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Swift/XRT observations of high-energy selected BL Lacertae source PKS 2155-304

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Abstract. PKS 2155-304 has been targeted more than 100 times by the Swift/XRT since 2005 November. It showed an overall flux variability between 0.6 cts s^{-1} to 14.1 cts s^{-1} through 0.3-10 keV band with typical timescales of 1.0-1.5 months for longer flares. We detected 17 cases of intraday flux variability with timescales of 0.4-40 ks. The source showed also X-ray spectral variability during which the position of the synchrotron peak was in the (1.56 - 2.72) keV interval. The photon spectral index also varied between 2.3 and 2.9. It is in a negative correlation with the 2-10 keV flux showing thus the dominance of a harder-when-brighter evolution in the source during its flux variability. In the hardness ratio - flux plane, we observe both clockwise and counterclockwise evolution of the X-ray spectrum during the separate flares. The spectrum was mainly curved and the corresponding parameter showed a negative correlation with hardness ratio, SED peak position and height that can be explained by the presence of different emission components of synchrotron and inverse Compton origin.

Key words. galaxies: BL Lacertae objects: individual: PKS 2155-304

1. Introduction

PKS 2155-304 has been observed more than 100 times in 0.3-10 keV band by the X-ray Telescope (XRT) onboard the Swift satellite (102 pointings) since November 17, 2005. The data were reduced by means of the XRTDAS software. The event files were calibrated and cleaned usung the standard procedures. Level 3 products (images, light curves, spectra) were obtained via the xrtproducts task. The 0.3-10 keV spectra of PKS 2155-304 were analyzed by means of the XSPEC package using a source model (power-law and log-parabola) plus photoelectric absorption (wabs).

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2. Flux variability

During 2006 August observations, the 0.3-10 keV flux decayed gradually to 2.07 ± 0.08 cts s^{-1} in 4 weeks, superimposed by the fluctuations of several days durations. The source was observed only once in 2007 when it was found in relatively high state (∼ 6 cts s^{-1}) and showing two fast flux variations (with timescales of about 9 hr and 21 hr). In 2008, 15 observations were performed and a flaring activity was revealed. In September-November when the source was observed relatively frequently, the flux increased up to 11 cts s^{-1} and then decayed more then 5 times in 50 days. During the 2009 September-November observations, there was a nearly symmetrical flare and decay with a factor of ∼ 4 within 39 days.

In 2010 April-November, the source exhibited relatively modest variability with a factor of ~ 3. The 2011 May-October campaign revealed a flux decay with a factor of ~ 6 to its historical minimum of 0.6 cts s^{-1}. Finally, the source has been observed 7 times since 2012 April 28 and showed a flux increase with a factor of ~ 2.5 in 3 weeks. 17 cases of the intraday flux variability are revealed at 99.9% confidence level using the chi-square test. In eight cases, the variability timescales are derived via the SF analysis which range from 40 ks down to 0.4 ks. No timescales are found in the remaining 9 occasions. For these events, the fractional rms variability amplitude was 7.5% - 30.0%.

3. Spectral variability

Generally, the 0.3-10 kev spectra of PKS 2155-304 fitted with the log-parabolic model provide a better fit compared to the power-law one since the source showed mainly a curved spectrum: in 78 out of 109 cases, significant downward curvatures with $b = 0.10-0.91$ are found. In addition, another spectrum revealed a negative curvature with $b = -0.19$. The curvature parameter revealed significant negative correlations with position of the SED energy peak, hardness ratio, and SED peak height. This could be explained with the suggestion that the X-ray spectrum of PKS 2155-304 should be a mixture of higher-energy part of synchrotron component and lower-energy part of IC emission (see Zhang 2008). The latter has a flatter spectrum compared to the former one and its increasing contribution may diminish a downward spectral curvature and even cause an appearance of upward (i.e $b < 0$) curvature. The SED peak location, E_p, varied between 1.56 keV and 2.72 keV. It shifted mainly to lower energies with increasing flux and vice-versa. Such behaviour is expected when the flares at higher frequencies come before those at lower ones and there are changes in synchrotron and in IC emission which should be more prominent in higher-energy part of 0.3-10 keV band. The photon index, Γ, varied between 2.28 and 2.94. It showed a negative correlation ($r = -0.50$) with 2-10 keV flux, i.e. the source followed mainly a harder-when-brighter trend during the flux variability. However, a significant scatter with respect to the linear fit to the data points shows that the opposite spectral evolution was not a very seldom case for the source. This shows that the flare evolutions differ from each other due to the different underlying physical conditions (Tramacere et al. 2009). In some cases, the hard X-ray emission showed higher variability compared to that in 0.3-2 keV band. In the latter case, the ratio of the highest historical flux to the lowest one was only 23 while this ratio amounts to 150 in the hard X-ray band.

4. Conclusions

During 6.5 yr Swift/XRT monitoring, PKS 2155-304 revealed a violent flux variability from sub-hour activities to the flares with weeks-months timescales. Each flare was accompanied with significant spectral variations which can be successfully explained on the basis of the assumption that the 0.3-10 keV spectrum of this source is a mixture of high-energy tail of synchrotron emission and lower-energy part of inverse Compton component. PKS 2155-304 is worth to be monitored intensively by Swift/XRT (and by other X-ray missions as well) in upcoming years. Tighter observing schedules would allow us both the detection of the fast variability events and to derive variability events at months timescales.

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