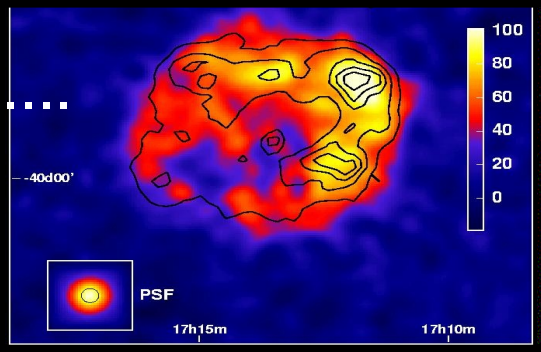
Studies of VHE Phenomena in Astrophysical Environments

Cosmic labs....



Gamma-Ray Origin:

electromagnetic

$$e/p+\gamma \rightarrow e/p+\gamma$$

strong

$$p+p \rightarrow p+p+\pi^0$$

600 mb $\approx \alpha^2 \left(\frac{hc}{m_e c^2}\right)^2$

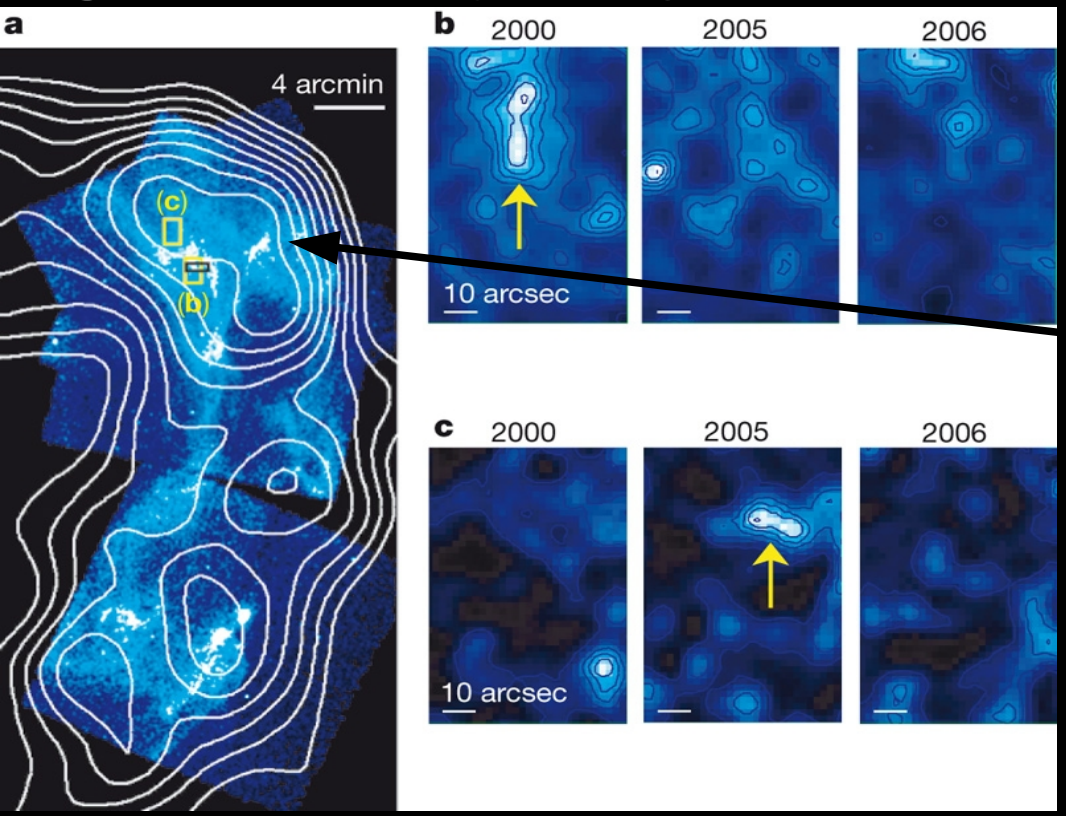
0.1 μb $\approx \alpha^2 \left(\frac{hc}{m_p c^2}\right)^2$

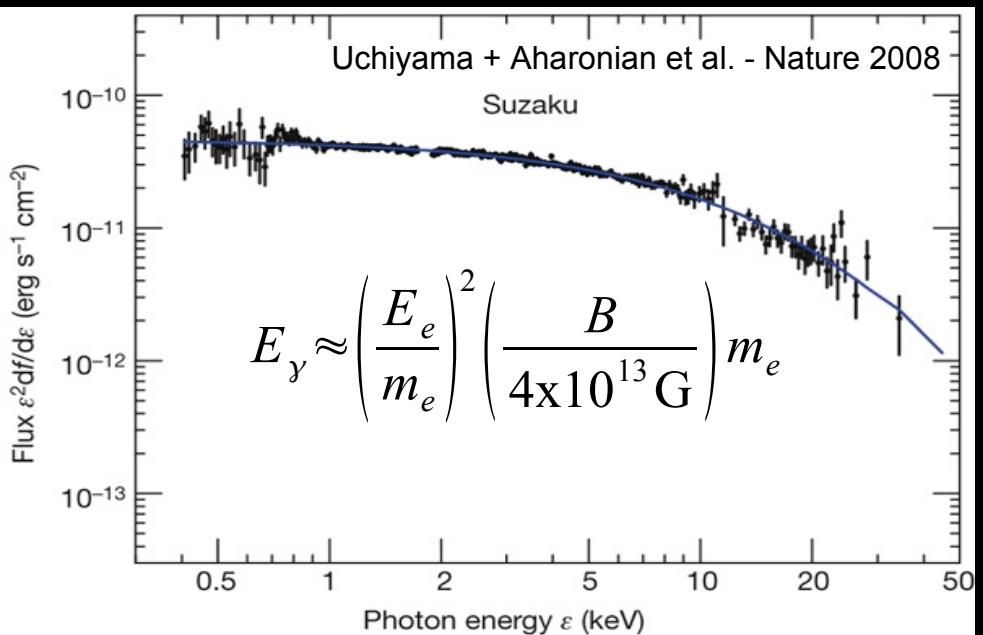
30 mb $\approx \left(\frac{hc}{m_\Delta c^2}\right)^2$

leptons or hadrons creating gamma-rays?.....investigate sources

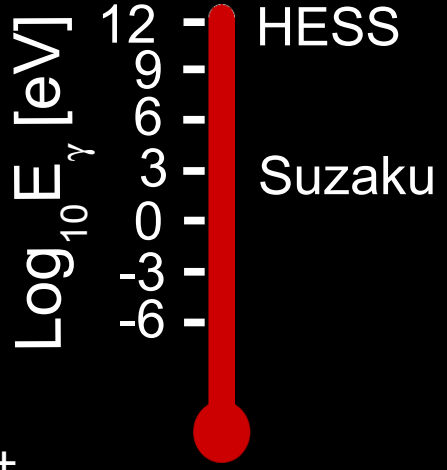
$$t_{\text{acc.}} = \eta \frac{r_{\text{Larmor}}}{c}$$

SNR- RXJ1713





$$E_\gamma \approx \left(\frac{E_e}{m_e}\right)^2 \left(\frac{B}{4\text{x}10^{13}\,\text{G}}\right) m_e$$



Fast acceleration + cooling occurring

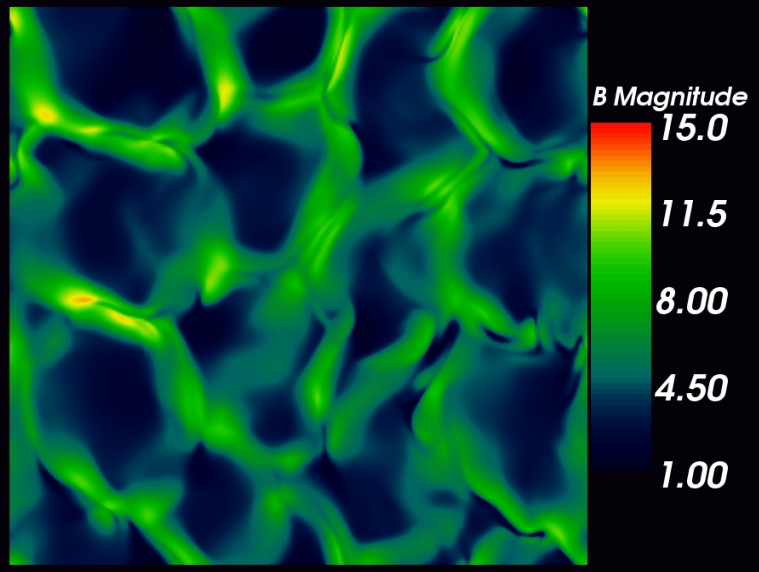
$$t_{\text{acc.}} = \eta \frac{r_{\text{Larmor}}}{c}$$

$$\frac{r_{\text{Larmor}}}{c} = \left(\frac{E_e}{10^{14}\,\text{eV}}\right)\left(\frac{\text{mG}}{B}\right) 10^{-4}\,\text{years}$$

$$t_{\text{acc}} = \xi \left(\frac{E_\gamma}{\text{keV}}\right)^{0.5} \left(\frac{B}{\text{mG}}\right)^{-1.5} \left(\frac{\beta_{\text{sh}}}{0.01}\right)^{-2}\,\text{years}$$

→ Very efficient acceleration seems to be occurring (ξ=1)-> Bohm

SNR Magnetic Field Amplification by cosmic-rays



$$U_{\mathrm{CR}} \approx 10^{4} U_{B(initial)}$$

$$U_{\mathrm{CR}} \approx 10^{2} U_{B(final)}$$

Efficient acceleration of cosmic-ray ions leads to significant amplification of magnetic field in shock precursor.

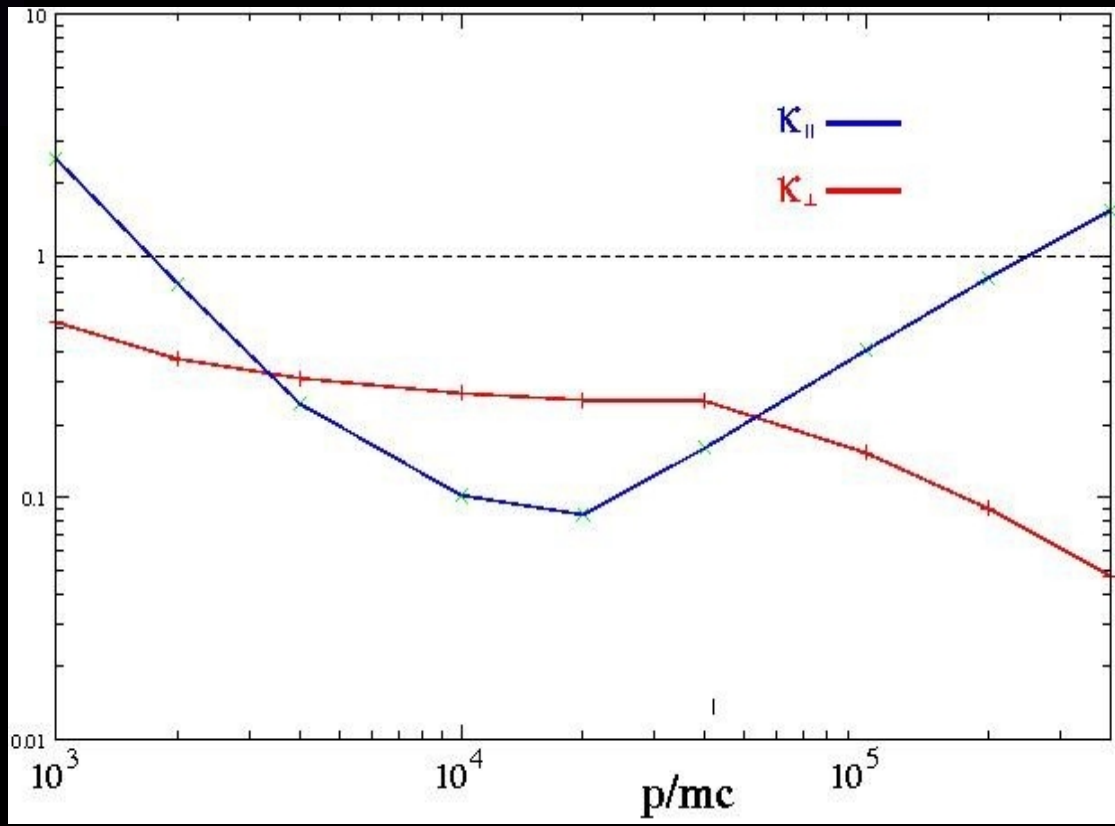
Diffusion coefficients are reduced in non-linear turbulence...sub Bohm diffusion in upstream region!

–> more rapid acceleration.

Acceleration time determined by longest residence time.

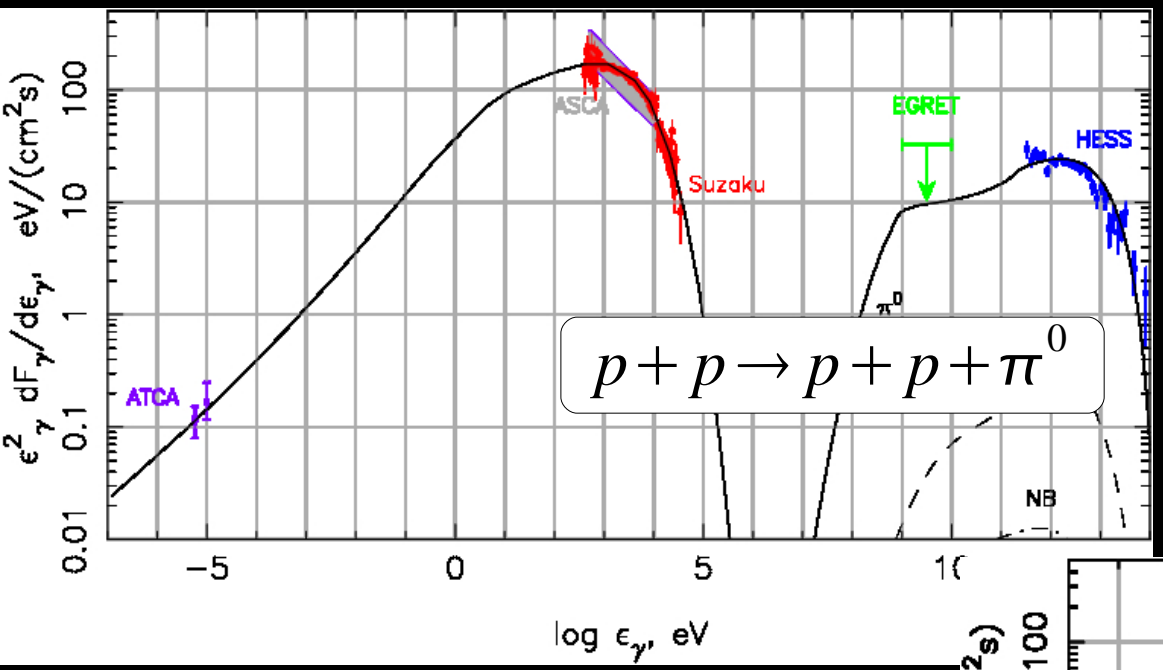
$$t_{res} \approx \frac{4\kappa}{\beta_{sh} c^{2}} \propto \frac{1}{B}$$

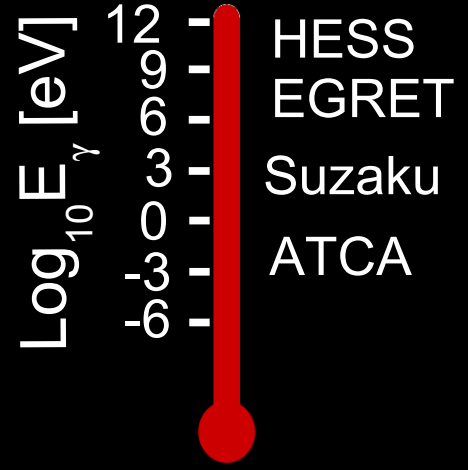
Non-linear field amplification **upstream** of shock front is essential



SNR- RXJ1713

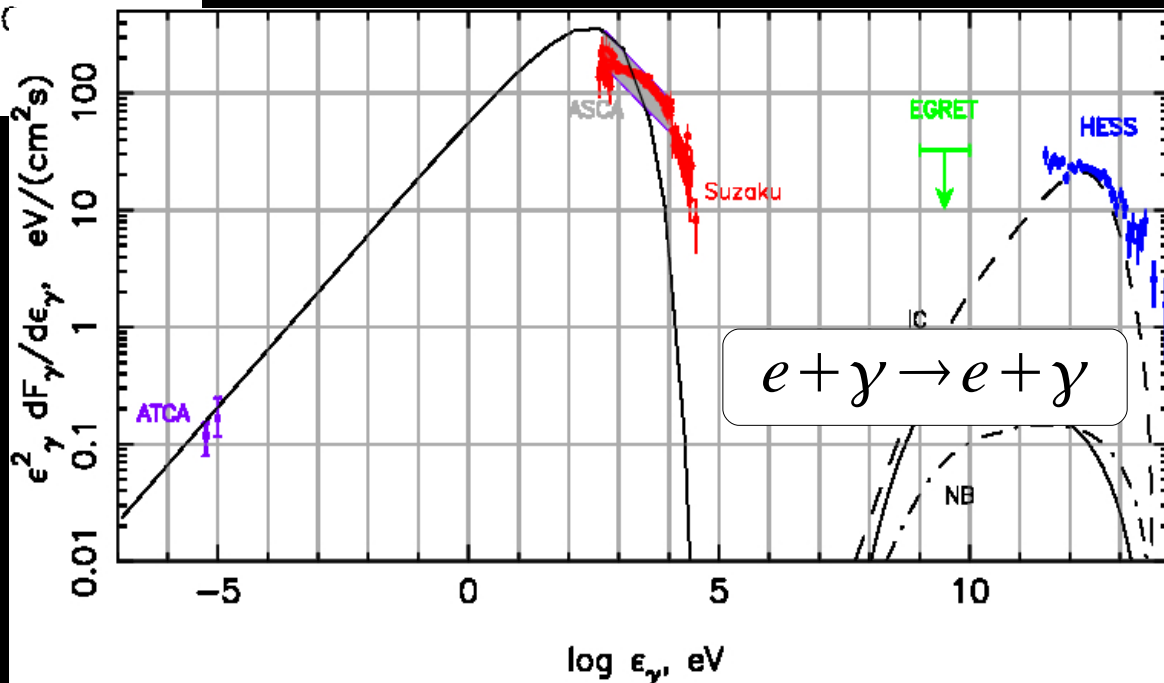
Emission Origin





Berezhko & Völk
A&A, 492, 695
(2008)

B-field amplification (130 μG)

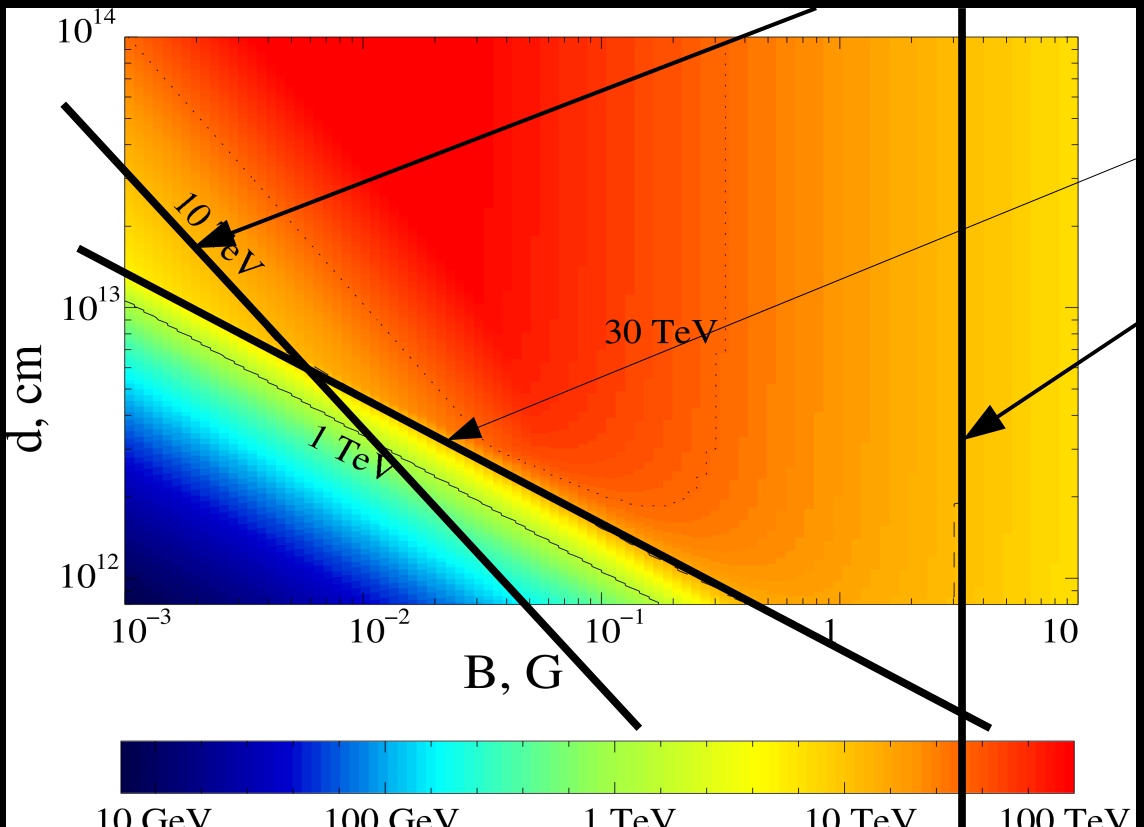


Gamma-Ray Binaries

$$t_{\mathrm{acc.}} = \eta \frac{r_{\mathrm{Larmor}}}{c}$$

Hillas condition

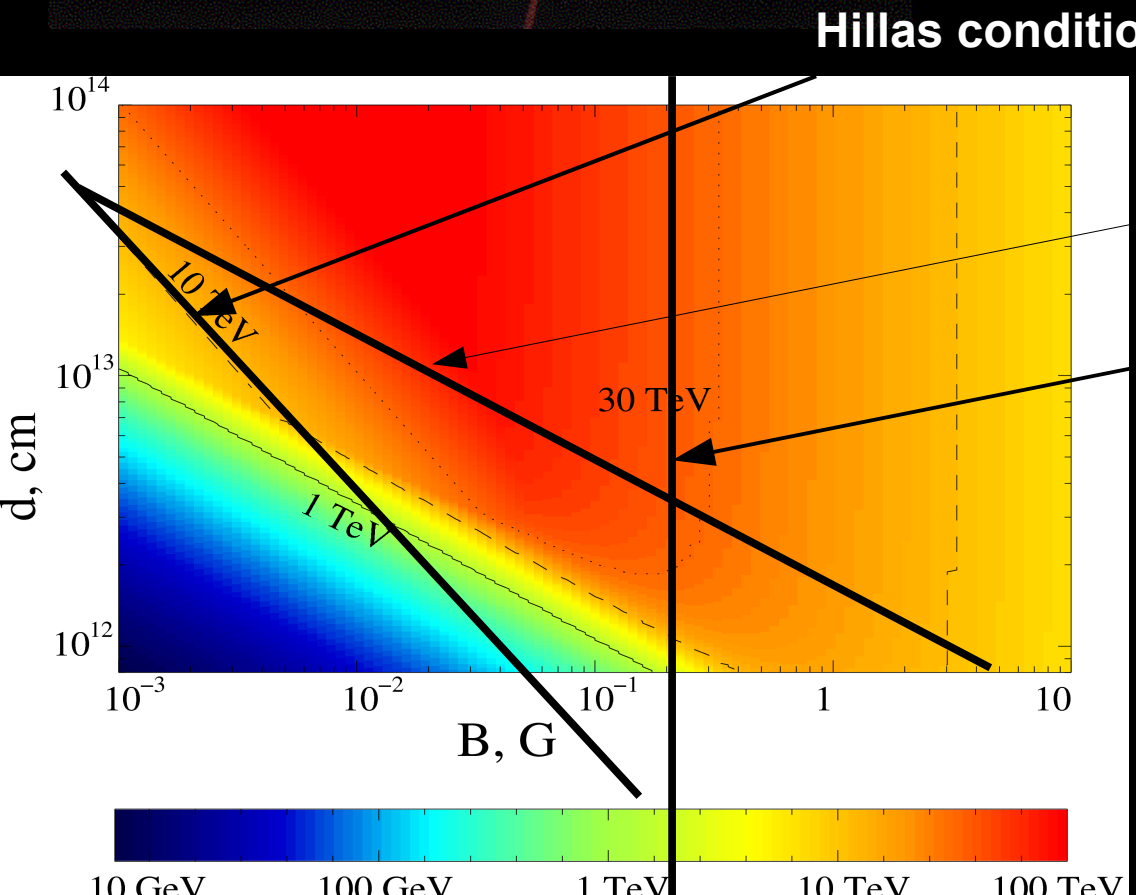
$$\frac{r_{\mathrm{Larmor}}}{c} = \left(\frac{E}{20\ \mathrm{TeV}}\right)\left(\frac{3\ \mathrm{G}}{B}\right) 0.6\ \mathrm{s}$$



Inverse Compton (η=3)

Synchrotron (η=3)

Gamma-Ray Binaries



$$t_{\mathrm{acc.}} = \eta \frac{r_{\mathrm{Larmor}}}{c}$$

$$\frac{r_{\mathrm{Larmor}}}{c} = \left(\frac{E}{20\ \mathrm{TeV}}\right)\left(\frac{3\ \mathrm{G}}{B}\right) 0.6\ \mathrm{s}$$

Inverse Compton (η=30)

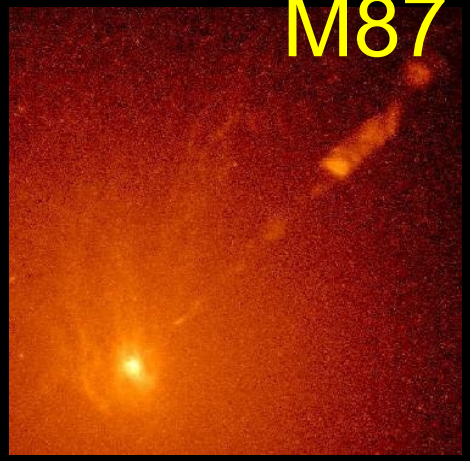
Synchrotron (η=30)

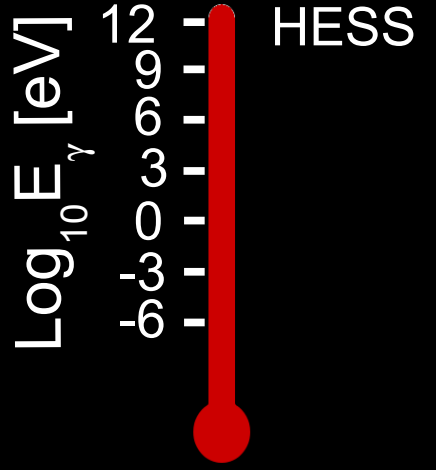
$$\eta \approx 3$$

$$t_{\mathrm{acc.}} = 2\ \mathrm{s}$$

→ Very efficient acceleration seems to be occurring (faster than the LHC!)

Supermassive Blackholes





$$M \approx 10^9 M_{\text{solar}}$$

$$R_{\text{Schwarz}} = 3 \left(\frac{M}{M_{\text{solar}}} \right) \text{km}$$

Rapid TeV variability on timescale (1-2) days

Variability source size:

R ~ c dt ~ (3-6) $R_{Schwarz}$

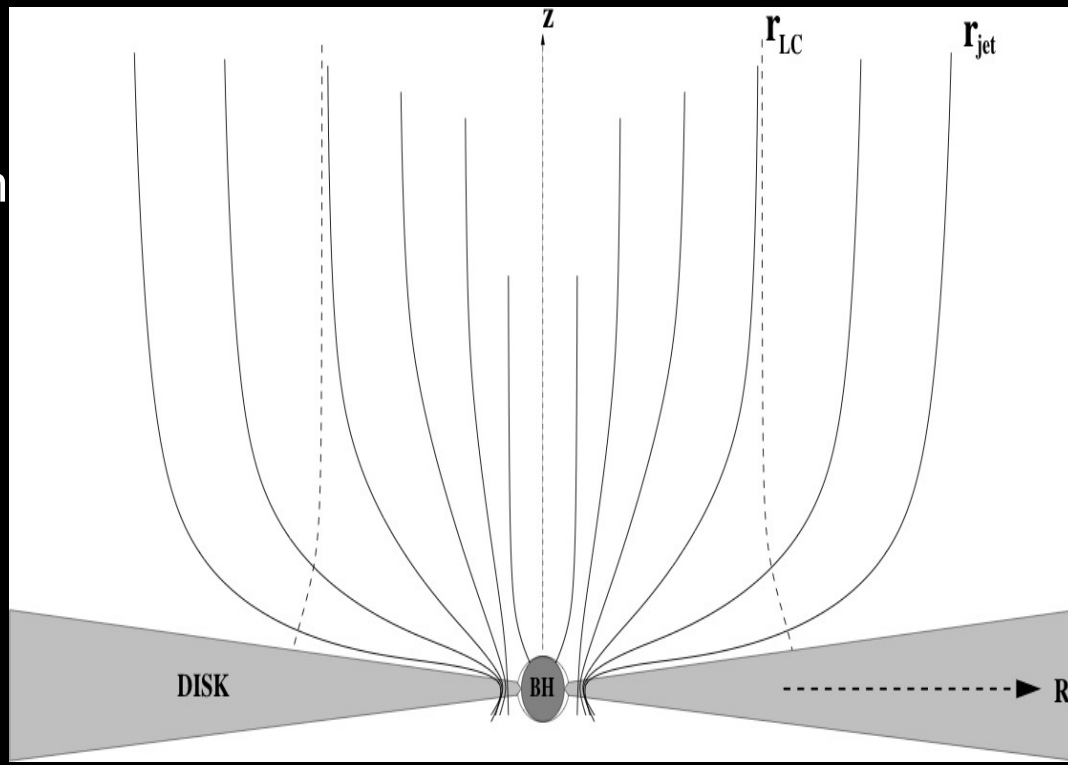
γ-rays originate from a very compact region

Only possible because is under-luminous ($10^{-6} L_{Edd.}$)

Able to study acceleration in BH magnetospheres!

$$R_{\text{magnetosphere}} \approx 5 R_{\text{Schwarz}}$$

=> *probing the event horizon region in AGN*



The CR Connection(s): UHE Photons + UHECR protons Sources

(PRIMARIES)

(SECONDARIES)

Max-Planck-Institut
für Kernphysik

Andrew
Taylor

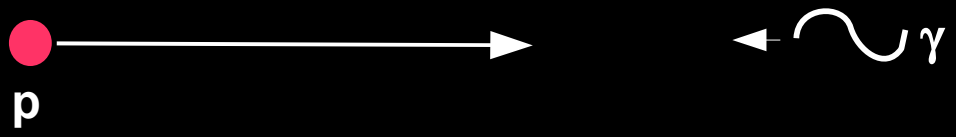
Different Interaction Scales

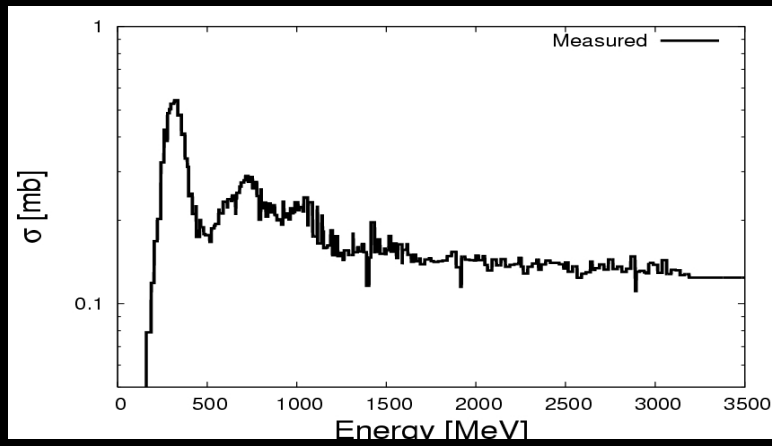
resonant-type cross sections

$> 10^{18}$ eV protons and nuclei

0.5 mb

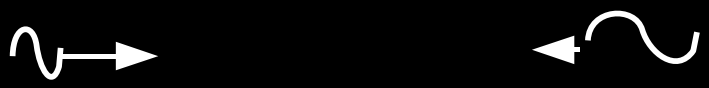
(primaries)

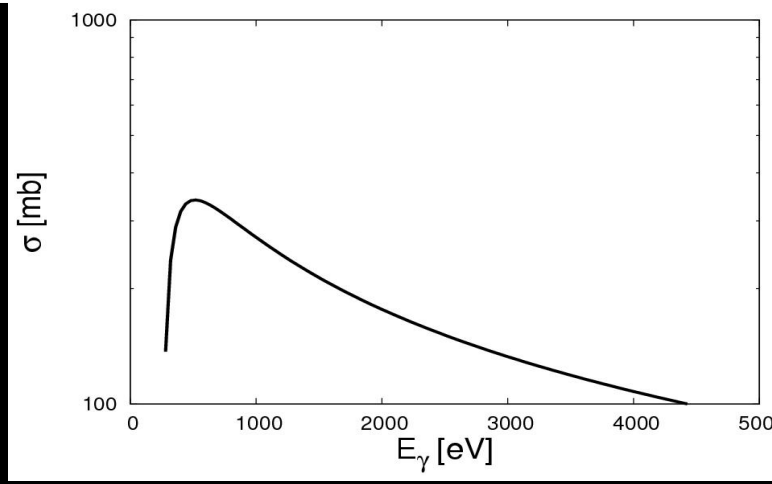




(secondaries)

200 mb





ν_μ

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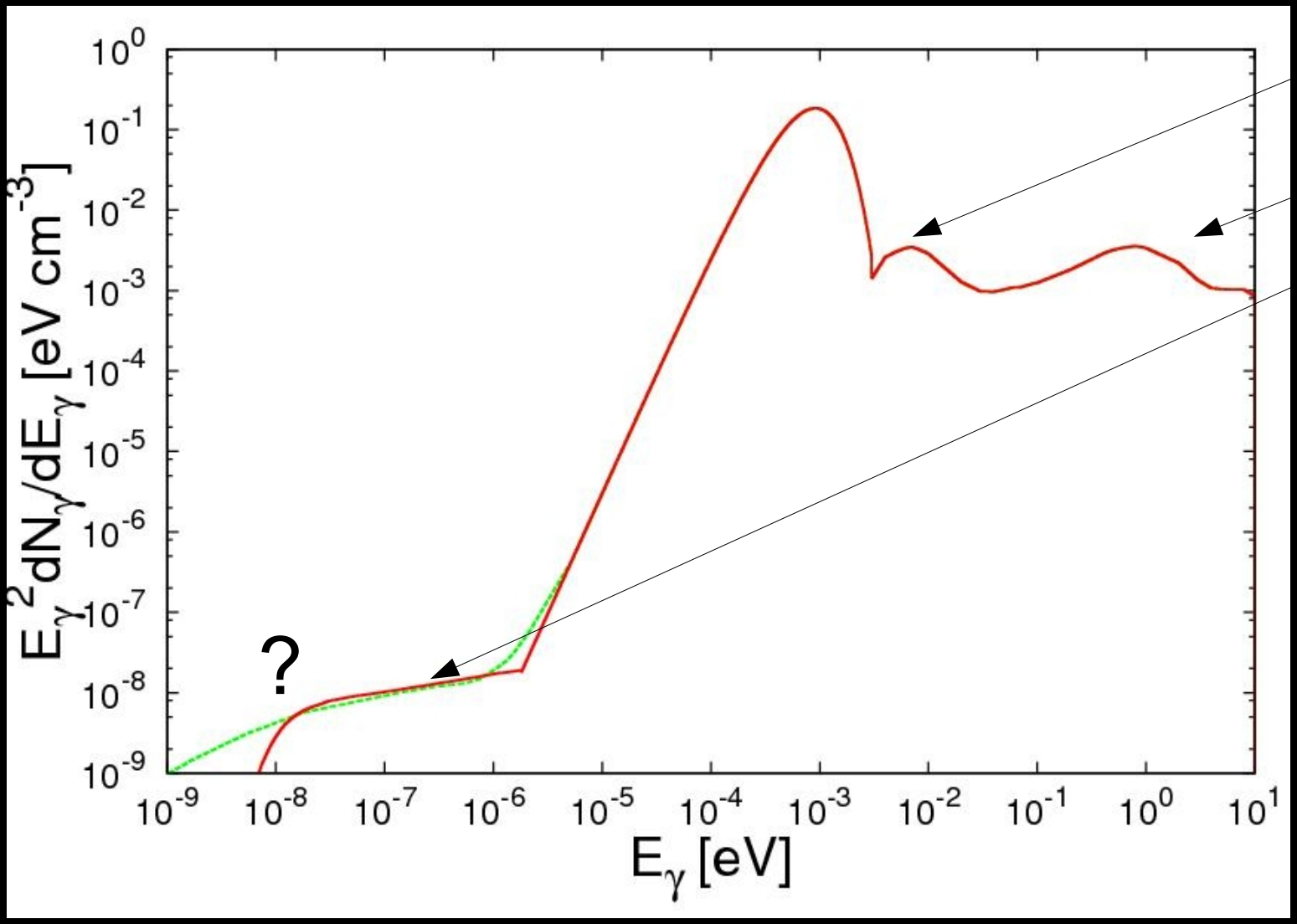
Cosmic Background Radiation Fields



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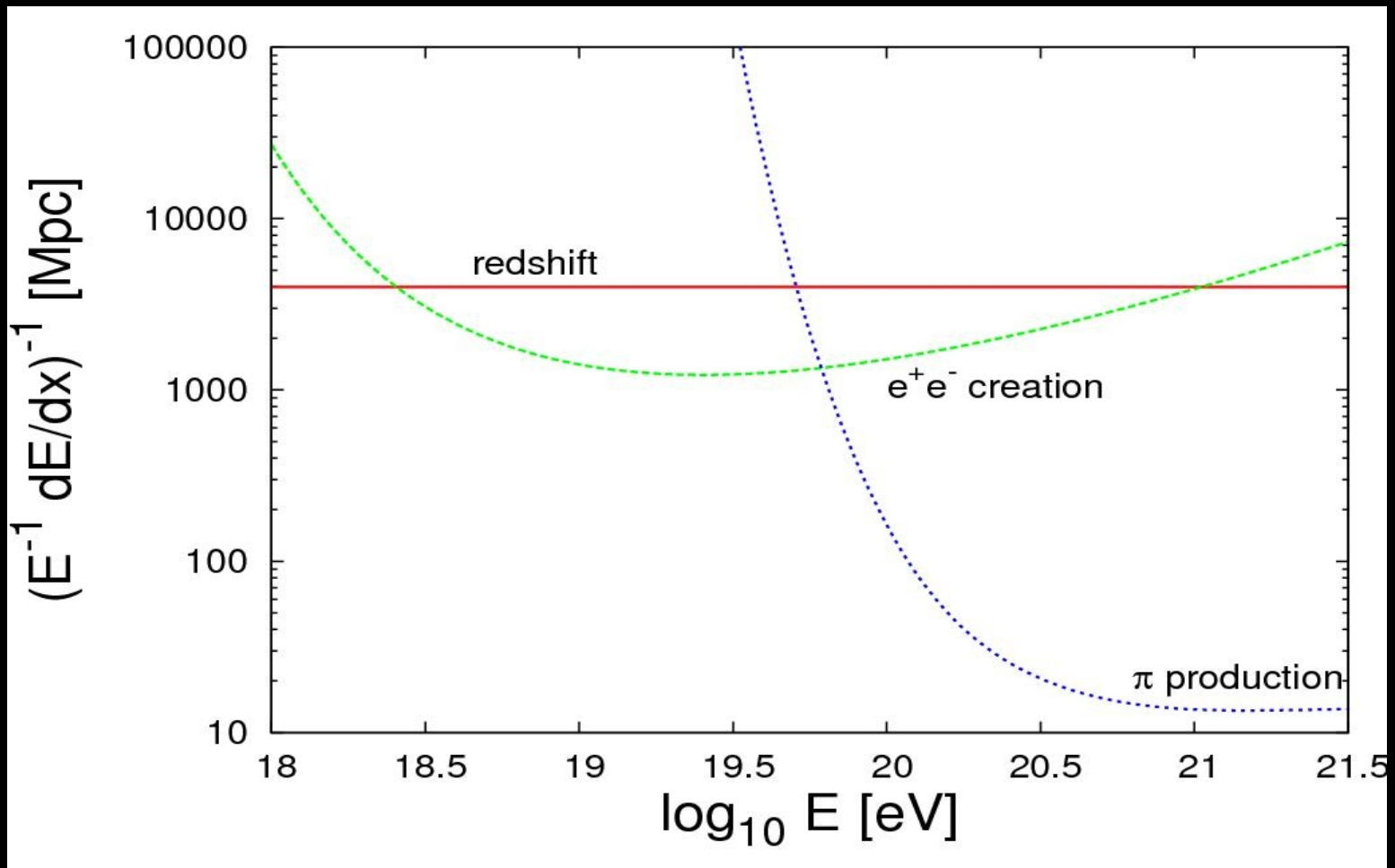
The Impedance of Background Radiation to High Energy Protons

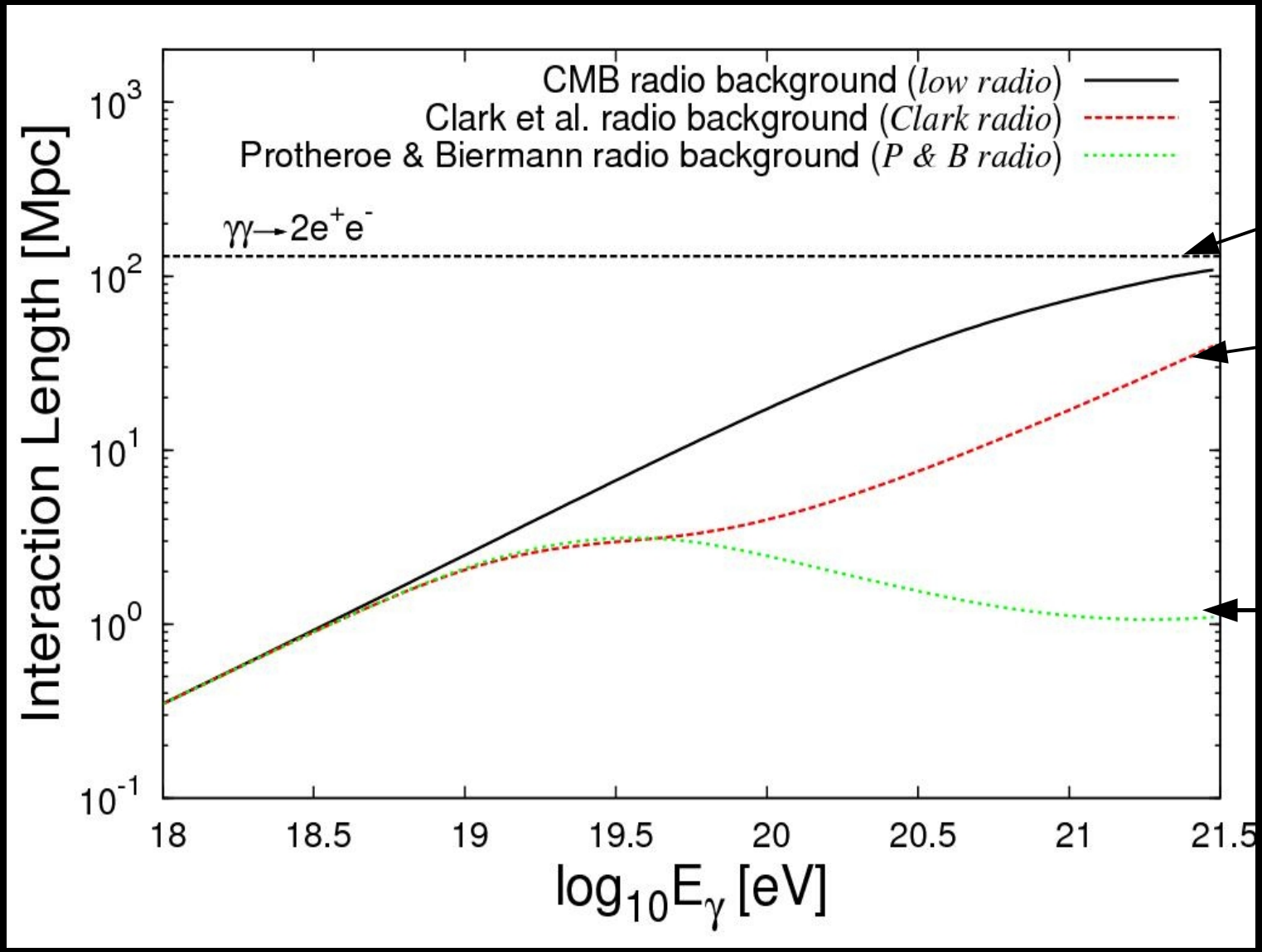
$$R = \frac{1}{2\Gamma_p^2}\int_0^\infty \frac{1}{\epsilon_\gamma^2}\frac{dn_\gamma}{d\epsilon_\gamma}\,d\epsilon_\gamma \int_0^{2\Gamma_p\epsilon_\gamma} d\epsilon_\gamma'\,\epsilon_\gamma'\,\sigma_{p\gamma}(\epsilon_\gamma')\,K_p$$

where R is the energy loss rate

where K_p is the proton inelasticity



The Impedance of Background Radiation to High Energy Photons

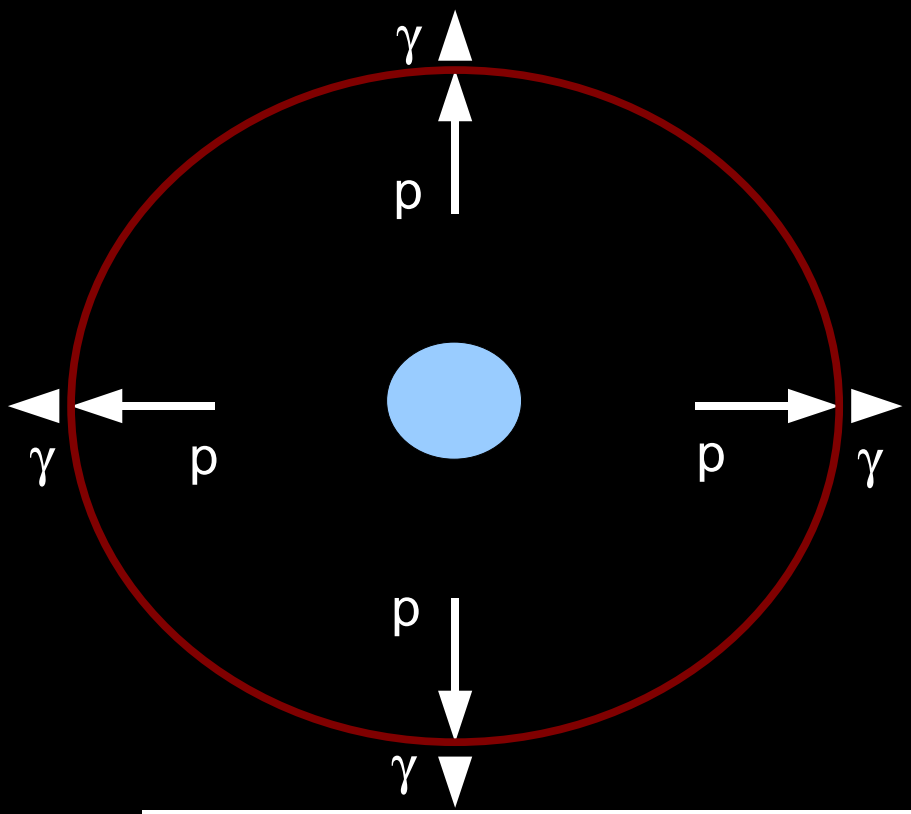


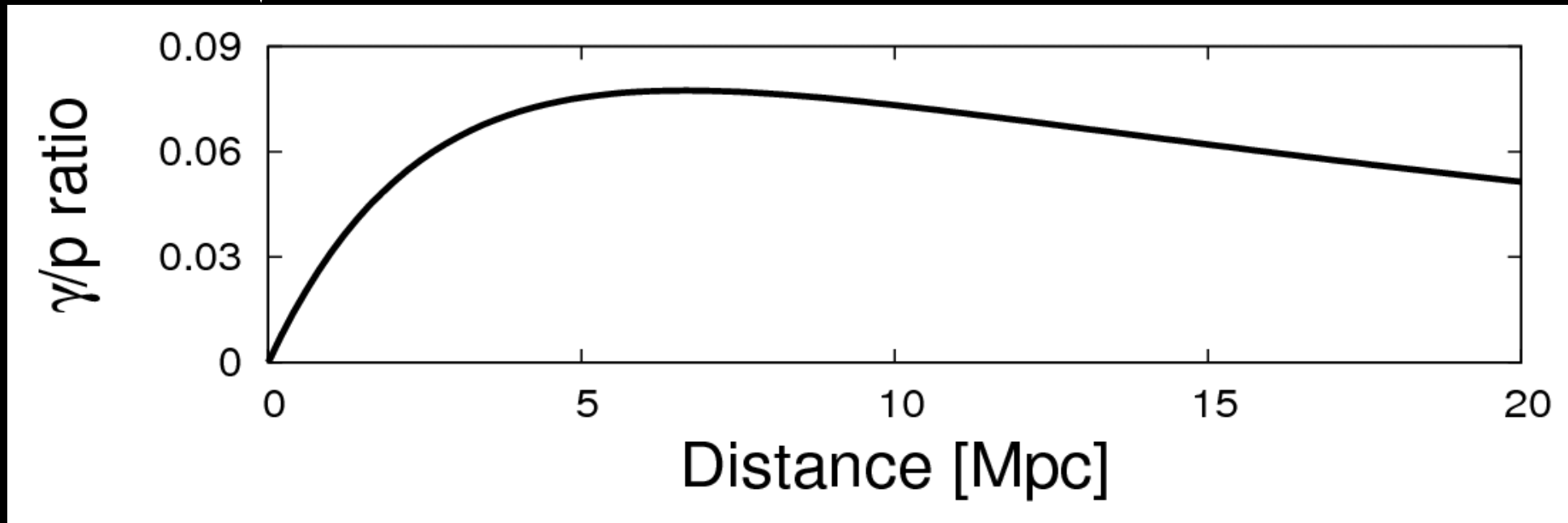
"*low radio*" background

"Clark *radio*" background

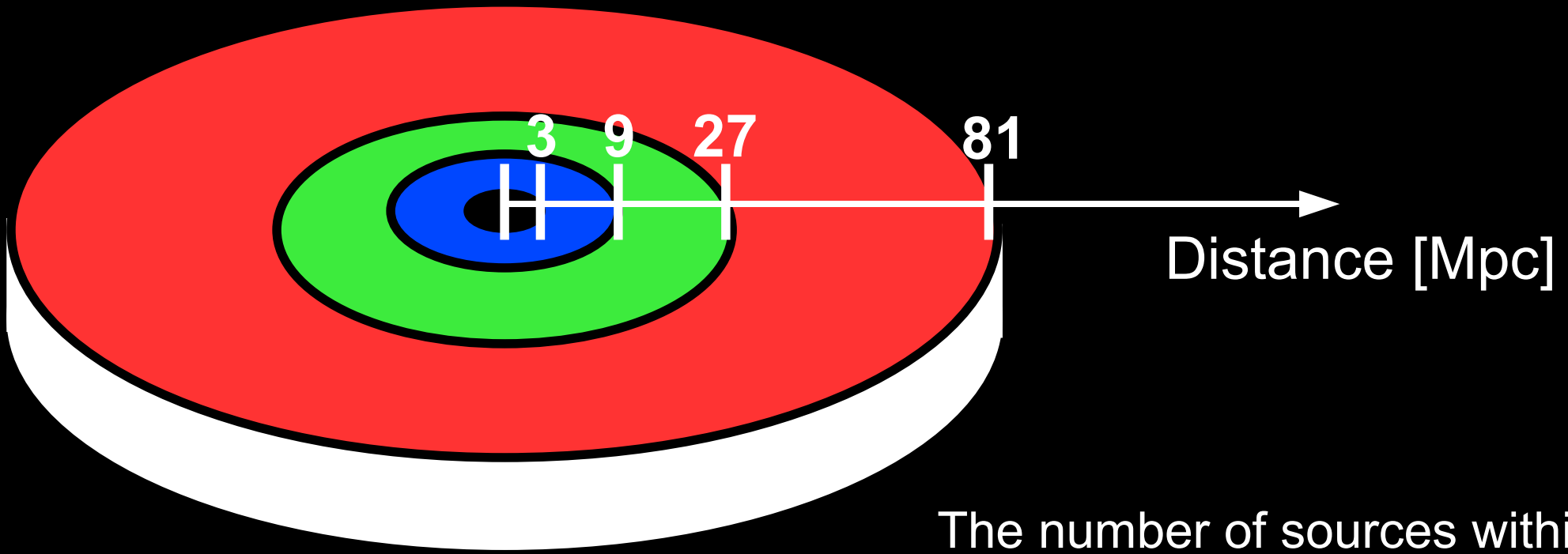
"P & B *radio*" background

The Halo Around Heavenly Bodies (which acc. UHECR)





A Homogeneous Source Distribution



The number of sources within a source shell of width dL would be proportional to dL for a local uniform source distribution

The ratio of sources from the different shells-

$$R_{n+1} : R_n = 1 : 0.3$$

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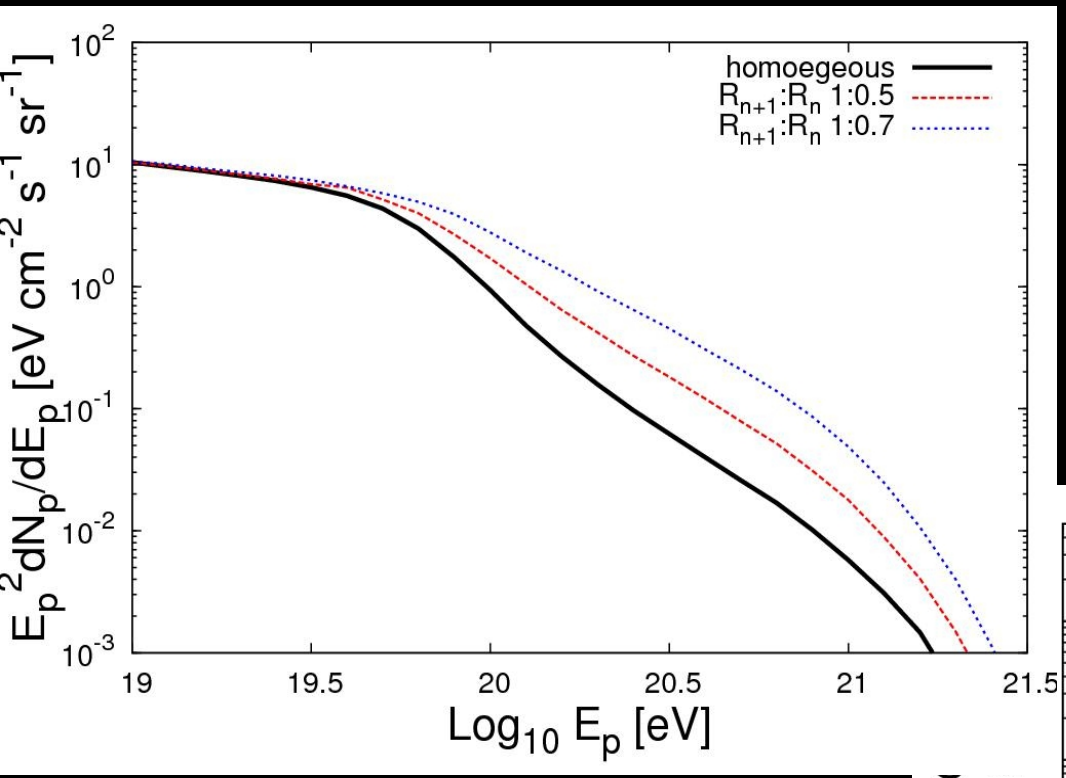
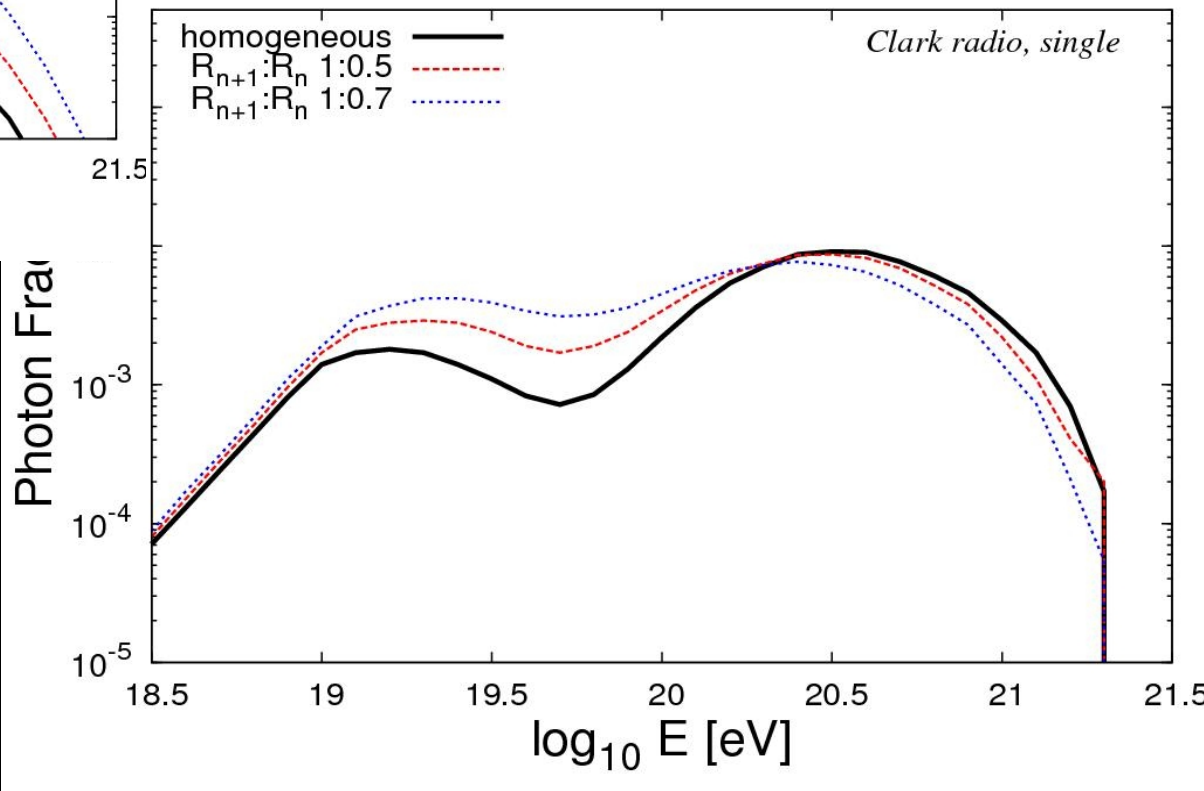
The Local UHECR Source Distribution- overdensity



Photon fraction and Cosmic Ray flux together allow you to probe the local UHECR source structure



Cen A as a Local UHECR Source