Flaring γ-ray emission from high redshift blazars

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INTRODUCTION: High redshift blazars are among the most powerful objects in the Universe. Although they represent a significant fraction of the extragalactic hard X-ray sky, they are not commonly detected in γ-rays. High redshift objects represent <10% of the AGN population observed by *Fermi* so far, and γ-ray flaring activity from these sources is even more uncommon. The characterization of the radio-to-γ-ray properties of high redshift blazars represent a powerful tool for the study of the energetics of such extreme objects and the Extragalactic Background Light (EBL). So far, only 10 blazars with z > 2 have been detected during high γ-ray activity. TXS 0536+145, with z=2.69, is the γ-ray flaring object at the highest redshift detected so far. At the peak of the flare the source reached an apparent isotropic γ-ray luminosity of about 7×10^{49} erg/s, which is comparable with the luminosity observed from the most powerful blazars.

Fermi light curve: TXS 0536+145 was not detected during the first two years of *Fermi* observations (Nolan et al. 2012, ApJS, 199, 31). The 2σ upper limit estimated for this period is 10^{-8} ph cm^{-2} s^{-1}. By contrast, during the fourth and fifth years of *Fermi* operation, the source was detected with a flux of $(4.2\pm0.6)\times10^{-8}$ ph cm^{-2} s^{-1} and a photon index $\Gamma=2.37\pm0.09$. On 2012 March 22 the source was detected during a γ-ray flare when it reached a flux of $(1.0\pm0.3)\times10^{-6}$ ph cm^{-2} s^{-1} with $\Gamma=2.05\pm0.08$, indicating a hardening of the spectrum (Orienti et al. 2014, MNRAS, 444, 3040).

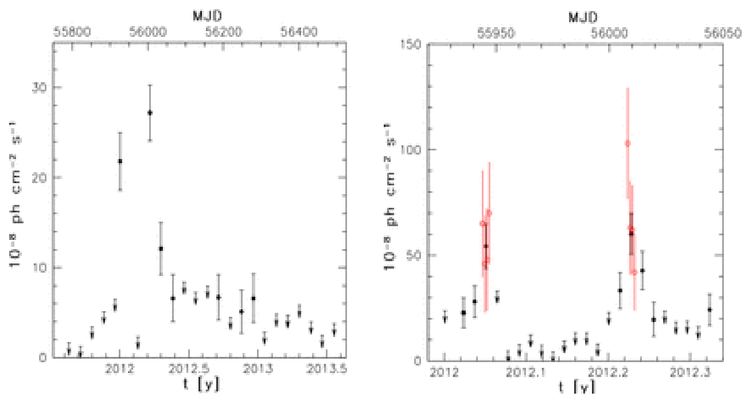

FIGURE 1. ***Left:*** integrated *Fermi*-LAT light curve (0.1-100 GeV) between 2011/08/04 and 2013/08/04 with 1-month time bins. ***Right:*** zoom of the *Fermi*-LAT light curve between 2012/01/01 and 2012/04/30 with 3-day and 1-day time bins. Arrows refer to 2σ upper limits.

Radio properties: Multi-epoch VLBA (at 8.4, 15 and 22 GHz), EVN (at 22 GHz) and Medicina (at 5.0 and 8.4 GHz) observations were triggered by the γ-ray flare with the aim of studying the parsec-scale structure and flux density variability. Observations took place between April 2012 and October 2013.The source has a core-jet structure and the variability originates from the core component. The radio light curves show an increase of the flux density ~2-3 month after the γ-ray flare, with longer delay occurring at longer wavelength. No new superluminal component associated with the flare was detected.

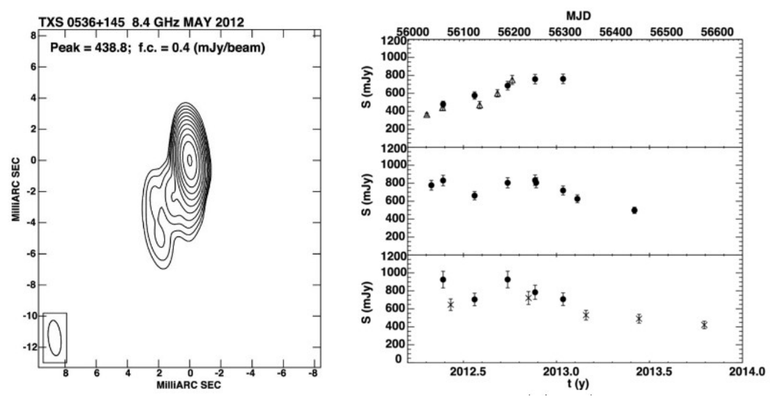

FIGURE 2. ***Left*:** VLBA image of TXS 0536+145 at 8.4 GHz. ***Right*:** Radio light curves at 8.4 GHz (top), 15 GHz (center) and 22 GHz (bottom). Filled circles, triangles and crosses represent VLBA, Medicina and EVN data, respectively.

SWIFT data and Spectral Energy Distribution: to investigate flux variability in optical/X-rays, *Swift* performed three observations of TXS 0536+145. The first two observations were carried out a few days after the γ-ray flare, while the last one took place a few months later. The source was observed in a high state in X-rays after the γ-ray flare, while the flux decreases by a factor of two in the following epochs. No detection in the optical bands were obtained by UVOT. The SED is well fitted by synchrotron/external Compton model where the seed photons may be those from the dusty torus (see e.g. Finke et al. 2008, ApJ, 686, 181). Due to the rather poor optical coverage, the model parameters are not well constrained.

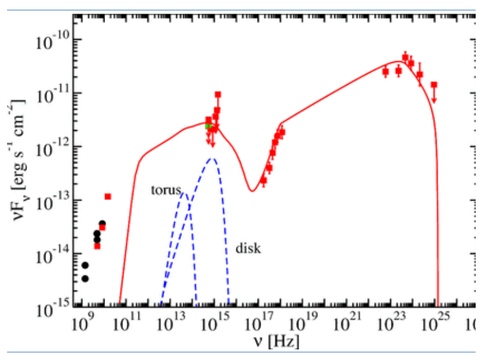

FIGURE 3. SED data (squares and circles) and model fit (solid curve) of TXS 0536+145 in flaring activity with the model components shown as dashed curves.

DISCUSSION: The flux density increase detected in γ-rays and at lower energies is a strong indication that the flaring γ-ray source is associated with the flat spectrum radio quasar TXS 0536+145, becoming the γ-ray blazar at the highest redshift observed so far. During the flaring episode the source reached an apparent isotropic luminosity (0.1-100 GeV) of 6.6×10^{49} erg/s, similar to the extreme luminosity reached by the FSRQ 3C 454.3 and PKS 1510-089 (Abdo et al. 2011, ApJ, 733, L26; Orienti et al. 2013, MNRAS, 428, 2418). We compared the properties of TXS 0536+145 with those shown by the population of high-z (z>2) γ-ray sources from the 2LAC (Ackermann et al. 2011, ApJ, 743, 171). The photon index of the target is in agreement with those shown by the other high-z blazar.

A hardening of the spectrum during the high activity state was observed, as in the high-z object 4C+71.07 (Akyuz et al. 2013, A&A, 556, 71). Despite the harder spectrum shown during the flaring state, no significant emission above 10 GeV is observed. This value is consistent with current EBL models (e.g. Finke et al. 2010, ApJ,712, 238), but the low statistics do not allow us to attribute the spectral curvature to this effect (Orienti et al. 2014, MNRAS, 444, 3040).

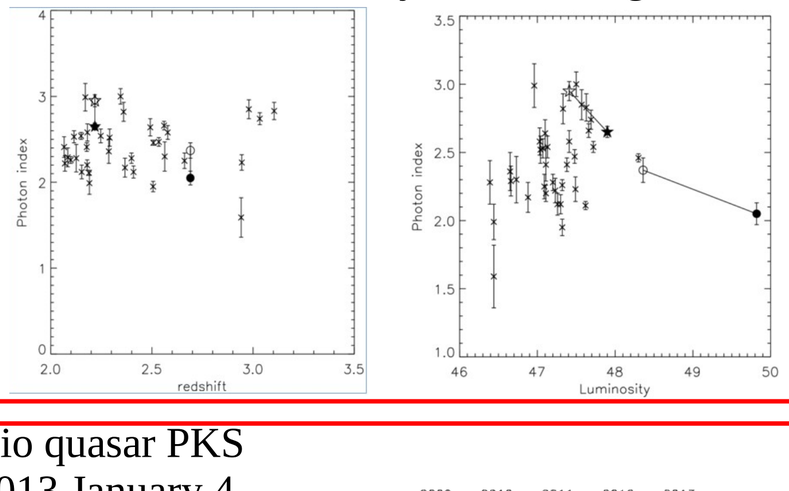

FIGURE 4. ***Left:*** photon index versus redshift. ***Right:*** photon index versus luminosity. Crosses are high-z sources from 2LAC, circles and stars are TXS 0536+145 and 4C+71.07, respectively. Filled and empty symbols refer to flaring state and average state, respectively.

Another flaring high-z object: PKS 2149-306. The flat spectrum radio quasar PKS 2149-306 was observed by *Fermi*-LAT during a flaring episode on 2013 January 4 (preliminary results were reported in D'Ammando & Orienti 2013, ATel, 4706). This source was already part of the 2LAC, indicating a higher level of γ-ray activity with respect to TXS 0536+145. During the first five years of *Fermi* observations the source was clearly detected for the whole period with one-month integration time. A first significant increase of activity from this source was observed in 2011 February and subsequently a strong flaring activity was detected in 2013 January, reaching a daily peak value of $(3.0\pm0.4)\times10^{-6}$ ph cm^{-2} s^{-1}. A dedicated analysis of this source is ongoing aiming at studying the high-energy SED in perspective of the next generation of high-energy telescopes.

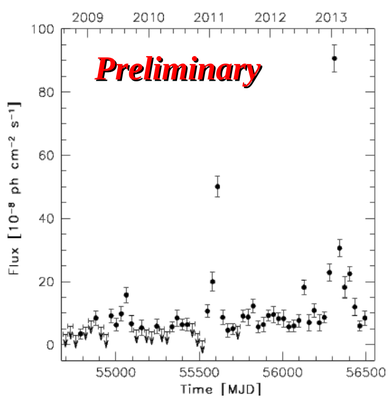

FIGURE 5. Integrated flux light curve of PKS 2149-306 obtained by *Fermi*-LAT in the 0.1-100 GeV energy range during 2008 August 4 - 2013 August 4 with 1-month time bins.