# Spectral candles to measure the Extragalactic Background Light

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The Extragalactic Background Light (EBL) reflects the time integrated history of cosmological star formation. Its shape must reflect the two humps that characterize the spectral energy distributions (SEDs) of galaxies: one arising from starlight and peaking at $\lambda \sim 1\,\mu$m (optical background), and one arising from warm dust emission and peaking at $\lambda \sim 100\,\mu$m (infrared background). However, direct measurements of the EBL are hampered by the dominance of foreground emission (interplanetary dust and Galactic emission), hence the level of EBL emission is uncertain by a factor of several.

One approach to evaluate the EBL emission level has been modeling the integrated light that arises from an evolving population of galactic stellar populations. However, uncertainties in the assumed galaxy formation and evolution scenarios, stellar initial mass function, and star formation rate have led to significant discrepancy among models. Another, more phenomenological approach deduces upper limits on the level of EBL attenuation making basic assumptions on the intrinsic VHE ($E_\gamma > 0.1$ TeV) $\gamma$-ray shape of AGN spectra (i.e., before the VHE photons are affected, on their way to the Earth, by $\gamma\gamma$ interaction with the intervening EBL photons). The only unquestionable constraints on the EBL are model-independent lower limits based on galaxy counts (e.g., Franceschini et al. 2008).

Here we describe a new method to *measure* the EBL that we have recently proposed (Mankuzhiyil et al. 2010). It stems from the consideration that neither the EBL nor the intrinsic VHE $\gamma$-ray spectra of background sources are separately known – only their combination is. Hence, as spectral beacons to measure the EBL at different $z$, one should choose a class of intrinsically bright sources whose spectra can be described by one well-known emission model. We choose BL Lac objects, i.e. AGNs whose relativistic jets point directly toward the observer so their luminosities are boosted by a large factor and dominate the source flux with their Synchrotron-Self-Compton (SSC) emission: and within BL Lacs, we specifically propose to use the sub-class of high-frequency-peaked BL Lacs (HBLs) because their Compton peaks fall within the typical operation range of Cherenkov telescopes – unlike for other types of BL Lacs. For a given source, our method involves using a simultaneous broad-band SED that samples the optical ($E_\gamma \sim$ eV), X-ray ($E_\gamma \sim$ keV), high-energy (HE: $E_\gamma > 0.1$ GeV) and VHE ($E_\gamma > 0.1$ TeV) $\gamma$-ray bands. Simultaneous data are crucial here, considering the strong and rapid variability displayed by most HBLs. A given observed SED will be best-fitted, from optical through HE $\gamma$-rays, with an SSC model. (Under reasonable circumstances, only VHE photons are affected by EBL attenuation.) Extrapolating such best-fitting SED model into the VHE regime, we shall assume the latter to represent the source's intrinsic VHE $\gamma$-ray emission. Contrasting measured vs. intrinsic emission leads to a determination of the universe's $\gamma\gamma$ opacity to VHE photons.

To show the potential of our method, we apply this procedure to the simultaneous SED data set of the southern HBL source PKS 2155-304, located at a redshift $z = 0.116$. The data and resulting best-fit SSC model (from optical through HE $\gamma$-rays) are shown in Fig.(1). The extrapolation of the model into the VHE $\gamma$-ray range clearly lies below the observational H.E.S.S. data, progressively so with increasing energy. We attribute this effect to EBL attenuation, $F_{\rm obs}(E;\, z) = F_{\rm em}(E;\, z)\, e^{-\tau_{\gamma\gamma}(E;\, z)}$. The corresponding values of $\tau_{\gamma\gamma}(E;\, z)$ for $E$=0.23, 0.44, 0.88, 1.70 TeV and a source redshift $z$=0.116 are, respectively, $\tau_{\gamma\gamma} = 0.12$, 0.48, 0.80, and 0.87. In Fig.(2) we compare our measured $\tau_{\gamma\gamma}$'s with some recent results (see references in Mankuzhiyil et al. 2010). Our values most closely agree with the corresponding values of Franceschini et al. (2008), which represent the light contributed by the galaxies' stellar populations prior to the epoch corresponding to source redshift $z$ – i.e., the minimum amount (the guaranteed level) of EBL.

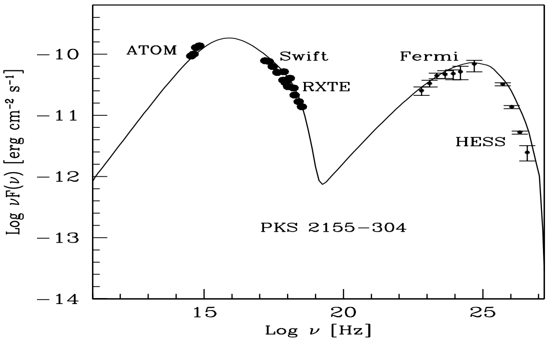

Figure 1: Data and best-fit SSC model of the SED of PKS 2155-304. See Mankuzhiyil et al. (2010) for details.

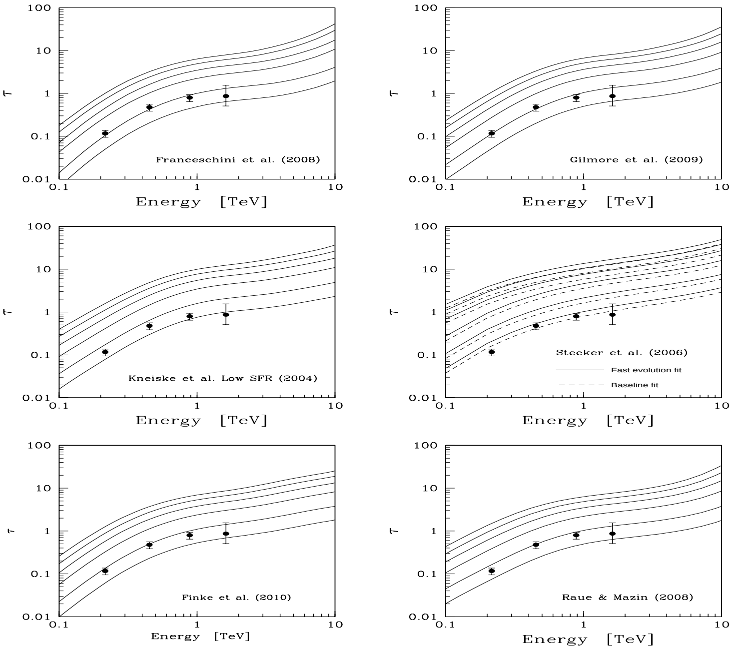

Figure 2: Values of $\tau_{\gamma\gamma}(E;\, z = 0.116)$ derived from comparing the simultaneous observed and 'intrinsic' VHE $\gamma$-ray emission of PKS 2155-304. Error bars on $\tau_{\gamma\gamma}$ reflect those on the VHE data. For redshifts $z = 0.05$, 0.1, 0.2, 0.3, 0.4, 0.5 (from bottom up), the curves represent $\tau_{\gamma\gamma}(E)$ according to recent EBL calculations (see Mankuzhiyil et al. 2010 for details).

## References

[1] A. Franceschini, G. Rodighiero, M. Vaccari 2008, A&A, 487, 837

[2] N. Mankuzhiyil, M. Persic, F. Tavecchio 2010, ApJ, 715, L16

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