Intrinsic spectral curvature in TeV Blazars

The XMM-Newton view

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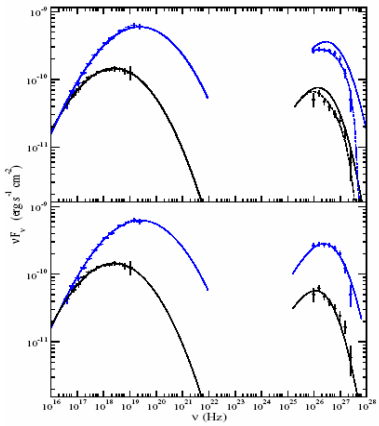
Abstract

All the extragalactic sources detected at TeV energies are nearby BL Lac objects.
They are HBL objects, i.e. BL Lac objects with the synchrotron peak in the keV region (Padovani & Giommi 1995). The study of these objects simultaneously at TeV and X-ray energies is useful not only test the spectral and flux correlation predicted by the Self Synchrotron Compton (SSC) scenario and for the understanding of the shape and intensity of the Extragalactic Background Light (EBL).
Recently, Massaro, Tramacere et al. (2006) showed that the intrinsic X-ray spectral curvature in the SSC scenario predicts curved TeV spectrum implying a lower EBL contribution to reproduce the observed TeV spectra (see Figure). This result remarks the importance of the knowledge of intrinsic X-ray curvature to study the intrinsic TeV spectra and to explore the energy distribution of EBL. In this contribution we present a preliminary analysis of the observations of seven TeV Blazars observed by XMM-Newton satellite. We found for these objects a remarkable X-ray spectral curvature in agreement with the BeppoSAX and the most recent SWIFT observation (Giommi, Tramacere et al., this Conference).

Spectral Energy Distribution of Mrk 501



Sample of TeV blazars observed by XMM-Newton

Name	RA	DEC	z	N_H,Gal [$10^{20}cm-2$]
• 1ES 1101-232	11 03 37.6	-23 29 30	0.186	5.76
• 1H 1219+301	12 21 21.9	+30 10 37	0.182	1.73
• 1H 1426+428	14 28 32.6	+42 40 21	0.129	1.38
• 1ES 1553+113	15 55 43.0	+11 11 24	0.360	3.67
• MRK 501	16 53 52.2	+39 45 37	0.033	1.71
• 1ES 1959+650	19 59 59.8	+65 08 55	0.047	10.0
• PKS 2155-304	21 58 52.0	-30 13 32	0.116	1.69

Fig 1. shows two SED of Mrk 501 during the high state on 7 and 16 April 1997,taken from Massaro, Tramacere et. al 2006. X-ray points are from SAX (Massaro et al. 2004b),TeV simultaneous data are from CAT (Djannati-Ataj et al. 1999) Solid line are spectra computed for one zone SSC model. In the lower panel IC component has been absorbed (dashed lines) by EBL photons interaction according to the LLL model by Dwek & Krennich (2005).

Spectral Analysis

The energy range considered in all the analyses is 0.5–10 keV. To estimate correctly the spectral curvature in this band, it is crucial the knowledge of the absorption at low energies due to interstellar gas.
The value of the column density has been fixed, for all the sources, at the galactic values. This choice implies that we assumed the intrinsic absorption in the source negligible, according to previous analisys of X-rays blazars spectra (Fossati et al. 2000, Tanihata et al. 2004, Massaro et al. 2004).

$$S(E) = E_p^2 F(E_p)^{-b\,Log(E/E_p)} \qquad F(E) = F(E_1)\,(E/E_1)^{-a-b\,log(E/E_1)}$$

The power-law model is often not adequate to describe the spectral shape. Residual inspection shows that the model systematically deviates from data moving towards the edges of energy range, giving unacceptable statistics. This feature is a clear indication that the intrinsic spectral shape is more complex than a simple power-law description, according to Fossati et al. (2000). A power-law model with an exponential cut-off (PLC) and a broken power-law (BPL) model gives a better description of spectral continuum respect to the simple power-law, but they show some limits. In details, the PLC model estimates often the high energy cut-off out of the 0.5–10 keV range, and the BPL model cannot take into account any spectral curvature at high energies tail. Finally, the log-parabolic (LP, see formulas above) model describes the spectral shape more satisfactory than the previous ones, giving systematically lower $\chi 2$ values. In addition this model has a physical interpretation in terms of statistical particle acceleration mechanism (Massaro et al. 2004a, 2005, Tramacere et al. in prep.), whose acceleration probability decreases with the electron energy.

Best fit spectral parameters

Obs ID	a	b	E_{peak} [keV]	$F_{(2-10)keV}$ 10^{-11} erg cm^{-2} s^{-1}	χ^2_r (d.o.f.)
1ES 1101-232					
29 Mag 2001	FLARE	FLARE	FLARE	FLARE	FLARE
1H 1219+301					
11 Jun 2001	2.281±0.038	0.381±0.066	0.428±0.109	2.7	0.95 (154)
1H 1426+428					
16 Jun 2001	1.774±0.021	no	no	3.7	1.09 (320)
04 Aug 2004	1.962±0.023	0.197±0.036	1.252±0.122	3.2	1.10 (271)
06 Aug 2004	1.914±0.027	0.330±0.043	1.348±0.082	2.3	0.99 (231)
24 Jan 2005	1.972±0.023	0.269±0.037	1.125±0.095	2.7	1.17 (261)
19 Jun 2005	1.831±0.019	0.211±0.028	2.507±0.010	5.0	1.22 (322)
25 Jun 2005	1.921±0.032	0.268±0.050	1.407±0.115	3.4	1.00 (199)
04 Aug 2005	2.043±0.027	0.314±0.045	0.855±0.103	2.5	1.10 (216)
1ES 1553+113					
06 Sep 2001	2.198±0.080	0.383±0.139	0.551±0.245	3.1	1.12 (79)
Mrk 501					
12 Jul 2002	2.123±0.063	no	no	4.2	0.85 (103)
14 Jul 2002	2.171±0.064	no	no	4.3	1.04 (105)
1ES 1959+650					
16 Jan 2003	FLARE	FLARE	FLARE	FLARE	FLARE
09 Feb 2003	1.877±0.048	0.241±0.073	1.801±0.168	6.7	1.04 (155)
PKS 2155-304					
30 May 2000	2.460±0.026	0.181±0.046	no	4.4	1.27 (201)
31 May 2000	2.507±0.020	no	no	5.1	1.04 (252)
19 Nov 2000	2.679±0.012	0.133±0.021	no	3.0	1.10 (320)
20 Nov 2000	2.758±0.022	0.155±0.041	no	2.1	1.13 (209)
30 Nov 2001	2.599±0.015	0.338±0.028	0.129±0.028	4.6	1.36 (274)
30 Nov 2001	2.471±0.009	0.361±0.016	0.223±0.021	8.0	1.35 (360)
30 Nov 2001	2.610±0.013	0.338±0.025	0.125±0.024	5.1	1.27 (296)
24 May 2002	2.352±0.012	0.183±0.021	no	3.7	1.33 (340)
29 Nov 2002	2.524±0.014	0.408±0.027	0.228±0.030	1.6	1.24 (291)
29 Nov 2002	2.433±0.014	0.433±0.026	0.316±0.034	2.5	1.21 (292)
23 Nov 2003	2.768±0.039	0.141±0.074	no	1.3	1.12 (140)
22 Nov 2004	2.762±0.024	0.310±0.048	no	1.2	1.58 (186)
23 Nov 2004	2.627±0.024	0.313±0.046	no	2.0	1.17 (193)
12 May 2005	2.587±0.039	no	no	3.5	0.95 (142)
30 Nov 2005	2.537±0.014	0.169±0.026	no	3.7	1.49 (301)

The curved SED of PKS 2155-304

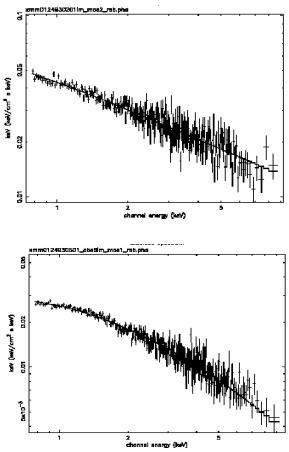


Fig 2. SED of PKS 2155-304 as observed on 31 May 2000 (up) and on 29 Nov 2002 (bottom).

Table: best fit spectral parameters.
•'FLARE' means that the observation is contaminated by solar flares.
•'no' means that the b parameter is consistent with zero, or that the estimated energy peak is outside XMM energy range.

Two different spectral states of 1H 1426+428

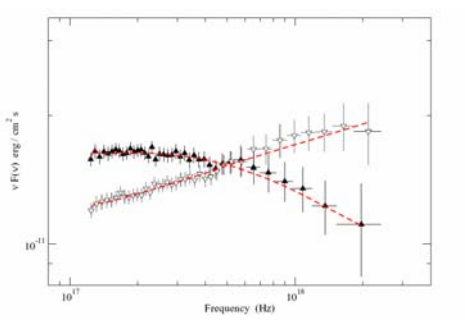


Fig 3. SED of 1H 1426+428 as observed on 16 Jun 2001 (white circles) and on 4 Aug 2004 (filled triangles). A claer evidence of SED peak shift at hgher energy, outside XMM-Newton energy range.

Summary of main results

1. All TeV BL Lac objects show intrinsic spectral curvature in the X-rays band. In particular we found that this curvature cannot be described with a power-law model combined with an high absorption as previously made for Mrk 501 and 1H 1219+301 (Blustin et al. 2004) beacuse this absorption requires strange features: absence of lines or edges and temporal variability and does not perform a good fit as the logparabolic model.
2. PKS 2155-304 in our sample is the source with the first SED energy peak out of XMM-Newton energy range but in the fall of the spectrum does not show an exponential cut-off. No spectral curvature due to high energy exponential cut-off were found in other sources. PKS 2155-304 showed also two spectral variations during XMM-Newton, observations, changing from curved to not curved shape.
3. 1H 1426+428 during XMM-Newton observations showed a change of the SED peak energy from the 0.5-10 keV range to higher energy.

•References

Padovani, P. & Giommi, P., 1995 MNRAS 277, 1477
Massaro, E., Tramacere, A., Perri, M., et al. 2006 A&A 448, 861
Fossati G., Celotti, A., Chiaberge M., et al. 2000 ApJ 541, 166
Tanihata, C., Kataoka, J., Takahashi, T., et al. 2004 ApJ 601, 795
Massaro, E., Perri, M., Giommi, P., et al. 2004 A&A 423, 935 (a)
Massaro, E., Perri, M., Giommi, P., et al. 2004 A&A 422,103 (b)
Tramacere, A., Massaro, F., Cavaliere, A., in preparation
Blustin, A. J., Page, M. J., Branduardi-Raymond, G., 2004 A&A 417,61
Djannati-Atai, A., Piron, F., Barrau A., et al. 1999m A&A, 350,17
Dwek E., & Krennrich, F., 2005, ApJ, 618, 657