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TEMPORAL AND SPECTRAL ANALYSIS OF BLAZAR OJ 287: INVESTIGATING ITS POTENTIAL AS A HIGH-ENERGY NEUTRINO SOURCE

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Abstract

We conducted a study on temporal and spectral analysis of X-ray observations of Blazar OJ 287, which was observed from April 2005 to April 2020 on various observation periods. Among all observations, the most intense flaring was observed in April 2020 and flaring was observed in soft sub-bands 0.3–2 keV. The detected flare was dominated by thermal process. The best fit model was (log-parabola+blackbody). Both synchrotron and inverse Compton mechanisms contribute to the X-ray emission. The observations interpreted as being driven by the inverse Compton emission mechanism typically exhibit a lower energy flux in soft sub-bands and a higher energy flux in hard sub-bands. Both the May 2015 and April 2020 observations exhibit a pattern where their energy flux values are higher in the soft sub-bands and lower in the hard sub-bands. This pattern indicates that in these two observations, the emission is likely influenced by the synchrotron emission mechanism. The observation of synchrotron and inverse Compton emission mechanisms suggests that the astrophysical processes occurring within the source OJ 287 involve internal shocks and give rise to γ-ray bursts. It is highly likely that OJ 287 is a high energy neutrino source, as the flaring occurs due to non-thermal process in soft sub-bands.

Introduction

Blazars exhibit characteristics that span various wavelengths and timescales. The light curves of blazars display an irregular and unpredictable nature regarding the intensity and duration of flares, with variations occurring from one event to another. OJ 287 (with a redshift of $z = 0.306$) stands out as among the brightest and swiftly changing BL Lacertae objects (BLLs) across the radio and optical spectra.

Materials and Methods

We used eight publicly available X-ray observations for the blazar source OJ 287. These observations can be obtained from the *XMM-Newton* science archive. The dataset comprises observations made between April 2005 and April 2020.

Table 1: **Log of the observing campaign**

Obs.	Obs. IDs	Start date	End date	OD (s)	ED (s)
Apr, 2005	0300480201	2005-04-12	2005-04-13	38913	4659
Nov, 2005	0300480301	2005-11-03	2005-11-04	48059	23370
Nov, 2006	0401060201	2006-11-17	2006-11-17	47211	41730
Apr, 2008	0502630201	2008-04-22	2008-04-23	55815	39130
Oct, 2011	0679380701	2011-10-15	2011-10-15	23917	20170
May, 2015	0761500201	2015-05-07	2015-05-08	129200	62780
Apr, 2018	0830190501	2018-04-18	2018-04-19	25500	17810
Apr, 2020	0854591201	2020-04-24	2020-04-25	15000	8995

Notes: { **Here, OD represents observational time duration and ED represents exposure time duration.**}

Results and Discussion

Temporal Analysis

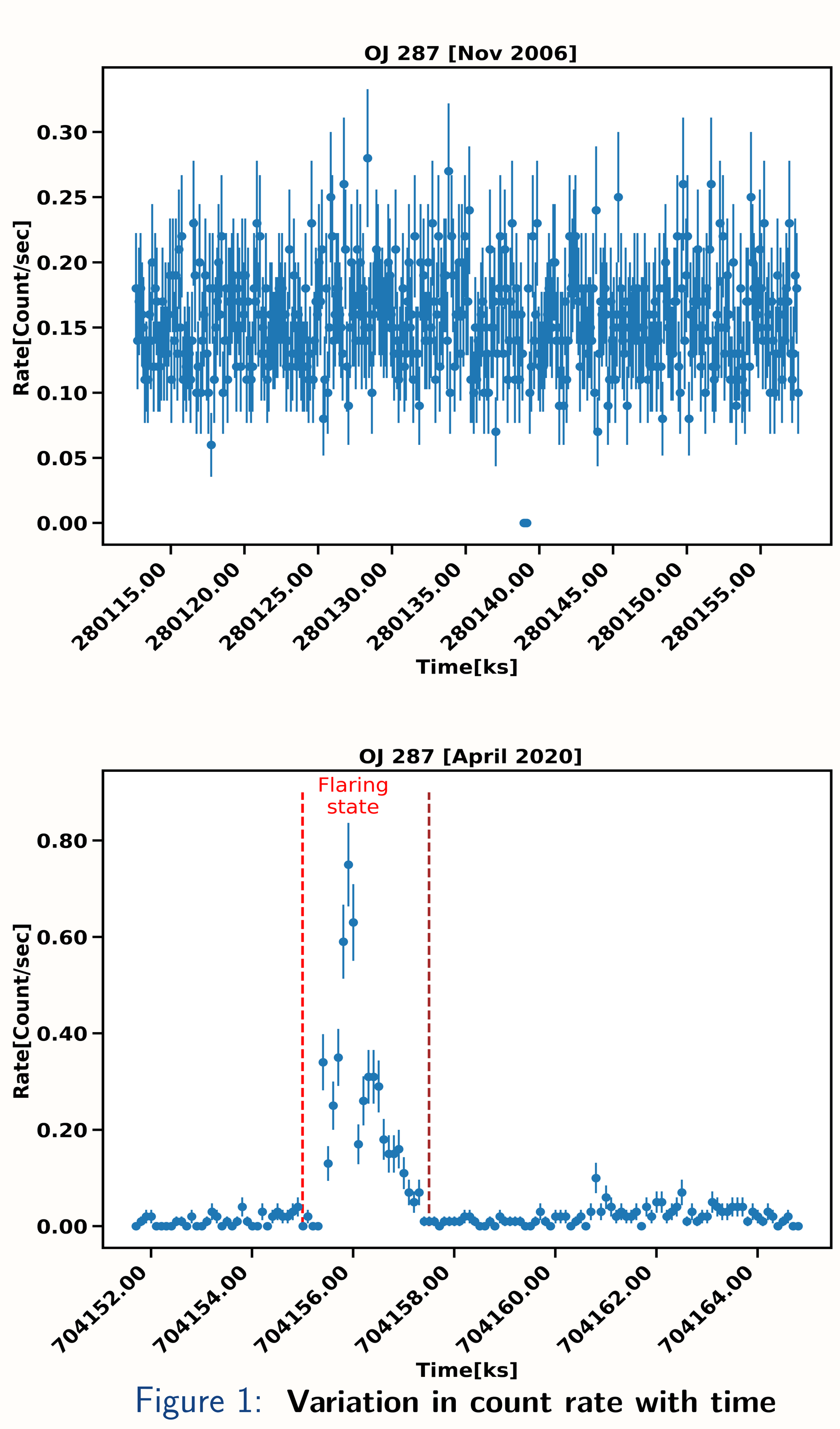

Figure 1: **Variation in count rate with time**

Fractional Variability Analysis

Table 2: **Fractional variability and error measurements**

Obs.	Apr,2005	Nov,2005	Nov,2006	Apr,2008	Oct,2011	May,2015	Apr,2018	Apr,2020
F_{var}	1.057	1.500	0.010	2.674	0.156	1.713	0.3154	2.073
$err(F_{var})$	0.004	0.004	0.063	0.005	0.026	0.002	0.012	0.037

Spectral Analysis

Table 3: **Net count rate (CR) of the source**

Obs.	Apr,2005	Nov,2005	Nov,2006	Apr,2008	Oct,2011	May,2015	Apr,2018	Apr,2020
Net CR	1.213	1.280	0.980	0.972	3.197	2.721	0.590	5.651
err (Net CR)	0.016	0.007	0.005	0.005	0.013	0.007	0.009	0.025

Assessing Flare Occurrence through Energy Flux Analysis

Table 4: **X-ray energy flux across different observations**

Obs.	E.F. (0.3–2)	E.F. (2–10)	$C_{err}R$ (0.3–2)	$C_{err}R$ (2.0–10.0)	χ_r^2	N_H
Apr, 2005	1.375	2.699	(1.213–1.509)	(2.544–2.884)	0.812	0.907
Nov, 2005	1.505	1.940	(1.487–1.529)	(1.875–2.010)	1.02	0.416
Nov, 2006	1.164	1.694	1.151–1.174)	(1.649–1.743)	0.96	0.631
Apr, 2008	1.159	1.740	(1.145–1.172)	(1.689–1.782)	1.07	0.265
Oct, 2011	3.940	5.665	(3.907–3.975)	(5.584–5.763)	1.29	0.009
May, 2015	3.115	2.013	(3.098–3.130)	(1.971–2.053)	1.53	< 0.001
Apr, 2018	3.740	4.135	(3.617–3.835)	(3.789–4.638)	1.22	0.048
Apr, 2020	18.656	5.340	(18.450–18.880)	(5.122–5.588)	0.97	0.584

Notes: { **Here, $C_{err}R$ represents the corresponding error range. The energy flux (E.F.) in both (0.3–2) keV and (2–10) keV bands, along with its associated error range, is in orders of magnitude 10^{-12} and expressed in units ergs s^{-1} cm^{-2}. N_H is the null hypothesis probability. χ_r^2 is the reduced chi-squared. The best fit model for each observations of the source is (log-parabola+blackbody).**}

Table 5: **Spectral index (SI) and error measurements**

Obs.	Apr,2005	Nov,2005	Nov,2006	Apr,2008	Oct,2011	May,2015	Apr,2018	Apr,2020
SI	1.517	1.830	1.650	1.590	1.628	1.938	1.817	2.541
err. SI	0.028	0.019	0.019	0.023	0.025	0.013	0.040	0.022

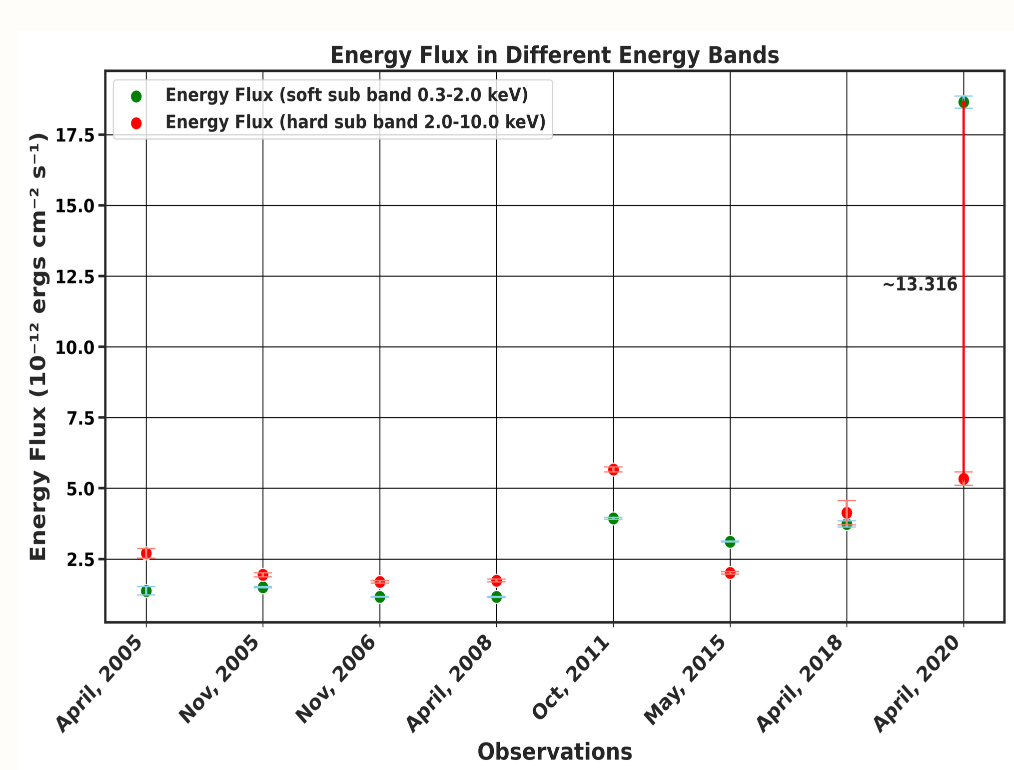

Figure 2: **Energy flux at different energy bands for different observations**

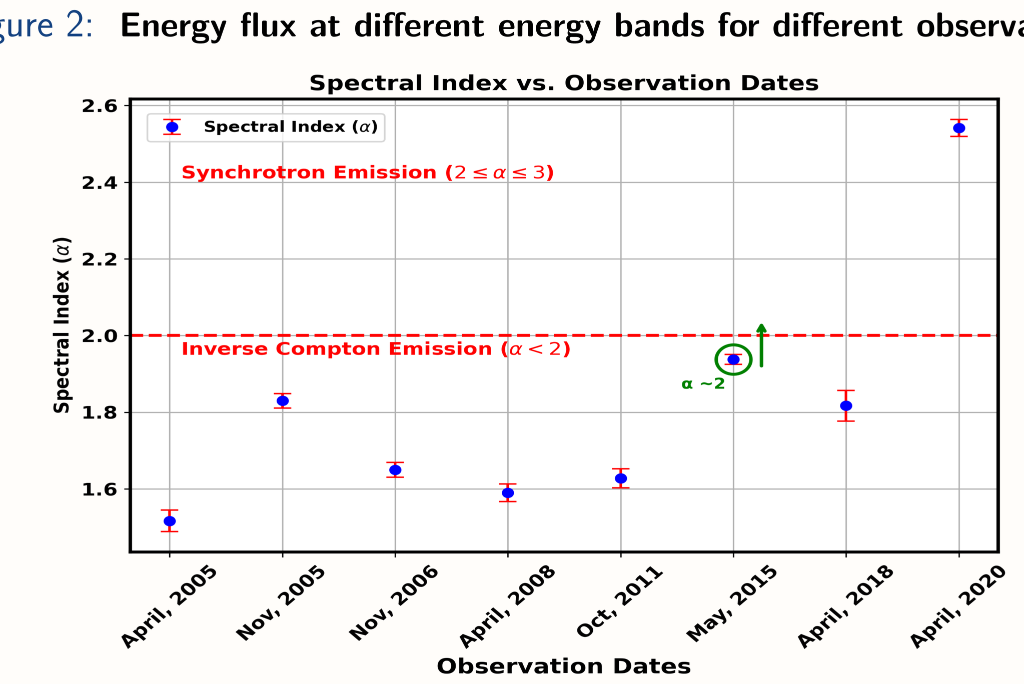

Figure 3: **Spectral index and observations plot**

Emission Mechanism in Flaring

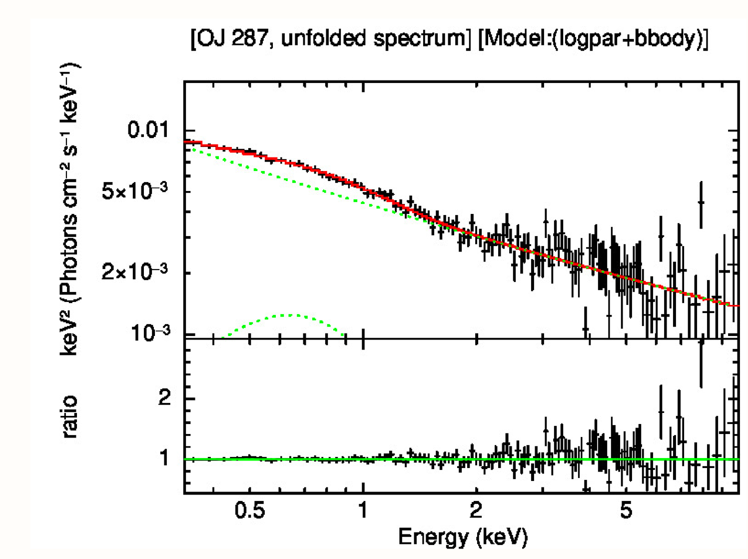

Figure 4: **Spectrum and ratio plot**

Distribution Analysis

Table 6: **Best fit statistics between distribution models**

Obs.	Normal fit AIC	Normal fit BIC	Lognormal fit AIC	Lognormal fit BIC
Apr, 2005	820.60	826.34	**657.40**	**666.02**
Nov, 2005	1767.70	1775.63	**840.64**	**852.54**
Nov, 2006	-1631.60	-1623.38	**-1671.10**	**-1658.80**
Apr, 2008	2047.50	2056.07	**50.32**	**63.18**
Oct, 2011	**-807.58**	**-800.89**	-804.36	-794.27
May, 2015	6164.36	6174.57	**2873.27**	**2888.58**
Apr, 2018	-322.18	-315.37	**-479.26**	**-469.03**
Apr, 2020	-189.13	-183.36	**-392.86**	**-384.96**

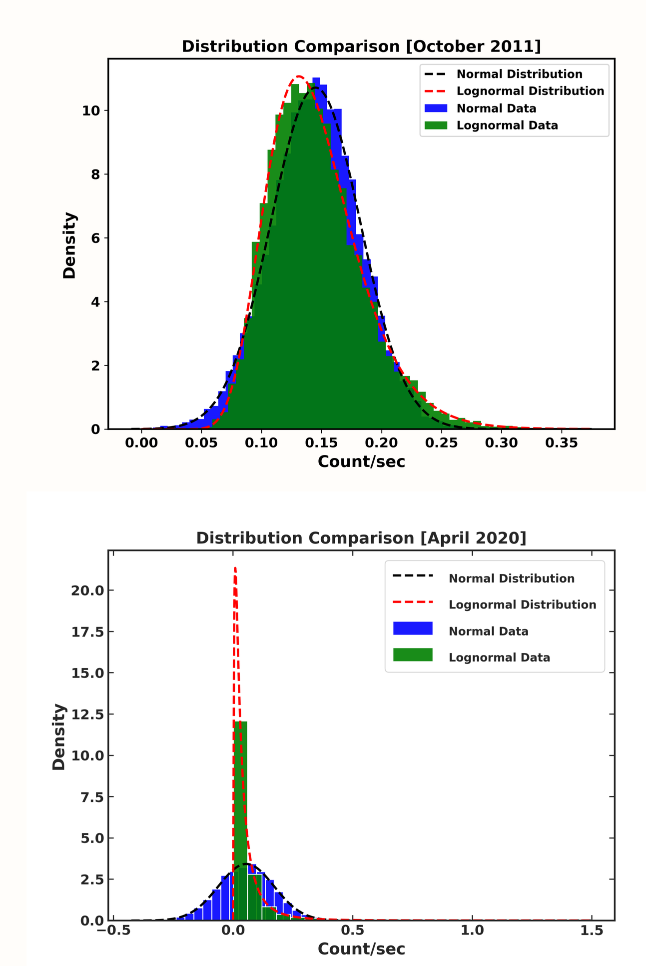

Figure 5: **Normal and lognormal PDF fitted on count rate histogram**

Conclusions

X-ray emission in OJ 287 is a result of both synchrotron and inverse Compton processes. The analysis of observations spanning from April 2005 to April 2020 reveals that it is unlikely to produce high-energy neutrinos.

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