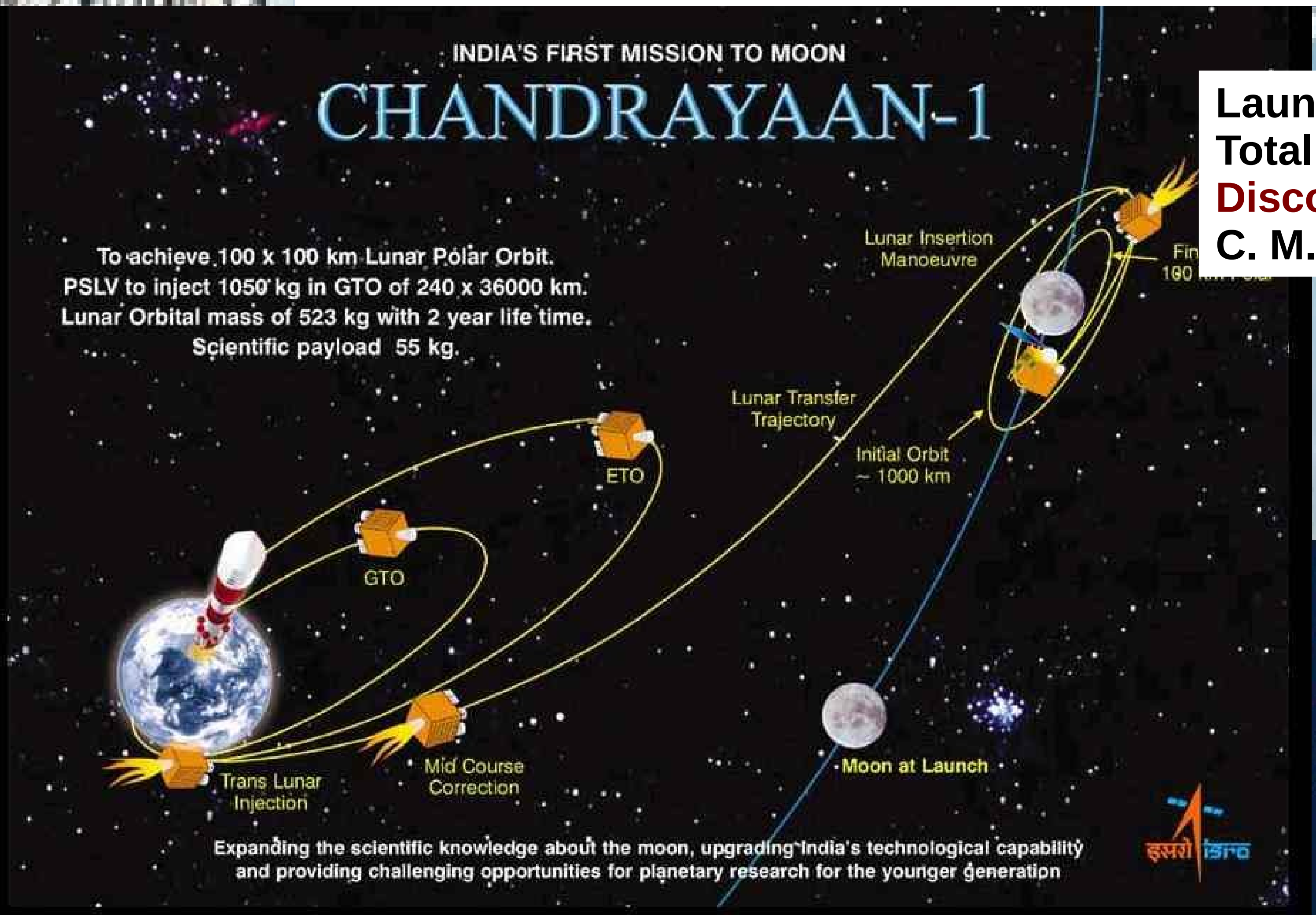
An Indian Step to Space-Based Astronomical Missions

SUNIL CHANDRA
CSR, NWU
SOUTH AFRICA

NWU®
NORTH-WEST UNIVERSITY
NOORDWES-UNIVERSITEIT
YUNIBESITI YA BOKONE-BOPHIRIMA

Collaborators:
M. Boettcher, K. P. Singh, S. Bhattacharyya,
G. C. Dewangan + AstroSat SXT Team

Total 97 satellite probes, till April 12, 2018

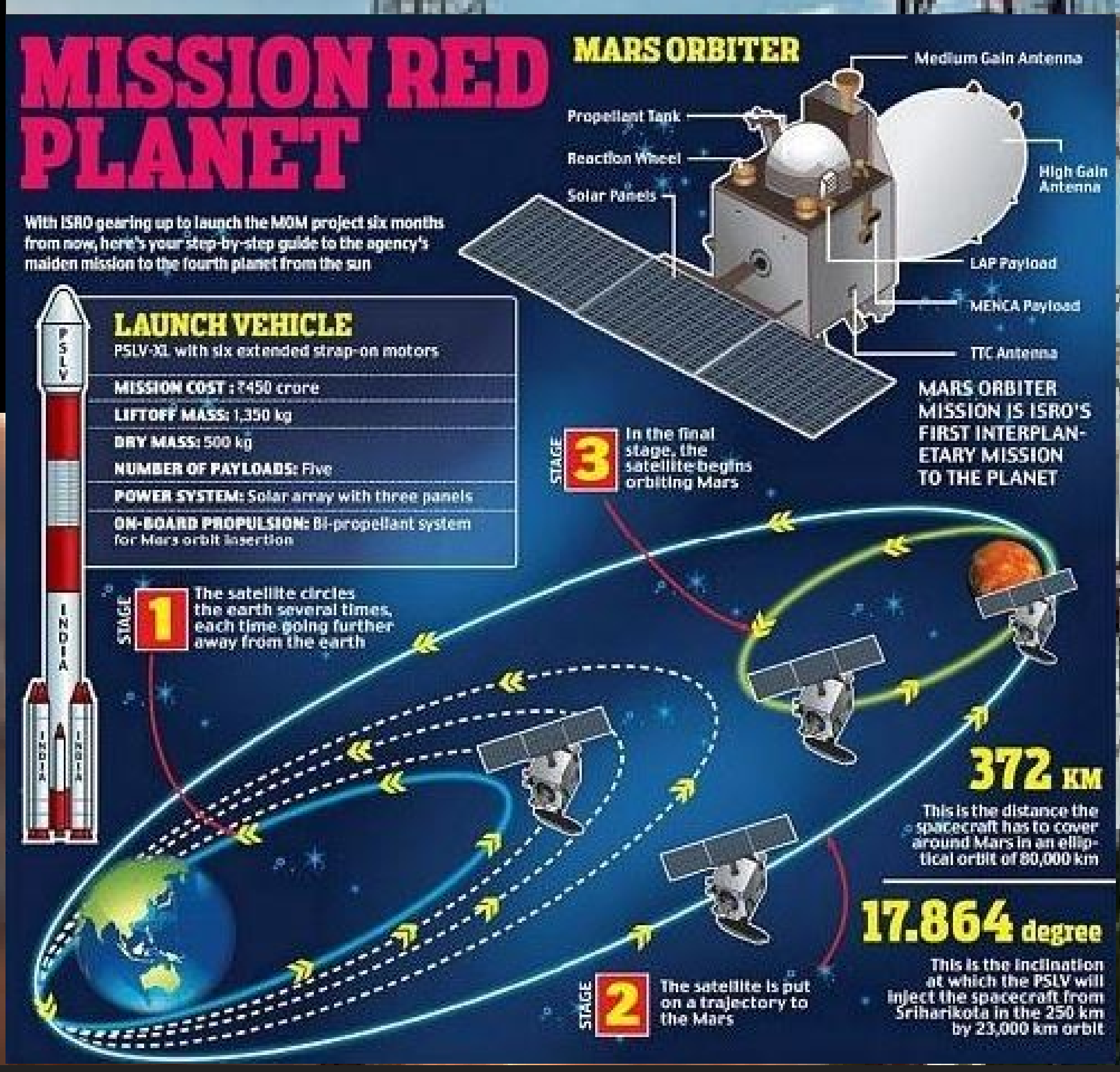


Launched on 22 October 2008
Total 10 month 6 days life:
Discovery of water on moon...
C. M. Pieters1,*, J. N. Goswami2,3, et al. 2009, Sci. 326, 568

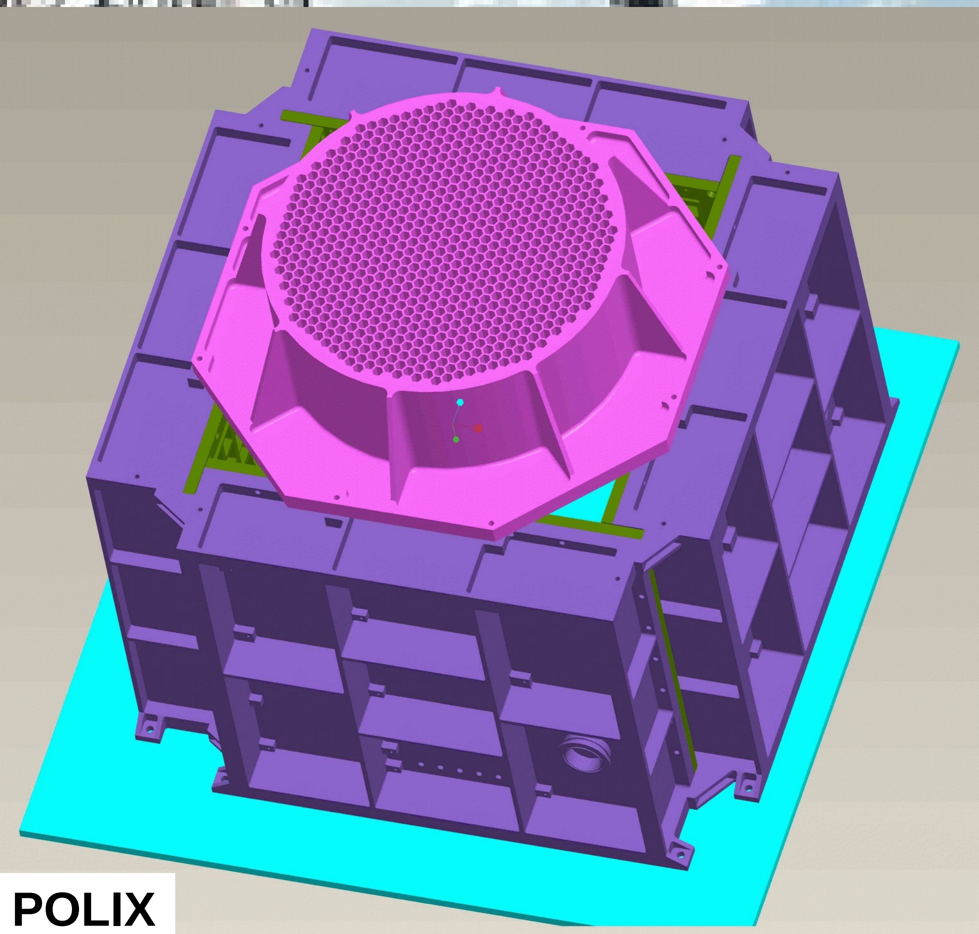
In orbit, Launched on Nov 05, 2013

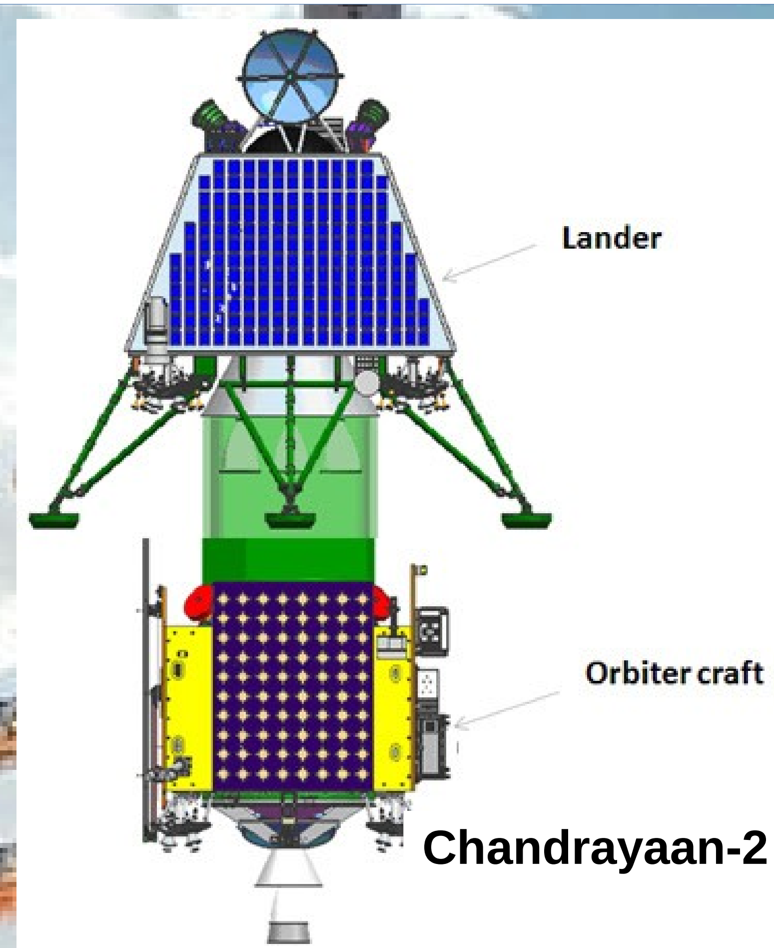
- **Mars Colour Camera (MCC)**
- **Thermal Infrared Imaging Spectrometer (TIS)**
- **Methane Sensor for Mars (MSM)**
- **Mars Exospheric Neutral Composition Analyser (MENCA)**
- **Lyman Alpha Photometer (LAP)**

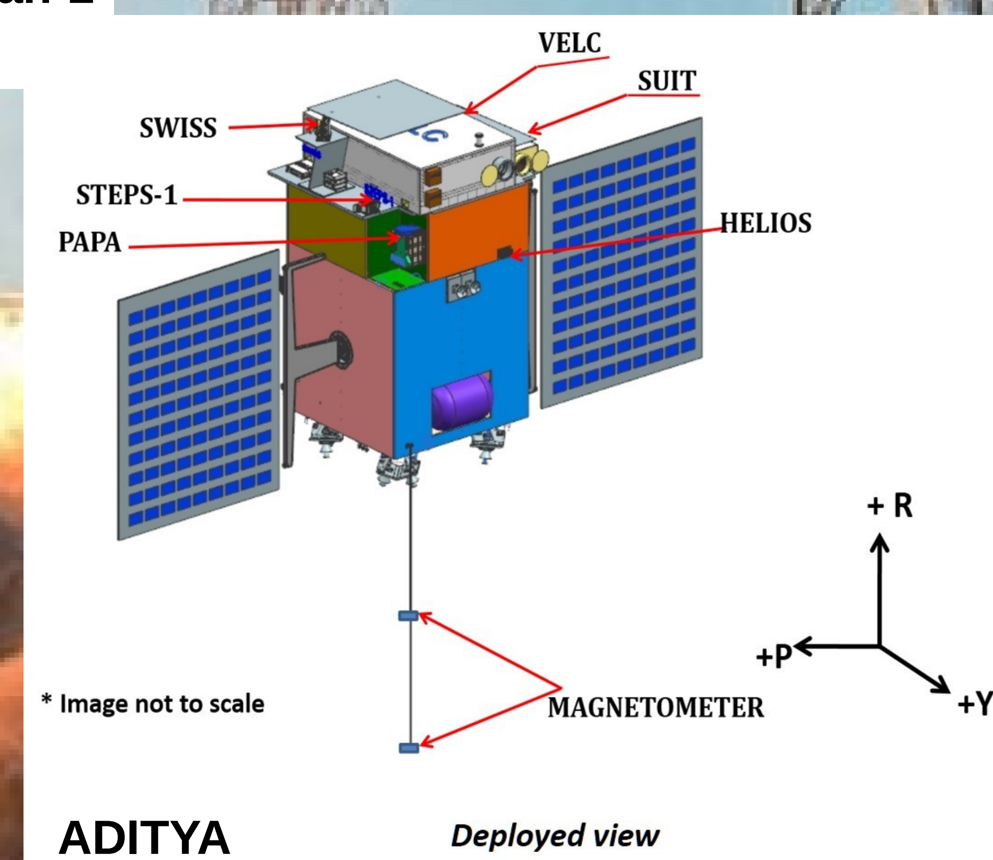
Bhardwaj A., at al., GRL, 43, 1862, 2016 ++



Probes planned for launches in near future...

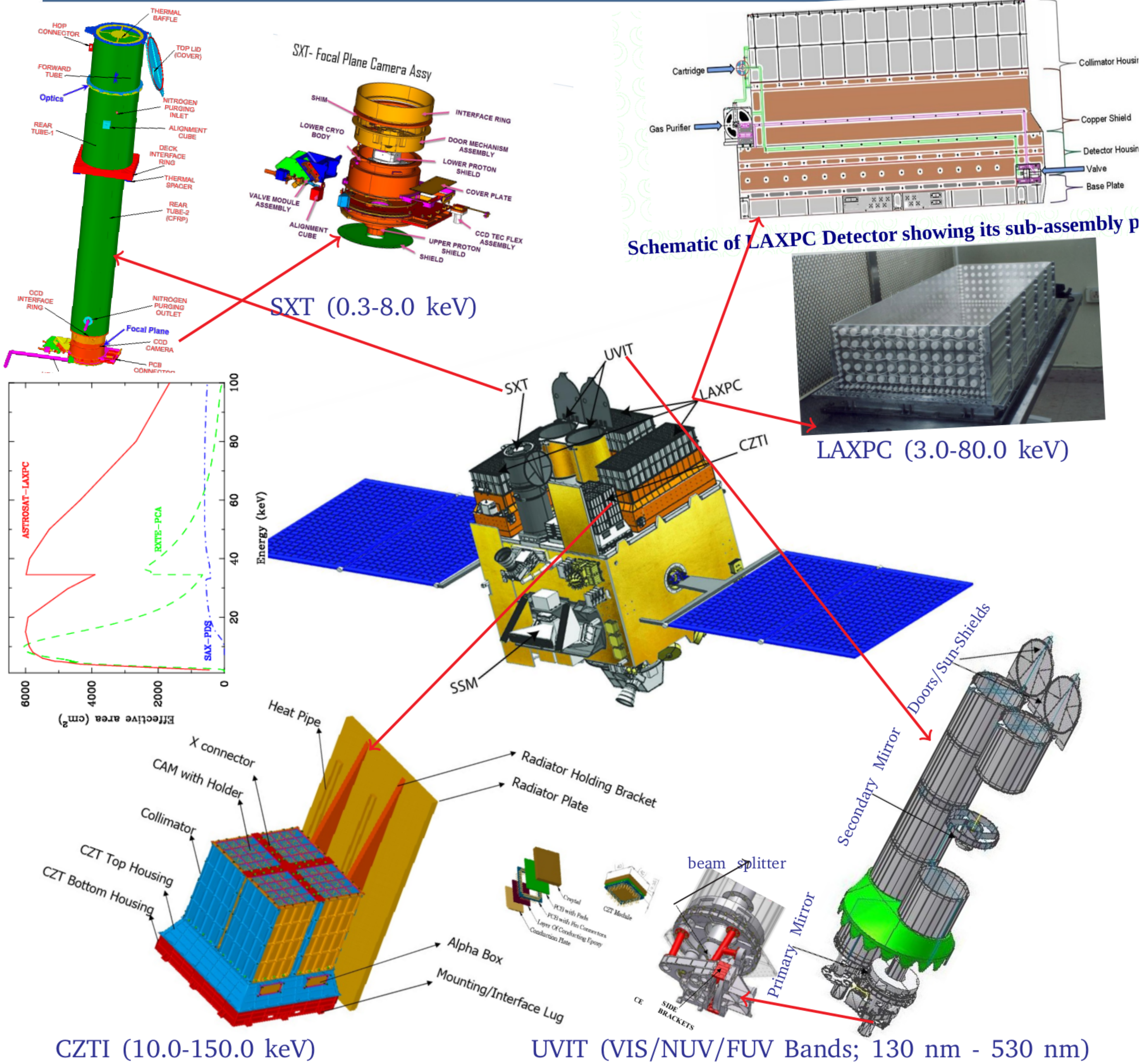







ASTROSAT
Launched on 28 September 2015

AstroSat; Introd **Launched on 28 September 2015**



General information

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
- 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.
- 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.
- Solid-state recorder with 200 Gb storage (4 orbits).
- Operational life of > 5 years

Cadmium Zinc Telluride Imager (

Area: 976 cm^2

Pixels: 16384 (64 modules of 256 pixels each)
Pixel size 2.46 mm X 2.46 mm (5 mm thick)

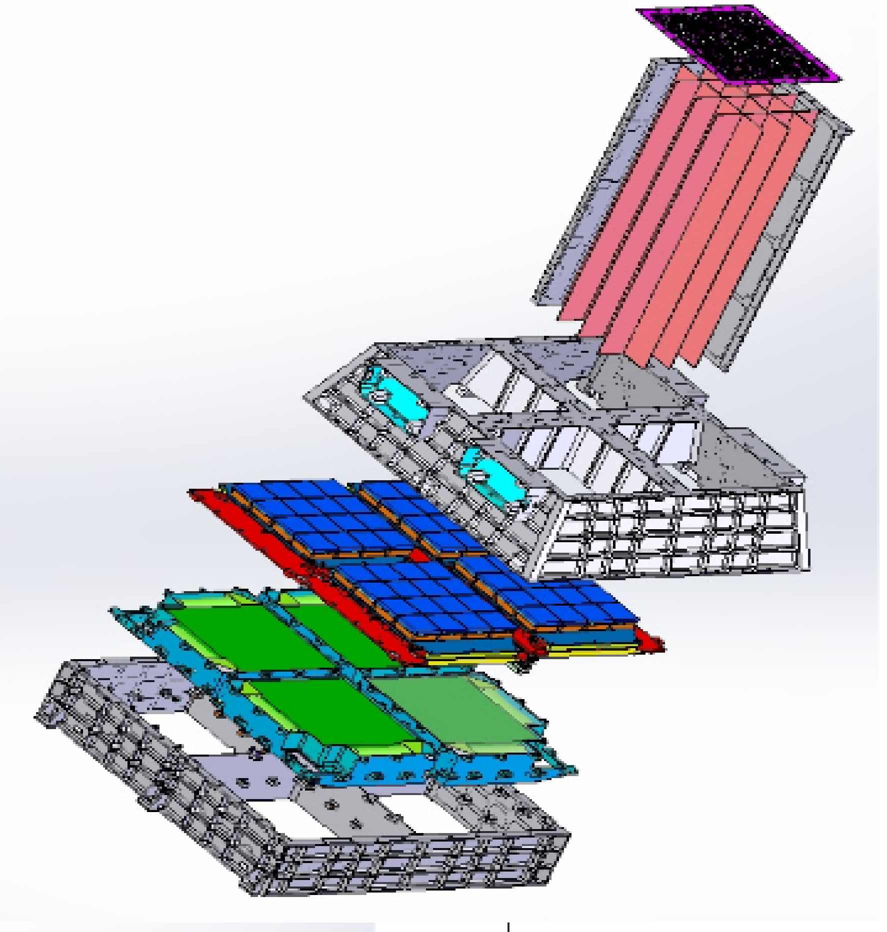
Imaging method Coded Aperture Mask (CAM

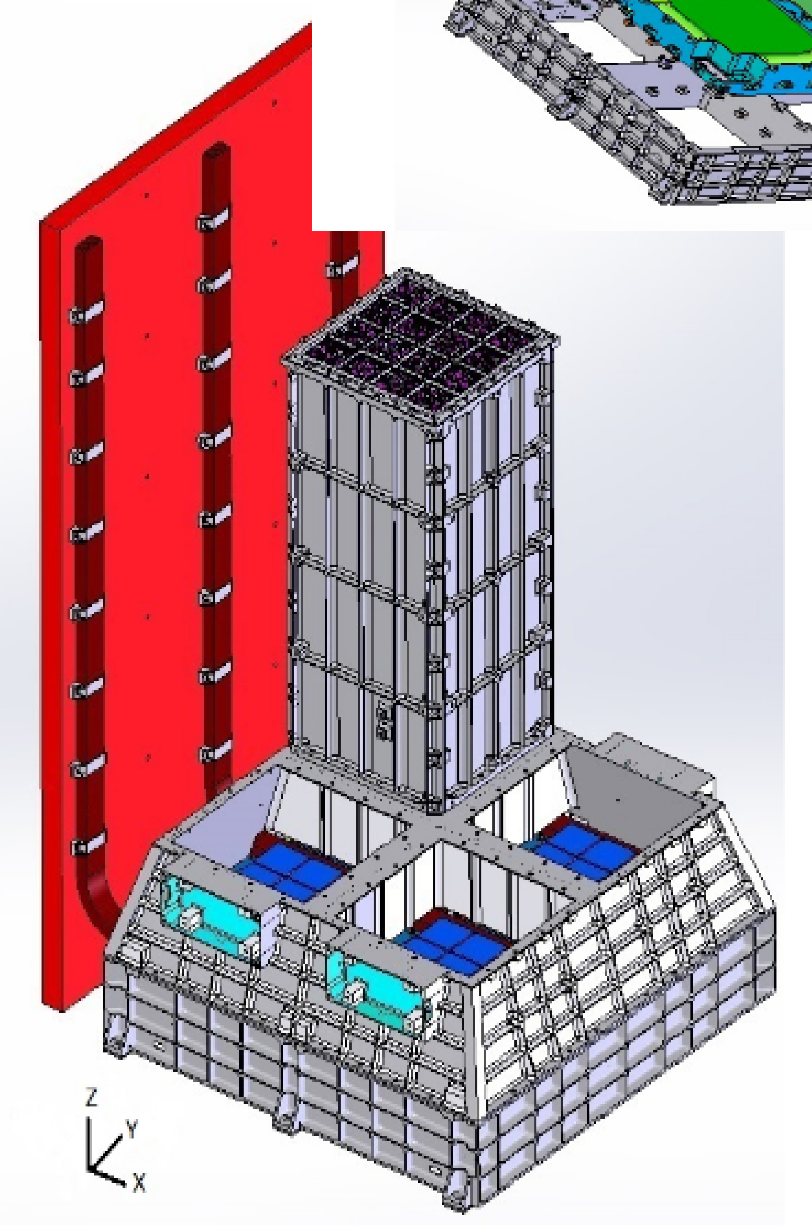
Field of View (10-100 keV):
4.6^o X 4.6^o FWHM (primary FOV)
11.8^o X 11.8^o FWZM (incl. illumination leakag

Angular resolution ~ 8 arcmin
Energy resolution ~ 8% @ 100 keV
Energy range: 10 – 100 keV

Up to 1 MeV (Photometric); no imaging abov
100 keV

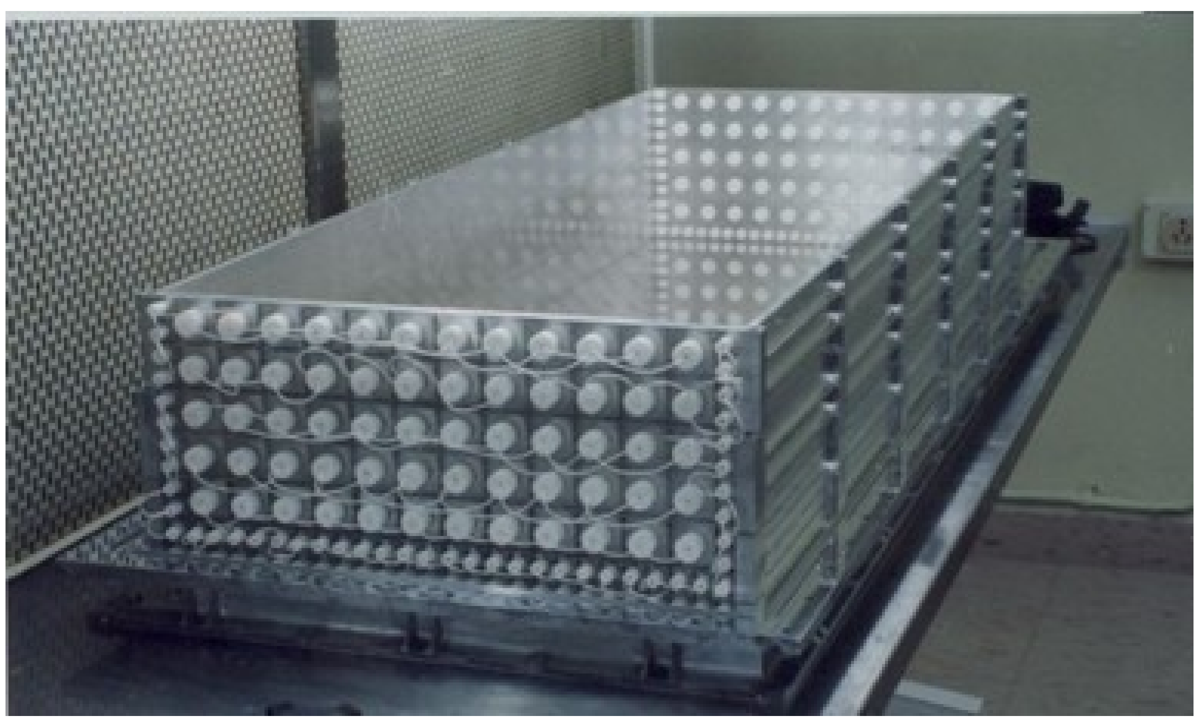
Sensitivity: 0.5 mCrab (5 sigma; 10^4 s)





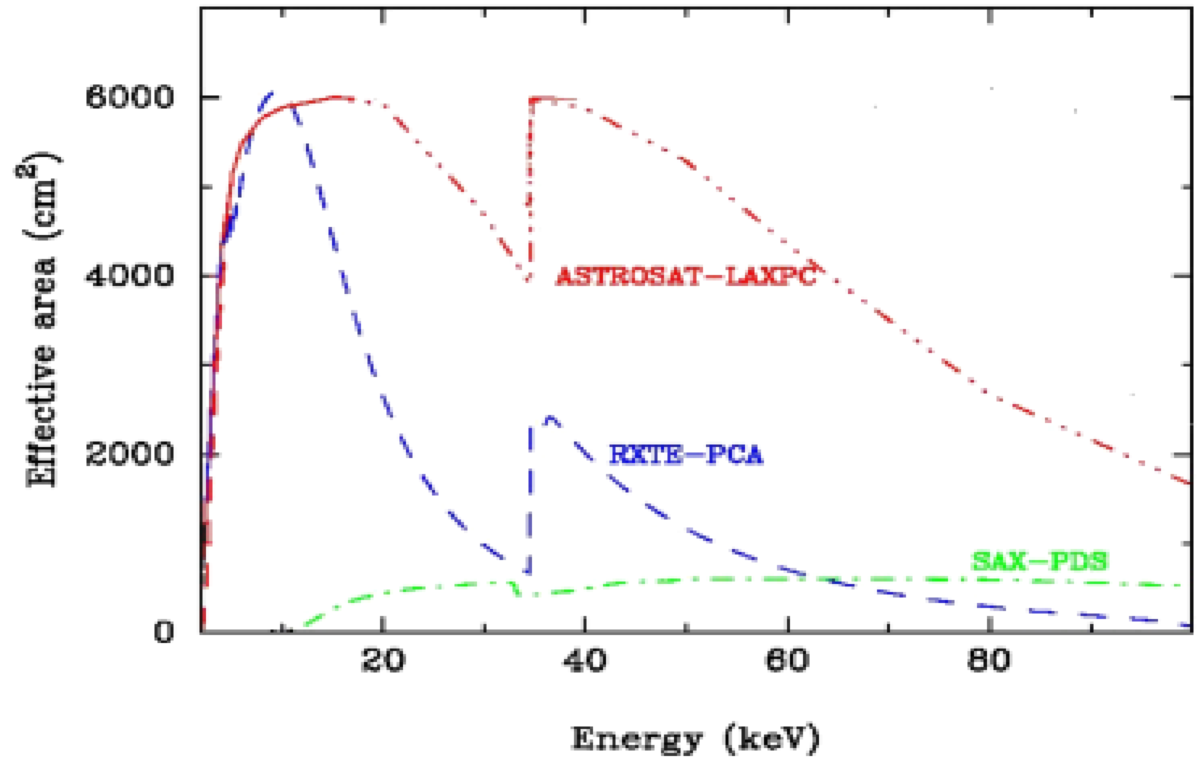
https://arxiv.org/pdf/1608.03408.pdf

Payloads, LAXPC



5 layers, 60 anode cells; veto layer on 3 sides

http://lanl.arxiv.org/pdf/1702.08624v2



FOV: 1° x 1° E ~ 3.0 - 80 keV

High Detection Efficiencies

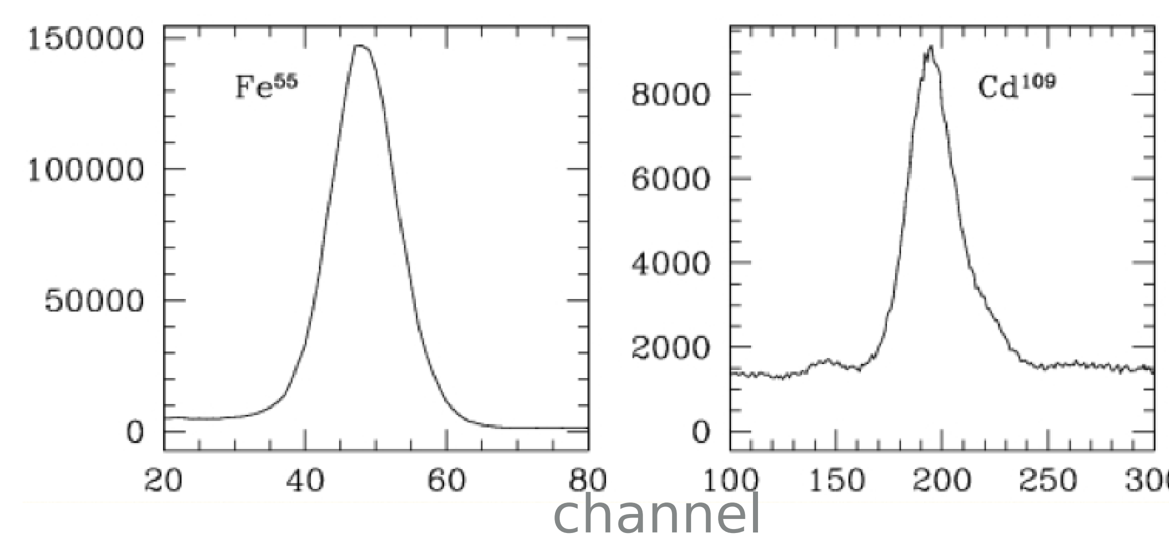
(100% E<15 keV & 50 upto 80 keV)

Moderate Energy Resolution

Timing accuracy: 20 micro sec

Sensitivity : 0.1 mCrab at 5 sigma for10^4 s

Small Internal Background



Payloads, Ultra-Violet Telescope (UVIT)

Table 1 Specifications of Ultra Violet Imaging Telescope

	FUV	NUV	VIS
Detector	Intensified CMOS Photon Counting/ Integration	Intensified CMOS Photon Counting/ Integration	Intensified CMOS Photon Counting/ Integration
CMOS chip	Fillfactory/ Cypress STAR250, 512x512, 25µm pixels		
Telescope Optics	Ritchey-Chertian 2 mirror System	Ritchey-Chertian 2 mirror System	Ritchey-Chertian 2 mirror System
Bandwidth	130-180 nm	200-300 nm	320-550nm
Geometric Area (cm^2)	~880	~880	~880
Effective Area (cm^2)	> ~15 at peak	> ~50 at peak	> ~50 at peak
Field of View	~28'	~28'	~28'
Spectral Resolution	<1000 A (depends on Choice of Filters)	<1000 A (depends on Choice of Filters)	<1000 A (depends on Choice of Filters)
Spatial Resolution	<1.8 arc second	<1.8 arc second	<1.8 arc second
Time Resolution	<10 ms (for Partial field)	<10 ms (for Partial field)	<10 ms (for Partial field)
Typical Observation time per target	30 min	30 min	30 min
Sensitivity (obs.time)	>20^{m} Magnitude (5σ) in 200 s	-	-
Photometry Accuracy	10%		
Total Mass (Kg)	230 Kg		
Total Power (watts)	85 watts (peak 117 watts)		
Sun-avoidance angle	45 deg		

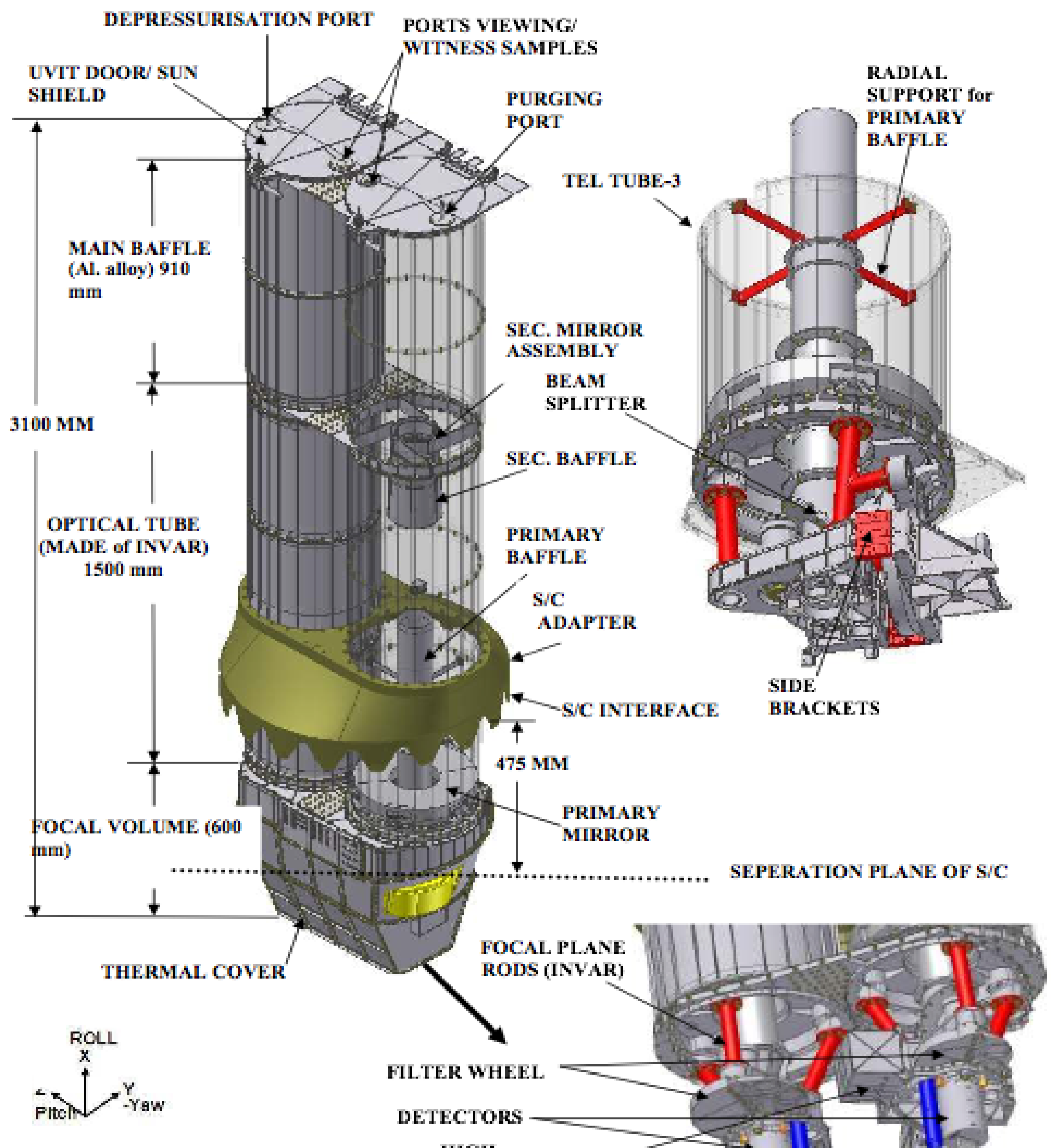
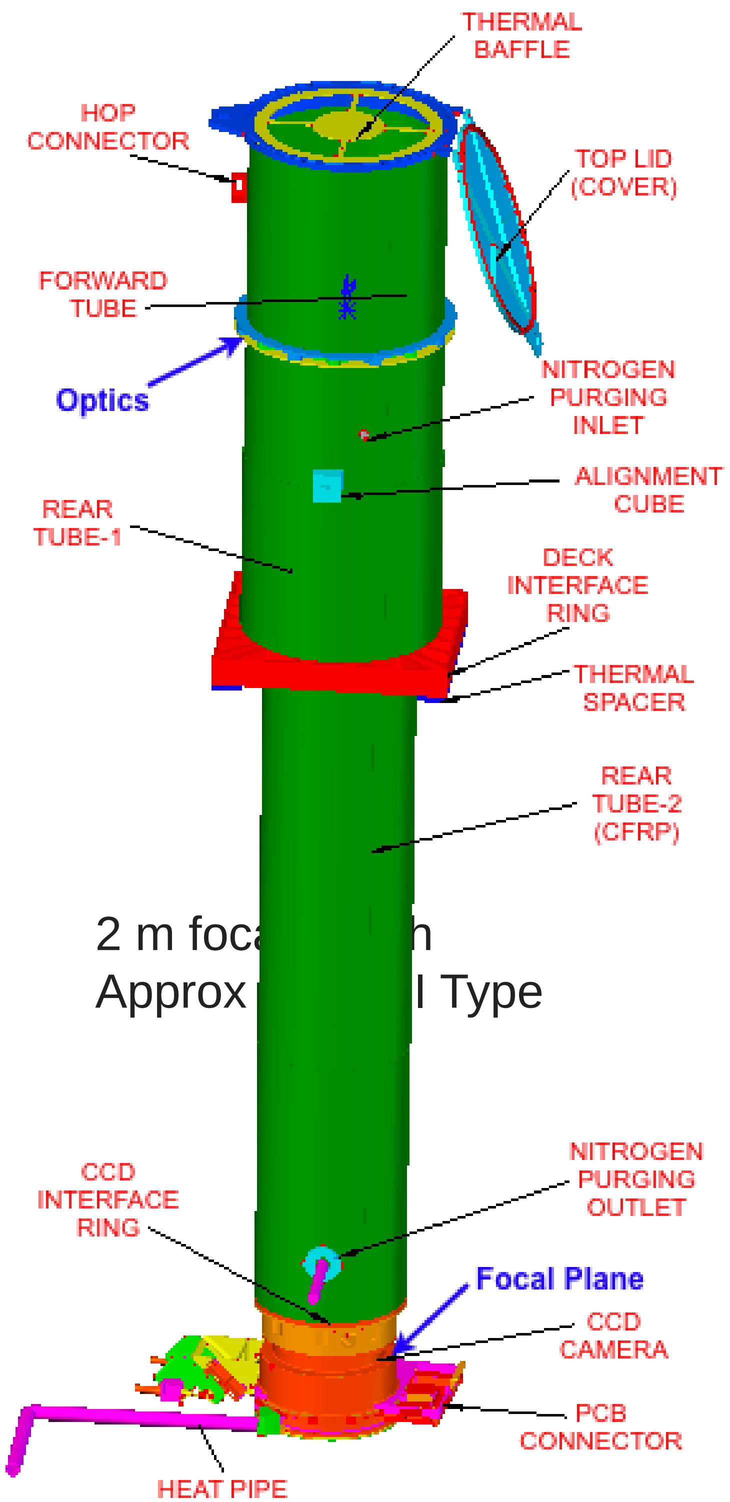


Figure 1: UVIT Configuration

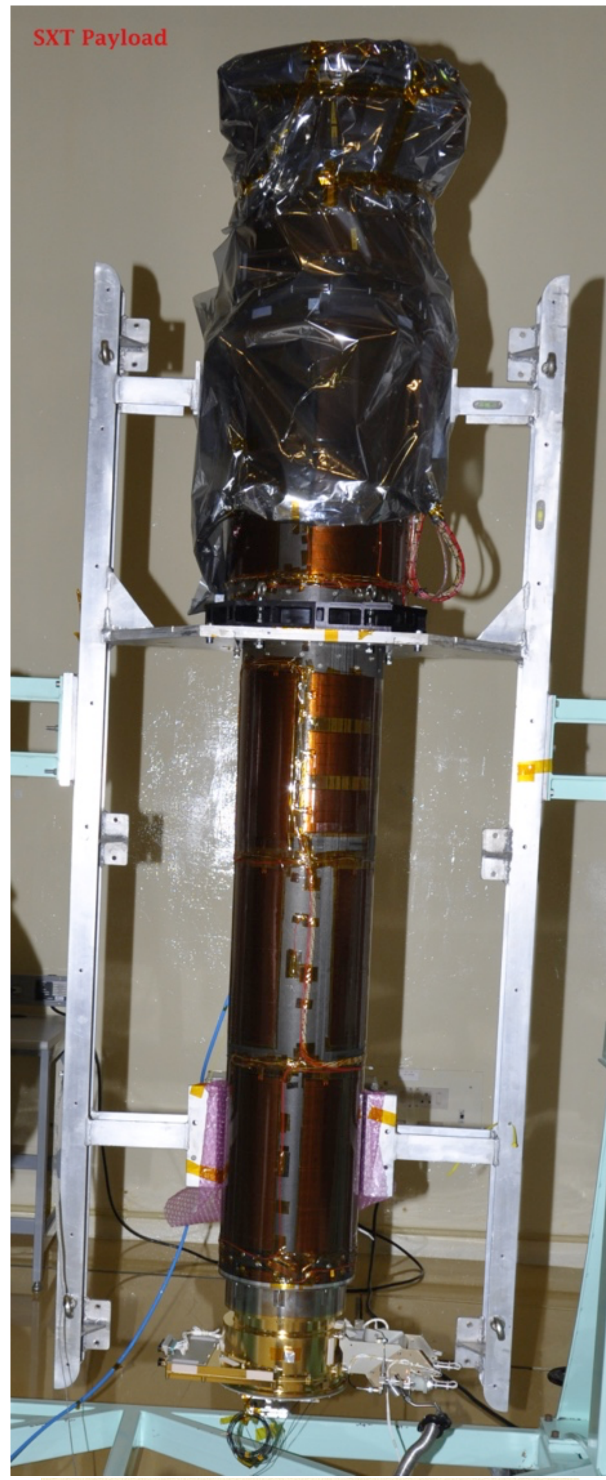
Twin 38 cm telescope

http://www.iucaa.ernet.in/~astrosat/uvit_specs.html

Payloads, Soft X-Rays Telescope (SXT)

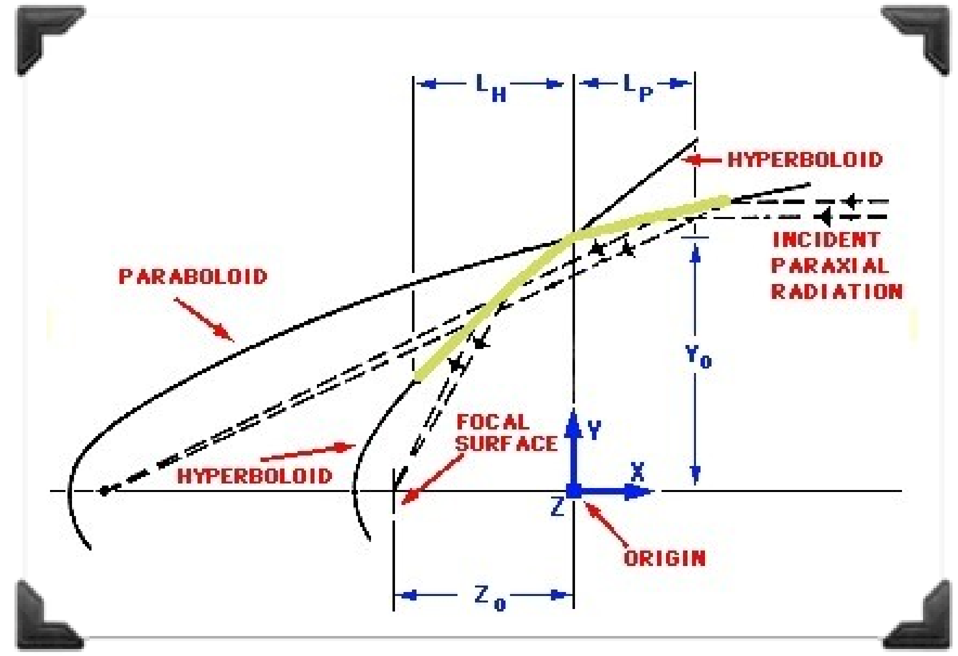


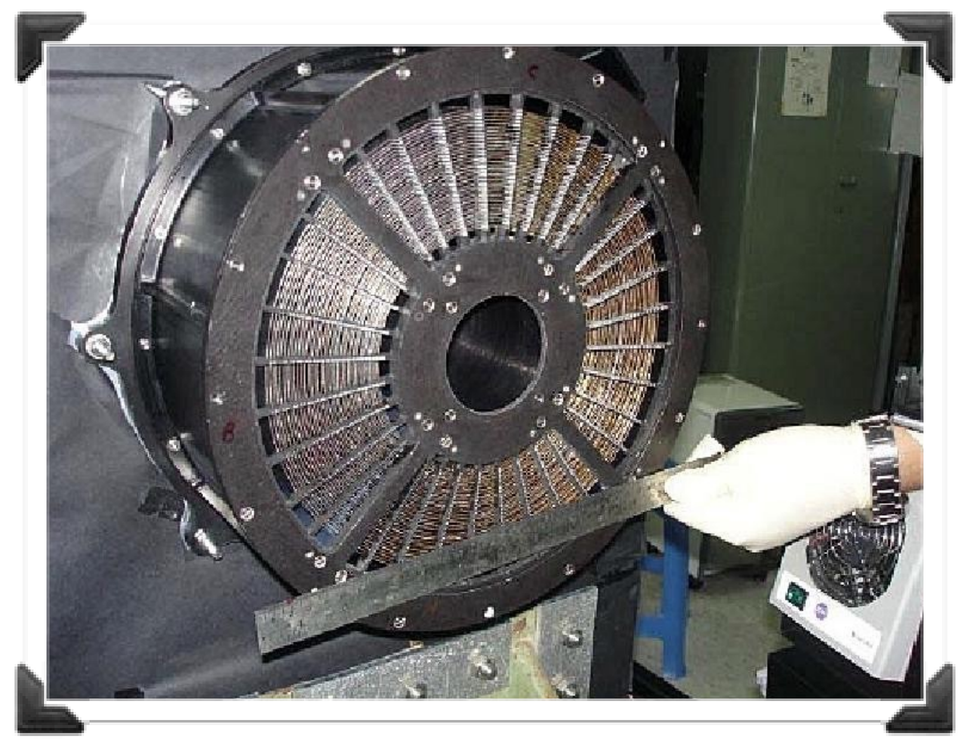
2 m foca h
Approx l Type



0.3-8 keV
Focussing Telescope
FOV 40 arcmin
Resoln 3 arcmin
Sensitivity
~10 microCrab

Mirrors: Nested & Segmented conical surfaces in Wolter type I geometry working at Grazing incidence. 39 nested shells

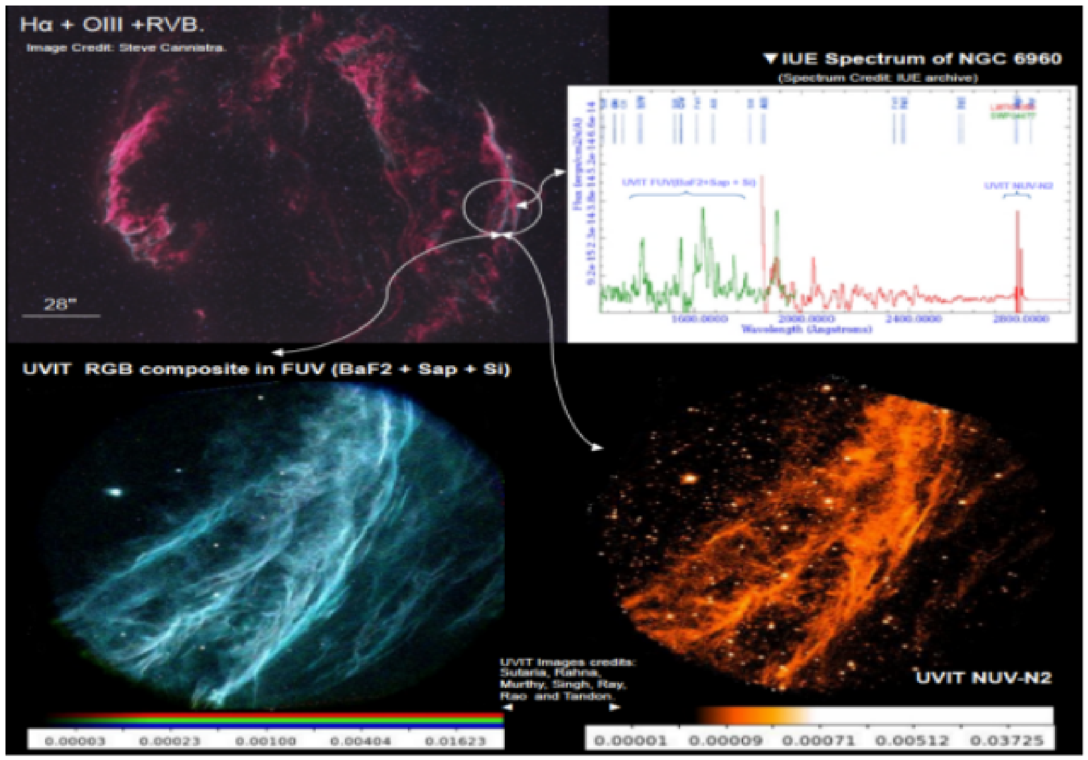


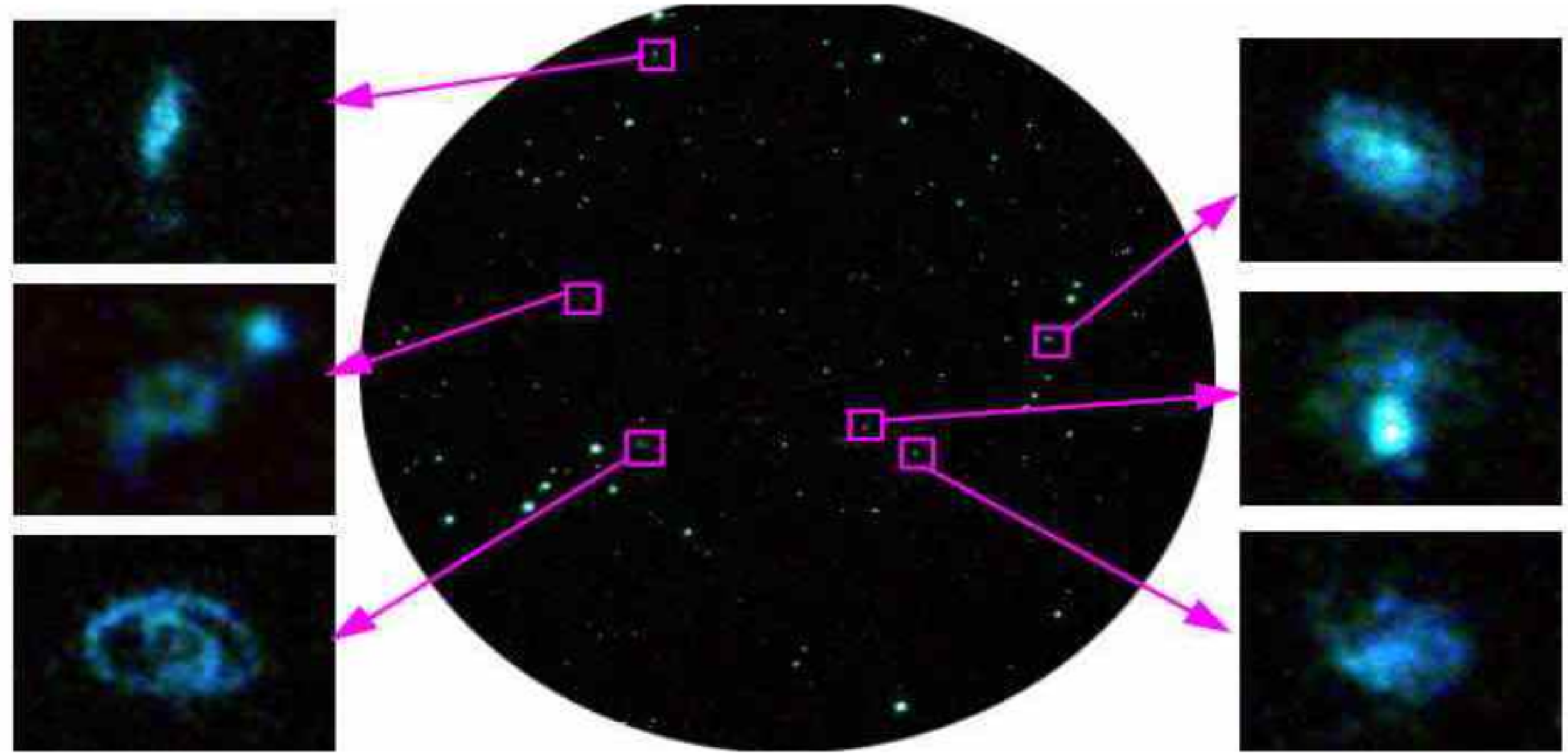


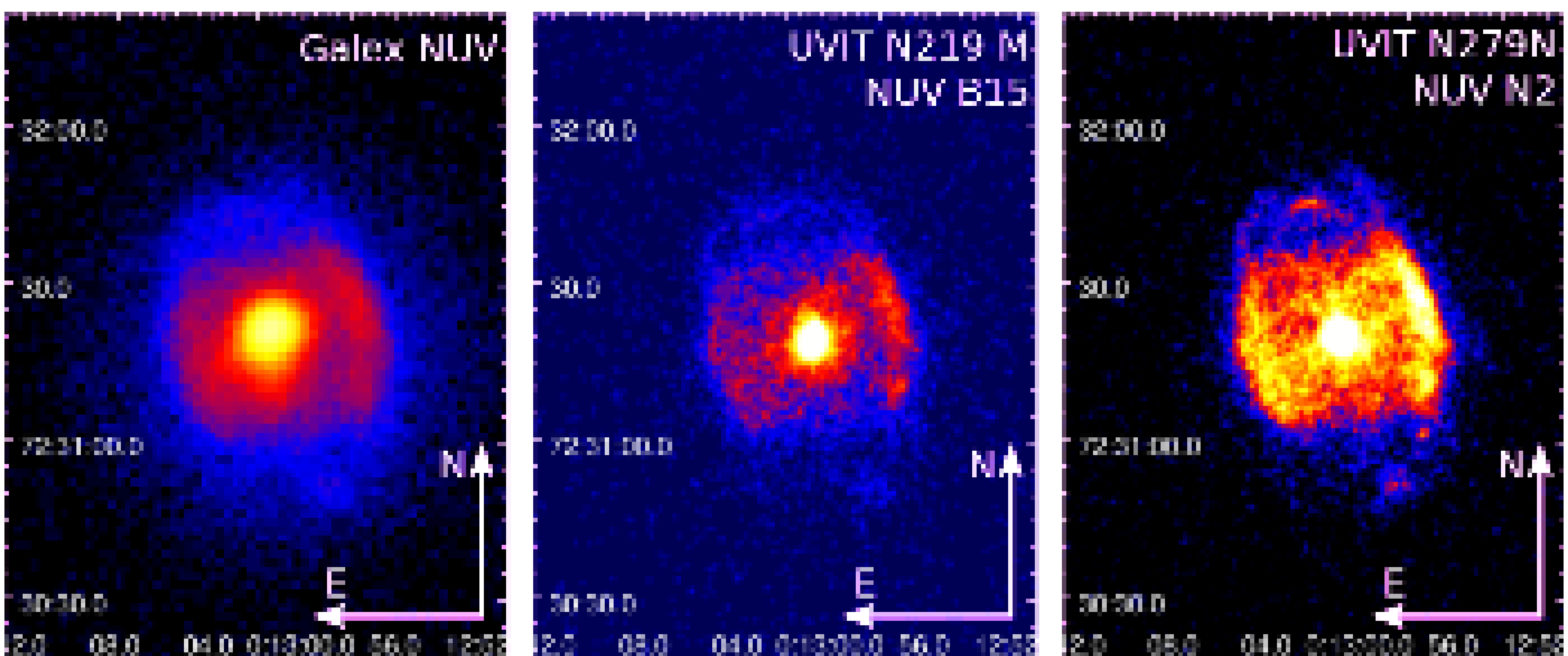
Telescope PSF	:	1.5 - 2.5 arcmin (rms)

UVIT NGC 40 (Bow Tie Nebula)

- Stunning UV Images of extended structures in our nearby universe : (Courtesy: UVIT Team and AstroSat Picture of the month; e.g. https://www.isro.gov.in/update/02-jul-2018/)

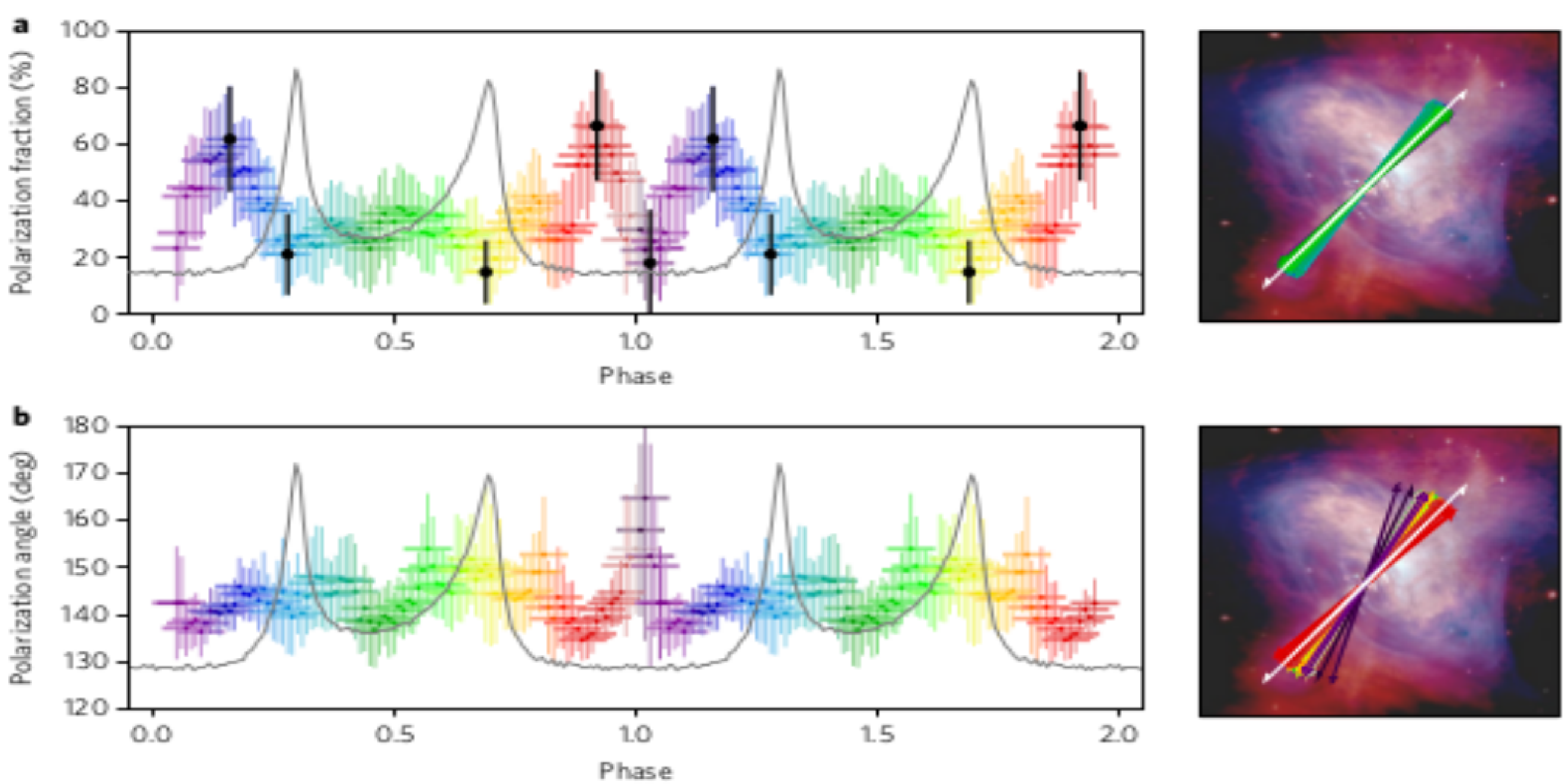




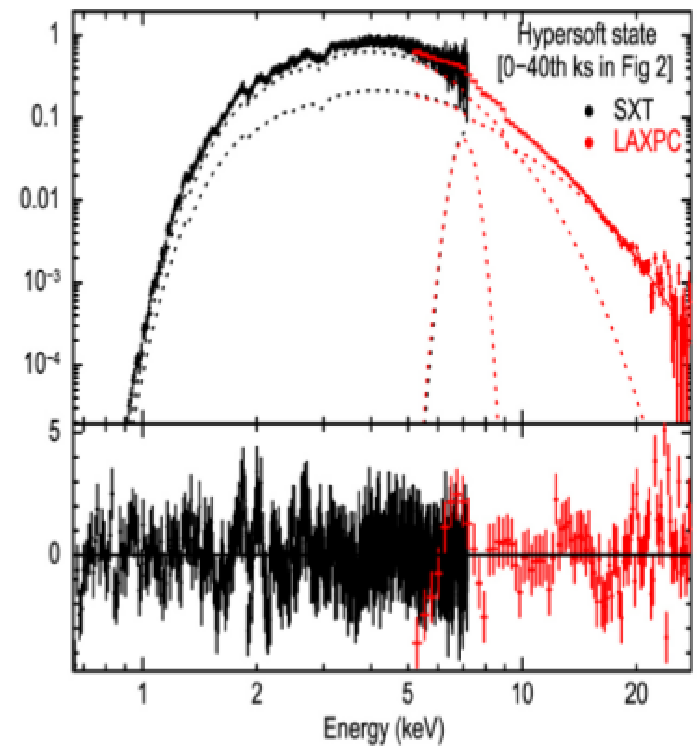


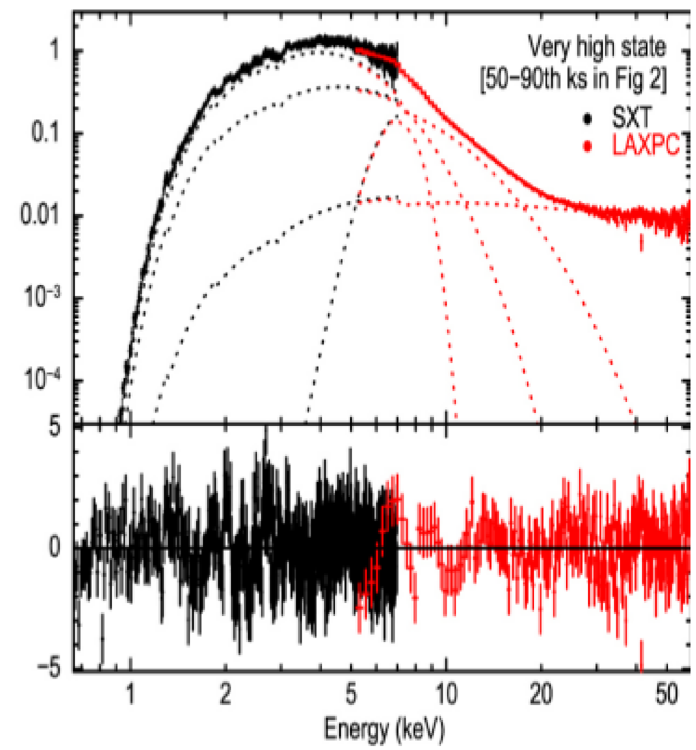
- Hard-Xray (>100 keV) polarization from Crab, GRBs and Cygnus X-1 (Example

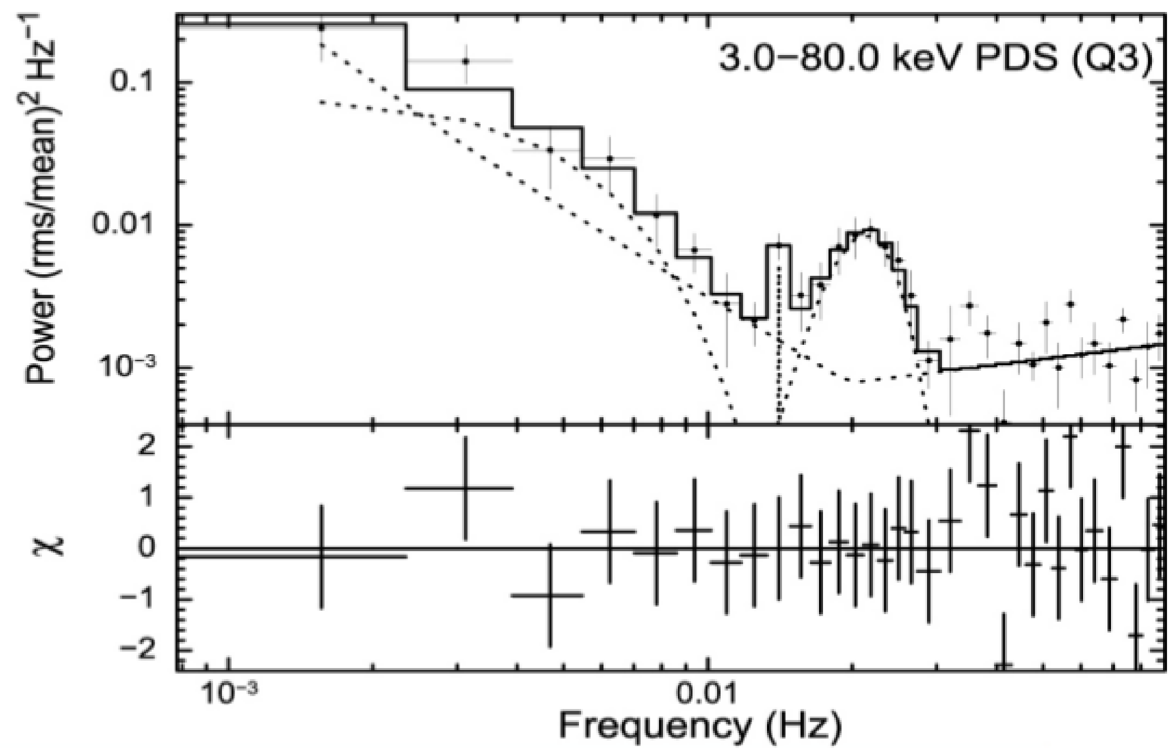
Phase-resolved X-ray polarimetry of the Crab pulsar, Vadawale et al., Nature Astronomy 2, 50, 2018)



Spectral and Timing Studies of XRBs(Example Cyg X-3, Pahari et al 2018a, 2018b)







Yadav et al. 2016

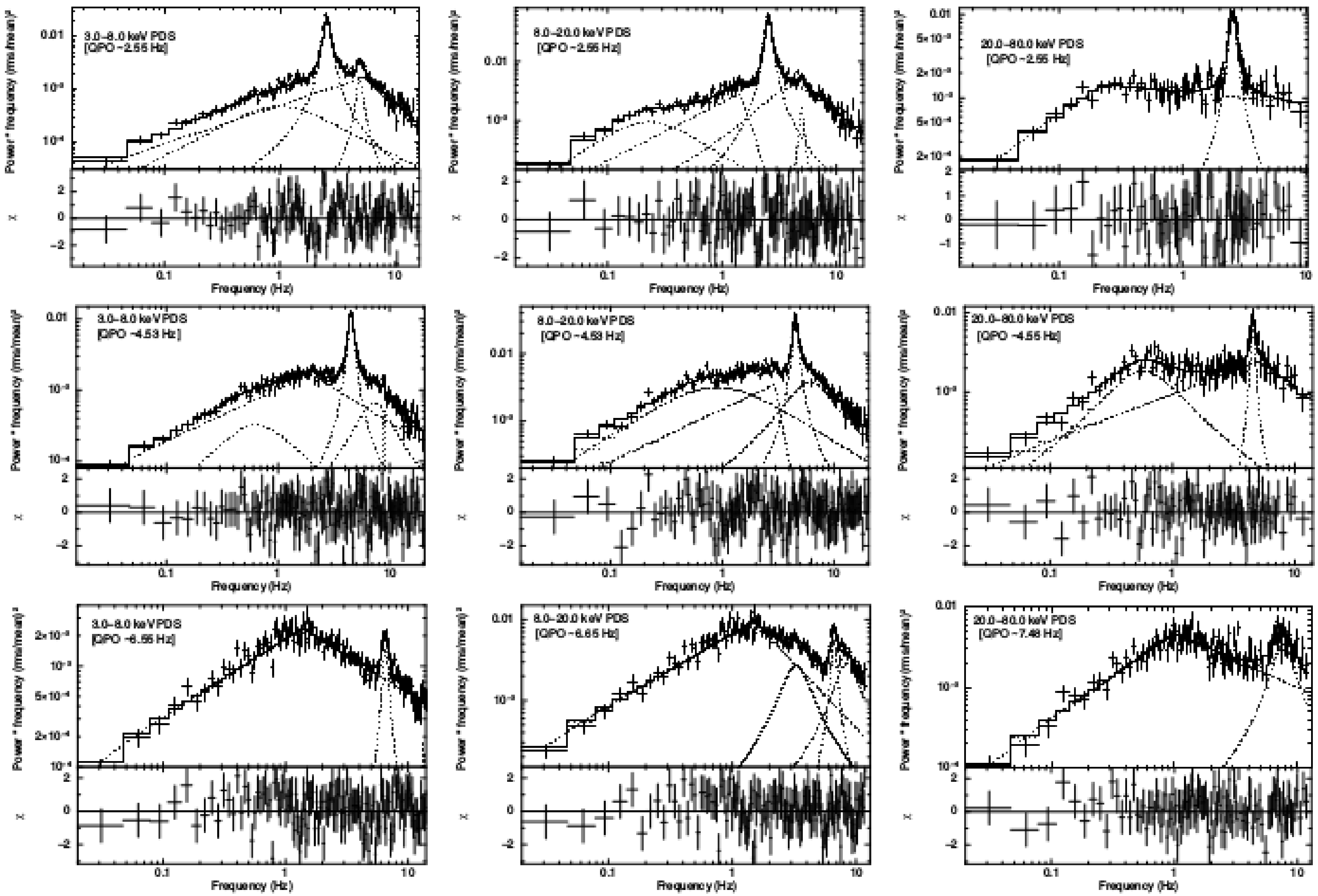
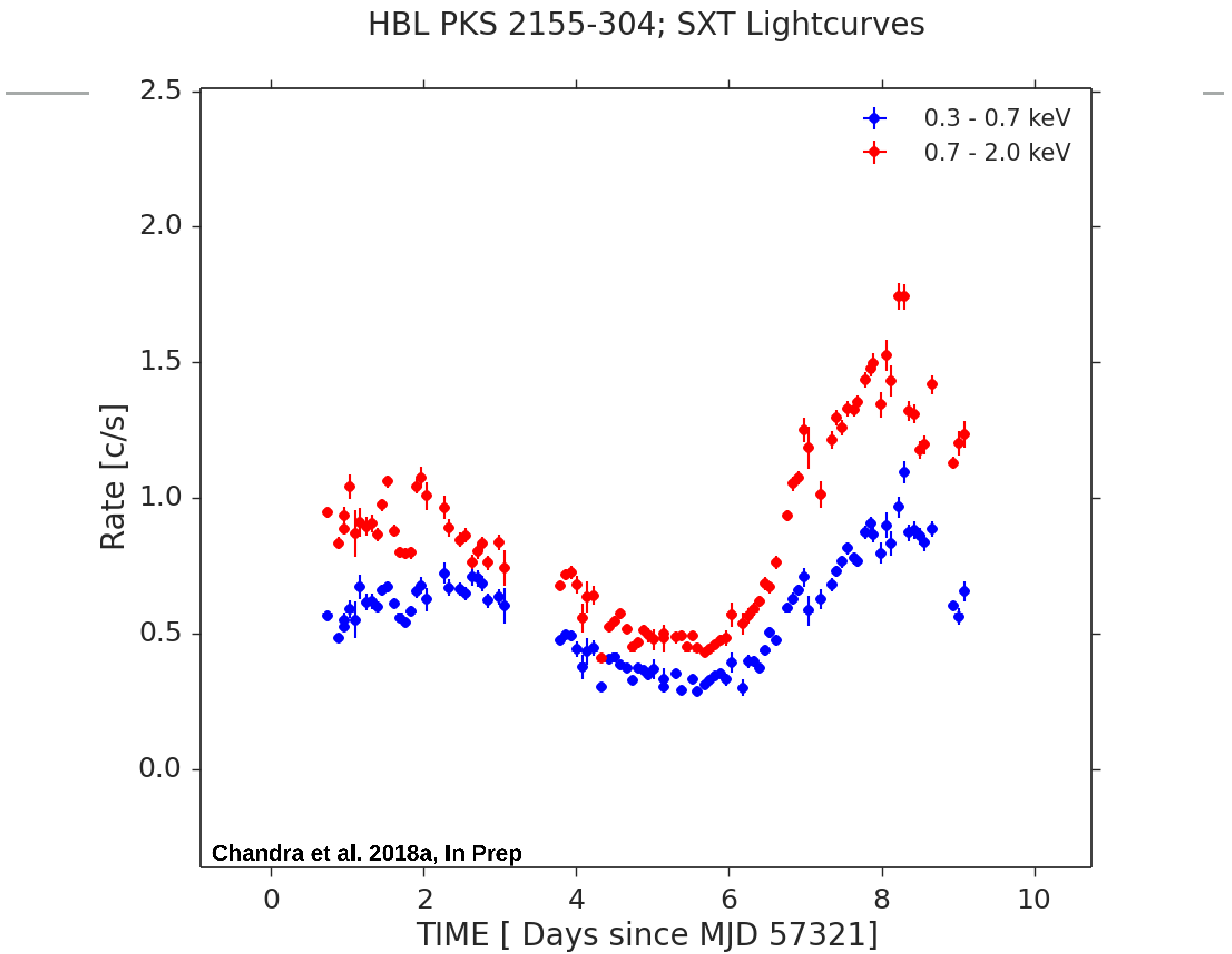
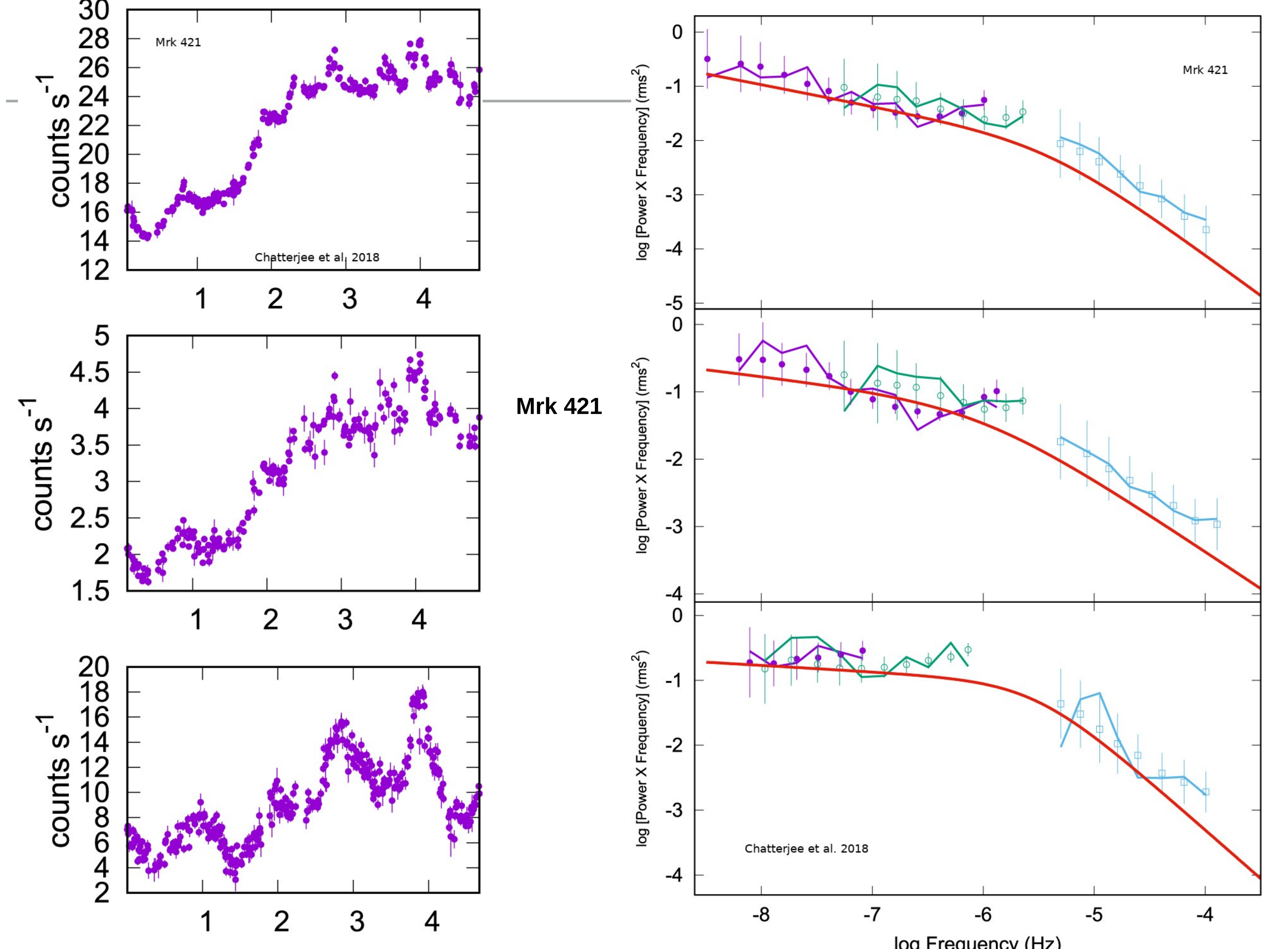


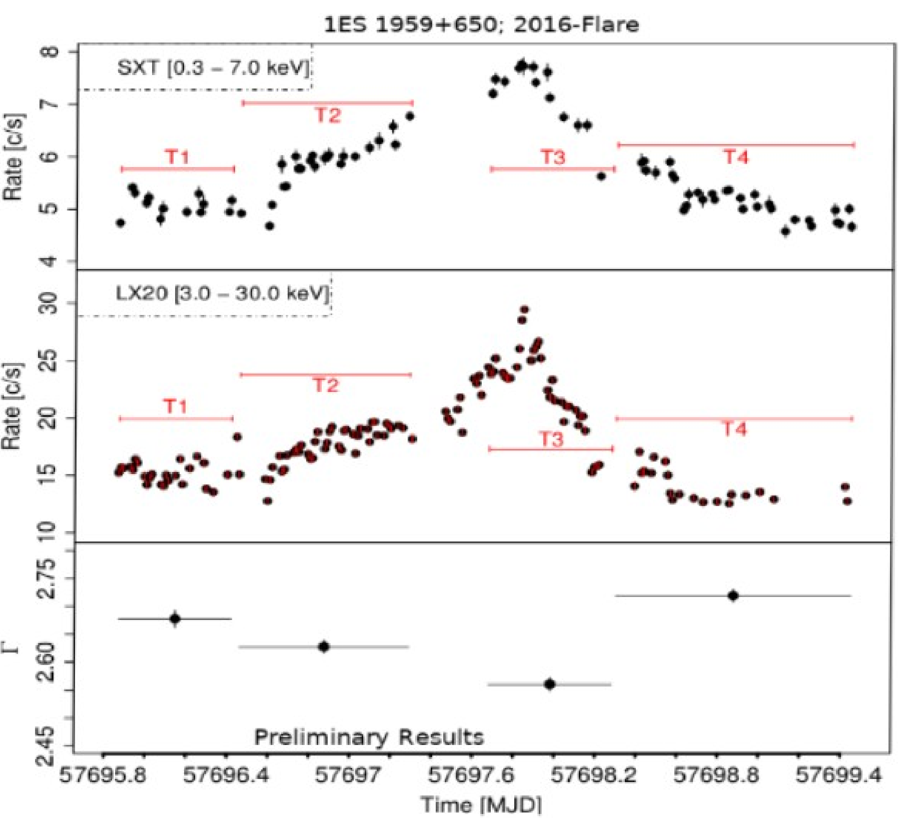
FIG. 7.— Power density spectra at three different energy bands 3.0–8.0 keV (first column), 8.0–20.0 keV (second column) and 20.0–80.0 keV (third column) are shown for three observations when strong QPOs are detected at ~ 2.55 Hz (top rows), ~ 4.53 Hz (middle rows) and ~ 6.55 Hz (bottom rows) respectively. Due to observed break in noise continuum, broken powerlaw model is used to fit the noise component while Lorentzians are used to fit QPO and harmonic features. It may be noted that a significant, excess noise component (modeled with broad Lorentzian) appears in the PDS with higher QPO frequencies at the energy > 8.0 keV. Such features were not detected by *RXTE* due to its highly reduced efficiency in 8.0–20.0 keV energy band.

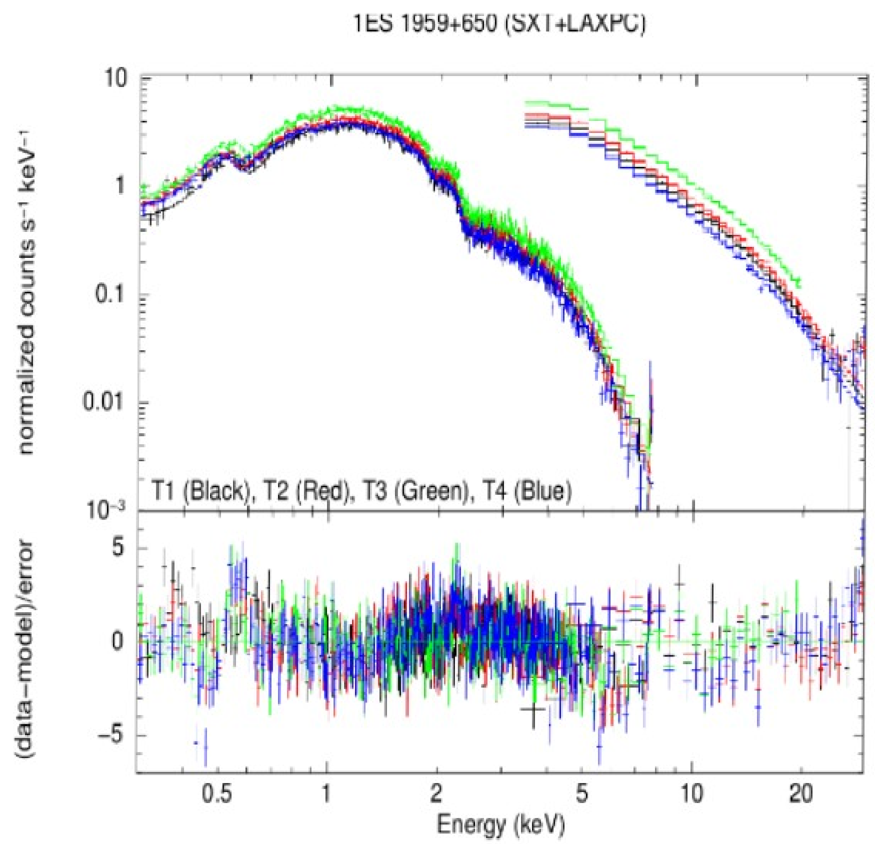


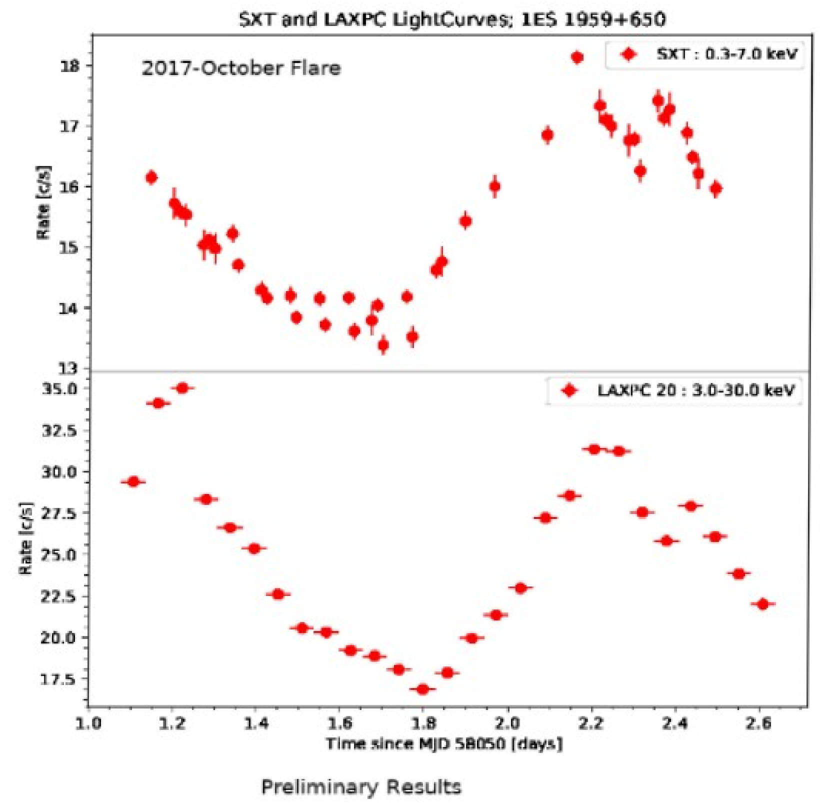
HBL PKS 2155-304; SXT Lightcurves
0.3 - 0.7 keV
0.7 - 2.0 keV
Rate [c/s]
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
TIME [Days since MJD 57321]
Chandra et al. 2018a, In Prep



Chatterjee R., et al., 2018, ApJL, 859, L21

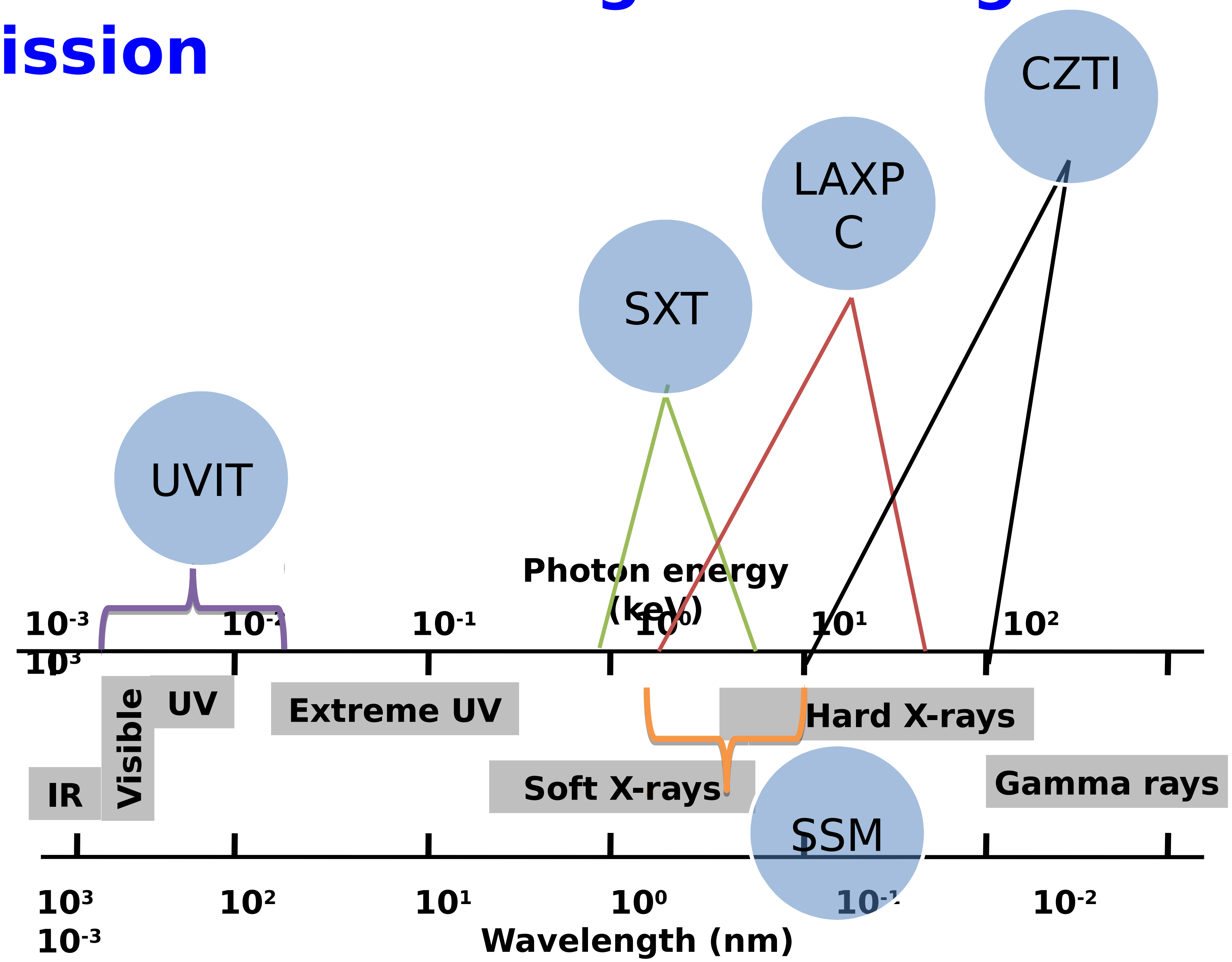






Chandra et al. 2018b, In Prep

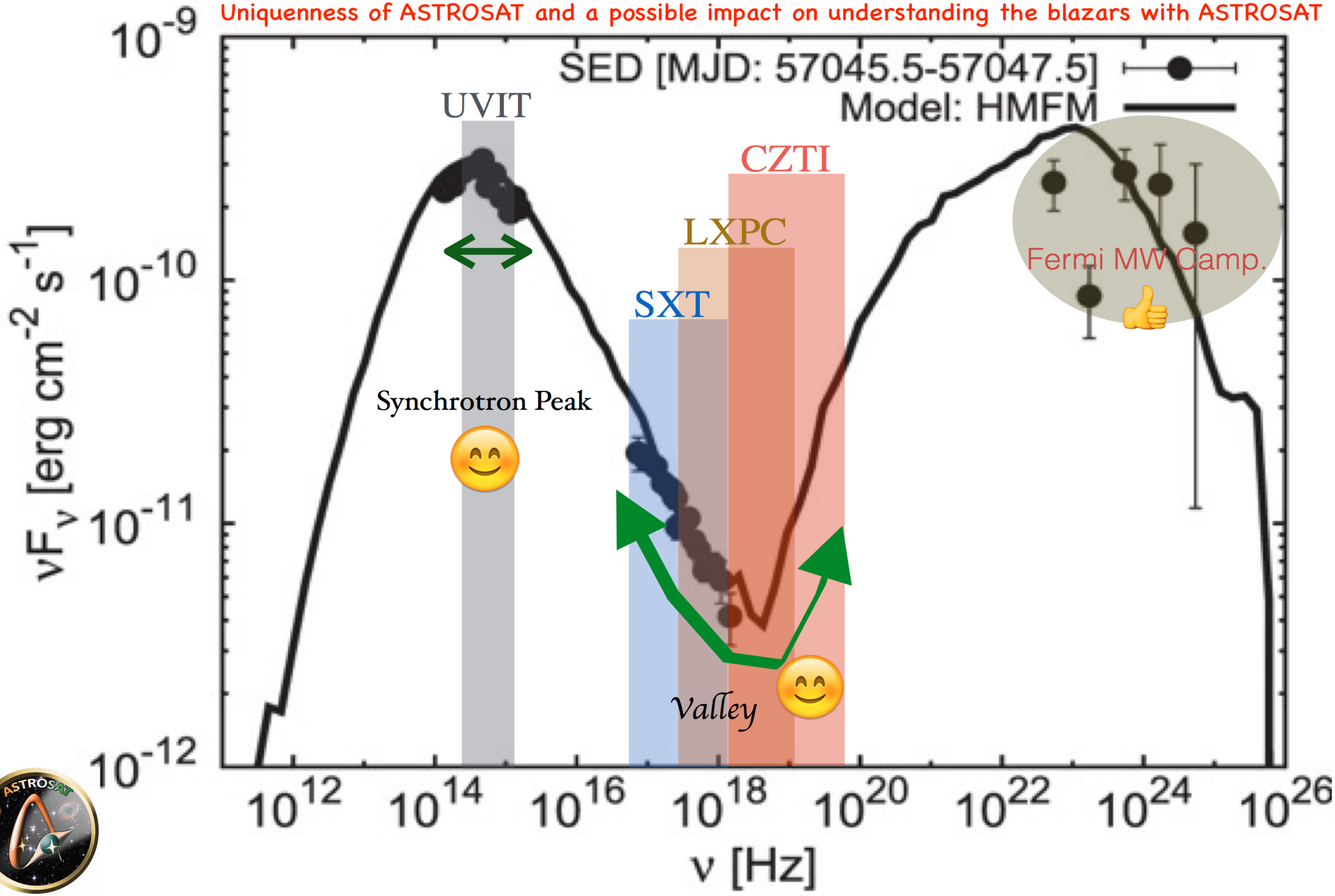
Broadband coverage in a single mission



Typical Electromagnetic Spectrum

ASTROSAT AND BLAZARS??

Uniqueness of ASTROSAT and a possible impact on understanding the blazars with ASTROSAT



AstroSat Observations Cycles

0 - 6 months (Oct. 2015 – Mar. 2016): Performance Verification (Complete)

6-12 months (Apr. 2016 – Sep. 2016): Guaranteed Time Observations (GTO) (Complete)

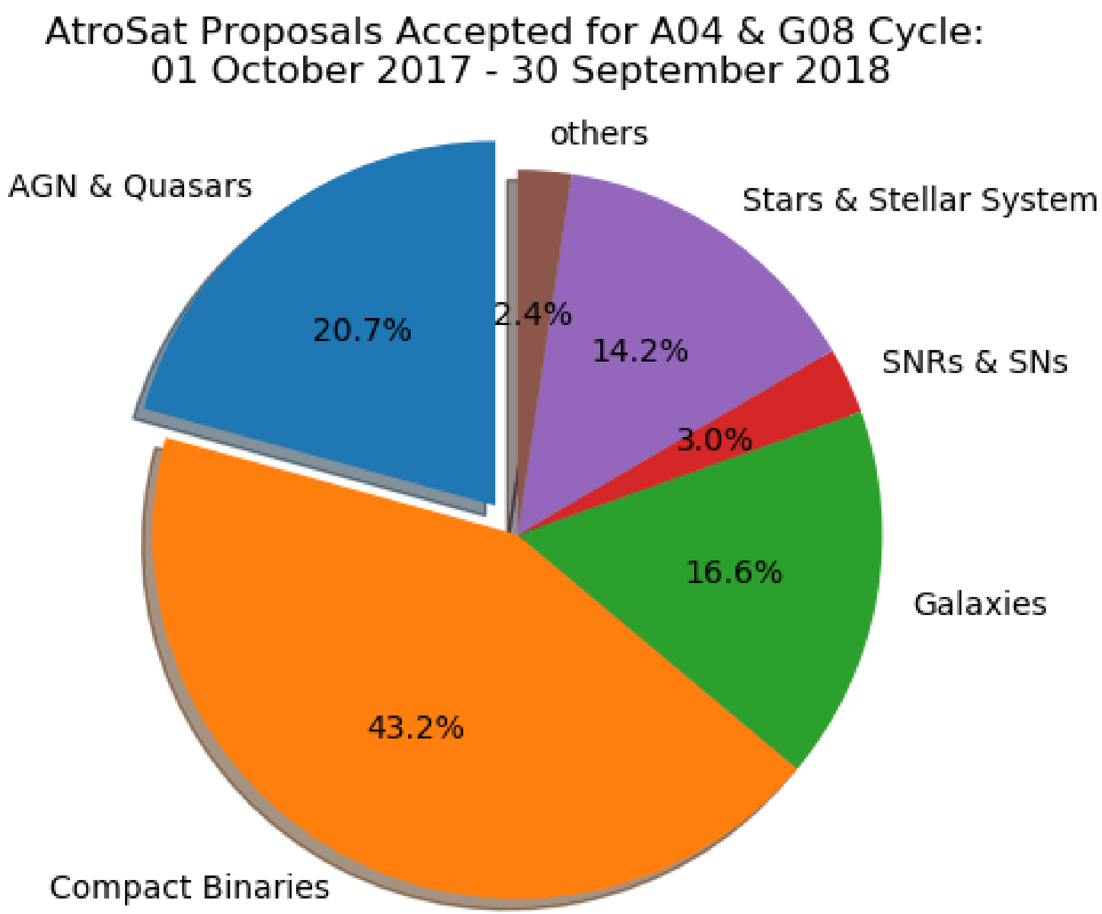
Year 2 (Oct. 2016 – Sep. 2017): AO: Indian PIs: 35% and GTO: 50% (complete)

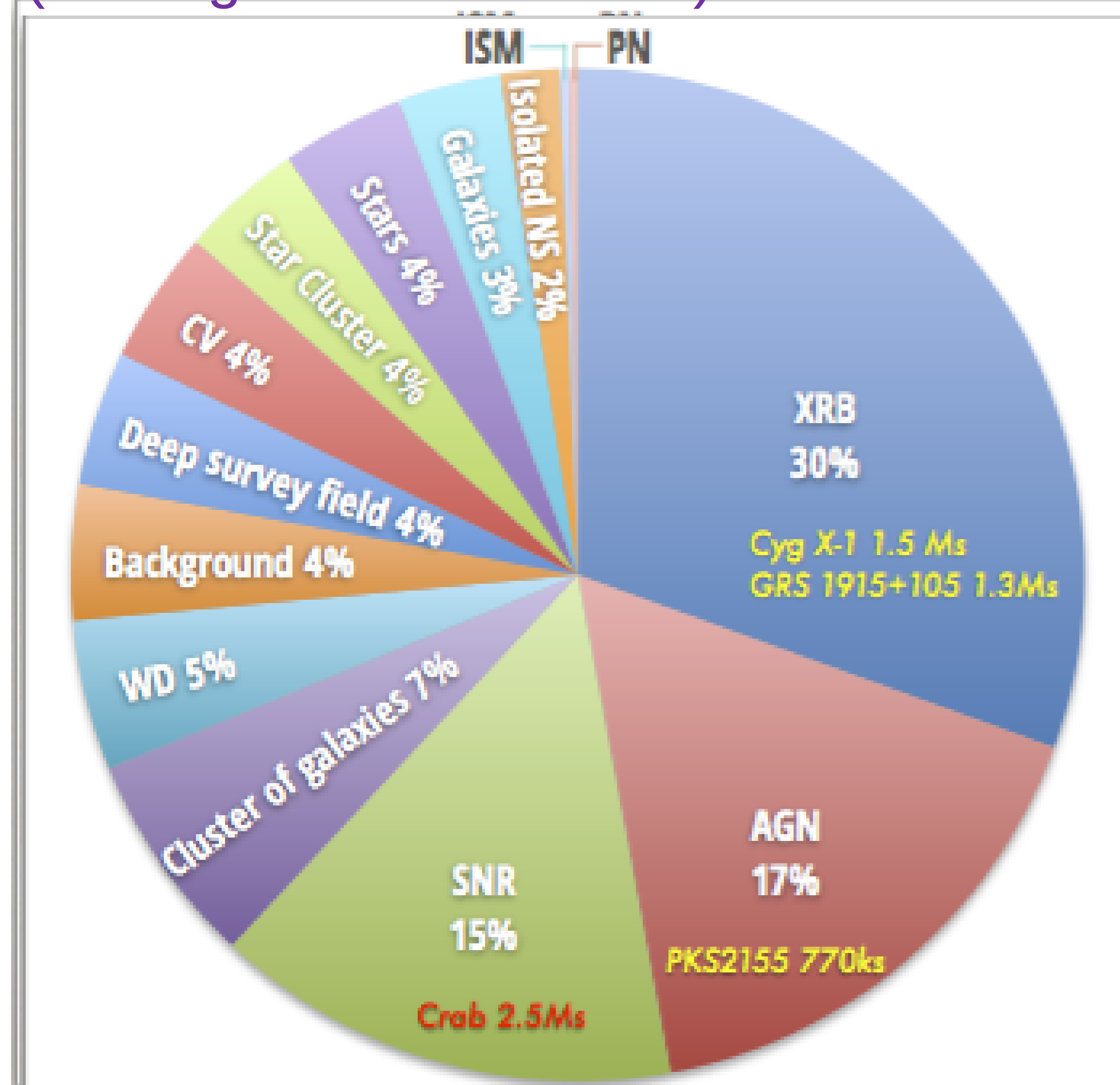
Year 3 (Oct. 2017 – Sep. 2018): AO: Indian PIs: 45%, International PIs: 10% and GTO: 30% (Ongoing....)

Year 4 (Oct. 2018 – Sep. 2019): AO: Indian PIs: 65%, International PIs: 20% (**Proposal selection don, observations starting next month)**

Year 5 (Oct. 2019 – Sept 2020) AO : Indian PIs: 65%, International PIs: 20%

From Year 2: CSA: 5%, Leicester: 3%, Target of Opportunity (ToO): 5% (Throughout the mission) Calibration: 2%



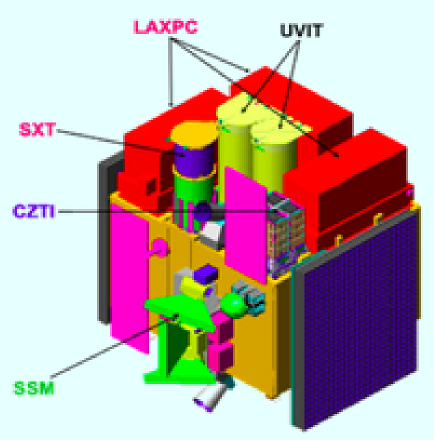


1st year : 140 sources, 337 targets

ASTROSAT SXT   Home   Team   Instrument   SXT PIPELINE   Data Analysis   Quick Look   More   Career   Contact

www.tifr.res.in/~astrosat_sxt

ASTROSAT



ASTROSAT is the first dedicated Indian astronomy satellite. It was launched from **Sriharikota, India on September 28, 2015.** It is a multi-wavelength (Optical + UV + X-ray) astronomy space mission in a near-Earth, near-equatorial orbit. For more detail click : **HERE** .

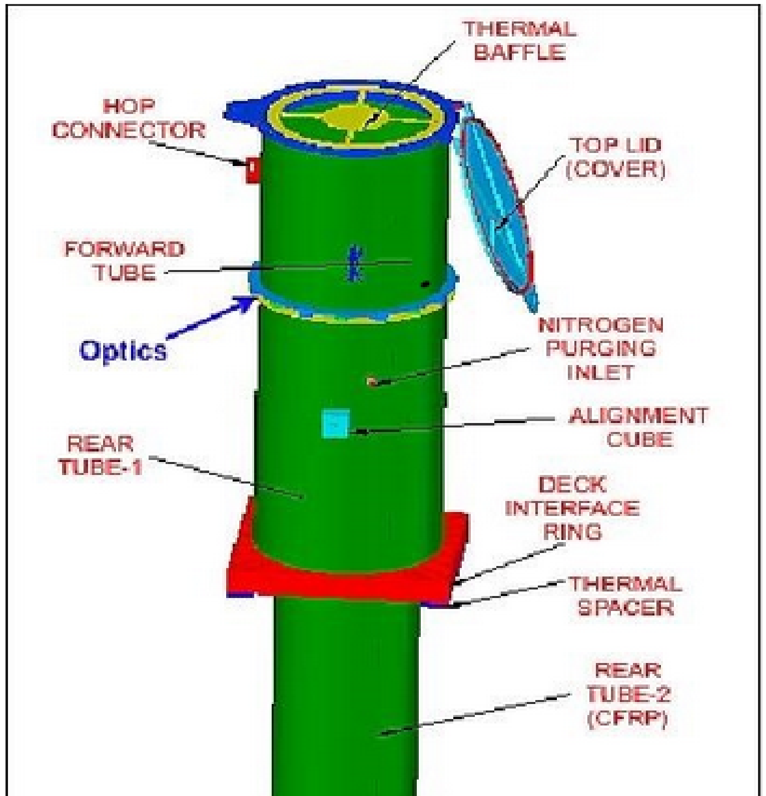
News

- **SXT Level2 pipeline version 1.4a released on 06 Dec 2017**
- **SXT Camera Door Opened (First Light Seen) on 26 Oct 2015**
- **SXT Telescope Door Opened on 15 Oct 2015**
- **SXT switched on 30 Sep 2015**
- **SXT aboard ASTROSAT launched on 28 Sep 2015**

X-RAY TELESCOPE

Telescopes make clear images of cosmic objects by collecting large amount of light using mirrors and by focusing them on a detector at the focal point. In case of X-rays, the reflections from the mirrors have to be at very small (grazing) angles. So the geometry of an X-ray telescope is quite diffrent from that of a telescope which works in visible light.

One such geometry is the Wolter-I geometry, in which X-rays are reflected twice, first by a paraboloid mirror and then by a hyperboloid mirror, before being focused. Usually many nested mirror shells are used to increase the collecting area. The surface quality of the mirror is required to be very good (roughness of a few Angstroms) to avoid scattering, and therein lies a challenge.



www.tifr.res.in/~astrosat_sxt/HTMLOUTDIR/input.html

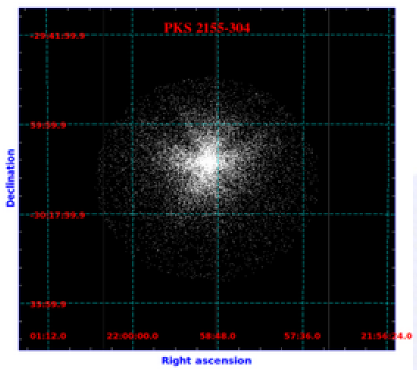
ASTROSAT SXT

Prelim. SXT Data Quality Check Report

Last updated on: 2018-09-14T10:54:20
Created by: Sunil Chandra
Maintained by: Nilima Kamble

Important Links : a) SXT POC TIFR
b) IUCAA Science Support Cell
c) ISRO AstroSat

FIRST X-RAY IMAGE BY SXT ON 26-OCT-2015



Data Folder	OBSID	Observer	Object	RA	Dec	Exposure [s]	Mode	Date/Time Start	MJD Start	MJD Stop
Search...										
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AS1A02_006T01_9000000776sxtPC00_level2	A02_006T01_9000000776	gulabd	NGC1365	53.402	-36.14	22645.6	PC	2016-11-07T11:11:30	57699.5	57700.4
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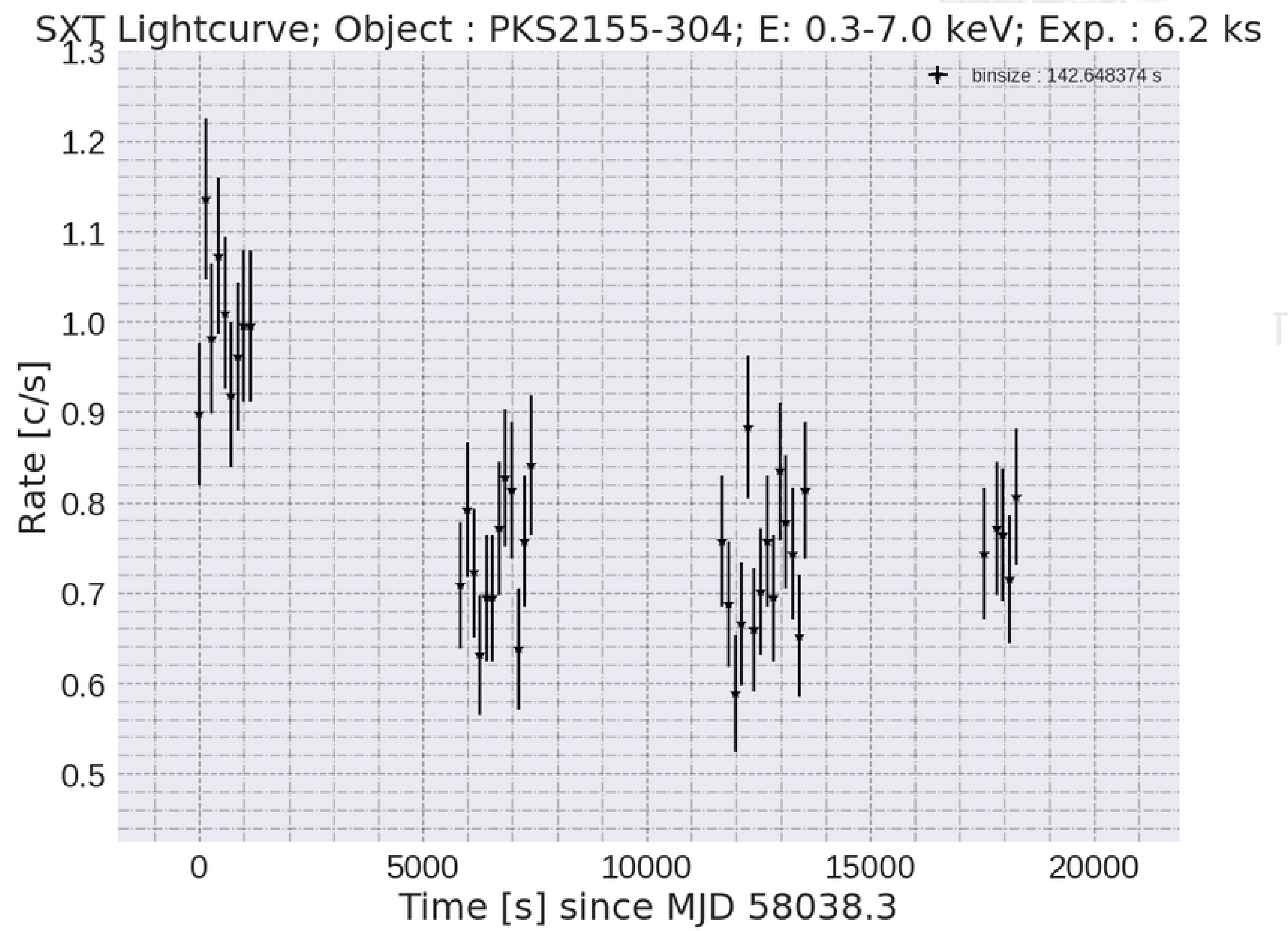
AS1A02_058T03_9000001870sxtPC00_level2	A02_058T03_9000001870	omkar	NGC1533	62.466	-56.118	4060.72	PC	2018-01-24T18:16:42	58142.8	58143.0
AS1A02_063T01_9000000702sxtFW0E_level2	A02_063T01_9000000702	sriramou	CYGX-2	326.171	38.321	12957.97	FW	2016-10-02T22:31:25	57664.0	57664.5
AS1A02_070T01_9000000832sxtPC00_level2	A02_070T01_9000000832	savithri	MRK0926	346.181	-8.686	21663.8	PC	2016-11-26T22:32:40	57718.9	57720.3
AS1A02_071T01_9000001078sxtPC00_level2	A02_071T01_9000001078	sudip	GX349+2	256.435	-36.423	309.07	PC	2017-03-12T14:05:20	57824.6	57824.6
AS1A02_073T02_9000000982sxtFW0E_level2	A02_073T02_9000000982	smriti	PGC36406	175.805	20.005	15339.76	FW	2017-01-25T23:29:13	57779.0	57779.7

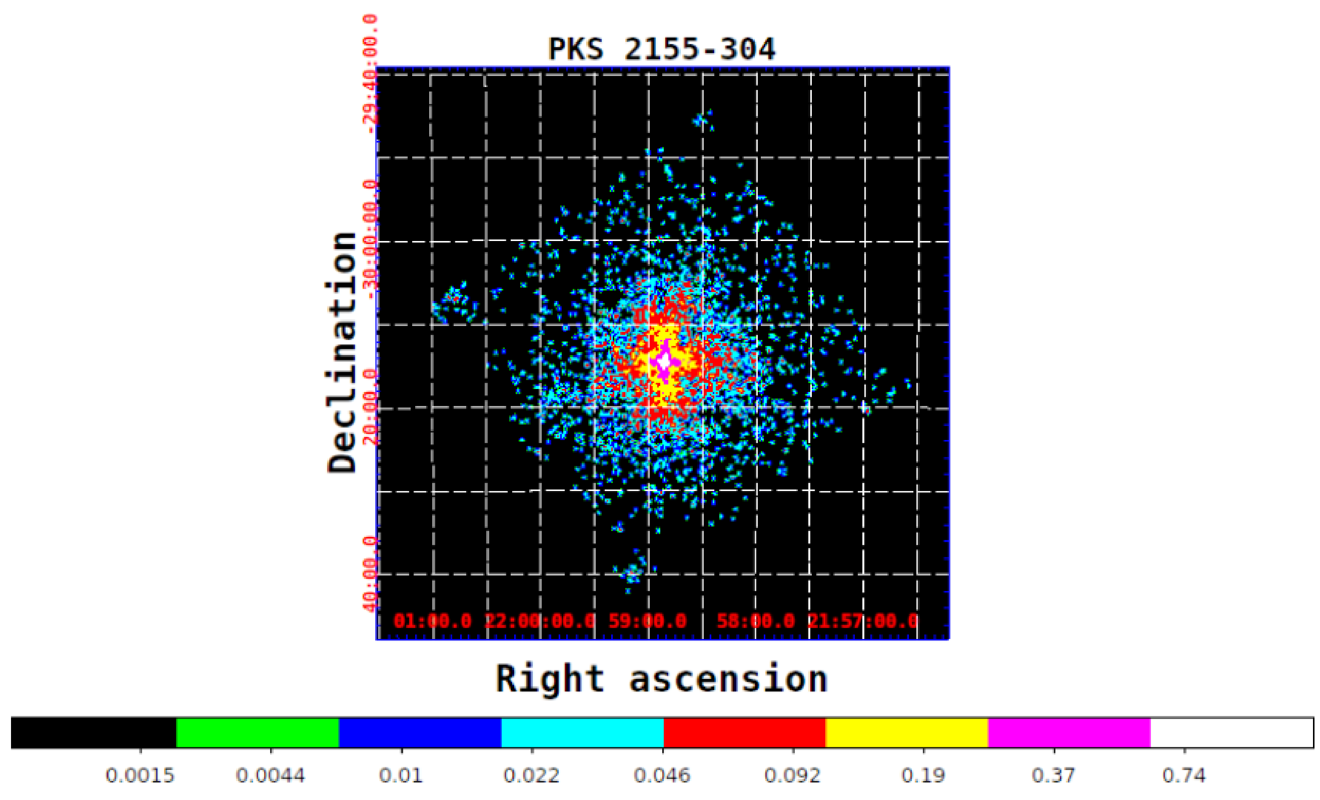
- **exposure**: 6183.80701277 second
- **sourceid**: PKS2155-304
- **observer**: DANIELA
- **ra_pnt**: 329.716937
- **dec_pnt**: -30.225589

Lightcurve (count rate v/s time) and Image

^TOP

Full Frame Lightcurve	Sky Image





SUMMARY

- ASTROSAT provides a unique facility with unprecedented energy coverage over the EM spectrum

- All the instruments on-board are now working in optimized mode

- The results from all the instruments are very much encouraging

- The simultaneous broad-energy energy … ideal instrument for correlation studies …connection s between Synchrotron, SSC and EC

- The MW campaigns … expected to provide us unique asset to improve the understanding of physical processes in a range of astrophysical systems

- The international community is having a dedicated block for observing time

THANK YOU ☺

Sunil Chandra