Constraining the Extragalactic Background Light using H.E.S.S Observations of M87

P. Zilberman, V. Barbosa Martins, I. Lypova, M. Naurois, S. Ohm, D. Parsons, S. Wagner
on behalf of the HESS collaboration

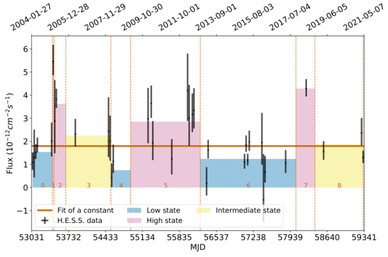
Presenter: Perri Zilberman

Introduction

- The diffuse Extragalactic Background Light (EBL) consists of total emitted light from all stars throughout history of the Universe.
- The EBL can be used to obtain important information about cosmic history, such as galactic and stellar evolution (Raue & Meyer 2012, Franceschini et al. 2008, Finke et al. 2010).
- Due to pair production with EBL, TeV spectra of extragalactic sources are attenuated.
- This can be used to measure the EBL. Typically, high redshift sources used for this.
- Messier 87 (M87) is a nearby (z ~ 0.0044) radio galaxy, with visible TeV γ emissions. From current EBL models (Franceschini et al. 2008, Finke et al. 2010, Dominguez et al. 2011), EBL attenuation in M87's TeV γ-ray spectrum should become detectable with H.E.S.S at >∼ 10 TeV
- Studying EBL absorption of M87's TeV γ-ray spectrum would be excellent probe of local EBL at mid-IR wavelengths.

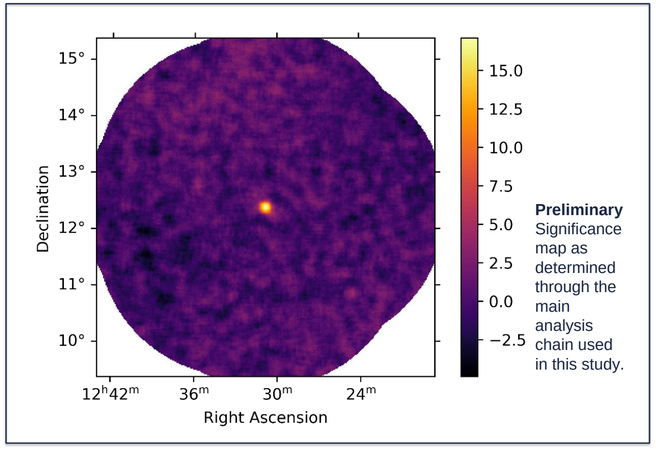
Observations

- Runs from 2004 - 2021 split into "low state," "intermediate state," and "high state" using a Bayesian Blocks analysis
- Only consider high states due to the shape of M87's spectrum varying with the state as well as the need for as many very high energy γ as possible.



	High State 1	High State 2	High State 3
Start Date – End Date	08.03.2005 – 14.05.2005	12.02.2010 – 22.06.2012	18.04.2018 – 24.04-2018
Live Time	18 hr 36 min	18 hr 42 min	16 hr 22 min
Excess Counts*	285	183	262
Excess Rate* (hr^{-1})	15.3	9.8	16.0

*The specific number of excess counts will slightly vary depending on analysis methods used



Preliminary
Significance map as determined through the main analysis chain used in this study.

Spectral Models

$$\phi(E) = \underbrace{\phi_0 \cdot \left(\frac{E}{E_0}\right)^{-\Gamma}}_{\text{Power Law}} \cdot \underbrace{exp(-\lambda E}_{\text{Exponential Cutoff}} \underbrace{- \alpha_{norm}\tau(E,z))}_{\text{EBL Absorption}}$$

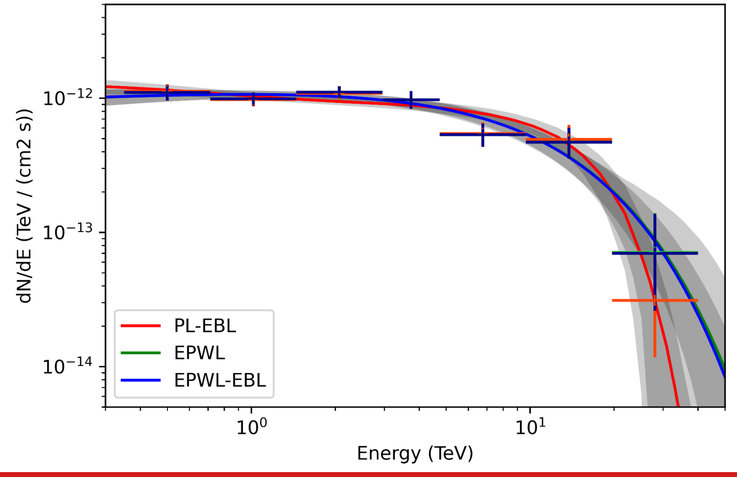
Consider four variations of above general model:

Pure Power Law (PL) - Fix λ = 0 TeV^{-1} and α_{norm} = 0

Exponential Cutoff Power Law (EPWL) - Fix α_{norm} = 0

Power law with EBL Attenuation (PL-EBL) - Fix λ = 0 TeV^{-1}
*The EBL optical depth τ (E, z) is model dependent. We consider three EBL models: Franceschini et al. 2008 (Fran08), Finke et al. 2010 (Finke10), Dominguez et al. 2011 (Dom11). Only results from Fran08 presented here.

Exponential Cutoff Power Law with EBL Absorption (EPWL-EBL) – Full spectral model

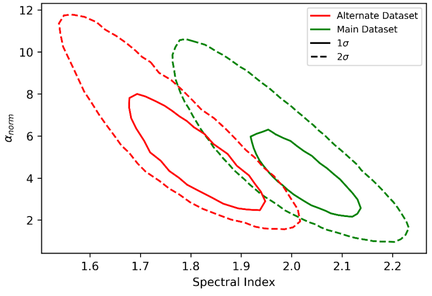


Preliminary
Fit PL-EBL, EPWL, and EPWL-EBL spectral models to our high state dataset.

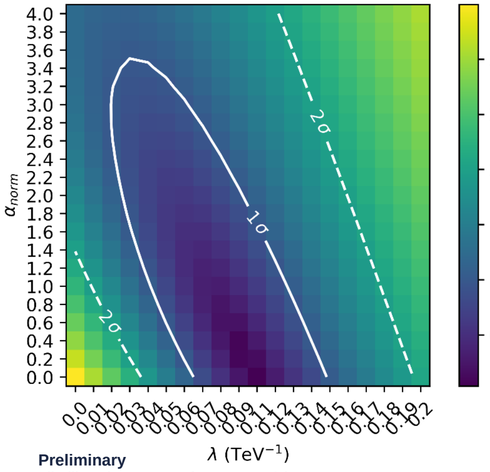
	Γ	α_{norm}	λ (TeV^{-1})	σ preferred at to PL
PL	2.27 ± 0.05	-	-	-
EPWL	1.90 ± 0.09	-	0.11 ± 0.03	3.50
PL-EBL (Fran08)	2.04 ± 0.08	3.81 ± 1.55	-	3.27
EPWL-EBL (Fran08)	1.90 ± 0.10	0.05 ± 1.96	0.10 ± 0.04	3.50

Comparison with Another High State Dataset

An alternative high state definition considers runs with an excess rate above a threshold. This dataset shares around ~ 30% of runs with the main dataset.



Preliminary
Likelihood contours of αnorm vs. λ of EPWL-EBL fits using the Fran08 model for the two datasets. The α_{norm} agree between the two datasets, which is expected from curvature due EBL absorption.



Preliminary
Likelihood contours of α_{norm} vs. λ in our EPWL-EBL fit using the Fran08 model.

Discussion & Conclusion

- **Curvature in M87's high state spectrum is preferred at > 3σ to no curvature.**
- **Location of curvature is consistent with location of curvature due to EBL attenuation.**

- Can not distinguish between intrinsic curvature in M87's spectrum, curvature purely due to EBL attenuation, or a combination of the two.
- Amount of curvature independent of PL spectral index.
- For PL-EBL fits, we find an α_{norm} > 1. This corresponds to more absorption than predicted by EBL models.
- For EPWL-EBL fits, find a preferred α_{norm} ~ 0, but uncertainties are large enough to include α_{norm} = 1 within 1σ.

Acknowledgements

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https://www.mpi-hd.mpg.de/hfm/HESS/pages/publications/auxiliary/HESS-Acknowledgements-2021.html

References

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