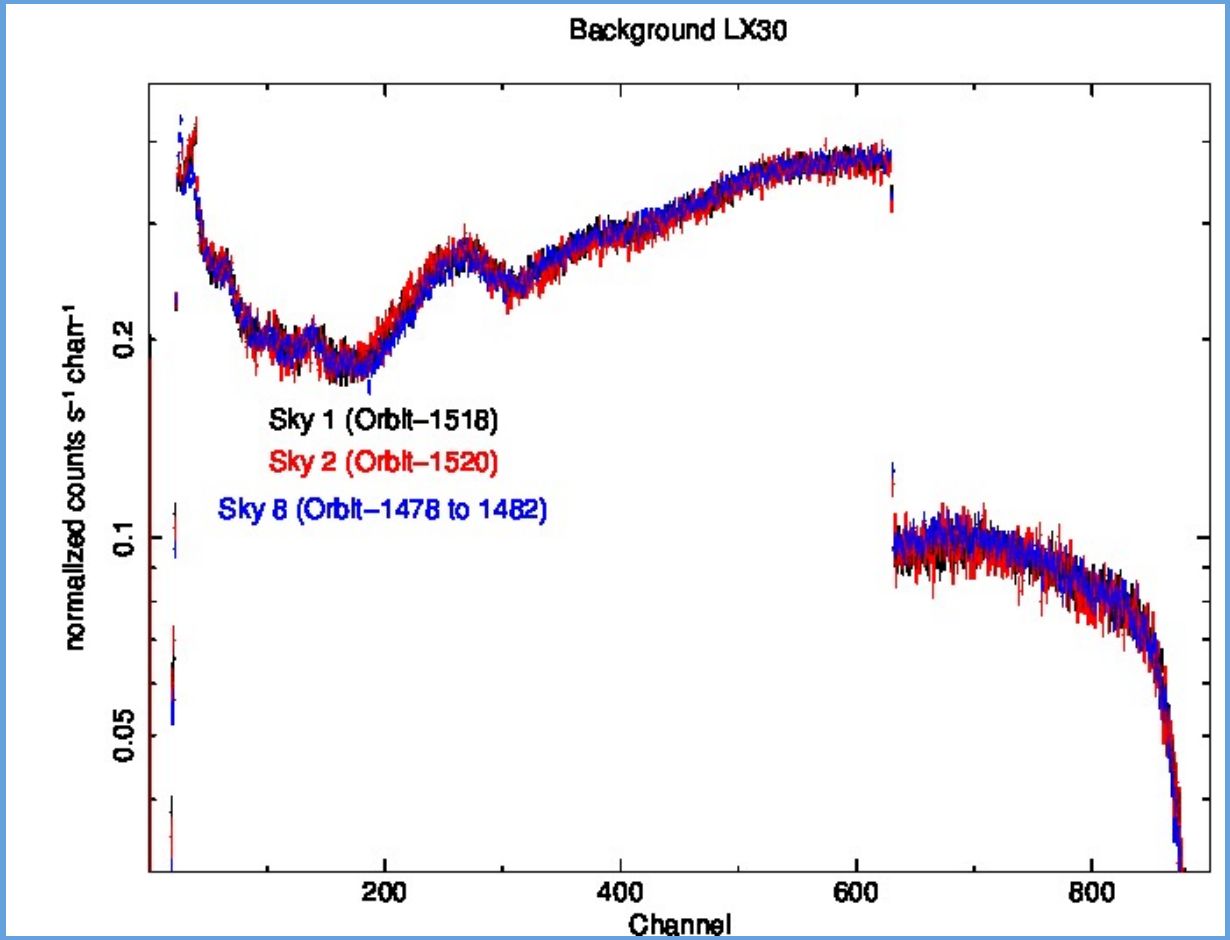

Time Lag as function of energy for orbit 713 and 714 15 Nov
713 orbit: 4.75-7.75 Hz
714 orbit: 4.75-7.75 Hz
Time Lag (milli-seconds)
Energy (keV)
0
5
10
15
20
25
30
10
100


Energy dependent power spectra of Cygnus X-1 from 713 orbit of LAXPC
3-10 keV
10-30 keV
30-100 keV
f X P(f)
0.01
0.001
0.0001
1e-05
0.01
0.1
1
10
100
Frequency (Hz)

3. Background : stable



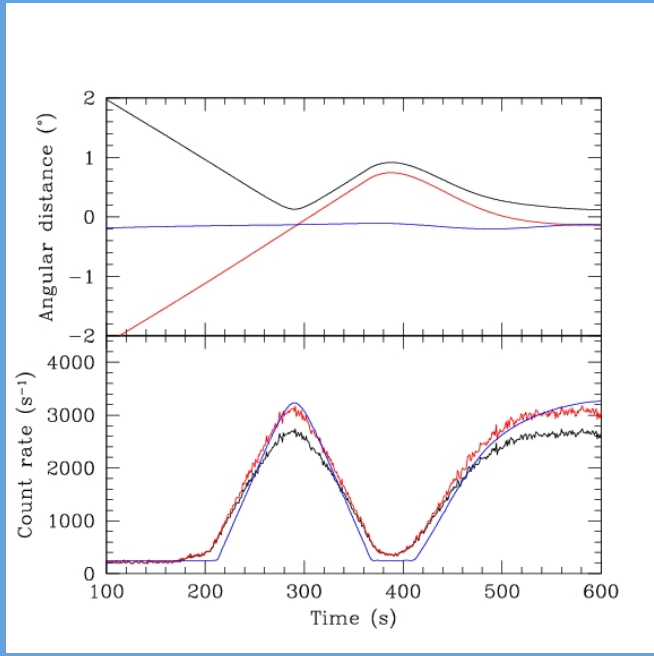

LAXPC LX30
Sky 1 (Orbit – 1518)
Sky 2 (Orbit – 1520)
Rate (counts/sec)
150
200
250
300
5000
10⁴
1.5×10⁴
2×10⁴
2.5×10⁴
Time (s)



We are working on background model for faint sources. Our background changes Even when no change in CPM count rate. We are studying change in background ; orbit to orbit which require background observation for longer duration.

4. Effective area and pointing accuracy

Cross scan to test alignment of the detectors: $+3^0$ to -3^0 in RA and DEC on Crab Source with 0.01^0/sec angular velocity



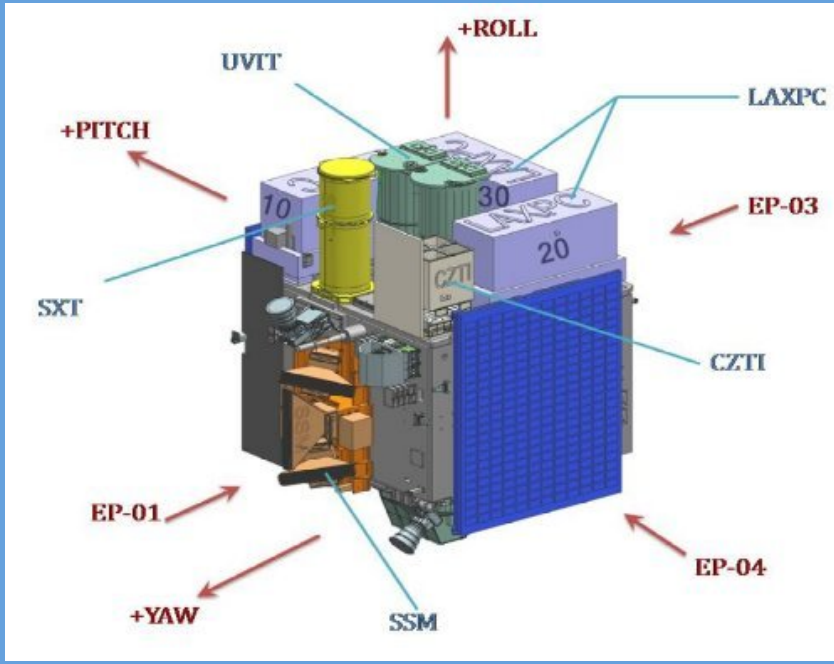
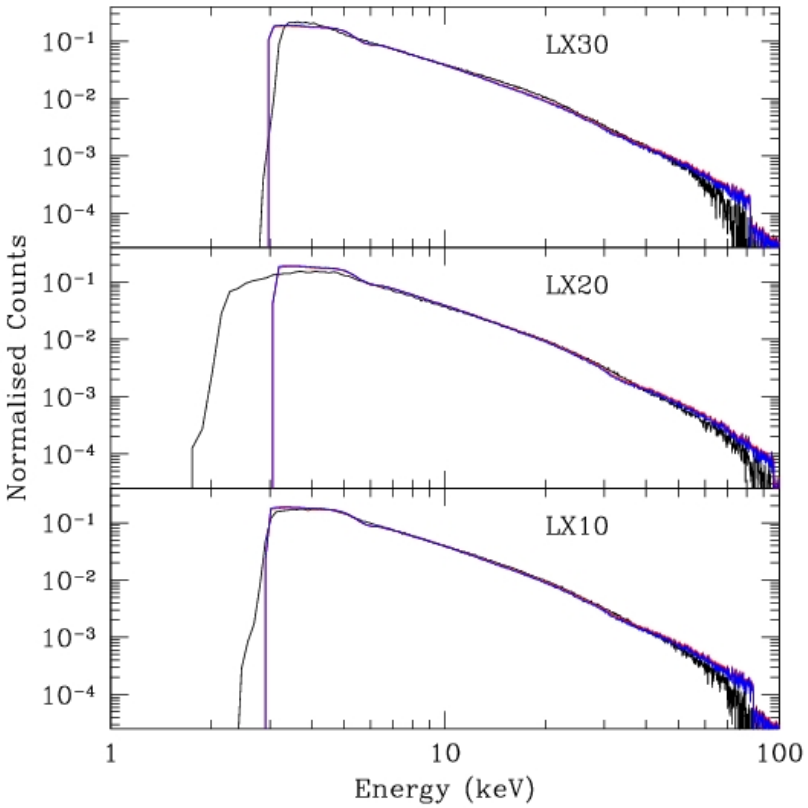
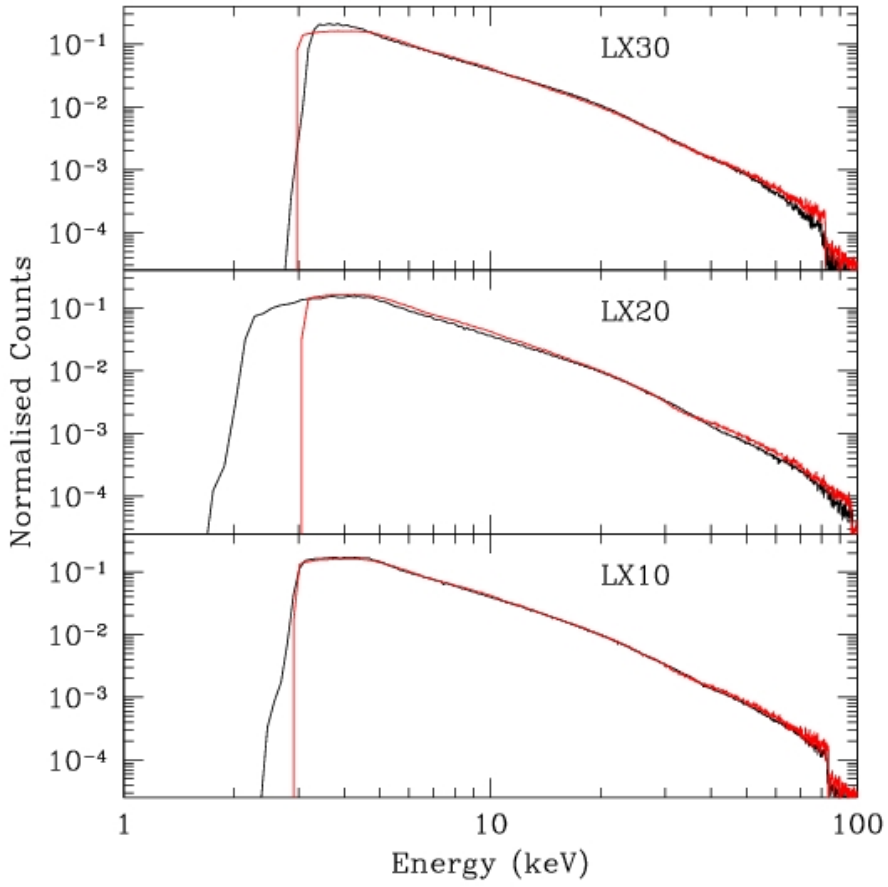
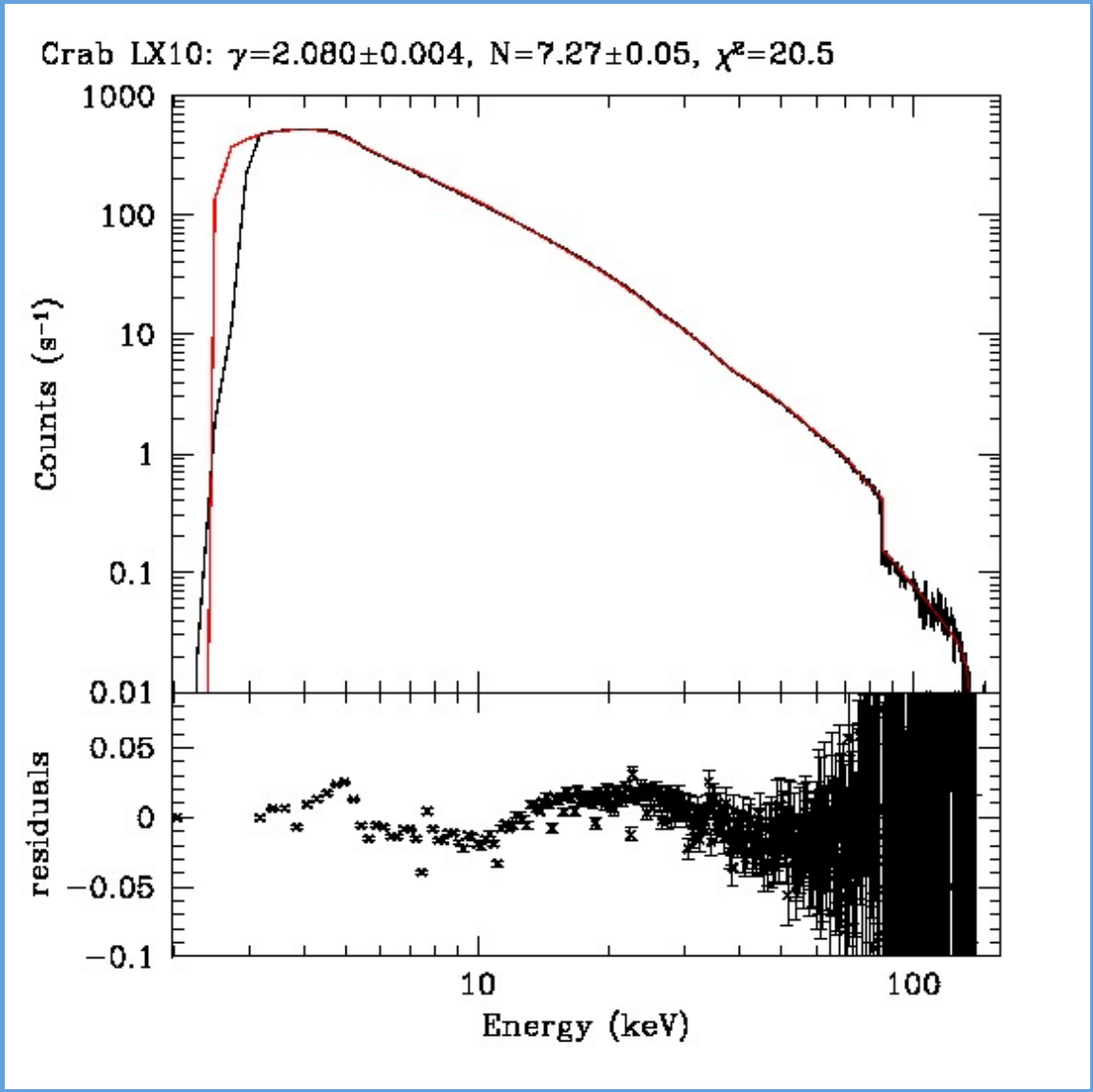


Figure: Top panel shows RA (red), DEC (blue), net angle (black). Bottom panel shows Observed count rat e(black), count rate corrected for dead time (red) and count rate Corrected for dead time as well as offset (blue). This gives following offset:

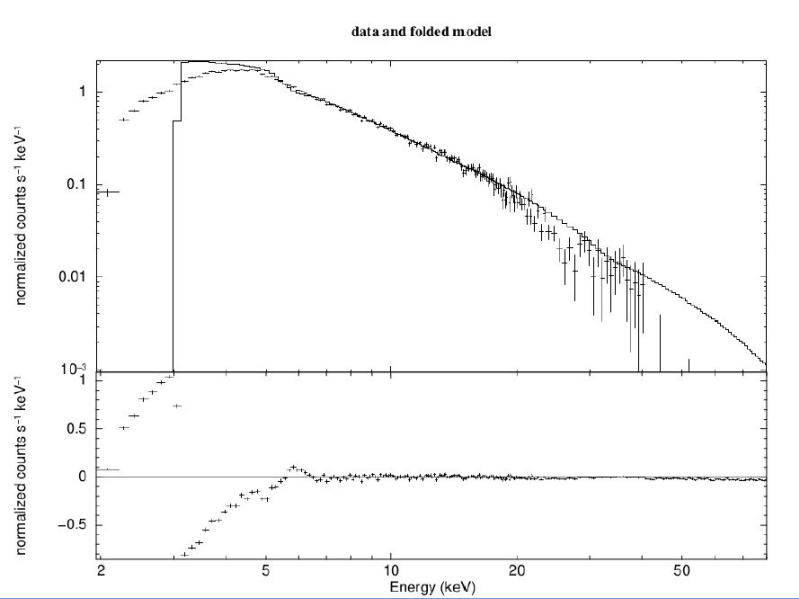
5. Energy spectrum: Crab energy spectra (for high count rate): right hand side corrected for dead Time and thermal blanket.

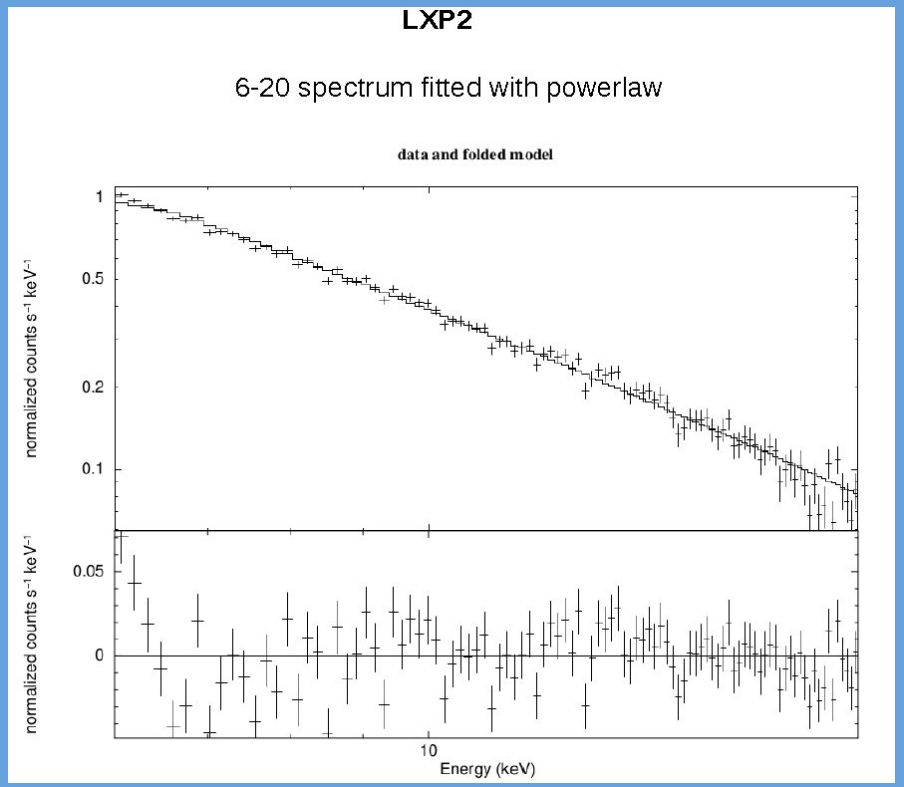





Crab LX10: γ=2.080±0.004, N=7.27±0.05, χ²=20.5
Counts (s⁻¹)
1000
100
10
1
0.1
0.01
residuals
0.05
0
−0.05
−0.1
10
100
Energy (keV)

Energy spectrum: quasar/blazer PKS2155-304





For faint X-ray sources, background observation for longer time is needed. Layer wise Spectral fitting provides better results. Further work is in progress.

Conclusions

We have observed microquasars, pulsars, AGNs, Blazers, Supernova remnants etc. LAXPC instrument has provided high quality data.

LAXPC instrument has achieved all the spectral and timing goals as proposed initially.

Background is stable. We are working on background model for Faint sources.

We have fit Crab spectrum in 3-100 keV with reasonable fit Parameters. We are working on detector effective area (associated uncertainties) and on improving detector response. We plan to have simultaneous observation with Nustar, Swift And XMM-Newton.