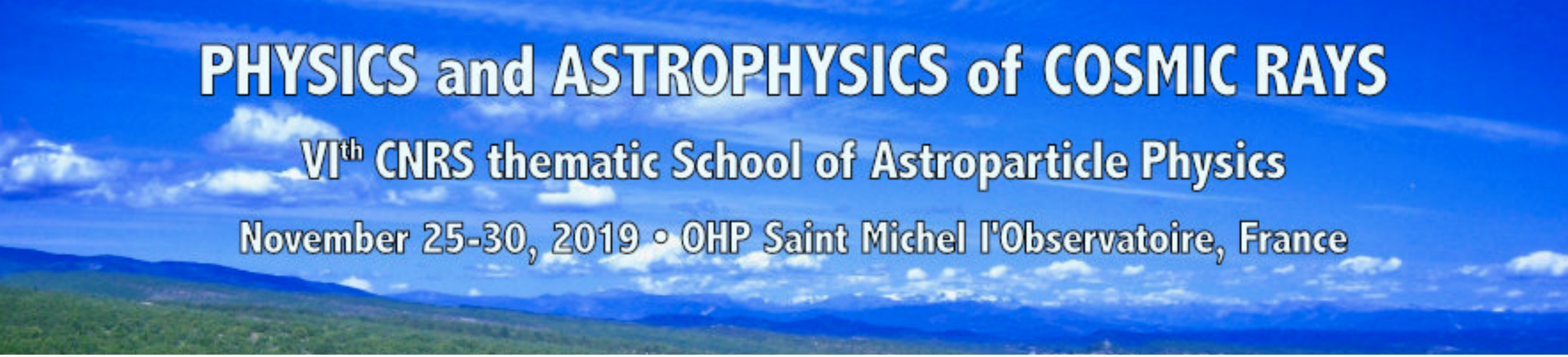


Université Paris Diderot - APC Laboratory - Theory Group

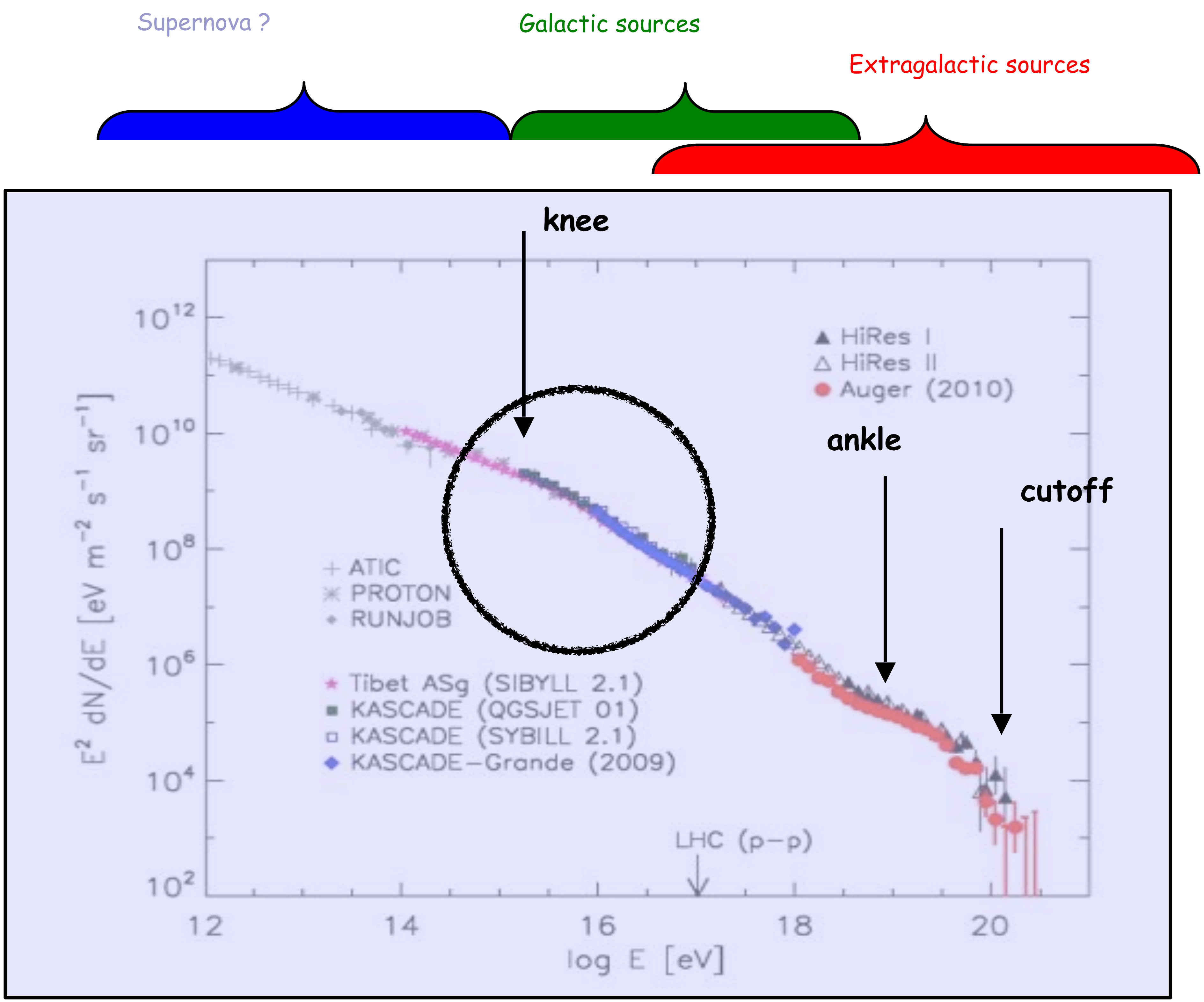
Vela as a source for galactic CR above 100 TeV and neutrinos below 100TeV

Speaker : Makarim BOUYAHIAOUI
In collaboration with : Dmitri SEMIKOZ
Michael KACHELRIESS

November 29, 2019


Part I
Cosmic rays

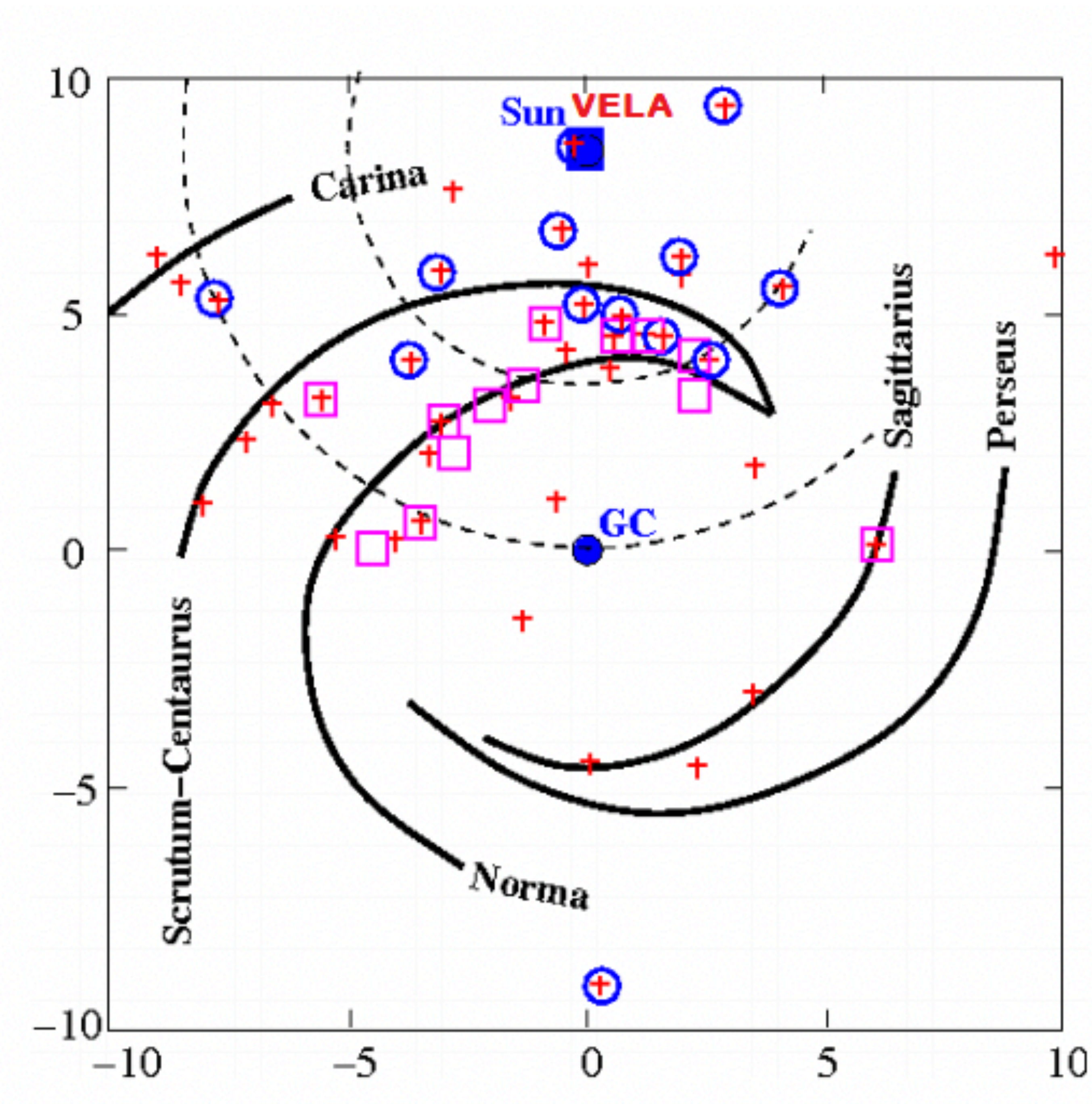
Introduction (Motivation)



Introduction (Explanations)

- Interaction changes in the multi-TeV region (excluded by LHC)
- Change of the diffusion properties of charged CR (V.L.Ginzburg and S.I.Syrovatskii 1964 , V.S.Ptuskin et al. 1993) (more on arXiv 1403.3380v2)
- **Dominant contribution of one single nearby source** (A.D. Erlykin and A. W. Wolfendale 1997)

Model of dominant source (Vela SNR)

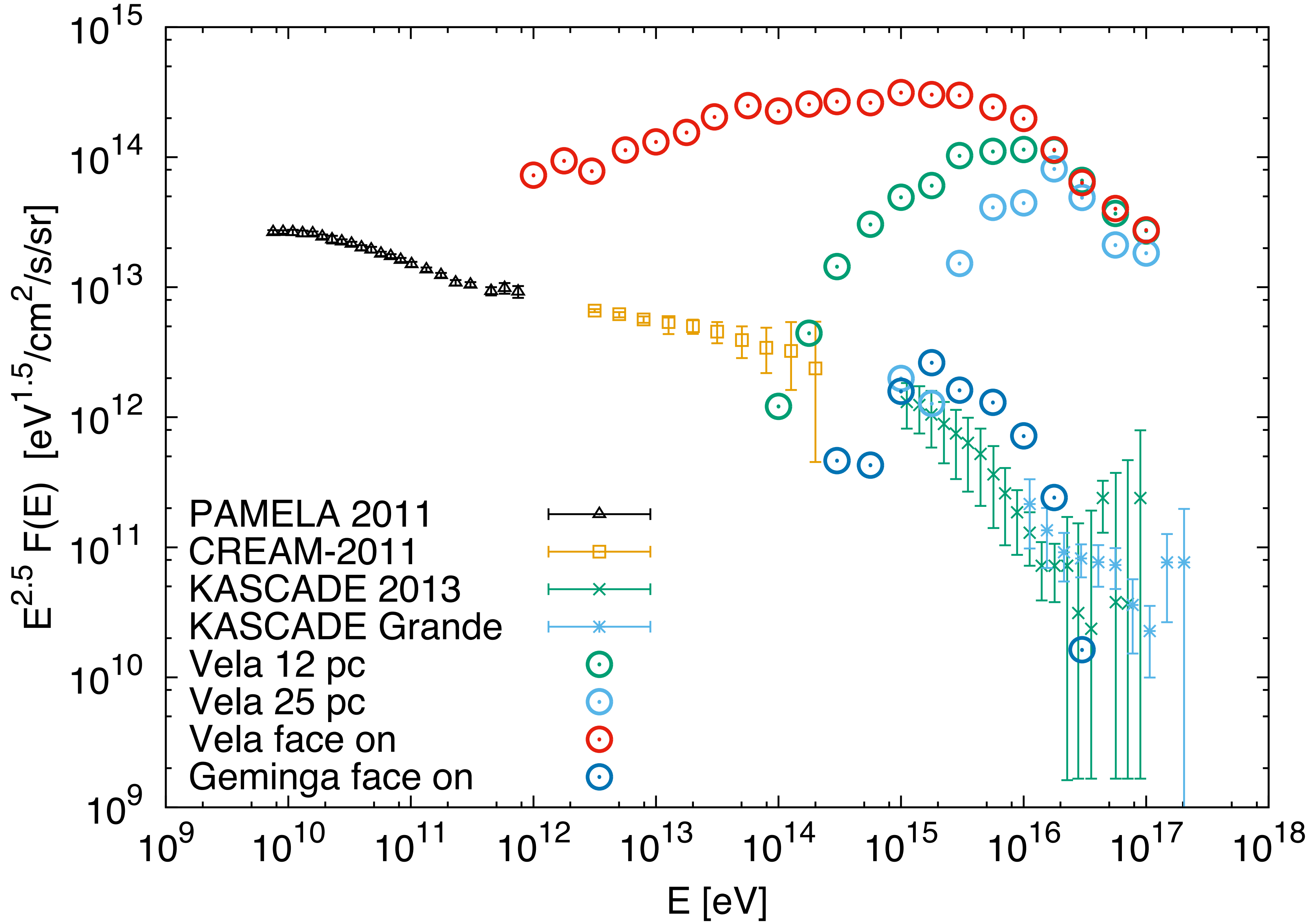


Kpc

Kpc

A.Neronov et D.V.Semikoz. 2012. arXiv 1201.1660

Model of dominant source (Vela SNR)



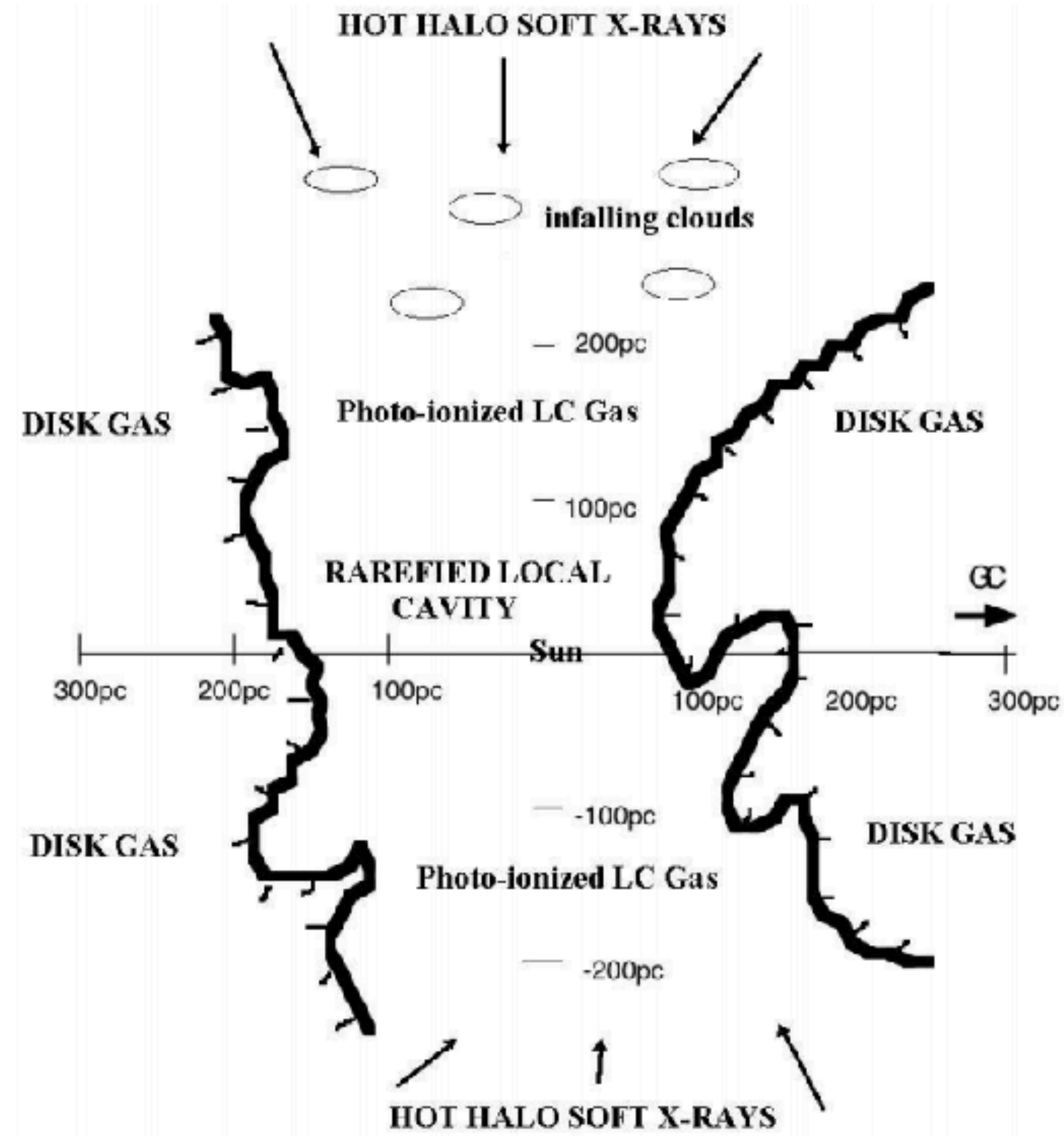
D.Smikoz

Model of propagation (Motivations for Local MF)

$$R_{bubble} = 100 - 175\,pc$$

$$B_{shell} = 8^{+5}_{-3}\,\mu G$$

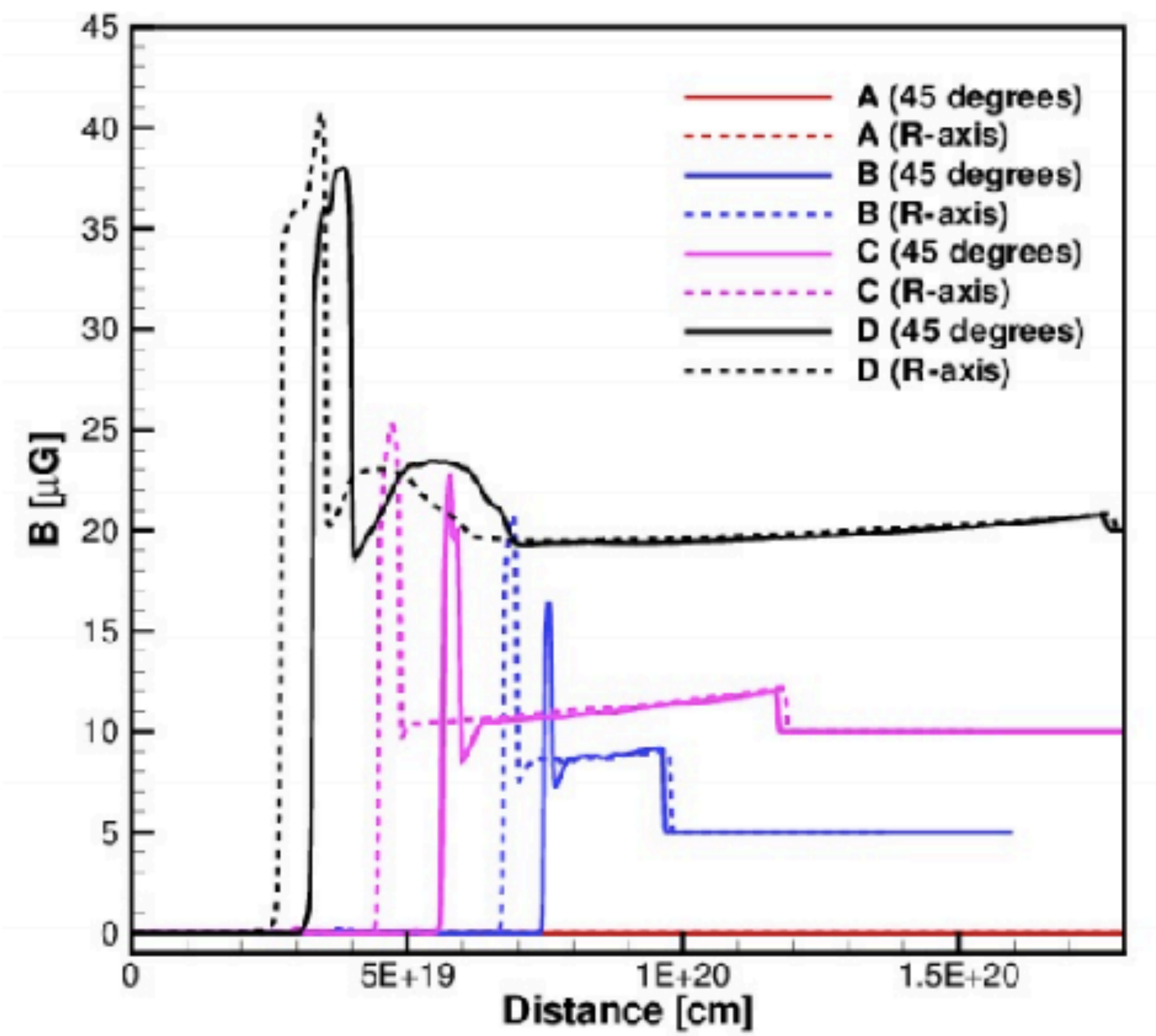
Ilija Medan & Anderson 2019
arXiv 1901.07692

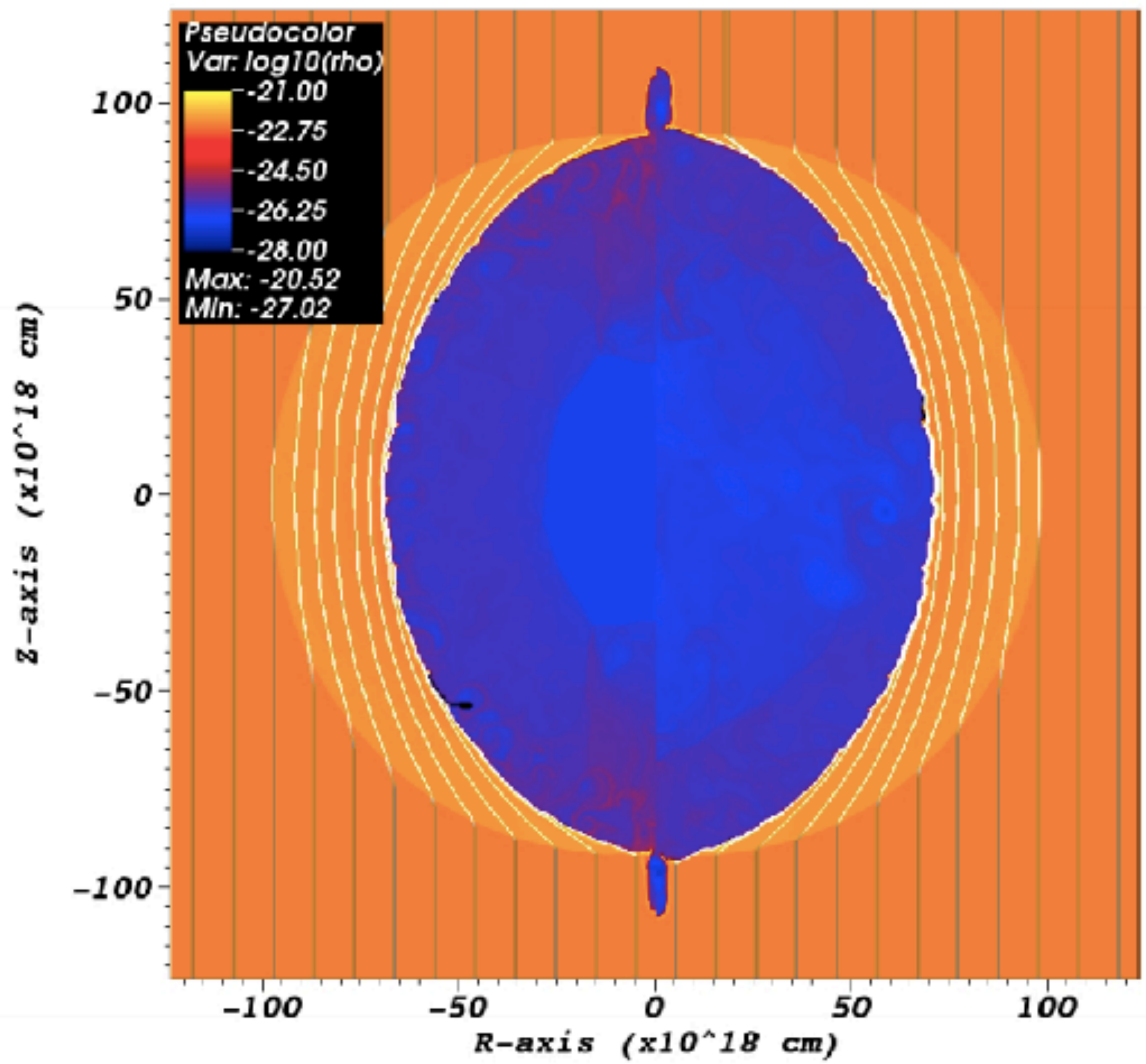


Welsh & Shelton 2009 arXiv 0906.2827

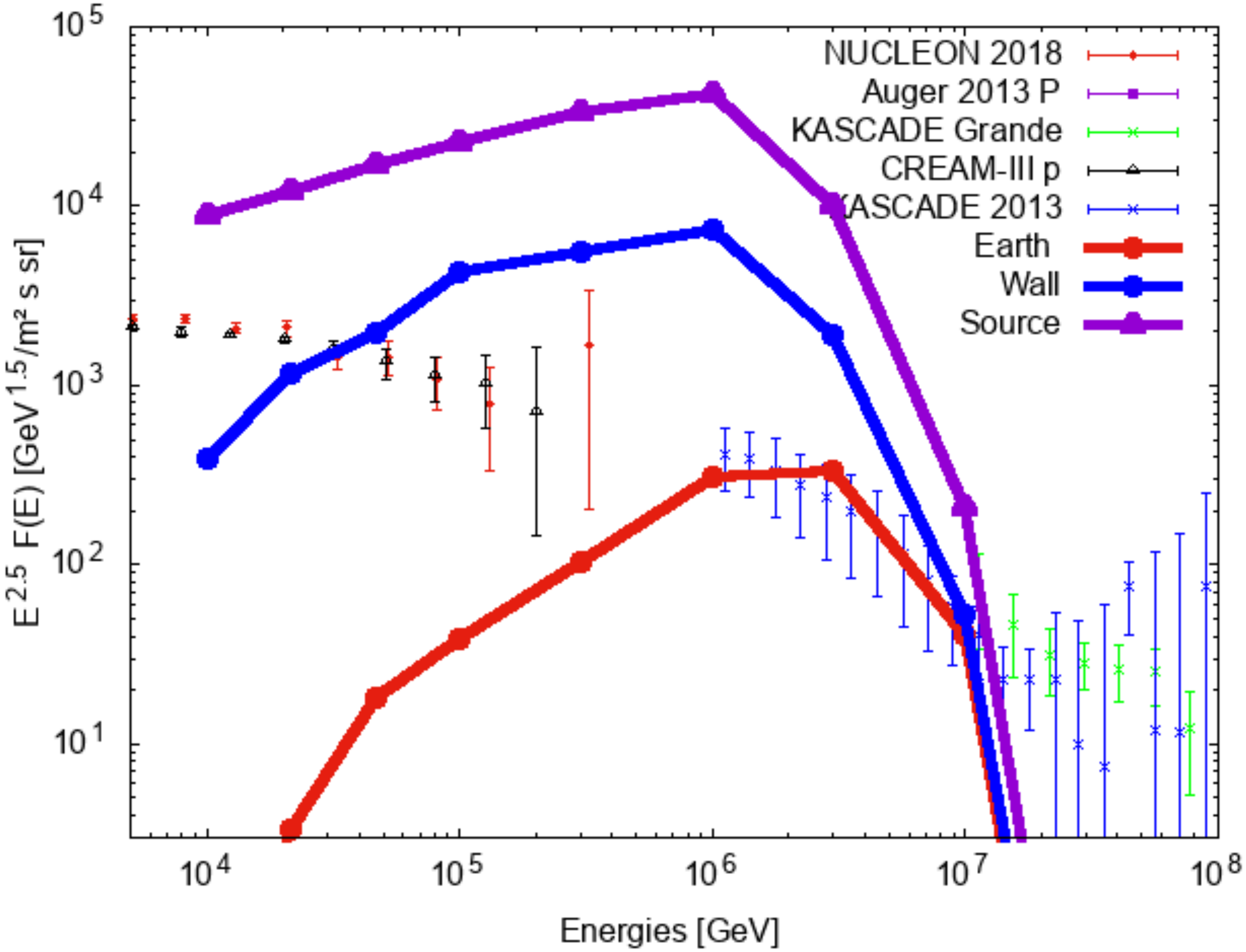
Model of propagation (Motivations for Local MF)

A. J. van Marle, Z. Meliani, and A. Marcowith. arXiv 1509.00192



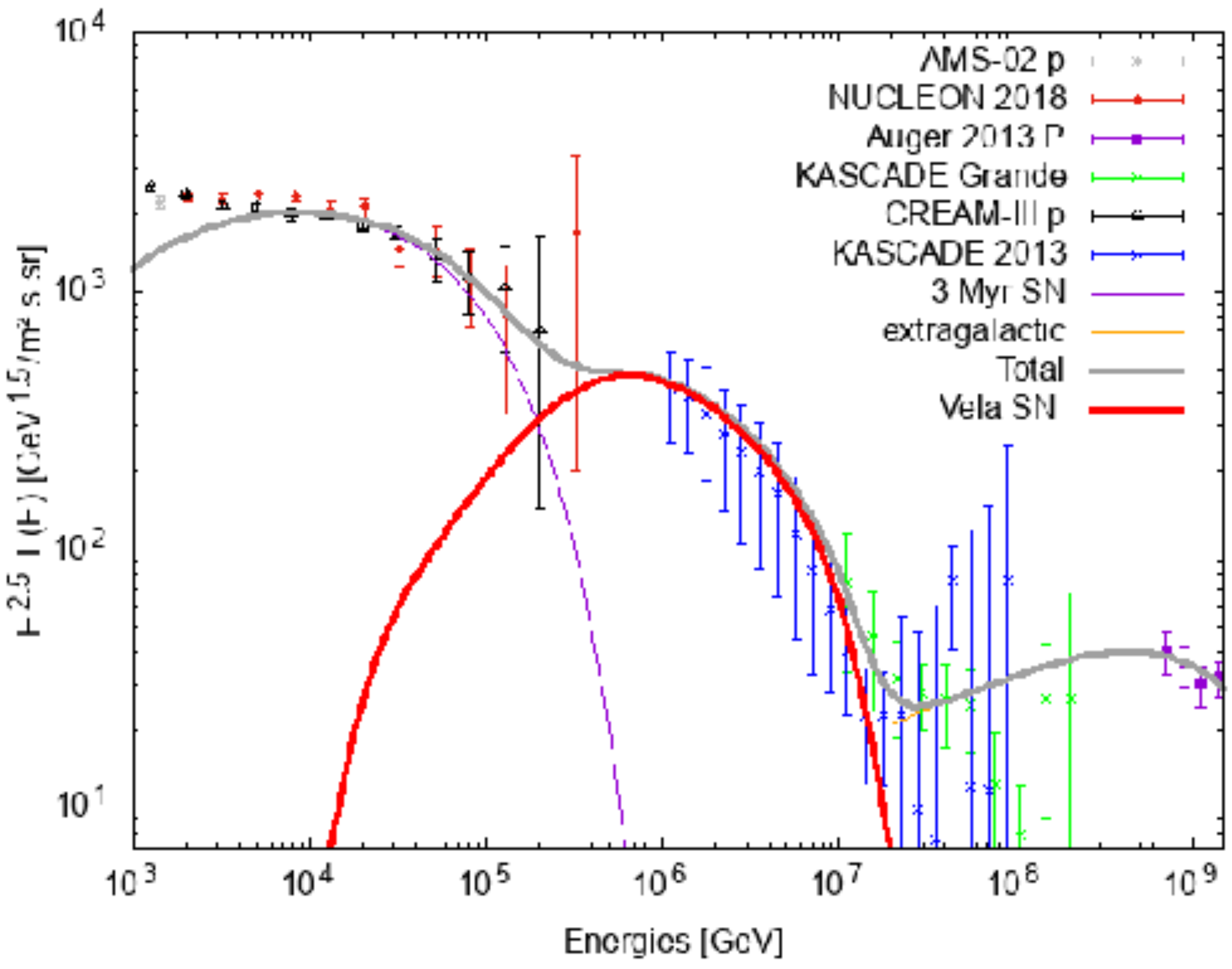


Results (Proton flux on earth wall and source)

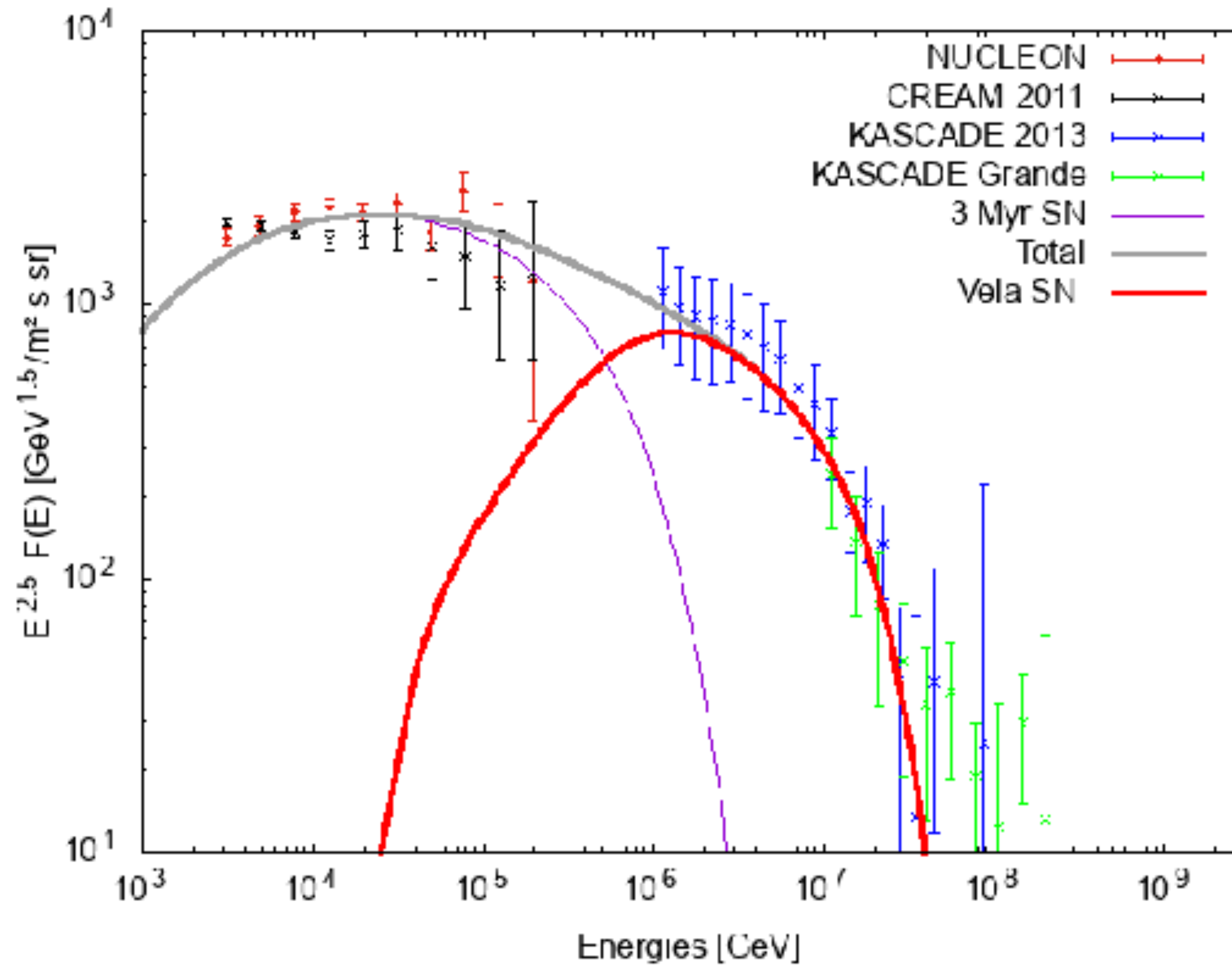


M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

Results (Light nuclei)



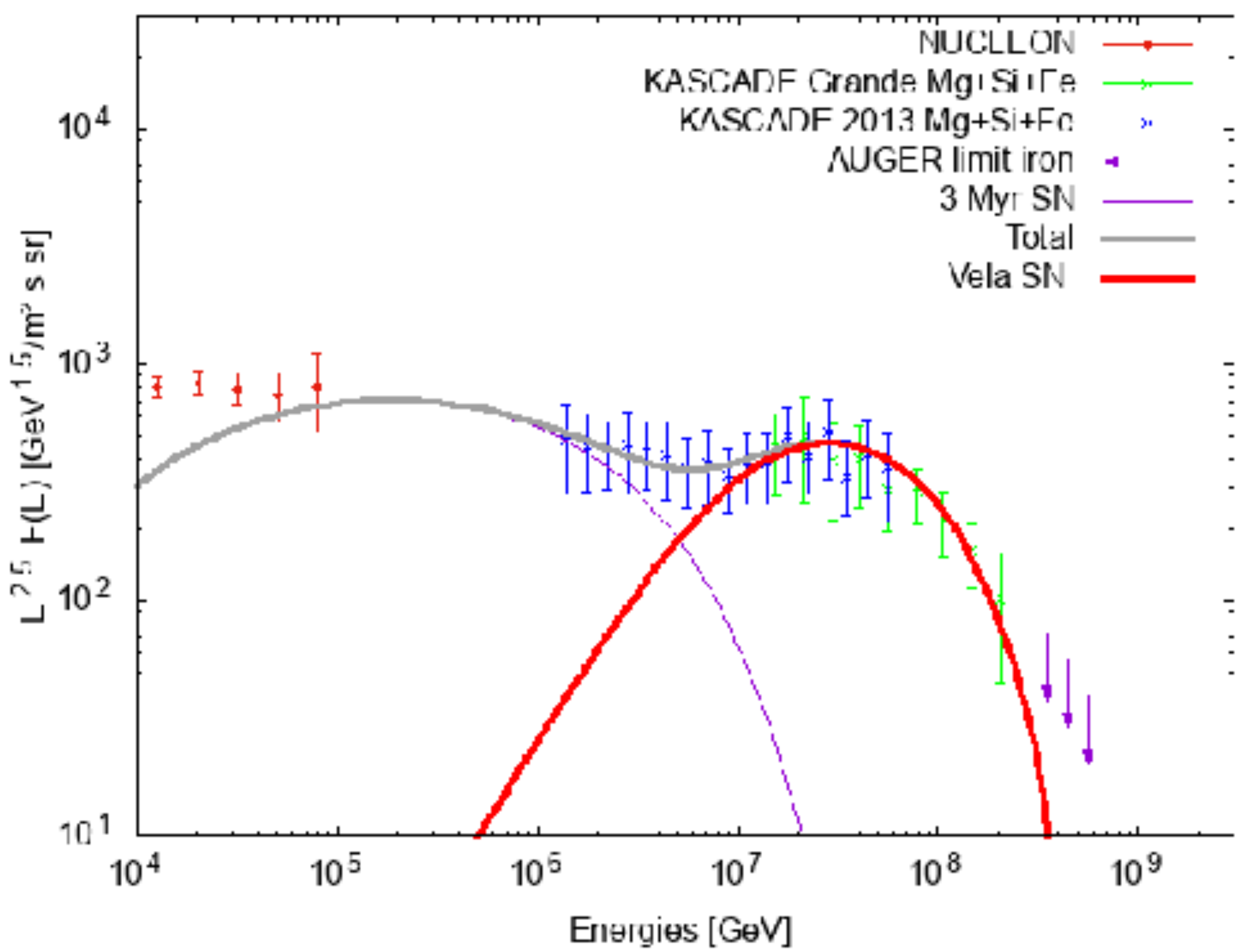
Proton

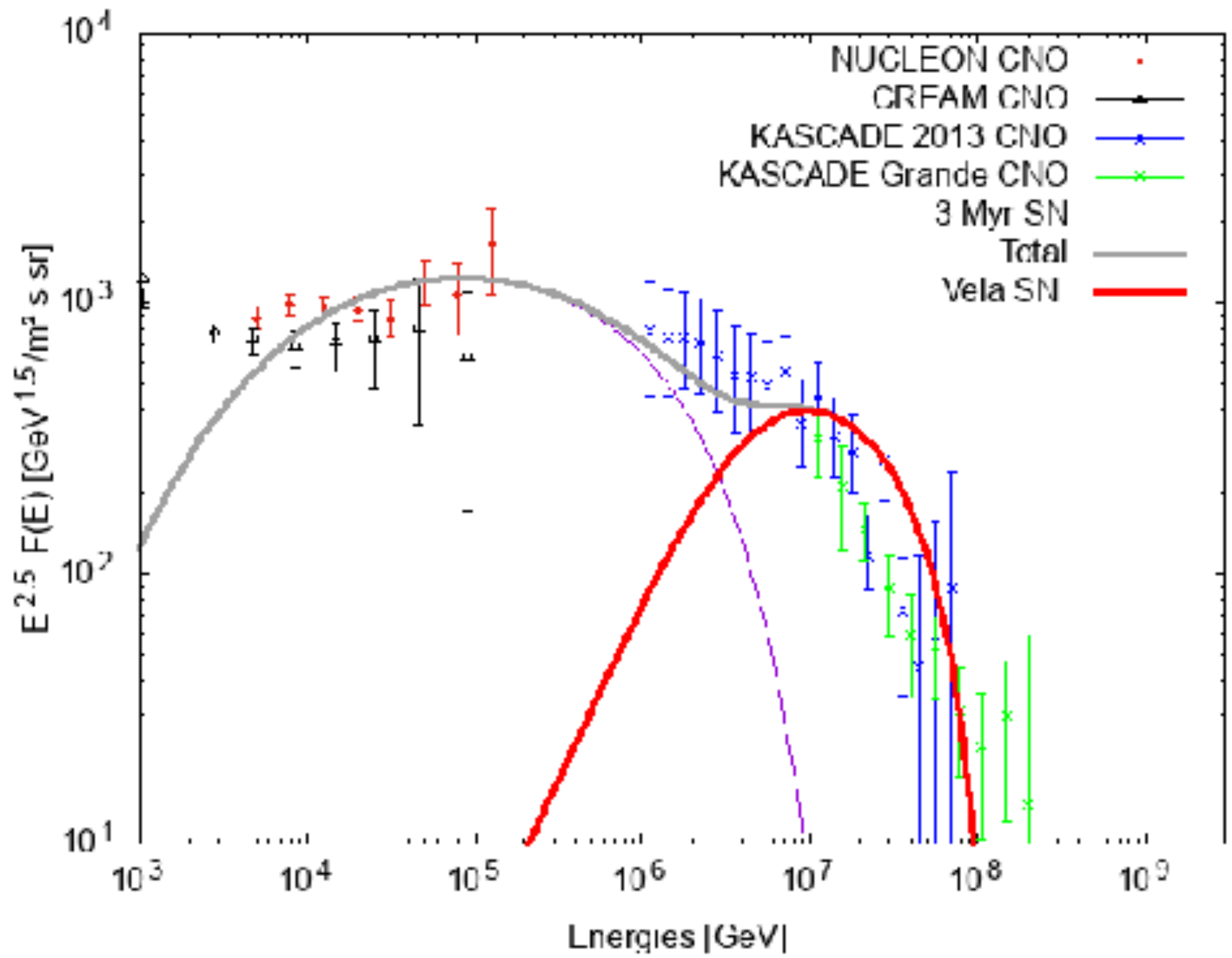


Helium

M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

Results (Heavy nuclei)



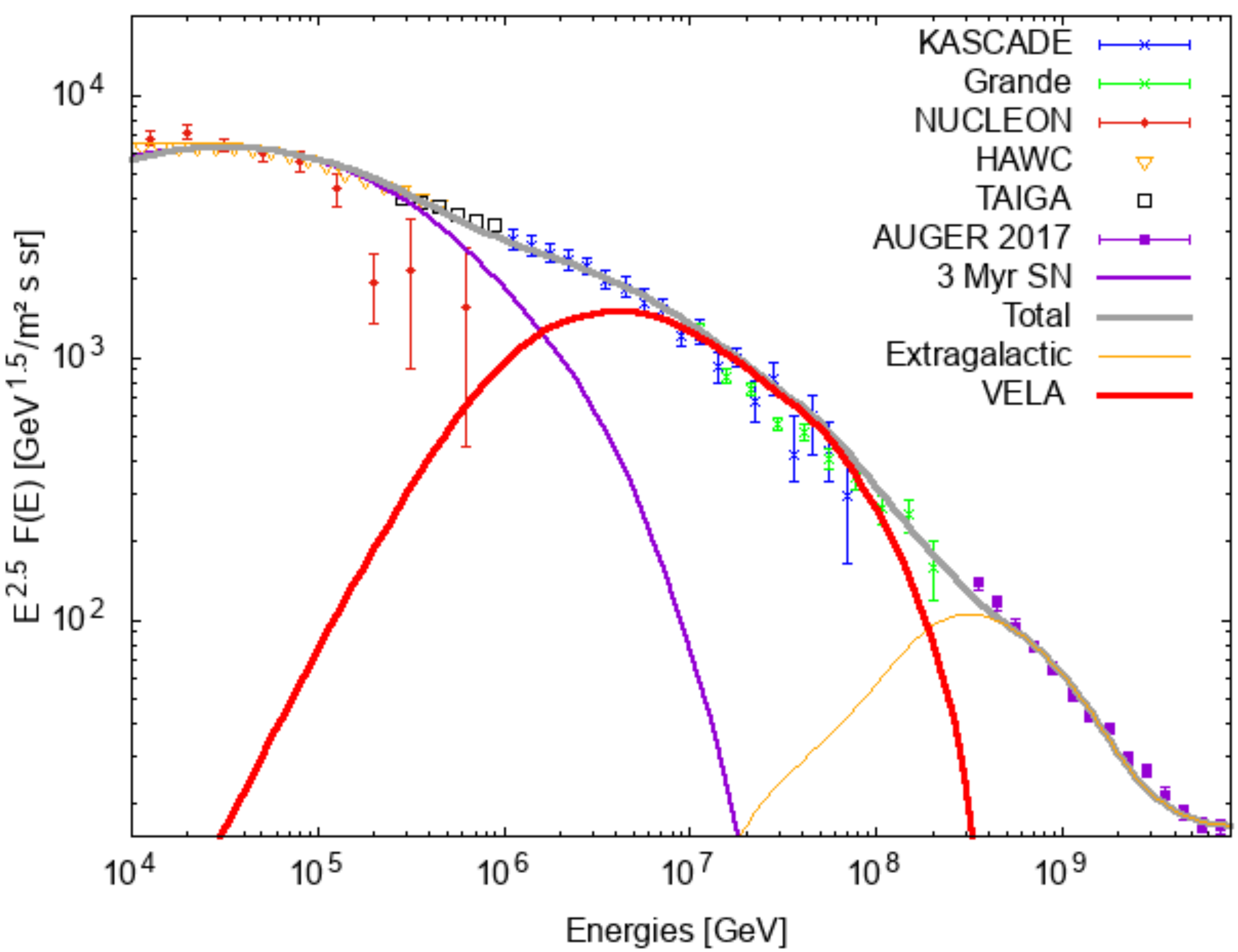


Fe + Si + Mg

CNO

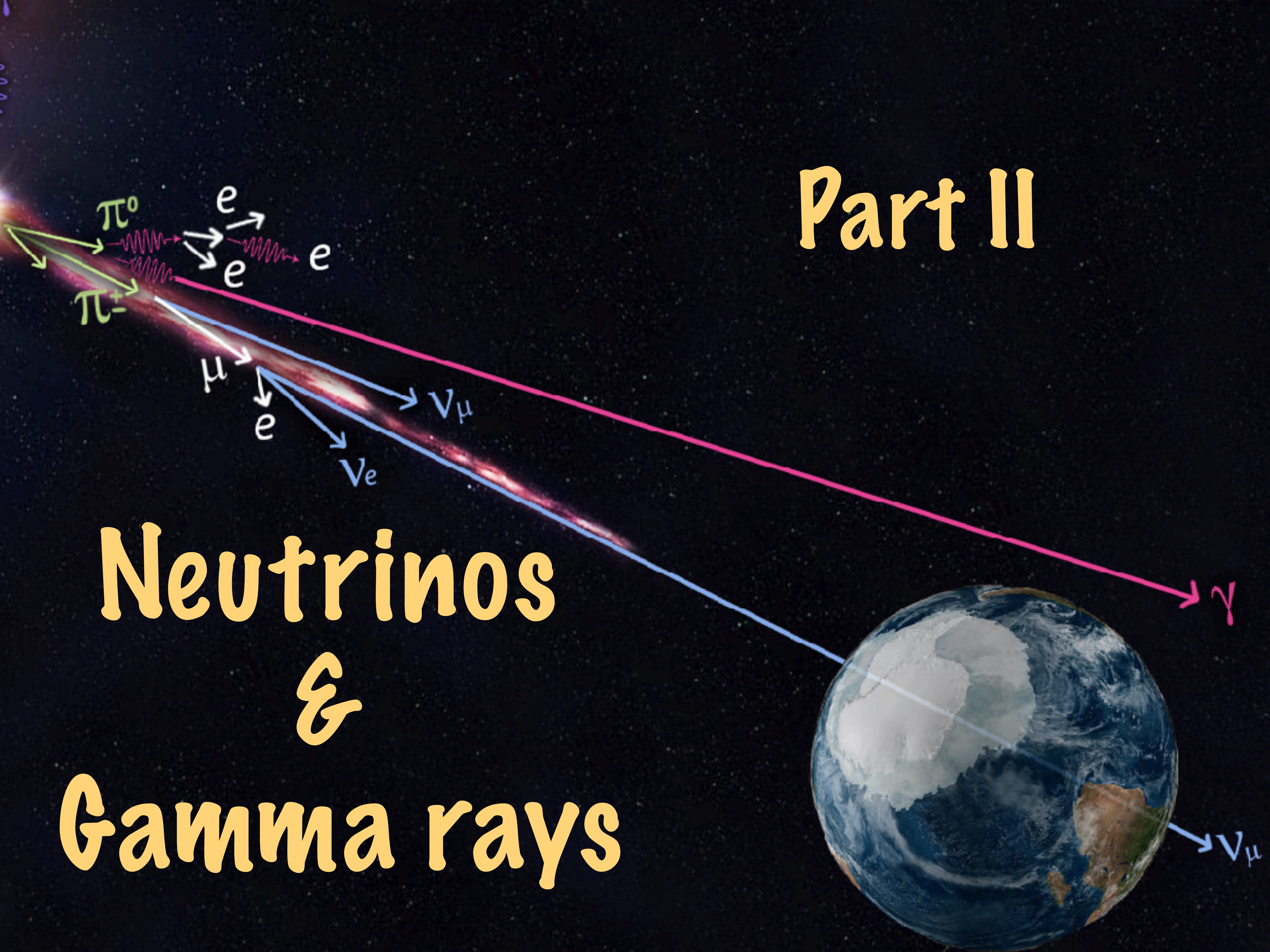
M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

Results (All particles)



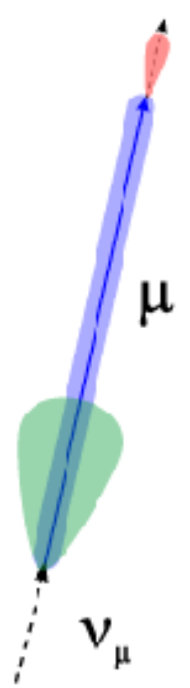
All particles

M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522


Part II
Neutrinos
&
Gamma rays
π⁰
π±
e
e
e
μ
e
ν_μ
ν_e
γ
ν_μ

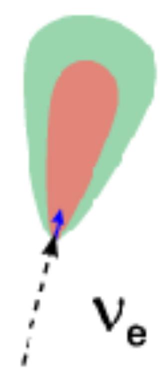
Introduction (Motivation)

Track event

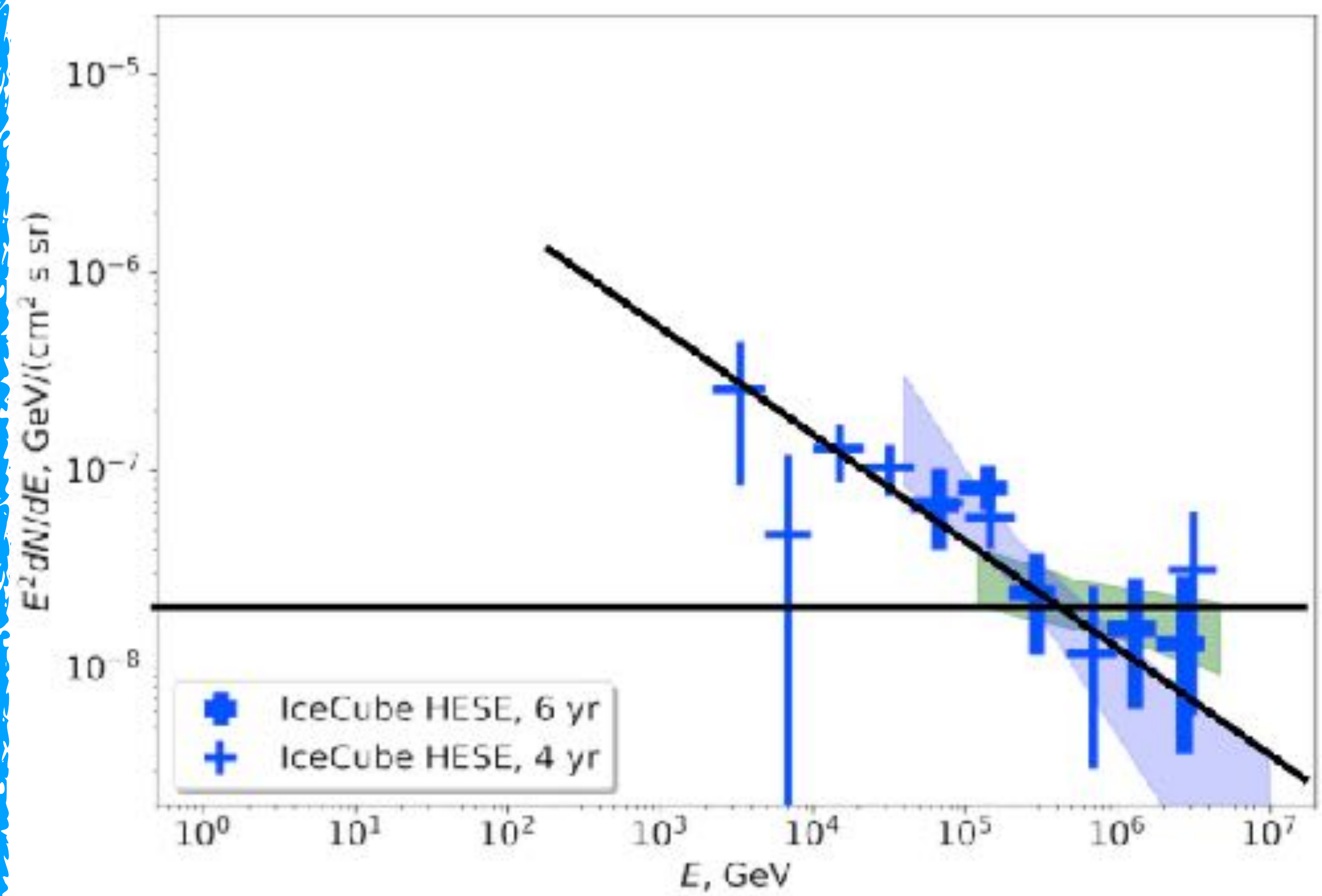


- Energy resolution (thumbs down)
- Angular resolution (thumbs up)

Cascade event

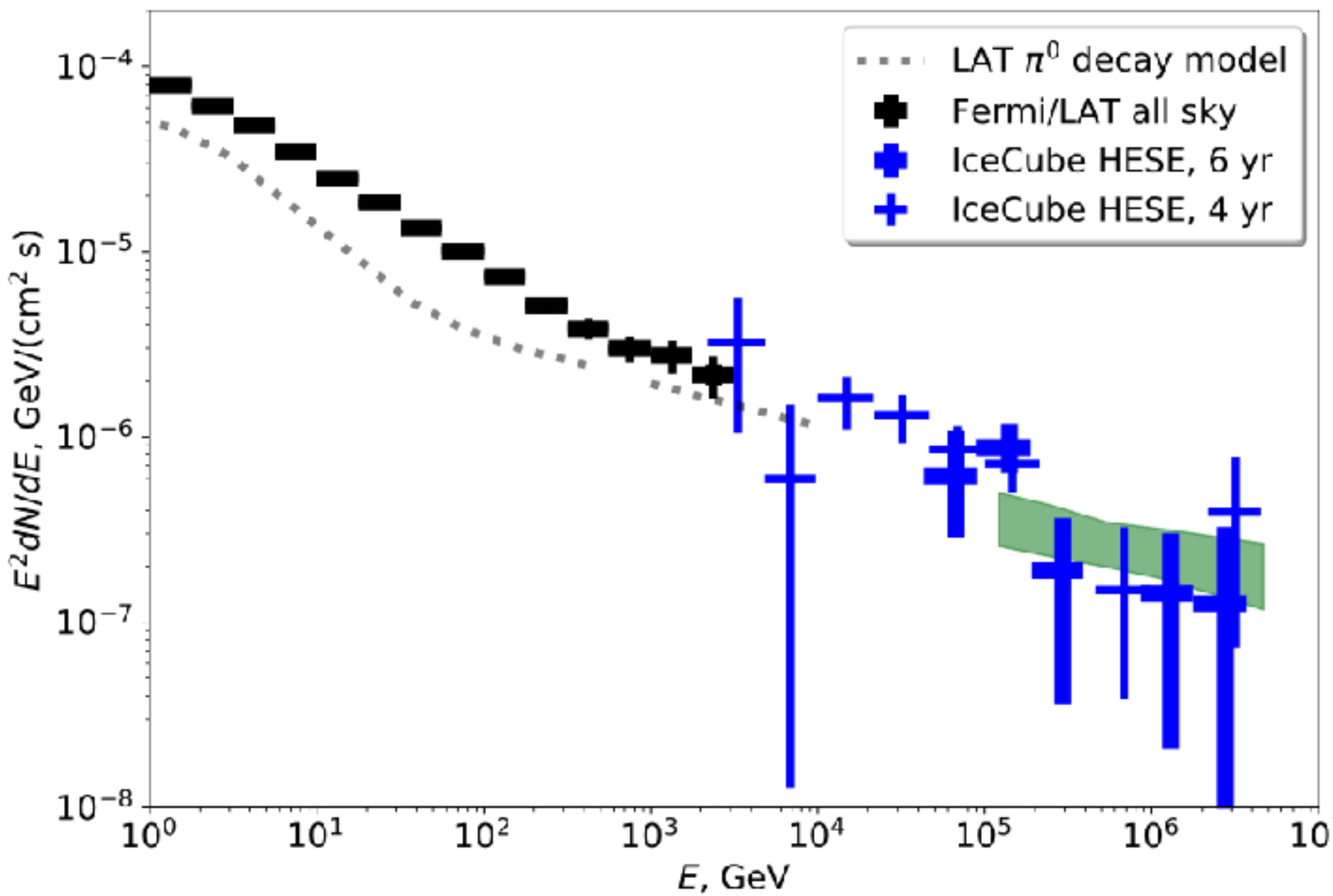


- Energy resolution (thumbs up)
- Angular resolution (thumbs down)



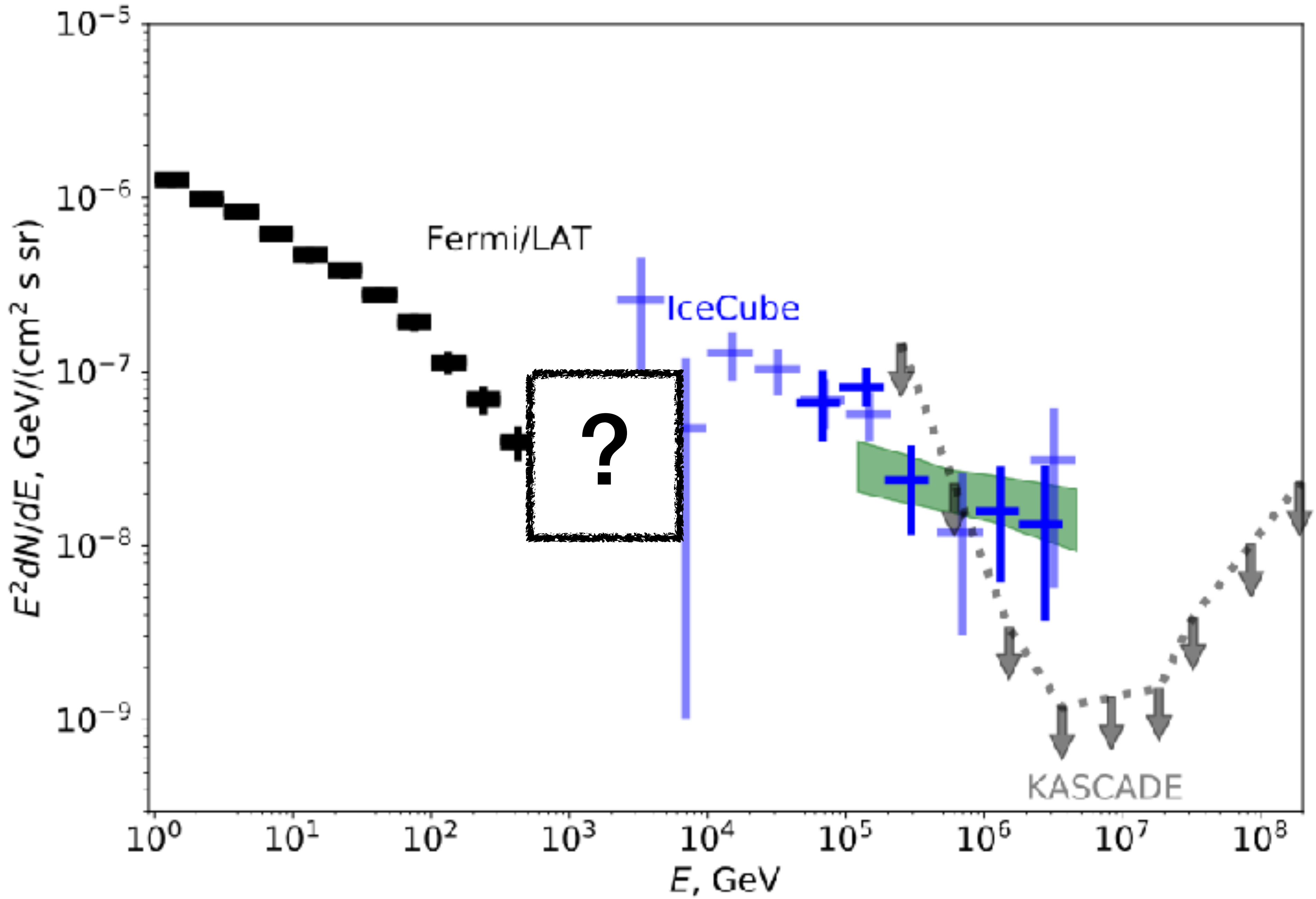
A.Neronov, M.Kachelriess and D.Semikoz.
arXiv:1802.09983

Introduction (Motivation)



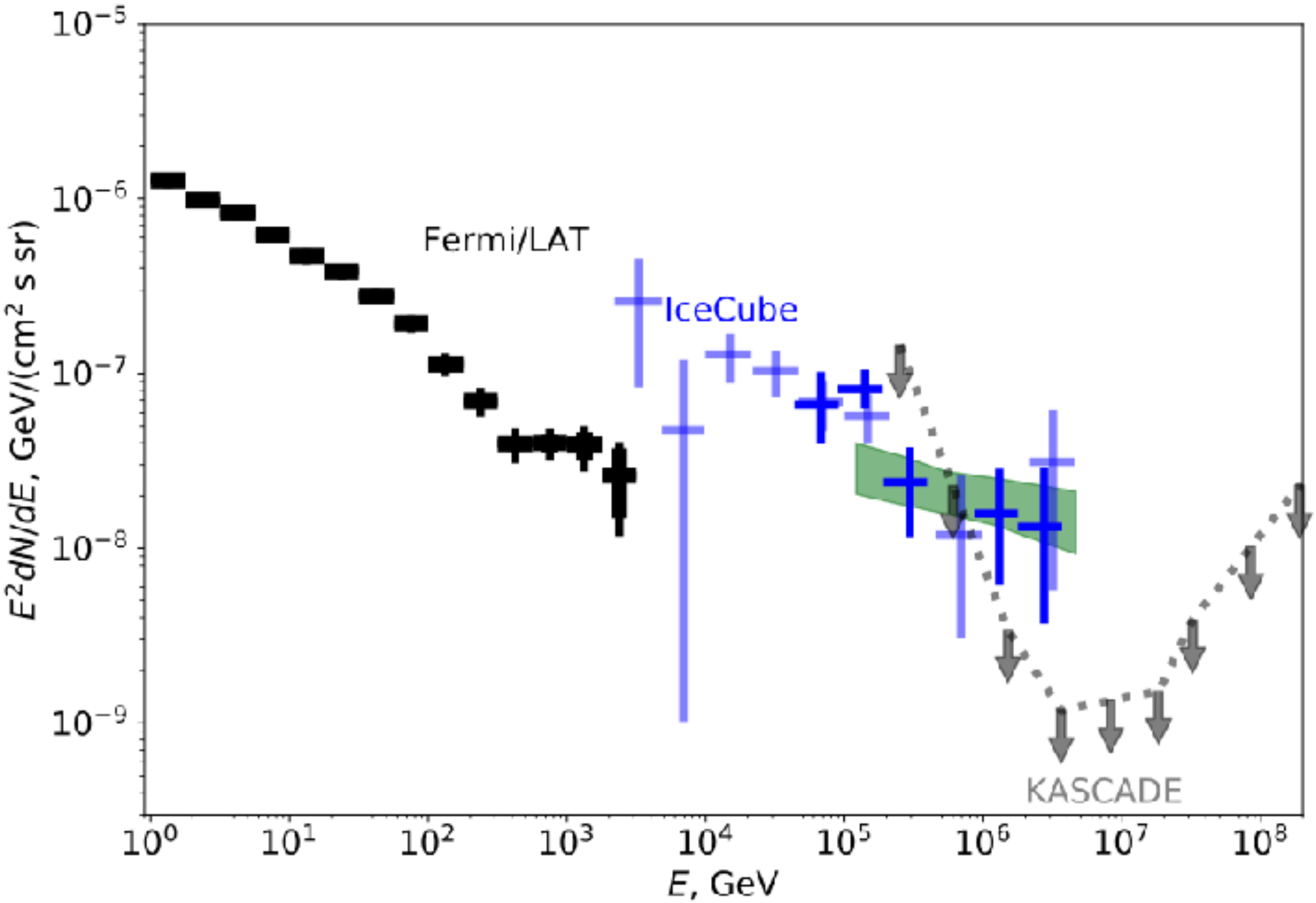
A.Neronov, M.Kacherlriess D.Semikoz arXiv 1802.09983v3

Introduction (Motivation)



A.Neronov, M.Kacherlriess D.Semikoz arXiv 1802.09983v3

Introduction (Motivation)

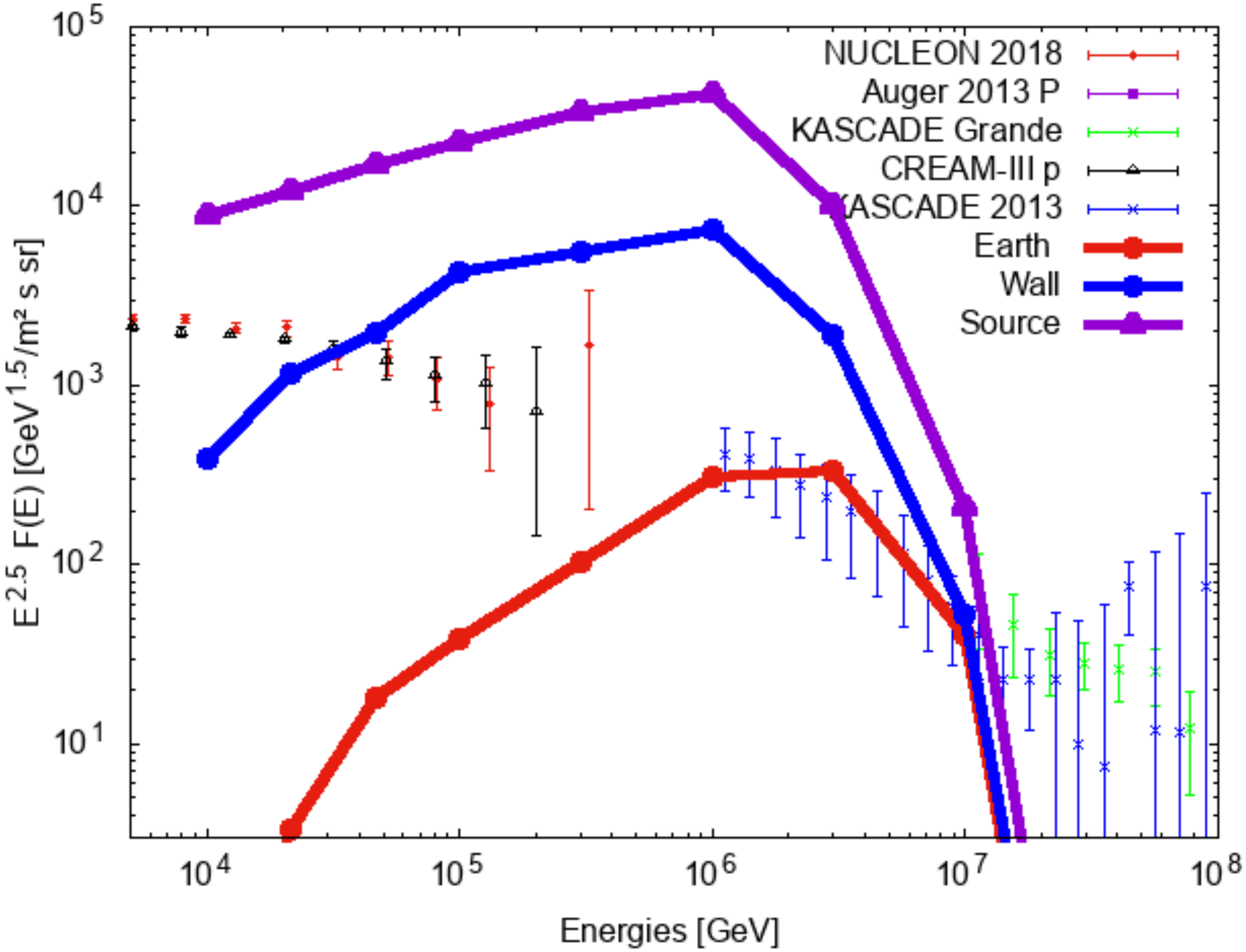


A.Neronov, M.Kacherlriess D.Semikoz arXiv 1802.09983v3

Introduction (Explanations)

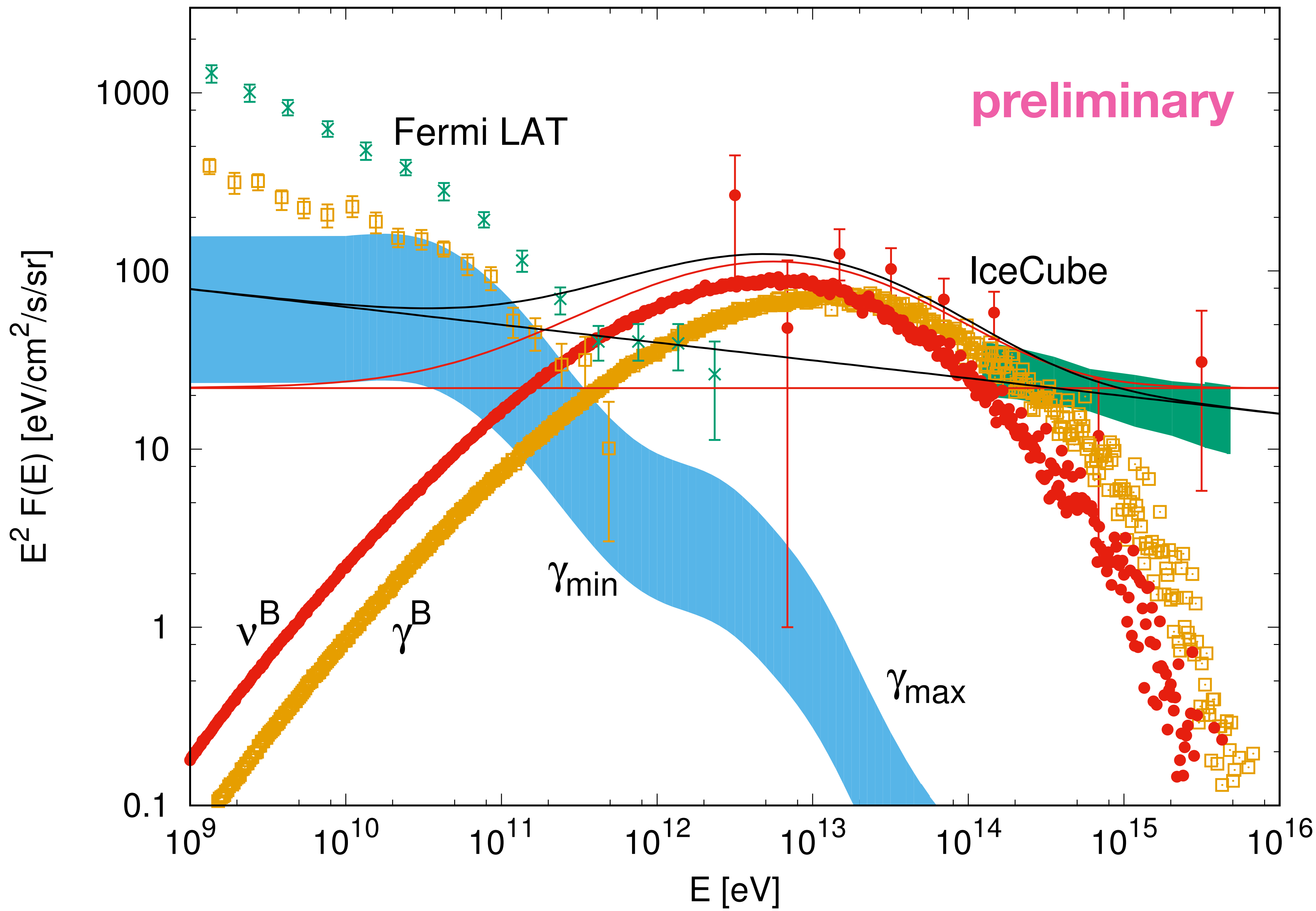
- Decay of Dark Matter particles (V. Berezinsky, M. Kachelriess, A.Vilenkin arXiv:9708217)
- Cosmic ray interaction in the large halo of MW (A. M. Taylor, S. Gabici, F. Aharonian arXiv:1403.3206)
- **Interaction of cosmic rays injected by a young nearby supernova with local bubble**

Results (Proton flux on earth wall and source)



M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

Results (neutrinos and gamma rays)



Summary

- In anisotropic diffusion model few sources contribute to CR local flux above TeV,
- Local super Bubble effect on CR spectrum is important
    - Flux reduction
    - Reduce anisotropy
    - Production of secondary neutrinos and gamma rays
- Studying the dependance on the properties of the bubble.

Summary

- Excess of gamma ray flux for $E > 1$ TeV outside the galactic plane

- Neutrino flux at $E < 100$ TeV should be galactic

- Multi-messenger signal from a young nearby SNR.

- Neutrino and Gamma ray flux could be explained by the interaction of Vela CR with the Local Bubble.

Thank you for your attention

BACK UP

Model (Construction)

- Magnetic field modelisation of the bubble :

K.J Anderson 2017

$$T_1 = \left[1 + \exp\left(-\frac{r - R + w/2}{w_1}\right)\right]^{-1}, T_2 = \left[1 + \exp\left(-\frac{r - R - w/2}{w_2}\right)\right]^{-1}$$

of the magnetic field for $r < R$ to :

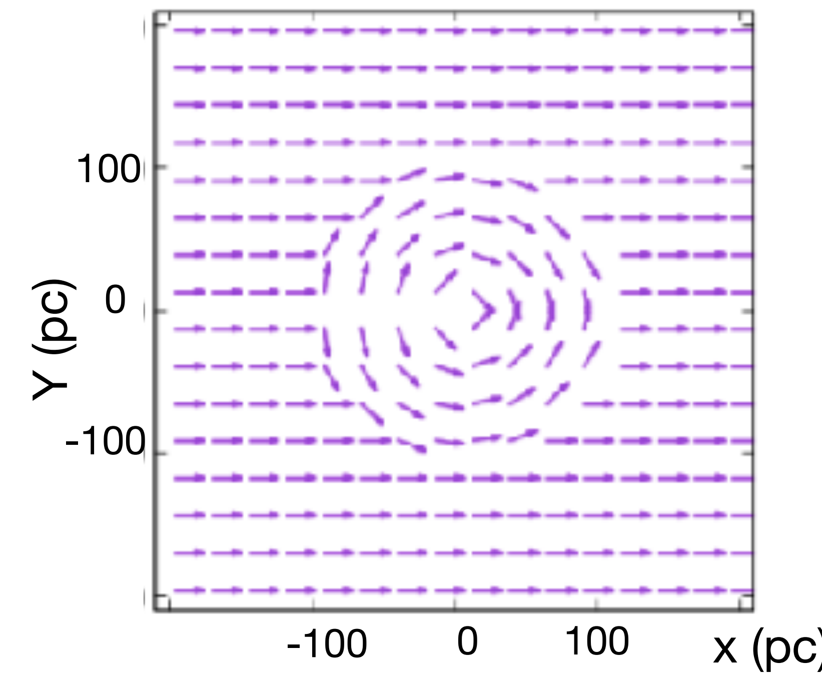
$$\begin{aligned} B_{\rm x} &= s\left[B_{\rm in}(1 - T_1) + B_{\rm sh} T_1\right] \sin(\vartheta) \exp(-z^2/z_{\rm b}^2) \\ &\quad + B_{\rm JFx}(1 - \exp(-z^2/z_{\rm b}^2)), \\ B_{\rm y} &= -s\left[B_{\rm in}(1 - T_1) + B_{\rm sh} T_1\right] \cos(\vartheta) \exp(-z^2/z_{\rm b}^2) \\ &\quad + B_{\rm JFy}(1 - \exp(-z^2/z_{\rm b}^2)), \\ B_{\rm z} &= B_{\rm JFz}, \end{aligned}$$

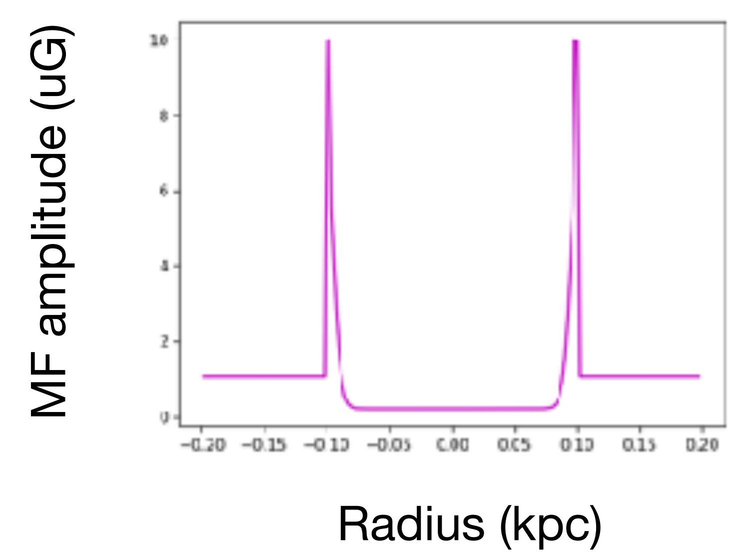
Similarly, the field is given for $r > R$ by

$$\begin{aligned} B_{\rm x} &= \left[s B_{\rm sh}(1 - T_2) \sin(\vartheta) + B_{\rm JFx} T_2\right] \exp(-z^2/z_{\rm b}^2) \\ &\quad + B_{\rm JFx}(1 - \exp(-z^2/z_{\rm b}^2)), \\ B_{\rm y} &= \left[-s B_{\rm sh}(1 - T_2) \cos(\vartheta) + B_{\rm JFy} T_2\right] \exp(-z^2/z_{\rm b}^2) \\ &\quad + B_{\rm JFy}(1 - \exp(-z^2/z_{\rm b}^2)), \end{aligned}$$

$$B_{\rm z} = B_{\rm JFz},$$

(





BACK UP

Model (Construction)

Injection of cosmic rays from the source :

$$\frac{dN}{dE} \propto \begin{cases} E^{\beta_1}, & \text{if} \quad E < ZE_{\rm br} \\ E^{\beta_2}\exp(-E/(ZE_{\rm max})), & \text{if} \quad E \geq ZE_{\rm br}. \end{cases}$$

L. O. Drury, E. van der Swaluw and O. Carroll (2003) astro-ph/ 0309820

Flux computation :

$$F(E) = c/(4\pi)n(E)$$

Our model parameters

Source acceleration :

E_{br} β_1

E_{max} β_2

Magnetic field configuration :

w w_1

$B(r,z)_{in,sh,out}$ w_2

BACK UP

Model (Construction)

E_{br} = 1 PeV

E_{max} = 3 PeV

β_1 = 2

β_2 = 2.9

w = 1pc

w_1 = 3 pc

w_2 = 0.1 pc

$|B(r,z)_{in,sh,out}|$ = 0.1 , 10 , 1 μG

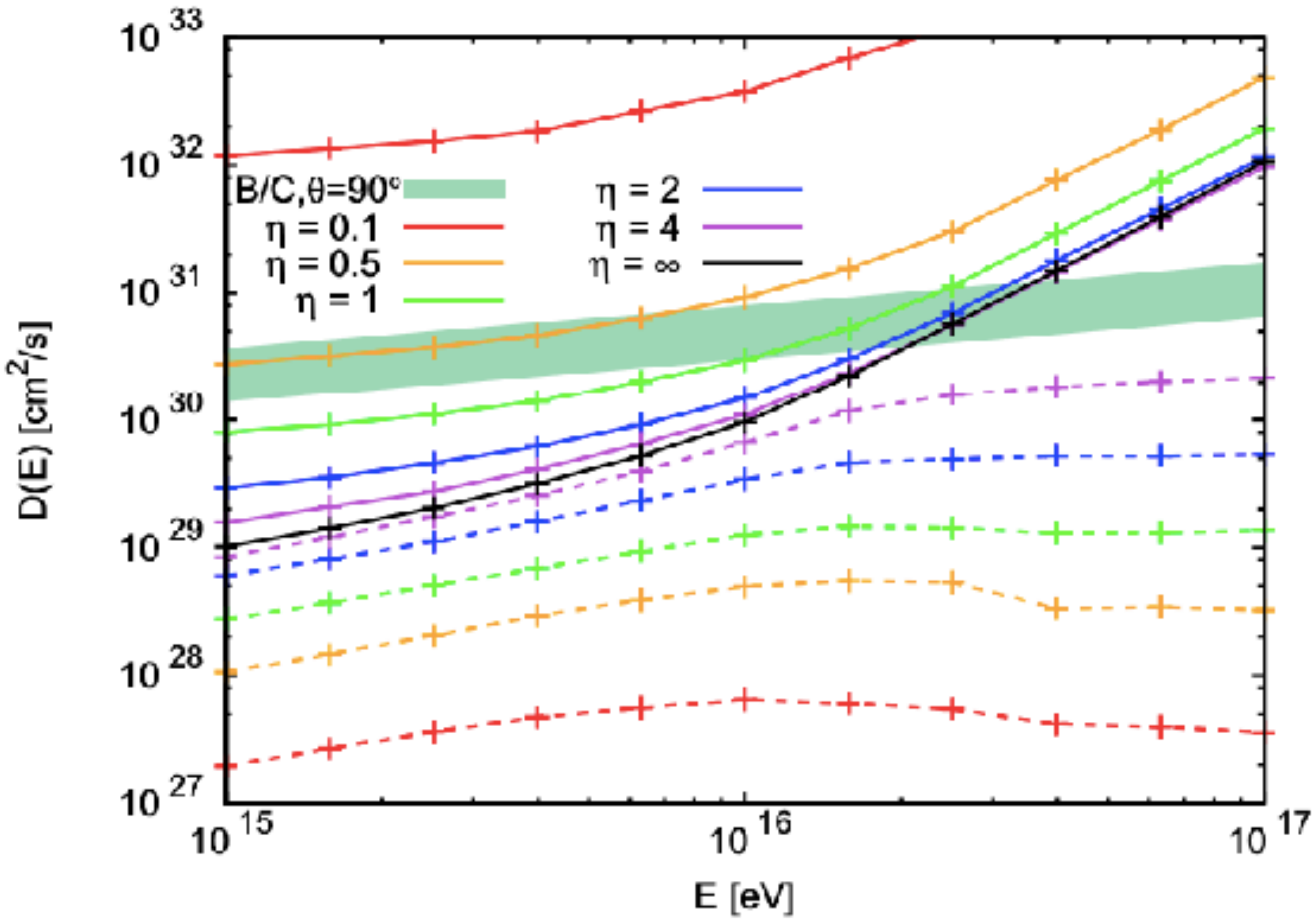
Total luminosity = 3.7×10^{49} erg

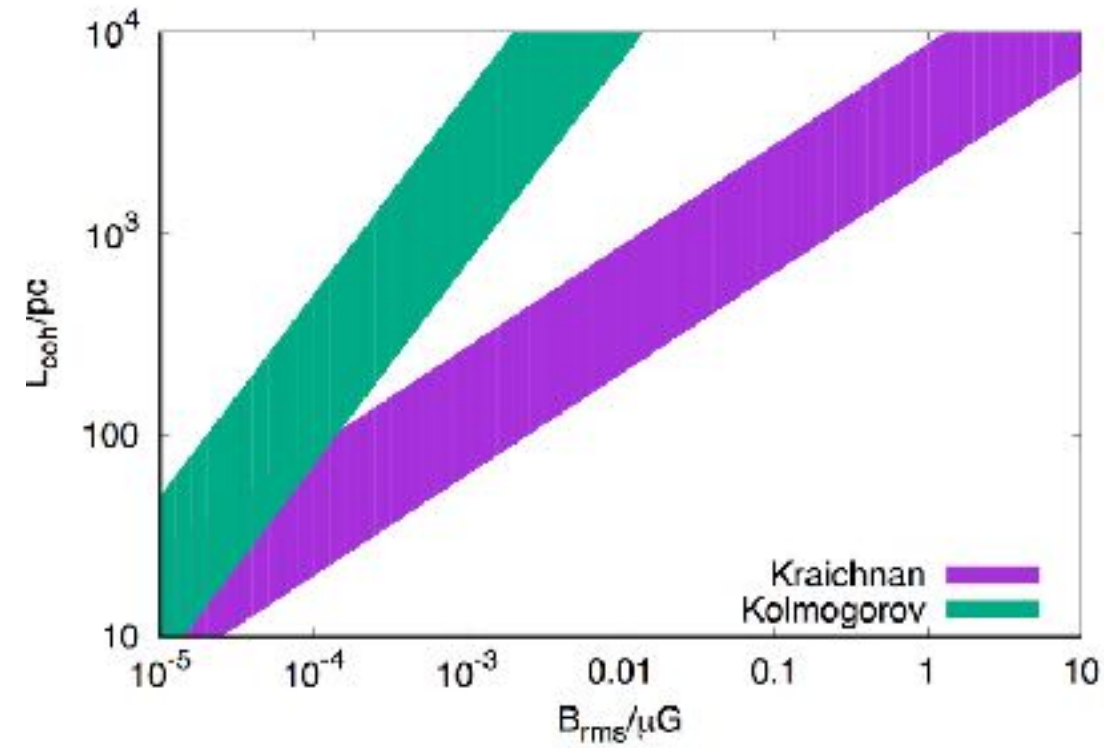
Vela kinetic energy = 1.4×10^{50} erg

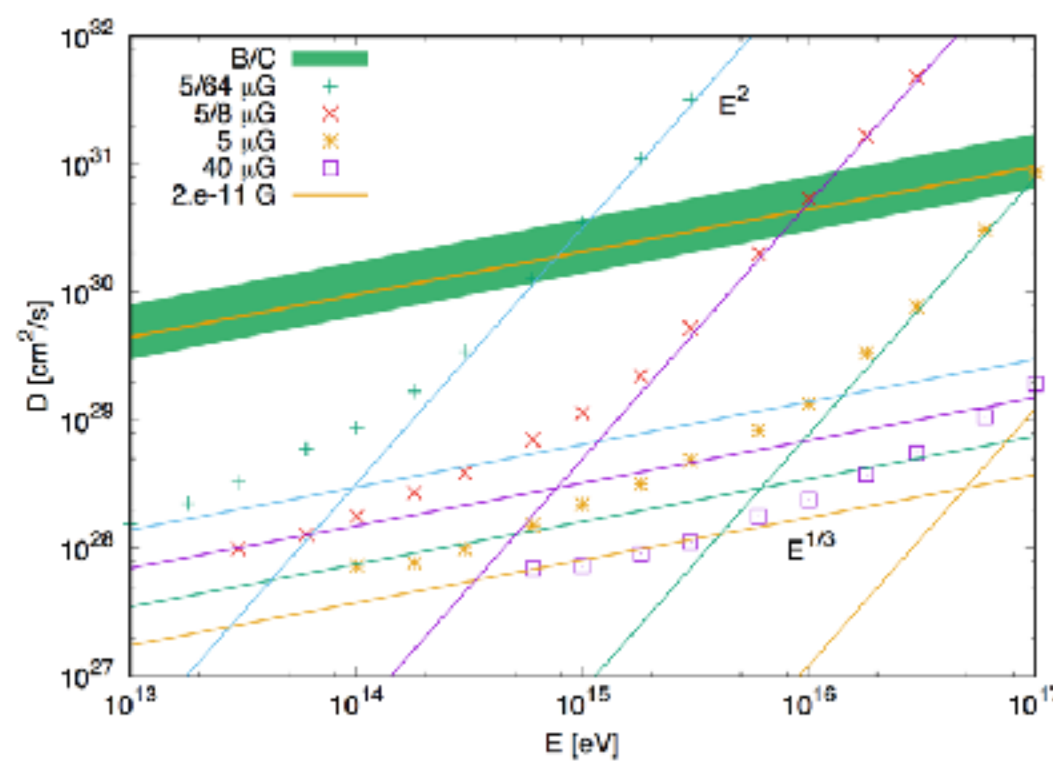
I. Sushch, B. Hnatyk and A. Neronov
arXiv 1011.1177

BACK UP

Anisotropic propagation (motivation)







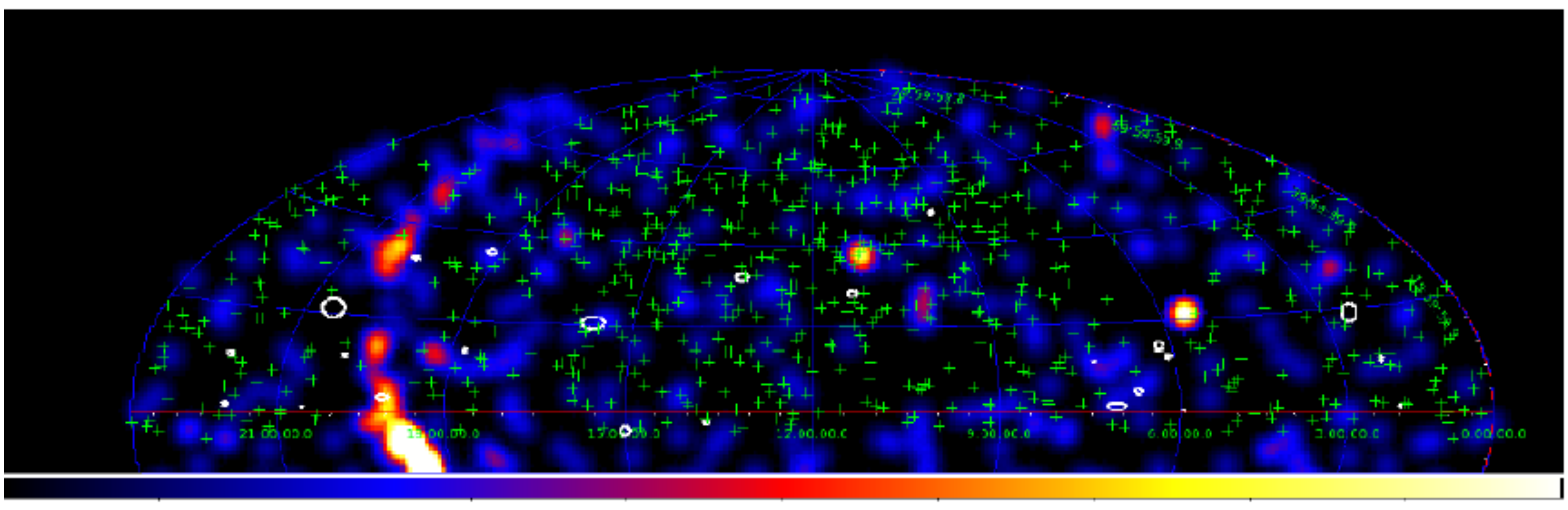
G. Giacinti, M. Kachelriss, D. Semikoz 1710.08205

BACK UP

Galactic contribution (motivation)

cm^{-2} s^{-1}). We employ a one-point photon fluctuation analysis to constrain the behavior of dN/dS below the source detection threshold. Overall the source count distribution is constrained over three decades in flux and found compatible with a broken power law with a break flux, S_b, in the range $[8 \times 10^{-12}, 1.5 \times 10^{-11}]$ ph cm^{-2} s^{-1} and power-law indices below and above the break of $\alpha_2 \in [1.60, 1.75]$ and $\alpha_1 = 2.49 \pm 0.12$ respectively. Integration of dN/dS shows that point sources account for at least $86^{+16}_{-14}\%$ of the total extragalactic γ-ray background. The simple form of the derived source count distribution is consistent with a single population (i.e. blazars) dominating the source counts to the minimum flux explored by this analysis. We estimate the density of sources

Fermi collaboration, arXiv:1511.00693



A.Neronov, D.Semikoz, K.Ptitsyna arXiv 1611.06338v2