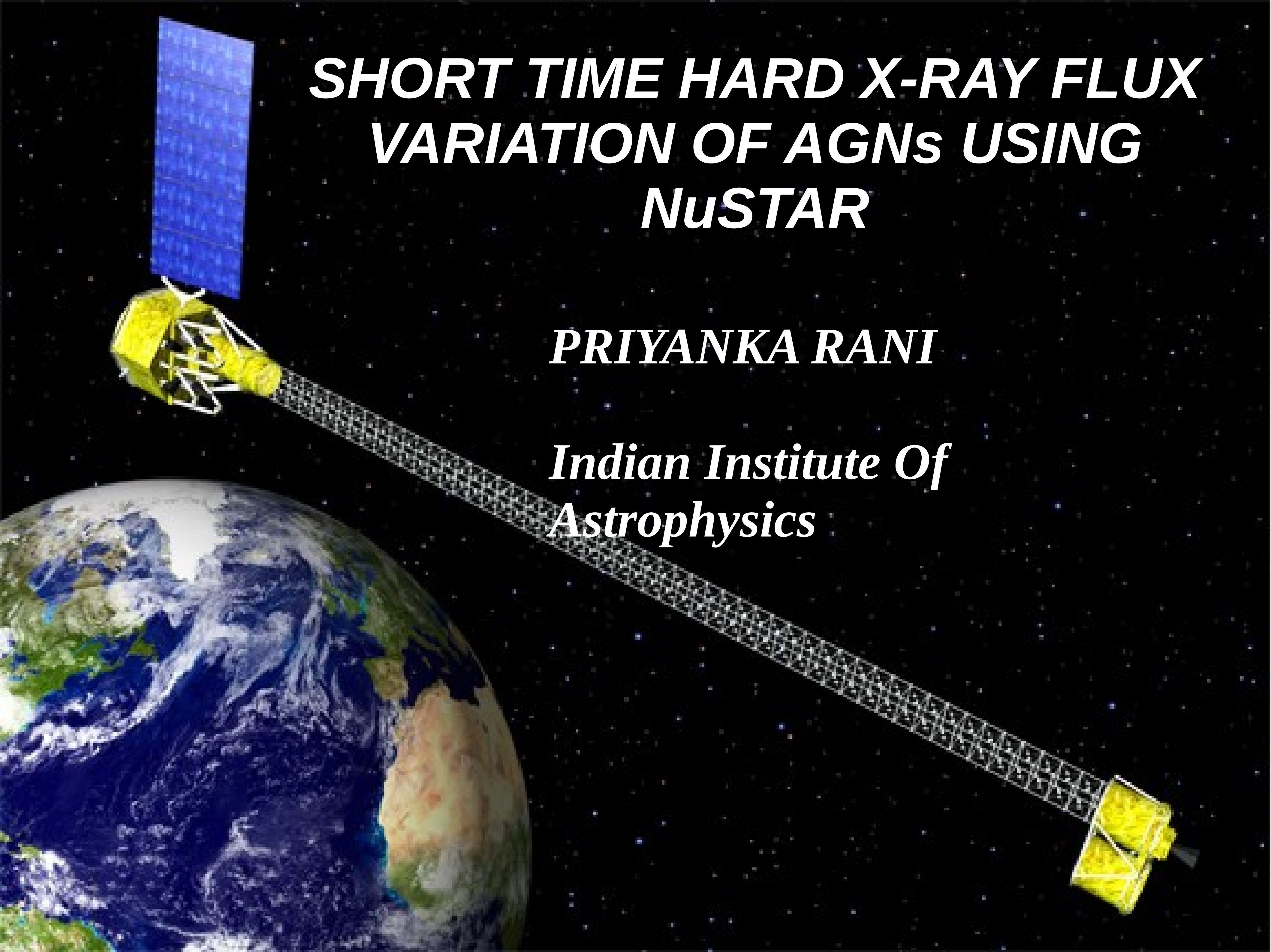

SHORT TIME HARD X-RAY FLUX VARIATION OF AGNs USING NuSTAR

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Radio-Quiet AGN (~90%)

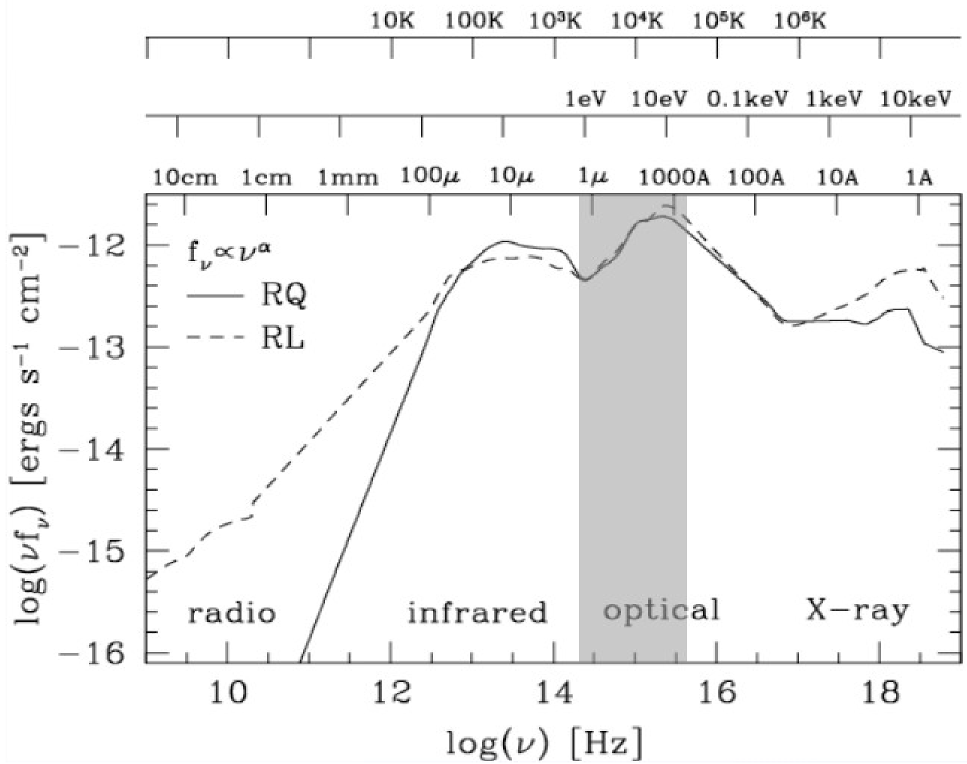
- Radio-quiet quasars
- Seyfert galaxies

  Seyfert 1: both narrow and broad emission lines

  Seyfert 2: only narrow emission lines

Radio-Loud AGN (~10%)

- Radio-loud quasars
- Radio galaxies
- Blazars



- 1 micron - .2 keV: Thermal emission from optically thick accretion disk
- X-rays: Synchrotron, Inverse Compton, Hot corona + reflection
- Mm-1 micron: Dust emission

  Radio: Synchrotron

AGN Variability

- Known since their discovery
- Vary over the accessible electromagnetic spectrum
- Vary over different time scale (minutes to hours)

WHY IS THE AGN VARIABILITY SO IMPORTANT?

- **Geometry**: delays in the flux variations provide the sizes and the correlations between the different regions producing the observed emission.

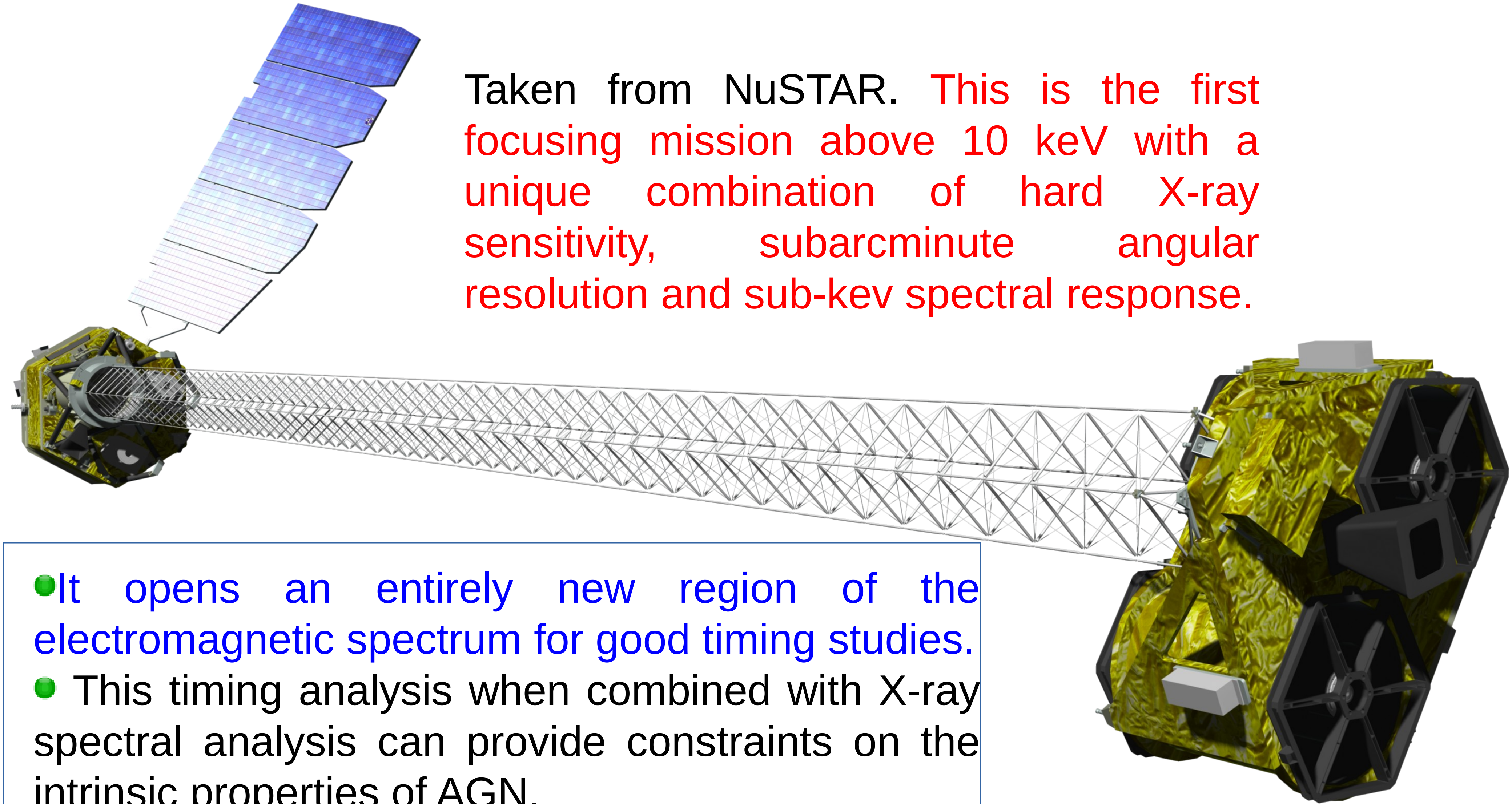
- **Physics**: variability studies provide clues to the nature of the physical processes at work in the inner most regions of the central region that could not be resolved using existing imaging techniques.

Why Hard X-rays?

- Relatively unexplored region of spectrum
- Unaffected by photoelectric absorption, either in Galaxy or intrinsic.
- Studies of non-thermal emission above where thermal X-rays ‘contaminate’.

Data:

Taken from NuSTAR. This is the first focusing mission above 10 keV with a unique combination of hard X-ray sensitivity, subarcminute angular resolution and sub-kev spectral response.



- It opens an entirely new region of the electromagnetic spectrum for good timing studies.
- This timing analysis when combined with X-ray spectral analysis can provide constraints on the intrinsic properties of AGN.

--Spectral Slope

--NH distribution

--Reflection Component

MOTIVATION:

- We have limited knowledge on the hard X-ray flux variations on AGN.

- Studies using INTEGRAL and Swift/BAT are limited to few sources that too on longer (month like) timescales.

- Using NuSTAR it is possible to study the hard X-ray flux variations of a larger sample of AGN on shorter (hour like) timescale.

So here our main aims are:

- What is the hard X-ray variability nature of AGN on hour like time scale?

- What is their spectral behaviour?

- How X-ray variability is related to the other physical properties of the sources?

Sample selection:

- We have analyzed NuSTAR observation of all publicly available data of different types of AGNs collected between 2012-2014.

- Standard procedures are followed for NuSTAR data analysis

Sample: (81 AGN, having 190 observations)

Radio Loud	BL Lacs	4
	FSRQ	3
Radio Quiet	Sy1	24
	Sy2	42
	NlSy1	8

DATA ANALYSIS

- Light curves are generated in 3-79 kev range for all sources.

- In further, all lightcurves are divided into two bands 3-10 kev and 10-79 kev respectively.

- Variations characterised by Normalized excess variance

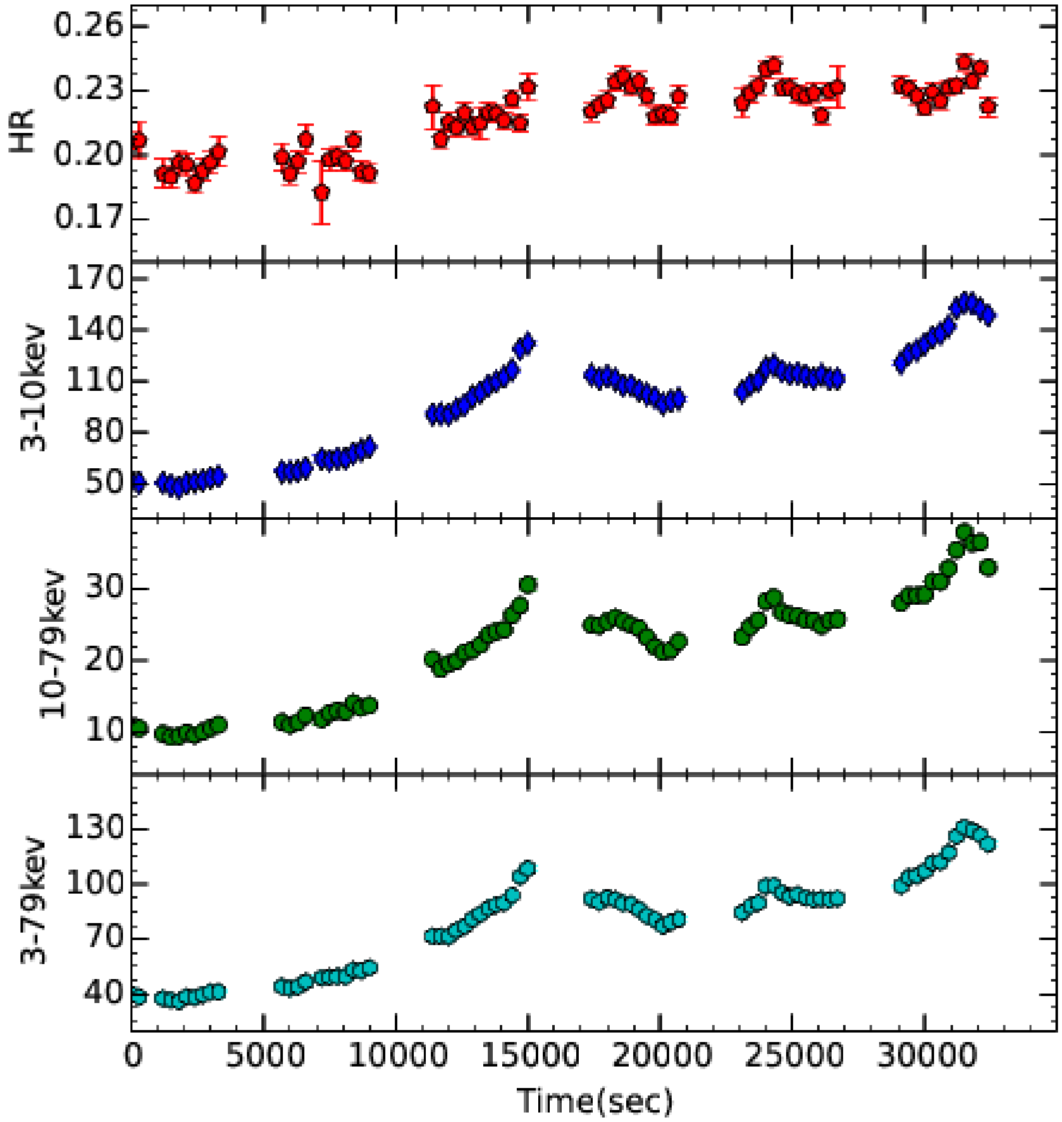
$$F_{\rm var} = \sqrt{\frac{S^2 - \langle \sigma_{\rm err}^2 \rangle}{\langle F \rangle^2}} \qquad err(F_{var}) = \sqrt{\left(\sqrt{\frac{1}{2N}}\frac{\overline{\sigma^2}_{err}}{\bar{x}^2 F_{var}}\right)^2 + \left(\sqrt{\frac{\overline{\sigma^2}_{err}}{N}}\frac{1}{\bar{x}}\right)^2}$$

- Lag/lead checked between flux variations in soft and hard bands

- Shortest flux variation time scales are also searched for using flux doubling/halving time scales:

$$F(t) = F(t_0) \cdot 2^{(t-t_0)/\tau}$$

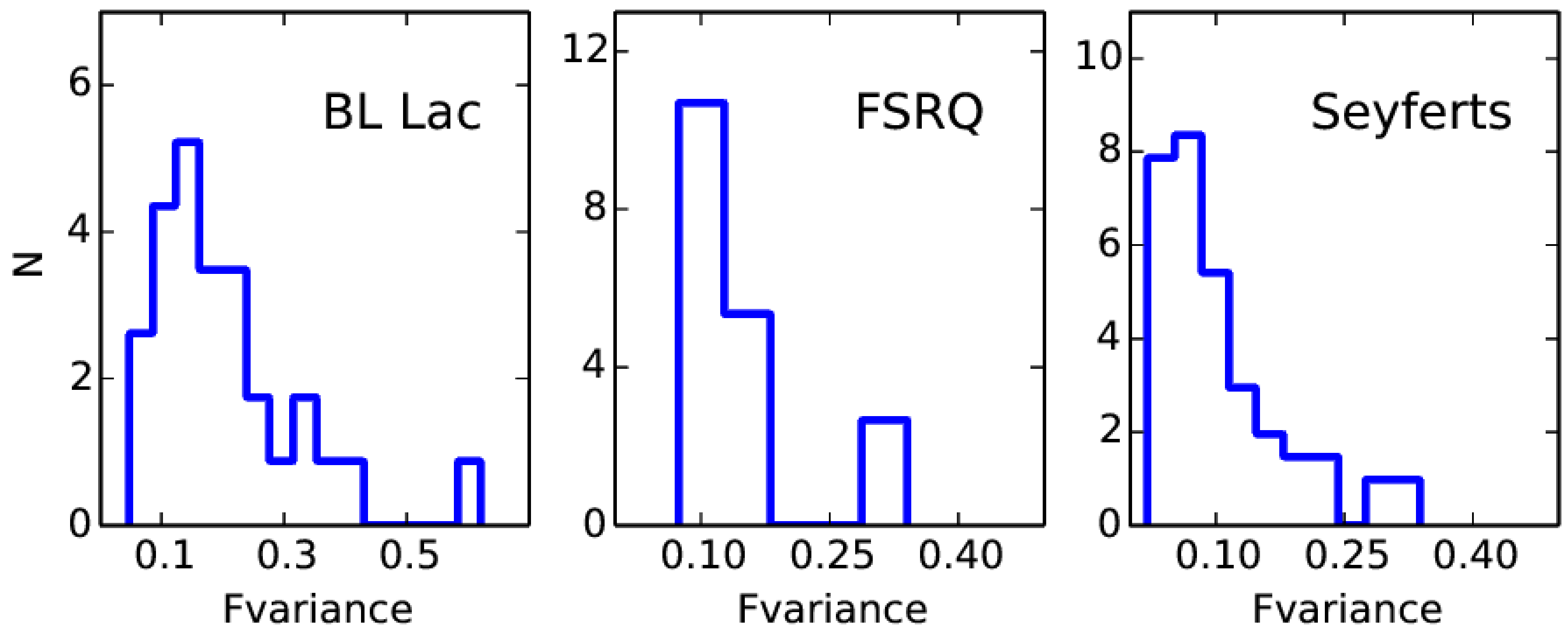
RESULTS:



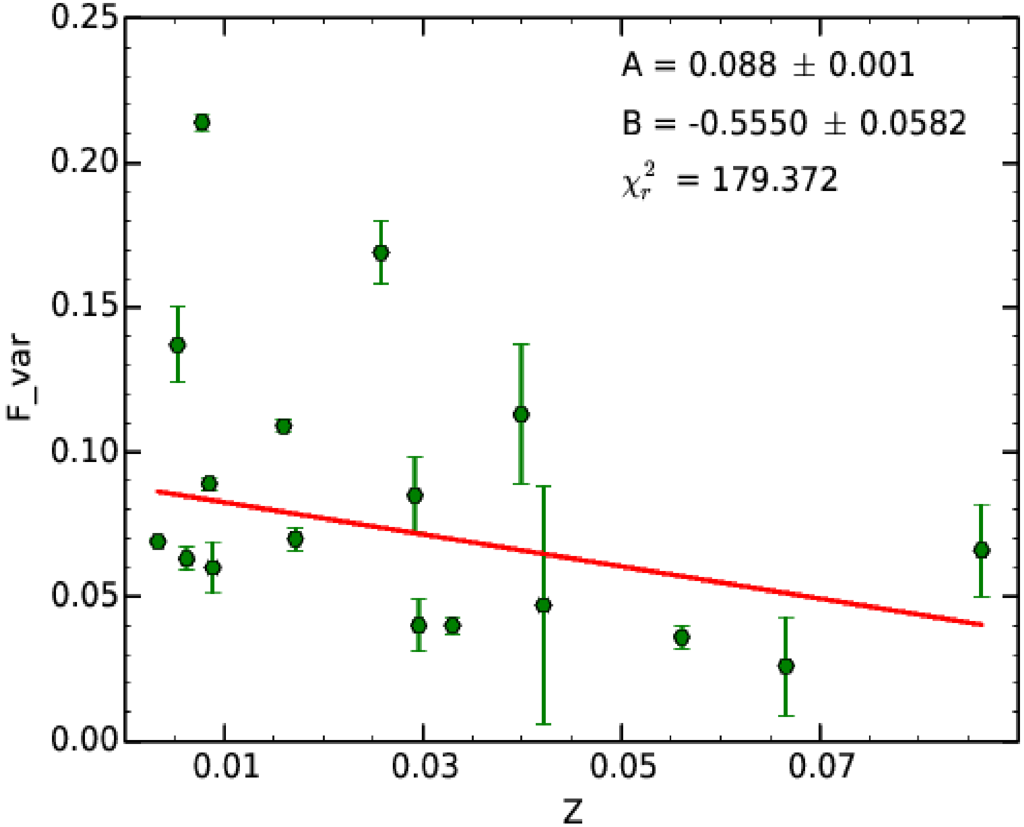
Lightcurve of Mrk 421 in different energy bands.

Amplitude of Variability

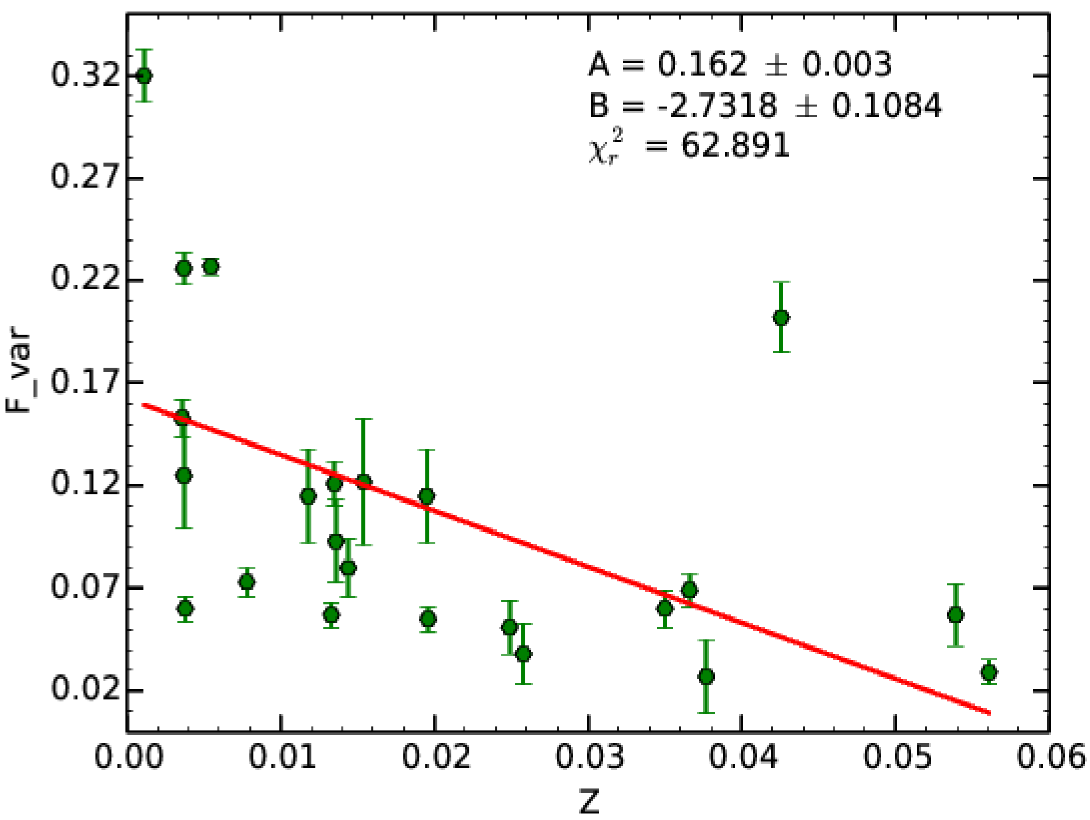
Energy range	BL Lacs	FSRQ	Sy1	Sy2	NLSy1
3-79 kev	0.200±0.003	0.152±0.004	0.093±0.003	0.113±0.002	0.151±0.004
3-10 kev	0.178±0.002	0.142±0.004	0.104±0.003	0.127±0.003	0.167±0.003
10-79 kev	0.248±0.004	0.152±0.006	0.103±0.004	0.106±0.004	0.121±0.006



F_var vs. Redshift plot for Sy1 and Sy2:

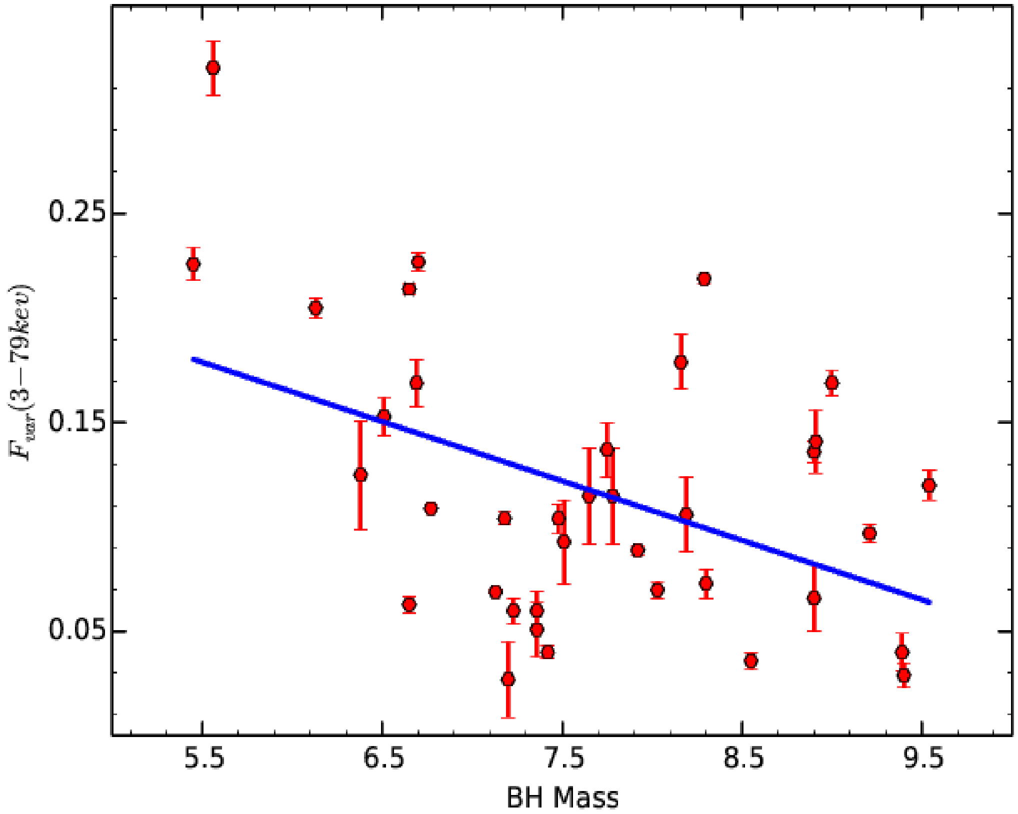


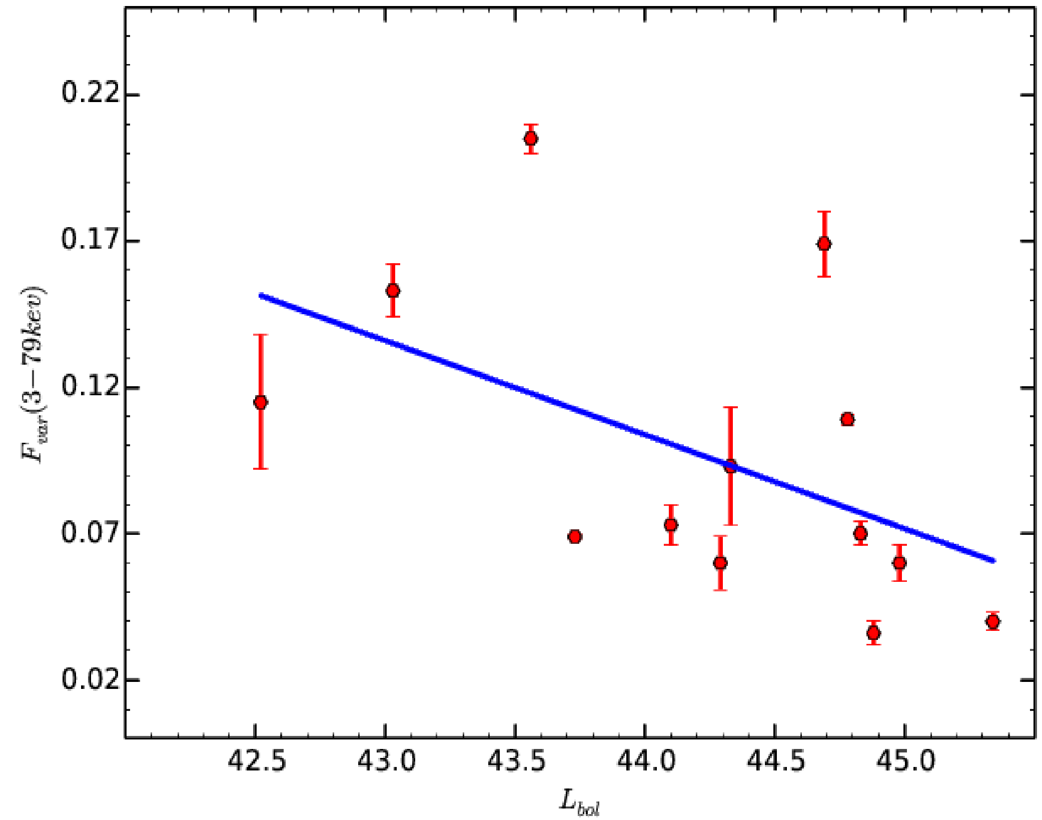
Sy1



Sy2

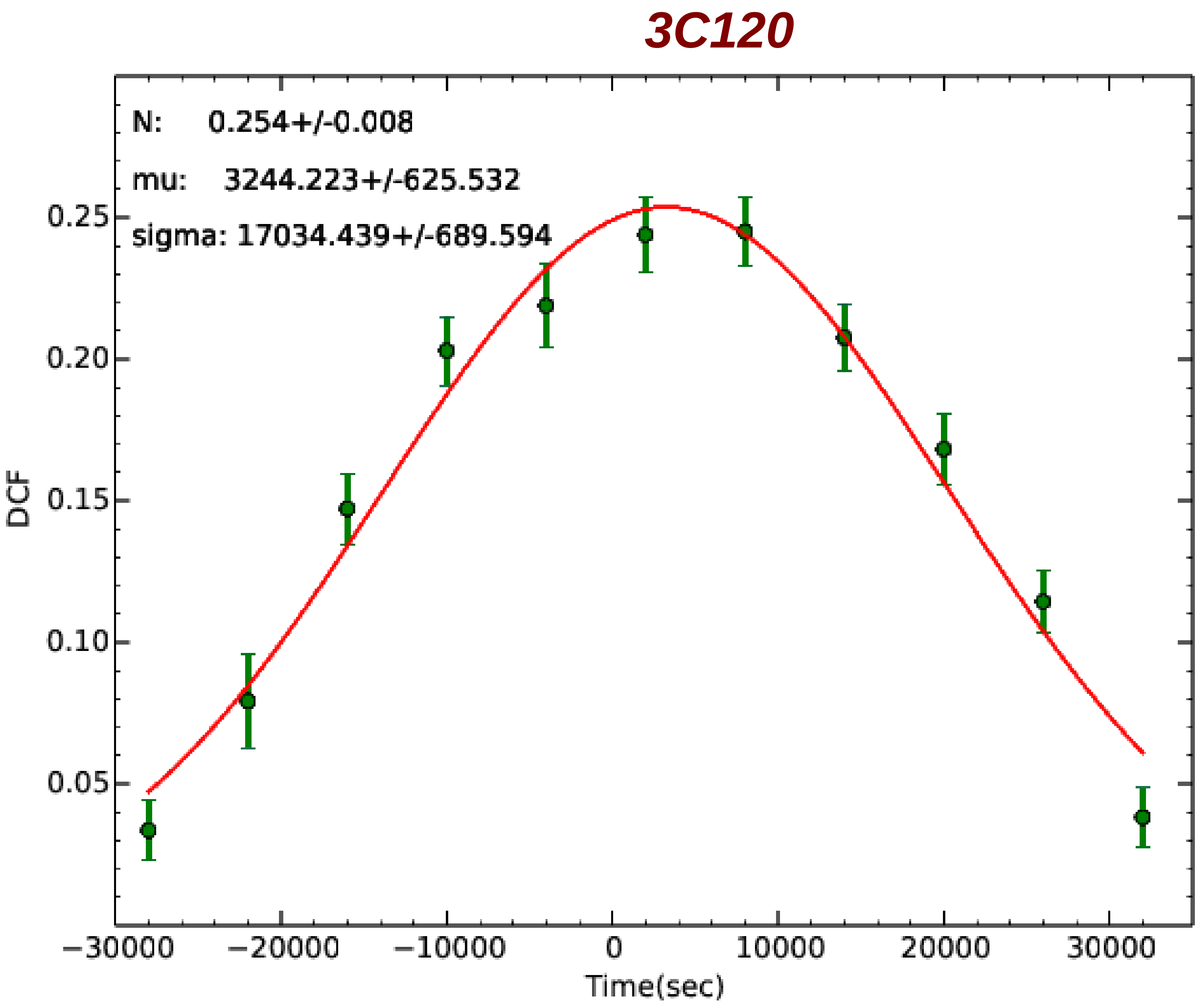
Correlation of F_var with physical properties:



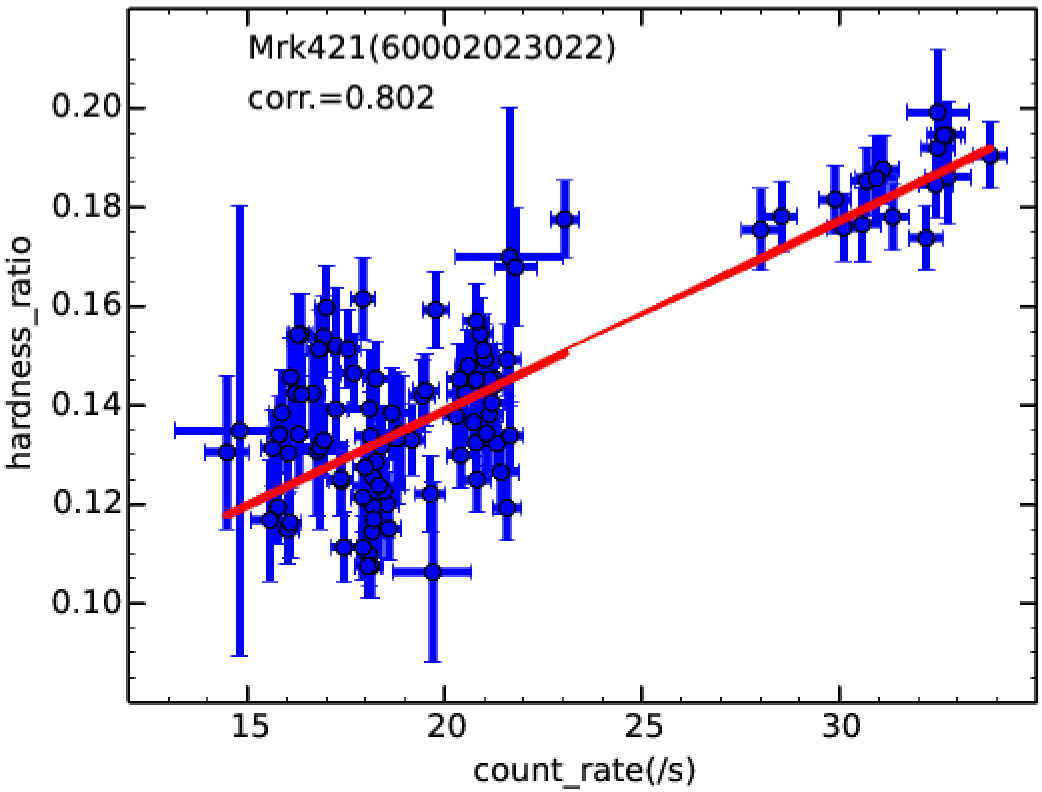


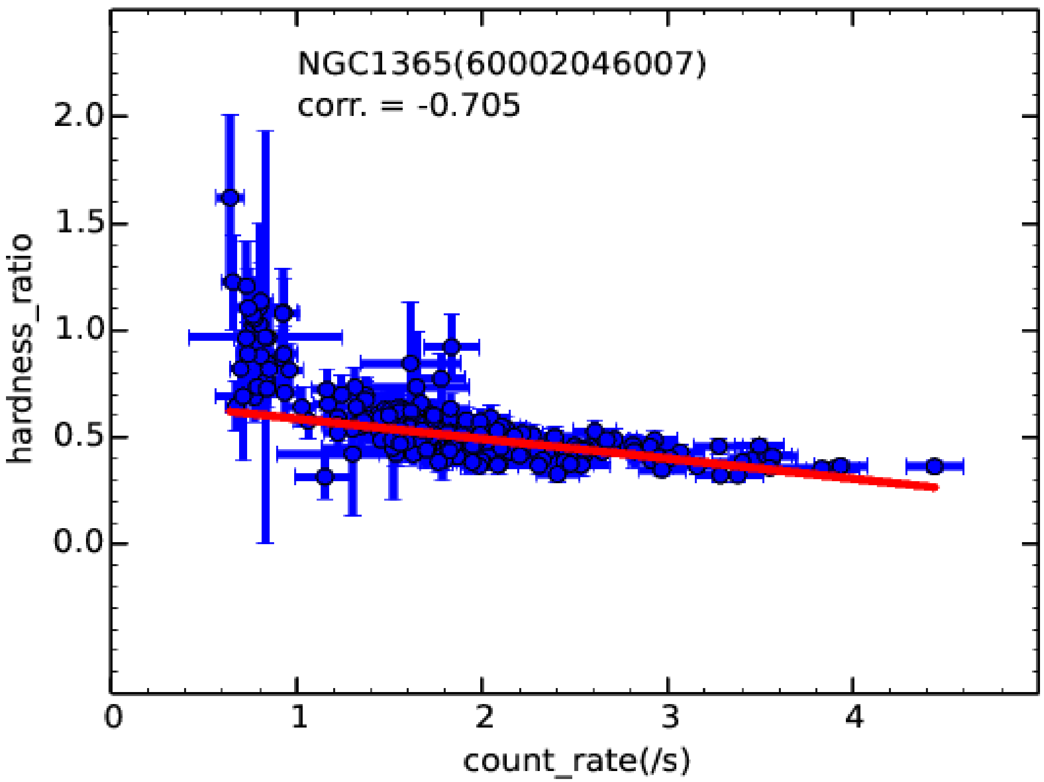
Nandra et al. (1997)and Leighly (1999a),G.C.Dewangan et al. (2008)

Discrete correlation funtion:



Spectral Behaviour:





Conclusions:

- 68% sources of our sample show hard X-ray variability on hour like time scales
- Radio loud (RL) sources in general are more variable than Radio Quiet (RQ)sources.
- Among RL, objects BL Lac objects are more variable compared to FSRQs.
- Among RQs, Sy2 are more variable than Sy1.
- Both FSRQs and BL Lac objects show more variations in the hard X-ray band compared to the soft X-ray band.
- Radio quiet sources are more variable in soft band compared to the hard X-ray band.

- Some radio loud sources show a harder when brighter behaviour(e.g. Mrk421).

- In some radio quiet sources a softer when brighter trend is noticed.

- For most of the sources, there is no lags between flux variations between hard and soft bands Some radio quiet sources do show a soft lag.

- For few sources, we found shortest variability of the order of minutes.

THANK YOU