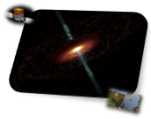
CONSTRAINING BLAZARS DISTANCES WITH COMBINED GEV AND TEV DATA



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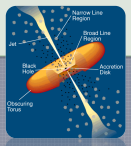
ABSTRACT -- Recently, a new method to constrain the distances of blazars with unknown redshift using combined observations in the GeV and TeV regimes has been developed. The underlying assumption is that the Very High Energy (VHE, E > 100 GeV) spectrum corrected for the absorption of TeV photons by the Extragalactic Background Light (EBL) via photon-photon interaction should still be softer than the gamma-ray spectrum observed by *Fermi*/LAT. The constraints found are related to the real redshifts by a simple linear relation, that has been used to infer the unknown or uncertain distance of blazars. The sample is revised with the up-to-date spectra in both TeV and GeV bands and the method applied to the unknown distance blazar PKS 1424+240 detected at VHE.

TEV BLAZARS...



- BLAZARS: "radio loud" AGNs with a jet almost aligned to the line of sight of the observer
- The typical blazar emission is non thermal and covers the entire e.m. spectrum (Fig. 1)
- It is composed by two bumps:
  - Synchrotron emission
  - High energy emission (Inverse Compton and/or hadronic processes)

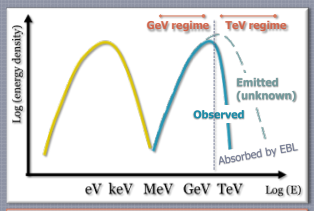
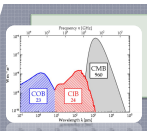


FIG. 1 - SIMPLIFIED SED OF A BLAZAR.

...AND THE EXTRAGALACTIC BACKGROUND LIGHT



- The Extragalactic Background Light (EBL) is optical and infra-red light emitted by stars and reprocessed by dust, red-shifted by the expansion of the Universe
- LARGE UNCERTAINTIES on the EBL determination
- EBL photons INTERACT with VHE photons emitted from cosmological distances via ELECTRON-POSITRON PAIRS PRODUCTION
  - The spectrum of distant blazars can be significantly deformed due to this interaction (Fig. 1)
  - The AMOUNT OF THE ABSORPTION largely depends on the DISTANCE of the emitter

AIM OF THE STUDY: constrain the distance of TeV blazars using TeV and GeV spectral information.

IDEA: use the GeV spectral index measured by *Fermi*/LAT as a LIMITING SLOPE for the TeV emitted spectrum in order to constrain the DISTANCE (REDSHIFT) of a blazar, once assumed an EBL model.

TEST ON BLAZARS WITH KNOWN DISTANCES: A NEW EMPIRICAL LAW

- We define z^* the redshift at which the slope of the de-absorbed TeV spectrum equals the slope measured by Fermi/LAT at lower energies (Fig. 2)
- z^* is an UPPER LIMIT on the source distance, if:
  - No additional peak at VHE
  - Not too "high" EBL model

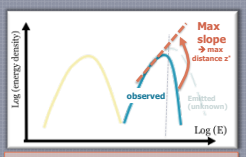


FIG. 2 – MAXIMUM HARDNESS FOR THE DE-ABSORBED SPECTRUM.

Source Name	z_{true}	Γ_{LAT}[1]	z^*	z_{rec}
Mkn 421	0.030	1.81±0.02	0.07±0.02	0.02±0.05
Mkn 501	0.034	1.85±0.04	0.08±0.02	0.02±0.05
1ES 2344+514	0.044	1.57±0.17	0.19±0.03	0.09±0.05
Mkn 180	0.045	1.86±0.11	0.21±0.11	0.11±0.05
1ES 1959+650	0.047	2.09±0.05	0.07±0.03	0.02±0.05
BL Lacertae	0.069	2.37±0.04	0.27±0.14	0.14±0.05
PKS 2005-489	0.071	1.90±0.06	0.18±0.03	0.09±0.05
W Comae	0.102	2.06±0.04	0.24±0.05	0.13±0.05
PKS 2155-304	0.116	1.91±0.02	0.22±0.01	0.11±0.05
RGB J0710+591	0.125	1.28±0.21	0.21±0.06	0.11±0.05
1ES 0806+524	0.138	2.09±0.10	0.23±0.15	0.12±0.05
H 2356-309	0.165	2.10±0.17	0.16±0.07	0.08±0.05
1ES 1218+304	0.182	1.70±0.08	0.21±0.08	0.11±0.05
1ES 1101-232	0.186	1.36±0.58	0.23±0.11	0.12±0.05
1ES 1011+496	0.212	1.93±0.04	0.60±0.18	0.36±0.05
S5 0716+714	0.310[a]	2.15±0.03	0.23±0.10	0.12±0.05
PG 1553+113	0.400	1.66±0.02	0.75±0.07	0.45±0.05
3C 66A	0.444[a]	1.92±0.02	0.39±0.05	0.22±0.05

TABLE 1 – SAMPLE USED IN THIS STUDY. DETAILED REFERENCES IN [4,5].

The method is tested on all the TeV blazars observed above 100 GeV with last generation of Cherenkov telescopes (MAGIC, H.E.S.S. and VERITAS) and detected also by *Fermi*/LAT at lower energies (Table 1). We adopt the EBL model [3].

THE SAMPLE:

- 16 sources with well known redshift
- 2 sources of uncertain redshift (S5 0716+714 and 3C 66A, open markers in Fig. 3)

RESULTS

- All the z^* values lie above the true redshift, z_{true} (bisector of Fig. 3, details on the error calculation in [4,5])
  - Therefore, z^* can be considered an upper limit on the source distance (as expected)
- In addition, the z^* values are related to the real redshifts by a LINEAR RELATION (supported by the study [6])
  - Hence, an ESTIMATE OF THE TRUE REDSHIFT can be done by using the inverse function (once known the TeV spectrum and the *Fermi*/LAT slope)

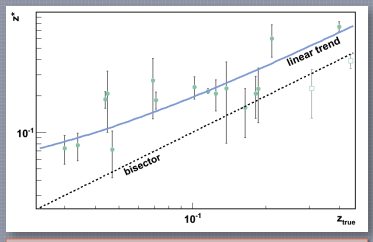


FIG. 3 – z^* VERSUS TRUE REDSHIFT DISTRIBUTION.

$$z^* = A + B\, z_{true}$$

A = 0.036 ± 0.014; B = 1.60 ± 0.14

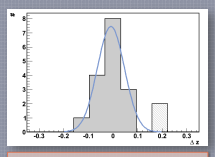


FIG. 4 – DISPERSION BETWEEN THE TRUE AND THE RECONSTRUCTED REDSHIFTS.

CONCLUSIONS – we found an empirical method to estimate blazars distances that can be applied to unknown distance TeV blazars.

APPLICATION THE DISTANCE OF PKS 1424+240

- PKS 1424+240 is a TeV blazar recently discovered by VERITAS [2] and observed by *Fermi*/LAT (Γ_{LAT}=1.83±0.03)
- The REDSHIFT IS UNKNOWN (lack of optical absorption/emission lines)
  - We can apply our empirical relation to give an estimate on its distance

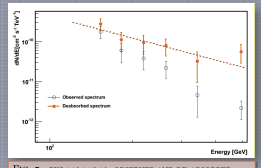


FIG. 5 –PKS 1424+240: OBSERVED AND DE-ABSORBED SPECTRA, ASSUMING THE LIMITING REDSHIFT z^*=0.45.

- The value of z^* is 0.45±0.03
- The corresponding value of the *reconstructed redshift*, obtained by applying the inverse formula: $z_{rec}=(z^* - A)/B$, is z_{rec}=0.26±0.05
- Compatible z_{rec} values are obtained with different EBL models

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