Determination of the extragalactic background light spectral energy distribution with H.E.S.S.

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H.E.S.S.

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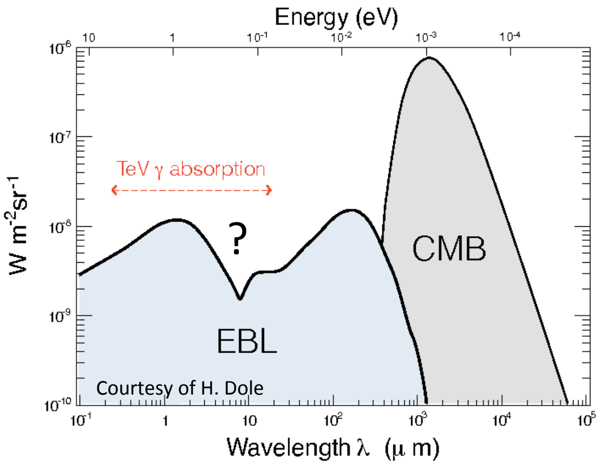
lapp

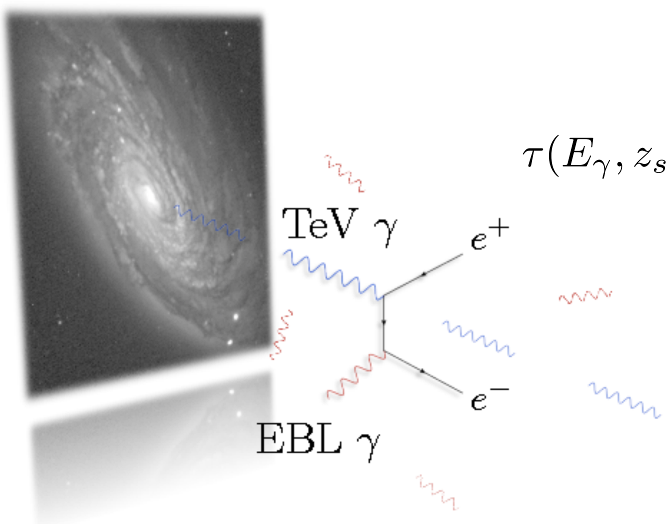
Extragalactic background light and γ-ray absorption



- **What is the EBL ?**
  Background photon field (IR to UV) originating from starlight and dust re-emission.
  Direct measurements are difficult

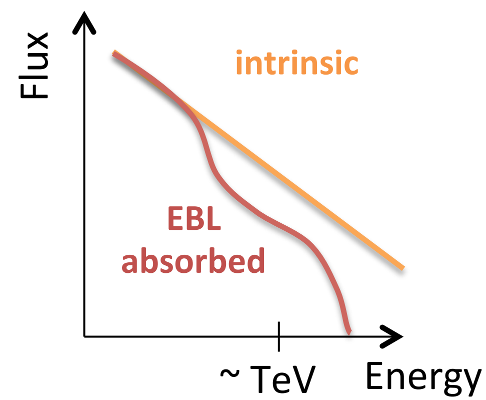
- **EBL absorbs γ rays by pair creation**
  Universe not transparent to γ rays over extragalactic distances : **optical depth τ**

  Attenuation pattern in VHE spectra of distant sources



$$\tau(E_\gamma, z_s) = c \int_0^{z_s} dz \frac{dt}{dz} \int_0^2 d\mu \frac{\mu}{2} \int_{\epsilon_{thr}}^{\infty} d\epsilon \frac{dn_{EBL}(\epsilon, z)}{d\epsilon} \sigma_{\gamma\gamma}\left(E_\gamma(1+z), \epsilon, \mu\right)$$

$$\Phi_{obs}(E_\gamma) = \Phi_{int}(E_\gamma) e^{-\tau(E_\gamma, z_s)}$$



High Energy Stereoscopic System

- **H.E.S.S. phase I :**
  - 4 telescopes with a 107 m^2 dish
  - Cameras with 960 PMTs
  - Field of view 5°
  - Energy range : 100 GeV to 50 TeV (~10% resolution)

- **H.E.S.S. phase II :**
  - Additional 5^{th} telescope, 600 m^2
  - Camera with 2048 PMTs
  - Field of view 3.5°
  - **Energy threshold lowered to ~30 GeV**

See numerous H.E.S.S. contributions at this conference…

Previous EBL study with H.E.S.S.

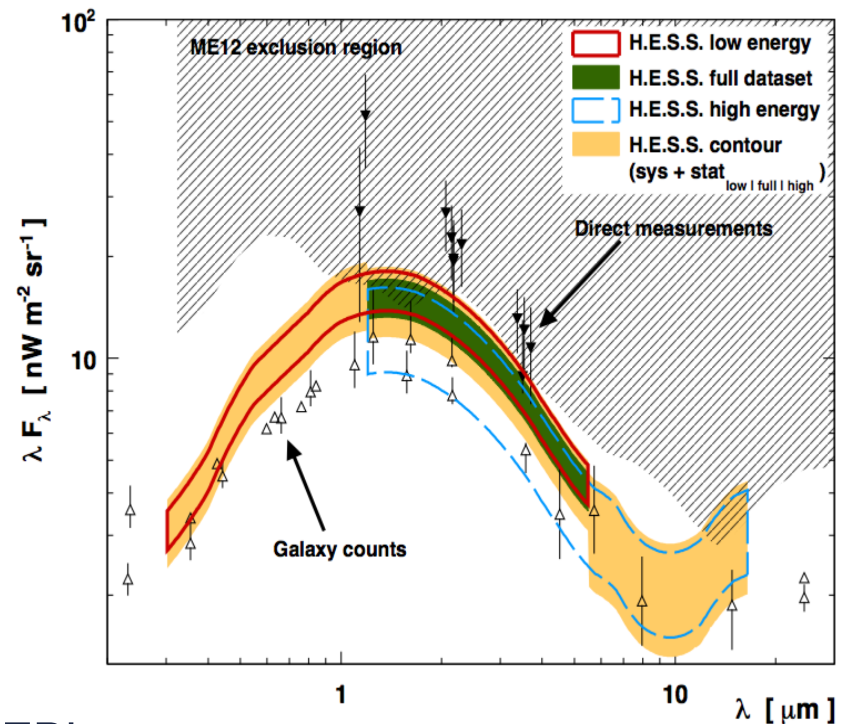
- **Model dependent approach**: model of Franceschini et al. 2008 (FR08)
- **Fixed shape**, normalization only
  - α= 0 : no EBL
  - α= 1 : EBL normalized to FR08
- EBL detection at 8.8 σ :

$\alpha = 1.27^{+0.18}_{-0.15}$ (stat) +/- 0.25 (syst)

- **Now, different approach :**

  Can we also determine the shape of the EBL with H.E.S.S. in a model independent way ?

H.E.S.S. collaboration (2013), A&A, 550, A4



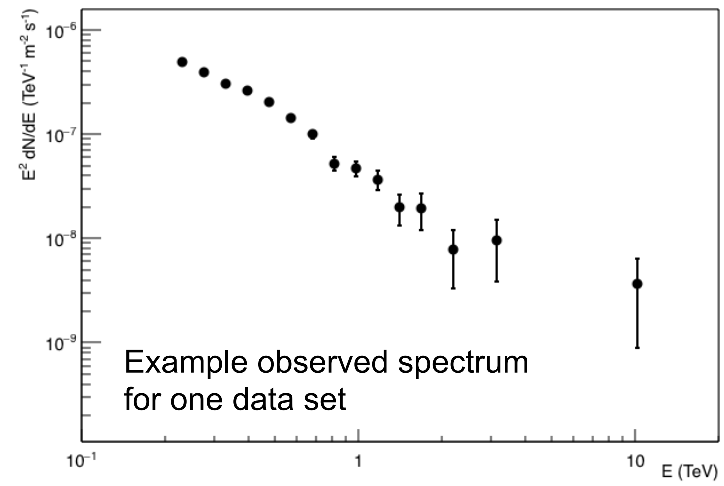
Spectra : the essential ingredient

$$\Phi_{obs}(E_\gamma) = \Phi_{int}(E_\gamma) e^{-\tau(E_\gamma, z_s)}$$

Measured

Hypotheses needed

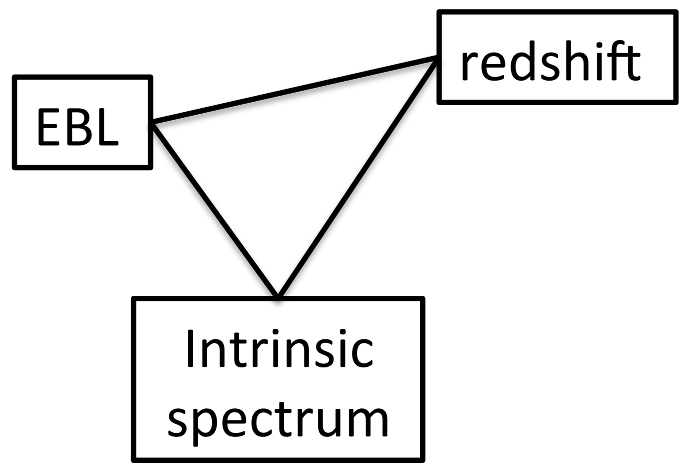
EBL information



- **Difficulty :** disentangle EBL effect and intrinsic curvature
  - Simple assumptions on intrinsic blazar spectra fitted :

Power law : $\dfrac{dN}{dE} \propto E^{-\alpha}$

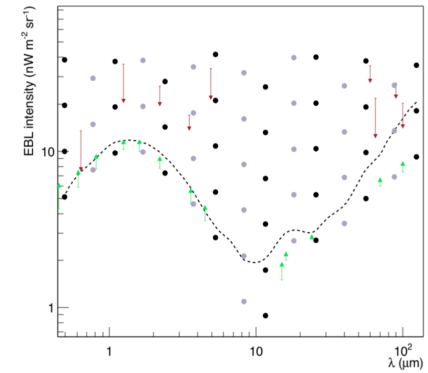
Log parabola : $\dfrac{dN}{dE} \propto E^{-\alpha-\beta\log(E)}$



EBL shape : from splines to envelopes

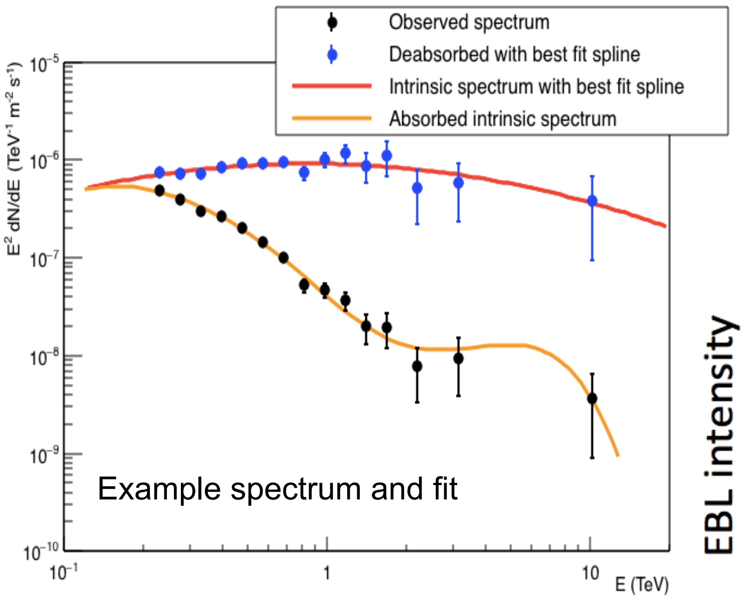
H.E.S.S. spectrum

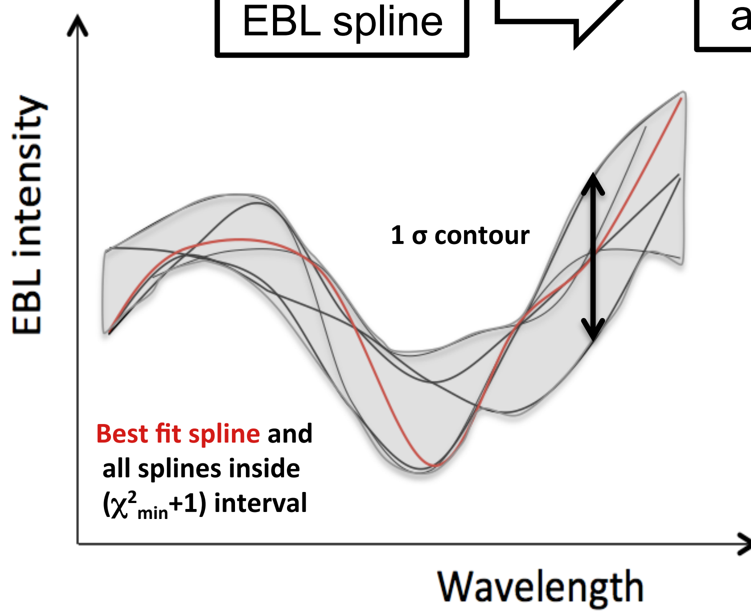
Grid scan :
Fit intrinsic + EBL absorption with every shape on the grid



Best Fit EBL spline

Envelope (χ^2_{min}+1) around best fit spline





Combine all data sets

A grid to test local EBL shapes

- **Local (z=0) EBL shapes as splines inside a grid**
  - Two grids shifted against each other to reduce constraints on shapes

$$\Phi_{obs}(E_\gamma) = \Phi_{int}(E_\gamma)e^{-\tau_i(E_\gamma, z_s)}$$

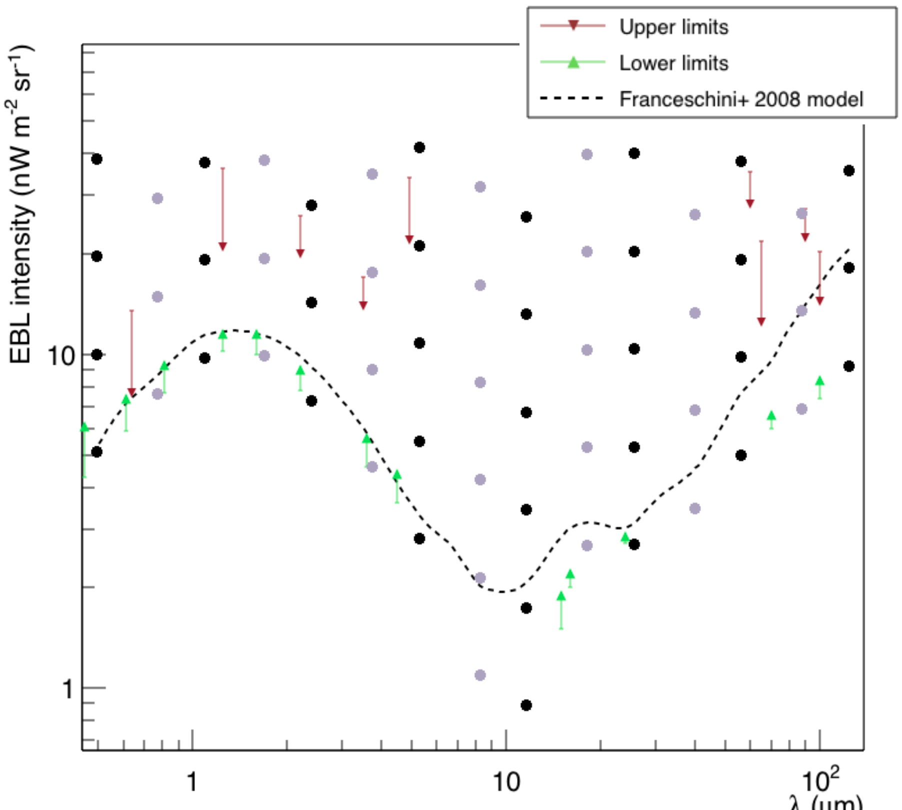
Optical depth computed for every shape on the grid

- **i = 0 …116,640 : # of spline tested**
  - Large variety of EBL shapes allowed

- **τ also depends on EBL evolution :** evolution hypotheses needed
  - Evolution function extracted from FR08

  No significant impact on results compared to simple effective scaling

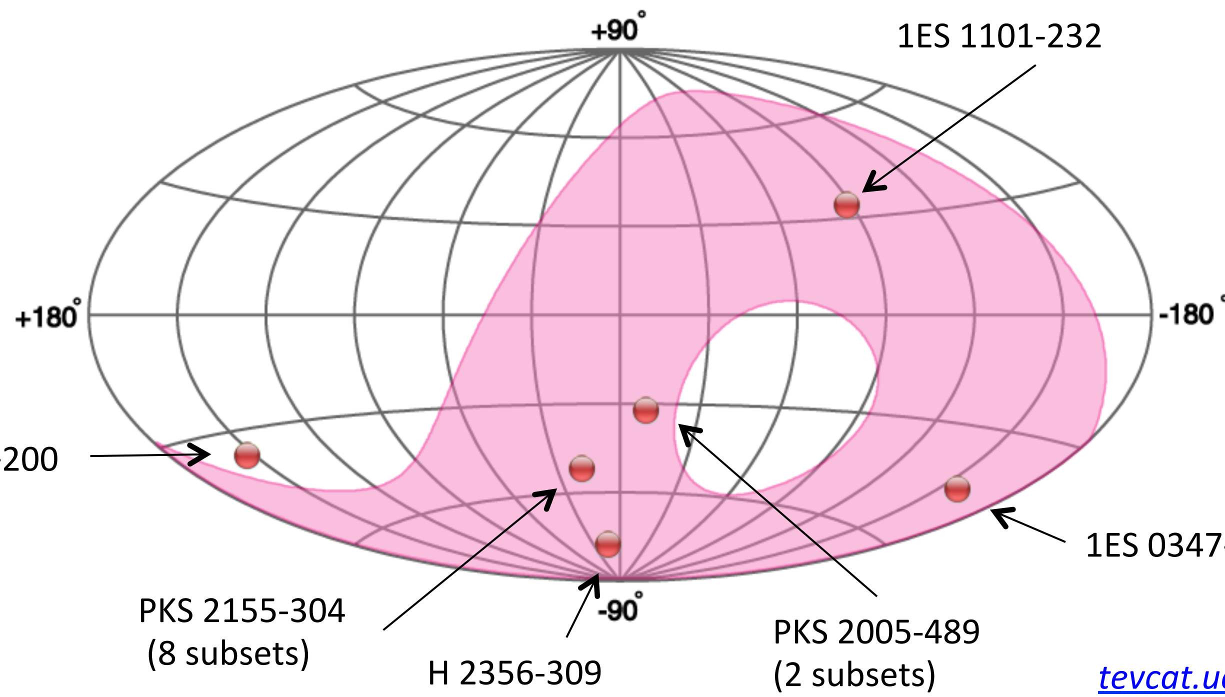
Similar model independent approaches :
Mazin & Raue (2007) A&A 471(2), 439-452.
Meyer et al. (2012) A&A, 542, A59.
Biteau & Williams (2015), arXiv:1502.04166



Data sample : high significance H.E.S.S. blazars

- Cut on significance >10 σ detection with H.E.S.S.
- 14 data sets with 6 sources (for now !)
- Redshift coverage : z from 0.071 to 0.188

Only H.E.S.S. phase-I data used here



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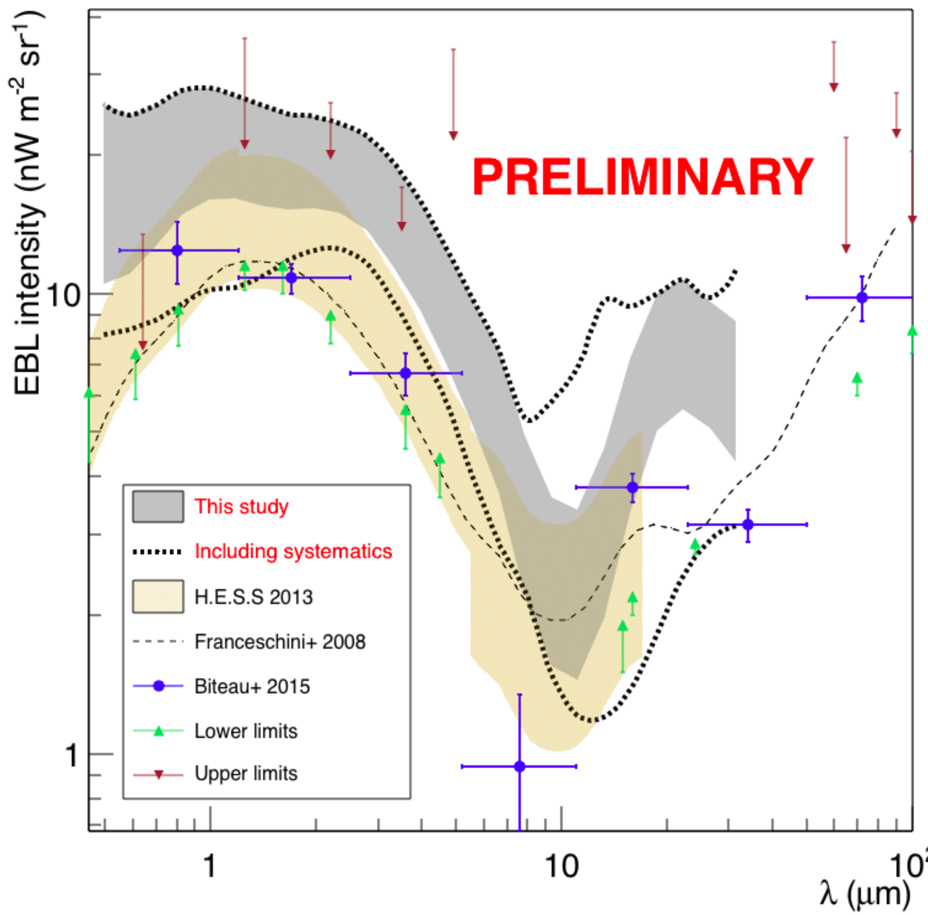
Preliminary results

- **The shape of the EBL is accessible**
  - **Grey area** : combined statistical contour with no assumptions on shape and normalization !
  - **Systematics** : largest contour including x-check analysis **+** relative exclusion of several data sets



Summary and perspectives

- **This study :** a 1st model-independent comprehensive study of the EBL with H.E.S.S.

Final study includes :

- **More sources :**
  - Stronger collective signal
  - Better redshift coverage
- **H.E.S.S. II data :**
  - More leverage on short wavelength range
- **Better assessment of systematics errors**
  - Adaptive grids : from coarse to fine
  - Other intrinsic spectral shapes assumptions
  - Influence of EBL evolution
- **Related study on intrinsic spectra of blazars**

Coming soon…