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Short-Term X-ray Variability during Different Activity Phases of Blazars S5 0716+714 and PKS 2155-304

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Abstract: We explored the statistical properties of short-term X-ray variability using long-exposure XMM-Newton data during high X-ray variability phases of blazars S5 0716+714 and PKS 2155-304. In general, the hardness ratio shows correlated variations with the source flux state (count rate), but in a few cases, mainly the bright phases, the trend is complex with both correlation and anti-correlation, indicating spectral evolution. Stationarity tests suggest the time series are non-stationarity or have trend stationarity. Except for one, none of the histogram fits resulted in a reduced-$\chi^2 \sim 1$ for a normal and log-normal profile but a normal profile is favored in general. On the contrary, the Anderson–Darling test favors log-normal with a test-statistic value lower for log-normal over normal for all the observations, even if out of significance limits. None of the IDs show linear RMS-flux relation. The contrary inferences from different widely used statistical methods indicate that a careful analysis is needed while the complex behavior of count rate with hardness ratio suggests spectral evolution over a few 10 s of kilo-seconds during bright phases of the sources. In these cases, the spectrum extracted from whole observation may not be meaningful for spectral studies and certainly not a true representation of the spectral state of the source.

Keywords: galaxies; active galaxies; jets—radiation mechanisms; non-thermal gamma-rays; galaxies

1. Introduction

Strong and rapid variability has been one of the defining criteria of blazars—active galactic nuclei with a powerful relativistic jet of plasma directed within a few degrees with our line of sight. Studies focusing on temporal flux variability have found them to be variable on all timescales accessible to us—from the shortest allowed by the observing facilities to the longest allowed by the archived data (e.g., [1]). Though the processes responsible for the observed behavior are still unclear except for a general understanding, studies of these observations have revealed some features that have resulted in empirical classification schemes to classify and identify astrophysical objects. In the blazar parlance, the observed variability on all timescales probed so far are now widely referred into three categories: intra-day variability IDV [2]—variability within a day; short-term variability (STV)—variability on days to months; and long-term variability (LTV)—variability over a few months and longer. Among these, IDV is now one of the main tools used to identify an extra-galactic source as a blazar. A spectacular prime example of this in recent times has been in establishing a subset of narrow-line Seyfert galaxies (NLS) as blazars [3,4].

Earlier and even now, optical bands have been primarily leading the IDV studies as photon statistic at higher energies has prohibited such studies in the past. However, with the continuous advancement in detector technologies, such sub-day studies have now been possible at X-ray, (e.g., [5–8]), gamma-ray, (e.g., [9,10]), and very high energies VHEs [11,12], albeit still for bright flares. These studies have