W.Essey, O.Kalashev, A.Kusenko, J.F. Beacom Phys.Rev.Lett.104:141102,2010

Secondary neutrinos and multi-TeV photons from distant blazars

Oleg Kalashev

Overview

- VHE photons observation
- Photons attenuation
- Secondary multi-TeV photons from distant blazars
- Secondary neutrino flux
- Conclusions

Multi-TeV photons observation

- HECRA (E>1 TeV)
- MAGIC (E>50 GeV)
- HESS (E>0.16 TeV)
- VERITAS (E>50 GeV)

Observation of photons from distant blazars

HESS

1ES 1101−232 (z=0.186) $\Gamma = 2.88 \pm 0.17$

H2356−309 (z=0.165) $\Gamma = 3.06 \pm 0.21$

$$\frac{dN}{dE} \sim E^{-\Gamma}$$

Nature 440 (2006) 1018–1021 $0.5 < E/TeV < 10$

VERITAS

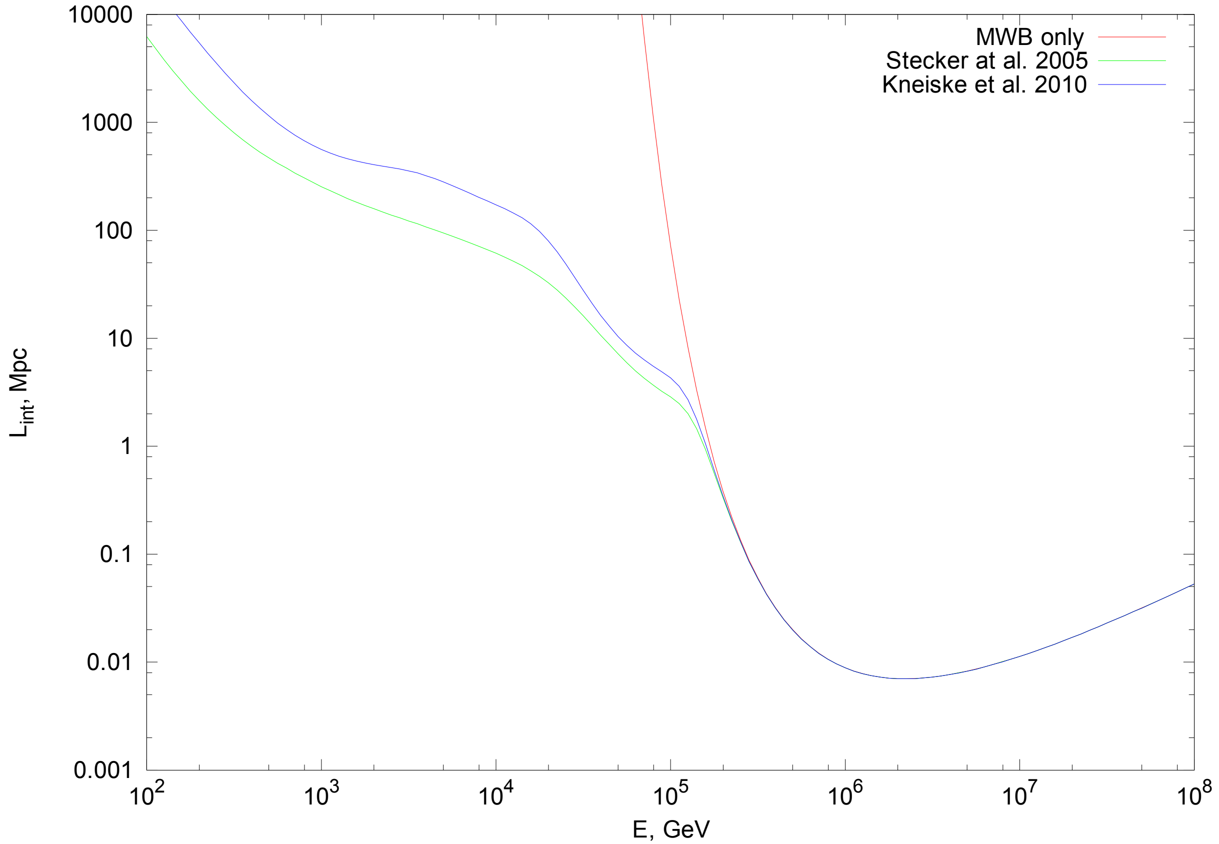
3C66A (z = 0.444) $\Gamma = 4.1 \pm 0.4_{stat} \pm 0.6_{sys}$

Astrophys. J. Lett. 693 (2009) L104–L108

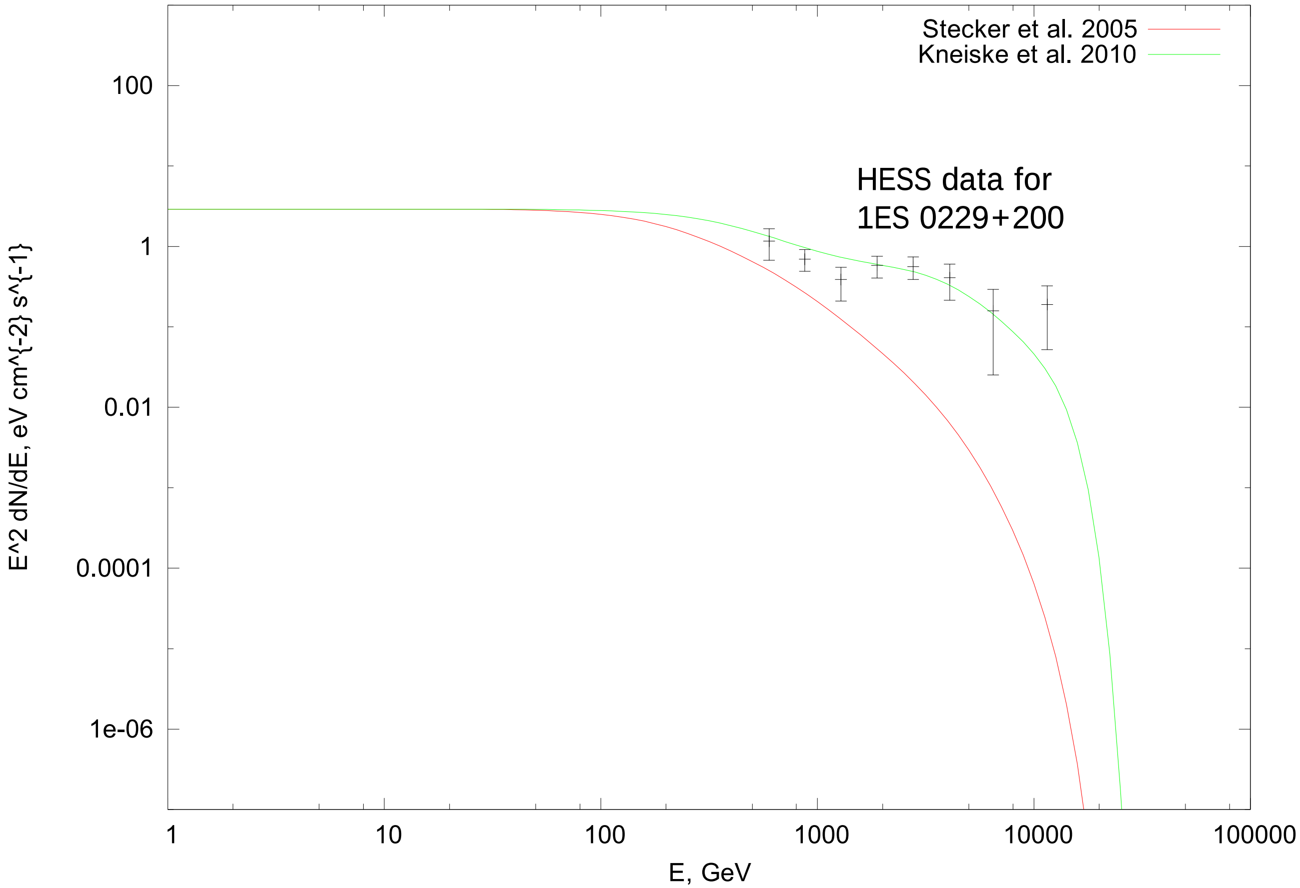
Problems with primary multi-TeV photons from distant blazars

- Unexpectedly hard spectra observed is only possible to explain by primaries if EBL (optical/near-infrared) is very close to the lower limit given by the integrated light of resolved galaxies
  - *F. Aharonian, et al., Nature 440 (2006) 1018–1021*

Attenuation of photons



Primary photons from the source at z=0.14



Problems with primary multi-TeV photons from distant blazars

- EBL close to minimal is required
  - *F. Aharonian, et al., Nature 440 (2006) 1018–1021*
- Intrinsic photon densities around sources may be too high
  - *J. Albert et al., Astrophys. J. Lett. 685 (2008) L23–L26*
- Lack of correlation between the optical and VHE bands of variable sources
  - *D. Horan et al., Astrophys. J. 695 (2009) 596–618*

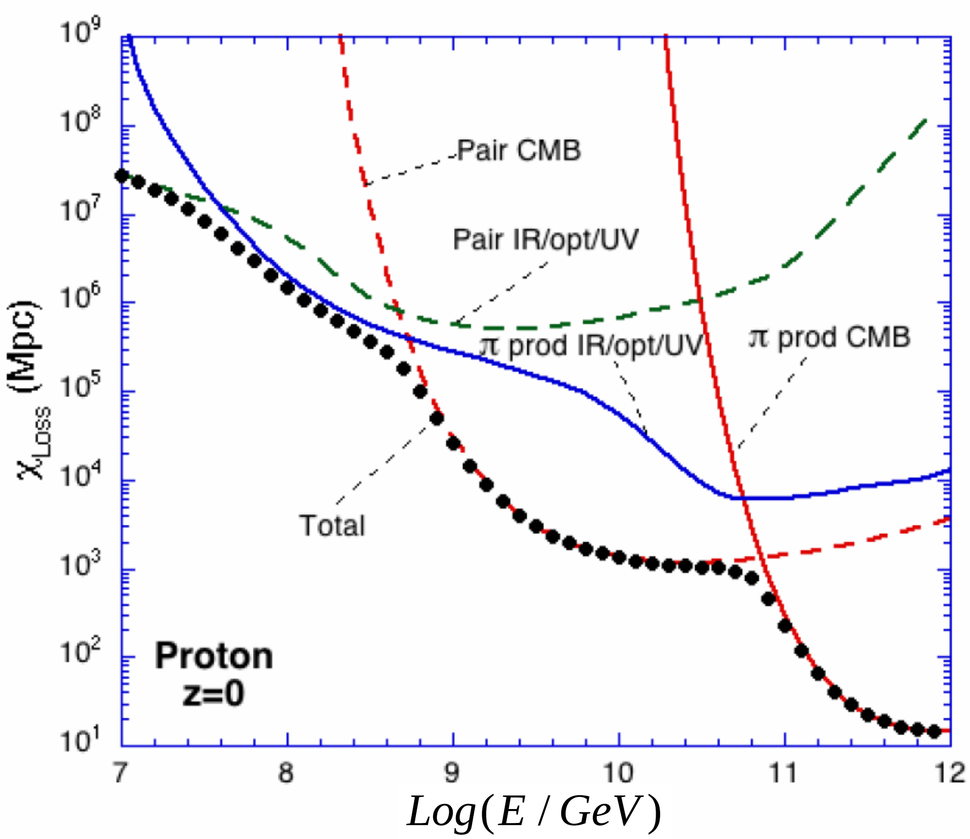
Possible explanations

- Photons may convert into some hypothetical axion-like particles that convert back into photons in the galactic magnetic fields
- Lorentz invariance violation may be the reason for the lack of absorption

Possible explanations

- Photons may convert into some hypothetical axion-like particles that convert back into photons in the galactic magnetic fields
- Lorentz invariance violation may be the reason for the lack of absorption
- Photons observed are secondary from protons interacting with EBL

Attenuation of protons



Deflection by magnetic field

- Intergalactic magnetic field

$$\Delta\theta \sim 0.1^\circ \left(\frac{B}{10^{-14}\mathrm{G}}\right) \left(\frac{4\times 10^7\,\mathrm{GeV}}{E}\right) \left(\frac{D}{1\,\mathrm{Gpc}}\right)^{1/2} \left(\frac{l_c}{1\,\mathrm{Mpc}}\right)^{1/2}$$

l_c - IGMF correlation length D-distance to the source

B - IGMF average value

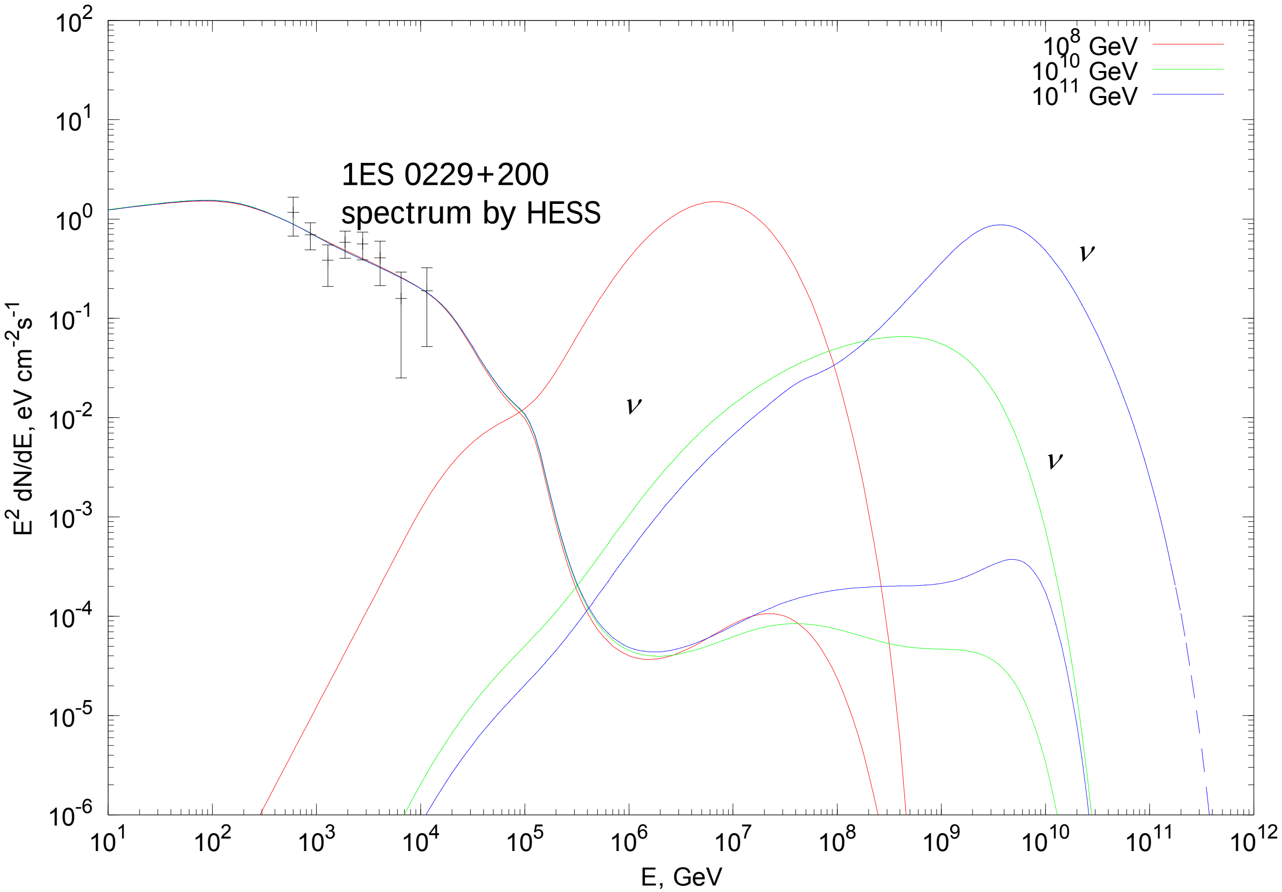
- Thin walls of magnetic fields intersecting the line of sight

$\Delta\theta \sim h/D_{\mathrm{wall}}$ h - wall thickness D_{wall}-distance to the wall

- Deflections in the host system

$\Delta\theta \sim L_{\mathrm{host}}/D \ll 0.1^\circ$, where L_{host} is the size of the host system.

Secondary photons from source at z=0.14



Luminosities in CR:

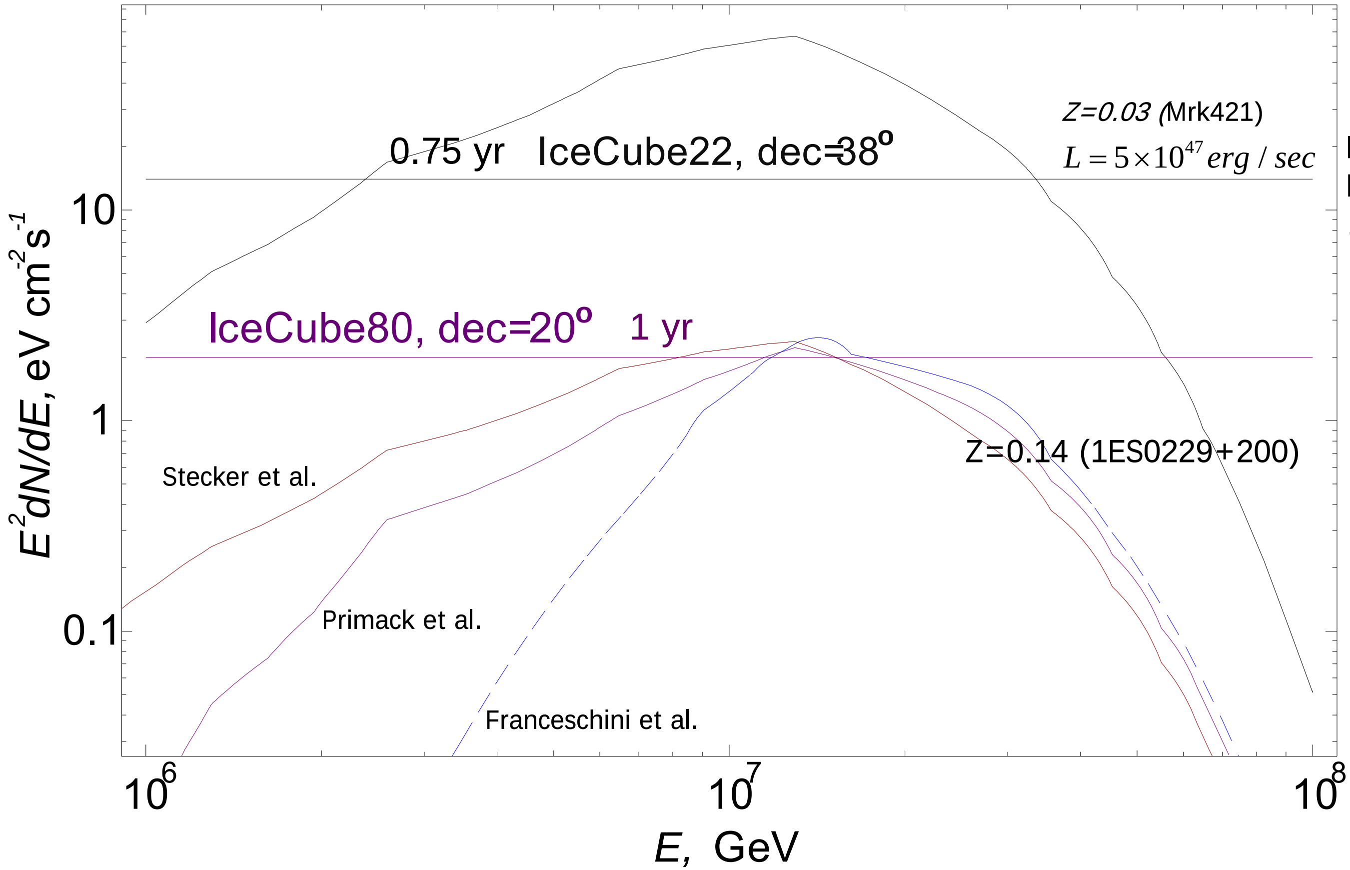
$E_{max} = 10^8 GeV; L = 6\times10^{46} erg / s$

$E_{max} 10^{10} GeV; L = 2\times10^{44} erg / s$

$E_{max} 10^{11} GeV; L = 9\times10^{43} erg / s$

$b = 100$ - beaming factor

Secondary neutrinos from distant blazars



IceCube:

R. Lauer et al., Int. J. Mod. Phys. D 18, 1587 (2009)

R. Abbasi et al. , Phys. Rev. Lett. 103, 221102 (2009)

T. DeYoung [for the IceCube Collaboration], arXiv:0910.3644

Luminosity in CR above 10^7 GeV:

$E_{max} = 10^8 GeV$ $\quad b = 10^2$

Stecker et al.	$6\times10^{46} erg / s$
Primack et al.	$1.5\times10^{47} erg / s$
Franceschini et al.	$2\times10^{47} erg / s$

Two possibilities

Primary photons

- Very low EBL
- No limitation on IGMF
- Time variability?

Secondary photons

- Low IGMF
- No limitation on EBL
- Time variability can be destroyed by IGMF

Two possibilities

Primary photons

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Secondary photons

- Low IGMF
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- Time variability can be destroyed by IGMF
- Limitations on the intrinsic background level can be relaxed

Two possibilities

Primary photons

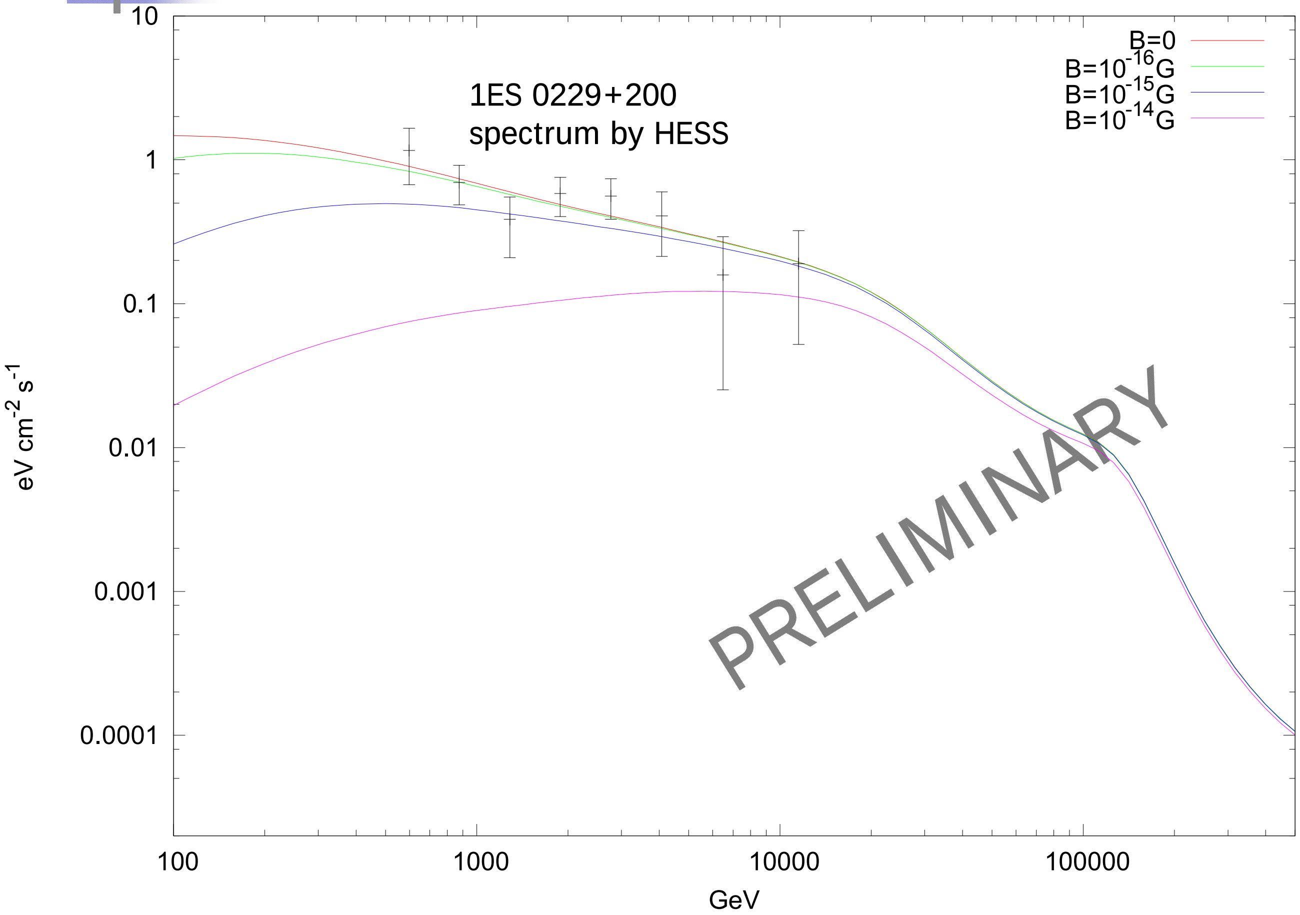
- Very low EBL
- No limitation on IGMF
- Time variability?
- Limitations on the intrinsic background level

Secondary photons

- Low IGMF
- No limitation on EBL
- Time variability can be destroyed by IGMF
- Limitations on the intrinsic background level can be relaxed
- Secondary neutrinos can be detected in future by IceCube

Appendix

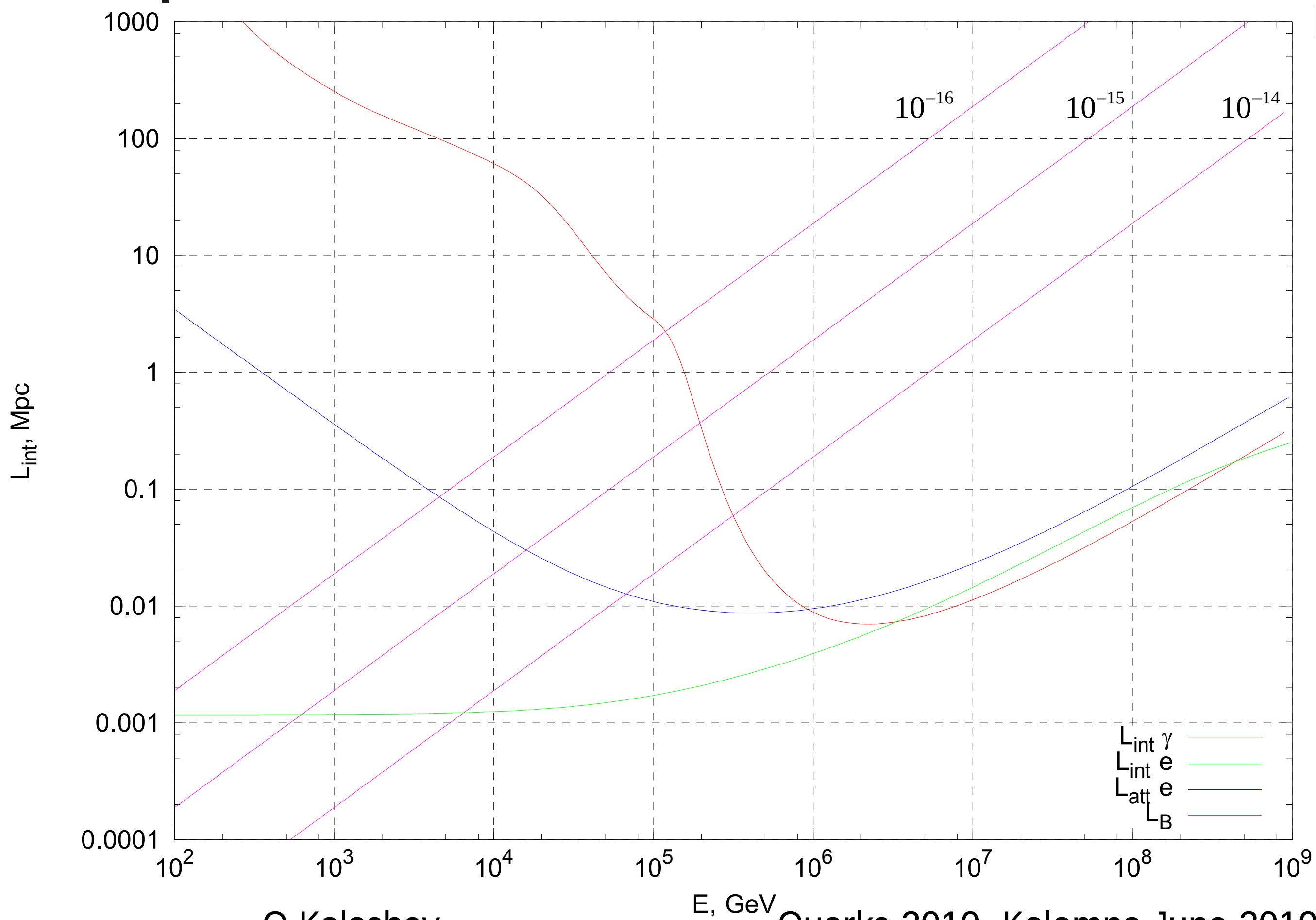
Dependence on IGMF



$Z = 0.14$

$E_{max} = 10^8 GeV$

Electrons attenuation



Defocusing length

$$L_B = R_{syn}\Delta\theta$$

$$L_{att} \leq l_{cor}$$

$$\Delta\theta = 0.1^{\circ}$$