VHE gamma-ray attenuation through localized photon fields

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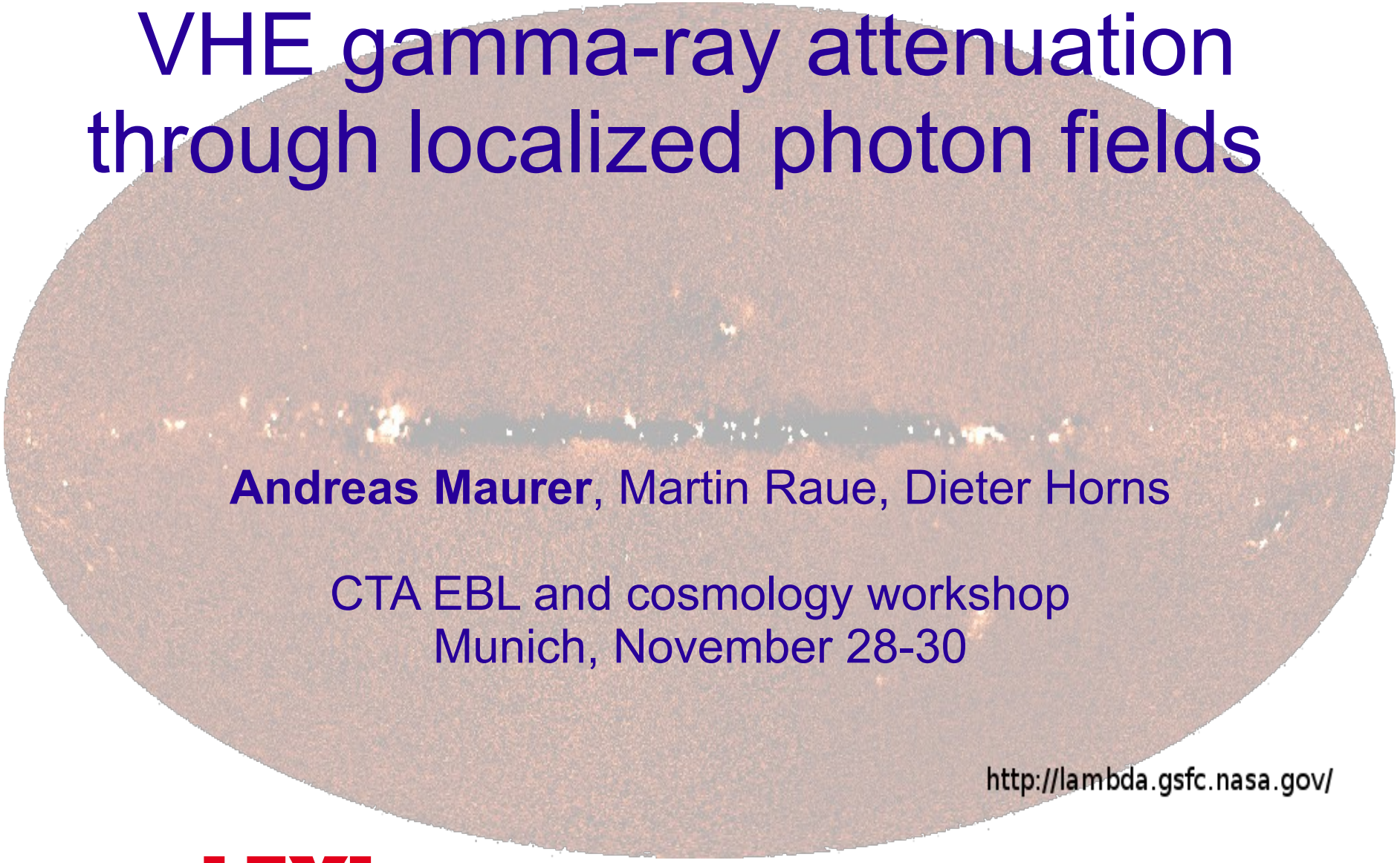
CTA EBL and cosmology workshop
Munich, November 28-30



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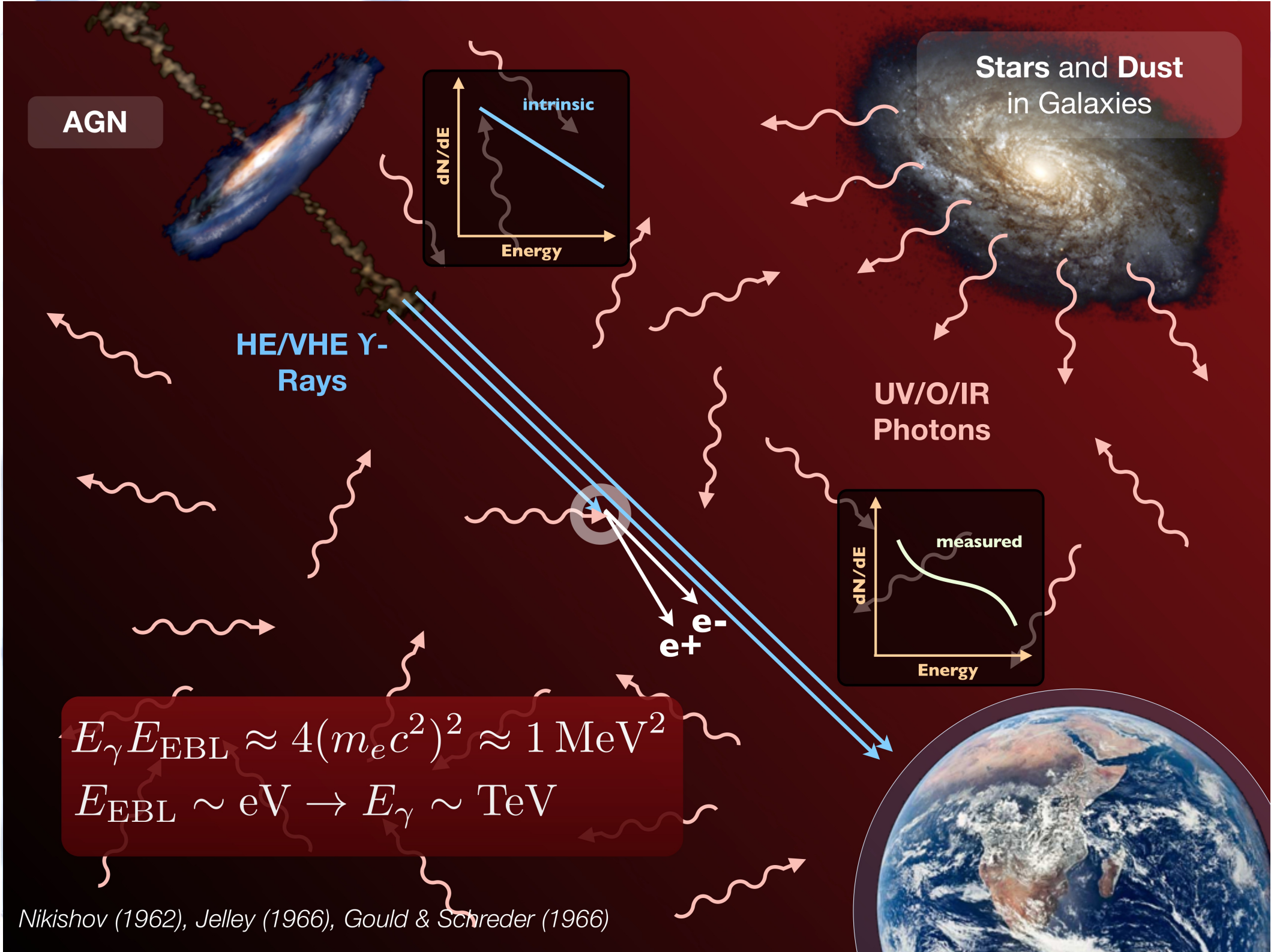
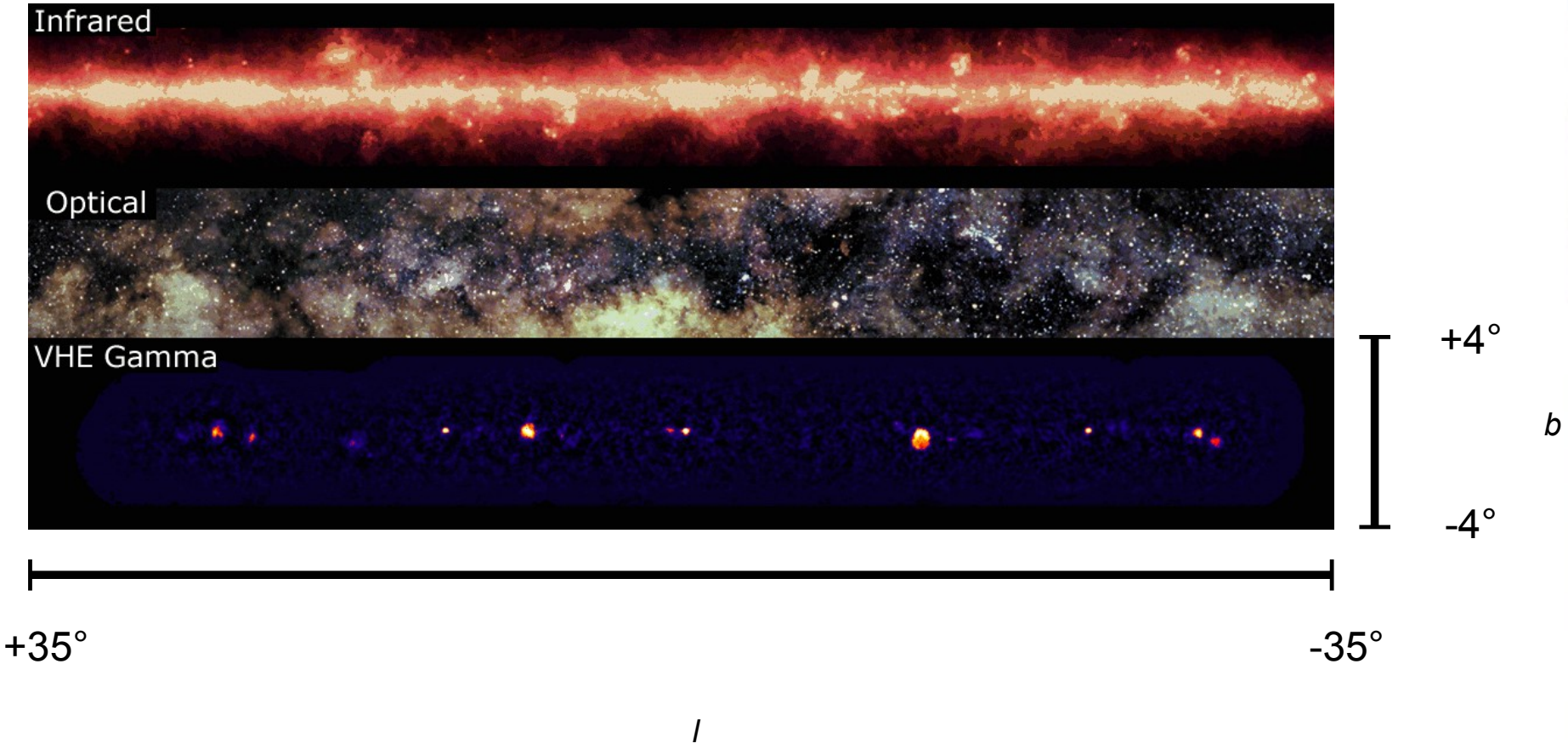
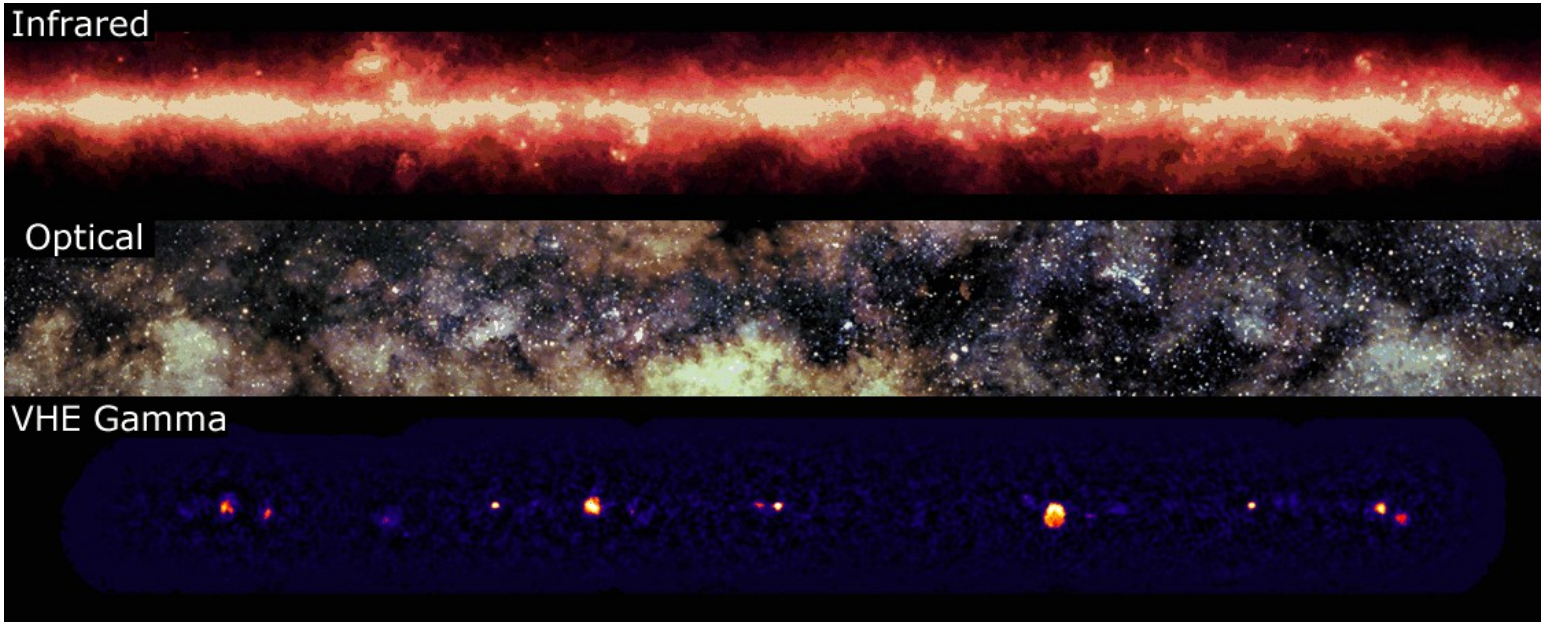

AGN
intrinsic
dN/dE
Energy
Stars and Dust
in Galaxies
HE/VHE γ-Rays
UV/O/IR Photons
e-
e+
measured
dN/dE
Energy
$E_\gamma E_{\rm EBL} \approx 4(m_e c^2)^2 \approx 1\,{\rm MeV}^2$
$E_{\rm EBL} \sim {\rm eV} \rightarrow E_\gamma \sim {\rm TeV}$
Nikishov (1962), Jelley (1966), Gould & Schreder (1966)

Galactic radiation field



Infrared: S.L. Wheelock, et al. 1994, IRAS Sky Survey Atlas Explanatory Supplement, JPL Publication 94-11
Optical: A. Mellinger, Publ. Astron. Soc. Pacific 121, 1180-1187 (2009)
VHE Gamma: HESS collaboration, Science (2005)

Galactic radiation field



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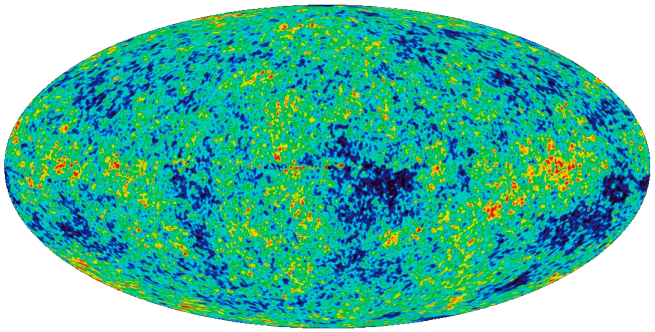


CMB

http://map.gsfc.nasa.gov

Calculation of optical depth

$$\tau_{\gamma\gamma}(E_\gamma) = \int_{\text{L.o.s.}} \mathrm{d}x \int_{-1}^{+1} \mathrm{d}\mu \; \frac{1-\mu}{2} \int_{\varepsilon_{\text{thr}}}^{\infty} \mathrm{d}\varepsilon \; n(\varepsilon, x) \; \sigma_{\gamma\gamma}(E_\gamma, \varepsilon, \mu)$$

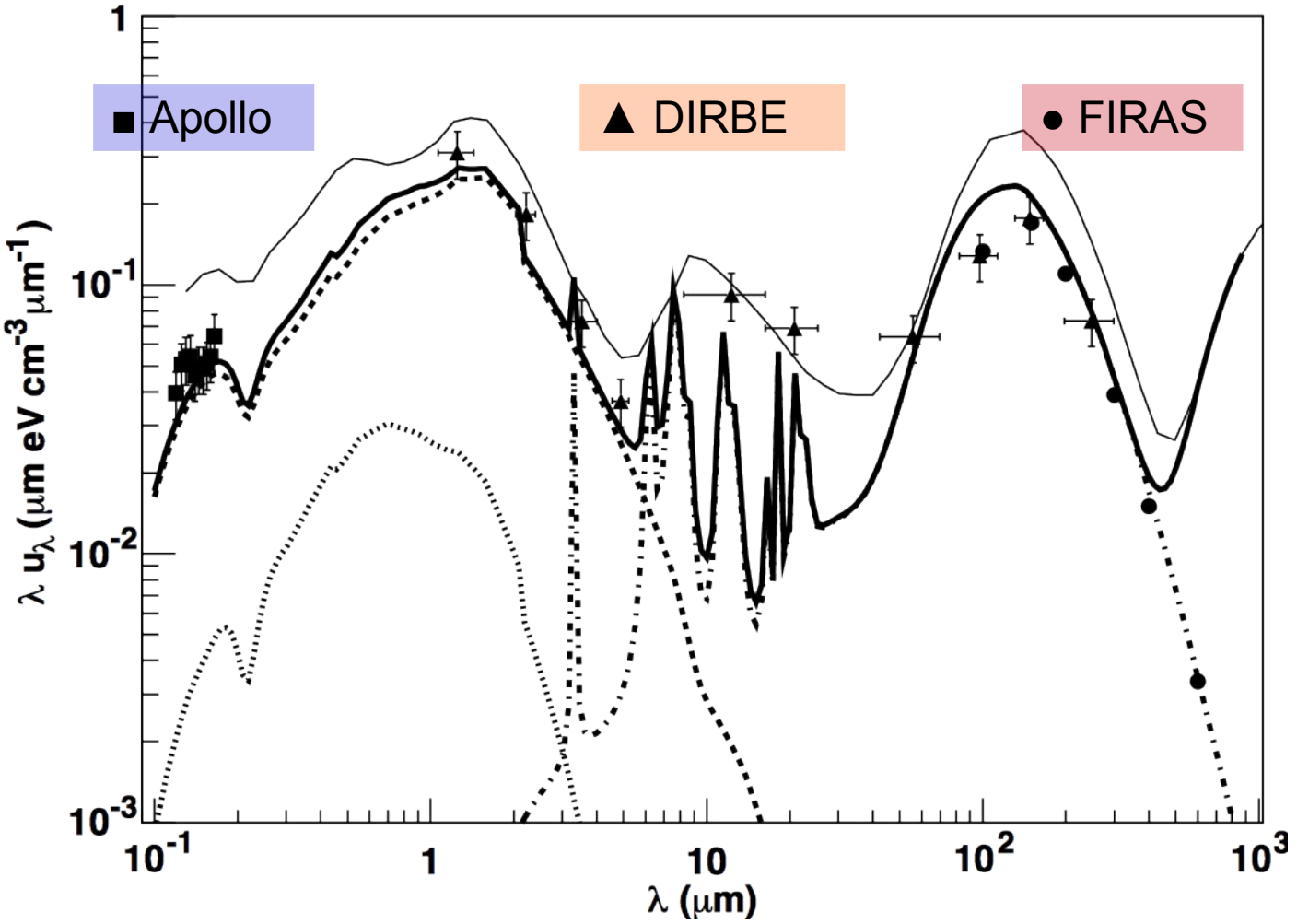
$$f(E)_{\text{obs}} = f(E)_{\text{int}} \times exp(-\tau_{\gamma\gamma}(E))$$

Distance

Pair production cross section

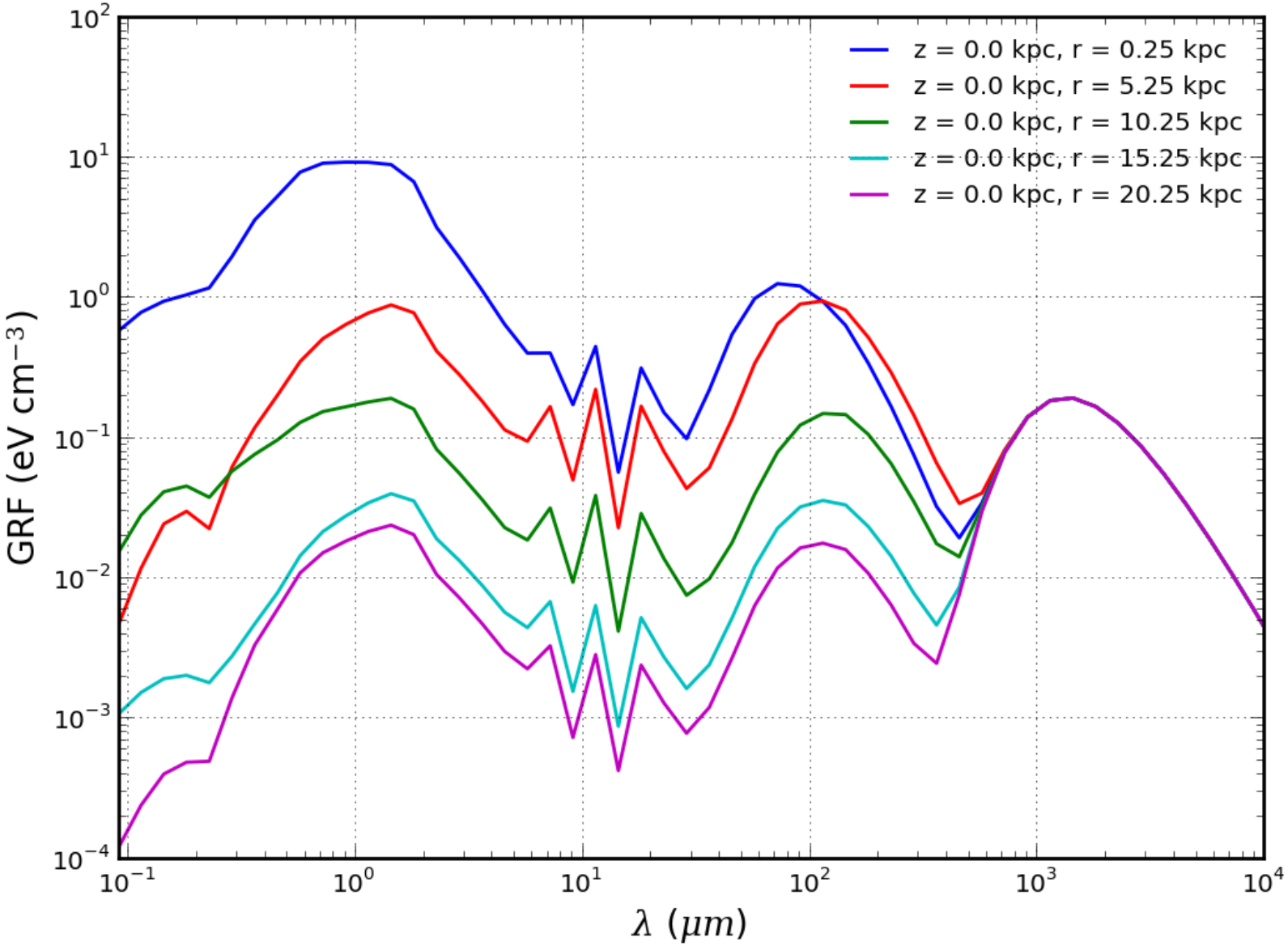
Radiation field [Strong & Porter 2005]

Galactic radiation field



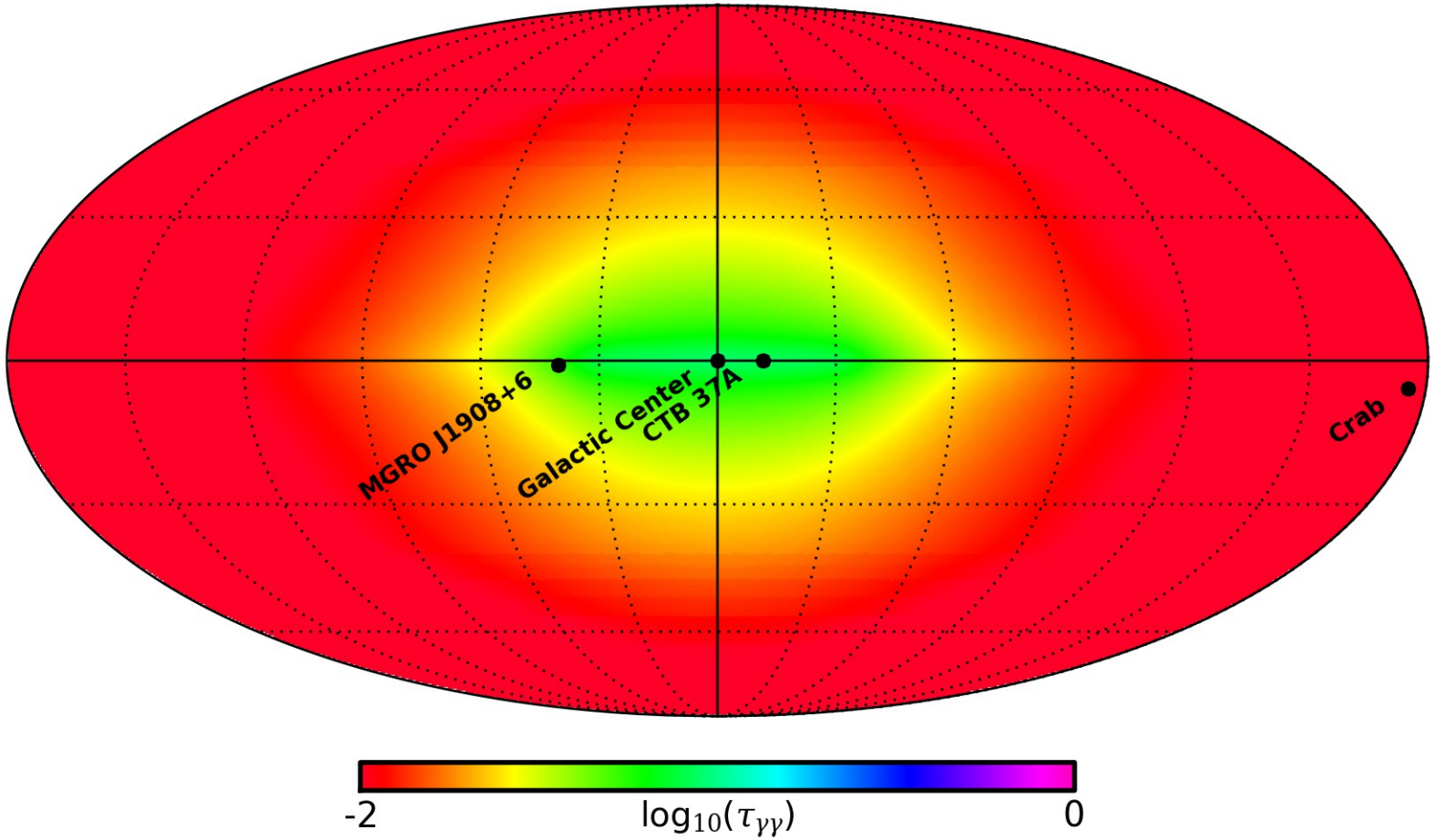
Moskalenko et al. 2006, ApJ (and references therein)

Galactic radiation field



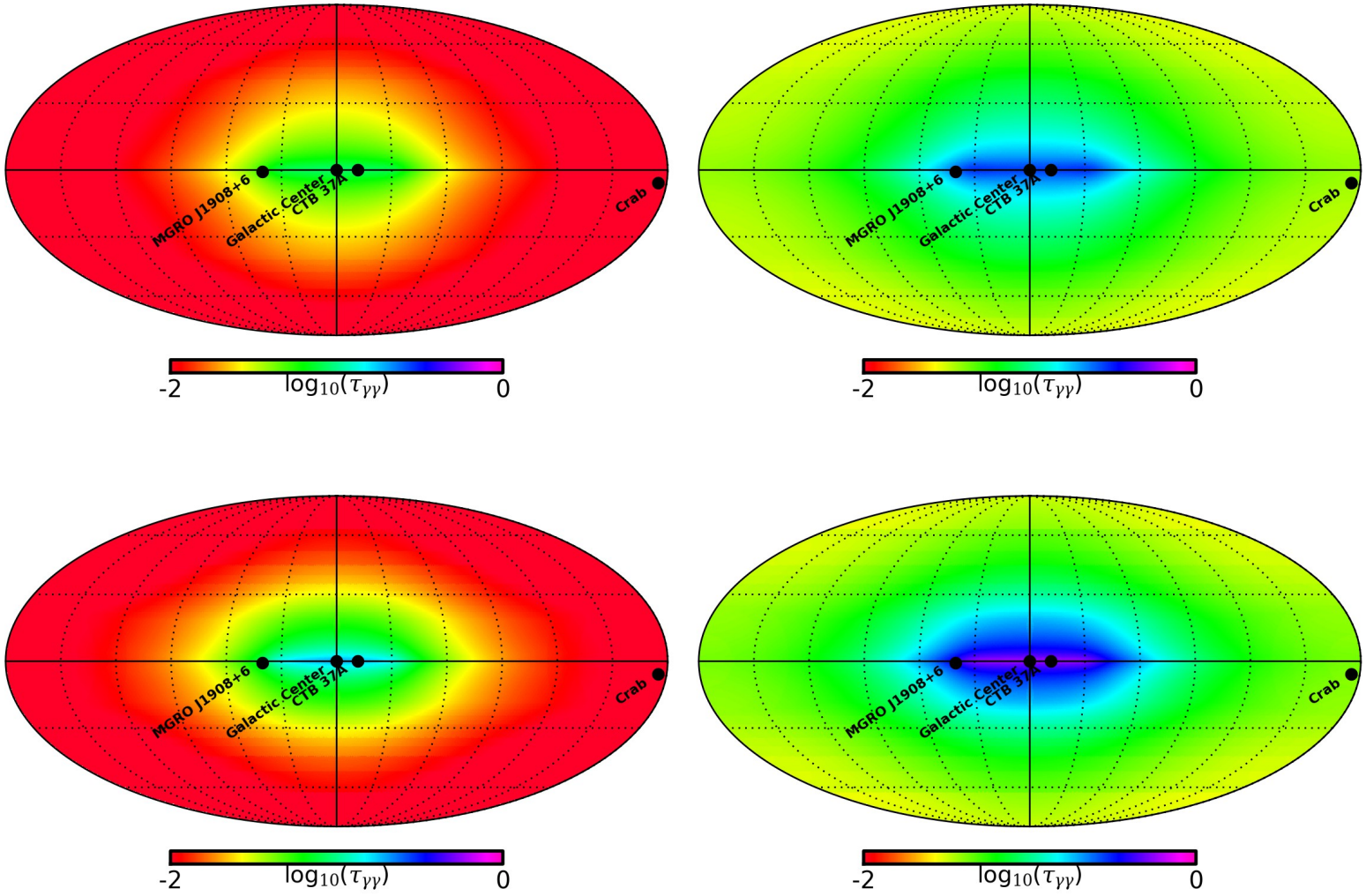
Strong & Porter 2005, astro-ph/0507119

Optical depth for VHE gamma-rays



Skymaps in Galactic coordinates showing optical depths for gamma-ray energie 30 TeV and distance 8 kpc. The overall strength of the attenuation is a percentage effect.

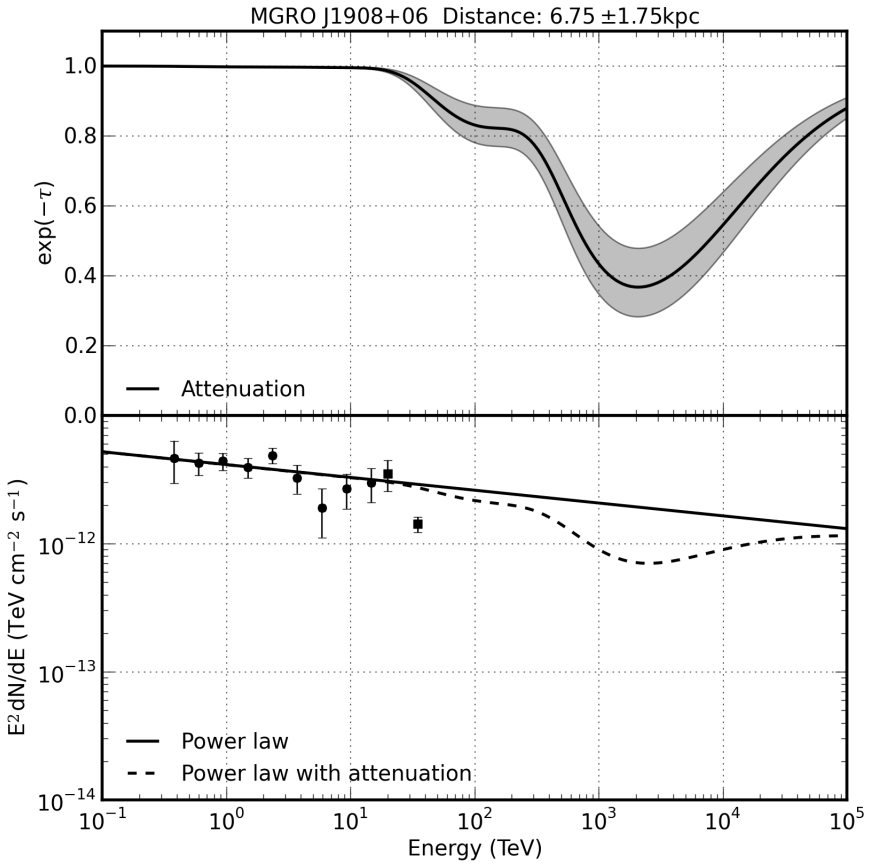
Optical depth for VHE gamma-rays

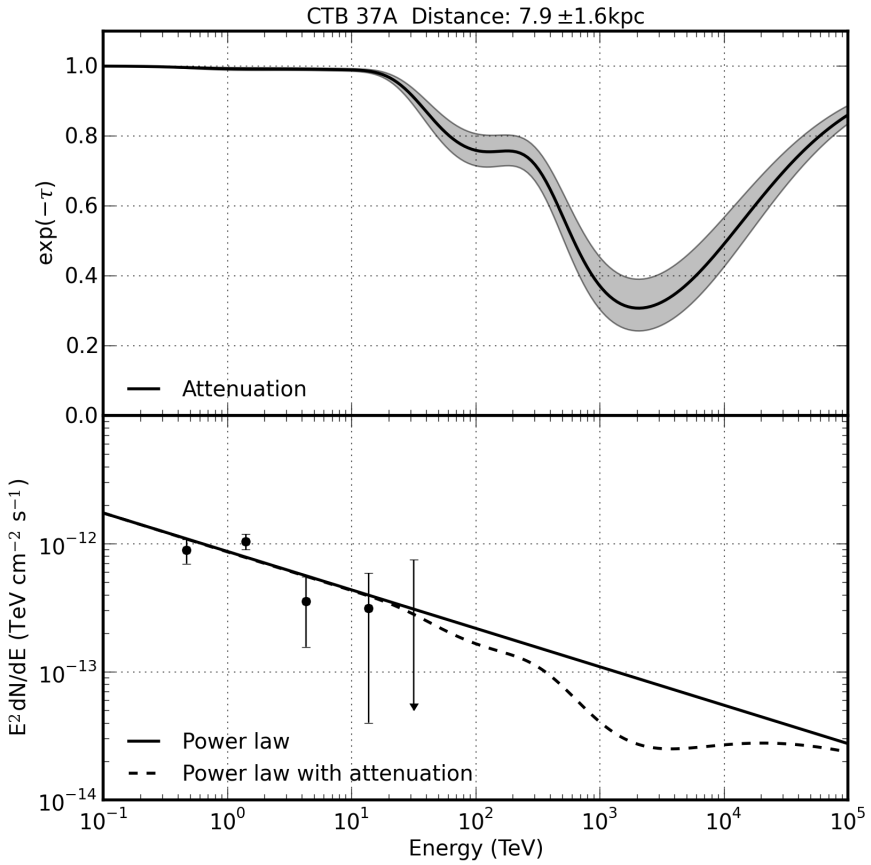


Skymaps in Galactic coordinates showing optical depths for different gamma-ray energies (30 TeV: left column; 100 TeV: right column) and different distances (8 kpc: upper row; 16 kpc: lower row).

[**AM**, Becerra-Gonzalez, Raue, Horns 2013]

Attenuation of VHE gamma-rays

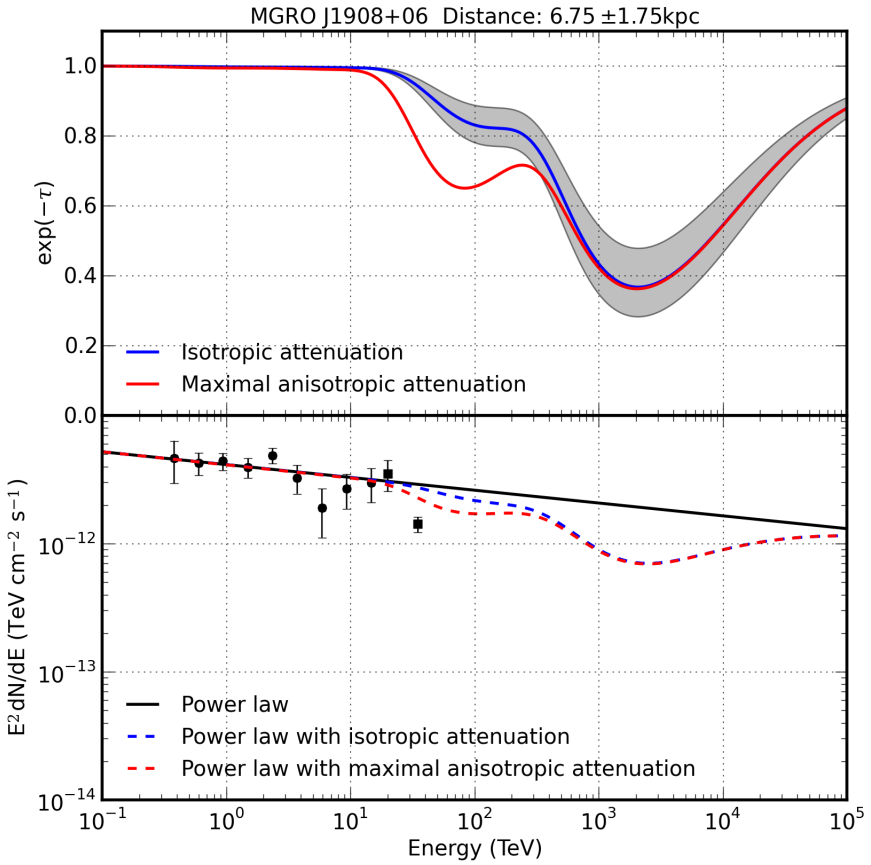


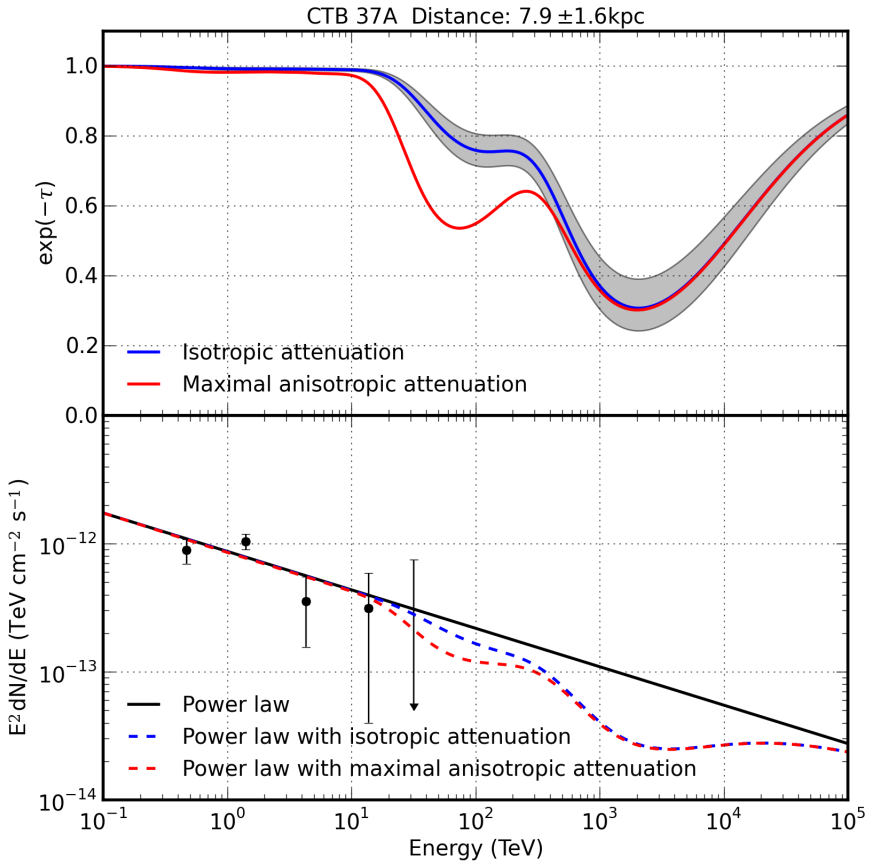


Upper panels: Attenuation for two VHE galactic gamma-ray sources (MGRO J1908+06 and CTB 37 A) due to the GRF and CMB. The shaded regions show the distance uncertainty.
Lower panels: Data from H.E.S.S. (circles) and Milagro experiment (squares) and power law fit to the data with and without attenuation.

[**AM**, Becerra-Gonzalez, Raue, Horns 2013]

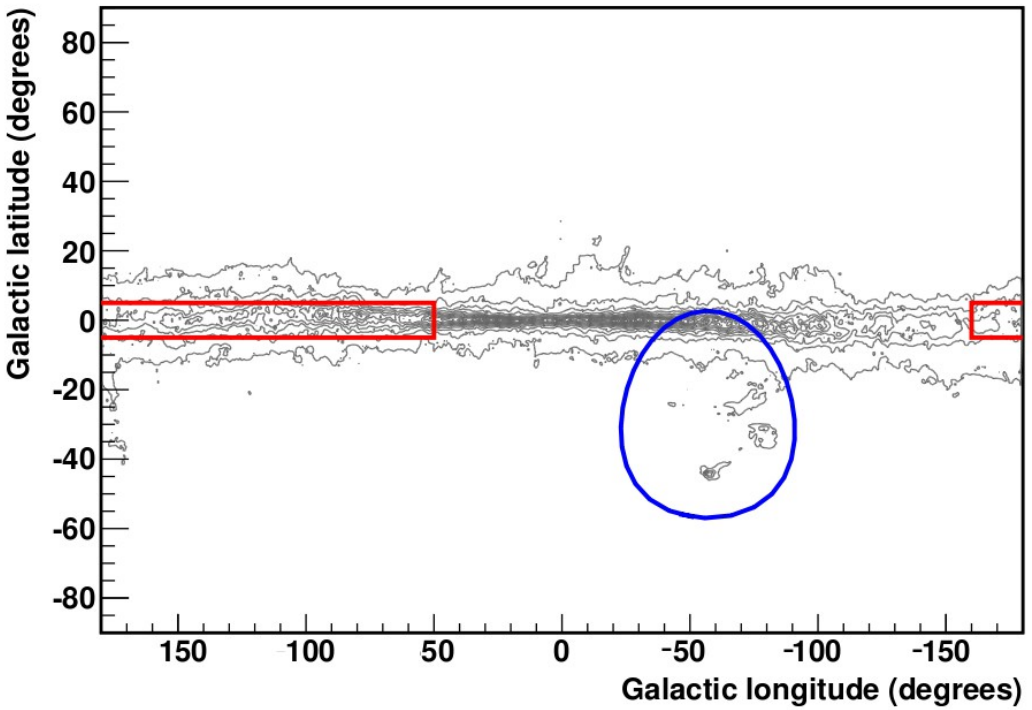
Influence of anisotropy in the Galactic radiation field





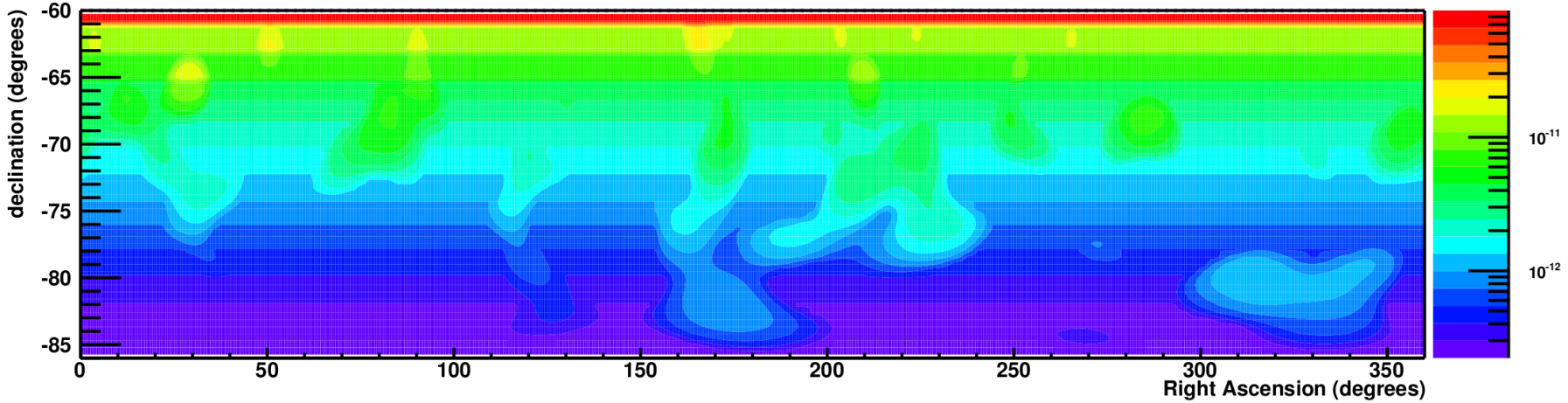
Upper panels: Attenuation for two VHE galactic gamma-ray sources (MGRO J1908+06 and CTB 37 A) due to the GRF(isotropic: blue; maximal anisotropic: red) and CMB. The shaded regions show the distance uncertainty.
Lower panels: Data from H.E.S.S. (circles) and Milagro experiment (squares) and power law fit to the data with and without attenuation.

Application to IceCube PeV gamma-ray search



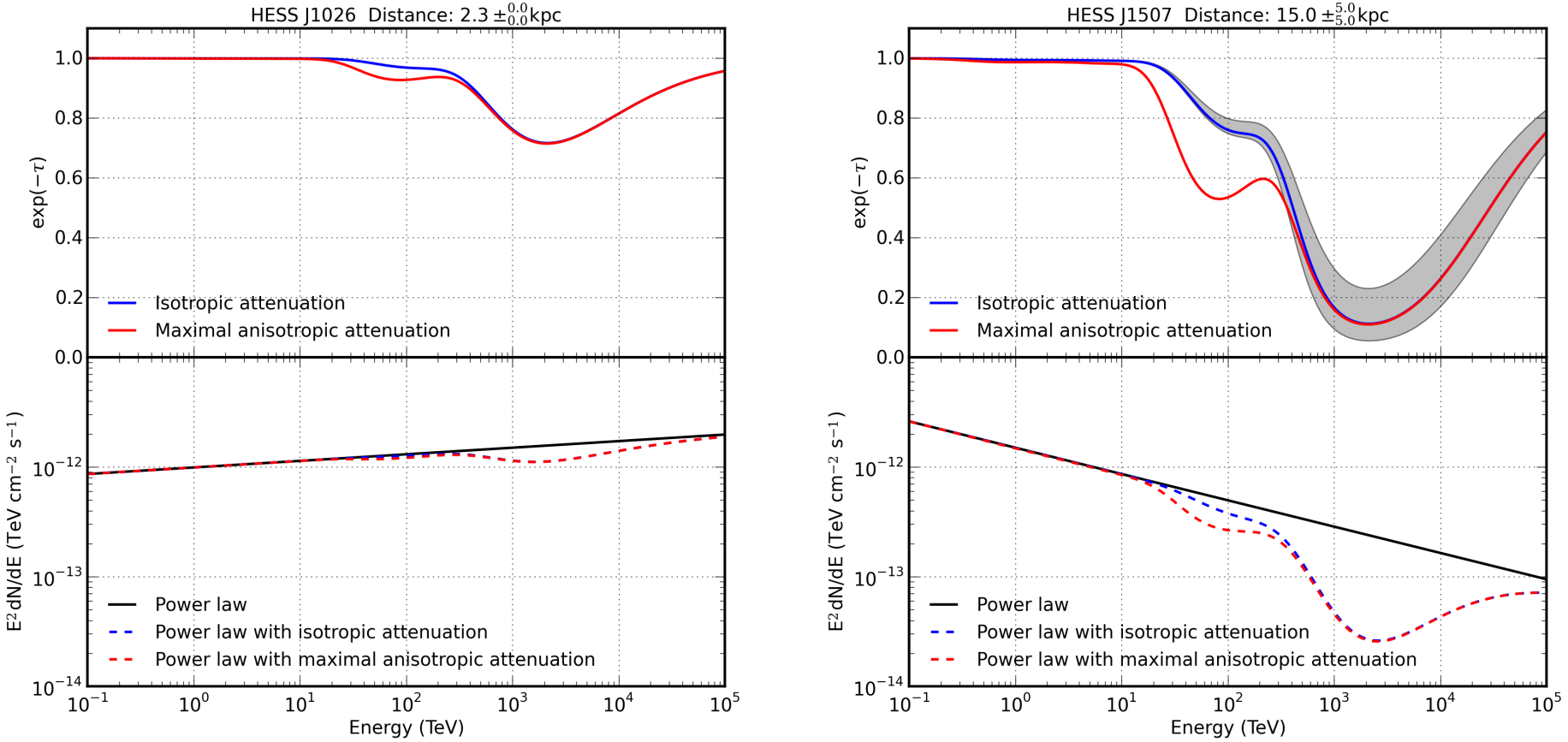
Left panel: Contours of integrated neutral atomic hydrogen (HI) column densities in Galactic coordinates (flat projection). The blue circle indicates the gamma-ray FOV for IceCube in the present IC40 analysis.

[IceCube collaboration: arxiv 1210.7992]



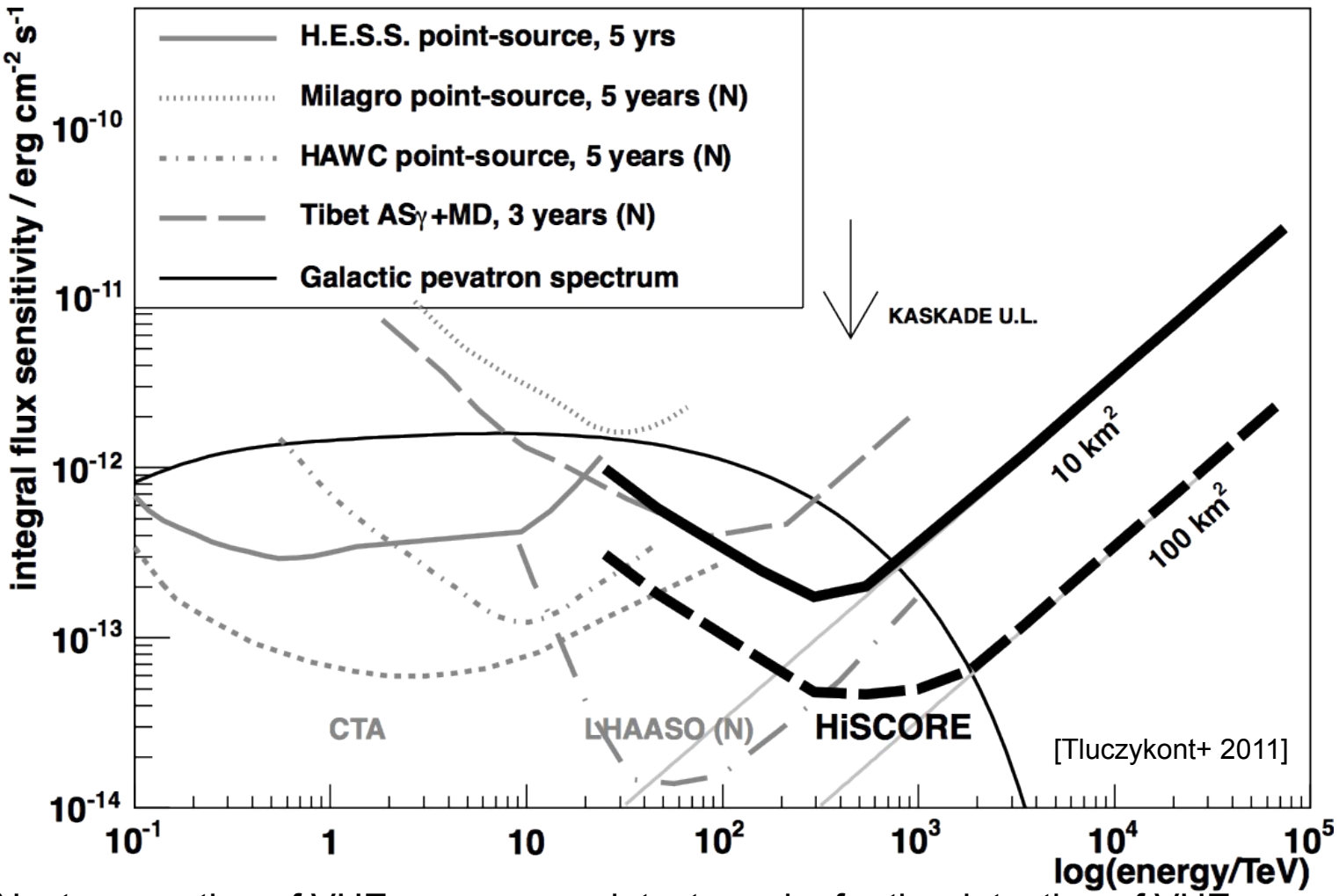
Lower panel: Sky map of 90% C.L. upper limits on point source flux $(E/TeV)^2\, d\Phi/dE$ in $cm^{-2}\, s^{-1}\, TeV^{-1}$ for E^{-2} source spectra in the energy range E = 1.2 - 6.0 PeV.

Attenuation for two example sources in IceCube FOV



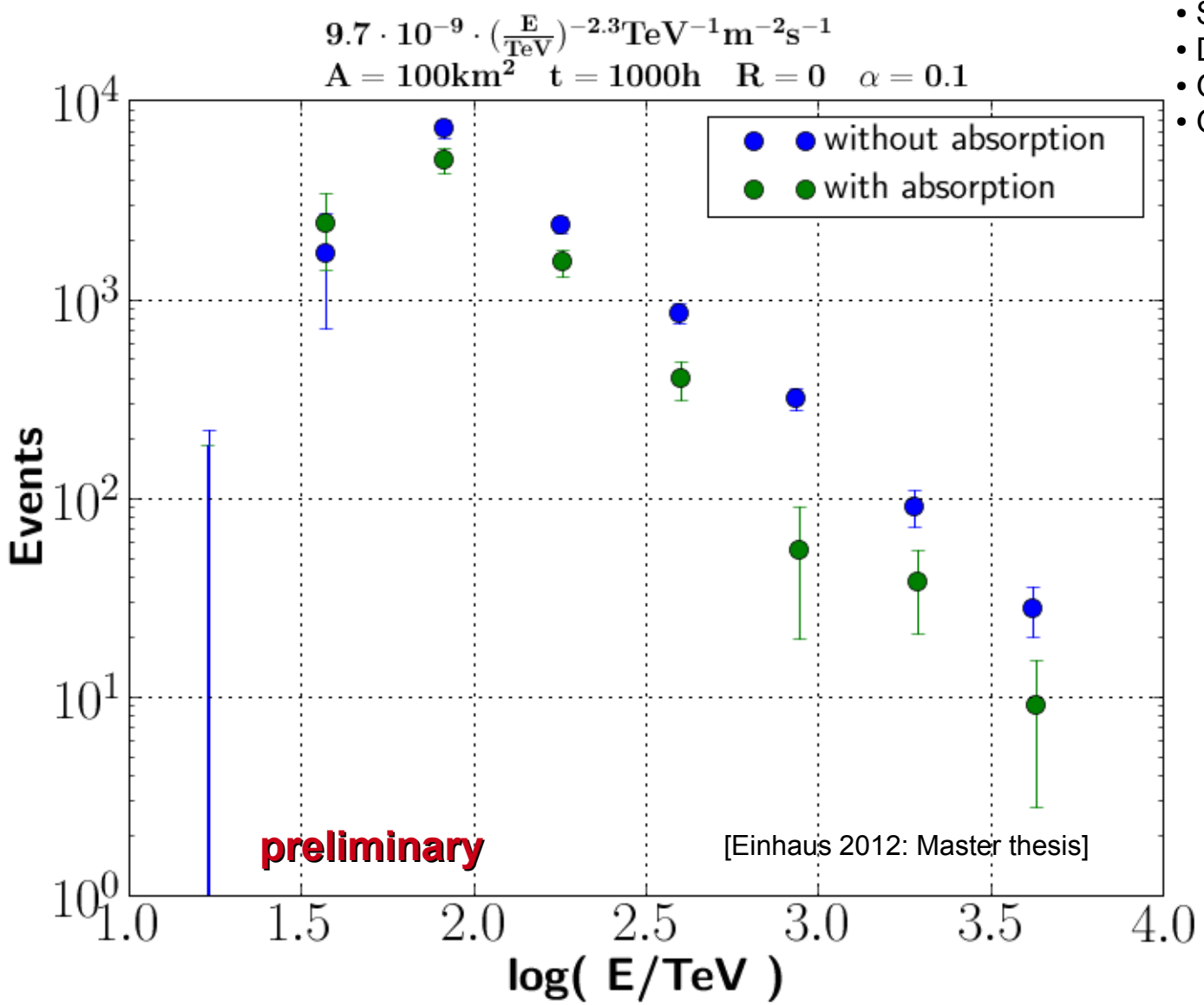
Upper panels: Attenuation for two VHE galactic gamma-ray sources (HESS J1026 [PWN] and HESS J1507 [UnId]) due to the GRF(isotropic: blue; maximal anisotropic: red) and CMB. The shaded regions show the distance uncertainty.
Lower panels: Power law fit to the data with and without attenuation.

Sensitivities of future instruments



Next generation of VHE gamma-ray detectors aim for the detection of VHE sources above 100 TeV and will have high sensitivities at multi-TeV energies.

HiSCORE simulation for CTB37 A



- SNR
- D = 7.9 ± 1.6 kpc
- Gal. Long. = 348.39°
- Gal. Lat. = 0.11°

Summary and Outlook

- The attenuation of VHE gamma-rays via the diffuse Galactic radiation field is an effect detectable by the next generation of instruments like CTA and HiSCORE

- Can localized diffuse radiation fields on other scales (cluster, filaments) possibly cause VHE gamma-ray attenuation? → most likely not (work in progress)
- Attenuation of gamma rays can be used to test the model of the GRF, distances to VHE sources, and constrain new particle physics