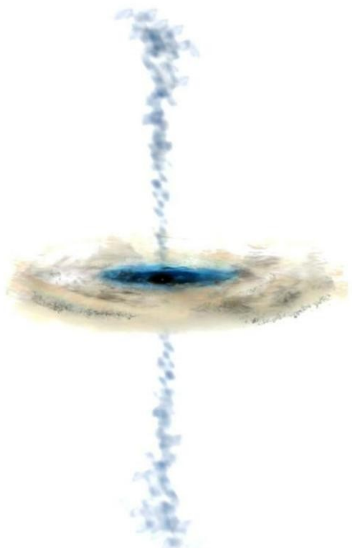
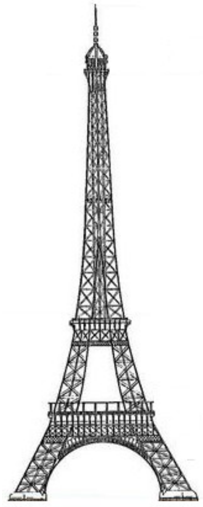
Estimation of neutrino spectra from AGNs using measured VHE γ-ray spectra



Garabed HALLADJIAN

December 9th, 2008

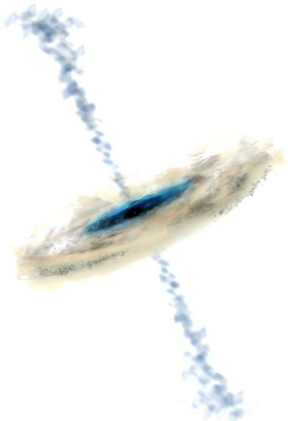
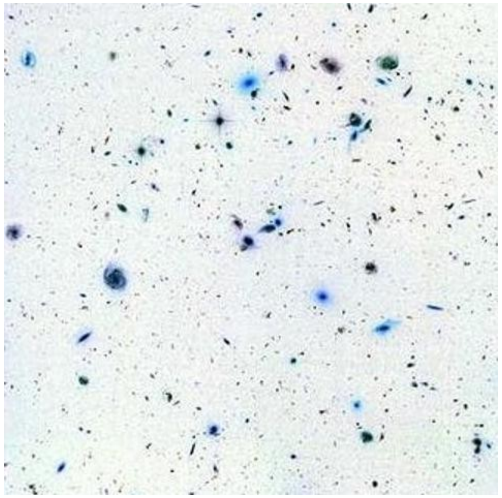
γ-cr-ν workshop, PARIS



Presentation plan

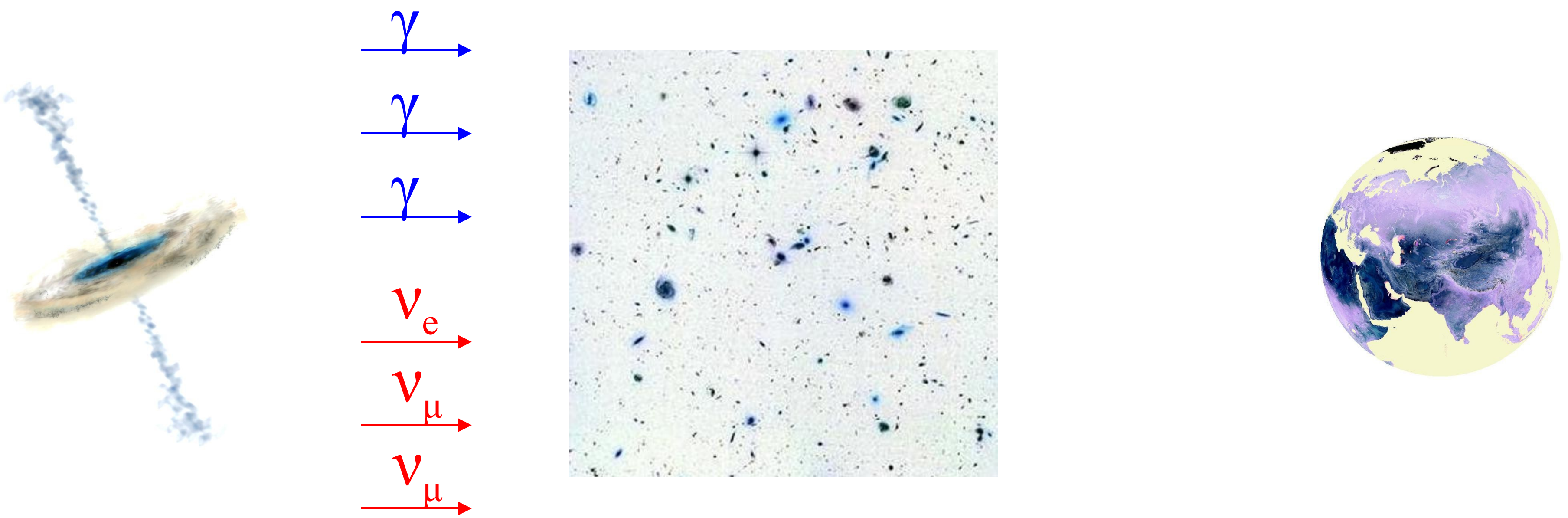
- Hypotheses & Aim
- Extra-Galactic Background Light (EBL)
  - Definition & characteristics
  - Interaction with VHE γ-rays
- Optical depth
  - Definition & Analyses
- Conversion of γ-ray energy spectrum to ν energy spectrum
- ν energy spectra for 1ES1101-232
- ν energy spectra index for different AGNs
- Questions

Hypotheses

AGN	Intergalactic Space	Earth
		

Hypotheses

1. γ-rays & ν emitted by π^0 decay (p-p interaction)



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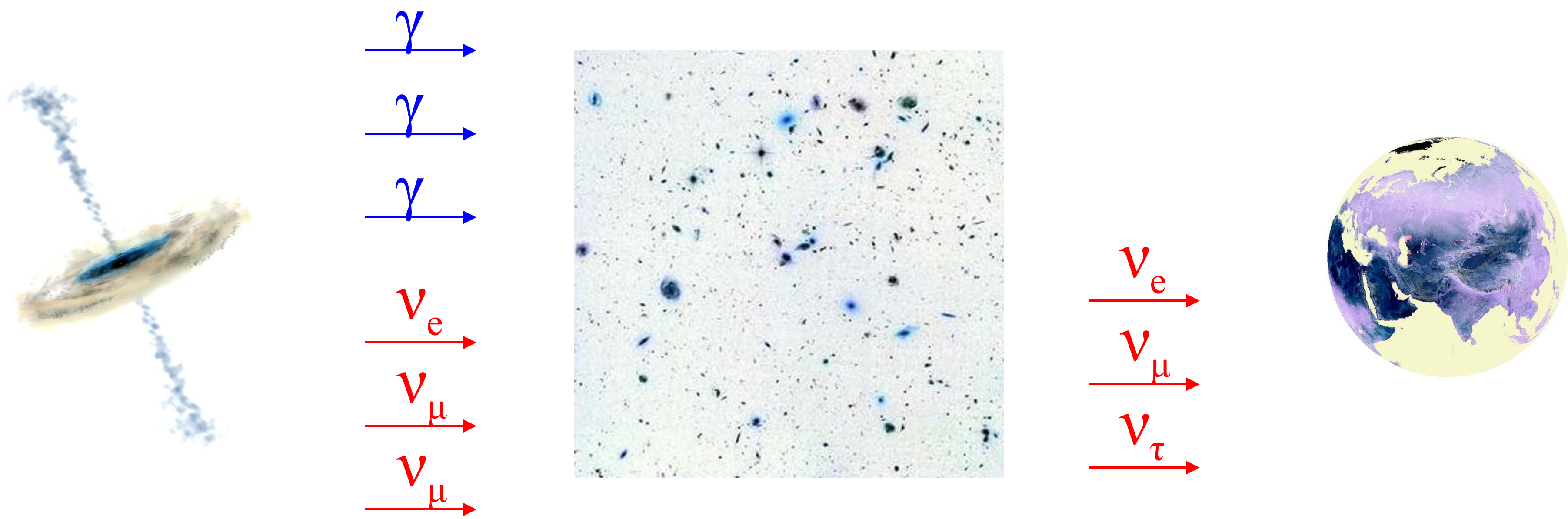
1. γ-rays & ν emitted by π^0 decay (p-p interaction)
2. ν oscillation phenomena



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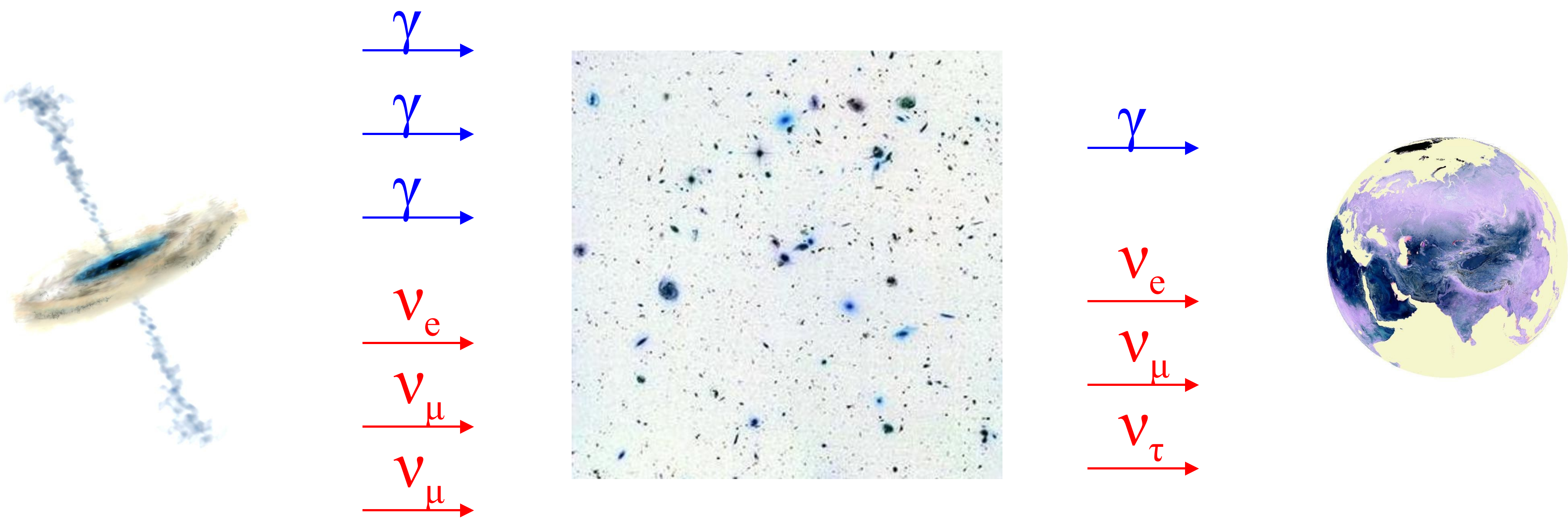
1. γ-rays & ν emitted by π^0 decay (p-p interaction)
2. ν oscillation phenomena
3. γ-rays absorption while they travel through space



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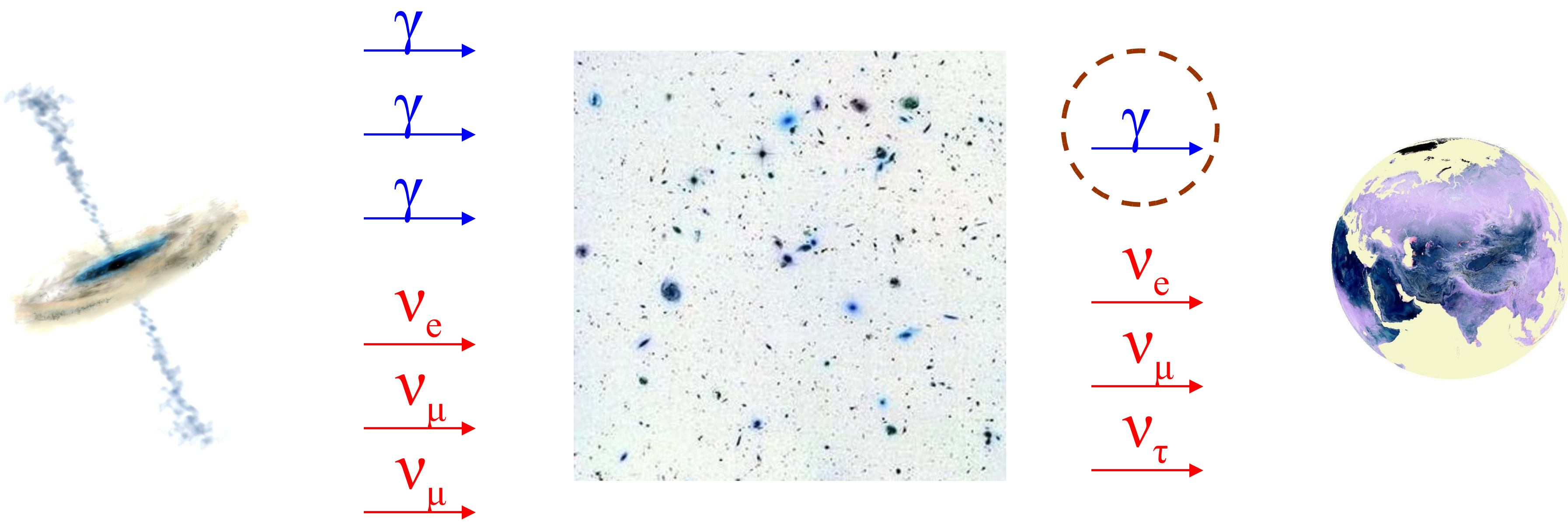

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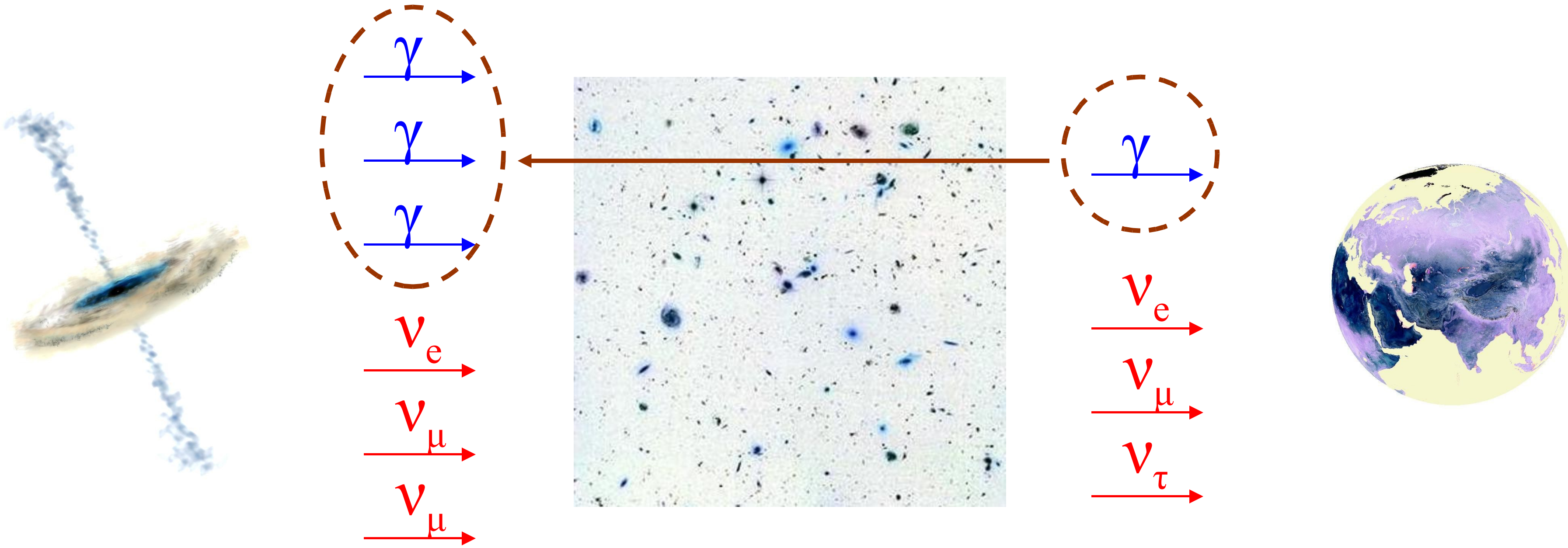

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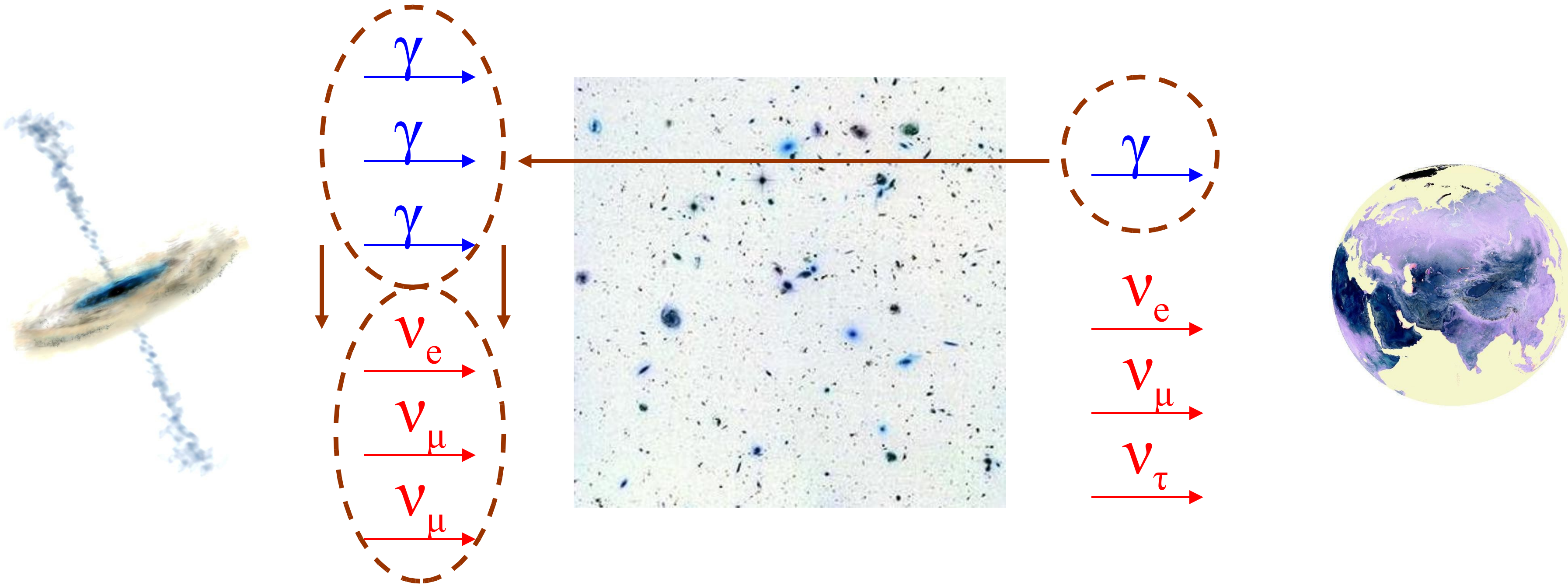

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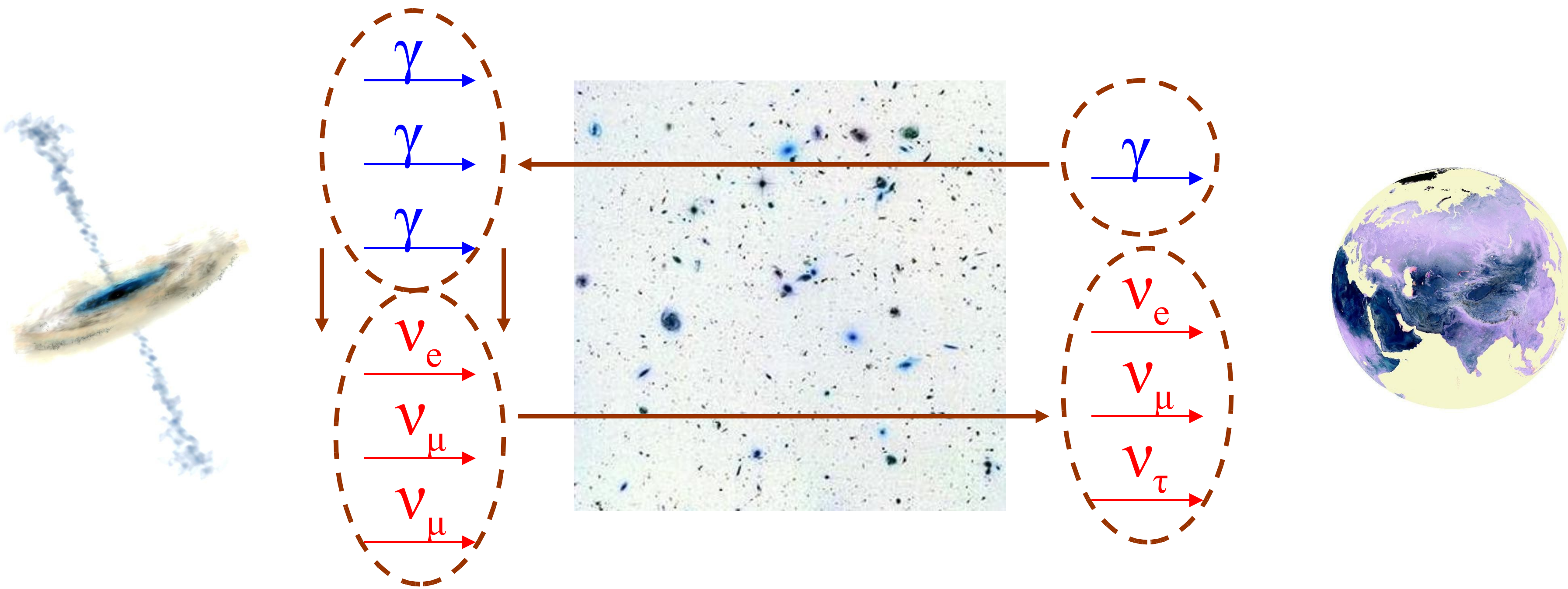
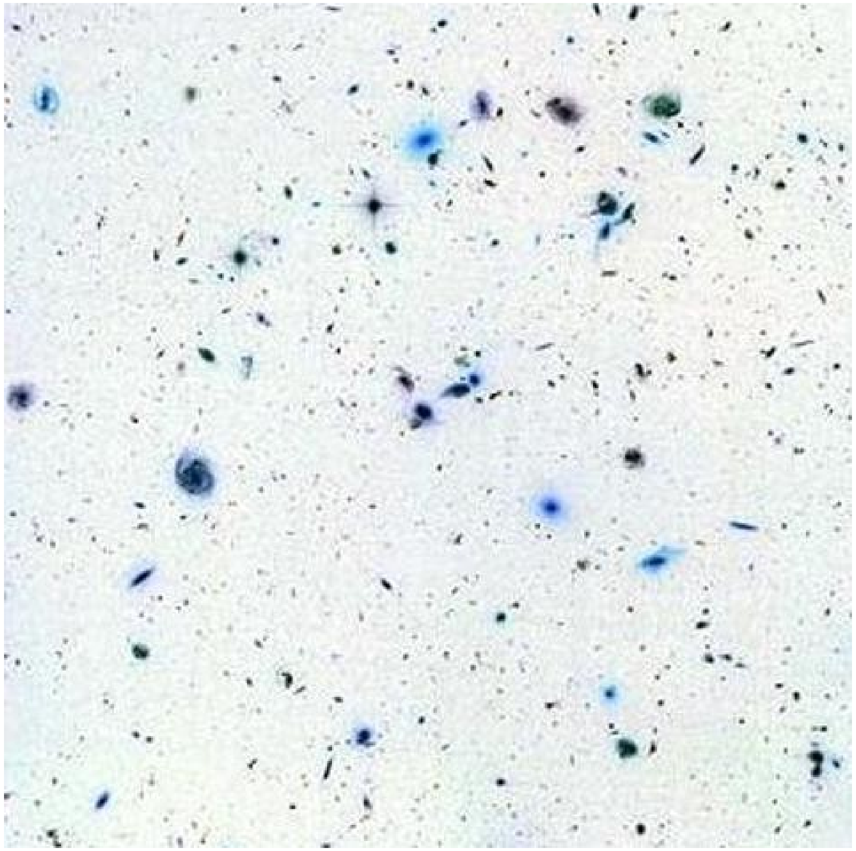
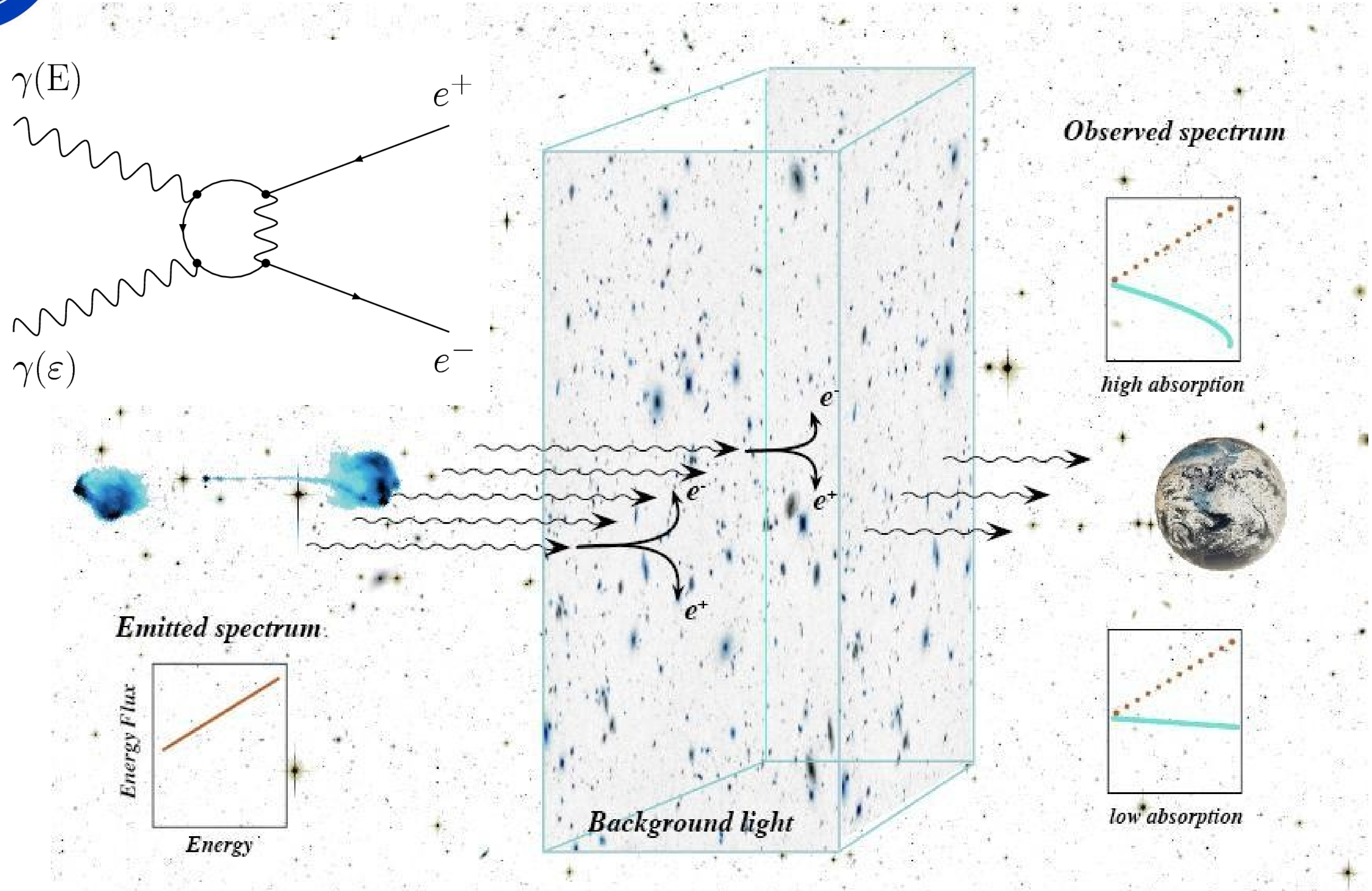


Extra-Galactic Background Light (EBL)

- EBL is the light emitted from all objects in the Universe during its entire history
- It forms a diffused sea of photons that permeates intergalactic space

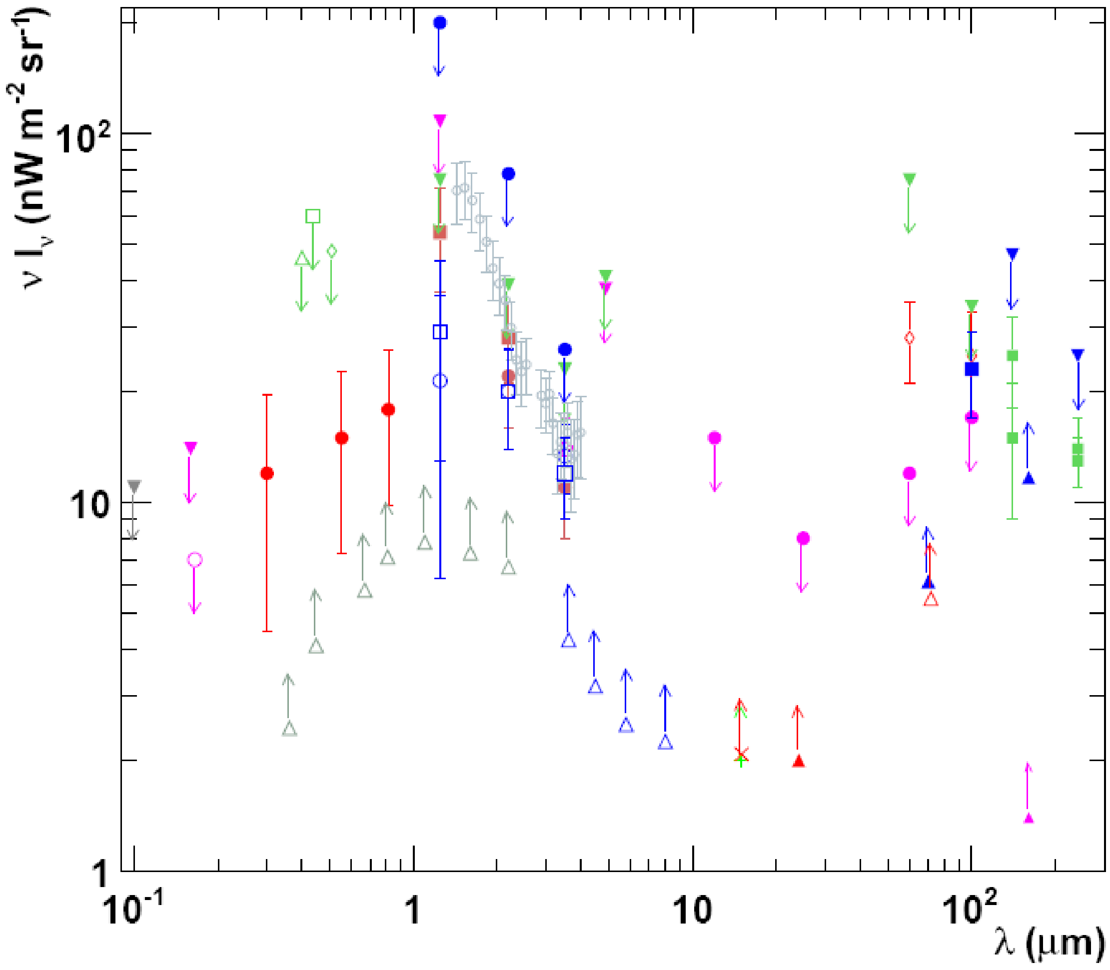


γ-ray attenuation by EBL



$$\gamma(E) + \gamma(\varepsilon) \rightarrow e^{+} + e^{-}$$

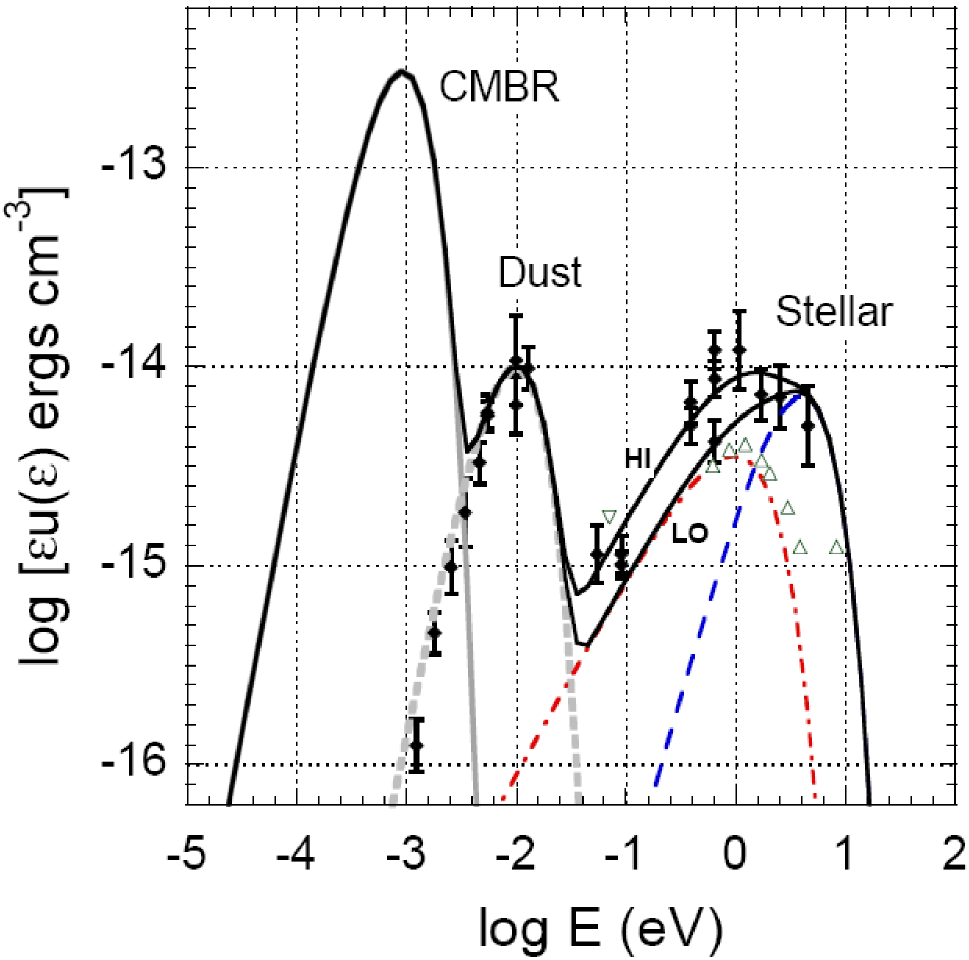
EBL (different experiments)



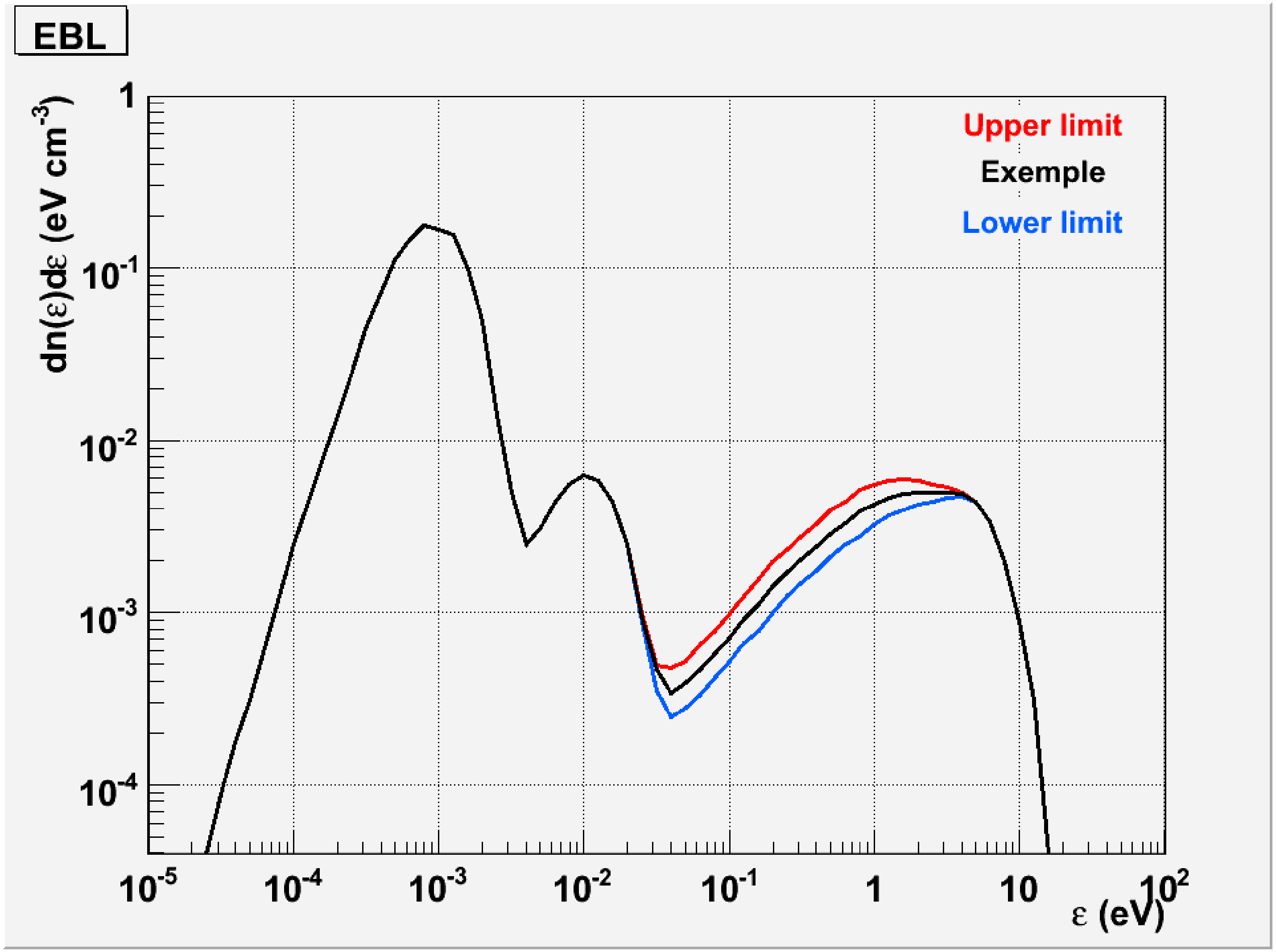
EBL spectra (Upper & lower limits)

On Gamma Ray Burst and Blazar AGN Origins of the Ultra-High Energy Cosmic Rays in Light of First Results from Auger

Charles D. Dermer



EBL spectra



EBL
dn(ε)dε (eV cm^{-3})
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
10
10^{2}
ε (eV)
Upper limit
Exemple
Lower limit

Optical depth τ

The optical depth expresses the quantity of light removed from a beam by scattering or absorption during its path through a medium. If $\mathbf{I_0}$ is the intensity of radiation at the source and $\mathbf{I}$ is the observed intensity after a given path, then optical depth $\boldsymbol{\tau}$ is defined by the following equation:

$$I = I_0 \, e^{-\tau}$$

Optical depth τ

$$\tau(E,z)=\int_0^z dz' \int_{-1}^{+1} d\mu \int_{\varepsilon'_{th}}^{\infty} d\varepsilon' \left[\frac{dl}{dz'}\times\frac{1-\mu}{2}\times n_{\varepsilon}(\varepsilon',z') \text{¿} \sigma_{\gamma\gamma}(E'_{\gamma},\varepsilon',\mu)\right]$$

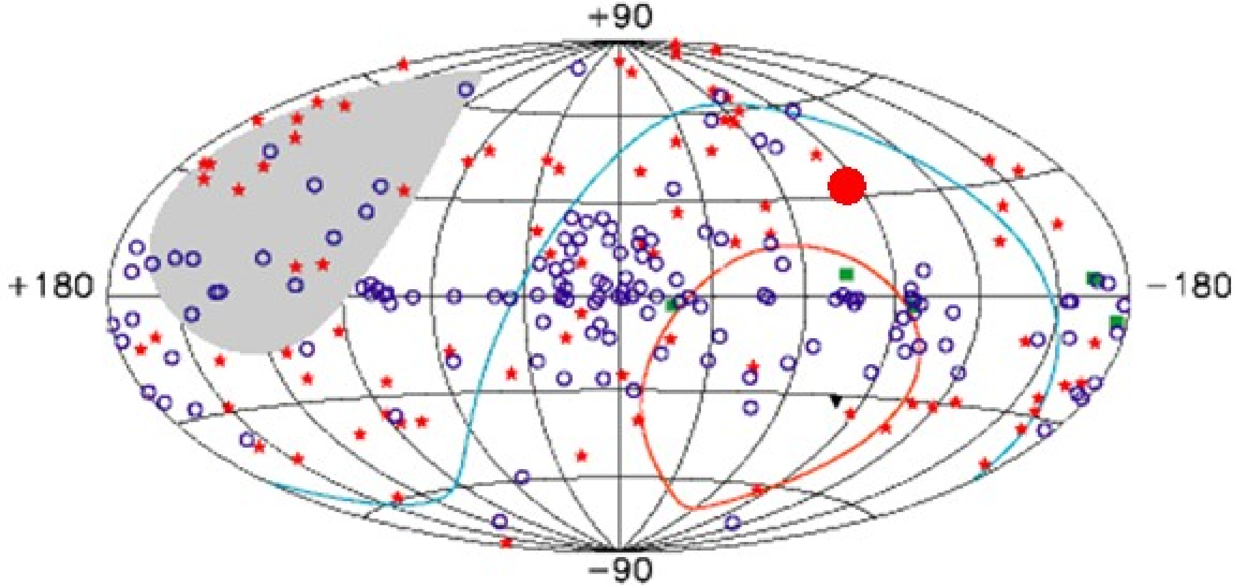
$$\frac{dl}{dz}=\frac{R_H}{(1+z)\left\{(1+z)^2(\Omega_m z+1)+z(2+z)\left[(1+z)^2\Omega_r-\Omega_\Lambda\right]\right\}^{1/2}}$$

$$\sigma(E,\varepsilon,\mu)=\frac{3\sigma_T}{16}(1-\beta^2)\left[2\beta(\beta^2-2)+(3-\beta^4)\ln\left(\frac{1+\beta}{1-\beta}\right)\right]$$

$$\beta=\sqrt{1-\frac{\varepsilon_{th}}{\varepsilon}} \qquad \varepsilon_{th}(E,\mu)=\frac{2m_e^2}{E(1-\mu)} \qquad \begin{aligned}\varepsilon'_{th}&=\varepsilon_{th}(E',\mu)\\ E'&=E(1+z')\end{aligned}$$

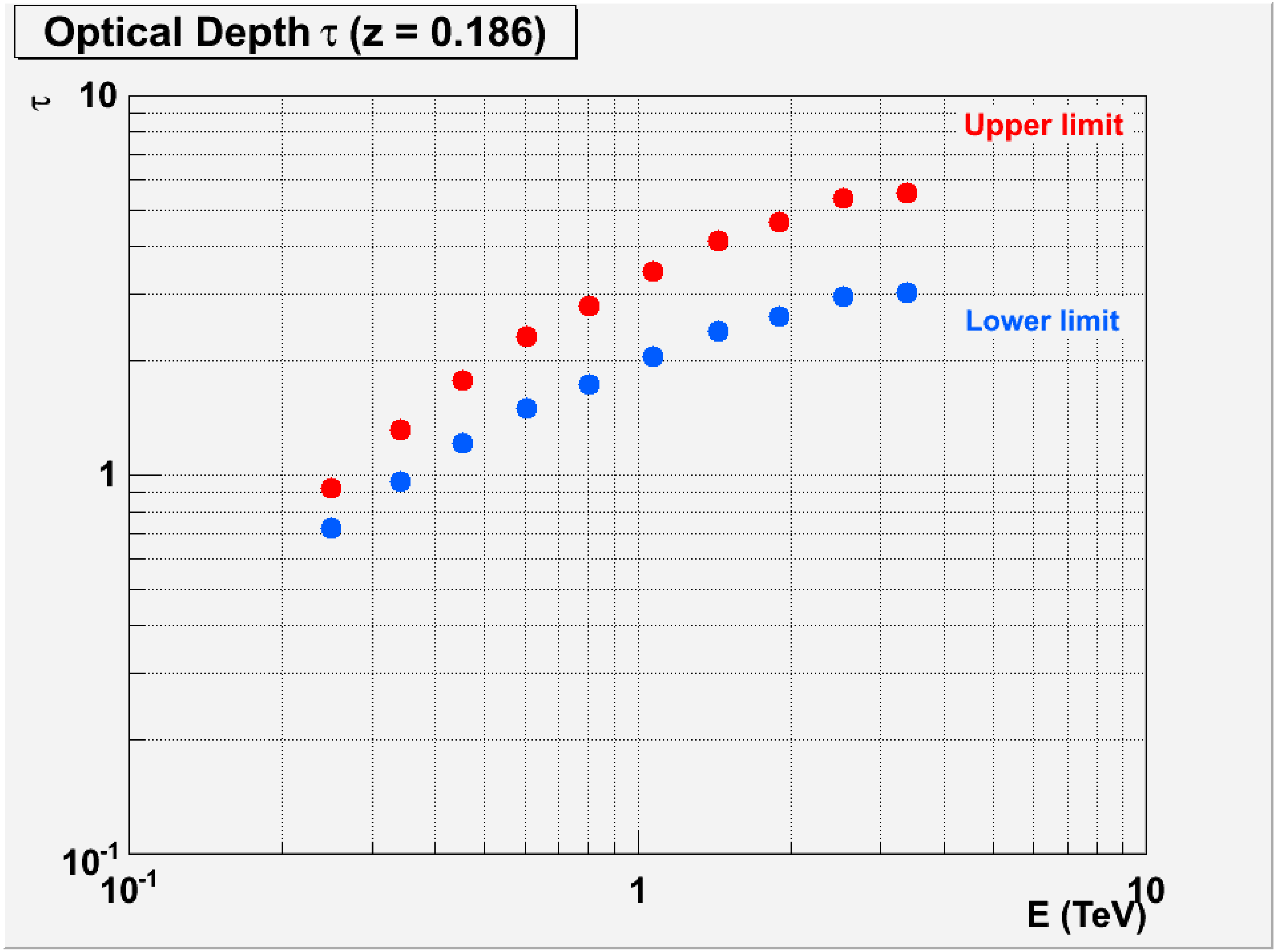
Simultaneous constraints on the spectrum of the extragalactic background light and the intrinsic TeV spectra of Mrk 421, Mrk 501, and H1426+428
Eli Dwek & Frank Krennrich

1ES1101-232



z = 0.186 Dec = -23°29'31'' Vis = 0.632017

Optical Depth τ



Optical Depth τ

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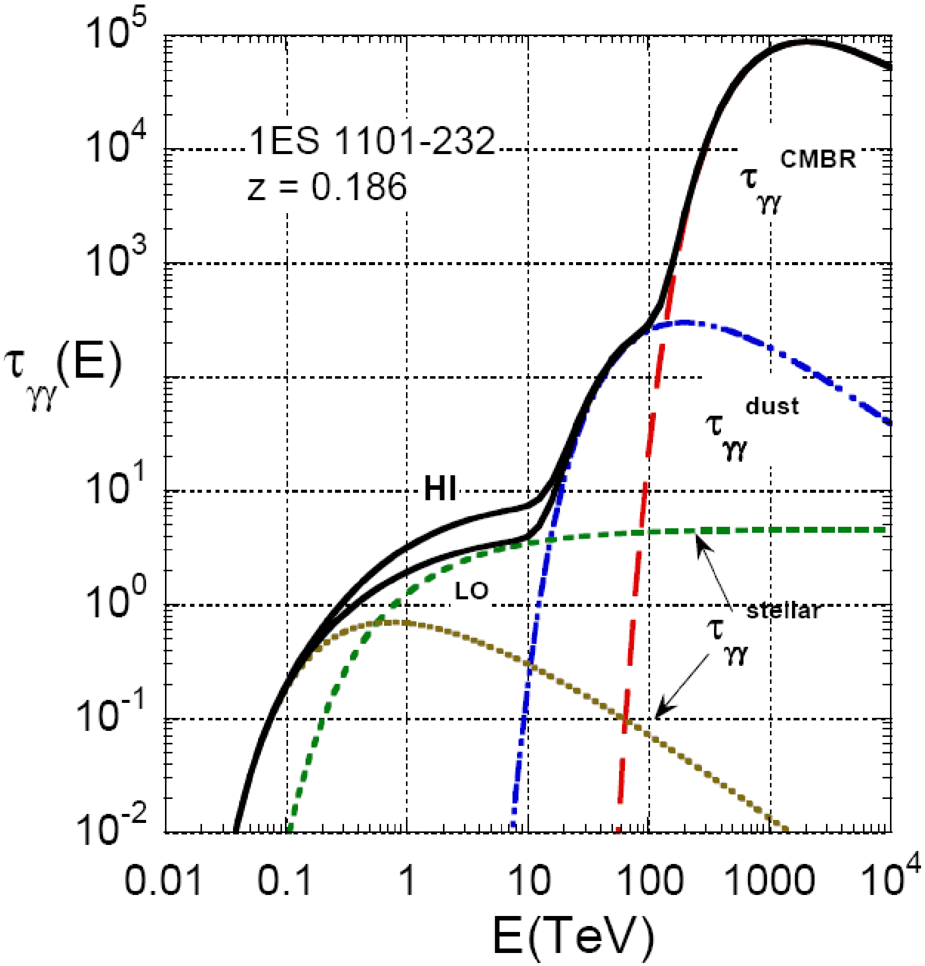
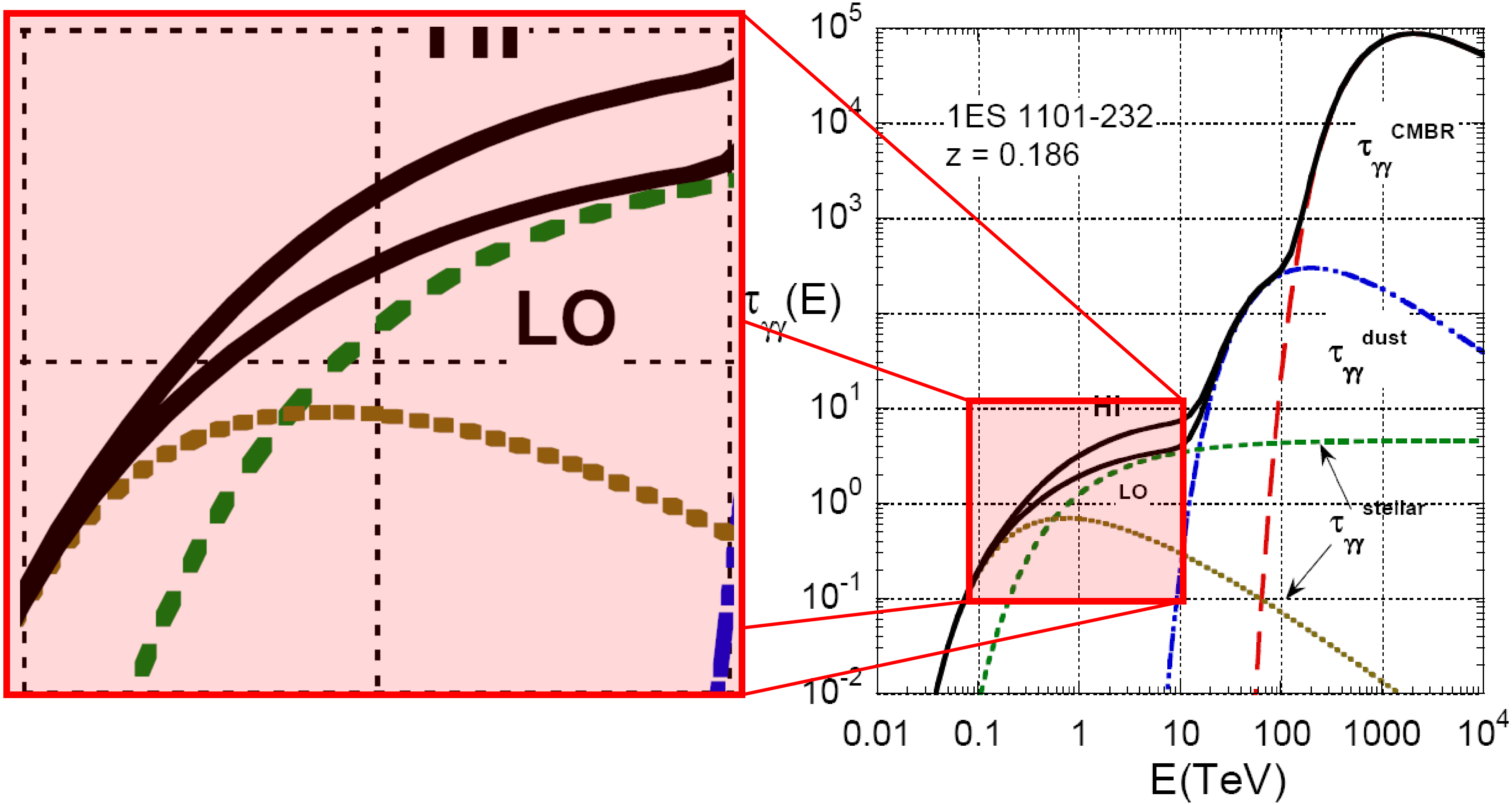
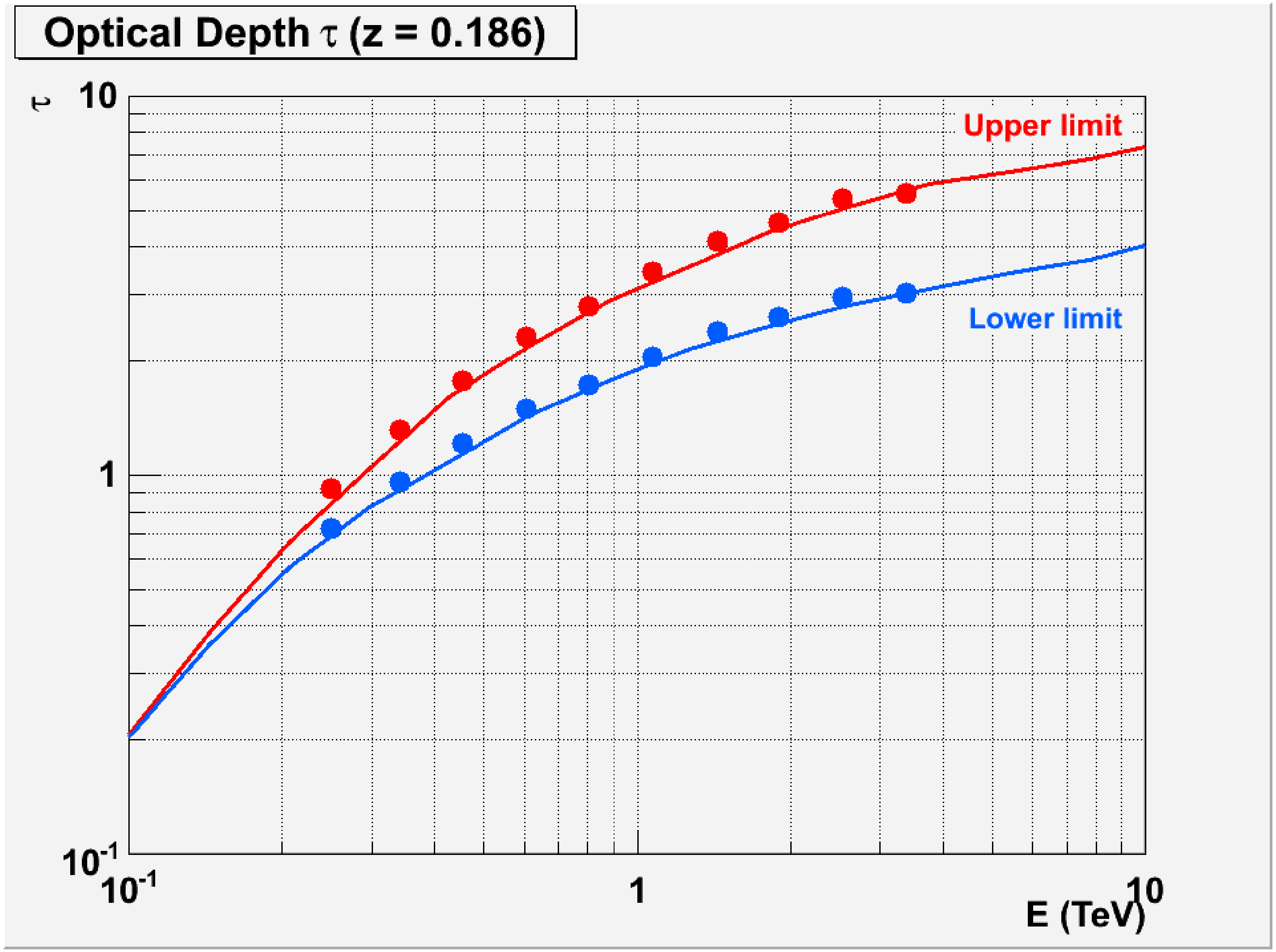


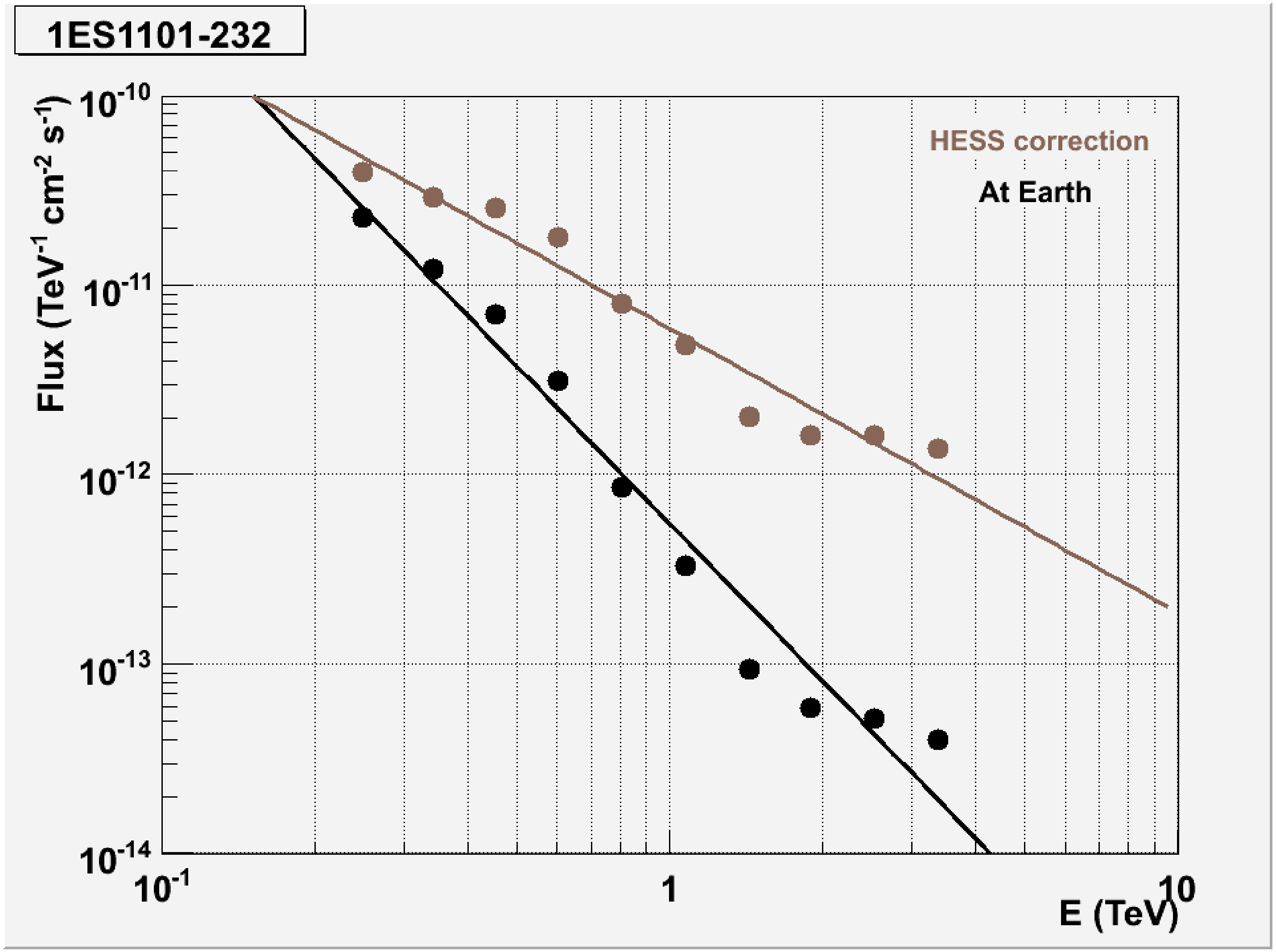
Optical Depth τ



Optical Depth τ



γ-ray spectra (Hess)



Conversion from γ-ray to ν spectra

Hypothesis: TeV γ ray emission is dominated by the decay of π^0 produced in **p-p** interactions

The following parameterization is for galactic sources

$$\frac{dN_p}{dE_p} = k_p \left(\frac{E_p}{1\,TeV} \right)^{-\Gamma_p} \exp\left(-\frac{E_p}{\varepsilon_p} \right)$$

$$\frac{dN_\gamma}{dE_\gamma} \approx k_\gamma \left(\frac{E_\gamma}{1\,TeV} \right)^{-\Gamma_\gamma} \exp\left(-\sqrt{\frac{E_\gamma}{\varepsilon_\gamma}} \right)$$

$$\frac{dN_\nu}{dE_\nu} \approx k_\nu \left(\frac{E_\nu}{1\,TeV} \right)^{-\Gamma_\nu} \exp\left(-\sqrt{\frac{E_\nu}{\varepsilon_\nu}} \right)$$

$$k_\nu \approx \left(0.71 - 0.16\,\Gamma_p \right) k_\gamma$$

$$\Gamma_\nu \approx \Gamma_\gamma \approx \Gamma_p - 0.1$$

$$\varepsilon_\nu \approx 0.59\,\varepsilon_\gamma \approx \varepsilon_p / 40$$

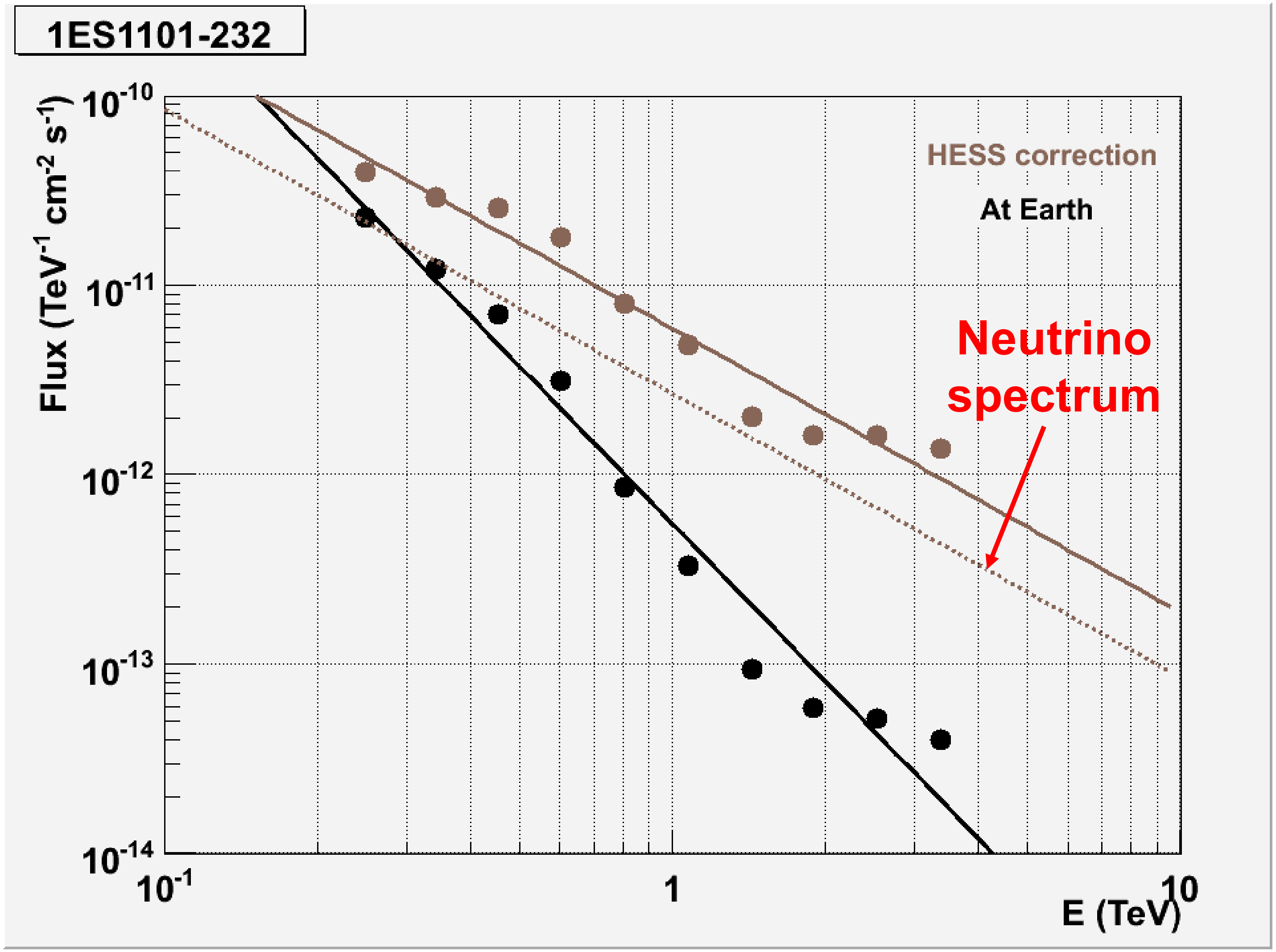
$$\varepsilon_p \to \infty$$

$$\varepsilon_\gamma \to \infty$$

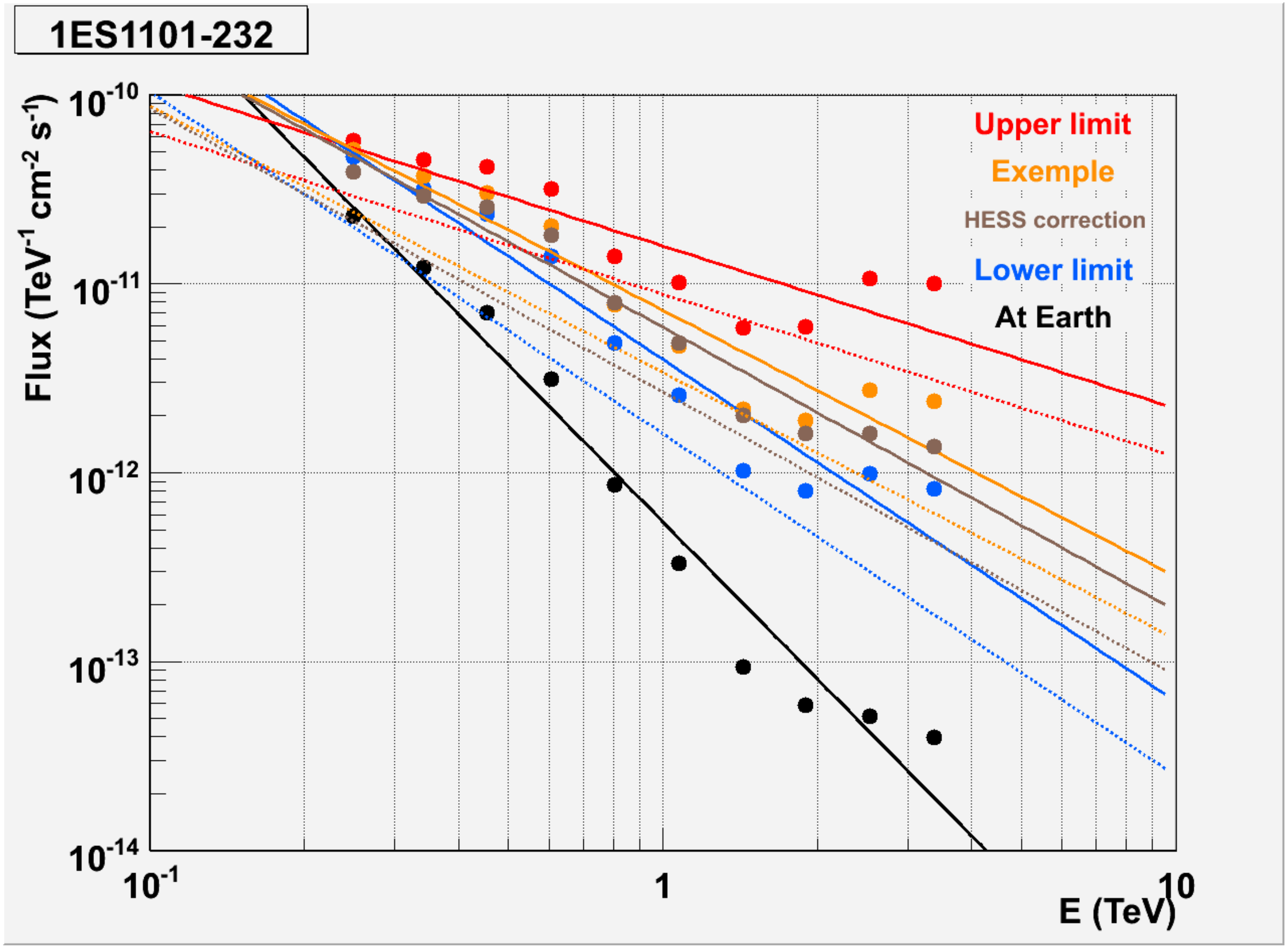
$$\varepsilon_\nu \to \infty$$

Potential Neutrino Signals from Galactic γ-Ray Sources (Aharonian & al.)

ν spectrum (Hess)



γ-ray & ν spectra



1ES1101-232 (γ-ray)

γ-ray spectra at Earth
$$F = 5.49541 \times 10^{-13} \left(\frac{E}{1\ TeV} \right)^{-2.76} TeV^{-1} cm^{-2} s^{-1}$$

γ-ray spectra at source (HESS)
$$F = 5.88844 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-1.5} TeV^{-1} cm^{-2} s^{-1}$$

γ-ray spectra at source (example)
$$F = 7.24436 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-1.41} TeV^{-1} cm^{-2} s^{-1}$$

γ-ray spectra at source (upper limit)
$$F = 1.58489 \times 10^{-11} \left(\frac{E}{1\ TeV} \right)^{-0.86} TeV^{-1} cm^{-2} s^{-1}$$

γ-ray spectra at source (lower limit)
$$F = 3.98107 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-1.81} TeV^{-1} cm^{-2} s^{-1}$$

1ES1101-232 (ν)

γ-ray spectra at Earth

$$F = 5.49541 \times 10^{-13} \left(\frac{E}{1\ TeV} \right)^{-2.76} TeV^{-1} cm^{-2} s^{-1}$$

ν spectra at source (HESS)

$$F = 2.67335 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-1.5} TeV^{-1} cm^{-2} s^{-1}$$

ν spectra at source (example)

$$F = 3.39326 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-1.41} TeV^{-1} cm^{-2} s^{-1}$$

ν spectra at source (upper limit)

$$F = 8.81835 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-0.86} TeV^{-1} cm^{-2} s^{-1}$$

ν spectra at source (lower limit)

$$F = 1.60995 \times 10^{-12} \left(\frac{E}{1\ TeV} \right)^{-1.81} TeV^{-1} cm^{-2} s^{-1}$$

Spectrum index

AGN	z	Dec.	Γ_{Earth}	Γ_{min}	Γ_{max}
1ES1101-232	0.186	-23°29'31"	-2.76	-1.81	-0.86
1ES0347-121	0.188	-11°59'27"	-2.82	-1.85	-0.87
PG1553+113	(0.35)	+11°11'24"	-4.41	-2.79	-1.37
1ES0229+200	0.14	+20°17'16"	-2.59	-1.88	-1.22
H2356-309	0.165	-30°37'22"	-3.08	-2.25	-1.55
PKS2155-304	0.116	-30°13'18"	-3.27	-2.65	-2.05
PKS2005-489	0.071	-48°49'19"	-3.59	-3.19	-2.81

Questions

- EBL correction:
  - $\Gamma < 1.6$ is physical?
  - Other models for EBL?
- Internal absorption model? (is going on the good way for us)
- Conversion γ-ray flux to ν flux:
  - Need model of p-γ may be use model developed for GRB in any case, what X-ray data will be used?

Thanks!