Understanding the X-ray spectral curvature of MKN 421 using broad band AstroSat observations

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Introduction

- Blazars are radio loud type of Active Galactic Nuclei (AGN) with the relativistic jet directed towards the observer (Padovani and Giommi 1995). Their broadband spectral energy distribution (SED), extending from radio to γ-ray energies, is characterized by two prominent peaks with the low energy component attributed to synchrotron emission and the high energy to inverse Compton processes.
- MKN 421 is one of the nearest (z=0.031) (Punch et al. 1992) and the brightest BL Lac object and classified as an High frequency peaked (HBL) source because its synchrotron peak falls at X-ray energies.
- The motivation of our work is to obtain a more consistent physical scenario responsible for the emission.

AstroSat observation of MKN 421

- During 2017 January 3 – 8, MKN 421 was observed by *AstroSat*/SXT and *AstroSat*/LAXPC instrument for a total observation time of 400 ksec.
- We carried a time resolved spectral study by dividing the total observation time into timesegment of 10 ksec.

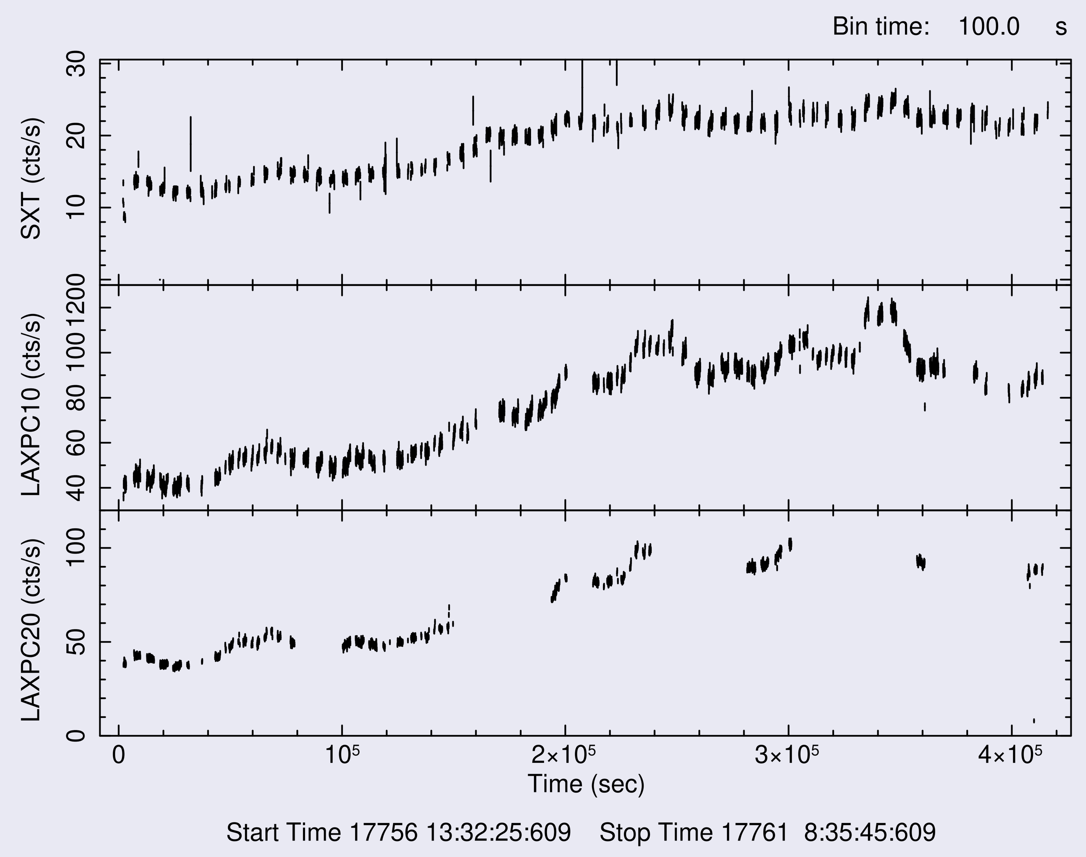

Figure 1. Light curve of MKN 421 in the energy range of 0.5 – 7.0 keV from SXT (top panel) and 3.0 – 30.0 keV from LAXPC10 (middle panel) and LAXPC20 (bottom panel).

Time-Resolved Spectral Analysis

- Synchrotron flux received by the Observer (Begelman et al. 1984)

$$F_{\rm syn}(\epsilon) = \frac{\delta^3(1+z)}{d_L^2} V\,\mathbb{A} \int_{\xi_{min}}^{\xi_{max}} f(\epsilon/\xi^2) n(\xi) d\xi \qquad (1)$$

This equation is solved numerically and included it as a local convolution model, $synconv \otimes n(\xi)$ in XSPEC

- The combined (SXT and LAXPC) X-ray spectrum in each 10 ksec time segment is fitted by synchrotron emission from different particle energy distribution e.g logparabola (LP), and physical models such as energy dependent diffusion (EDD) and energy-dependent acceleration (EDA).

Reduced χ^2

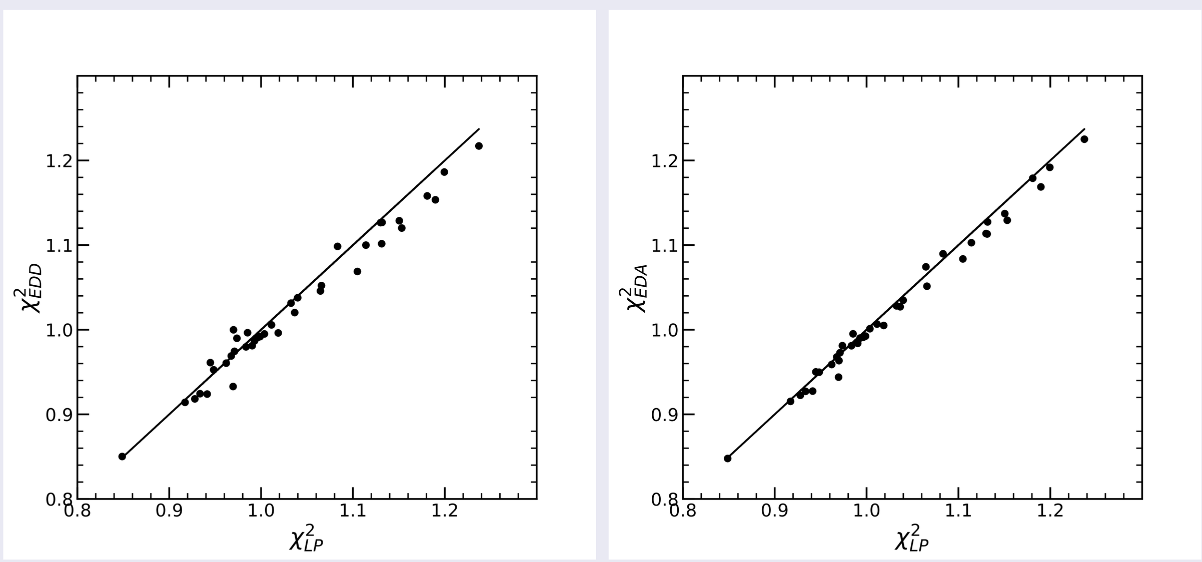

Figure 2. Comparison of reduced-χ^2 of synchrotron convolved logparabola model with: left panel: the reduced χ^2 of synchrotron convolved EDD model and right panel: the reduced χ^2 of synchrotron convolved EDA model. Solid line in each panel represents identity line.

Log-parabola Model

- Shape of input particle density as

$$n(\xi) = K(\xi/\xi_r)^{-\alpha-\beta\log(\xi/\xi_r)} \qquad (2)$$

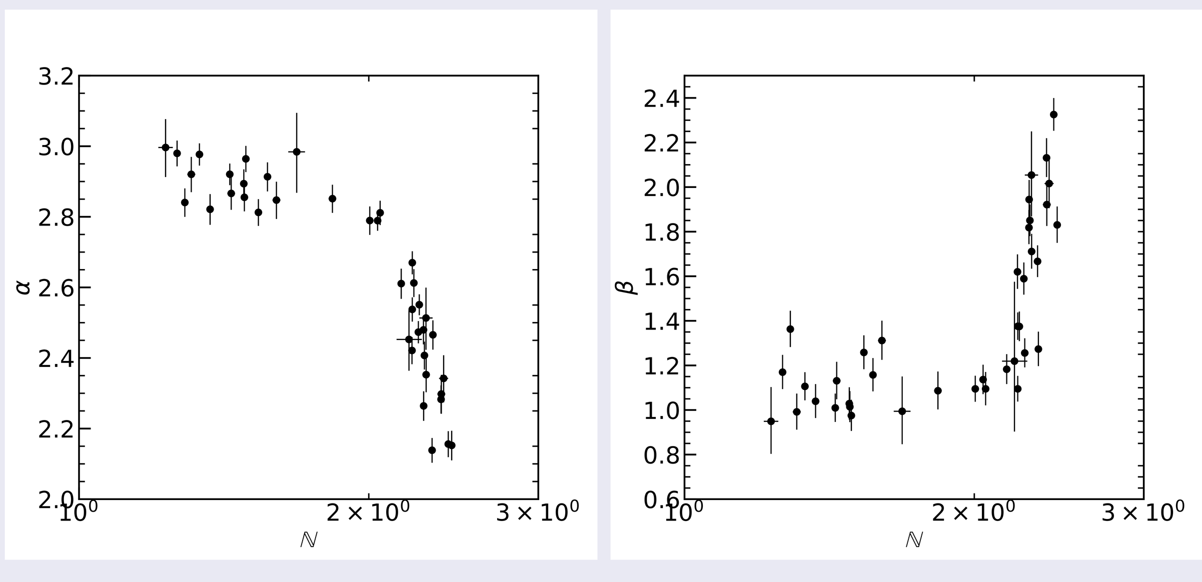

Figure 3. Left panel: scatter plot between best fitted $\mathbb{N}$ and α values, right panel: scatter plot between best fitted $\mathbb{N}$ and β values,

Issue:

- The exact relation of model parameters with the physical parameter is not clear.
- LP model is approximation of physical models like EDD or EDA model

EDD model

- Energy dependence of the escape time scale $\tau_{esc}(\gamma)$, $\tau_{esc} = \tau_{esc,R}\left(\frac{\gamma}{\gamma_R}\right)^{-\kappa}$
- The particle energy distribution

$$n(\xi) = K'\xi^{-1}\exp\left[-\frac{\psi}{\kappa}\xi^{\kappa}\right] \qquad (3)$$

where $\psi = \eta_R\left(\mathbb{C}\gamma_R^2\right)^{-\kappa/2} = \eta_R\xi_R^{-\kappa}$, and the normalization,

$$K' = Q_0\tau_{acc}\sqrt{\mathbb{C}}\exp\left[\frac{\eta_R}{\kappa}\left(\frac{\gamma_0}{\gamma_R}\right)^{\kappa}\right] \qquad (4)$$

- The free parameters for the model are ψ, κ, and $\mathbb{N}$ given by

$$\mathbb{N} = \frac{\delta^3(1+z)}{d_L^2} V\,\mathbb{A}K' \qquad (5)$$

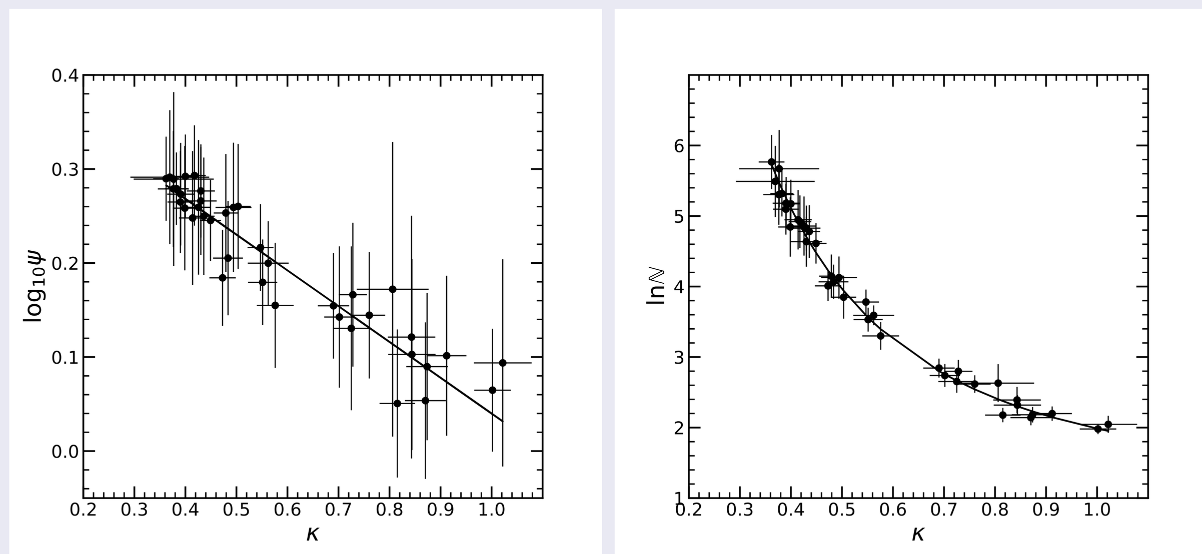

Figure 4. Left panel : Plot between best fitted κ and $\log_{10}\psi$ values, right panel: plot between $\ln\mathbb{N}$ and κ values.

- The correlations between the best-fitting spectral parameters are consistent with the prediction of the model.
- However, the inferred physical values ($\xi_R^2 \sim 5.75$ keV, $\gamma_0 \sim 0.26\gamma_R$) are not quite as expected.

EDA model

- Energy dependence of acceleration time-scale $\tau_{acc}(\gamma)$, $\tau_{acc} = \tau_{acc,R}\left(\frac{\gamma}{\gamma_R}\right)^{\kappa}$.
- The particle energy distribution

$$n(\xi) = K'\xi^{\kappa-1}\exp\left[-\frac{\psi}{\kappa}\xi^{\kappa}\right] \qquad (6)$$

where $\psi = \eta_R\left(\mathbb{C}\gamma_R^2\right)^{-\kappa/2} = \eta_R\xi_R^{-\kappa}$, and the normalization,

$$K' = Q_0\tau_{acc,R}\sqrt{\mathbb{C}}\xi_R^{-\kappa}\exp\left[\frac{\eta_R}{\kappa}\left(\frac{\xi_0}{\xi_R}\right)^{\kappa}\right] \qquad (7)$$

the parameters κ, ψ and the normalization $\mathbb{N}$ were kept as free parameters. Here $\mathbb{N}$ is defined as

$$\mathbb{N} = \frac{\delta^3(1+z)}{d_L^2} V\,\mathbb{A}K' \qquad (8)$$

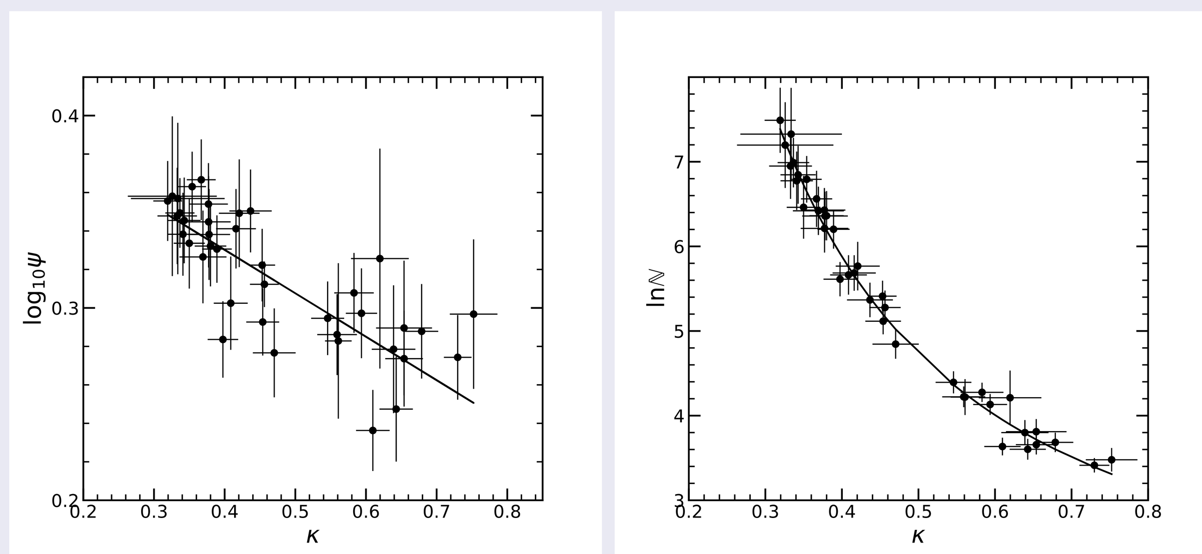

Figure 5. Left panel : Plot between best fitted κ and $\log_{10}\psi$ values, right panel: plot between $\ln\mathbb{N}$ and κ values.

- The EDA model is qualitatively similar to those obtained for EDD one ($\xi_R^2 \sim 2.89$ keV and $\gamma_0 \sim 0.19\gamma_R$).

Conclusion

- We have shown that the time resolved spectral analysis is the powerful tool to check the consistency of the models.
- The correlation between the spectral parameters and the inferred estimates of physical values can be used to constrain the models.
- The models considered in this works are simple ones which have analytical solutions, but in reality the physical situation may be more complex.

References

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