UV/X-ray Connection in Seyferts with AstroSat

work in progress

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AstroSat Team

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Shyam, Stalin, Joe Postma UVIT team

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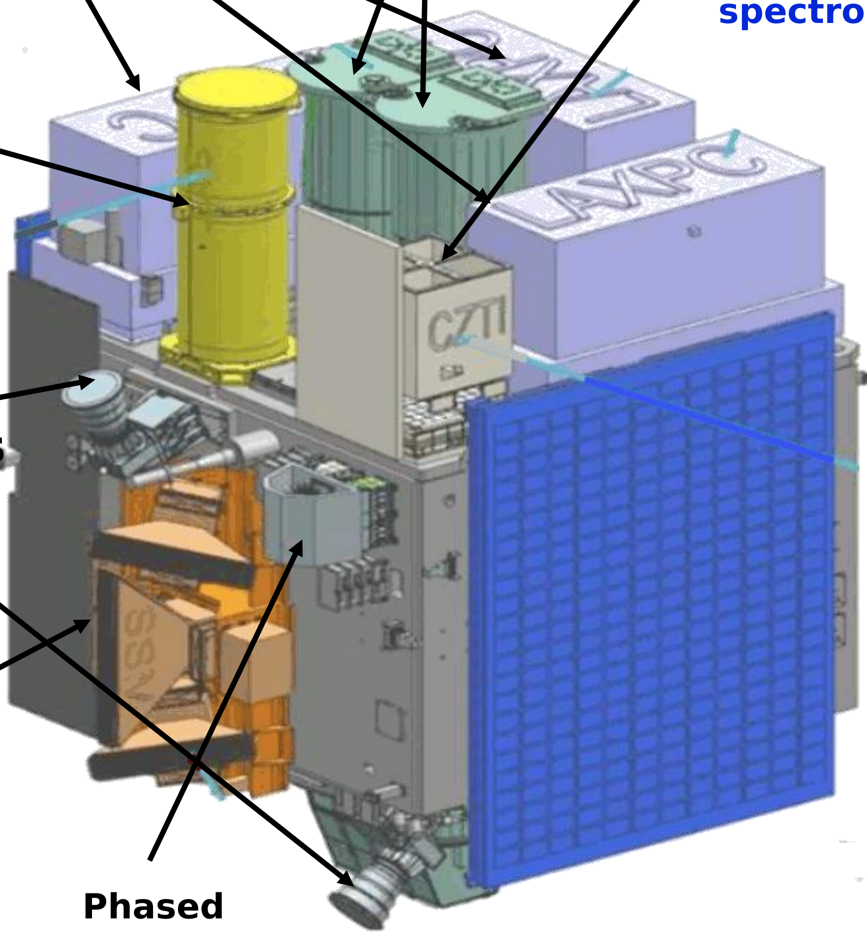
Iossif Papadakis, I. M. NcHardy

9th FERO meeting, 23-25 May, Heraklion, Greece

AstroSat



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PMs: S.N. Tandon (UVIT),
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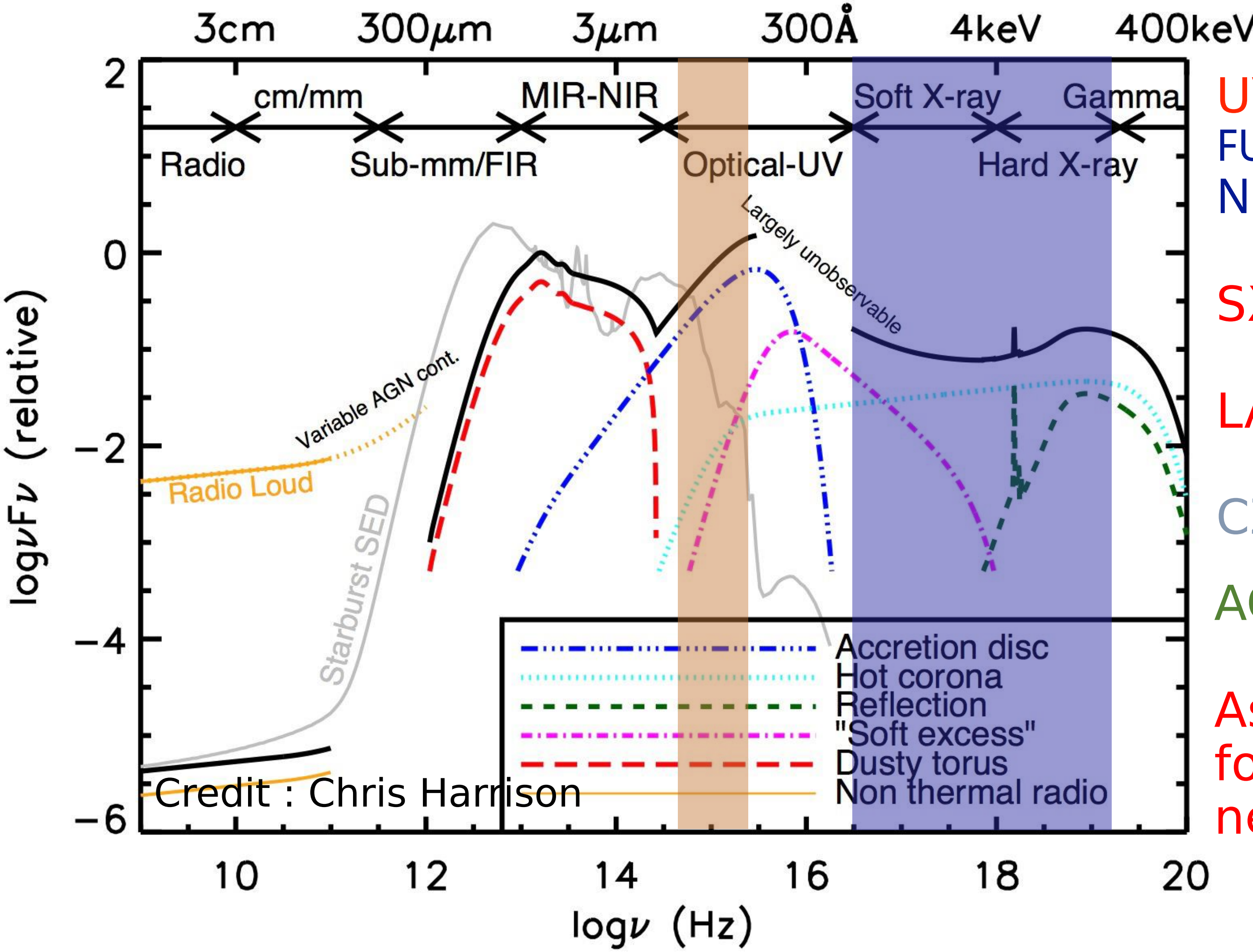
K.P. Singh (SXT)
A.R. Rao (CZTI)
M.C. Ramadevi (SSM

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

AstroSat & AGN Studies



UVIT : FUV/NUV/VIS

FUV : 5 filters, 2 gratings

NUV: 5 filters, a grating

SXT (0.2-8 keV)

LAXPC (3-80 keV)

CZTI (20-100 keV)

AGN truly MW objects

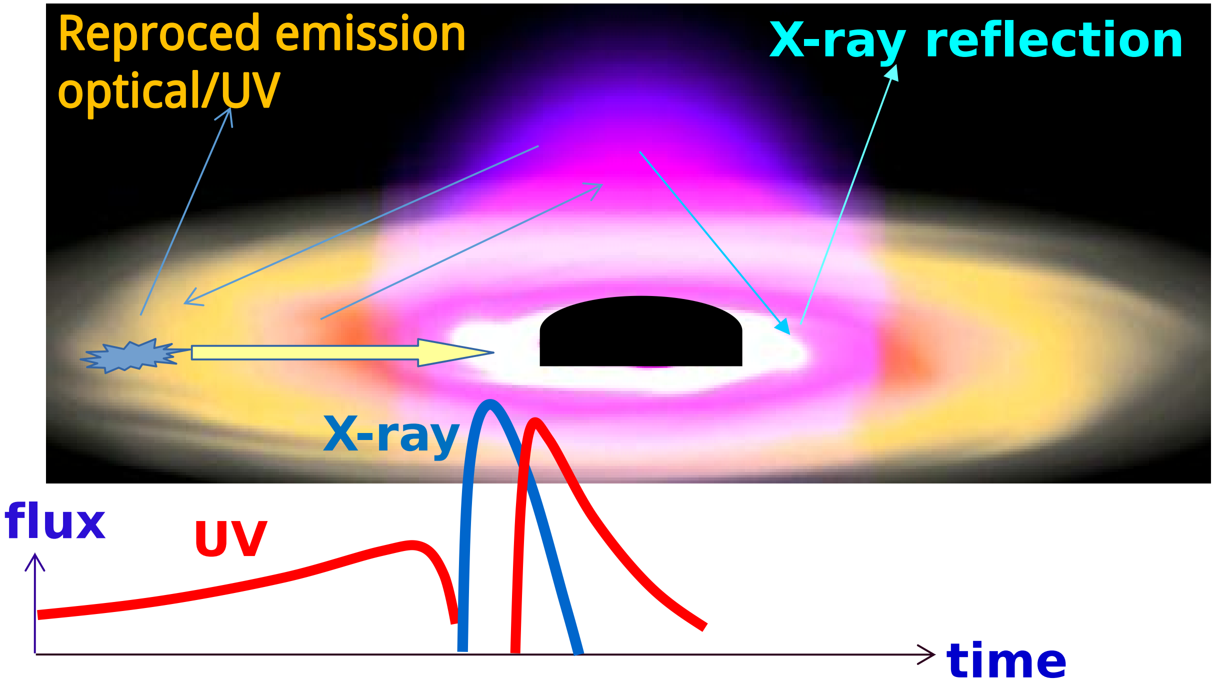
Astrosat well suited for MW study of nearby bright AGN

Issues to address with AstroSat

- Do AGN host standard SS accretion disks?
- Origin of UV/Optical variability - Intrinsic Vs X-ray reprocessing?
- UV-X-ray Spectral Energy Distribution, L_{bol} / L_{Edd}
- Spectral connection between far UV and soft X-rays, nature of soft X-ray excess in extreme NLS1s (RE 1034+39)
- Seed photons for thermal Comptonisation? Testing thermal Comptonsation model - cooling of hot corona by seed UV/optical UV photons?
- Disk truncation in LLAGN ?
- Absorption-induced X-ray variability ? (NGC1365)

UV/X-ray connection in Seyfets

- Propagation $\dot{m}$ of fluctuations



- Reprocessing of X-rays into optical/UV

Optical/UV lag behind X-rays with light crossing time $\tau \propto \lambda^{4/3}$

Time lag Vs wavelengh => Test standard disk model

- Compton upscattering of optical/UV photons into X-rays

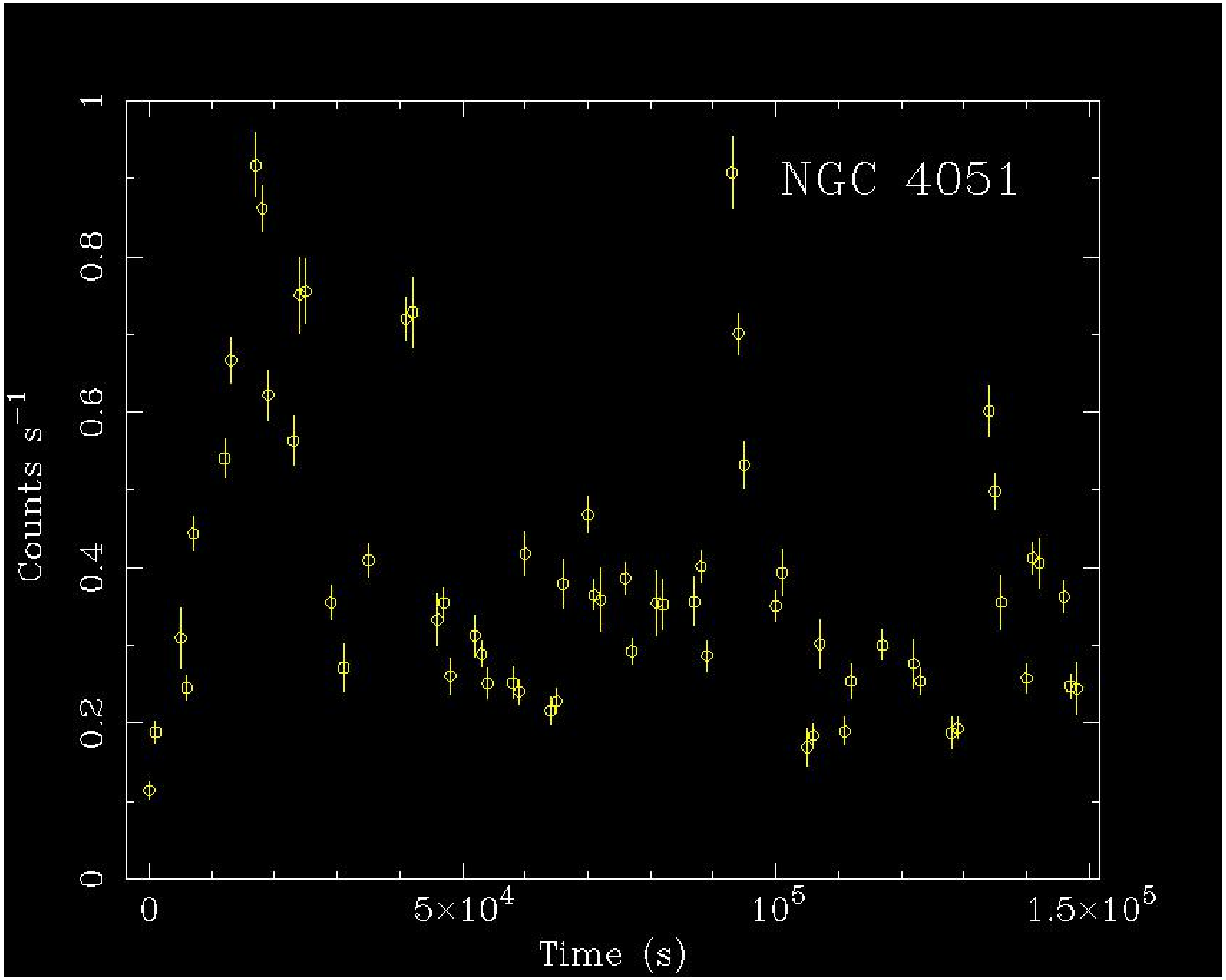
Optical/UV lead X-rays (Not seen?)

Seed photons for thermal Comptonisation

AstroSat : X-ray/UV varibility of Seyferts

NGC4051 (1.7 days)

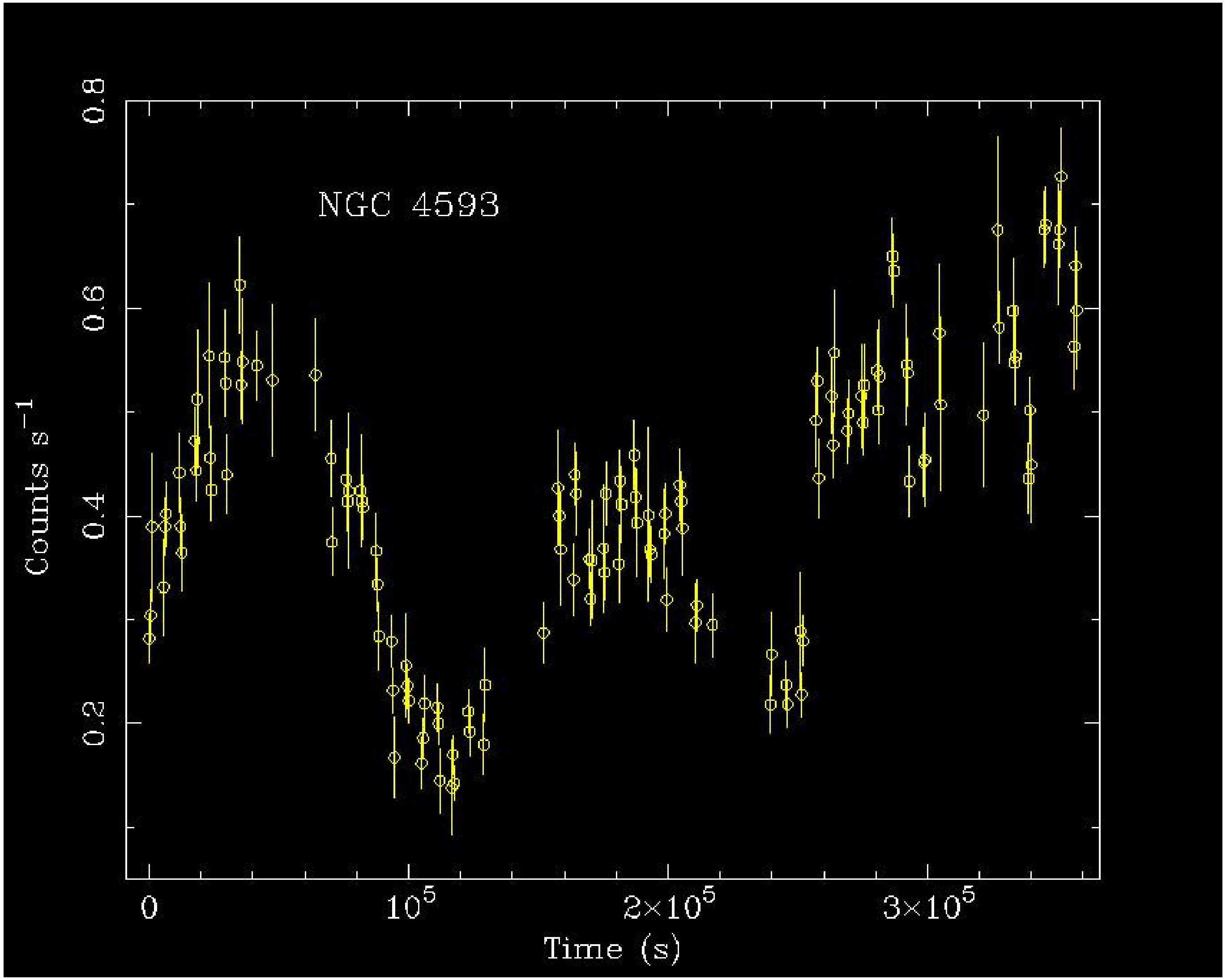
SXT GT observations



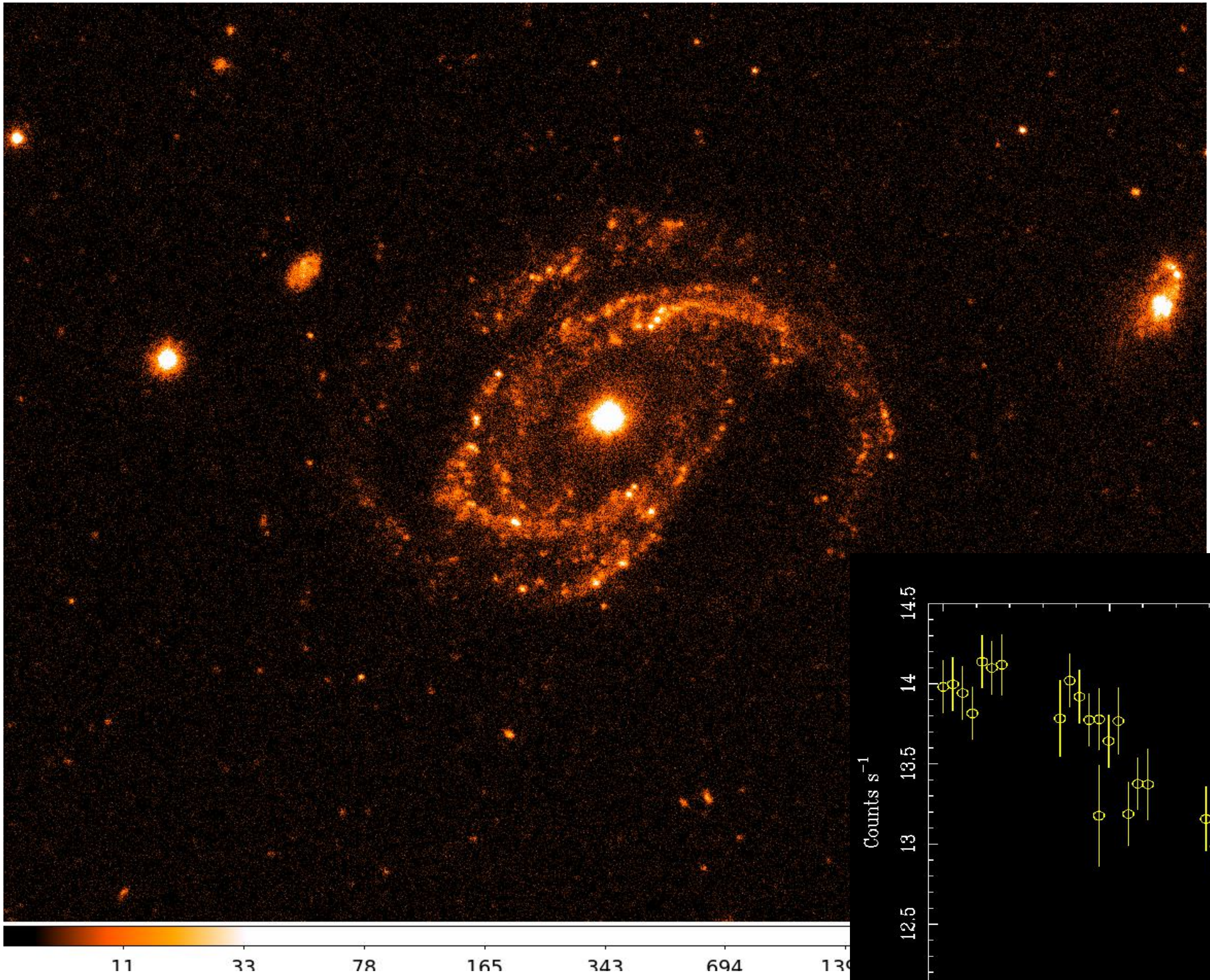
AstroSat : X-ray/UV varibility of Seyferts

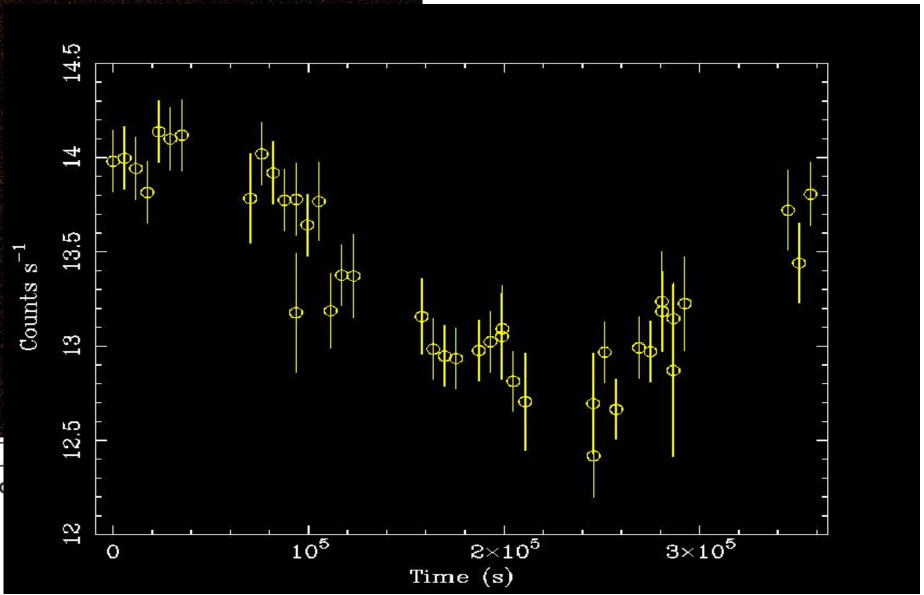
NGC4593 (~4 days)

CZTI GT

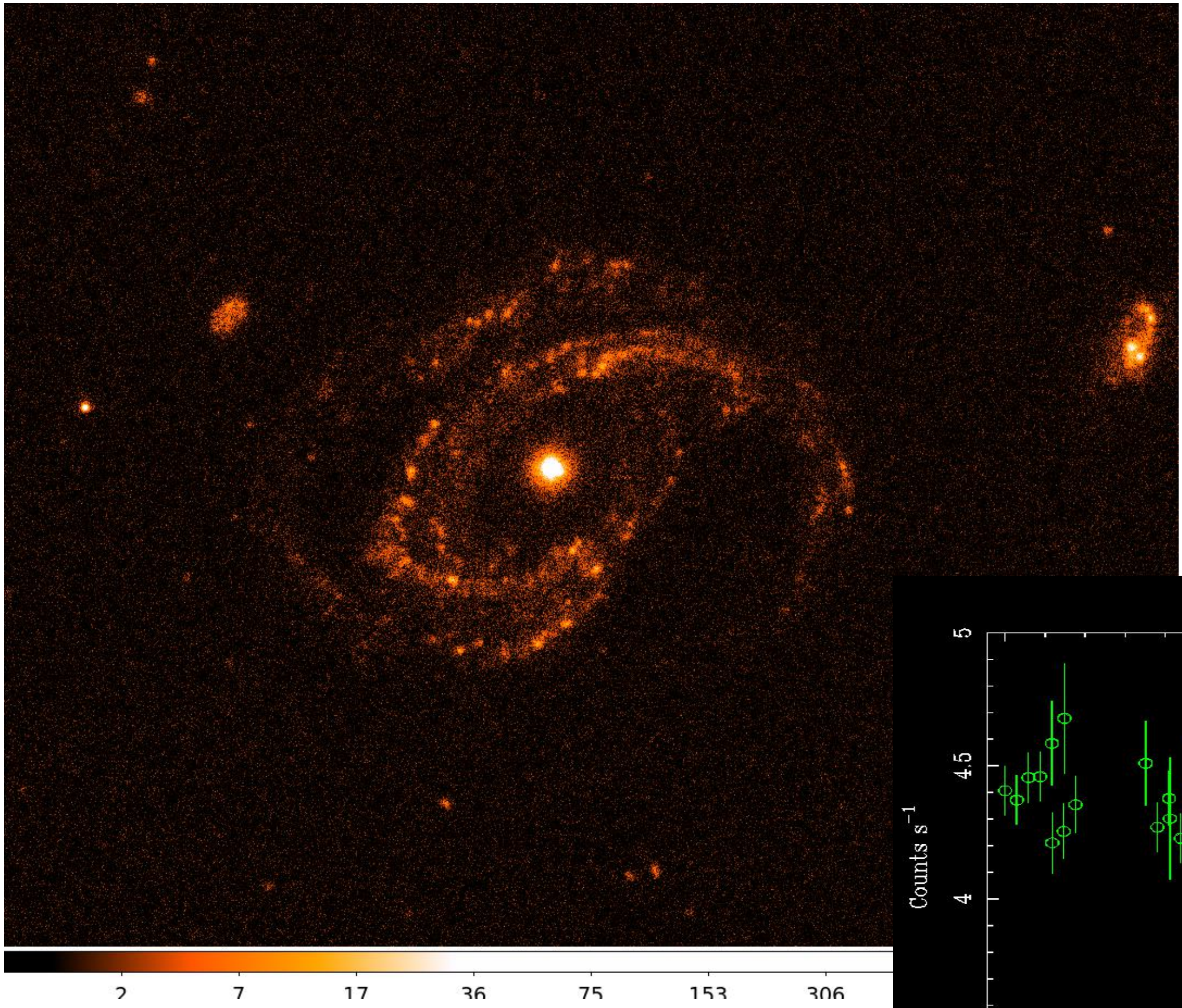


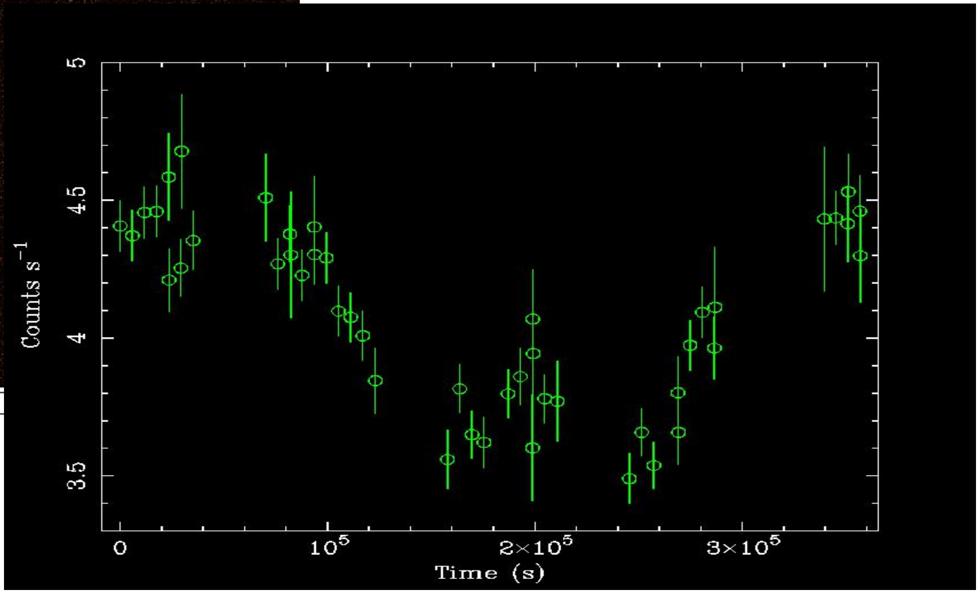
NGC4593 UVIT/NUV N245M





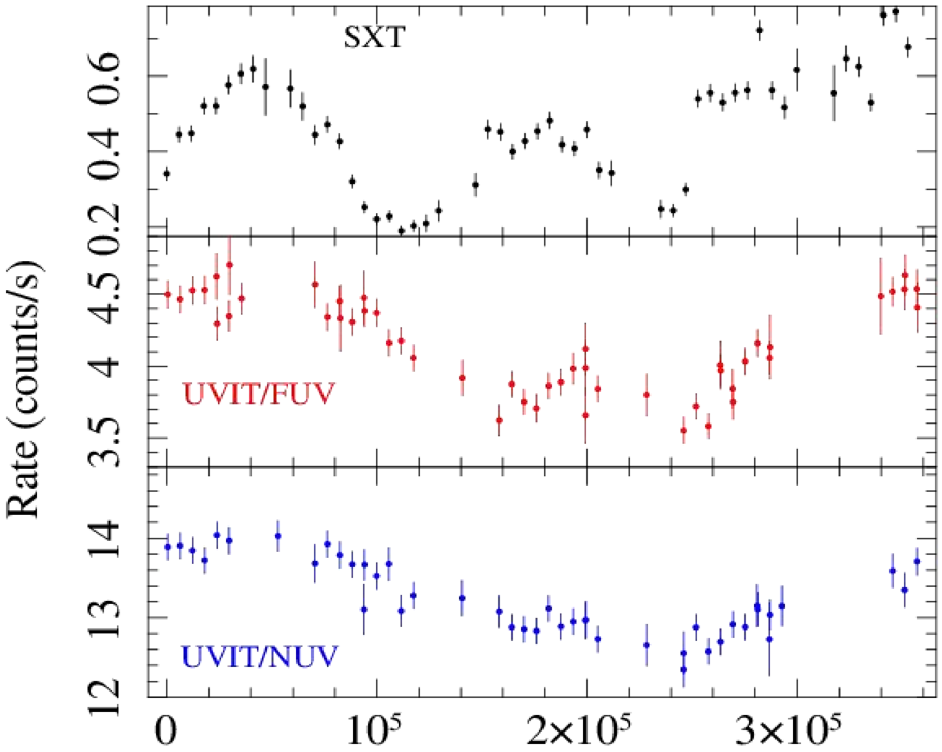
NGC4593 UVIT/FUV F154W





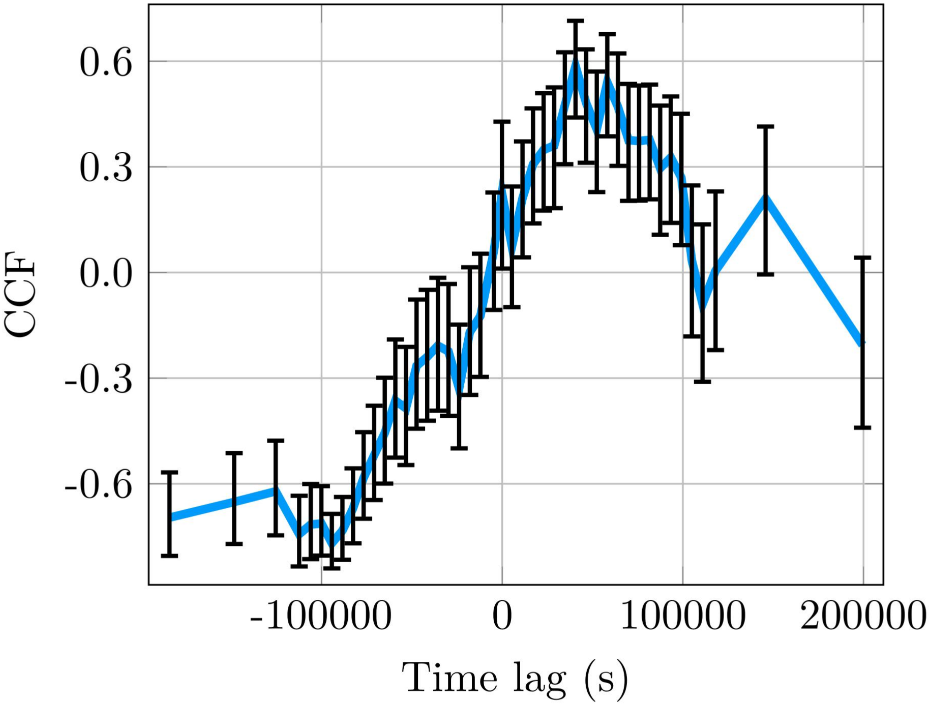
NGC4593 UV/X-ray variability

AstroSAT SXT/UVIT light curves



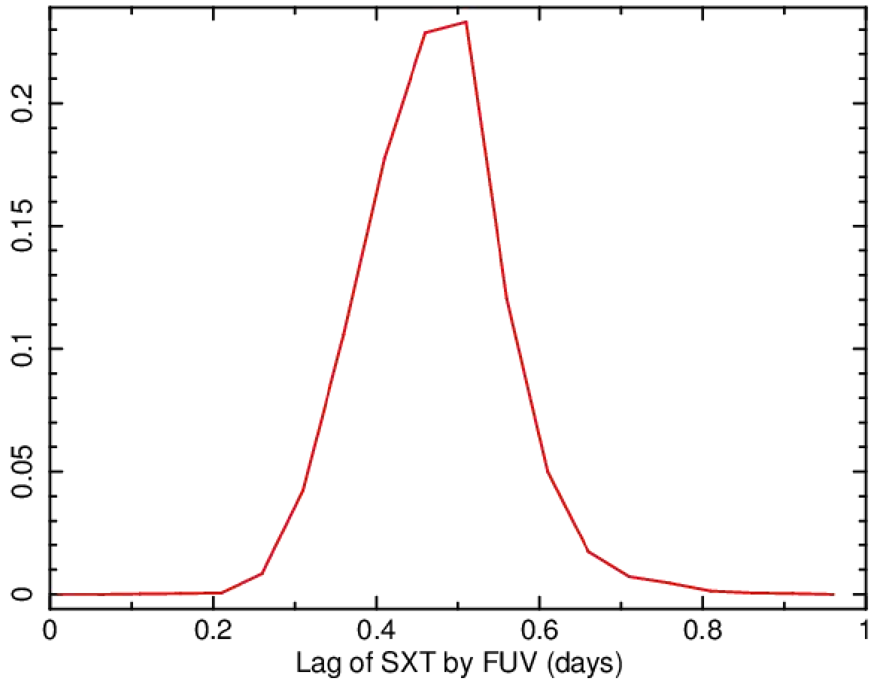
Elapsed Time (s)

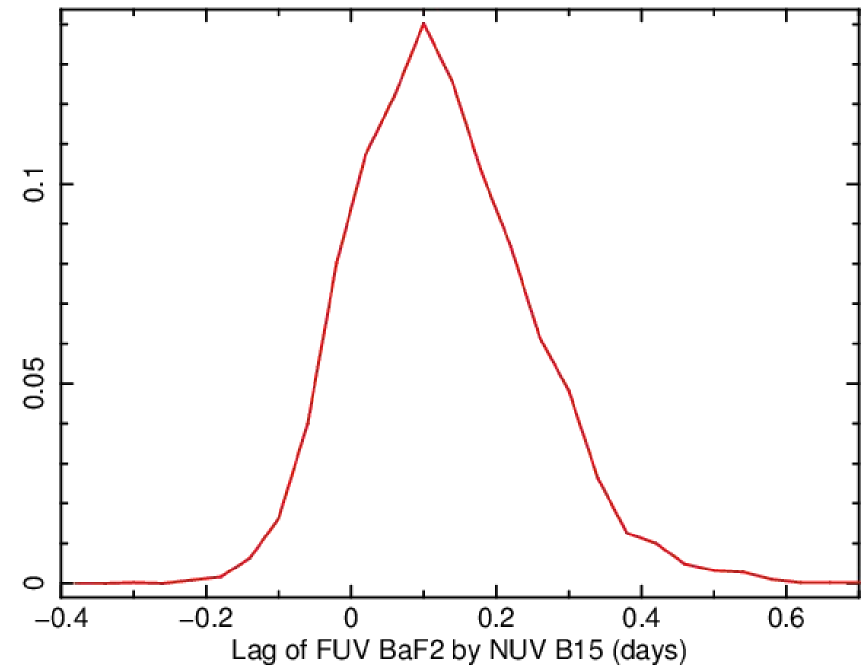
X-ray/FUV Cross-correlation



Time lag measurements

Time lag Distributions (FR/RSS technique)





FUV lag w.r.t. X-rays

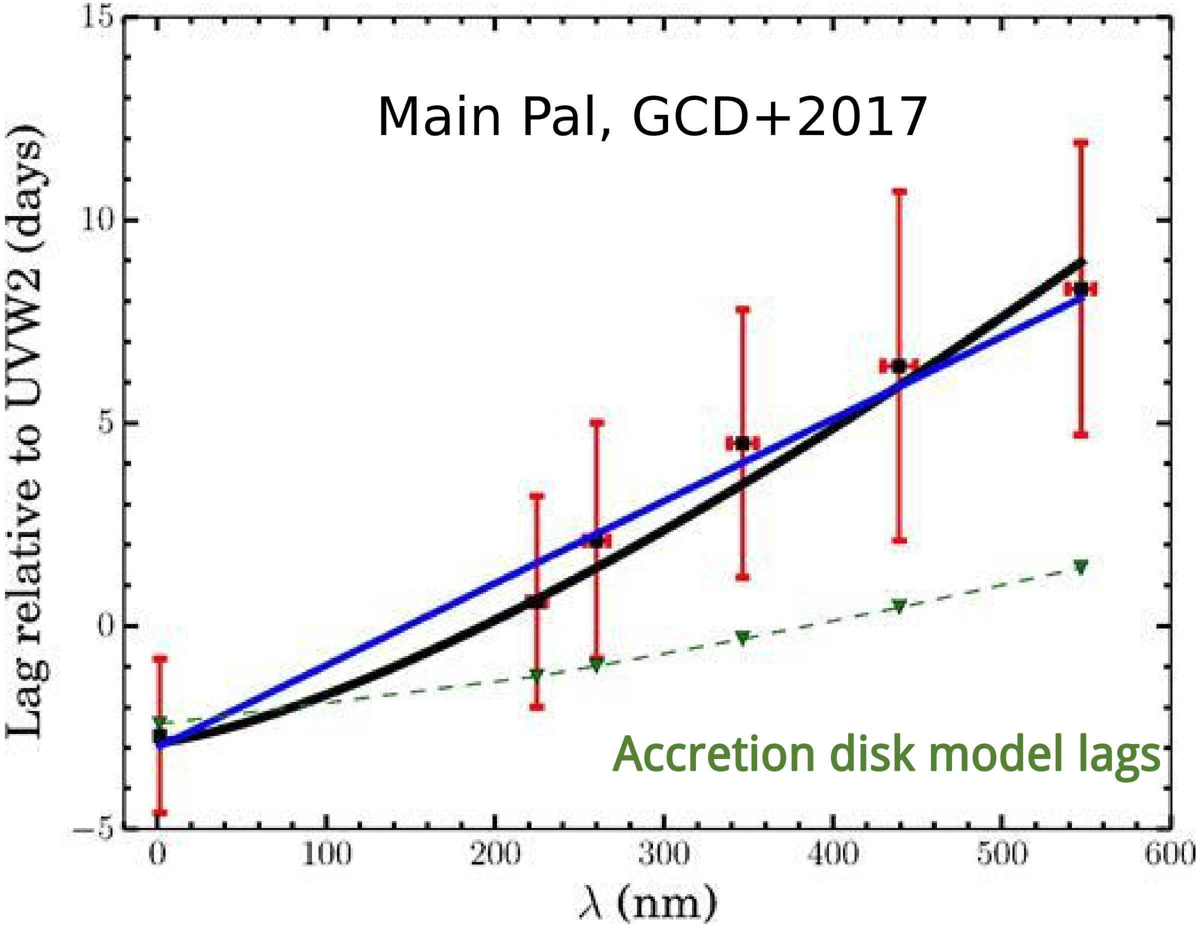
$\tau = 0.475 \pm 0.086 \text{ days}$

NUV lag w.r.t. FUV emission

$\tau = 0.124 \pm 0.124 \text{ days}$

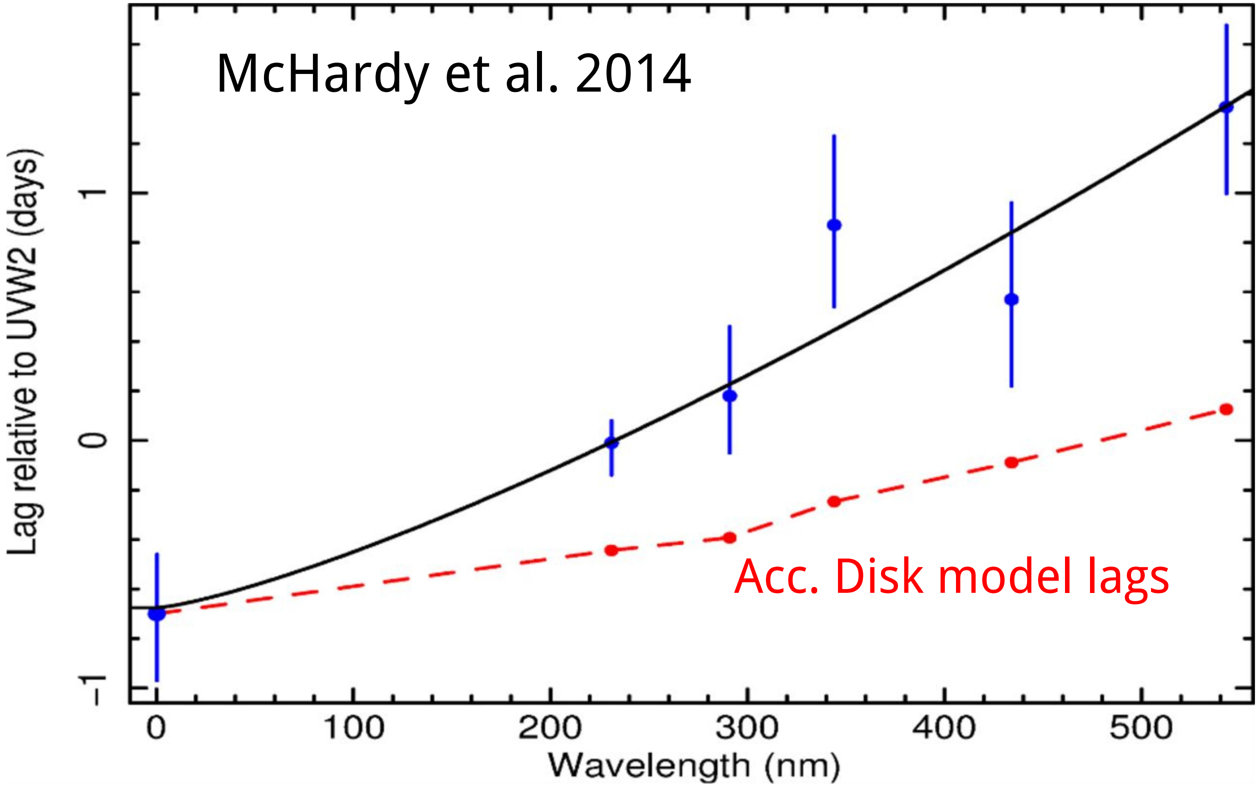
X-ray processing into UV

2 year Swift monitoring of Fairall 9: Larger disk size



Observed lags longer than expected for the mass and accretion rate

Swift monitoring of NGC5548



Same result in extensive follow up observations (Edelson et al 2015, Fausnaugh et al 2015)

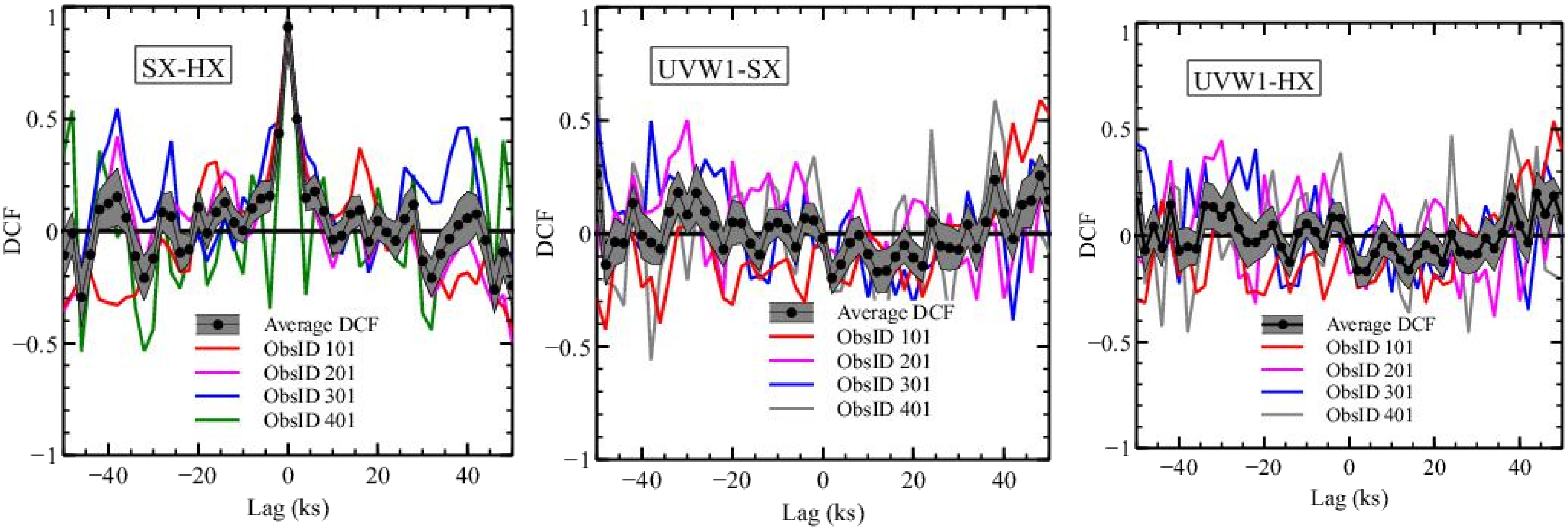
Buisson et al. 2017 : longer lags in half of their sample of 21 AGN

Microlensing observations also require larger disk sizes than standard disk model (e. g., Morgan et al 2010)

Larger Disk Sizes in Seyferts ?

Absence of UV/X-ray correlation in 1H0707-495)

Pawar, GCD, Papadakis+2018



Similar result from IRAS13224-3809 (Buisson et al. 2018)

Strong and broad iron K and L lines => strong light bending.
X-ray illumination mostly in the innermost Hot acc. disk.

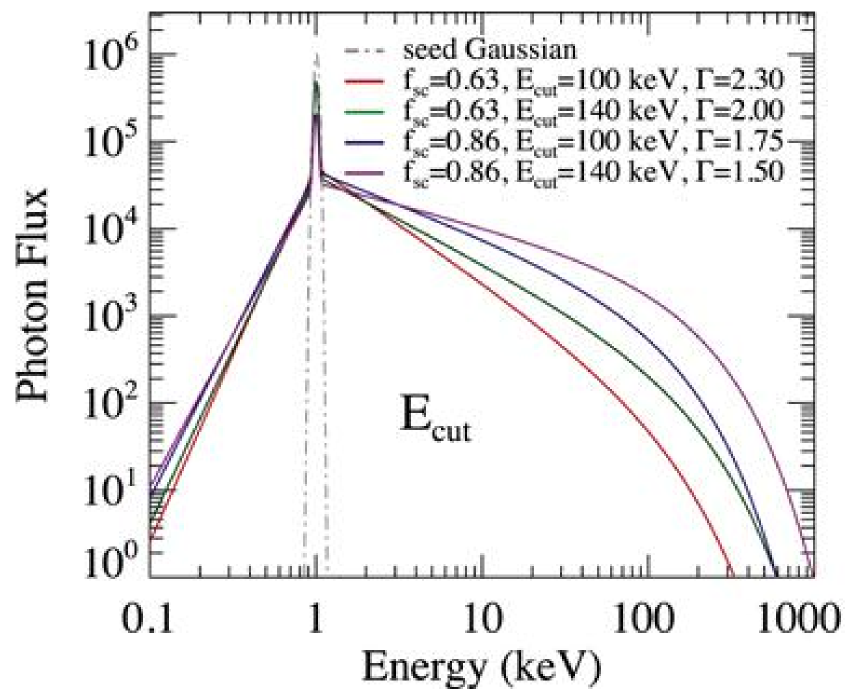
Origing of UV variability?

More results to come from AstroSat on NLS1s - NGC4051, Mrk110, Akn564, NGC5273, Mrk1044, Mrk766

Probing Thermal Comptonisation

- Measuring kT_e (NuStar)
- Variation in kT_e with optical/UV flux (nearly impossible to measure with current instruments)
- Variation in X-ray spectral slope with optical/UV flux
  - Simultaneous UV/X-ray observation with AstroSat
- X-ray spectral shapes below 10keV can be affected by complex absorption
- UVIT + LAXPC observations of bright Seyferts

Two phase model

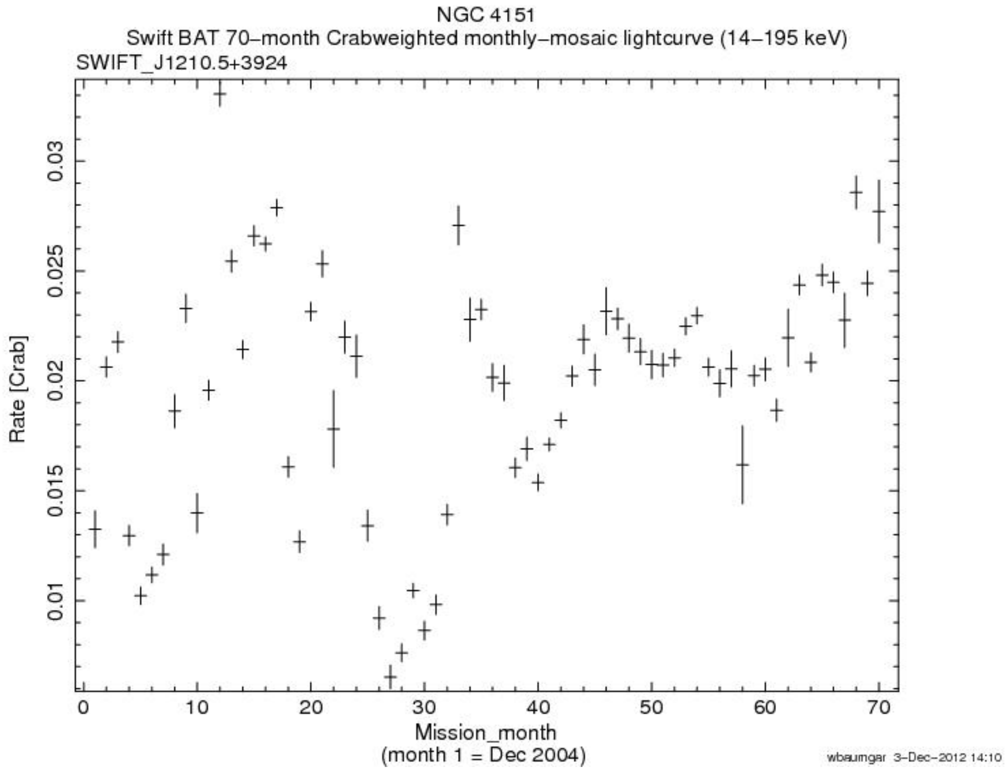


Steiner et al. 2017

Seyfert 1.5 : NGC4151

- Brightest hard X-ray Seyfert in the sky
  (14-195 keV flux ~ 5.4e-10 cgs)

Swift/BAT lightcurve

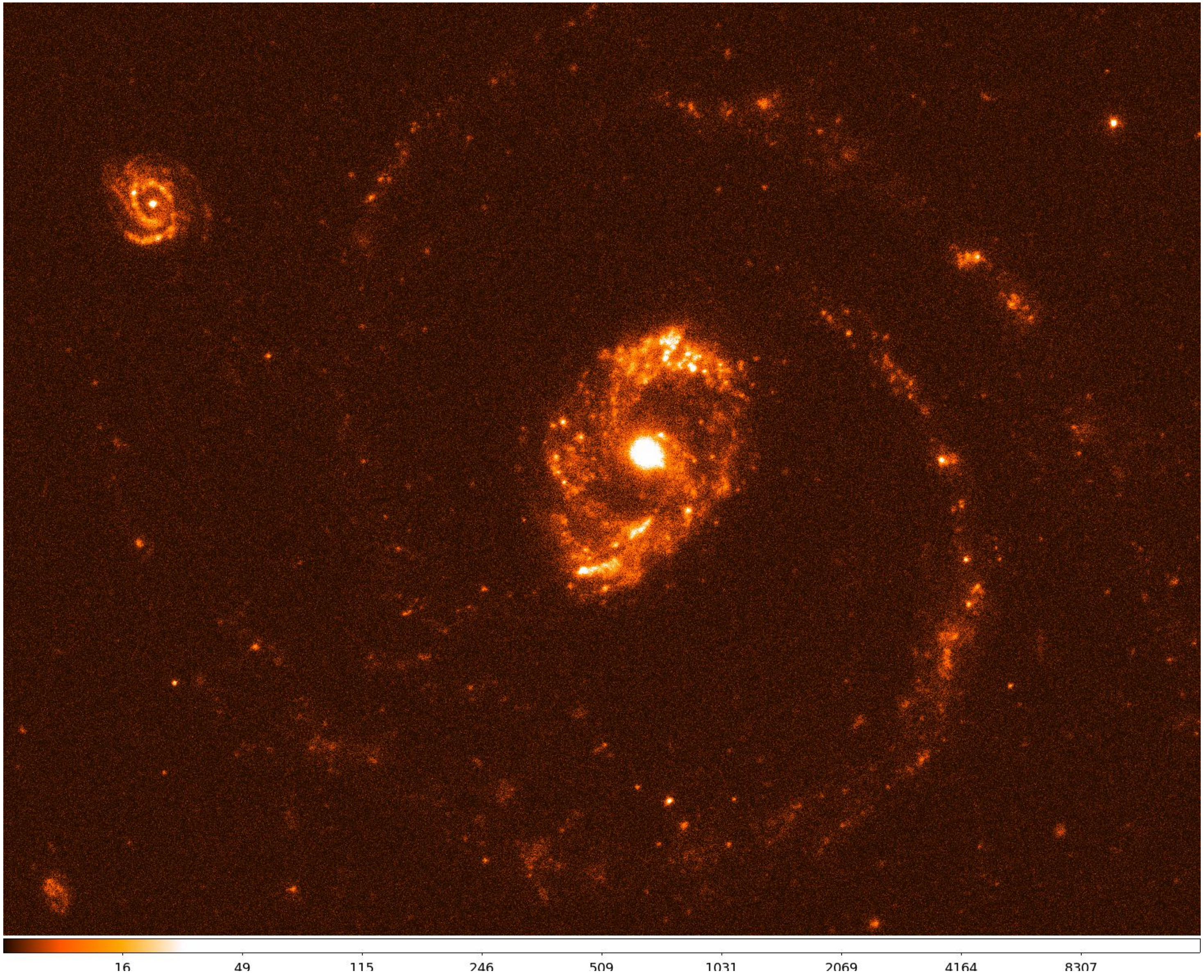


Four AstroSat observations of NGC4151 - each ~1 day duration

1st in the PV phase
3 Observations in G06

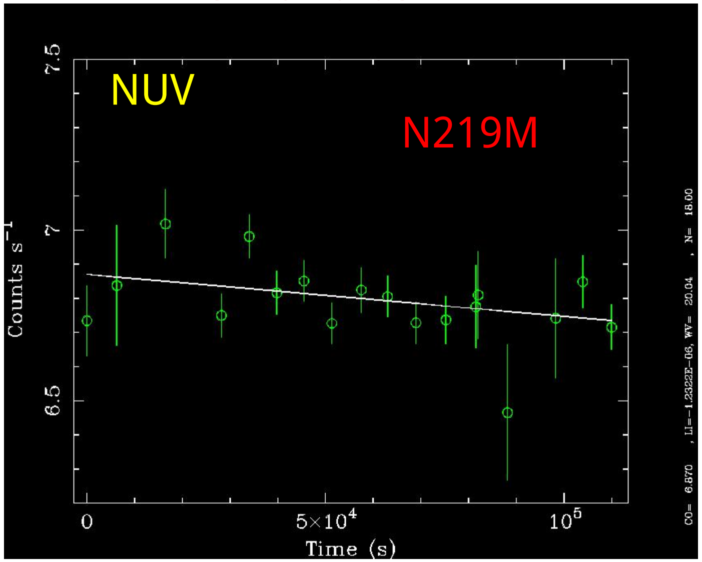
One more observations to be done in G08

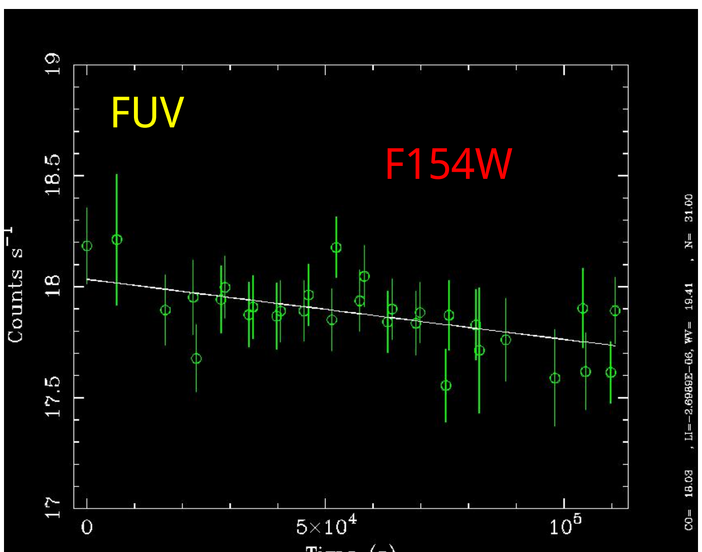
NGC4151 : AstroSat/UVIT FUV BaF2/F154W (G06-III)



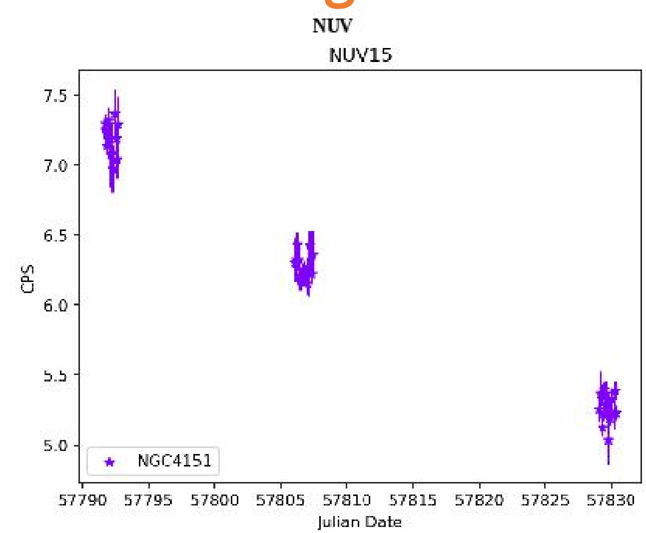
NGC4151 G06 UVIT lightcurves

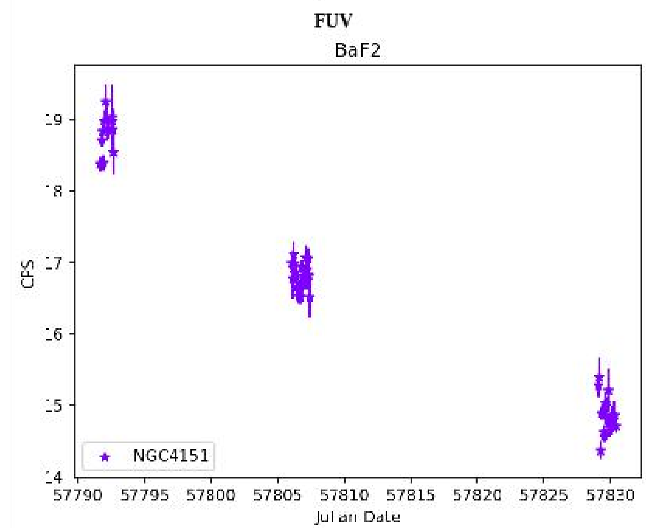
Short-term





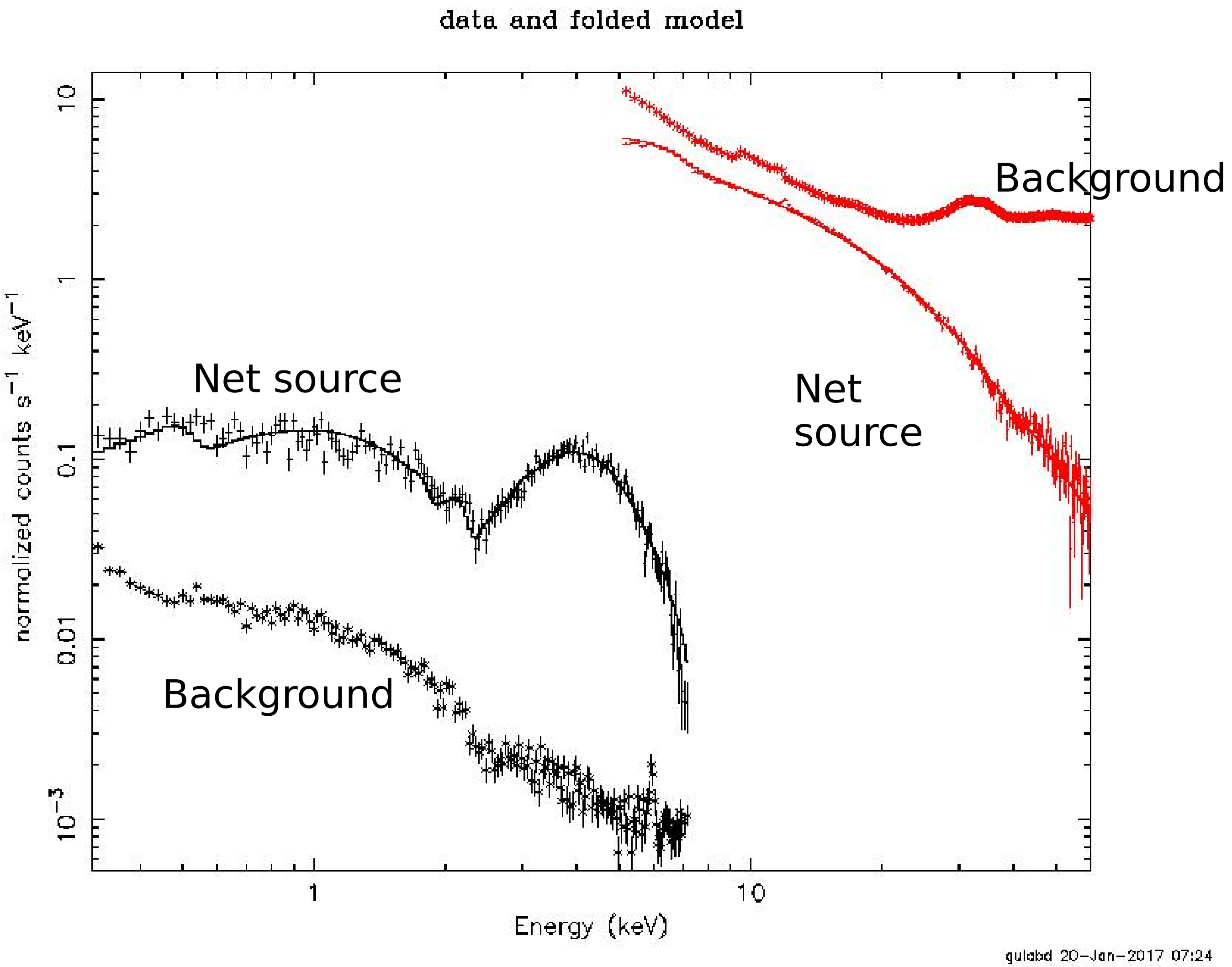
Long-term



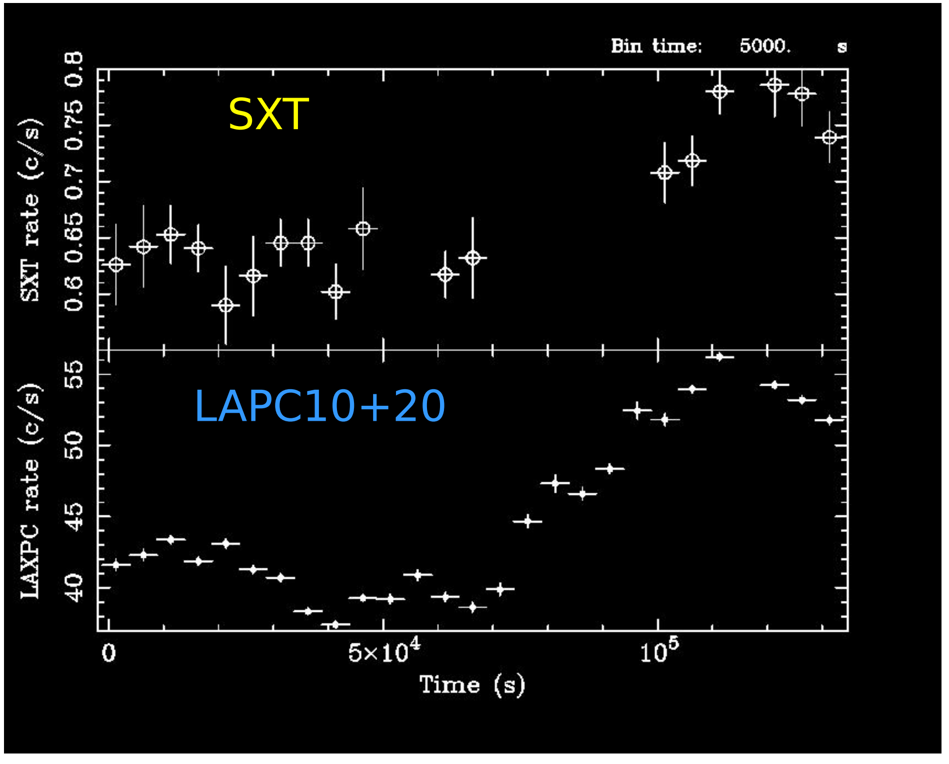


NGC4151 : AstroSat SXT/LAXPC data

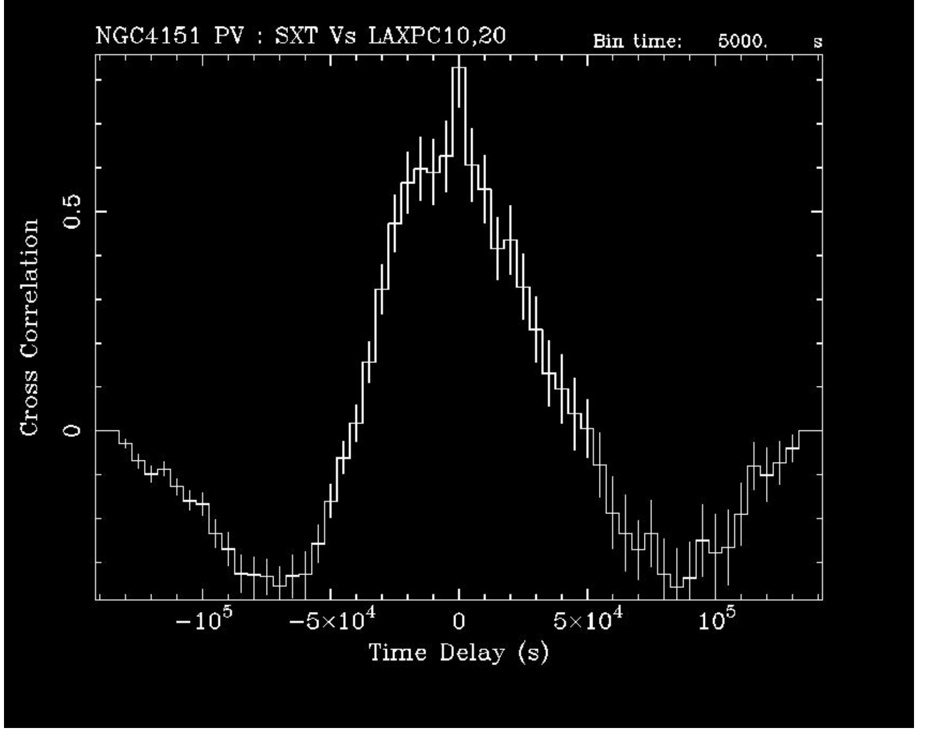
14-15 March 2016 (PV phase)



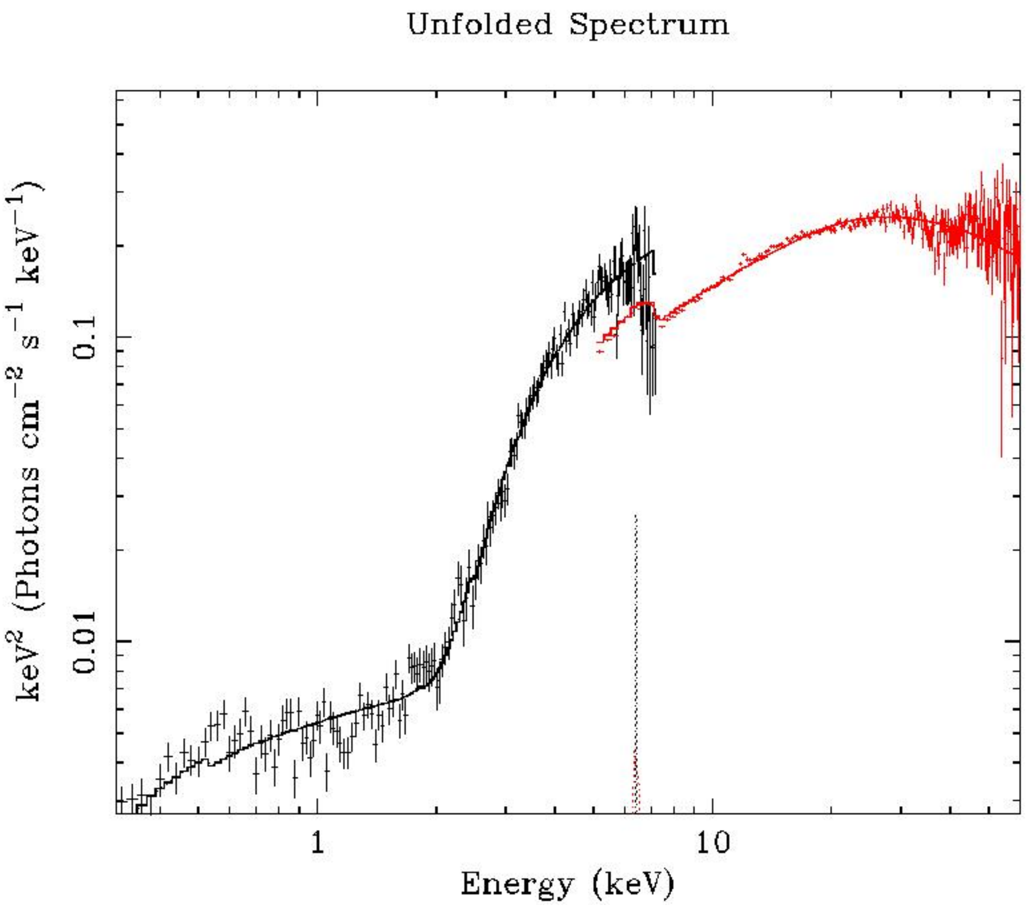
NGC4151: SXT/LAXPC lightcurves



Cross Correlation



NGC4151 : spectral model



Model : wabs*pcfabs(pexrav+gauss)

$$\Gamma \sim 1.7$$

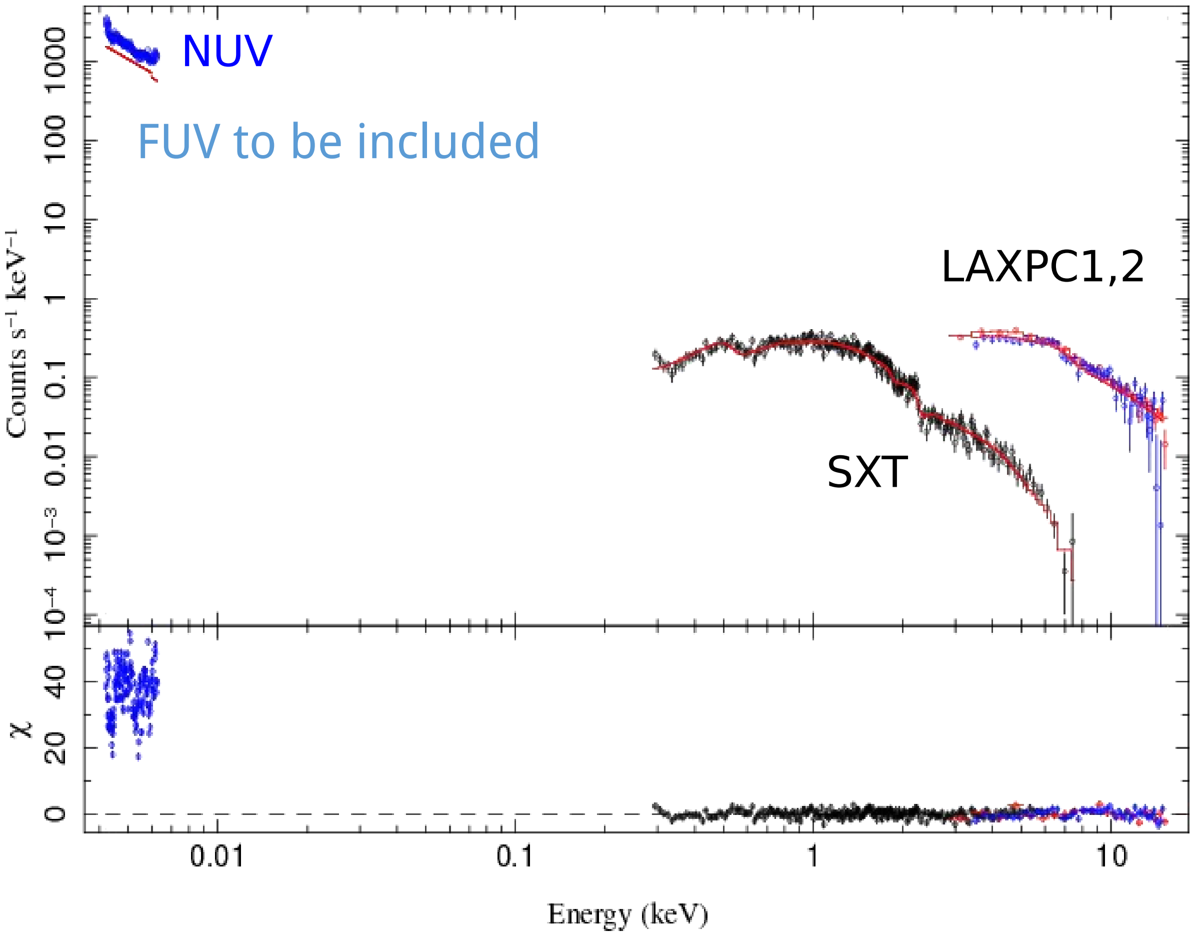
$$R \sim 1$$

LAXPC Background still an issue! In progress.

AGN SED Measurements

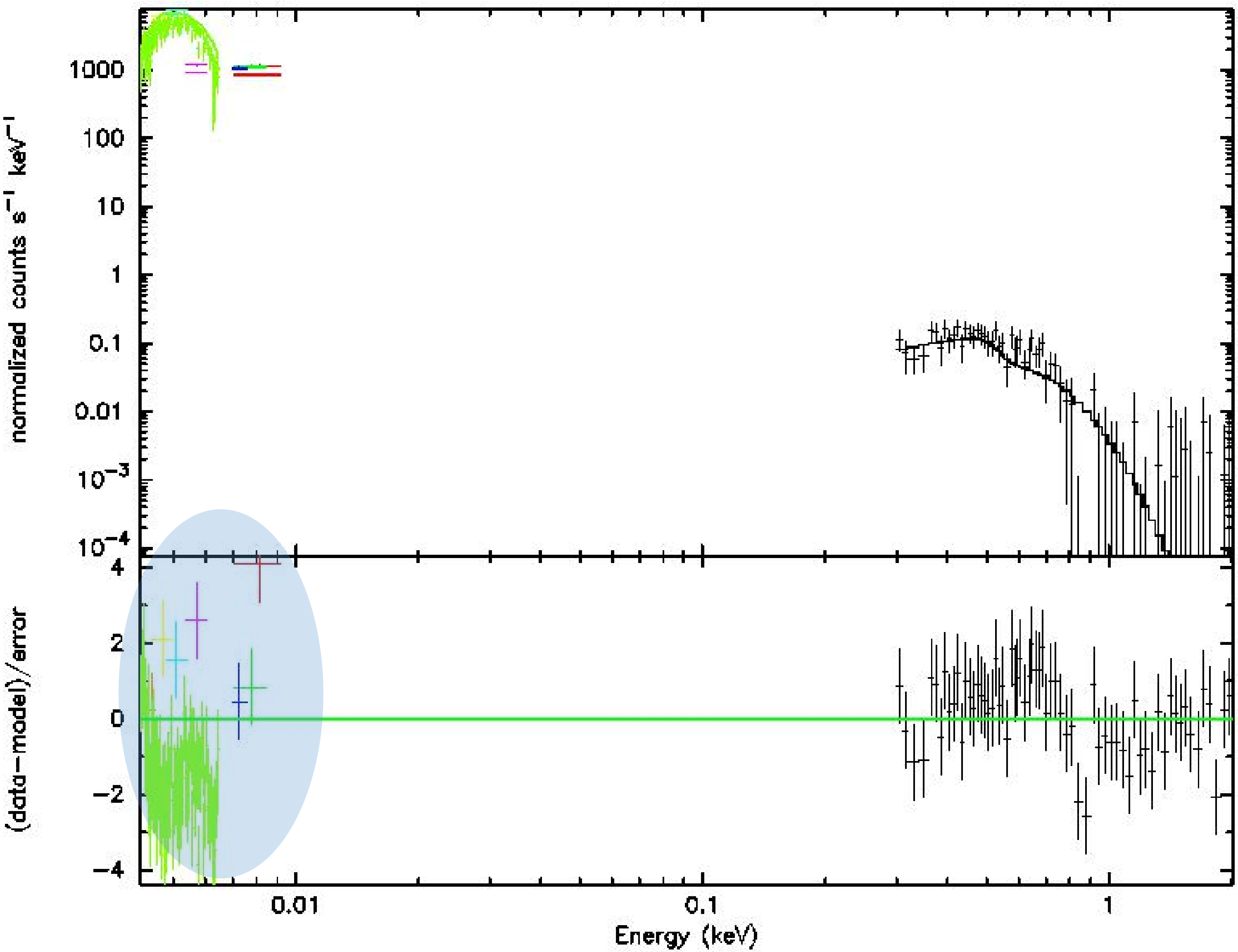
Fairall 9: SXT+LAXPC+NUV grating data

- Excess NUV emission



- SED
- L/L_{Edd}
- Accretion disk models
- UV/X-ray connection

ASASSN-16oh: Super Soft X-ray Source, an accreting WD
UVIT NUV grating, FUV/NUV filters + SXT spectrum



Summary

- Nearly 20 Seyferts have been observed with 1-day to a week long durations. More to be approved.
- UV/X-ray time lag measurements in low mass AGN is possible (NGC4593). Only AstroSat can measure Far UV to X-ray lags
- SED measurements with UV (with broadband filters) and SXT possible. UV grating calibration requires improvement.
- For broadband X-ray spectroscopy, LAXPC background needs to be improved.

Accretion disk: UV/Opt lag spectrum

Energy balance in an annulus of acc. disk

$$4\pi R^2 dR \sigma T^4 = \left(\frac{GM}{R} - \frac{GM}{R+dR}\right)\dot{m} \quad => R^3 = \frac{GM\dot{m}}{4\pi\sigma T^4}$$

with $\dot{m}_E = \frac{L_{bol}}{L_{Edd}}, L_{bol} = \eta \dot{m} c^2, L_{Edd} = \frac{4\pi G M m_p c}{\sigma_T}, kT = hc/\lambda$

Time lag - wavelengh relation

$$\tau = cR = \left(\frac{G^2 m_p k^4}{\sigma_T \sigma c^2 h^4}\right)^{1/3} \eta^{-1/3} M^{2/3} \dot{m}_E{}^{1/3} \lambda^{4/3}$$