Probing the accretion disk in Seyfert 1 galaxy NGC 4593

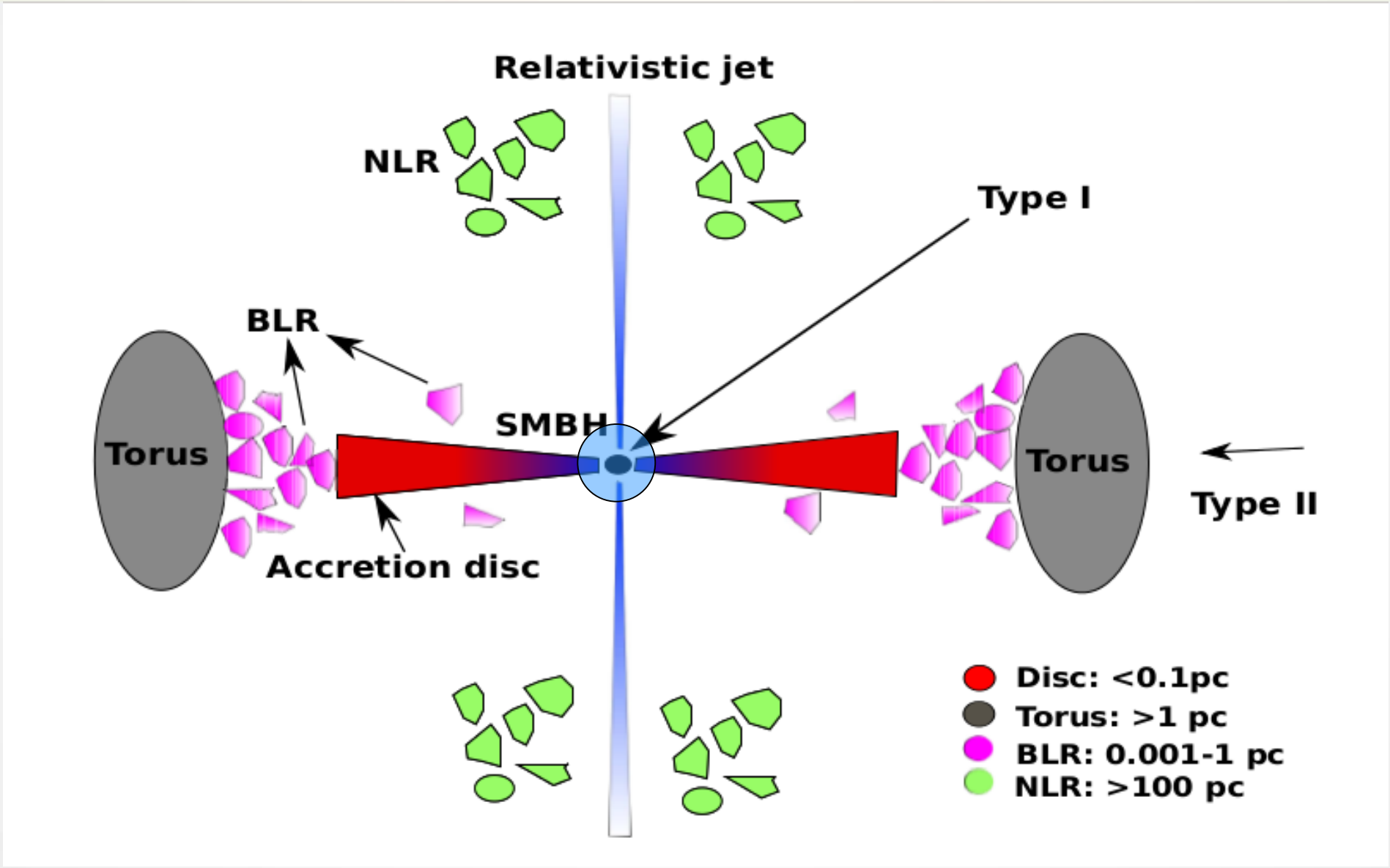
Sachindra Naik

Physical Research Laboratory, India

Outline of the Presentation

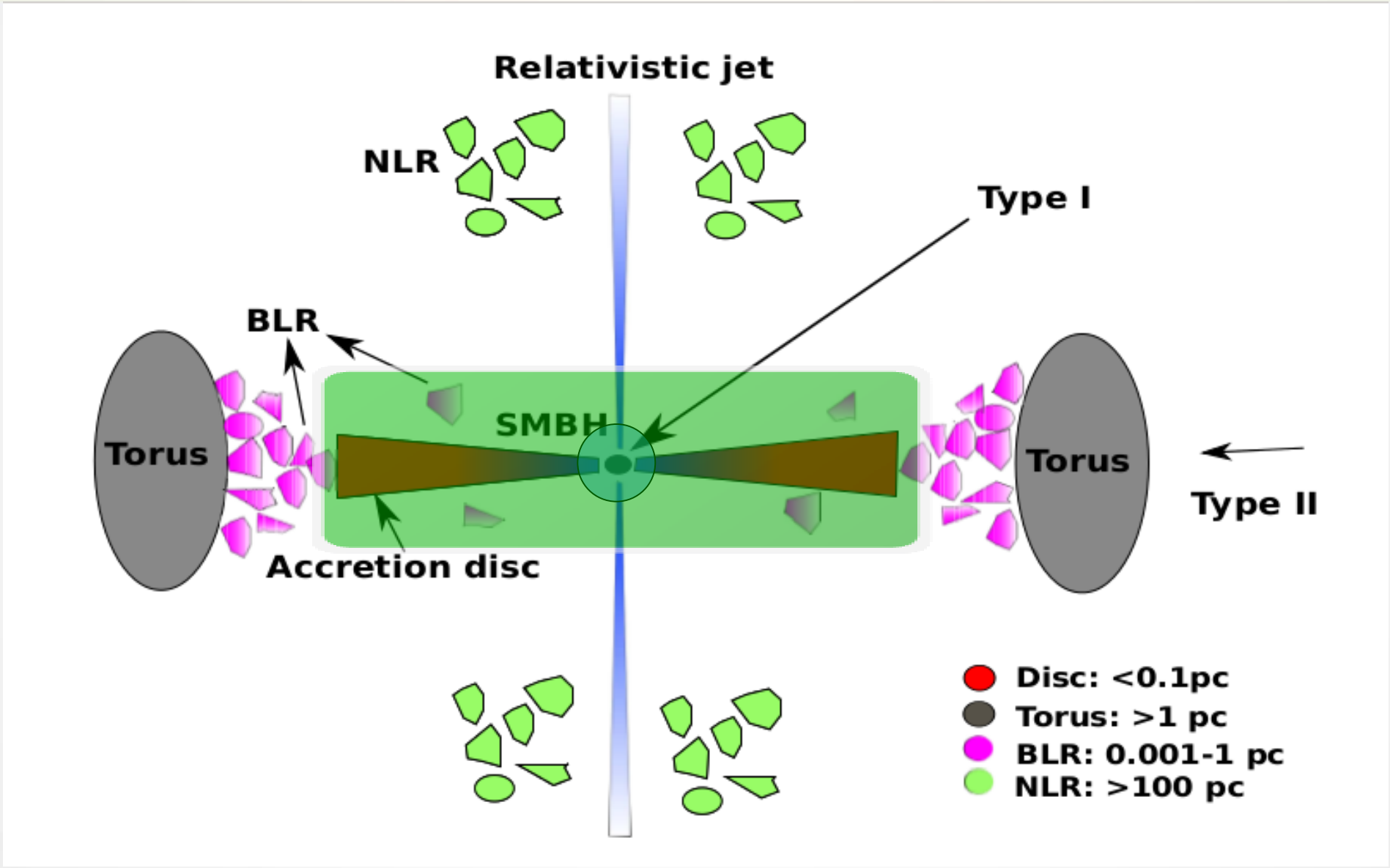
- Introduction : Central engine
- Broadband X-ray spectroscopy
- X-ray/UV/Optical light curves
- Cross-correlation between light curves
- Accretion disk and X-ray reprocessing
- Lag-Spectrum profile
- Flux-Flux profile
- Summary and results

Introduction: Unified Model



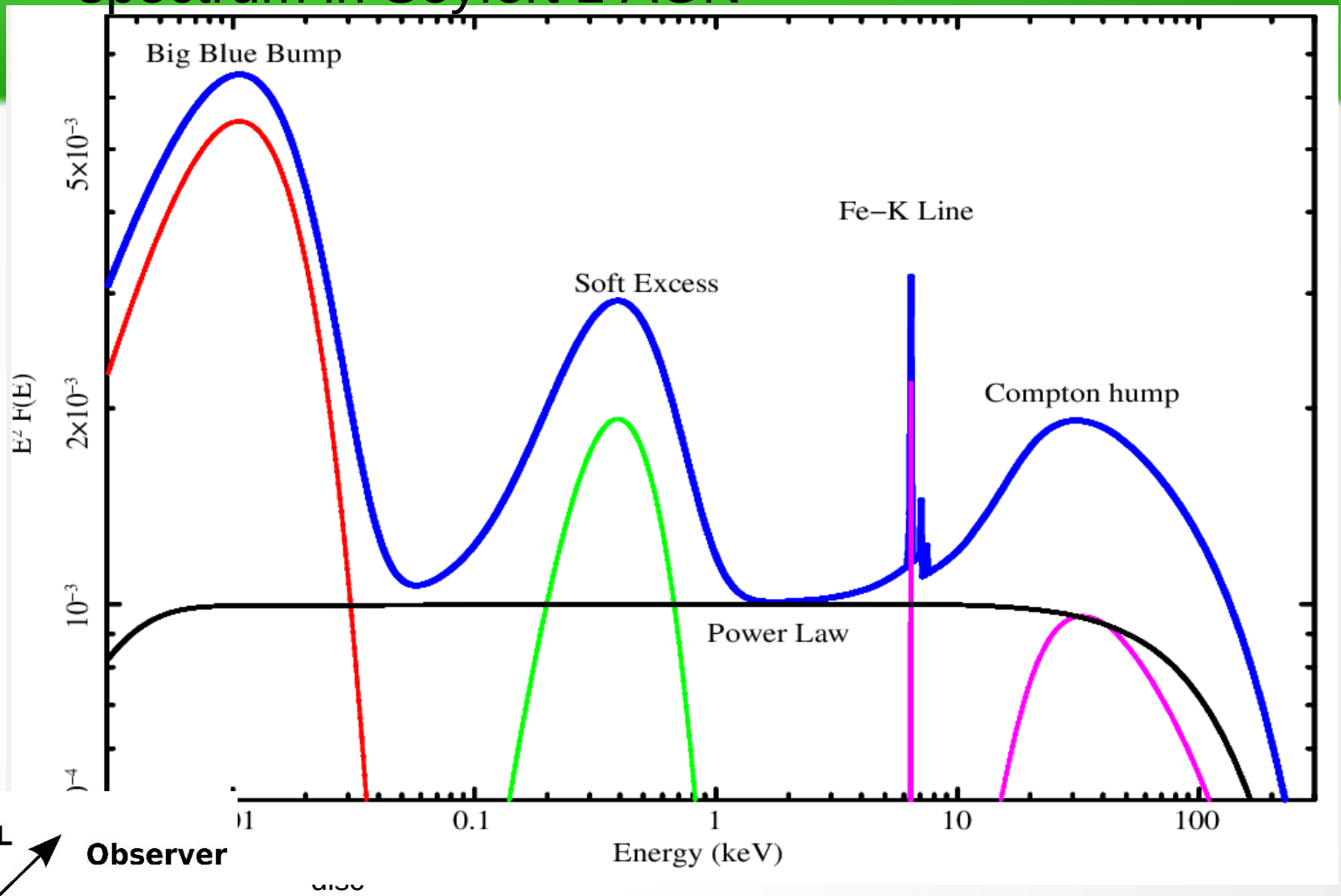
Antonucci 1993

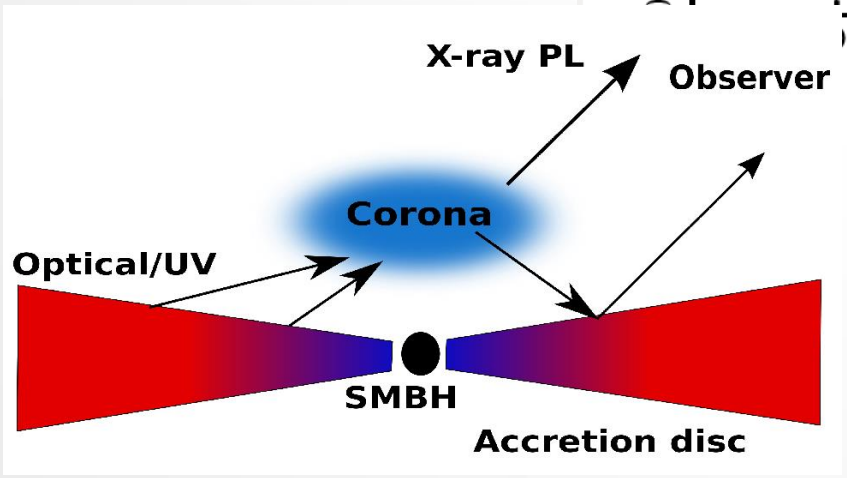
Introduction: Unified Model



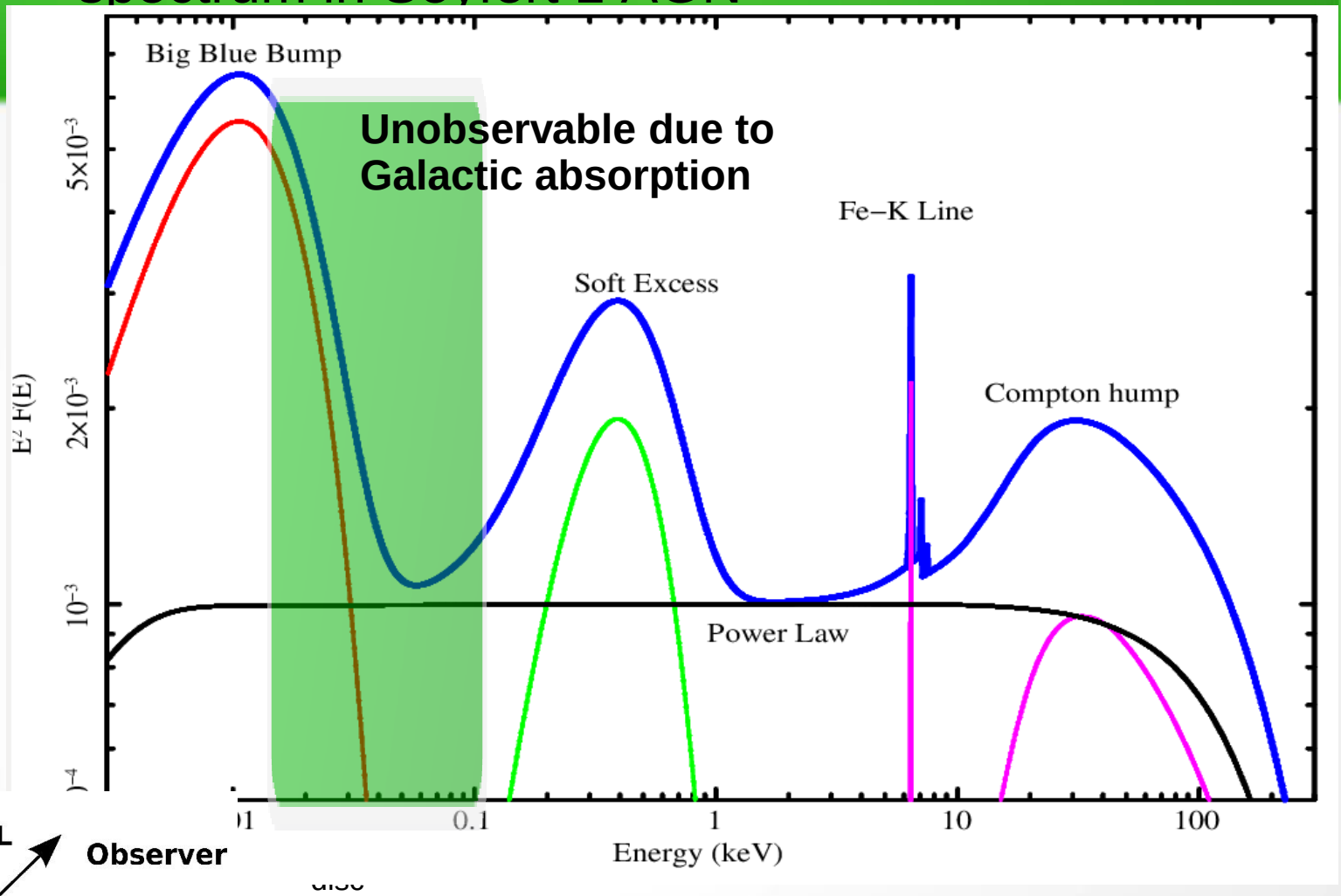
Antonucci 1993

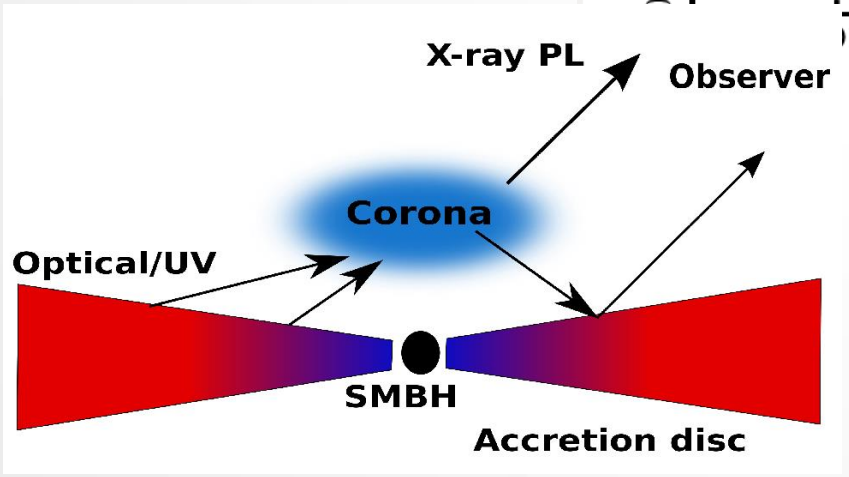
Introduction : Artistic representation of central engine and spectrum in Seyfert 1 AGN





Introduction : Artistic representation of central engine and spectrum in Seyfert 1 AGN





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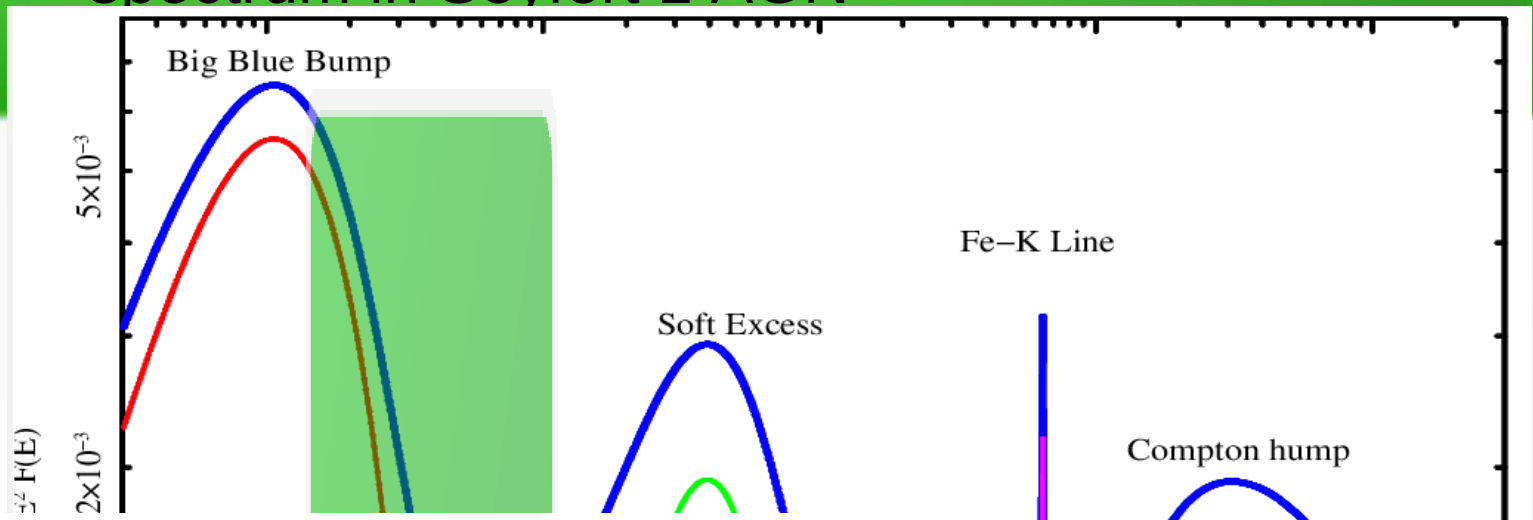
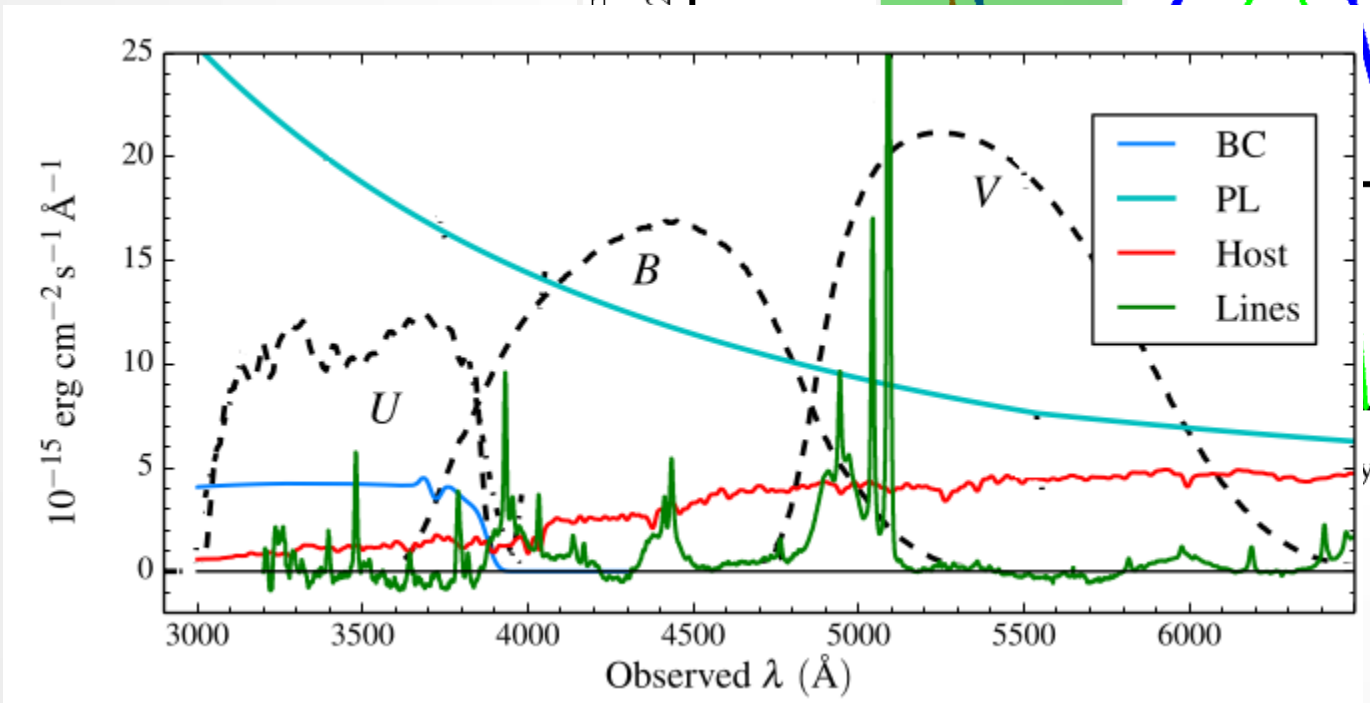
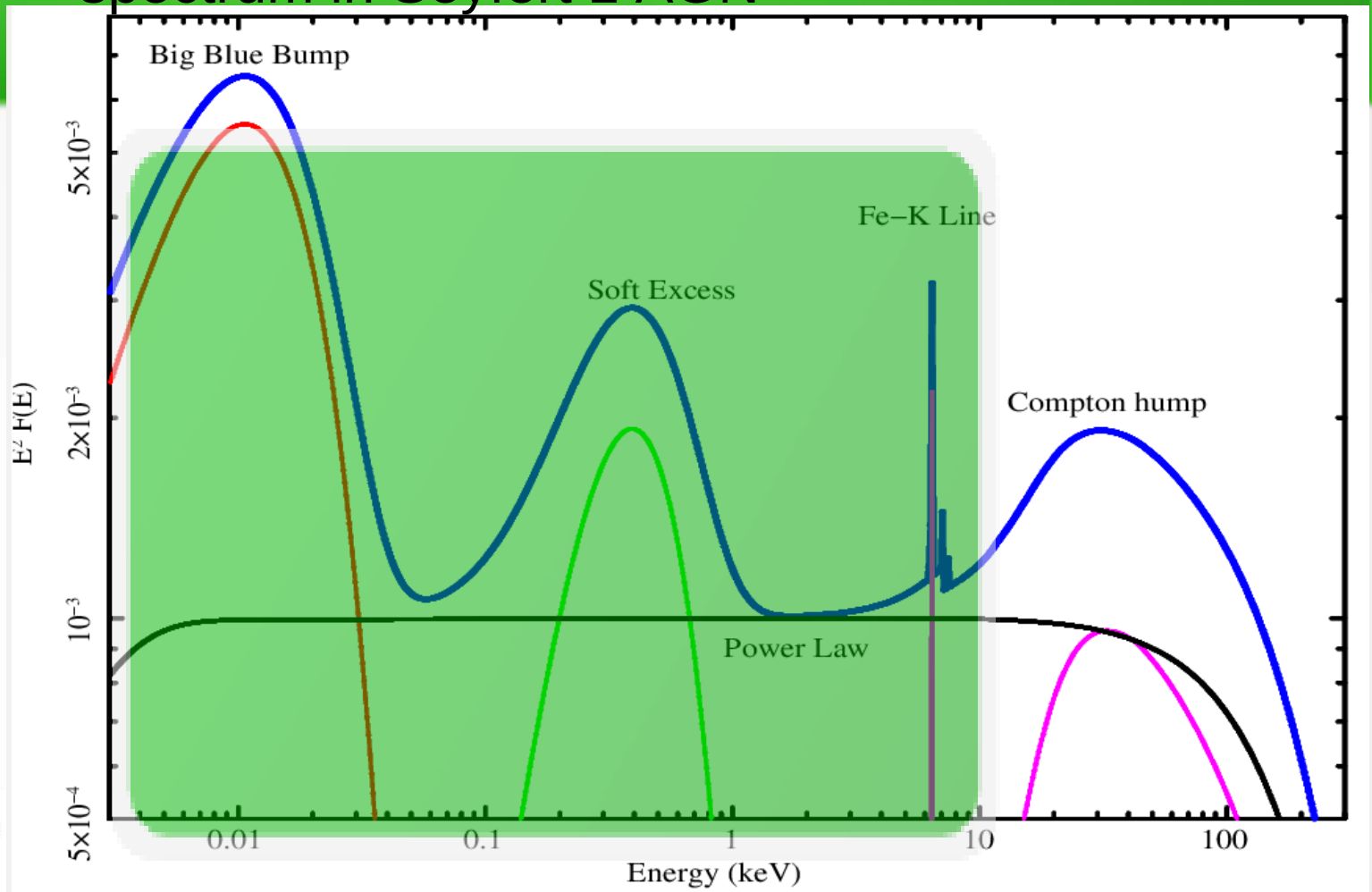
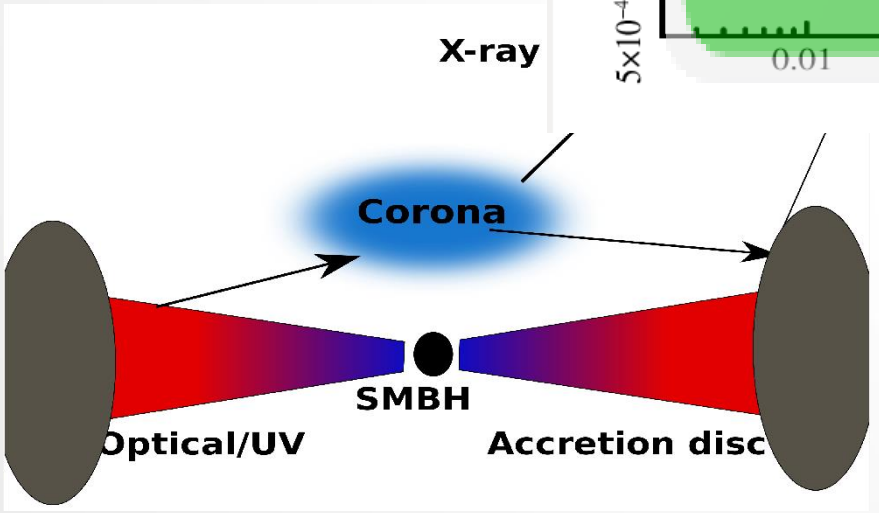




NGC 5548: Fausnaugh et al 2015

Introduction : Artistic representation of central engine and spectrum in Seyfert 1 AGN





Correlation between UV/optical and X-ray emission

Observed variability in X-ray/UV/optical emission from AGN is in wide time range -- days to years.

Case-I : Delay in fluctuation in UV/optical radiation compared to X-ray implies **X-ray reprocessing**

Case-2 : Fluctuation in UV/optical band is independent of the X-ray band implies implies **fluctuations are local to the disc.**

Case-3 : Rare rapid changes in optical band compared to X-ray band implies **distinct regions of origin.**

Correlation between UV/optical emission & X-ray emission is complex. Hence, intensive exploration is required.

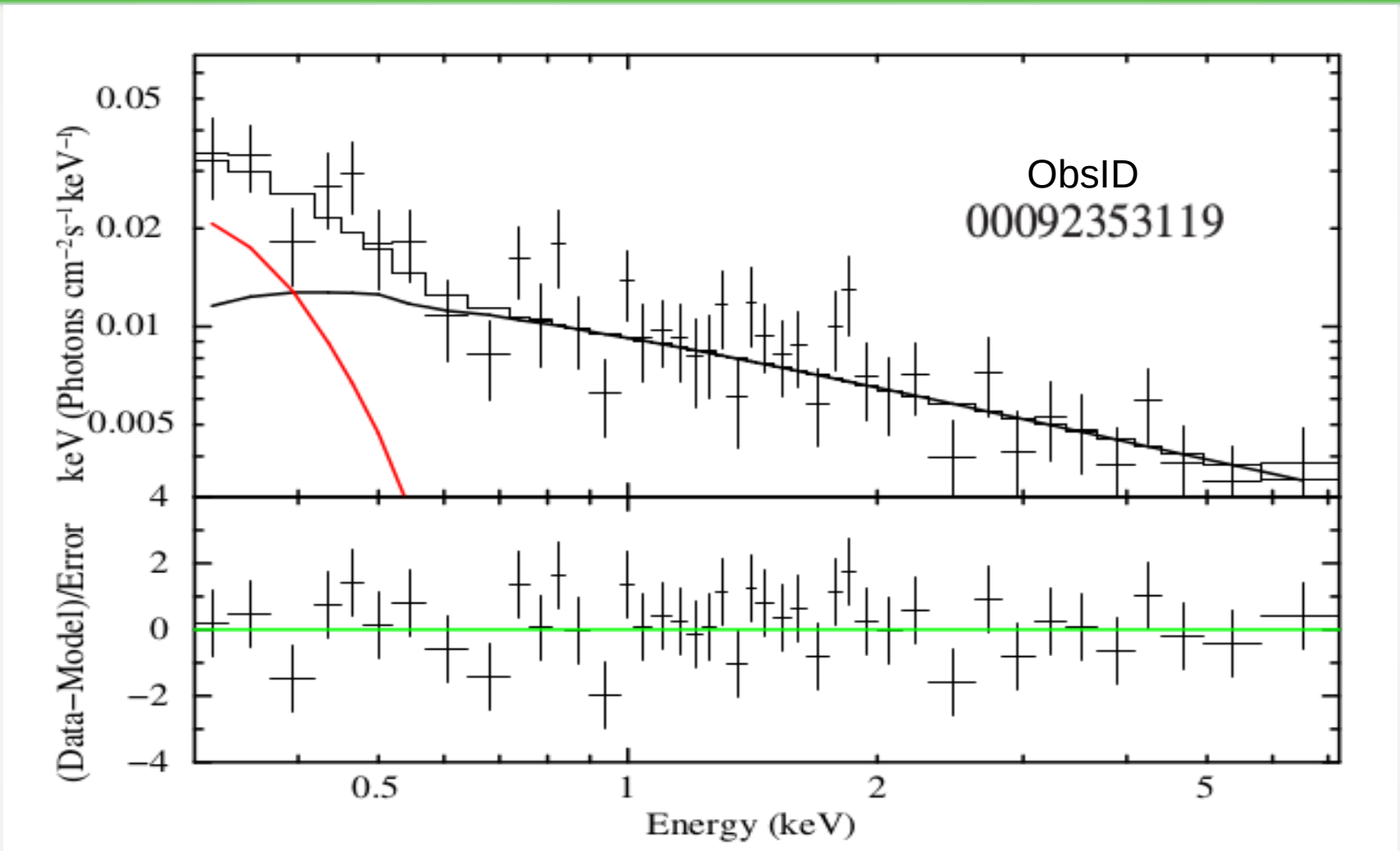
NGC 4593

- **NLS1, z=0.009**
- **M = ~10^7 M_{sun}**
- **Variable in X-ray and UV/optical on long and short timescale**

Log of observation of NGC 4593 with *Swift* XRT/UVOT

Observation ID	00092353001–00092353201
Date of Observations	2016 July 13 - 2016 August 5
MJD	57582.8 - 57605.4
No. of IDs for XRT	185
No. of IDs for UVOT	160-184

X-ray spectroscopy



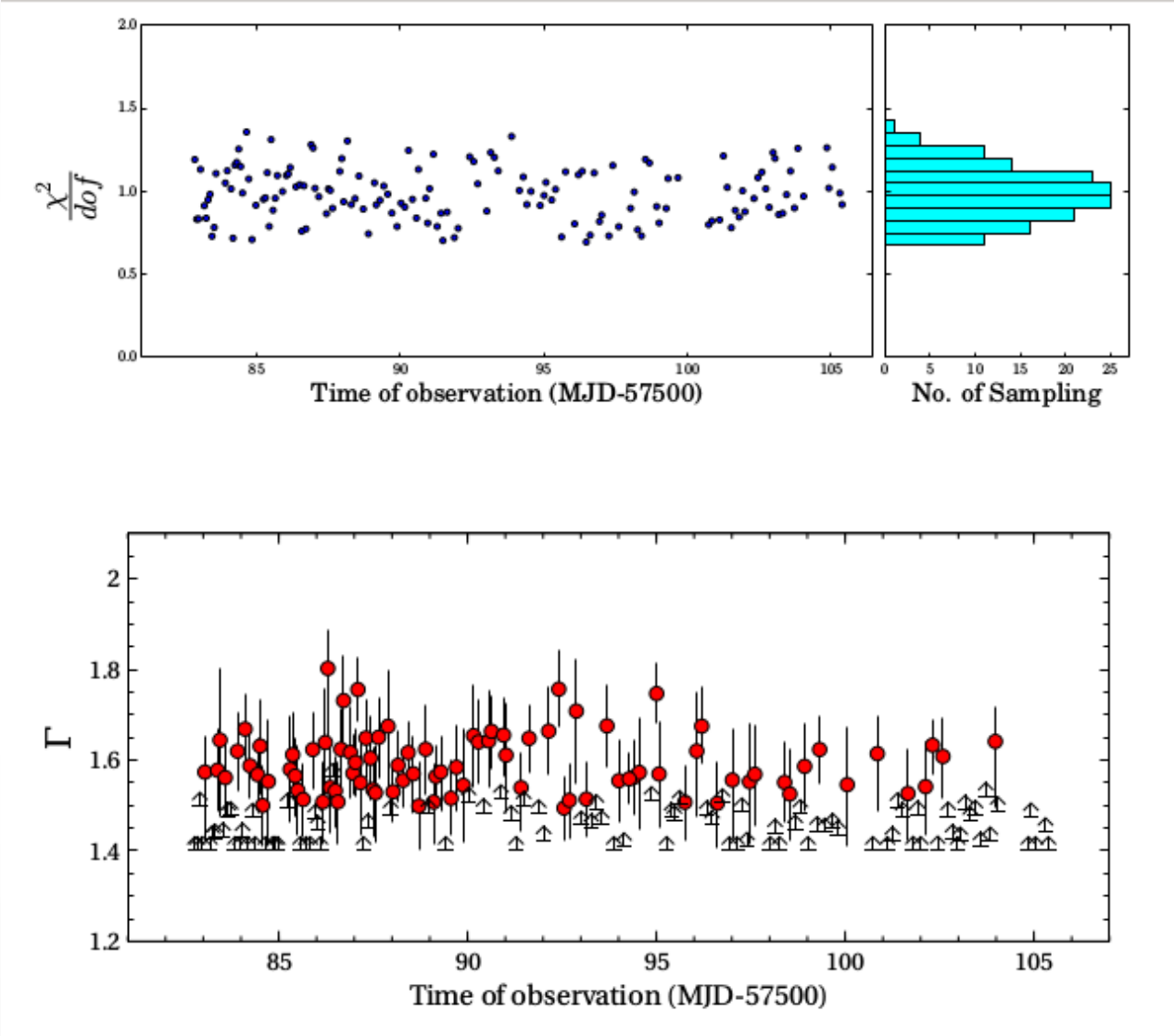
- Powerlaw plus blackbody model modified by Galactic absorption
- No Intrinsic absorption required

X-ray spectroscopy - results

- Reduced χ^2 is close to unity

- Photon index

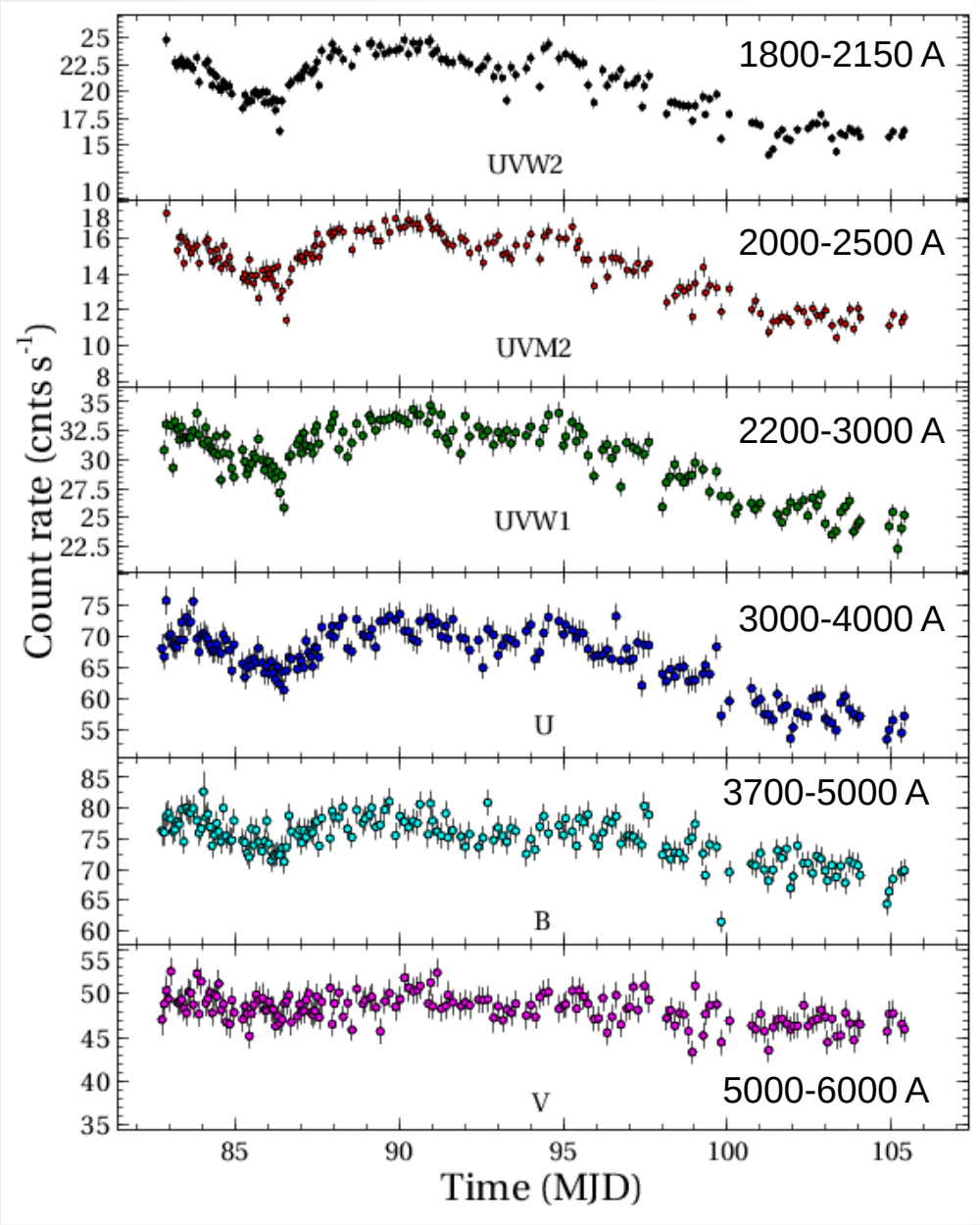
does not vary significantly- no significant Comptonization

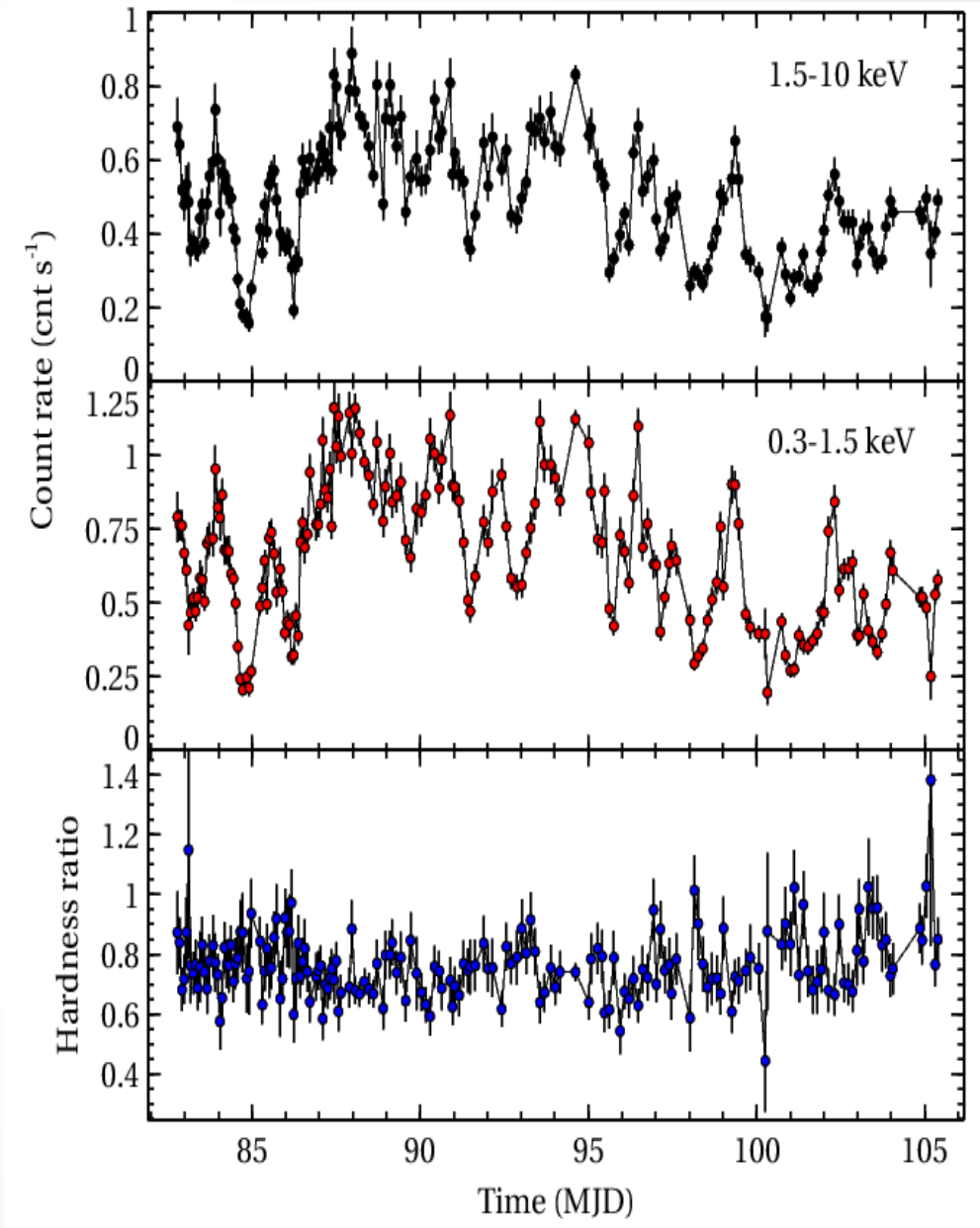


There seems no variation in seed photon flux.

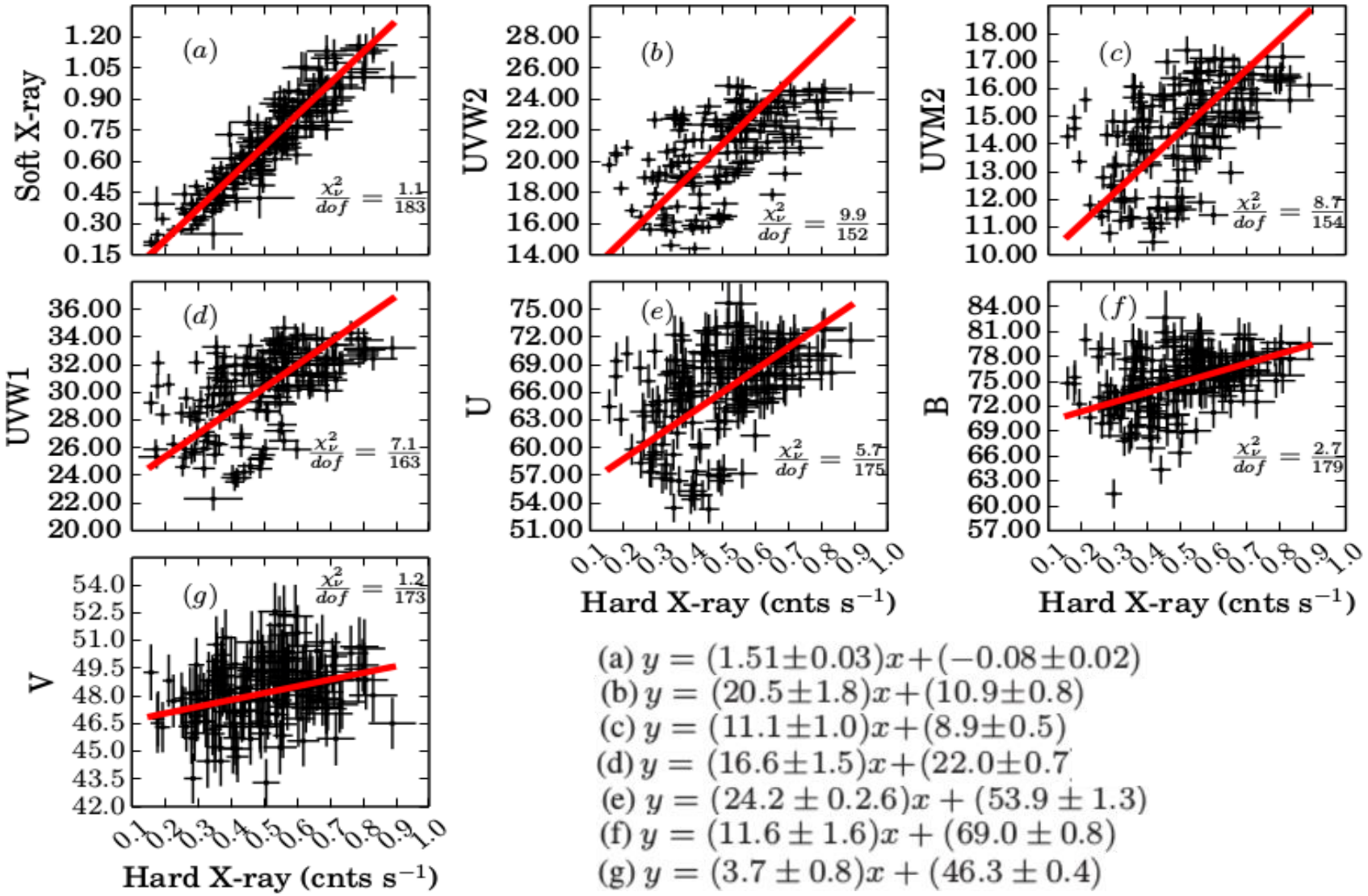
Swift XRT/UVOT light curve

After removing data-points of low sensitivity patches, bad tracking





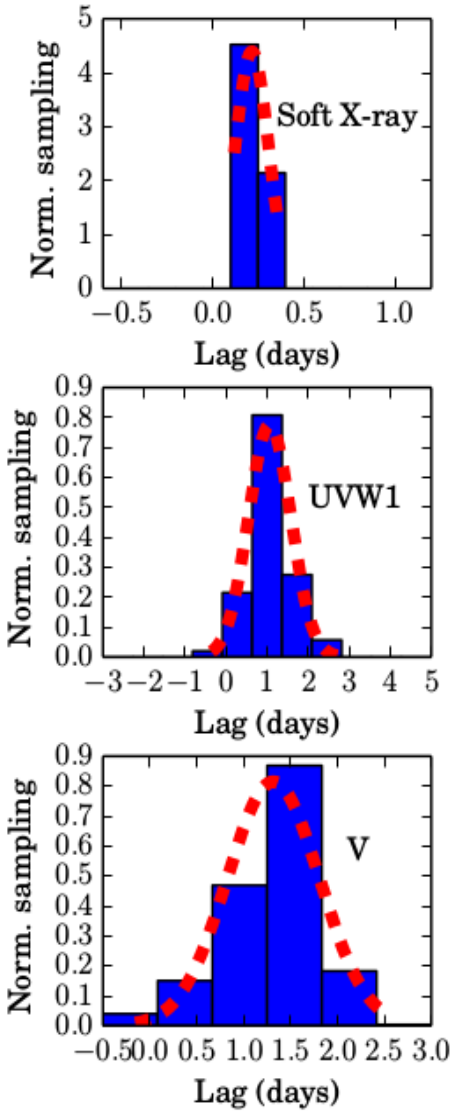
Linear fit for soft band and hard band (y=mx+c)

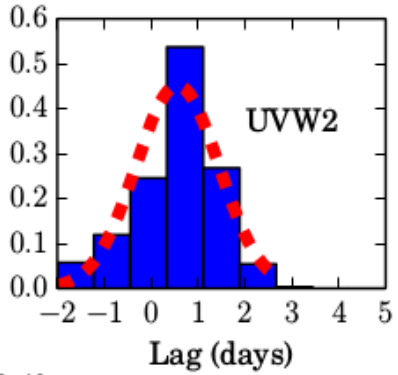


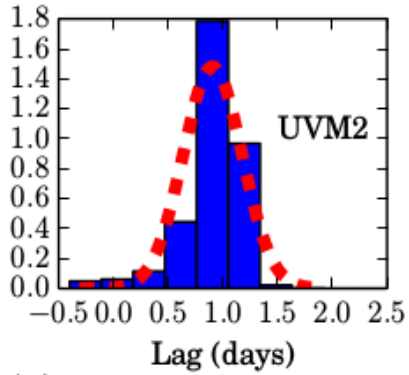
(a) $y = (1.51 \pm 0.03)x + (-0.08 \pm 0.02)$
(b) $y = (20.5 \pm 1.8)x + (10.9 \pm 0.8)$
(c) $y = (11.1 \pm 1.0)x + (8.9 \pm 0.5)$
(d) $y = (16.6 \pm 1.5)x + (22.0 \pm 0.7$
(e) $y = (24.2 \pm 0.2.6)x + (53.9 \pm 1.3)$
(f) $y = (11.6 \pm 1.6)x + (69.0 \pm 0.8)$
(g) $y = (3.7 \pm 0.8)x + (46.3 \pm 0.4)$

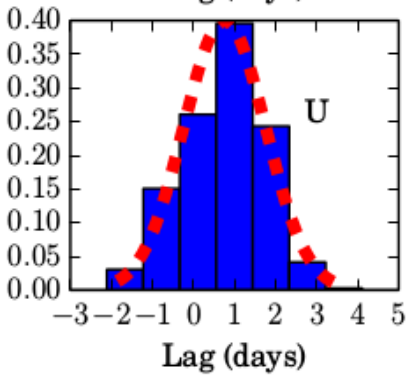
Positive intercept C: Slowly variable component i.e. disk emission

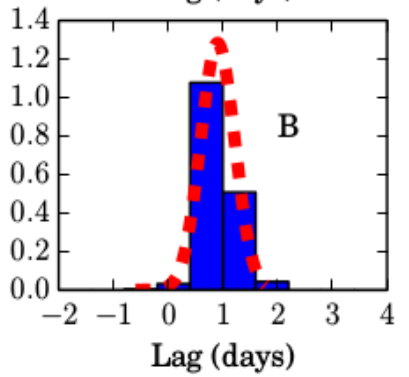
Cross-correlation lags





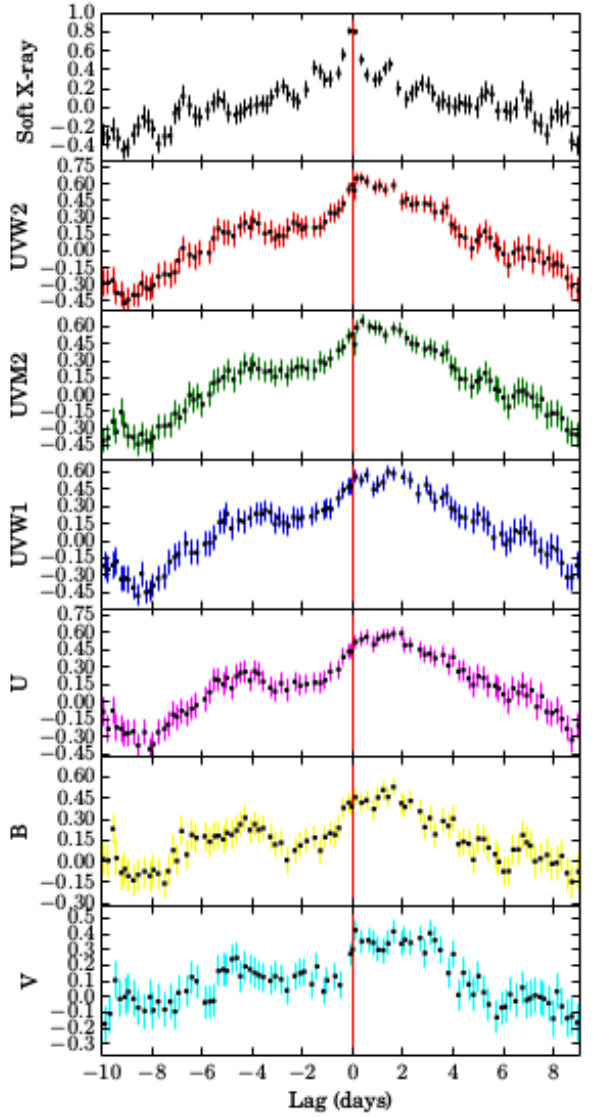






Lags in days	Soft	W2	M2	W1
Javelin	0.22 ±0.02	0.56±0.88	0.91±0.27	1.1±0.5
ZDCF	0.11±0.18	0.36±0.35	0.38±0.36	1.45±0.70

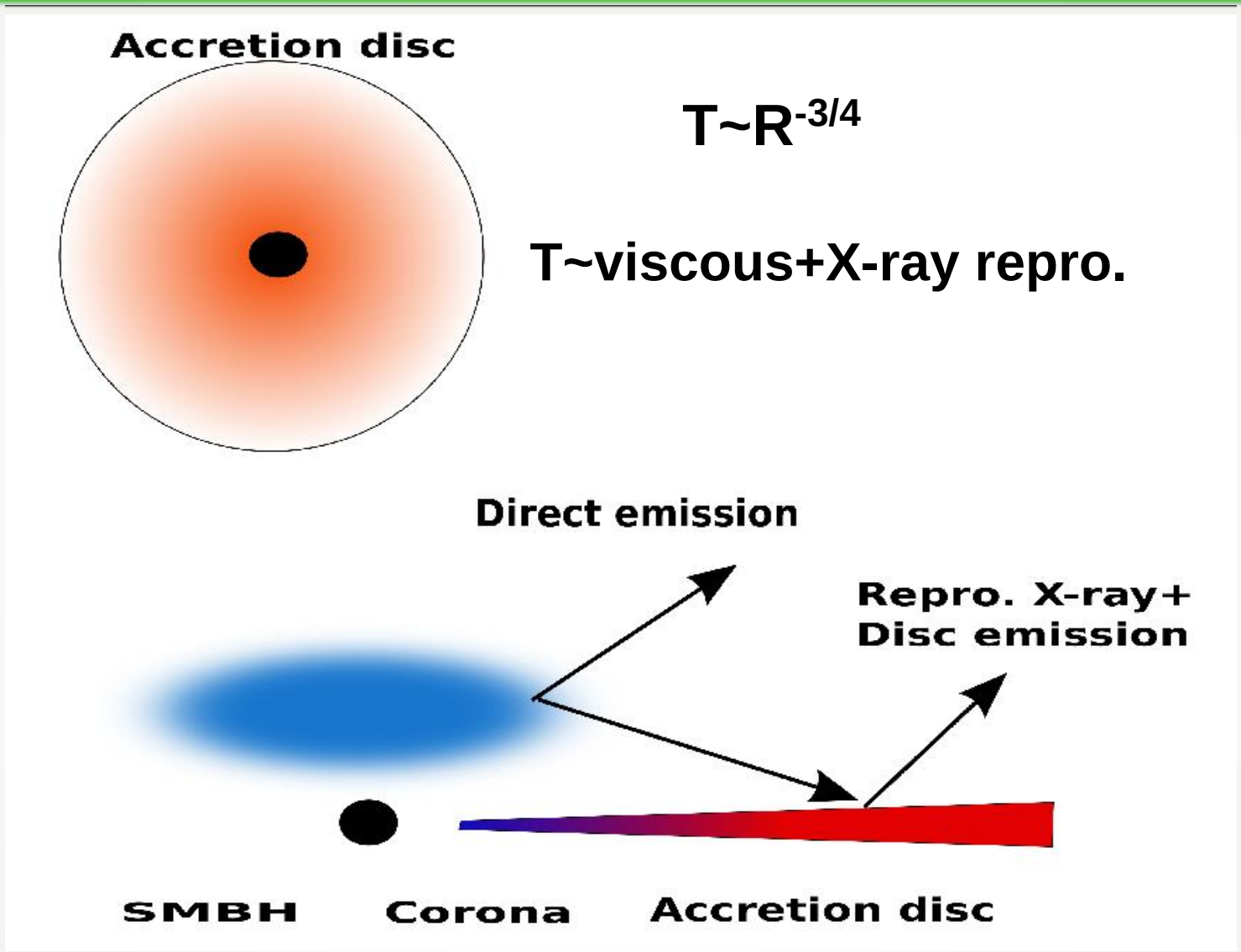
Lags in days	U	B	V
Javelin	0.76±1.0	0.9±1.3	1.3±0.5
ZDCF	1.94±0.44	1.62±0.35	1.14±1.62



Javelin : Zu et al 2011

ZDCF: Alexander 1997

X-ray reprocessing model



Timescale ~light travel time ~hours to days

Optical/UV emission lag the X-rays

(Krolik et. al 1991)

Lag profile of standard disk

- Gravitational heating + X-ray illumination on the disc (H<<R, R_{in}<<R), temperature

$$T(R) = \left(\frac{3GM\dot{M}}{8\pi\sigma R^3} + \frac{(1-A)L_{\rm X}H}{4\pi\sigma R^3} \right)^{1/4}$$

- Lag with respect to lambda0

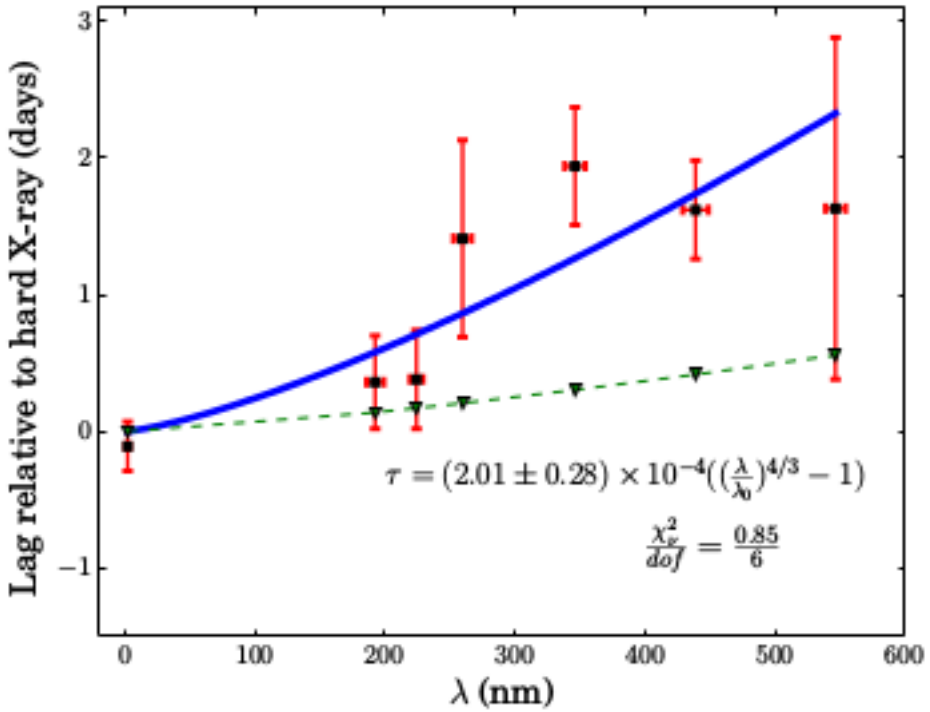
$$\tau - \tau_0 = \left(\frac{1}{c}\right)\left(\frac{\lambda_0}{k}\right)^{4/3}\left(\frac{3GM\dot{M}}{8\pi\sigma} + \frac{(1-A)L_{\rm X}H}{4\pi\sigma} \right)^{1/3} \left[\left(\frac{\lambda}{\lambda_0}\right)^{4/3} - 1\right].$$

- Functional form of the lag

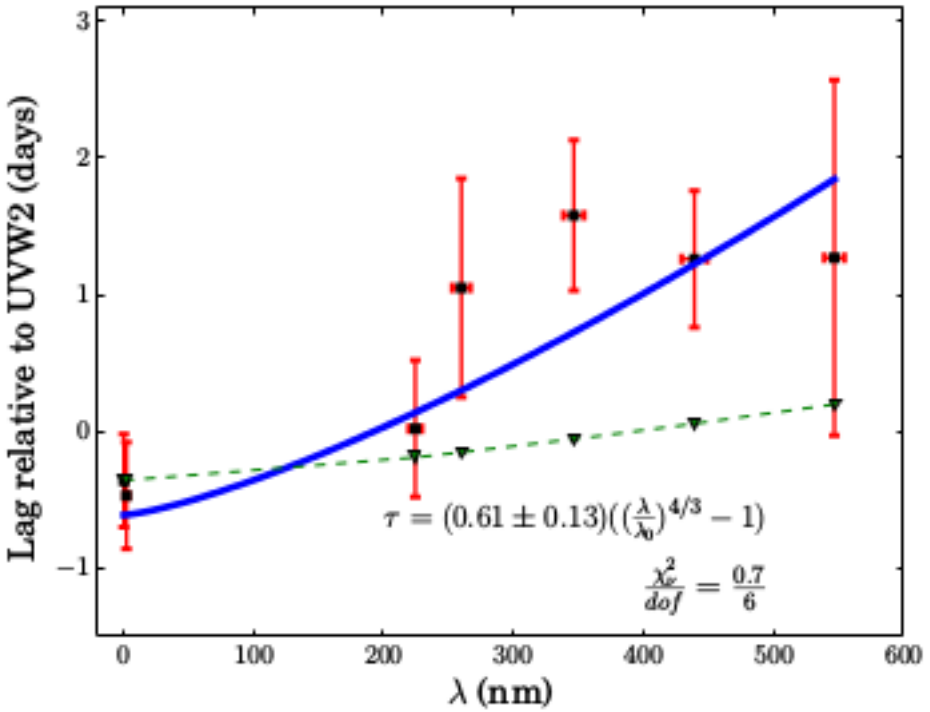
$$\tau = \alpha\left[\left(\frac{\lambda}{\lambda_0}\right)^{\beta} - 1\right]$$

Power law model ?

Std. Disk model : dashed line



Functional form of disk lag : Blue

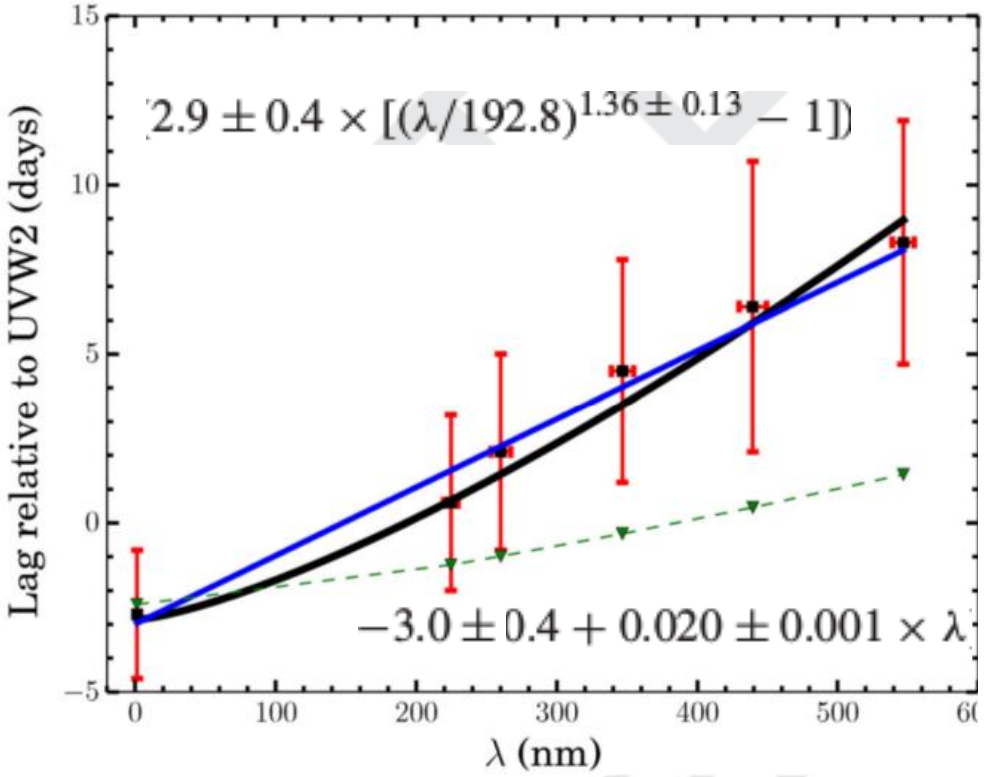


M=10**7 M_{sun}, Accretion rate = 0.04*Eddington rate; h=6r_g ; R_{in}=6r_g; L_x=10**43.7 ergs s^{-1}

Real disk seems larger than expected from standard disk

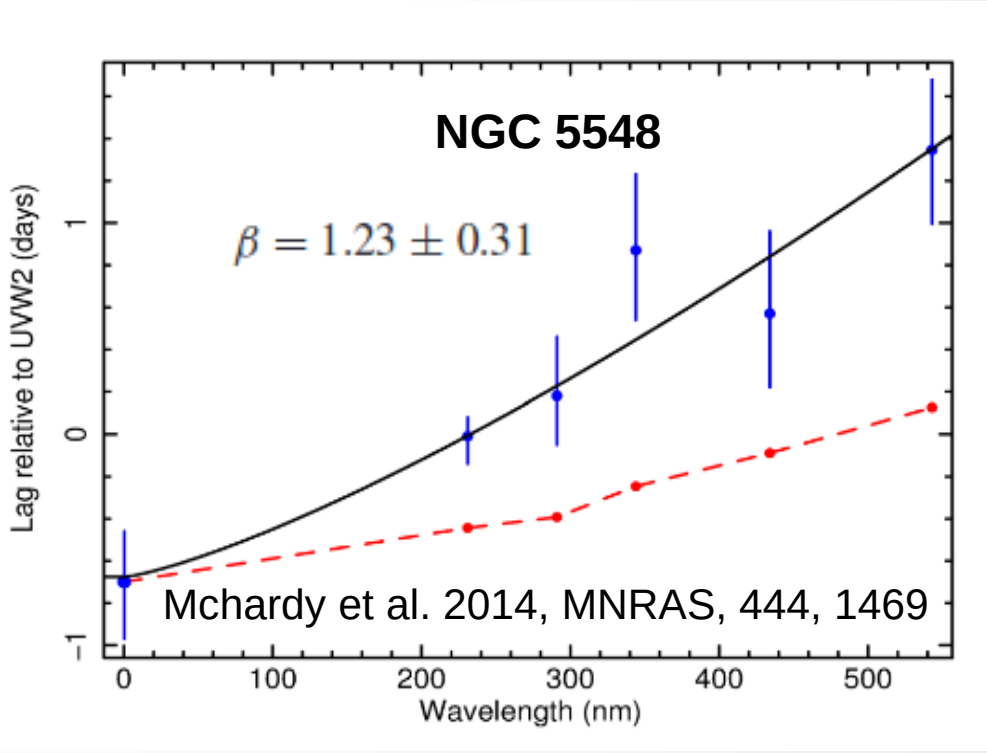
Other two examples of similar results

Fairall 9



Pal, M. et al. 2017, MNRAS, 466, 1777

$$\tau = \alpha \left[\left(\frac{\lambda}{\lambda_0} \right)^{\beta} - 1 \right]$$



Real disk seems larger than expected from standard disk

Summary

- Existence of slowly and highly variable components
- X-rays and UV/optical emission are strongly correlated
- Variability observed in the UV/optical emission is due to the reprocessing of X-ray emission
- Lags are longer than that predicted from standard disk theory
- Longer lags infer larger size of real accretion disk

Ongoing work on AGN with AstroSat

- NGC 4748 : Simultaneous X-ray/UV (AstroSat) and Infrared (Mount Abu Telescope) observations are over.

- Mrk 359, UGC 06728, NGC 424, NGC 4388, NGC 4945

Thank you for Your Attention