AstroSat & UV/X-ray Observations

Gulab Chand Dewangan
IUCAA, Pune

On Behalf of
AstroSat Team

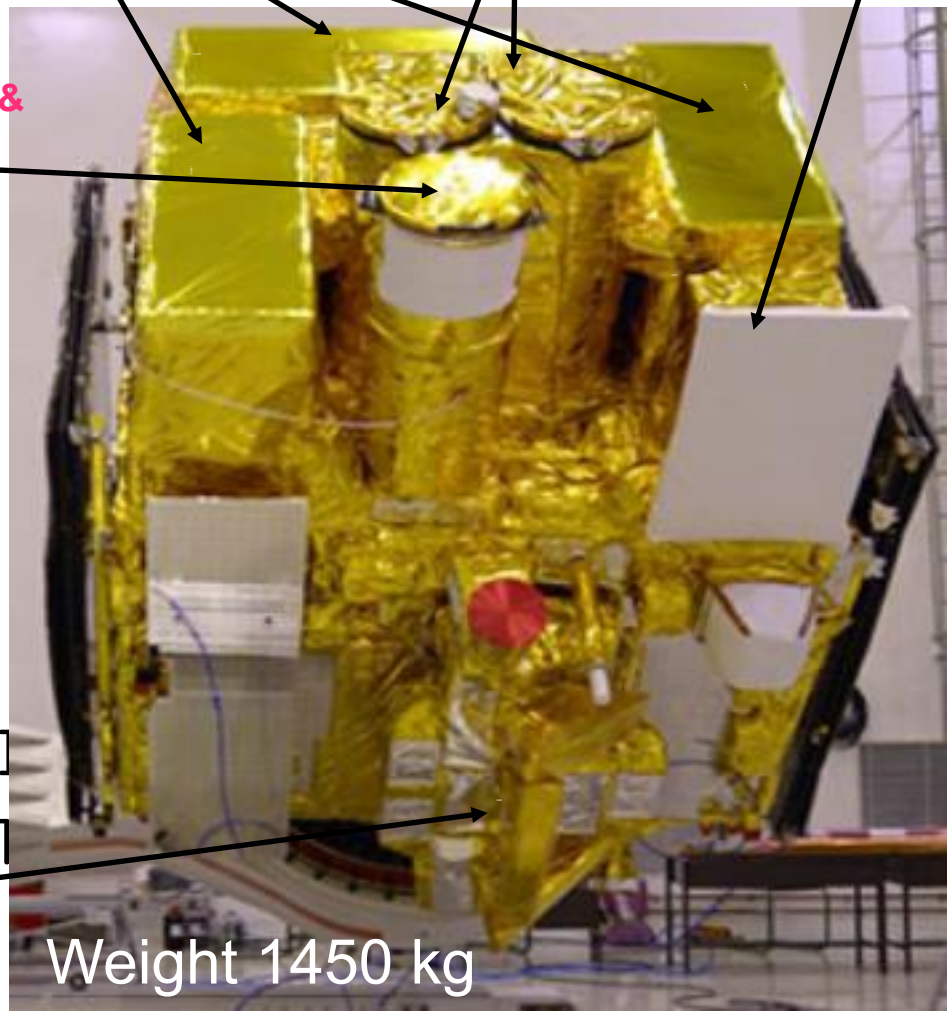
AstroSat

LAXPC
3-100 keV X-ray Timing, broadband spectroscopy

UVIT
1.4” UV imaging
1200 - 5500 A

CZTI
1Hard X-ray imaging, timing, spectroscopy

SXT
0.2-8 keV imaging & line spectroscopy



SSM
rotating 2-10 keV monitor

Launched 28 September 2015,
Orbit 650 km altitude circular 6deg inclination

PI: S. Seetha (ISRO)
PMs: S.N. Tandon (UVIT),
H. M. Antia (LAXPC),
S. Bhattacharyya (SXT)
A.R. Rao (CZTI)
M.C. Ramadevi (SSM)

LAXPC: TIFR, RRI
SXT: TIFR, ISRO, UoL
CZTI: TIFR, ISRO, IUCAA, RRI, PRL
SSM: ISRO, IUCAA, RRI
UVIT: IIA, ISRO, IUCAA, CSA

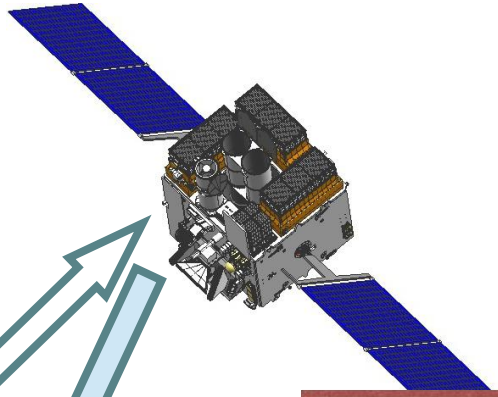
Spacecraft: ISRO
Operations: ISRO
Ground software: ISAC, SAC, TIFR, RRI, IIA, IUCAA, NCRA, PRL

Integrated AstroSat before launch
weight: 1.5 ton

PSLV XL Rocket
Launched: 28 Sept. 2015

इसरो isro tifr iia IUCAA PRL RRI CSA ASC University of Leicester

AstroSat - Proposal driven Operation



USER COMMUNITY

DATA ANALYSIS & MODELING

PROPOSALS (APPS)

REVIEW &TIME ALLOCATION (ATAC, ATC)

ISTRAC (ISRO) SCHEDULING OBSERVATIONS

commands

data

ISSDC (ISRO)

raw data

Processed data

Payload Operation Centres (POCs)

LAXPC: TIFR, RRI
UVIT: IIA
SXT: TIFR
CZTI: IUCAA
SSM: ISAC, IUCAA

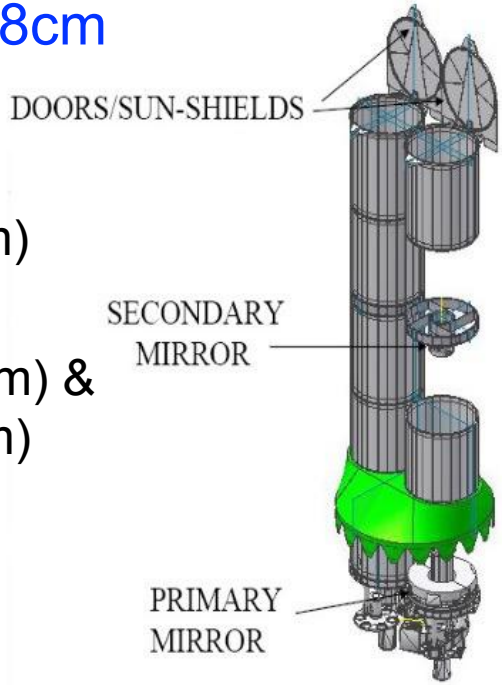
ASTROSAT DATA ARCHIVE

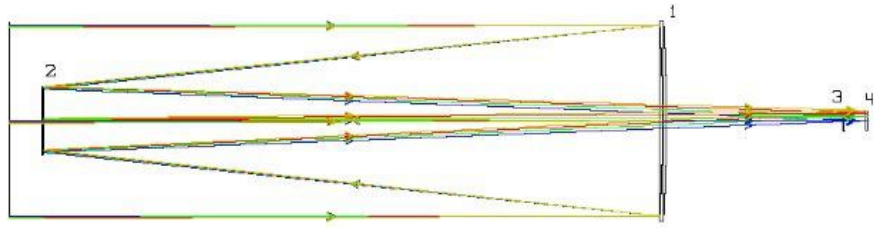
ASTROSAT SCIENCE SUPPORT CELL (IUCAA)

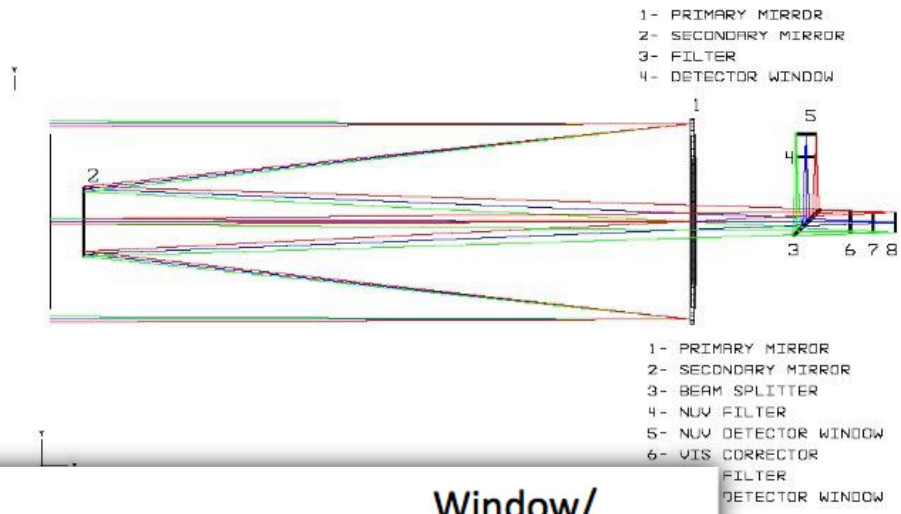
Ultra-Violet Imaging Telescope (UVIT)

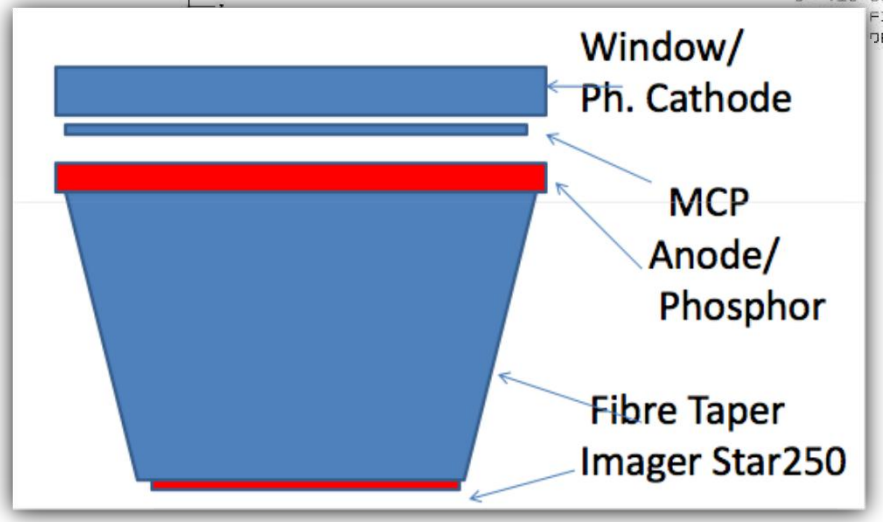
Payload Manager : S. N. Tandon (IUCAA, IIA)

- Twin Cassegrain telescopes, each 38cm aperture.
  - Far UV (130-180 nm)
  - Near UV (200-300nm) & Visible (320 - 550nm)
- FOV ~ 28 arcmin (diameter)
- FWHM: 1.3-1.5 arcsec (UV),
- Sensitivity (130-180nm) ~ AB mag 20 in 200s exposure

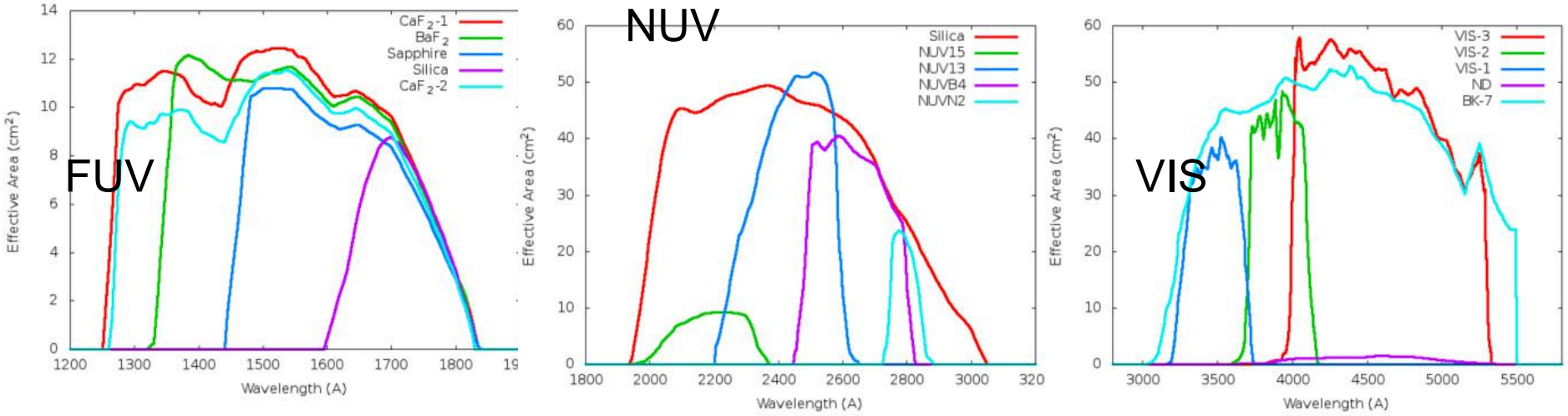








- Simultaneous observations in FUV, NUV & VIS
- A suit of filters allow selection of narrower bands
- Photon counting and imaging modes



Low resolution FUV and NUV gratings!

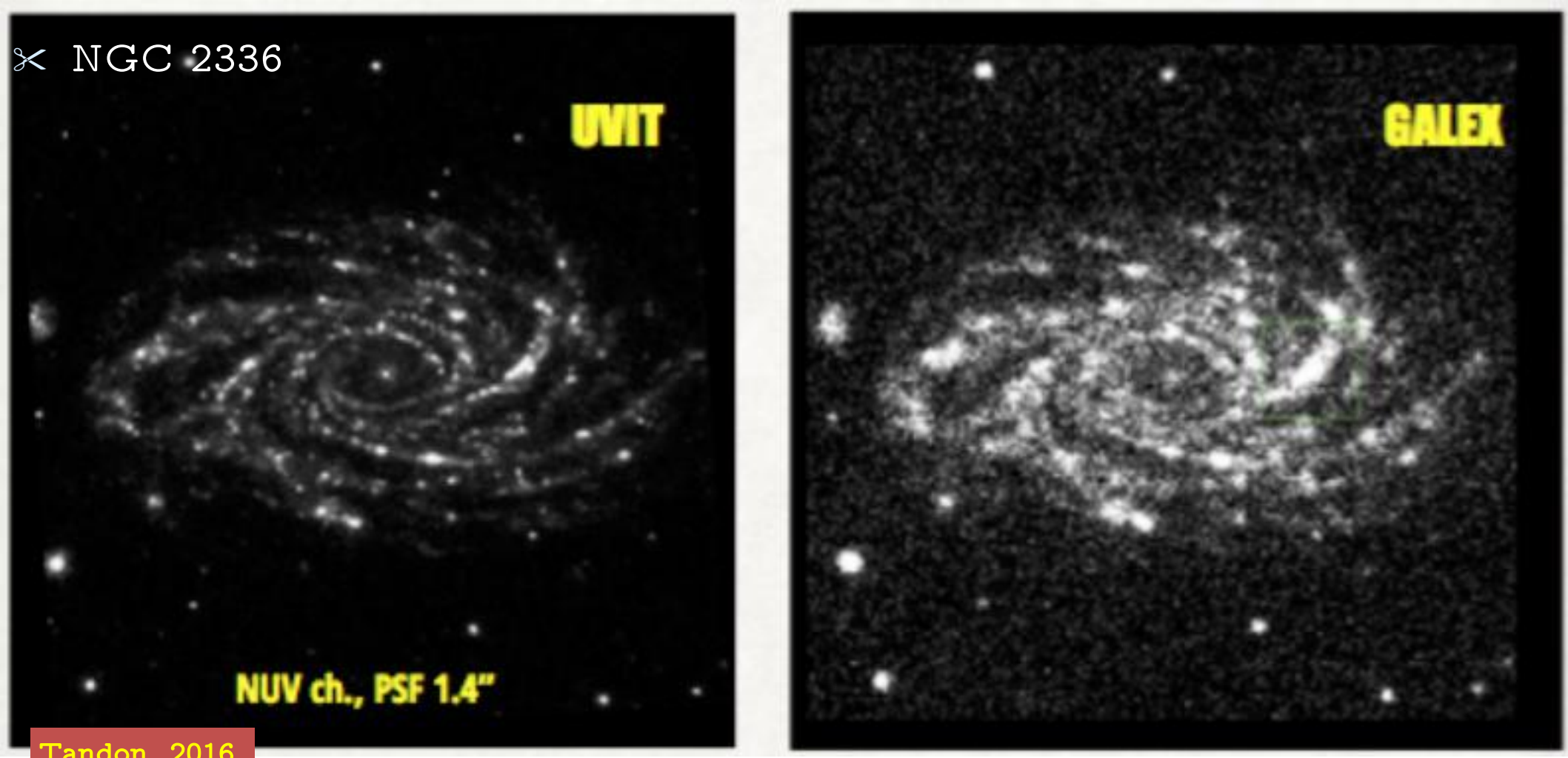
UVIT Status: **NUV control electronics failure, not in operation.**
FUV and VIS channels functioning normally

Ultra Violet Imaging Telescope (UVIT)

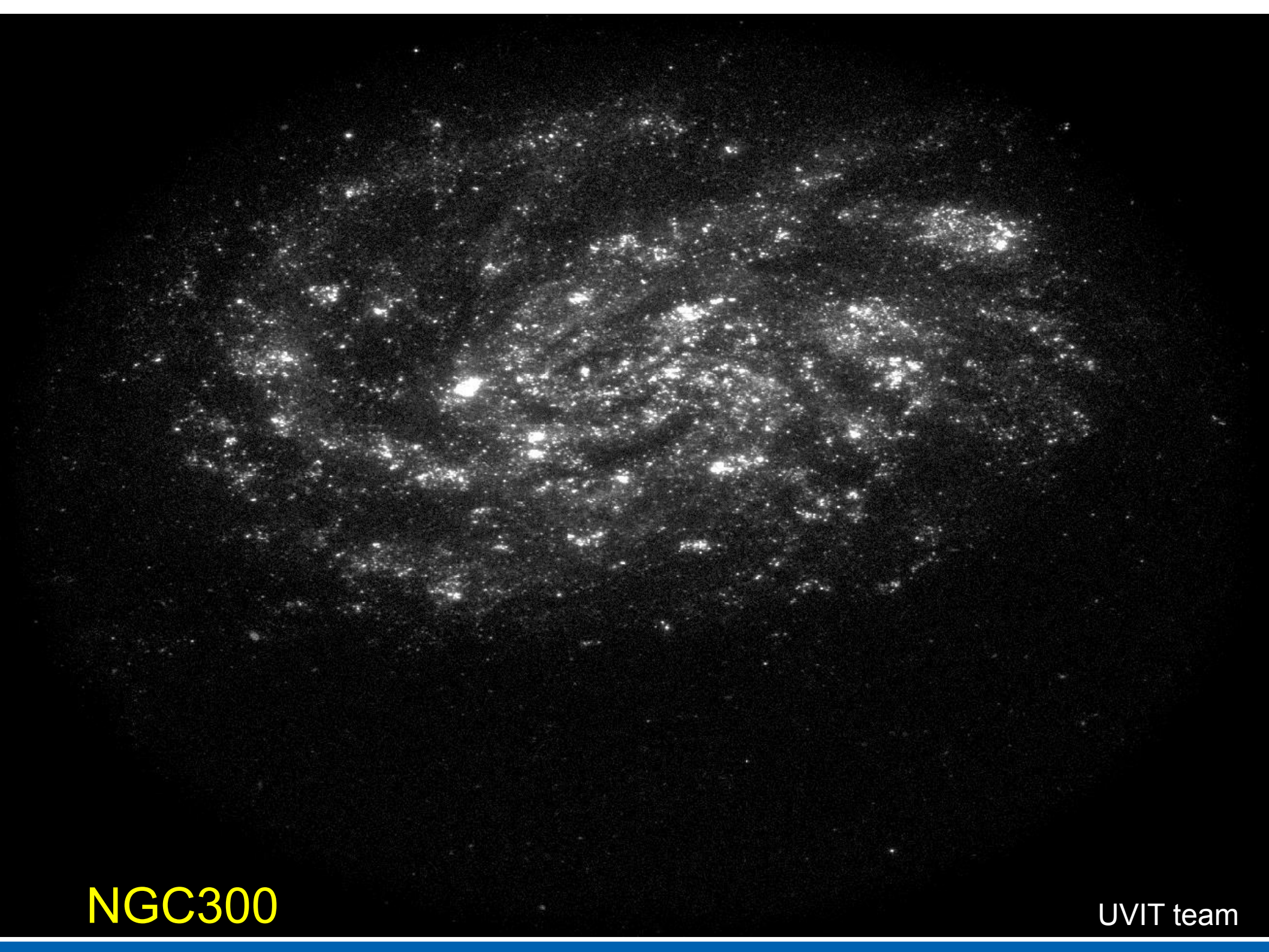
Sensitive Photon counting device: extreme care needed

Bright object region excluded.

Low observation efficiency : 15%



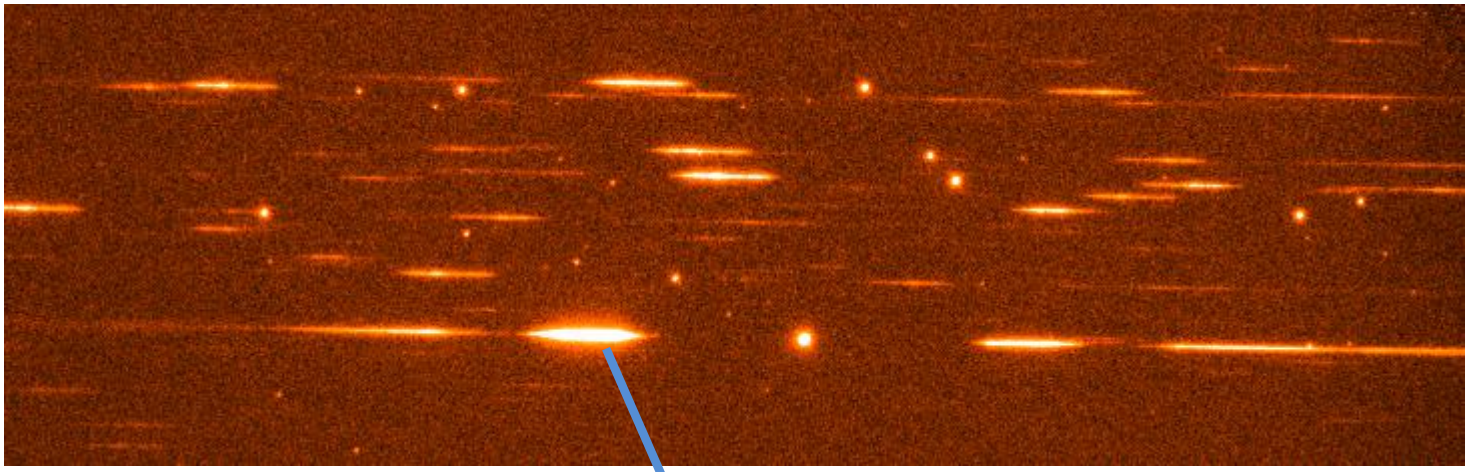
Tandon 2016


NGC300
UVIT team

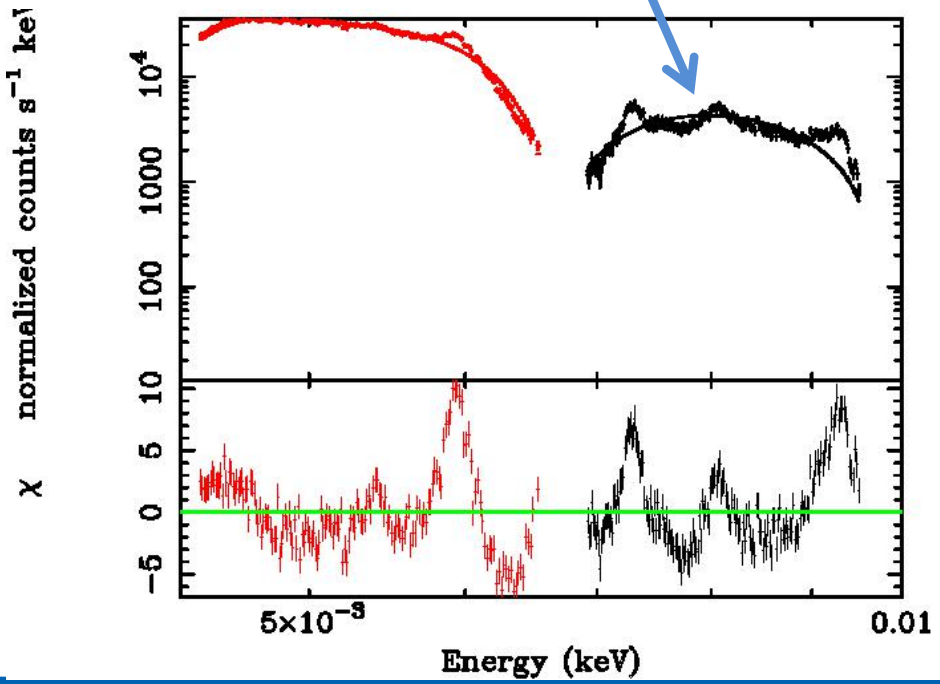
UV-X-ray SED and L_{bol}/L_{Edd}

PG0804+761 : AstroSat view

A bright RQ quasar (V=14.7 mag) at z=0.1, $M_{BH} = 5.4 \times 10^8 M_\odot$



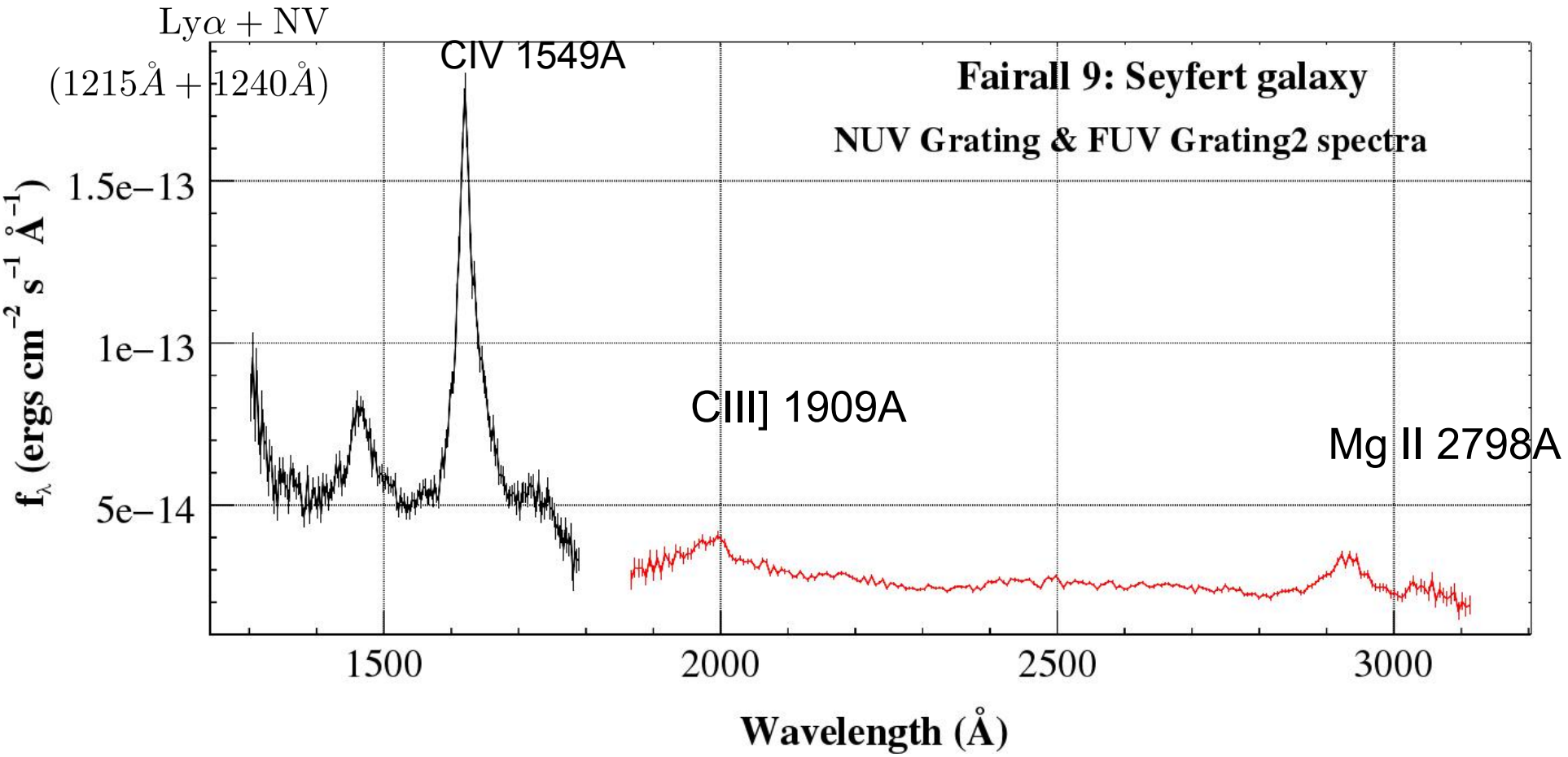
NUV Grating
Exposure : 4ks



FUV Grating: 4ks

Fairall 9: UVIT Grating Spectra

A Bare Seyfert 1

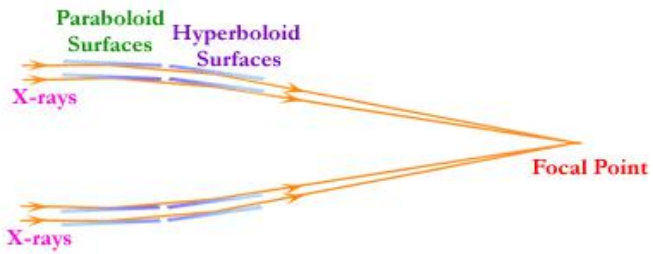


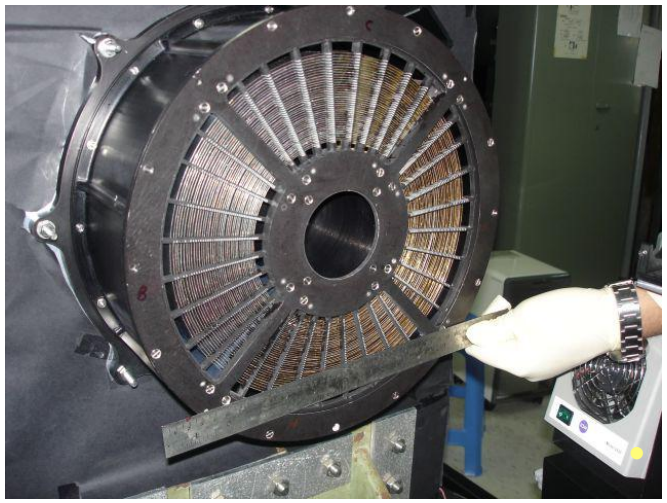
SXT: Soft X-ray Telescope

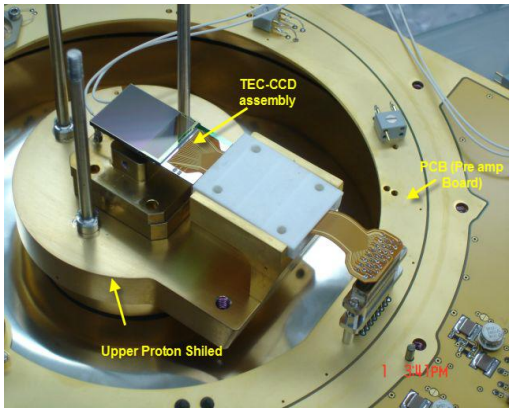
PM : K. P. Singh
POC : TIFR

Medium resolution soft X-ray Imaging Spectrometer (0.2-8keV)

40 shells (130–260 mm dia)
2m focal length







- CCD 600x600, 40 micron pixels
- Four Fe-55 calibration source
- Thin optical blocking filter

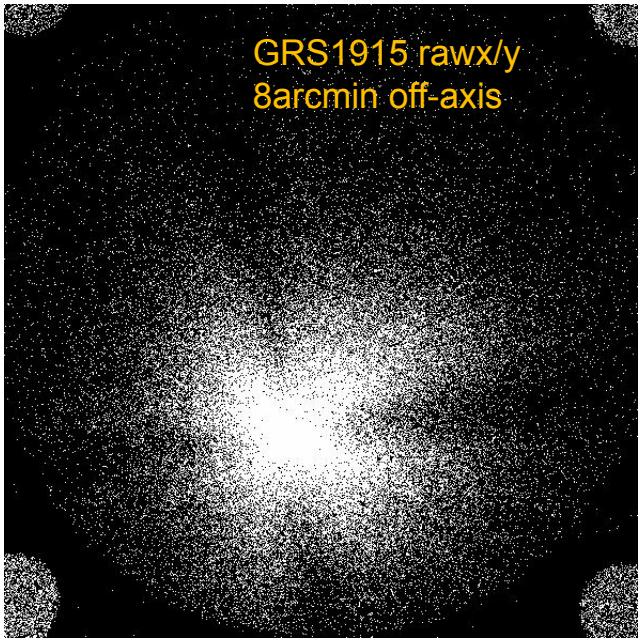
Status

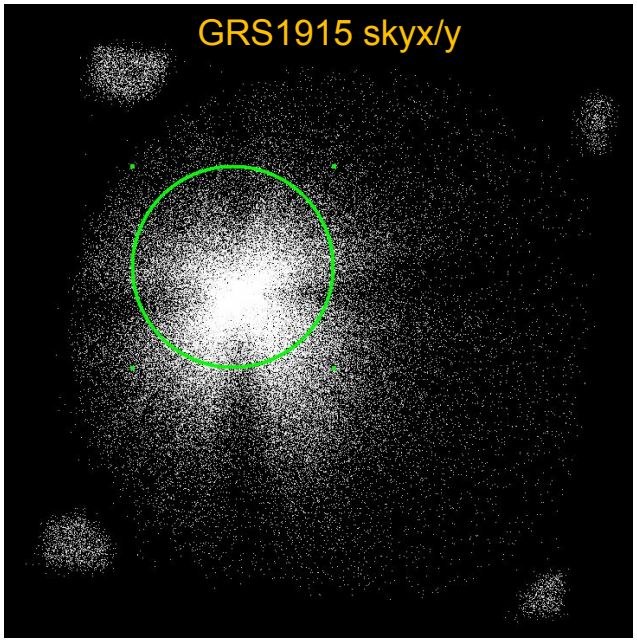
Working fine, minor change in the CCD gain with time
Spectral resolution ~140eV@6keV, time resolution : 2.37sec (PC), 278msec (FW), PSF : 2arcmin, broad wings upto 10arcmin

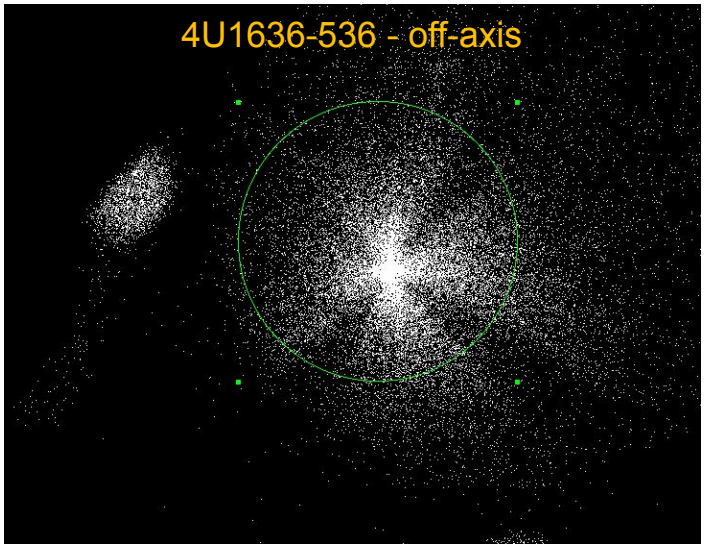
Excellent for bright sources such as XRB, Unlike Chandra/XMM-Newton, SXT does not suffer with photon pile-up

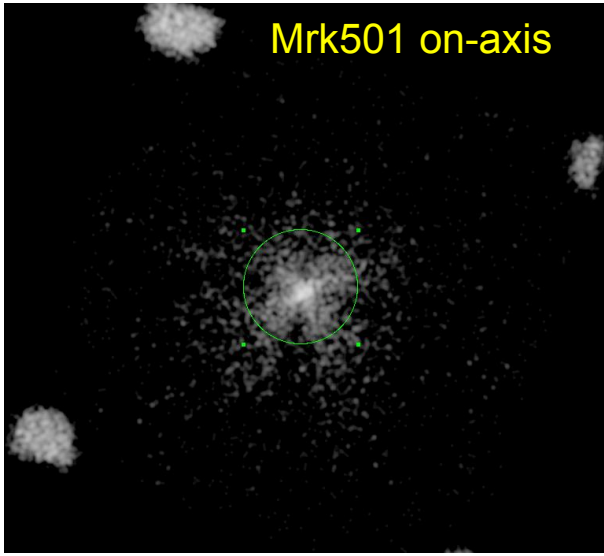
SXT Performence : Imaging

- **New coordinator tool**
  - Attitude jitter correction
  - WCS coordinates
  - Position accuracy : 1' (on-axis), 1-2.5' (off-axis)





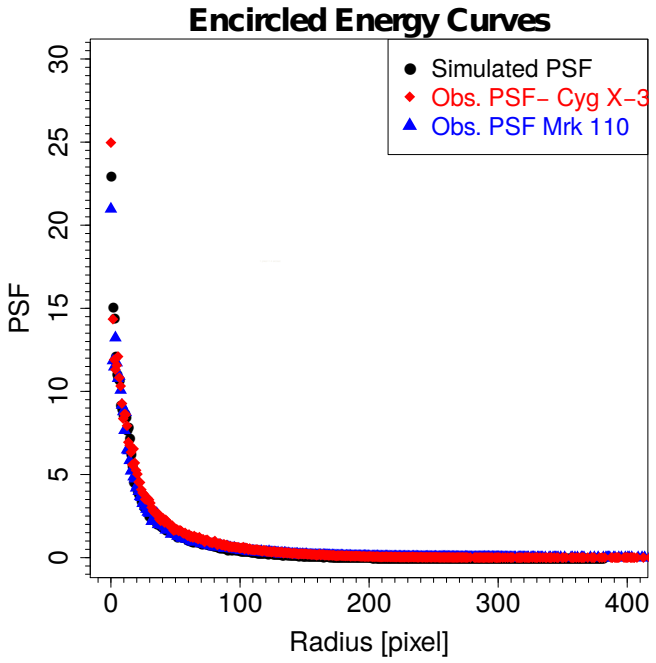


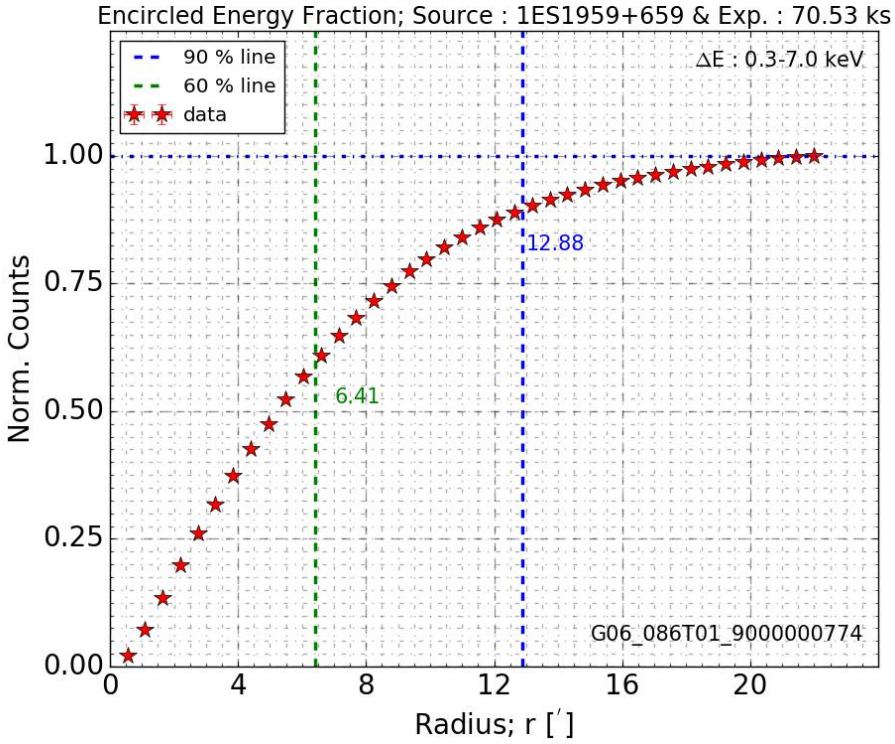


Joint effort of
SXT team (GCD),
ISAC (K. Subbarao),
SAC team (Tanul, Navita, Arvind)

SXT Performence : Imaging

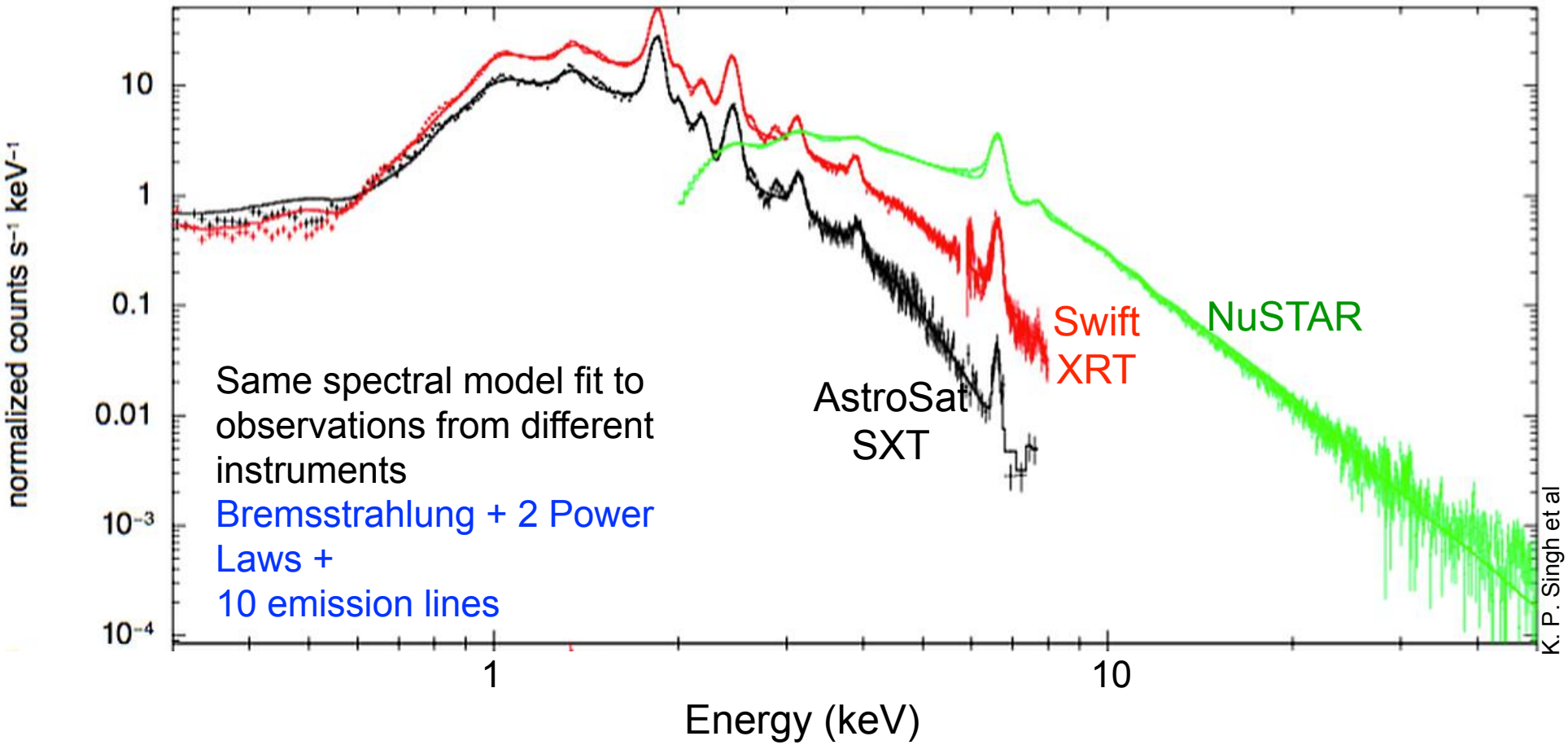
- PSF : 2' (FWHM), broad wings
- Advantage : No pile-up for bright sources < 200 mCrab





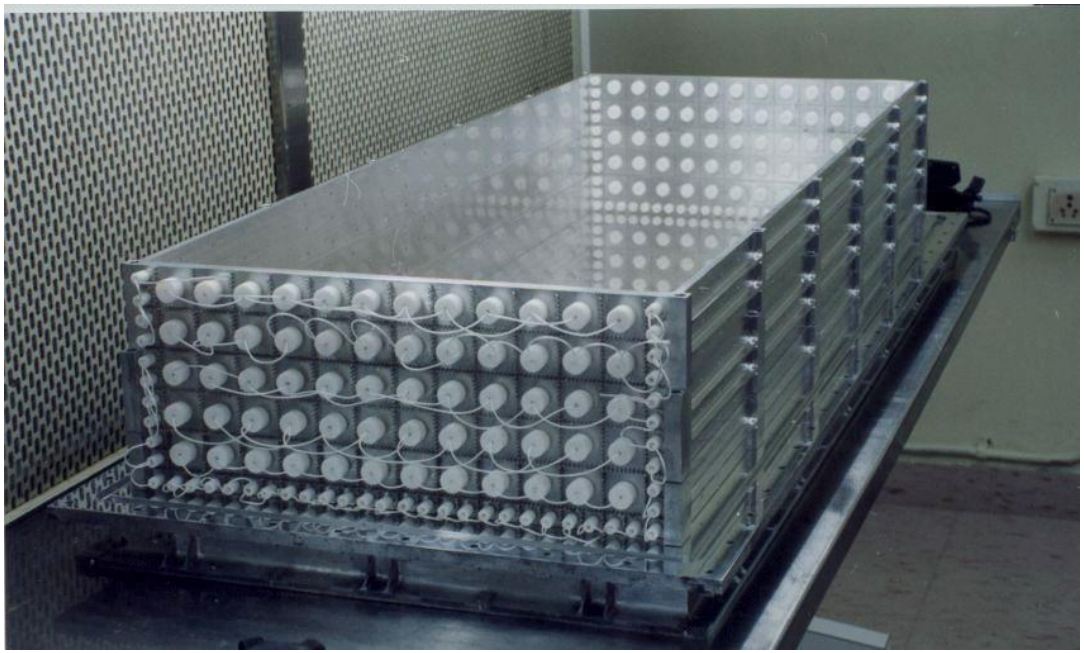
No significant energy or offset dependence

Spectrum of Supernova Remnant Cassiopeia A



LAXPC Capabilities & Status

PM : J. S. Yadav
POC : TIFR, RRI



Courtesy: J. S. Yadav

Large Area Timing instrument
(Effective. area: 6000 cm^2 (3 units), time resolution : 10 μs)

Broadband (3-80 keV), low resolution spectrometer
(Energy resolution : 12% @22keV)

Non-imaging, Coll. FOV: 0.9^o X 0.9^o

Status

LAXPC: Unit 3 had gas leak. Switched off on 8 March 2018
Unit 1 showed anomalous counts since 26 March 2018
- Operated with reduced HV since 29 March 2018
- Erratic behavour again started on 9 April 2019
- HV was further lowered on 17 April 2019, data not usable.

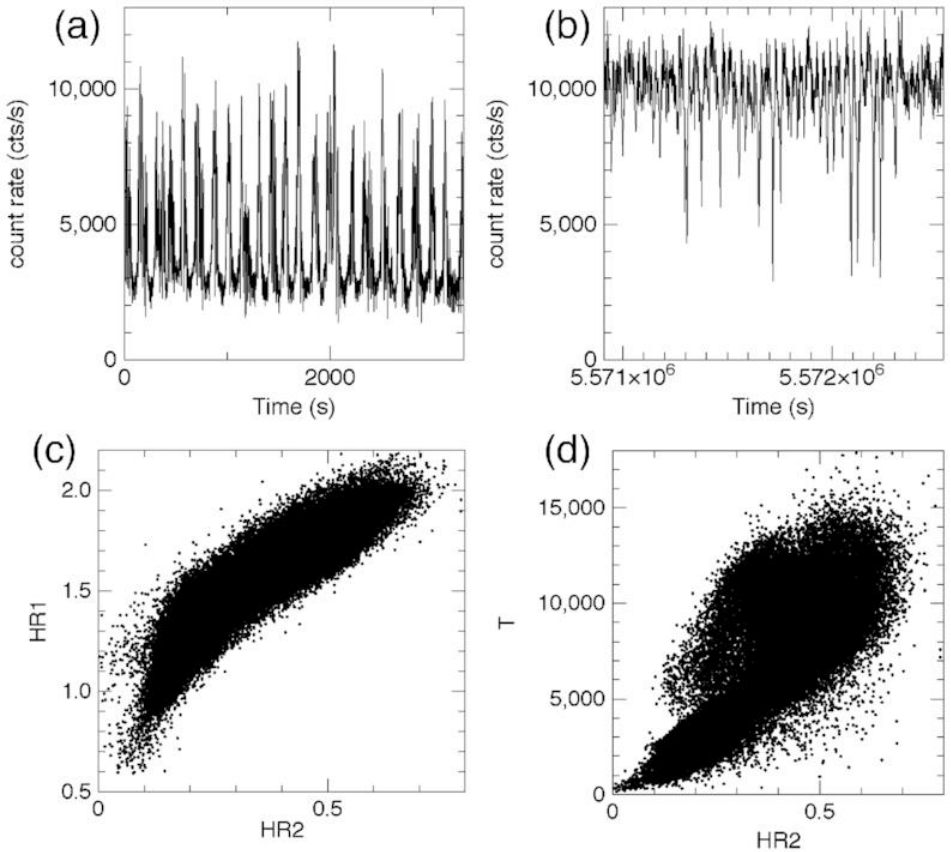
Unit 2 functioning normally

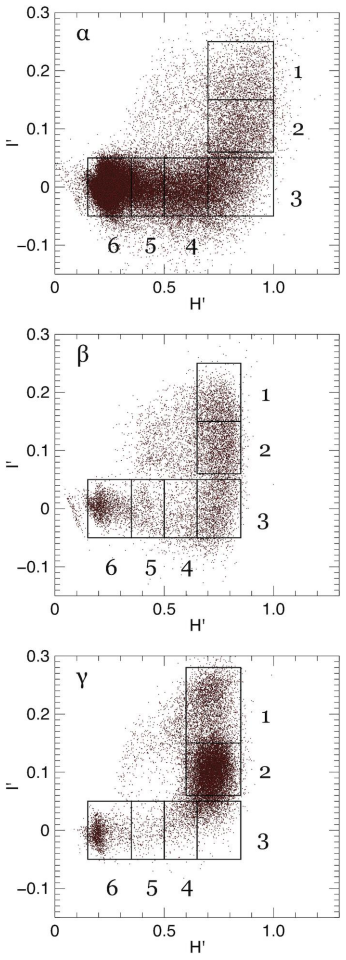
Best instrument ever flown for high time resolution studies!

Timing capability of LAXPC: GRS1915+105

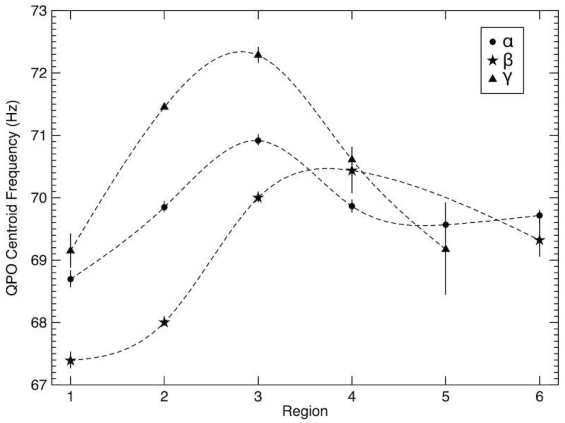
Very large count rates

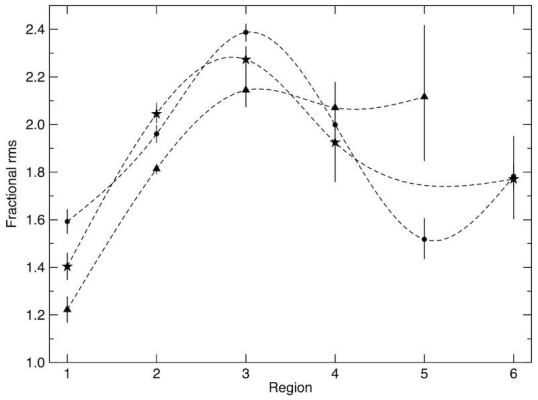
Variation of High frequeny QPOs detected with LAXPC





Belloni et al. 2019





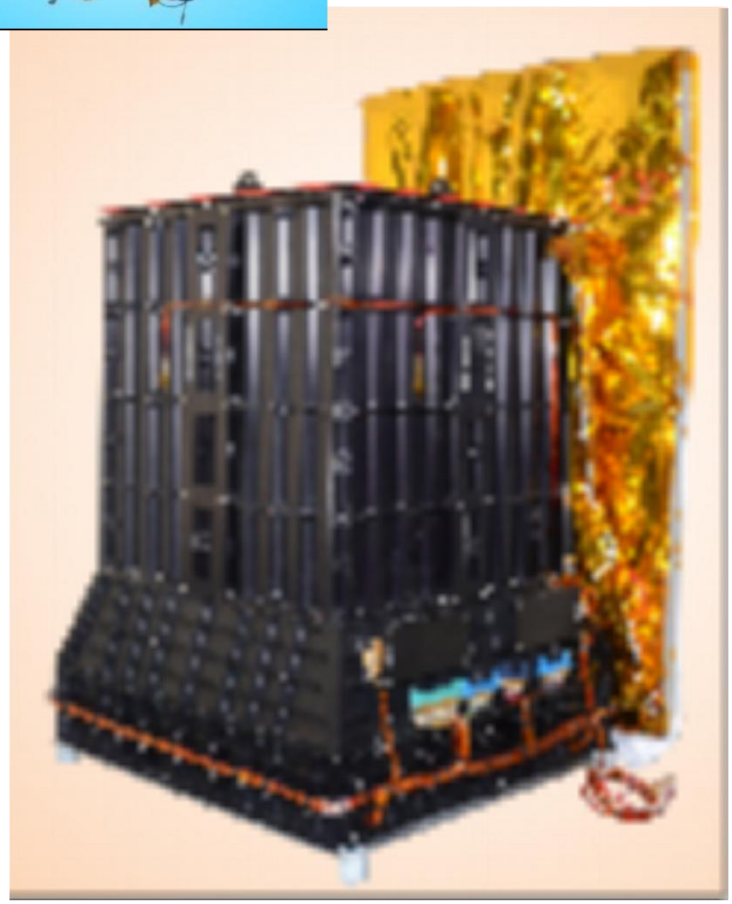
Cadmium Zinc Telluride Imager (CZTI)

PI : A. R. Rao
POC : IUCAA

Hard X-ray (10-100keV) Imaging Spectrometer, Hard X-ray Compton polarimeter, GRB monitor

Four quadrants
Pixels : 16384, 2.46mm X 2.46 mm, 5 mm thick

Pixelated CZT detector array + CsI as Veto + Coded Aperture Mask (CAM) for imaging



Angular resolution ~ 8 arcmin
Energy resolution ~ 9% @ 100 keV
Energy range: 25 – 100 keV, 20microsec time res.
Up to 1 MeV (Photometric); no imaging >100 keV

Status

Functioning normally

Hot pixels increased from 5% (launch) to ~10% (present). Effective area ~420cm^2

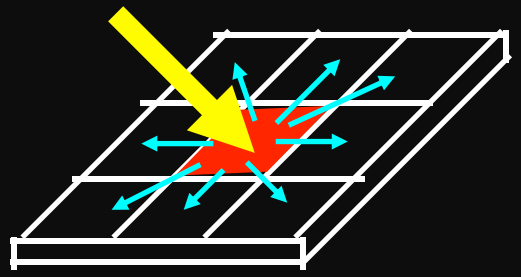
Suitable for sources brighter then 150mCrab
Sperior Hard X-ray polarimeter, GRB monitor

CZTI as a Hard X-ray Polarimeter

(100-380 keV)

Compton Polarimetry

$$\frac{d\sigma}{d\Omega} = \frac{3\sigma_T}{16\pi}\left(\frac{\omega'}{\omega_0}\right)^2\left(\frac{\omega_0}{\omega'} + \frac{\omega'}{\omega_0} - 2\sin^2\theta\cos^2\eta\right)$$

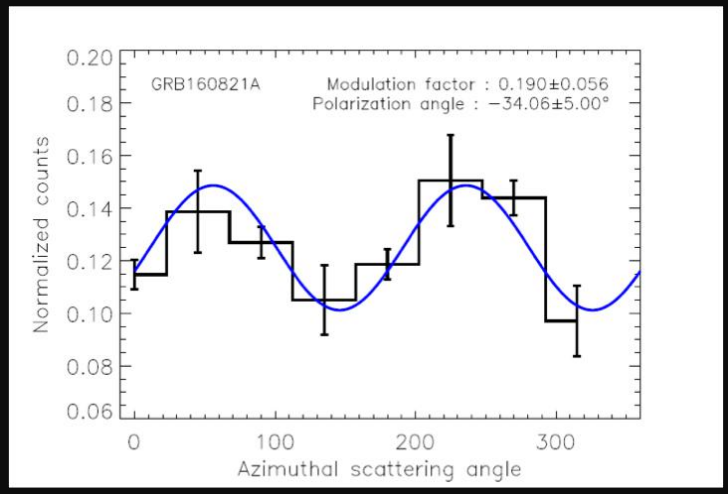


Distribution of azimuthal scattering angle η is measured

count rate $C(\eta) = A + B\cos^2(\eta - \phi)$

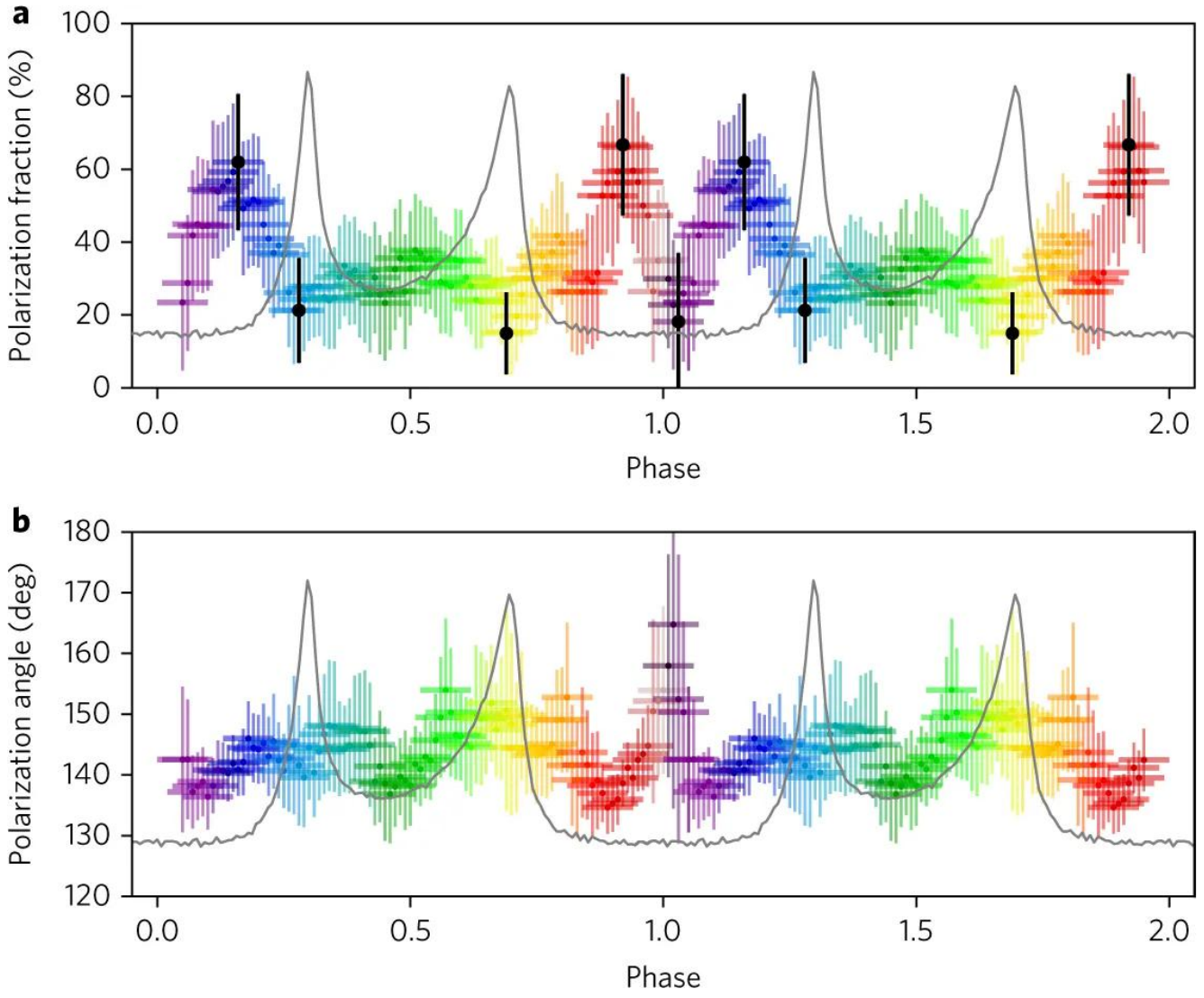
B = polarisation degree

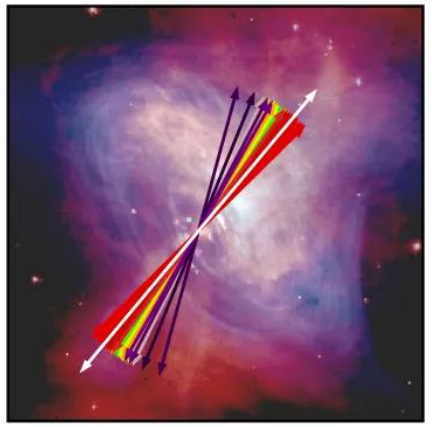
ϕ = incident polarisation angle



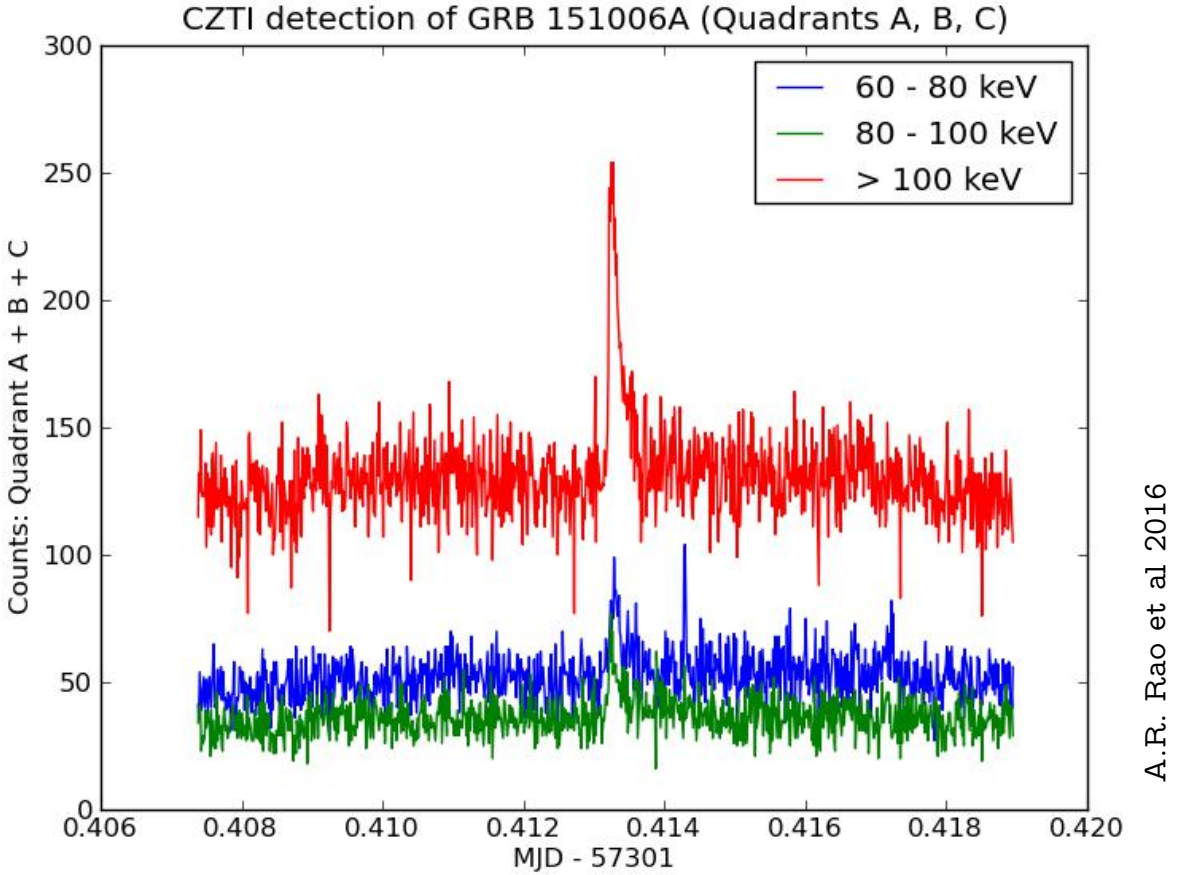
Phase-resolved polarisation of Crab nebula and the pulsar with AstroSat/CZTI

Vadawale et al. 2018, Nature Astronomy





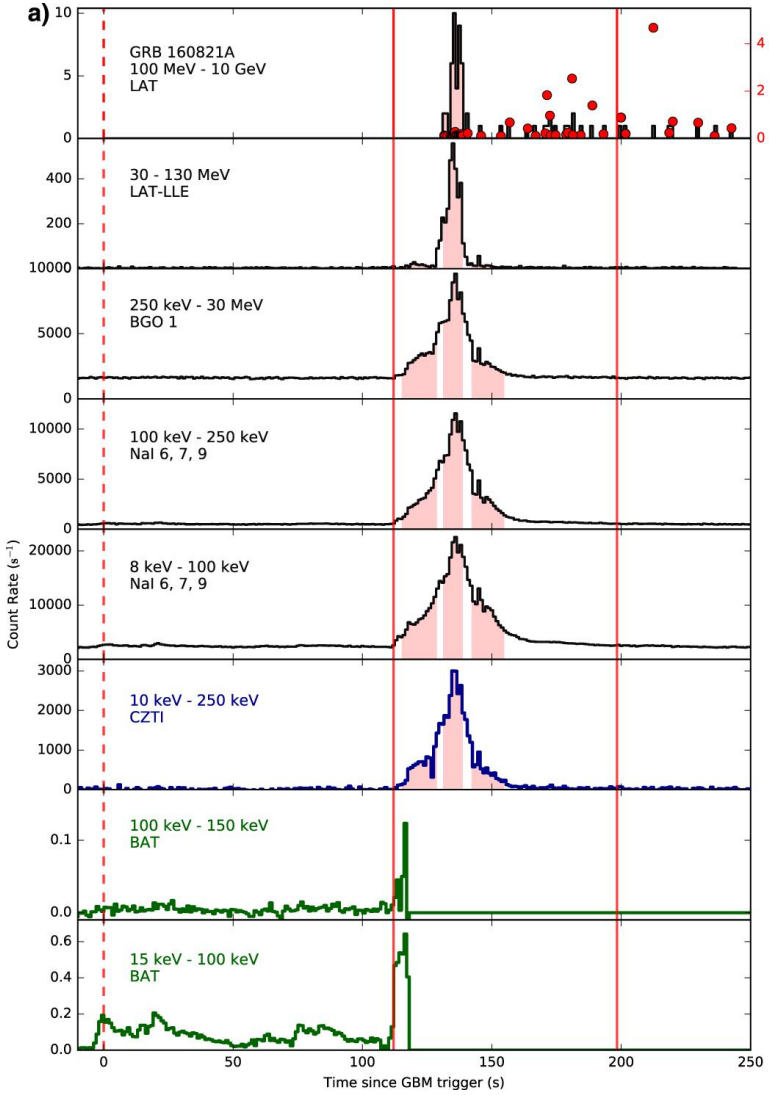
Gamma Ray Bursts with ASTROSAT CZTI

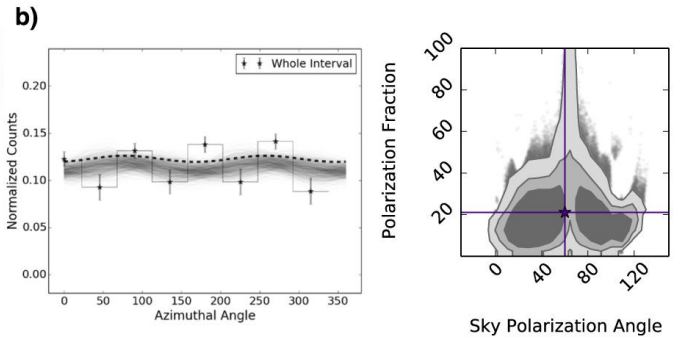


GRB 151006A

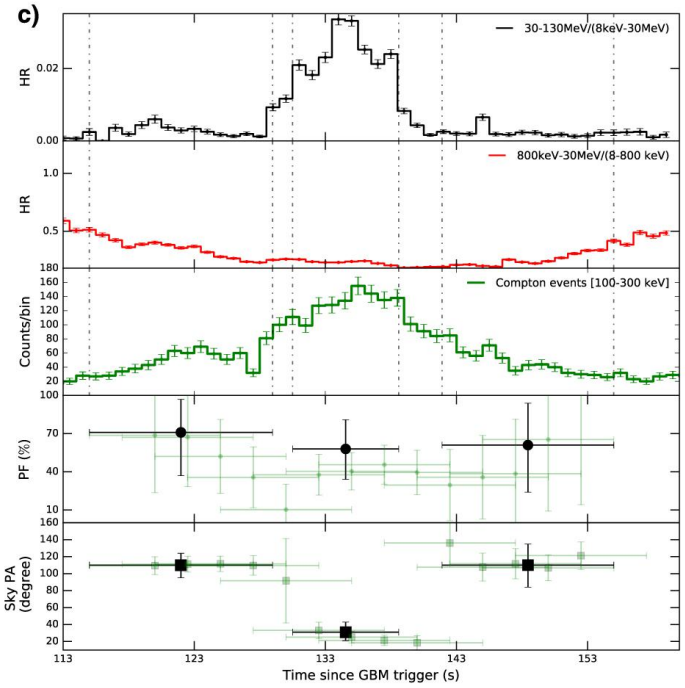
- AstroSat CZTI acts as an all sky detector above 100 keV
- First cosmic source detected by AstroSat was a GRB
- CZTI can detect polarisation of high-energy (> 100 keV) emission of Bright GRBs
- Counterparts of G Wave events are being routinely searched for

CZTI observation of 3rd brightest Fermi Blazar: GRB 160821A





Vidushi Sharma et al 2019



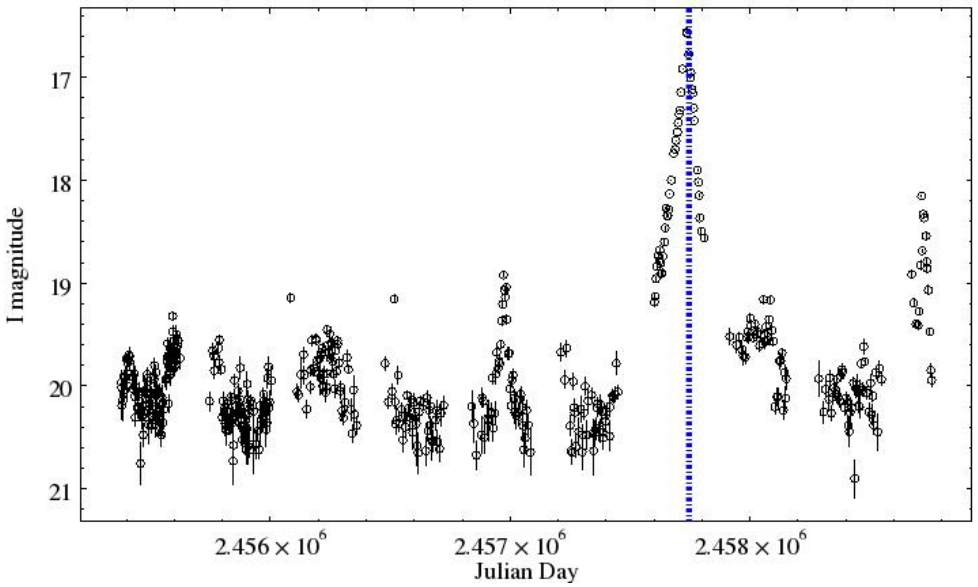
High linear polarization (66+/- 26% at 5.3sigma)

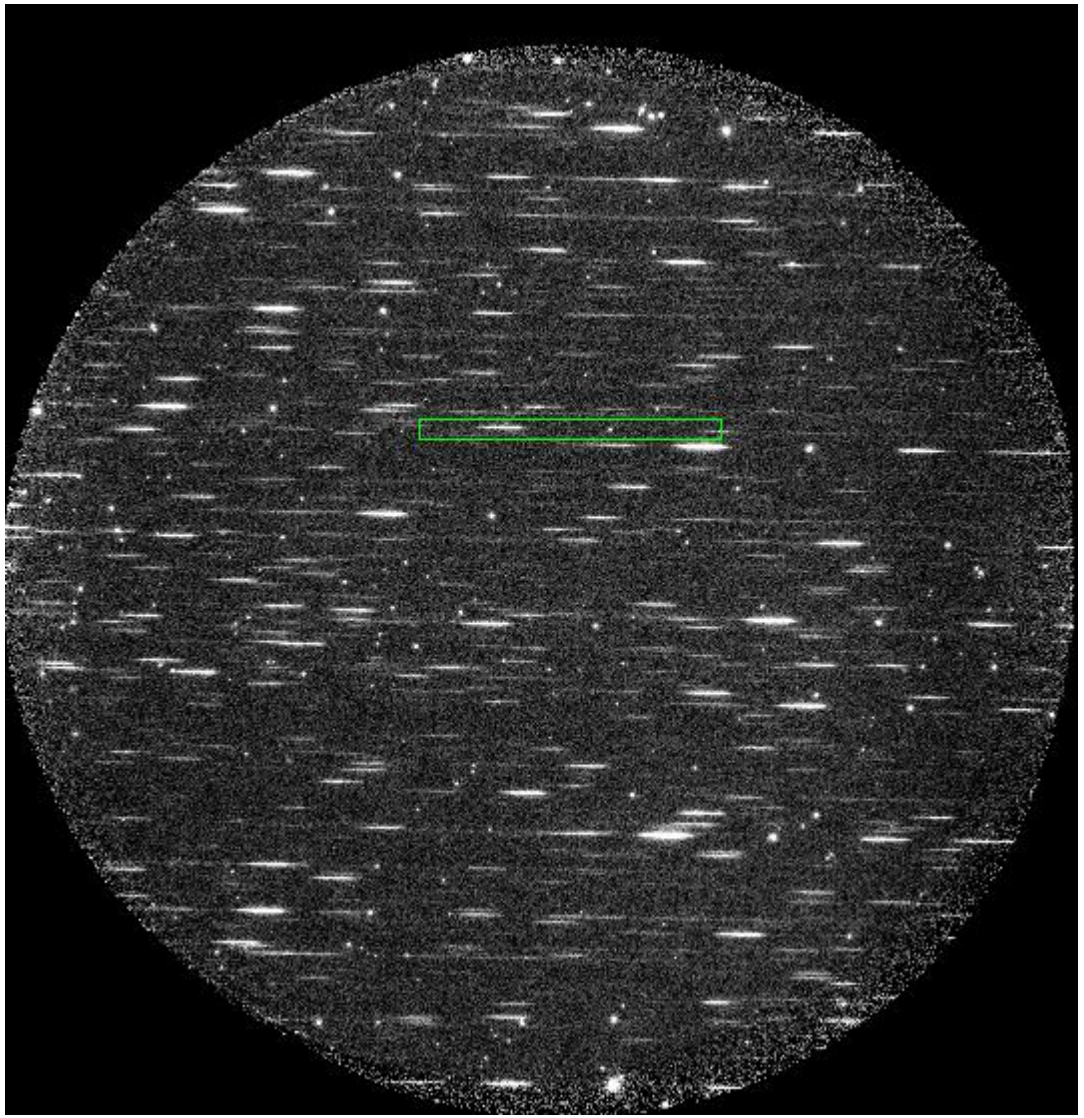
Variation of polarization angle

UV/X-ray Observations

A Super soft X-ray transient - ASASSN-16oh in SMC

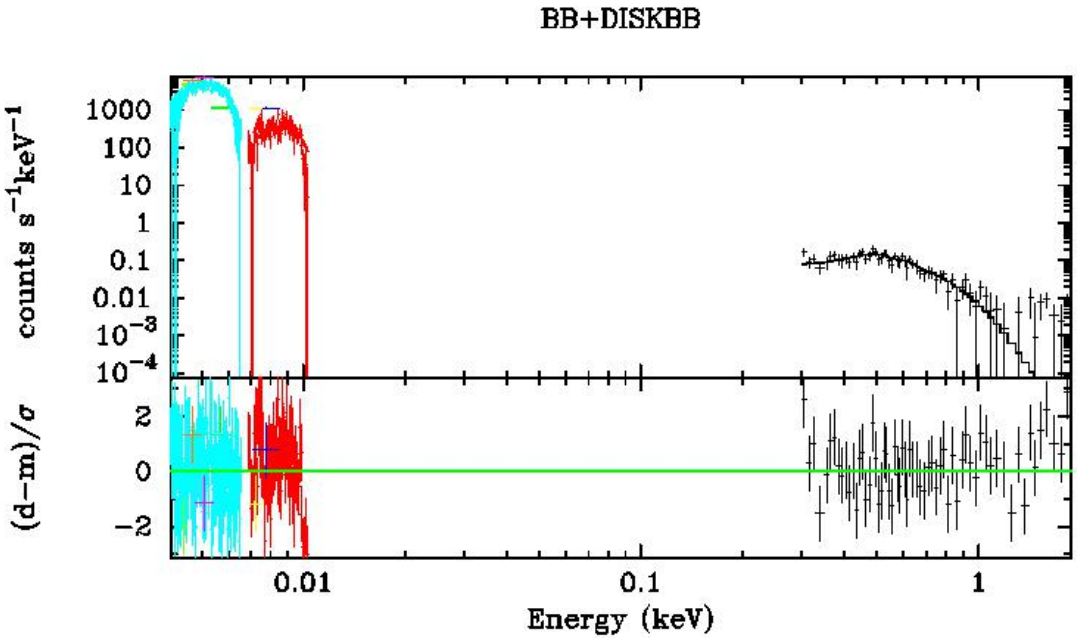
AstroSat ToO Observation

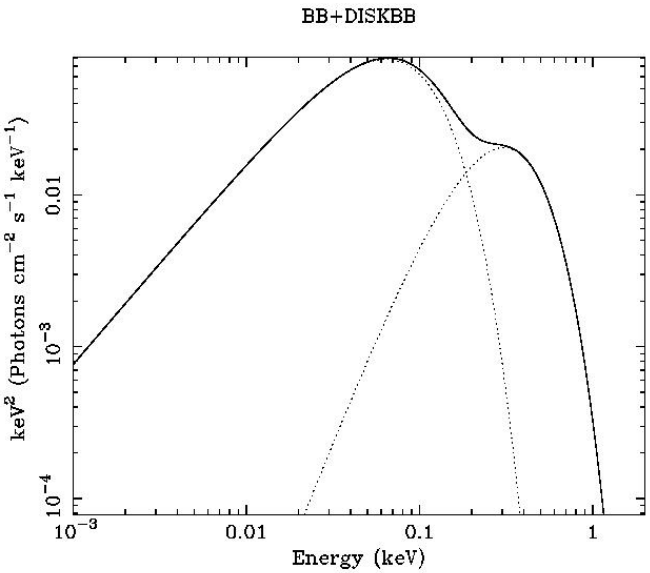




ASASSN-16oh

ASASSN-16oh : UV/X-ray broadband spectrum





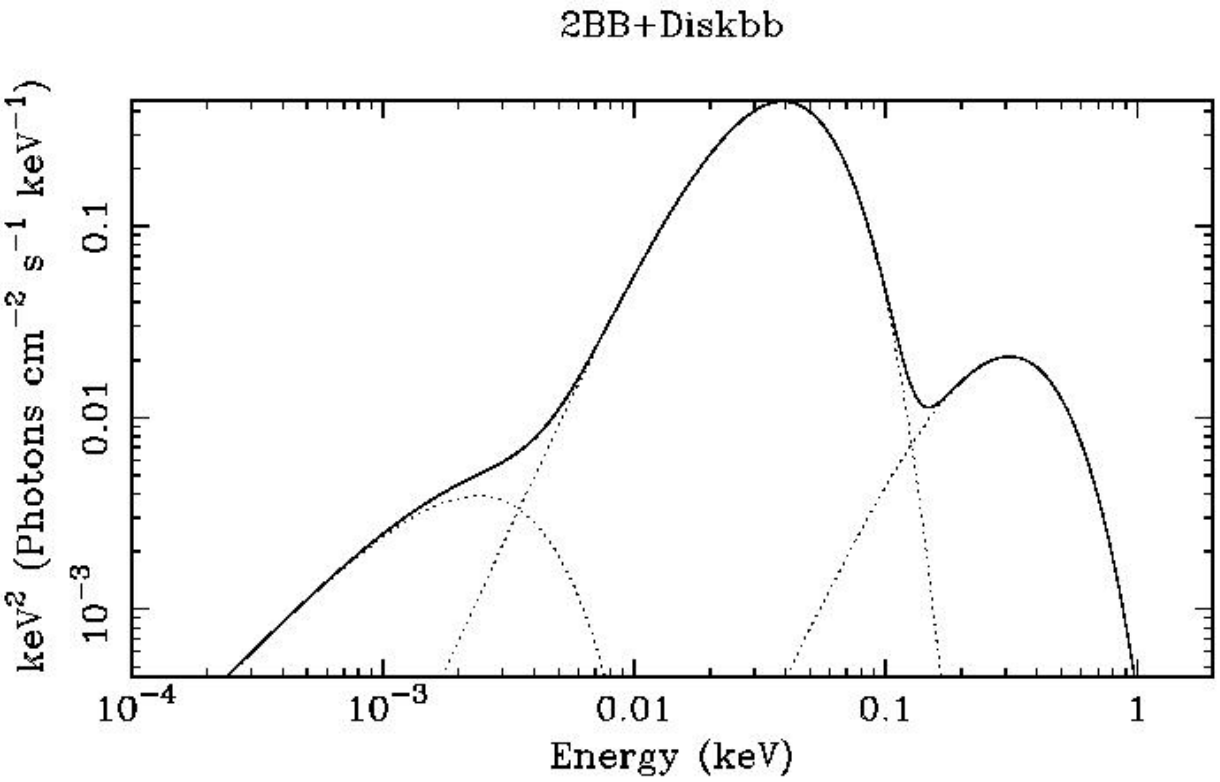
UVIT FUV/NUV gratings, filters + SXT data

Blackbody from WD (kT~80eV),

Accretion disk emission with kT_in ~27eV >> for a disk around a WD

ch^2/dof = 495.8/367

ASASSN-16oh : 2 Blackbody + DBB components



kT_{BB2} = 80eV (WD)

kT_{BB1} = 10eV
(boundary layer?)

kTin = 0.6 - 2.4eV
(Accretion disk?)

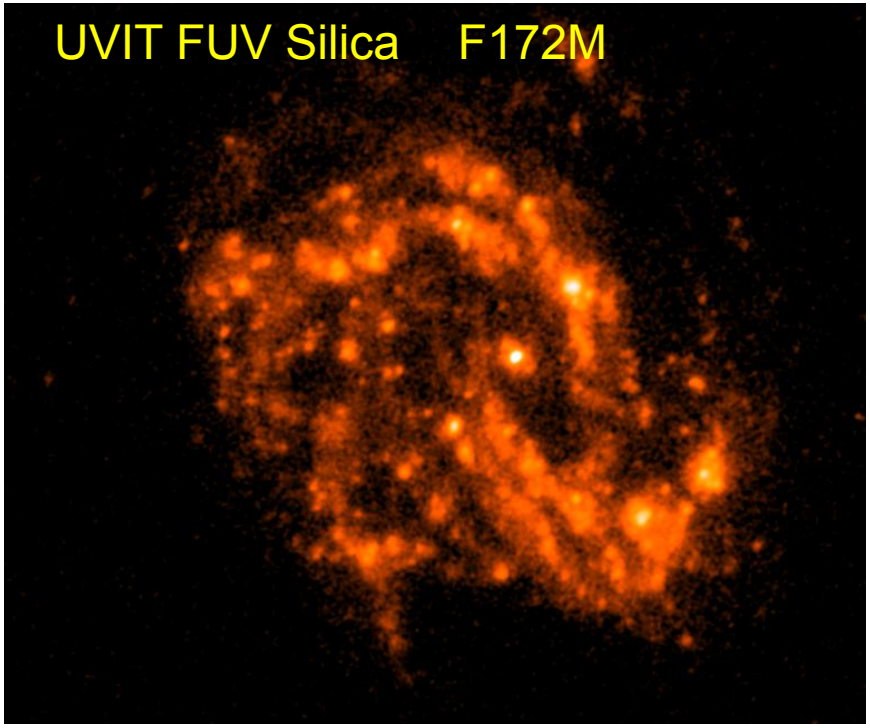
chi2/dof = 491/365

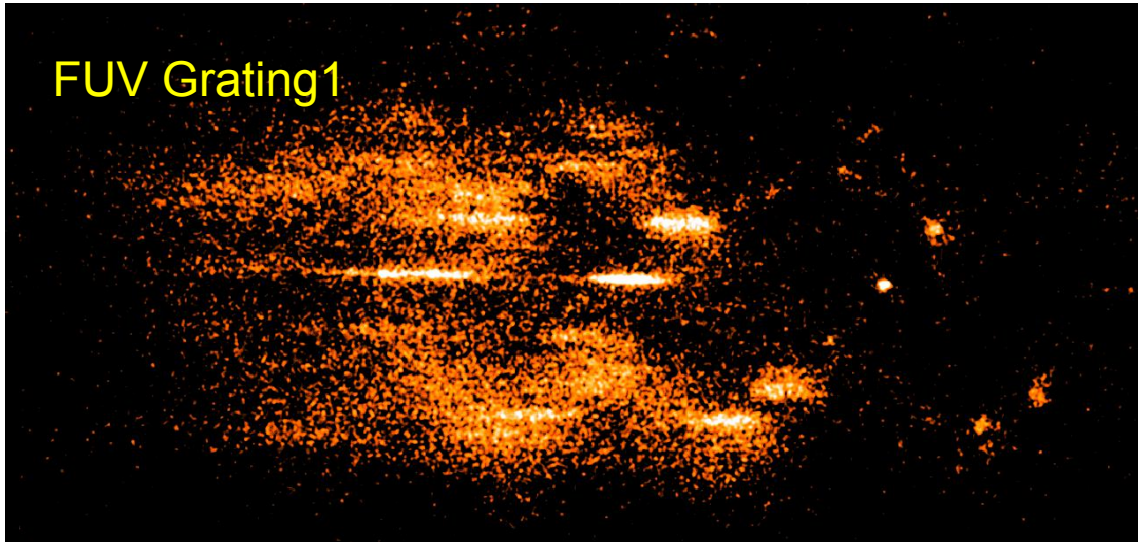
(GCD, Phil Charlse, K. P. Singh)

AstroSat observations of NGC4051

A nearby narrow-line Seyfert 1 galaxy

$$M_{BH} = 1.34 \times 10^6 M_\odot$$

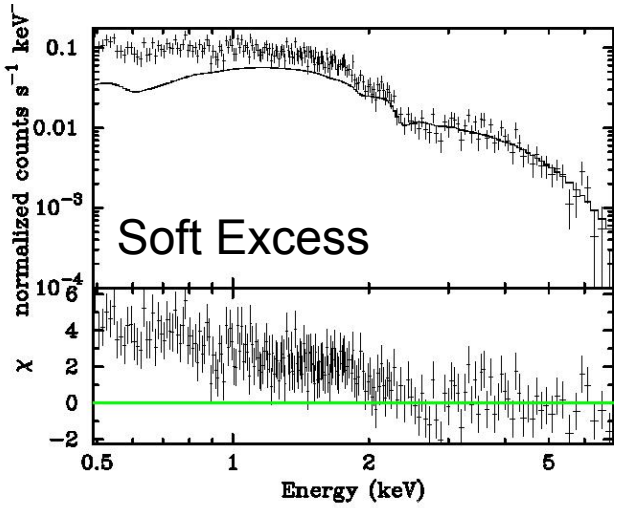


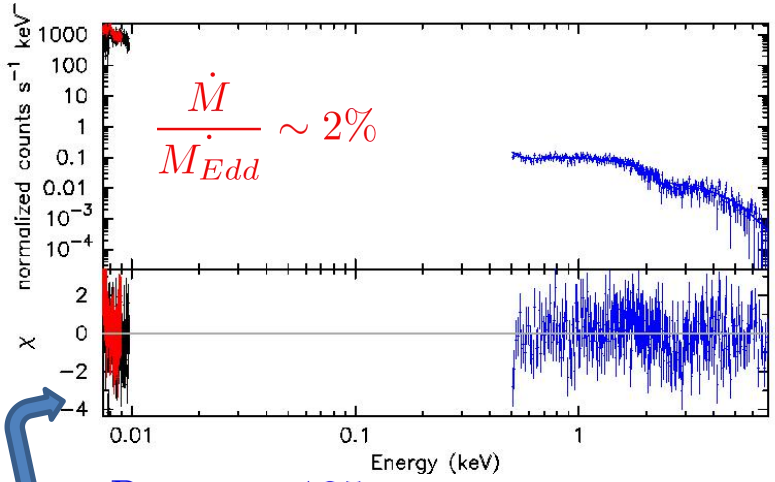


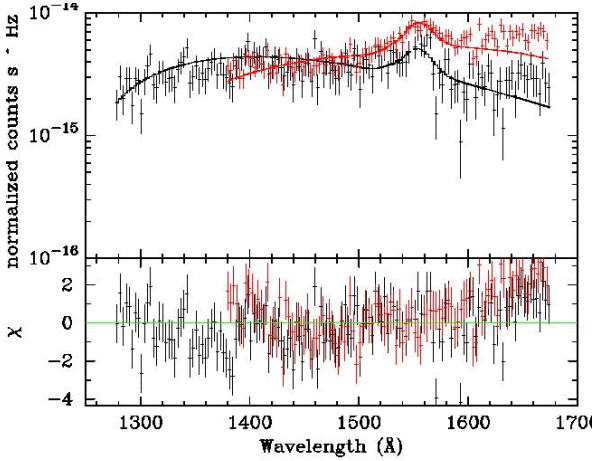
$$d = 13.84\mathrm{Mpc}$$

$$N_H = 1.15 \times 10^{20}\mathrm{cm}^{-2}$$

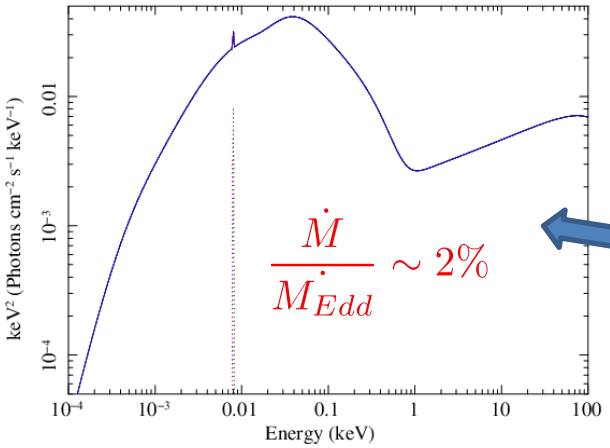
NGC4051: Soft X-ray Excess & UV emission

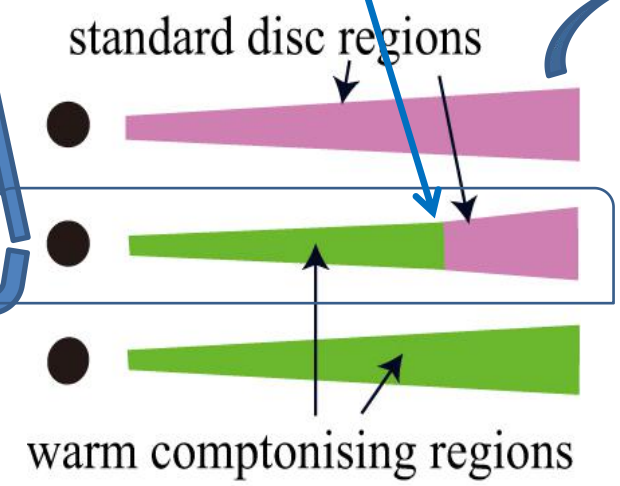


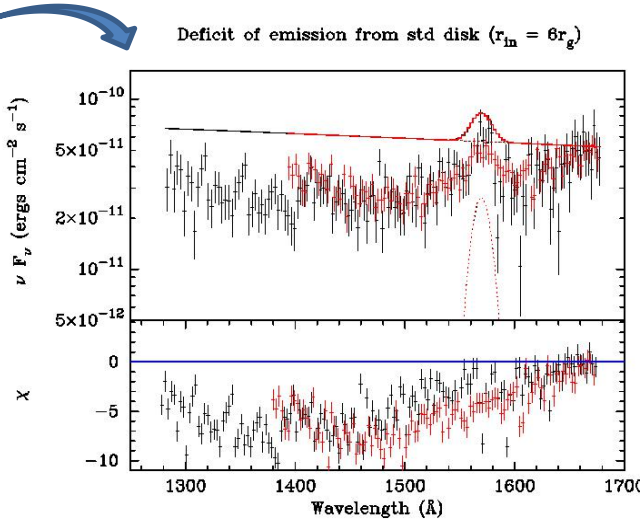




$R_{warm} \sim 135 r_g$







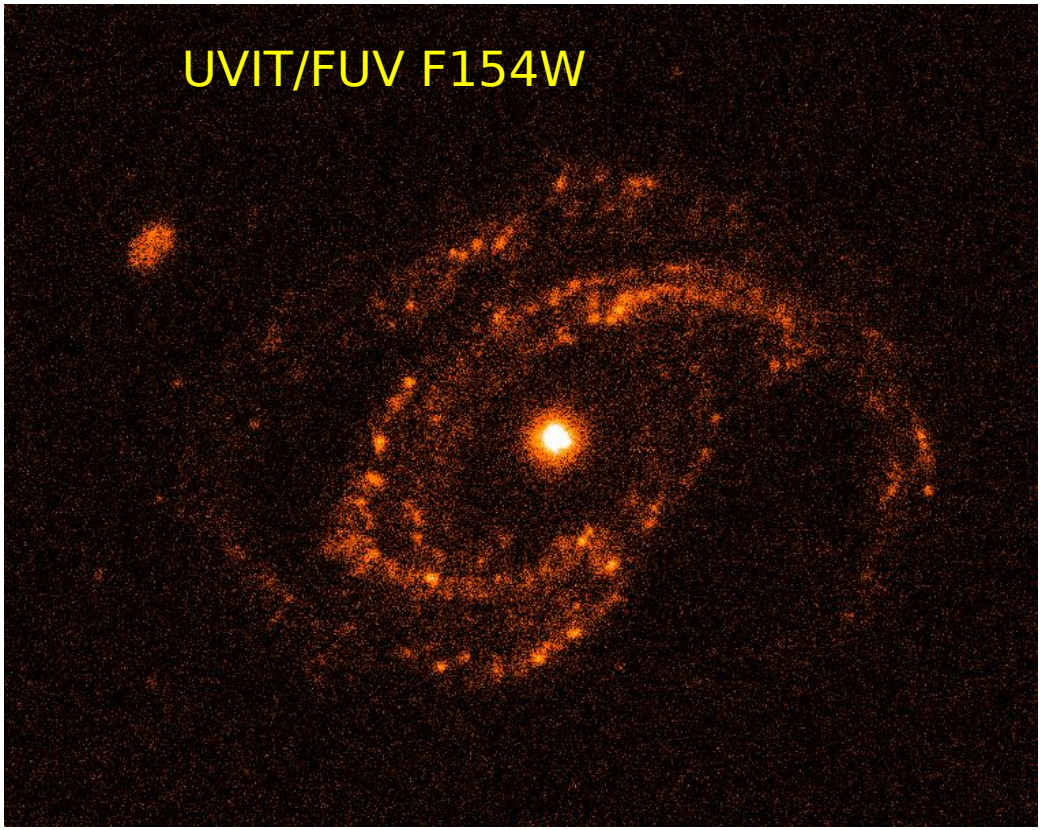
Deficit of UV emission compared to SS disk

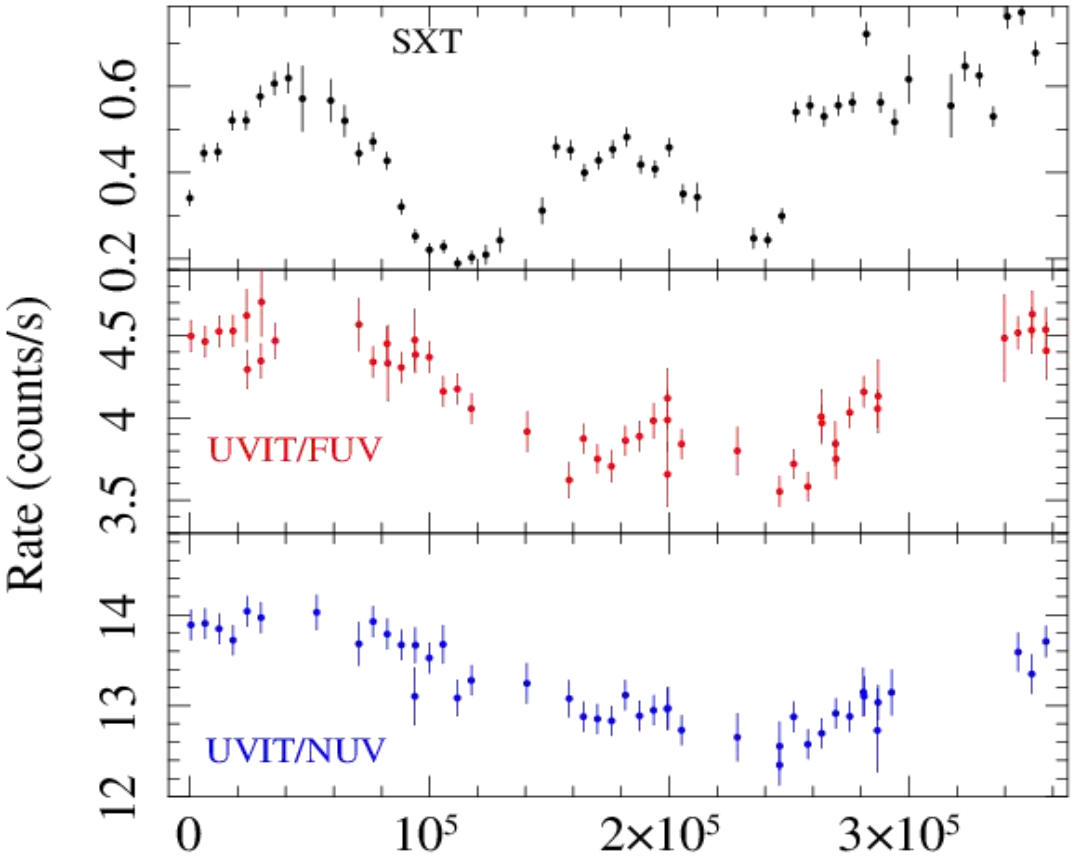
Intrinsic Extinction or truncated disk?

NGC4593 : A Seyfert 1 galaxy

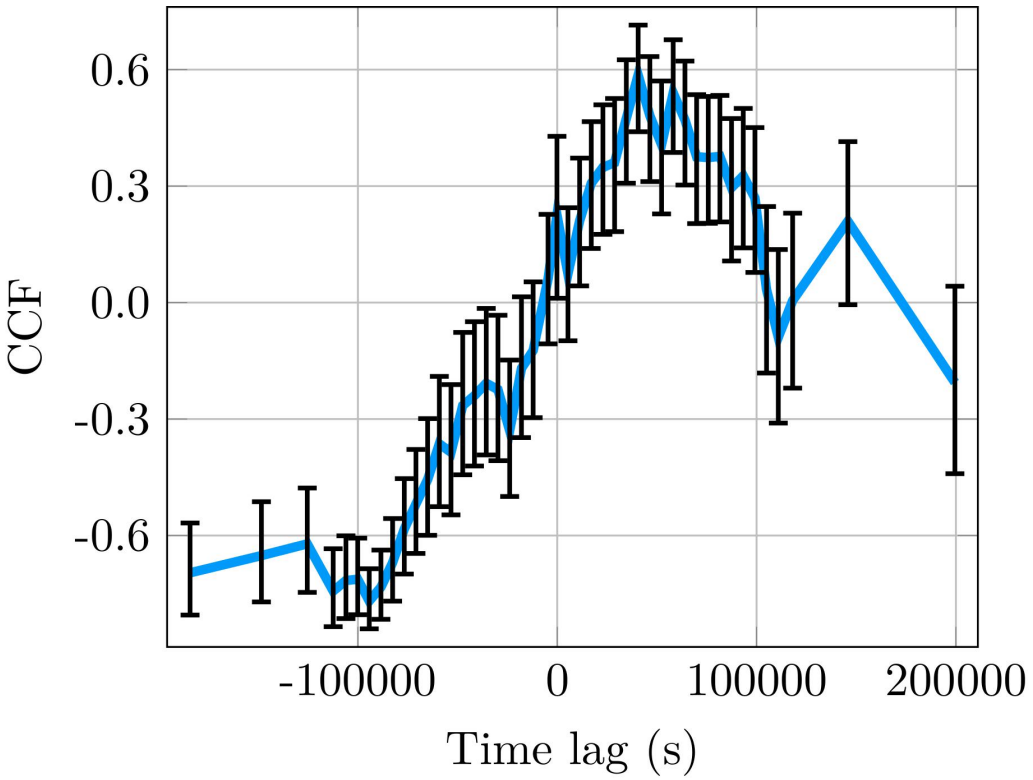
(GCD+, Ian McHardy

4 day long AstroSat observation + XMM



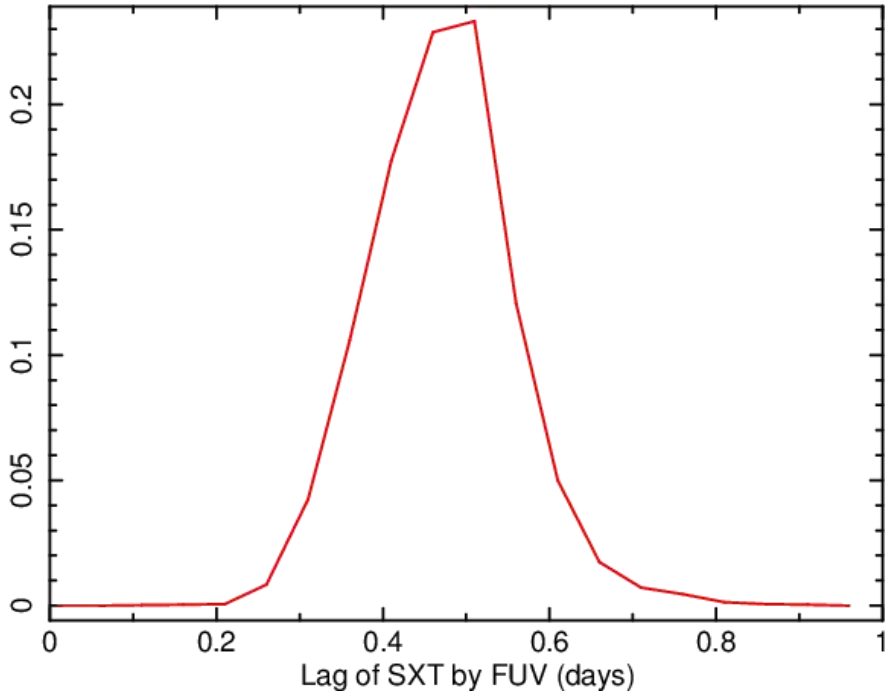


NGC4593: UV/X-ray variability



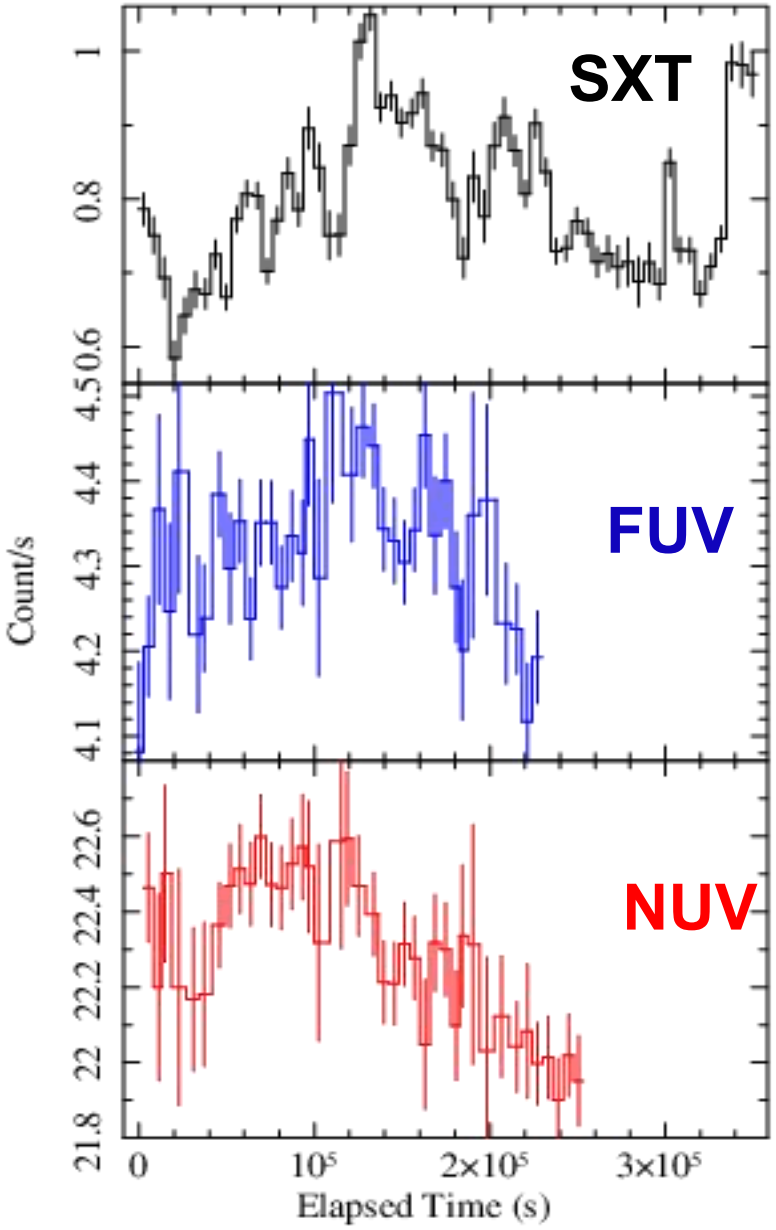
$\tau = 0.475 \pm 0.086$ days

Time lag Distributions
(FR/RSS technique)



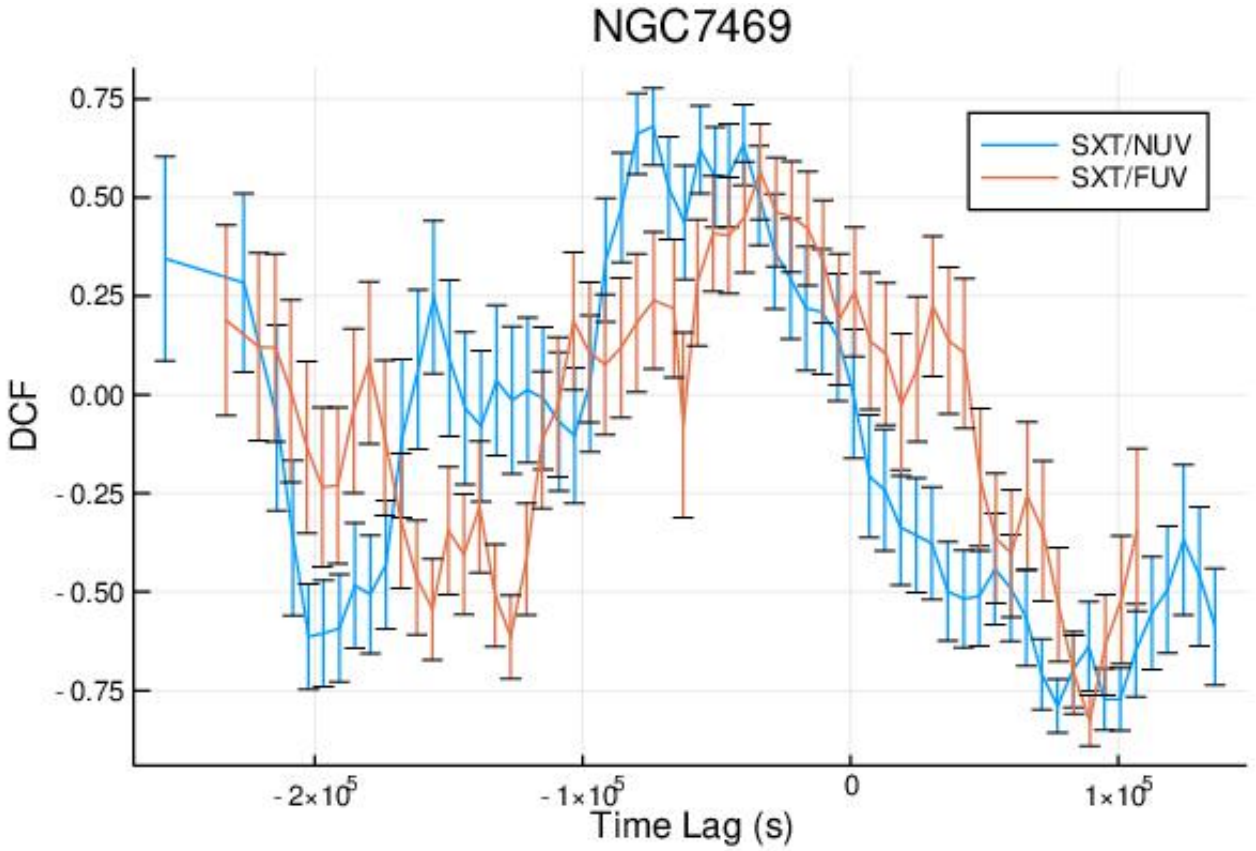
Confirms HST/Swift results.

AstroSat observations of NGC7469



GCD+ in prep

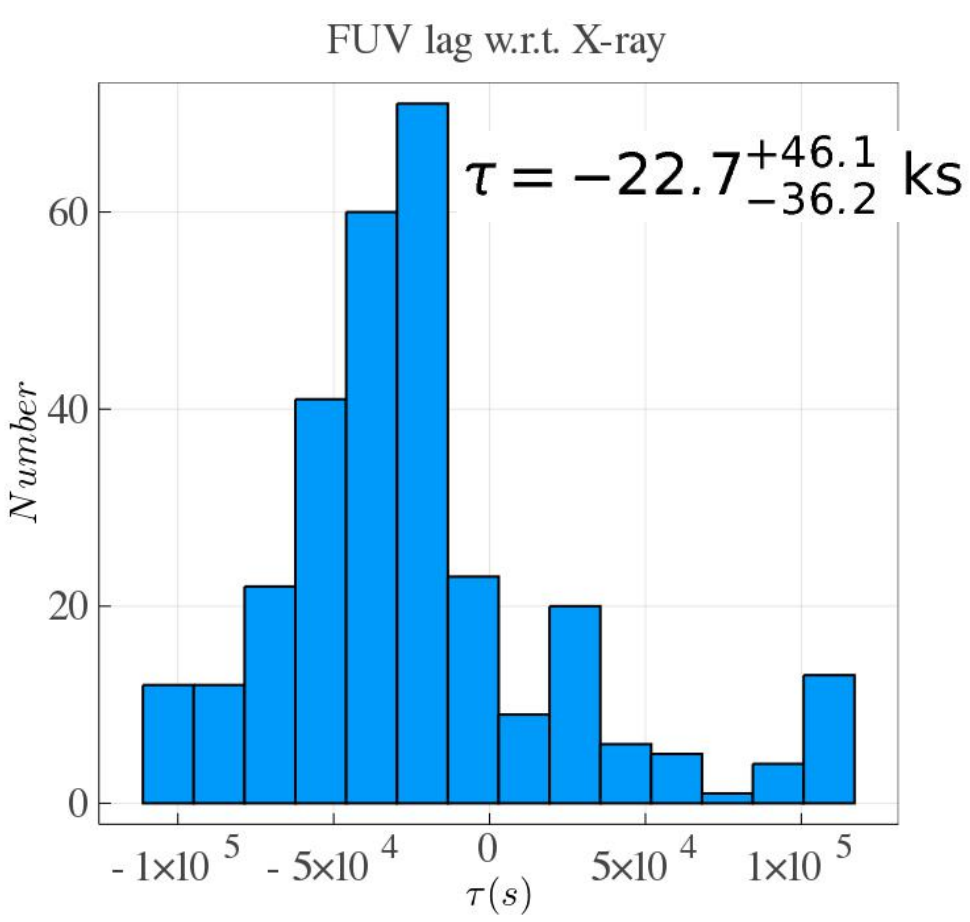
$$M_{BH} = (9 \pm 1) \times 10^6 \ M_\odot$$

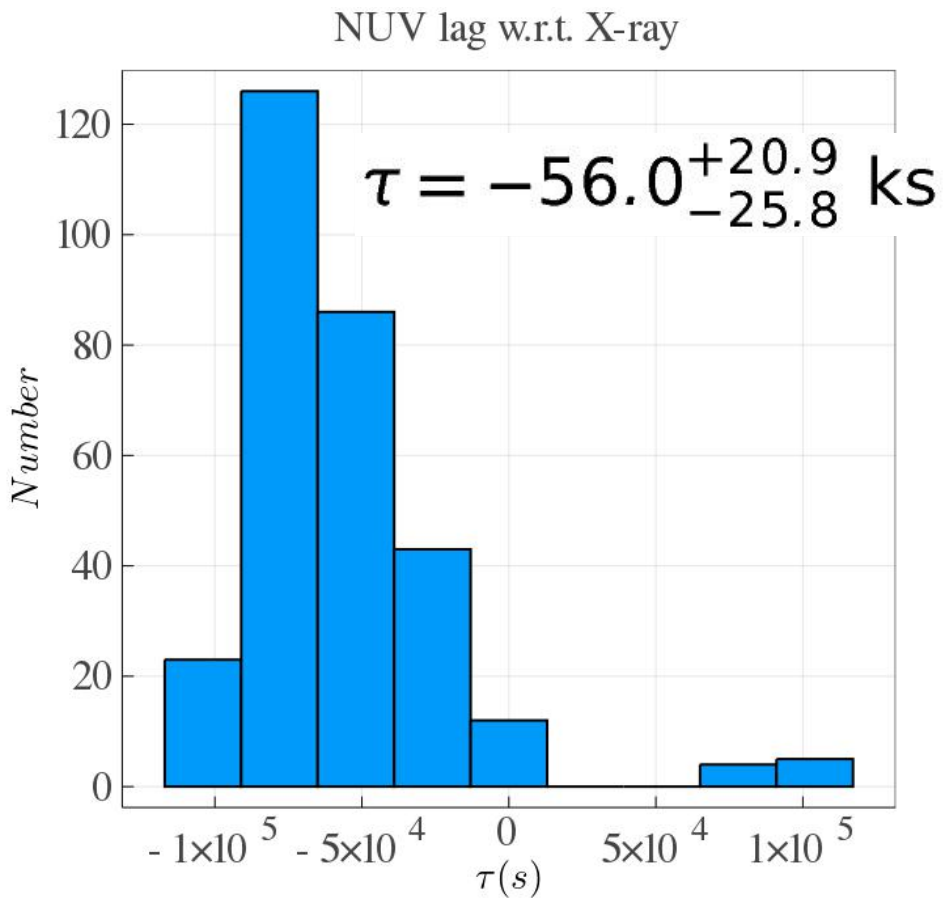


UV leading X-rays in NGC7469

Lag distribution from FR/RSS

(GCD+ in prep)





Among a few AGN to show Comptonization lag!

X-ray powerlaw thermal Comptonization of UV seeds

Summary

First Astronomy space mission by India. Multi-instrument calibration, data management, softwares/tools have taken time.

Nearly 4 years in orbit, ~22500 revolutions, 524 distinct targets, 135 Target of Opportunity observations. 952 users from 42 different countries registered in AstroSat proposal system either to submit proposals or to download archival data.

Science output has been low but lot of data yet to be analyzed.

Information on AstroSat : AstroSat science support Cell

Website: http://astrosat-ssc.iucaa.in/

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Thank You for your attention.