Probing the Universe with cosmological electromagnetic cascades

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(PhD student - 1st year)

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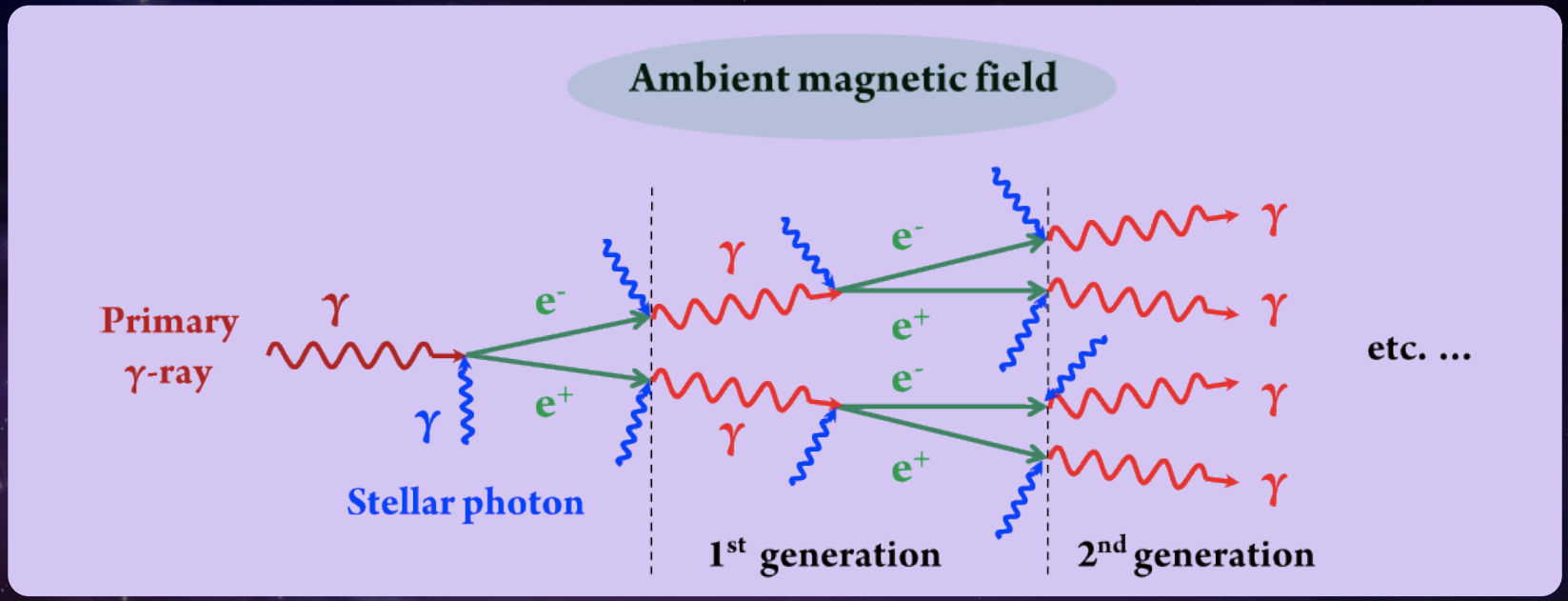
1. Cosmological cascades
   - Cosmological cascades
   - Intergalactic Magnetic Field (IGMF)
   - Extragalactic light
2. Expected observables effects
   - Energy redistribution
   - Halo effect
   - Time delay
3. Thesis works
   - Monte Carlo simulation
   - Compare to analytic results
   - Future works
4. Conclusion

Cosmological cascades



- Distant source of γ-rays (100GeV to 100TeV)
- Pairs production (e^-/e^+) on EBL (IR $\rightarrow$ UV)
- Inverse Compton scattering on CMB
- EGMF $\Rightarrow$ lepton trajectory deflected

Intergalactic Magnetic Field (IGMF)

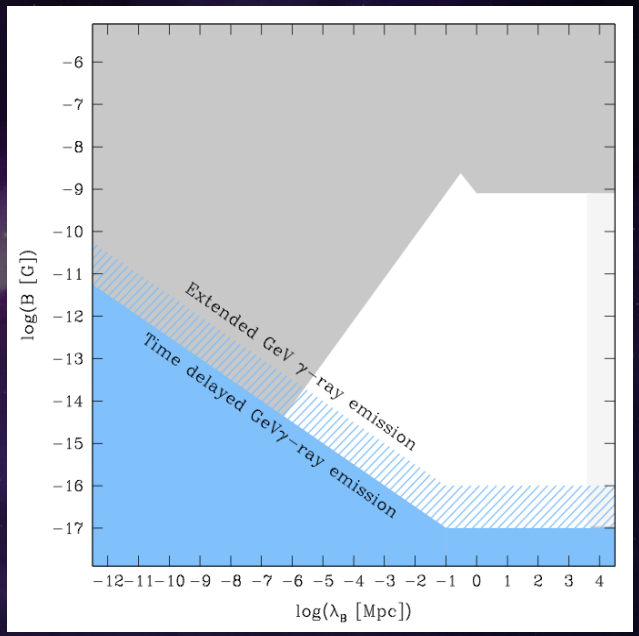
In galaxies

- Strong magnetic filed ($B \approx 10^{-5} G$)
- Generated by dynamo effect
- Required a seed to exist

EGMF generation

- Created during the inflation
- Created during phase transition (QCD or electroweak decoupling)
- Associated to large structure development

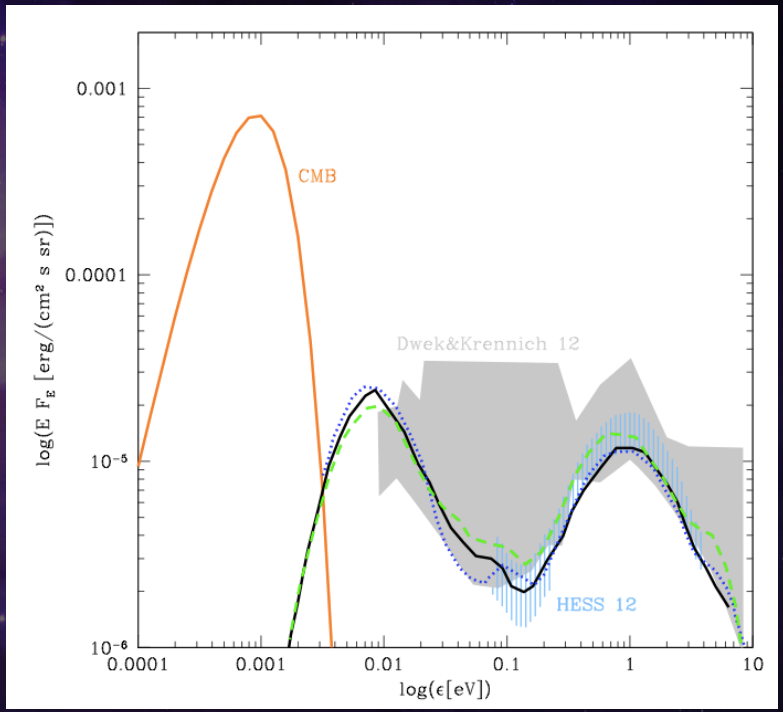
Models predict $B \approx 10^{-25}$ to 10^{-9} G !!



Durrer & Neronov 2013

Extragalactic light

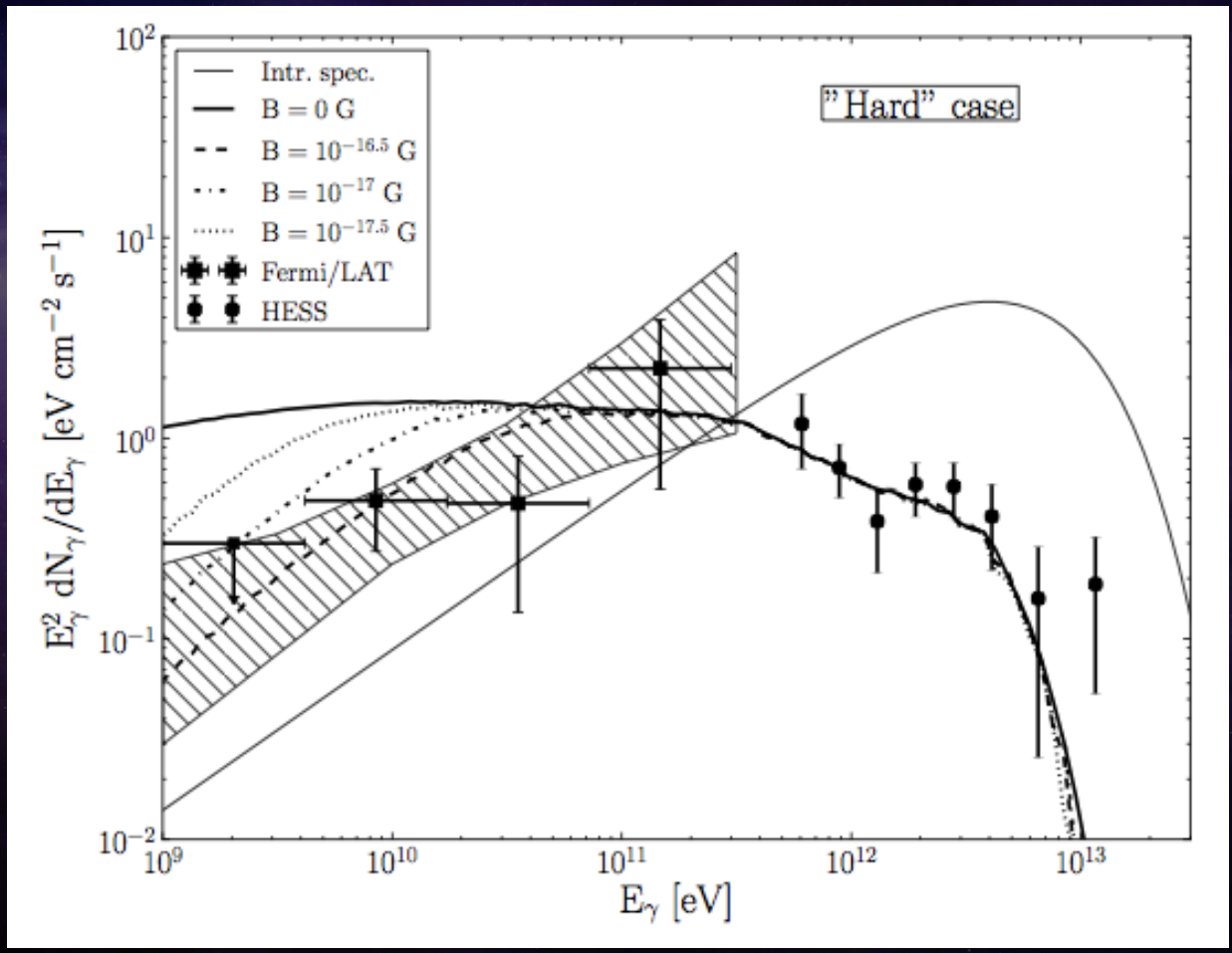
1. CMB
   - Black body at $T_0 = 2.725K$
2. EBL: light from star:
   - $0.1 \rightarrow 1000\mu m$
   - History of stellar formation
   - Galactic evolution
   - Depends on redshift



Energy redistribution

lepton trajectory deflected by EGMF ⇒

- Energy redistributed from TeV to GeV

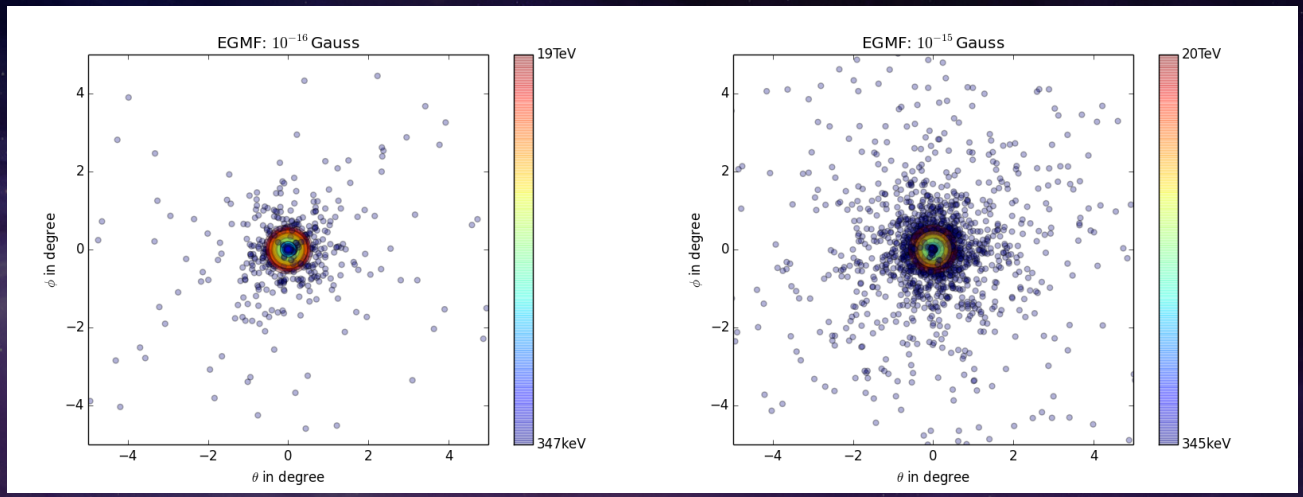


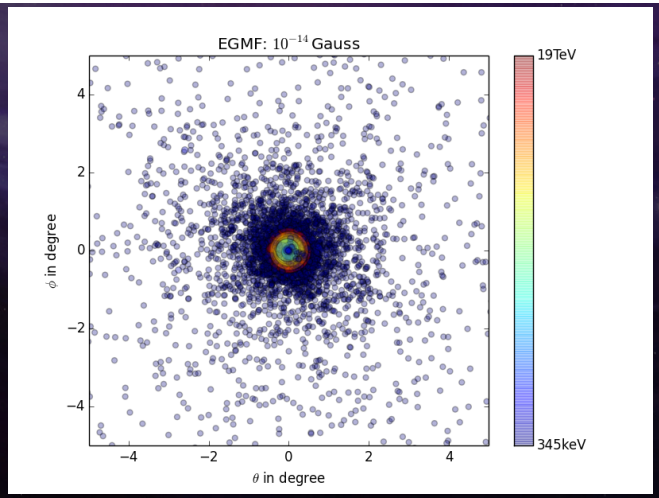
Vovk et Al. (2012): Blazar 1ES 0229+200

Halo effect

lepton trajectory deflected by EGMF $\Rightarrow$

- Halo effects = size of the source extended



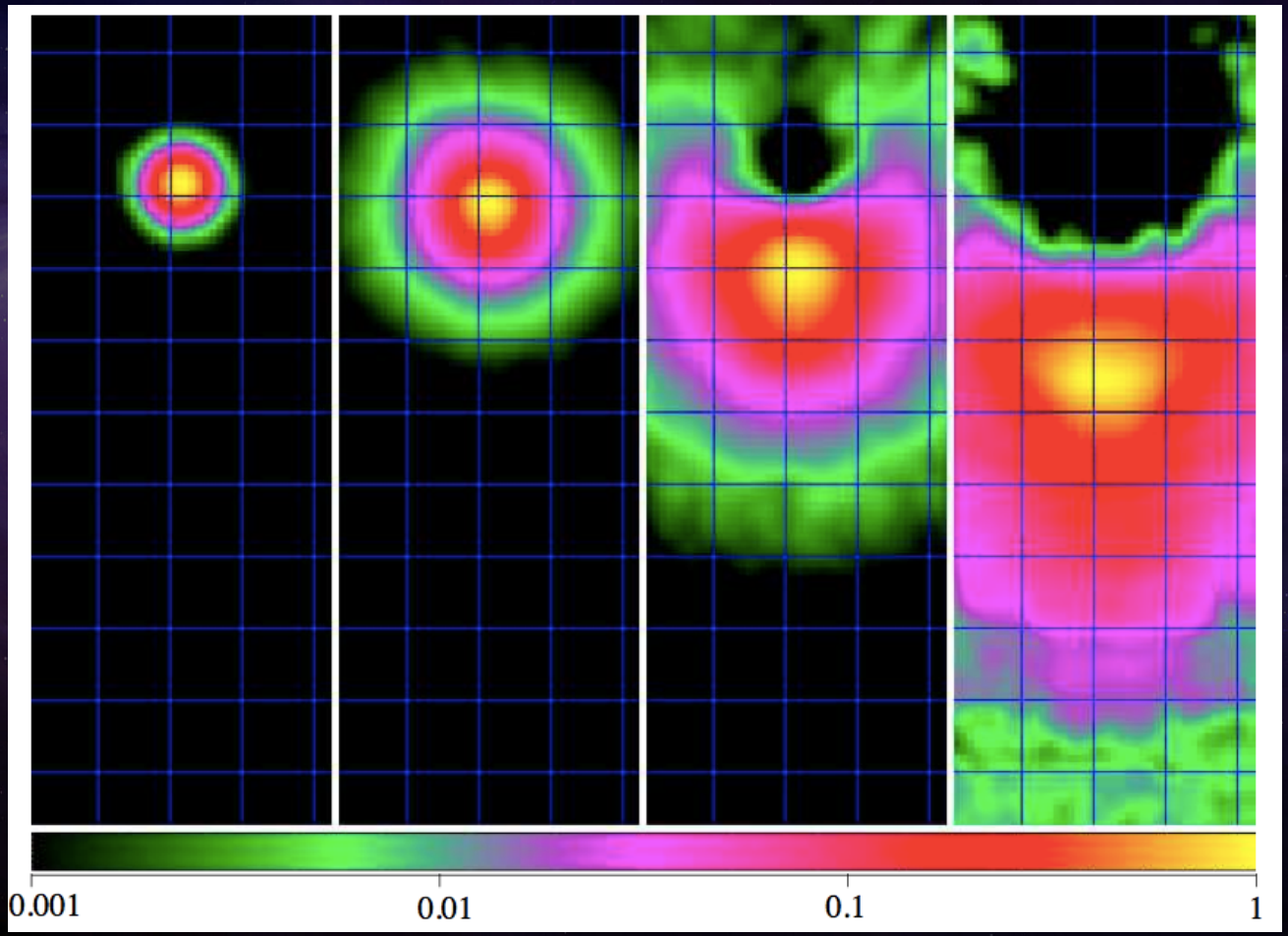


One direction and monokinetic jet ($10^5\,GeV$)

Time delay

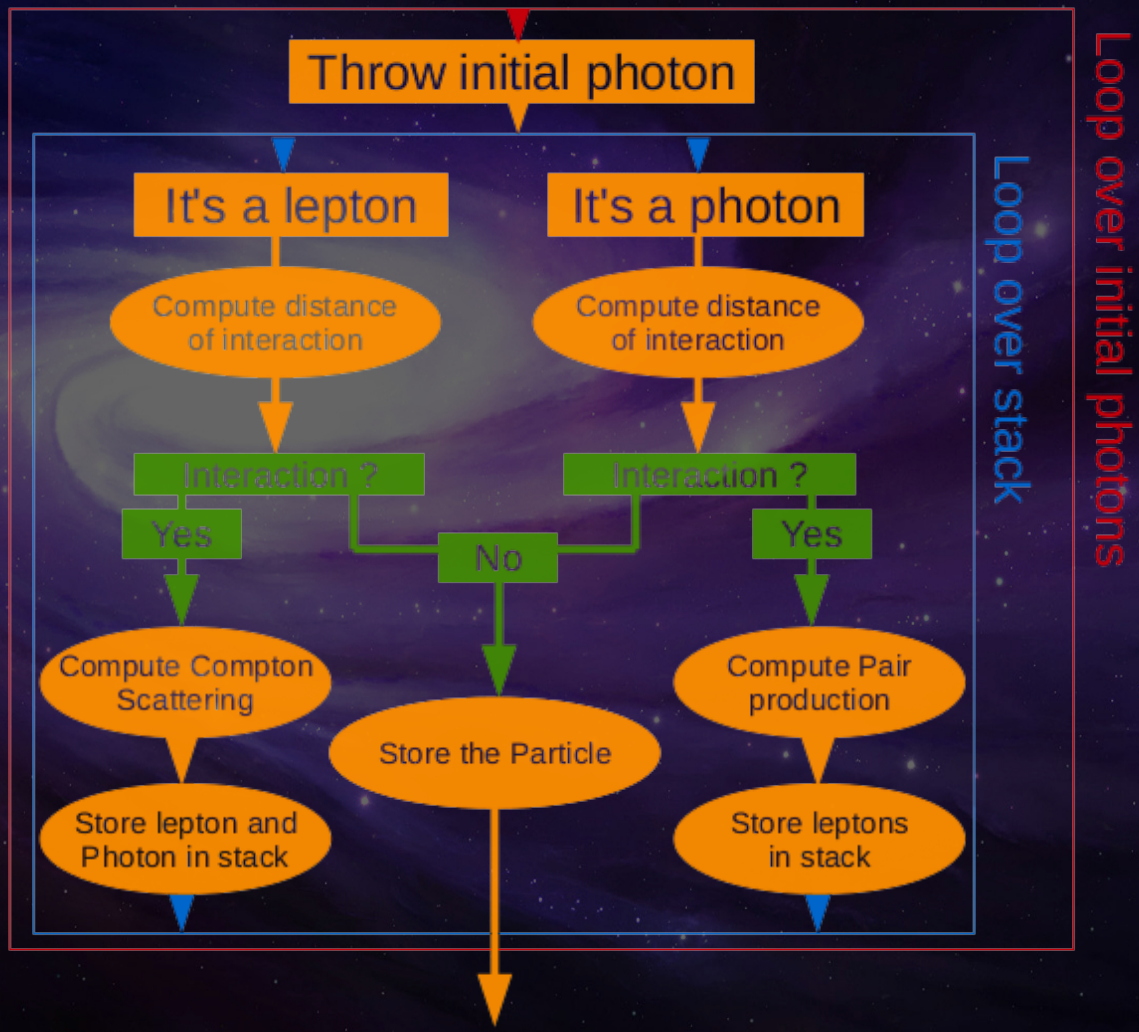
lepton trajectory deflected by EGMF $\Rightarrow$

- Time delay in the arrival of the particles

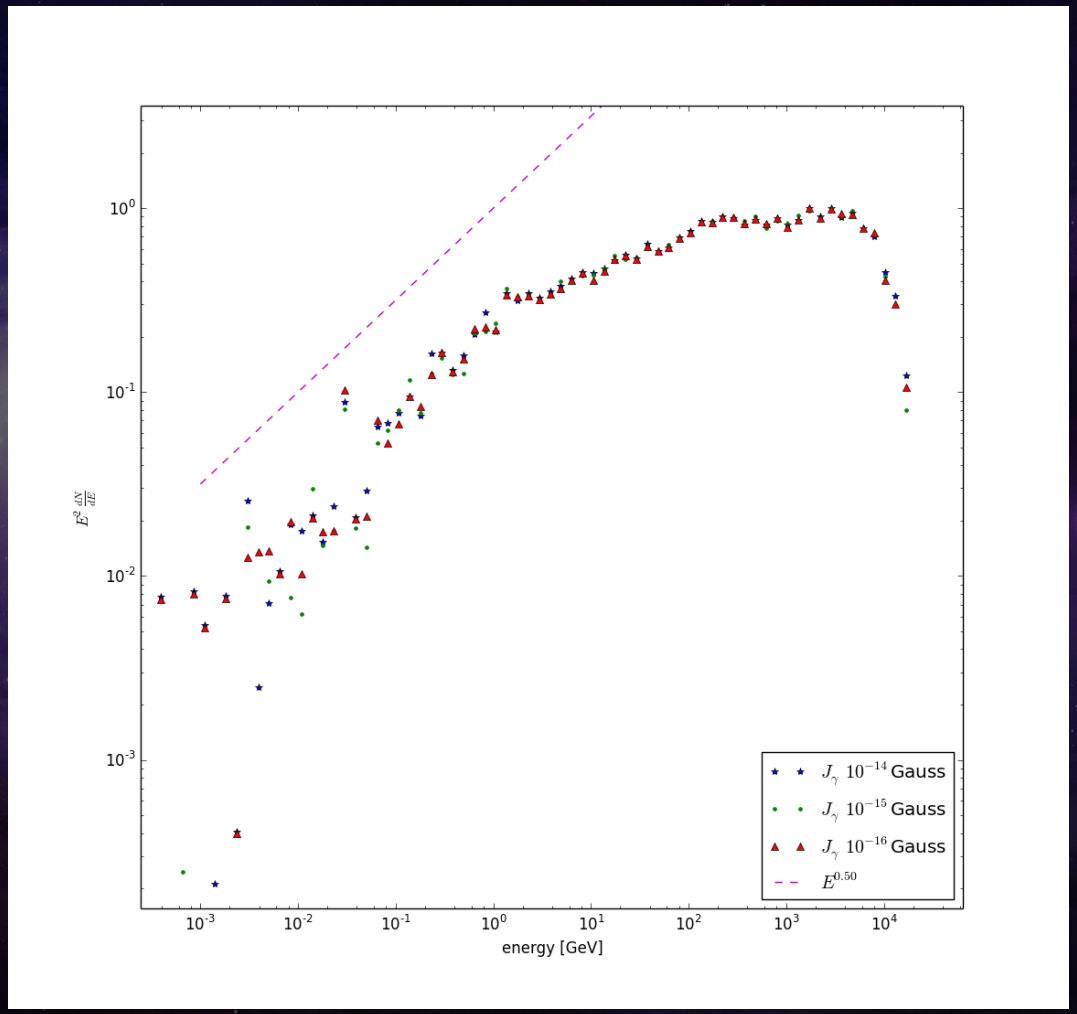


$B \approx 10^{-16} G$ (Source: Neronov & al. 2010)

Monte Carlo simulation



Compare to analytic results



One direction and monokinetic jet ($10^5\,GeV$)

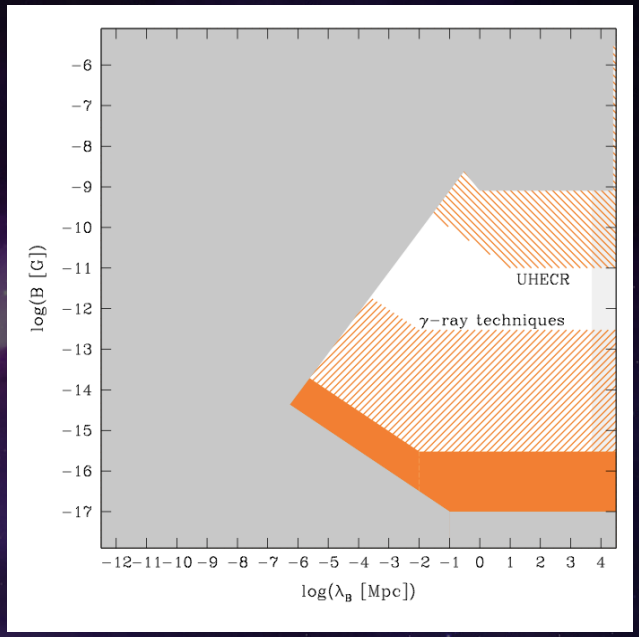
Future works

- Explore parameter space, make predictions for observables
- Compare with Fermi, and HESS data, predictions for CTA
- Model the capture, transport and annihilation of cascade positrons in our galaxy, compare with INTEGRAL 511 keV maps.

Conclusion

Cosmological cascades could improve our knowledge on

- Extragalactic magnetic field and its origin
- Spectrum and physics of γ-rays sources
- Extragalactic background light
  $\Rightarrow$ Evolution of galaxies
- Annihilation of galactic positrons



Source: Durrer & Neronov 2013

Thank you!
Questions?