

Université Paris Diderot - APC Laboratory - Theory Group



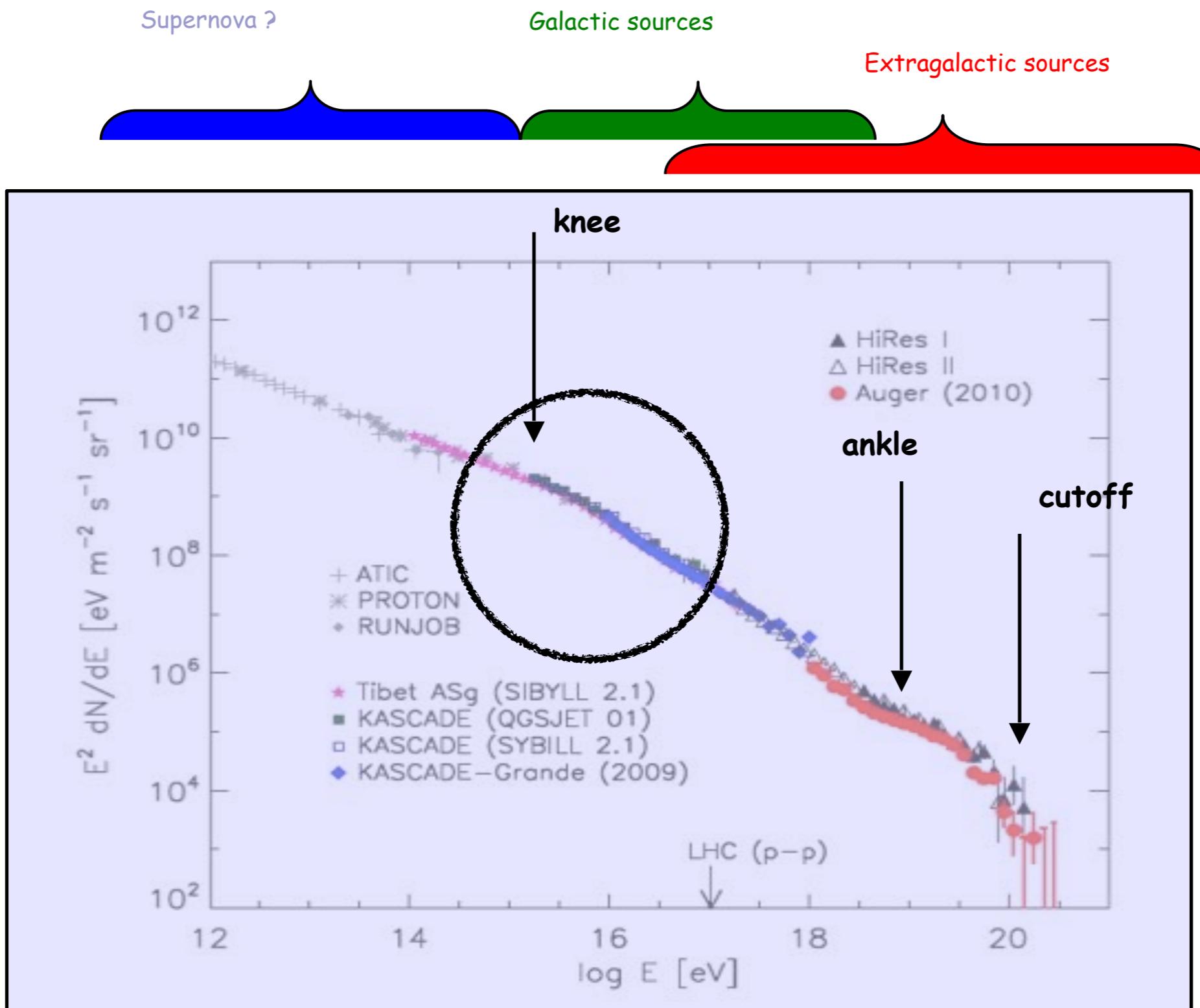
Vela as a source for galactic CR above 100 TeV

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

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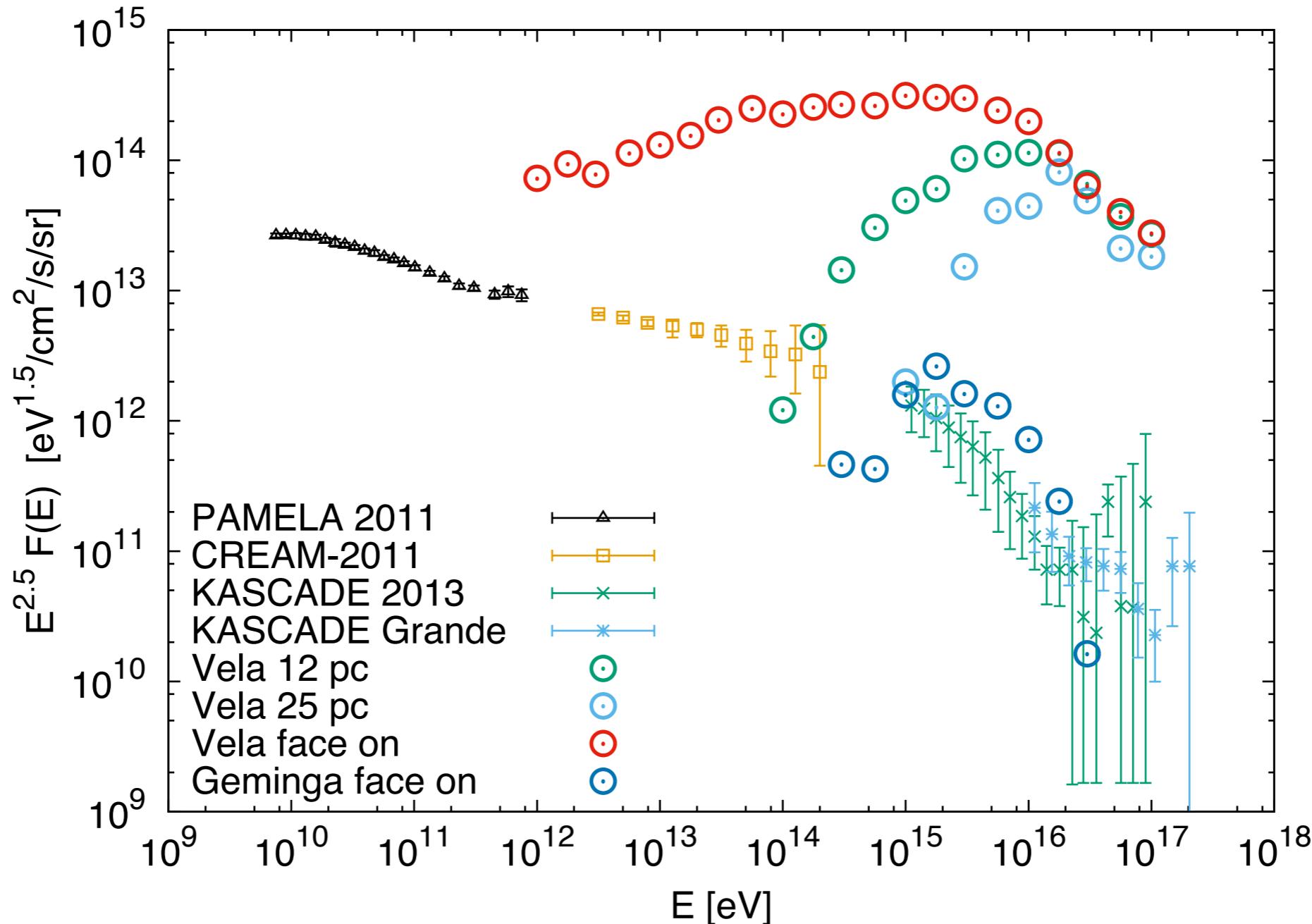
Introduction (Motivation)



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)



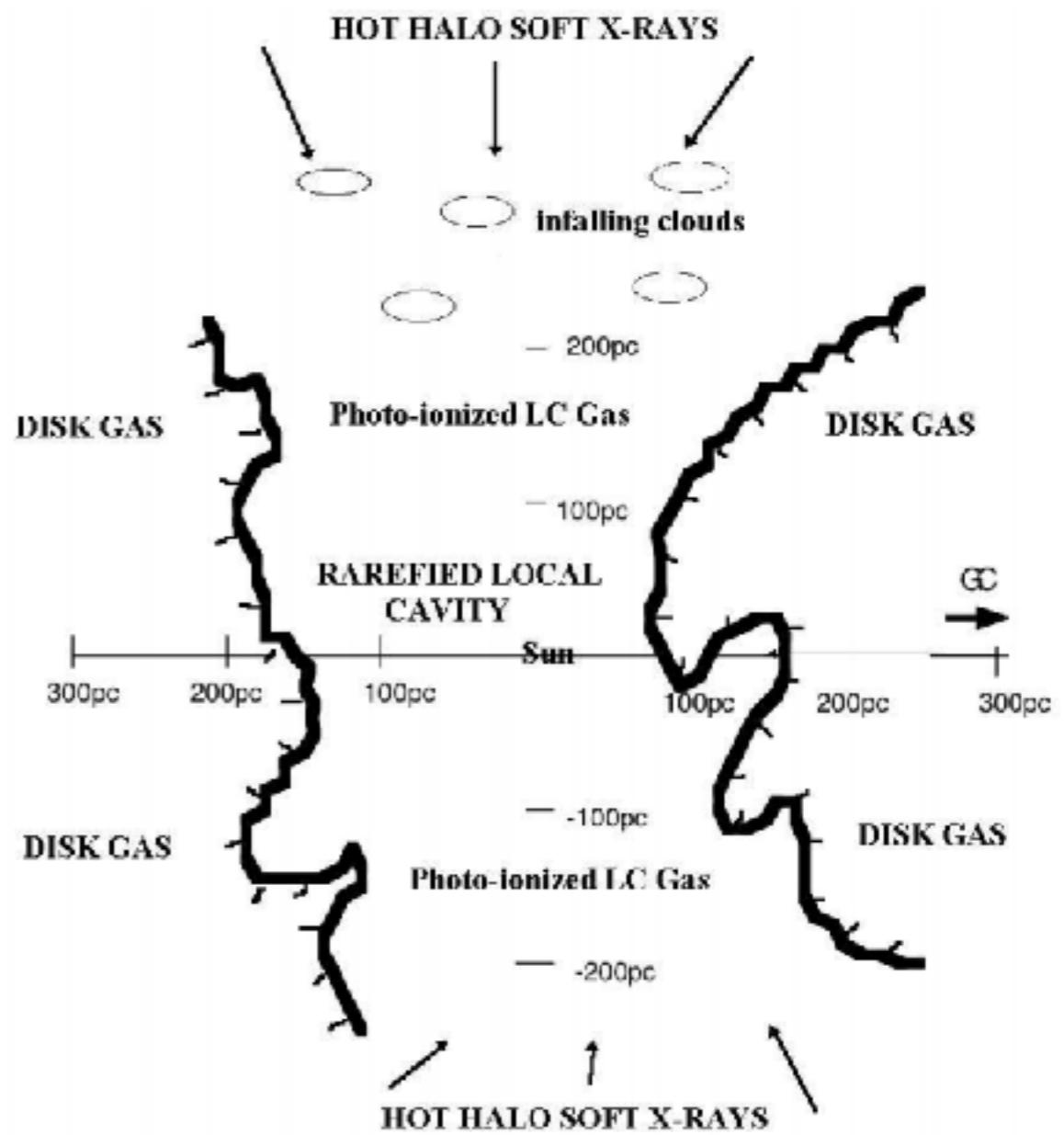
D.Smikoz

Model of propagation (Motivations for Local MF)

The immediate Galactic vicinity of the Sun is dominated by a low density ionized structure, commonly referred to as the “Local Bubble”. It is bounded by relatively higher density material as traced by Sodium and Calcium absorption line measurements, as well as extinction data (Lallement et al. 2003; Welsh et al. 2010; Lallement et al. 2014). Such measurements show a roughly cylindrical structure with a typical radius of about 100–175 pc, with missing ends towards the north and south Galactic poles. This structure is generally interpreted as being due to strong stellar winds and supernovae evacuating the space, with “blow-outs” in the directions out of the Galactic plane (Lallement et al. 2003).

analysis from Lehner et al. (2003) to estimate the gas pressure, density and turbulence, they derived a magnetic field strength of $B_{\perp} = 8^{+5}_{-3} \mu G$, equivalent to a magnetic pressure of $P_B/k \approx 18,000 \text{ K cm}^{-3}$, consistent with the results from the X-ray and the EUV observations.

Ilija Medan & Anderson 2019
arXiv 1901.07692

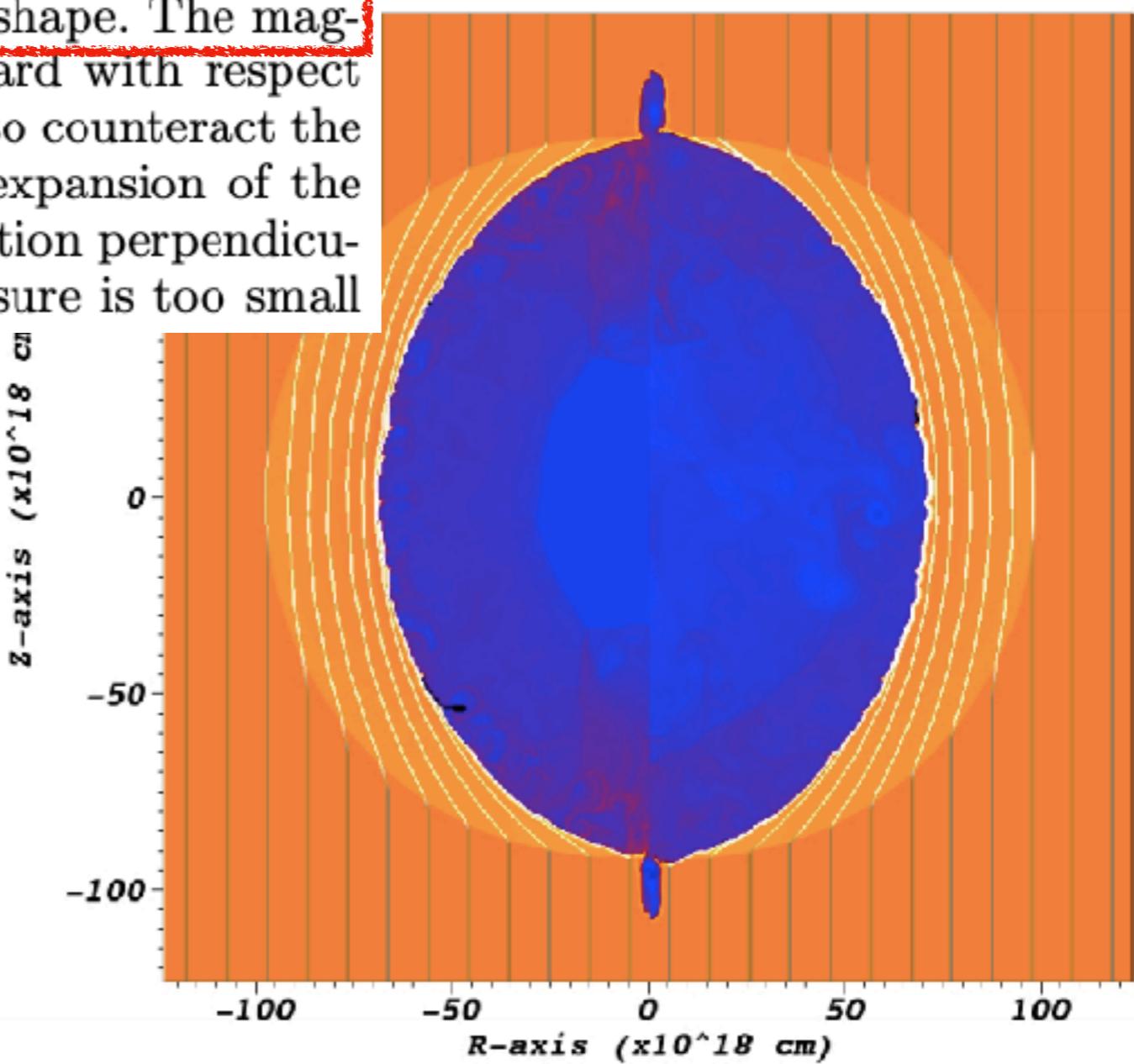
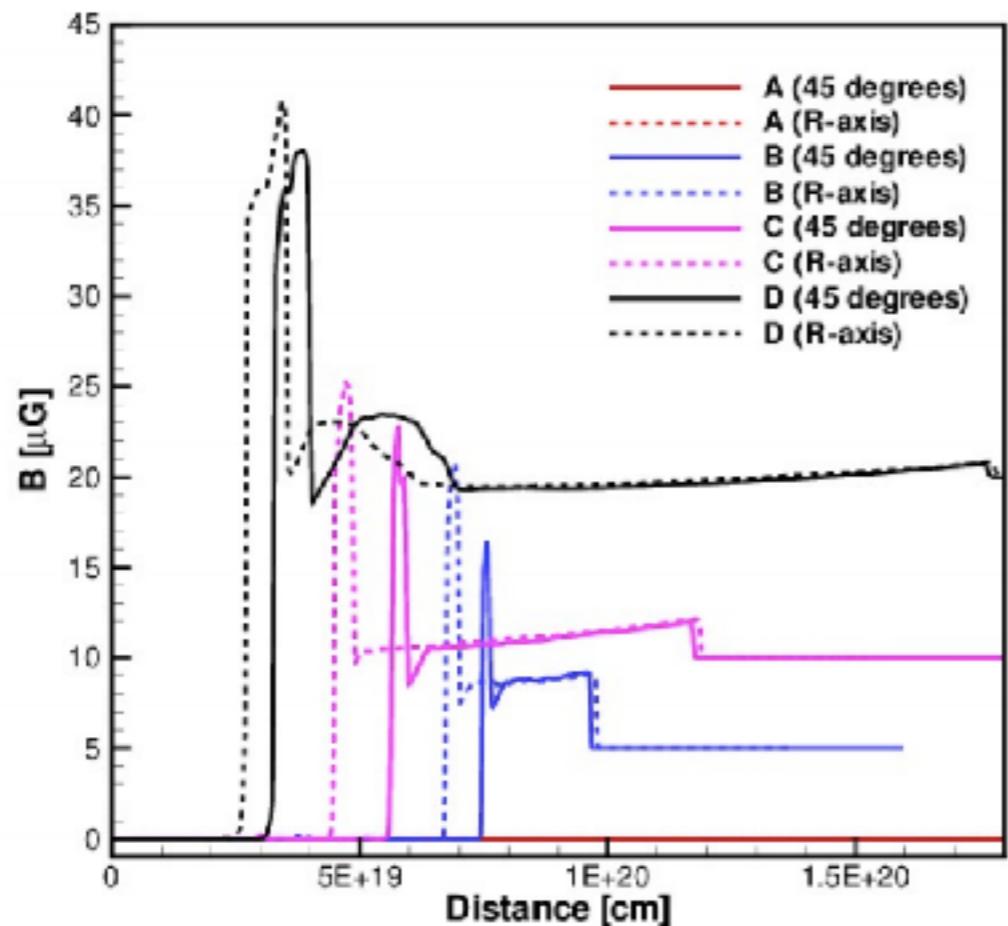


Welsh & Shelton 2009 arXiv
0906.2827

Model of propagation (Motivations for Local MF)

Beside the magnetic pressure, we also have to consider the magnetic tension force. As long as the field lines are parallel, the magnetic tension force is zero. However, when the circumstellar bubble expands, it will exert a force on the field lines, forcing them into a curved shape. The magnetic tension force, which is directed inward with respect to the curvature of the field lines, will try to counteract the expansion of the bubble. Therefore, the expansion of the bubble will always be reduced in the direction perpendicular to the field, even if the magnetic pressure is too small

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



Model (Construction)

Injection of cosmic rays from the source :

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

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 :

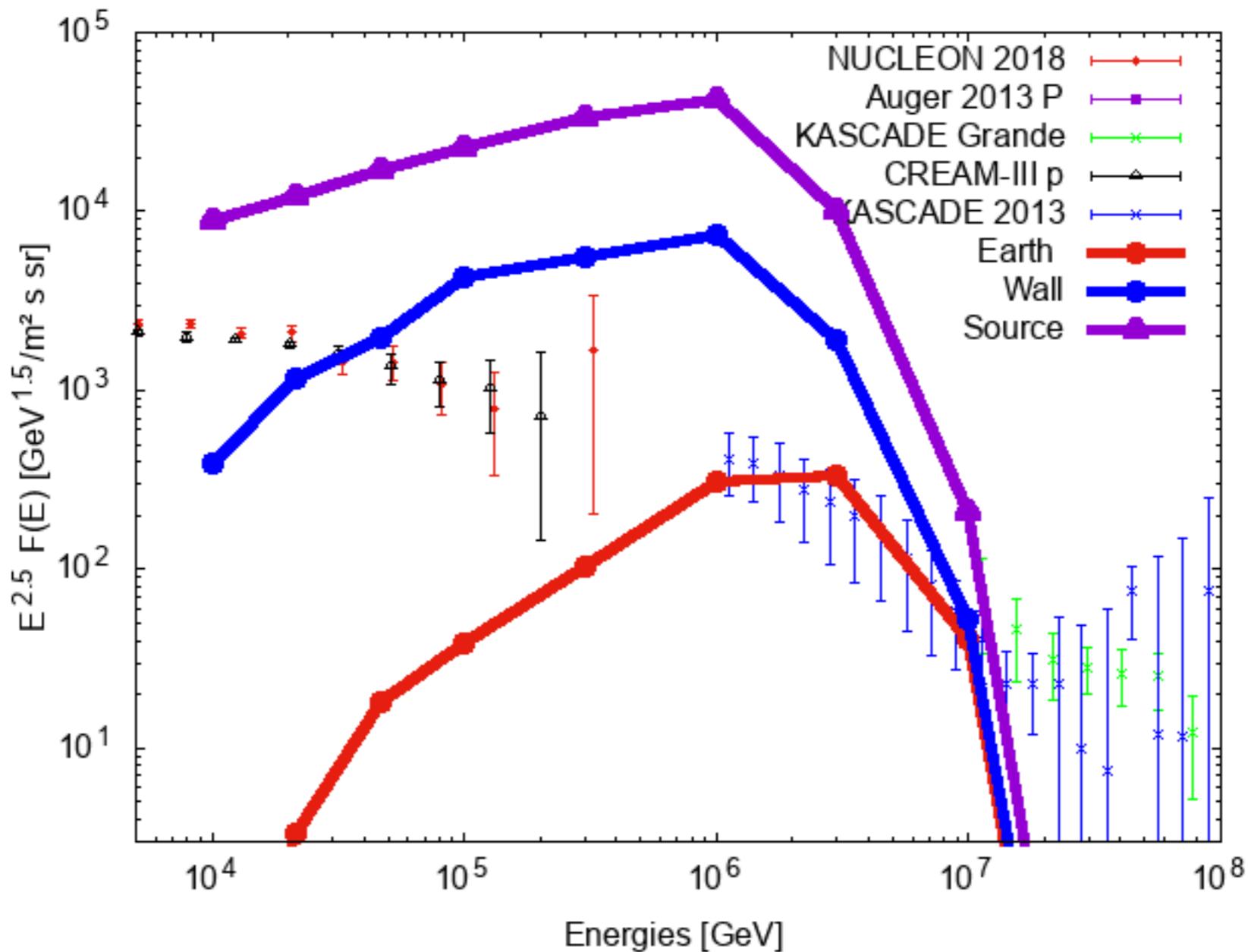
$$E_{br} \quad \beta_1$$

Magnetic field configuration :

$$w \quad w_1$$

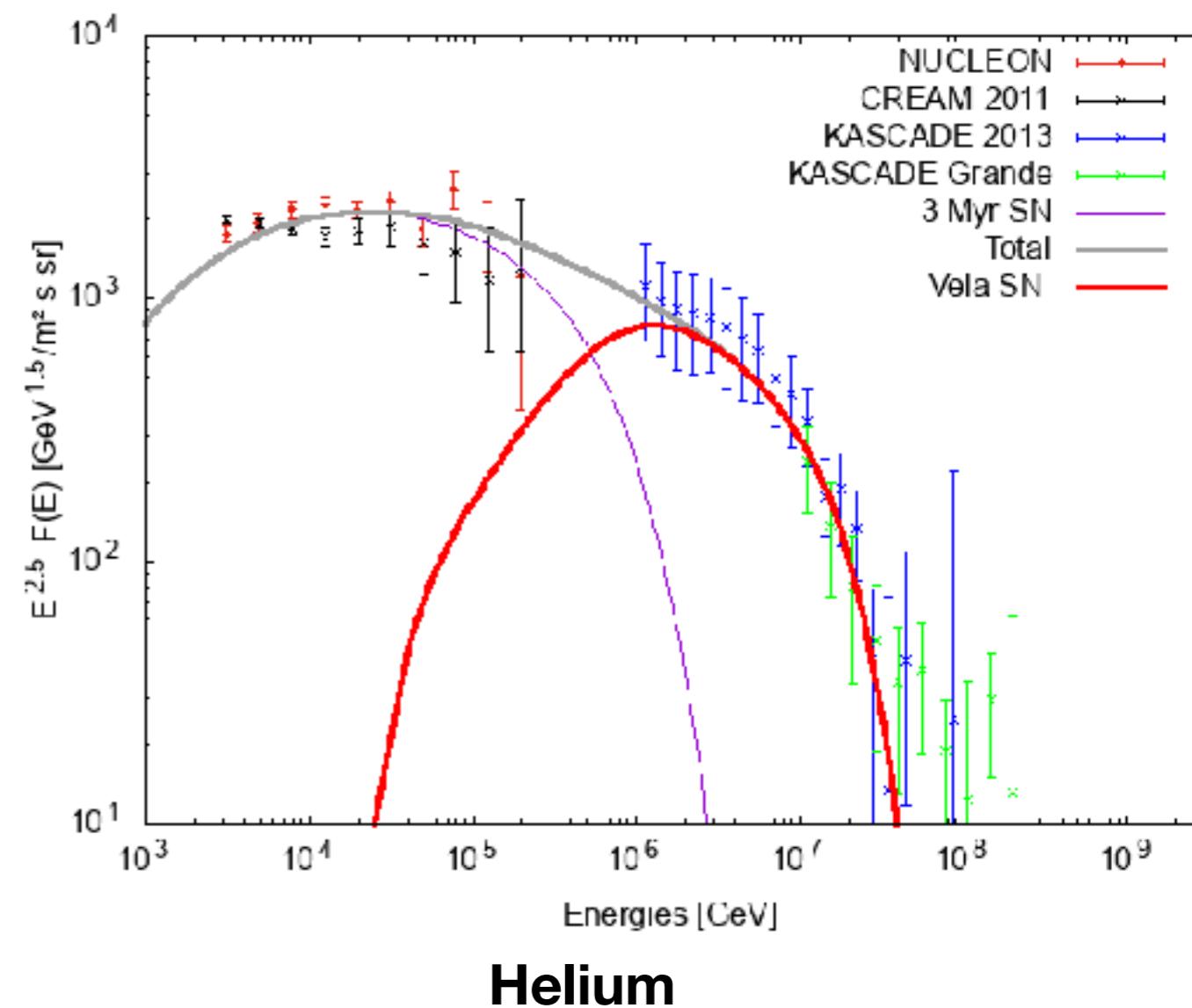
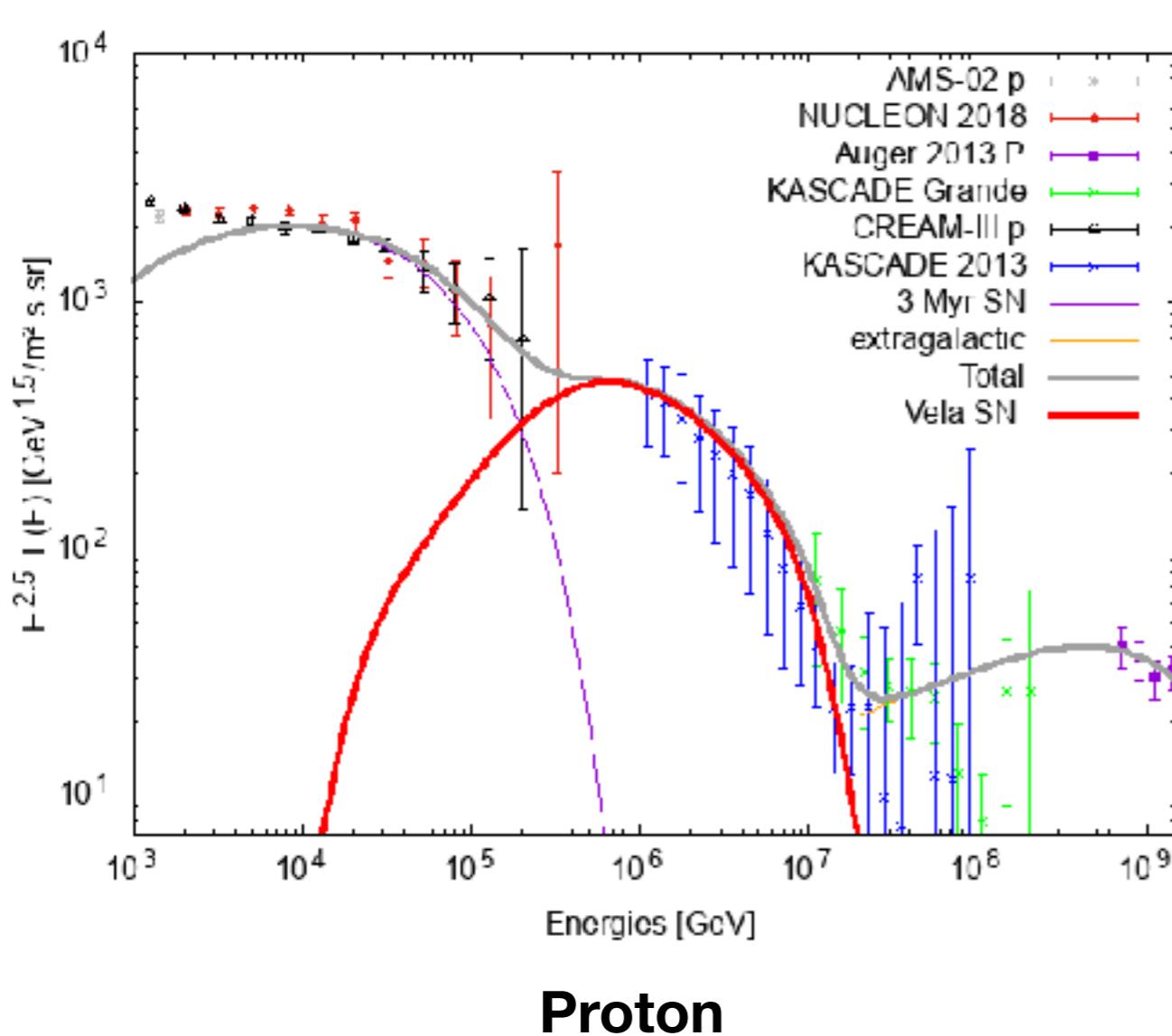
$$E_{max} \quad \beta_2 \quad B(r, z)_{in, sh, out} \quad w_2$$

Results (Proton flux on earth wall and source)



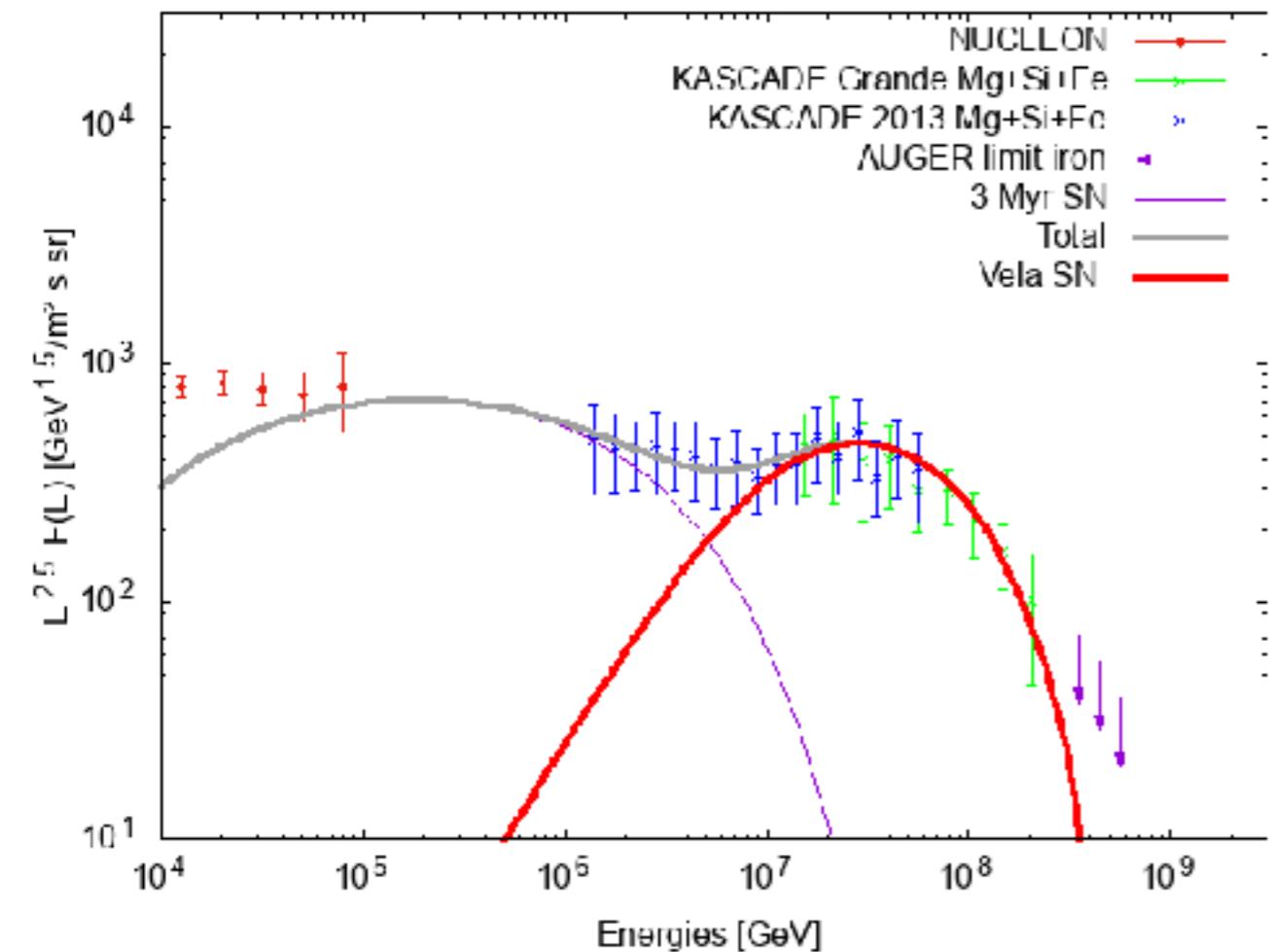
M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

Results (Light nuclei)

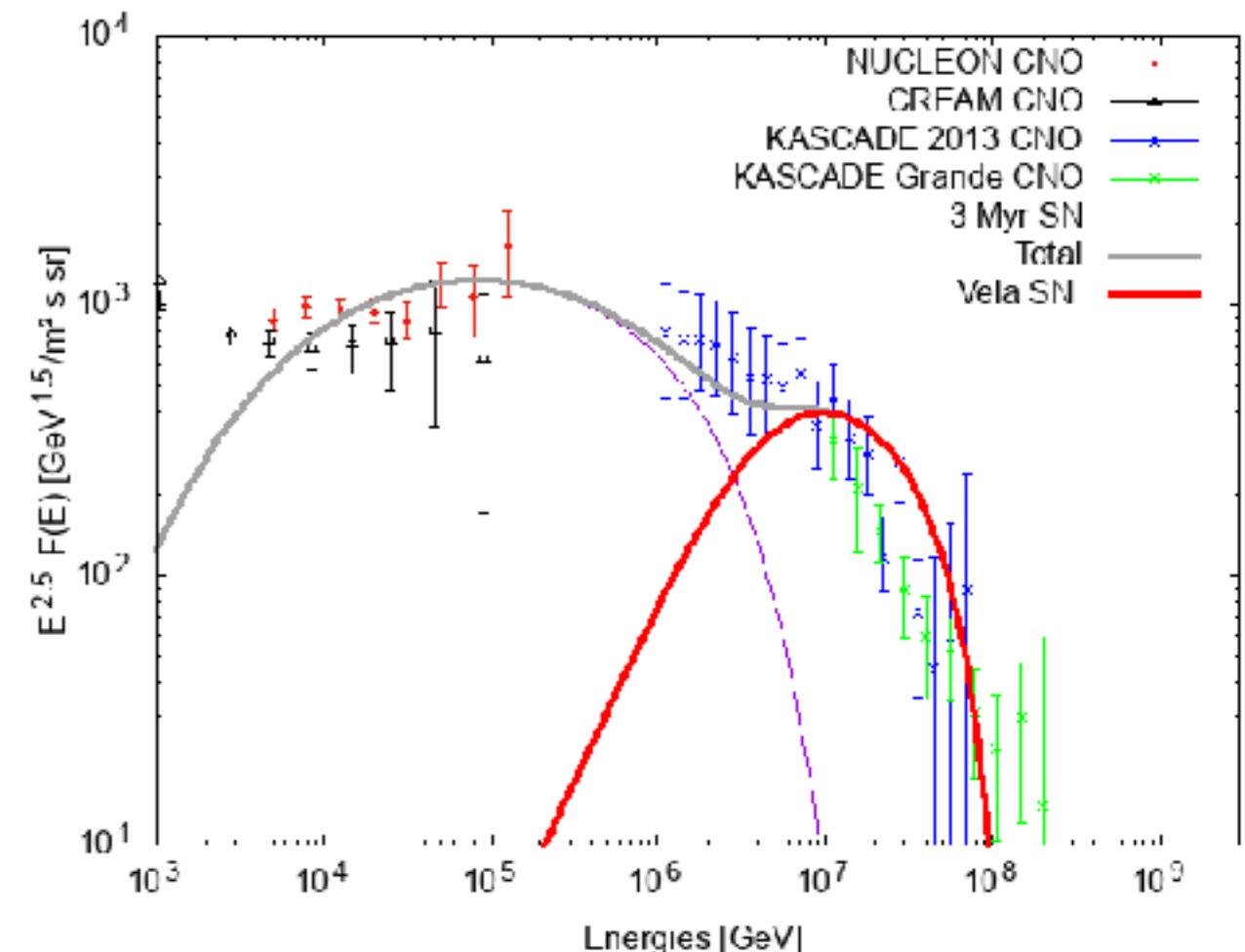


M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

Results (Heavy nuclei)



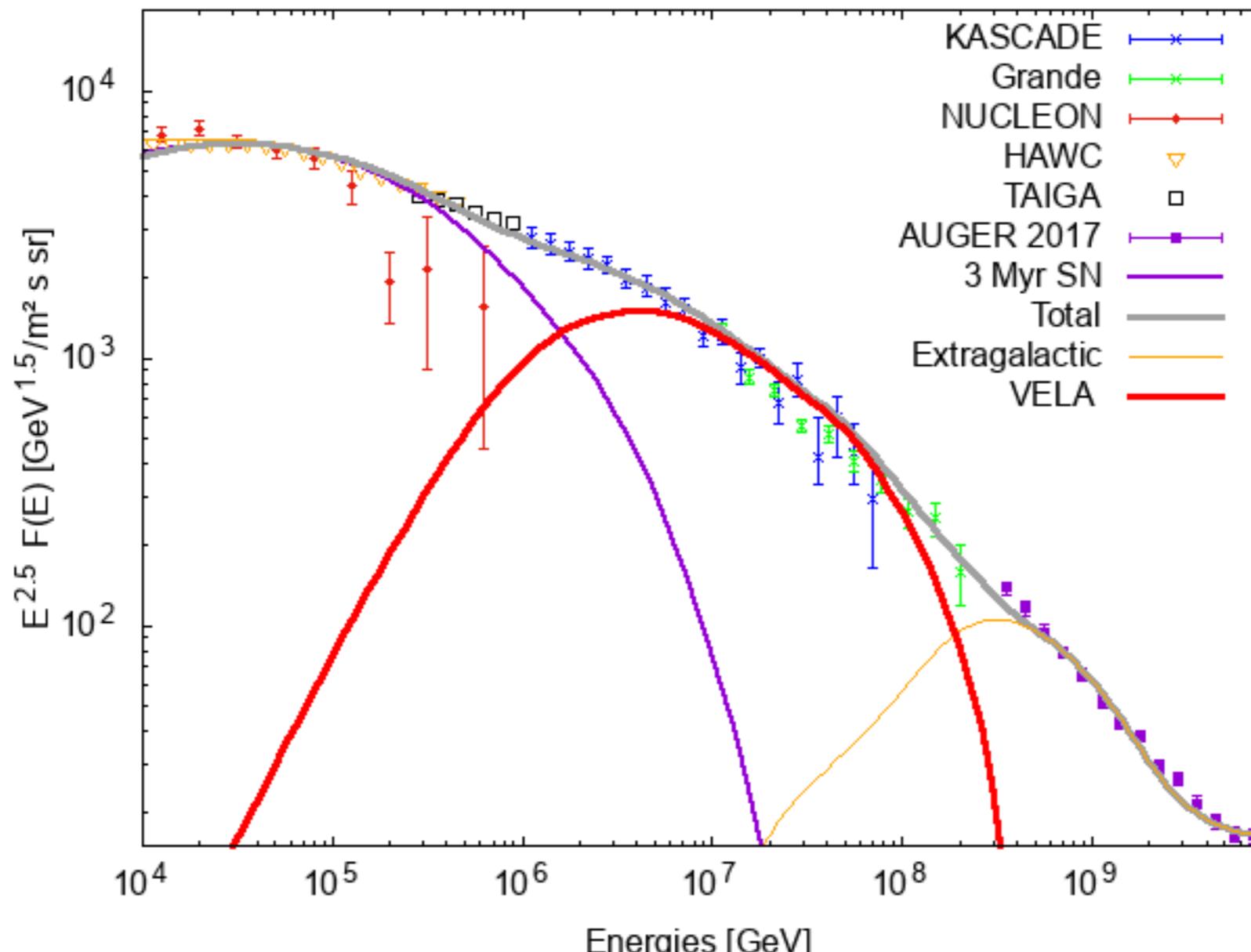
Fe + Si + Mg



CNO

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

Results (All particles)



All particles

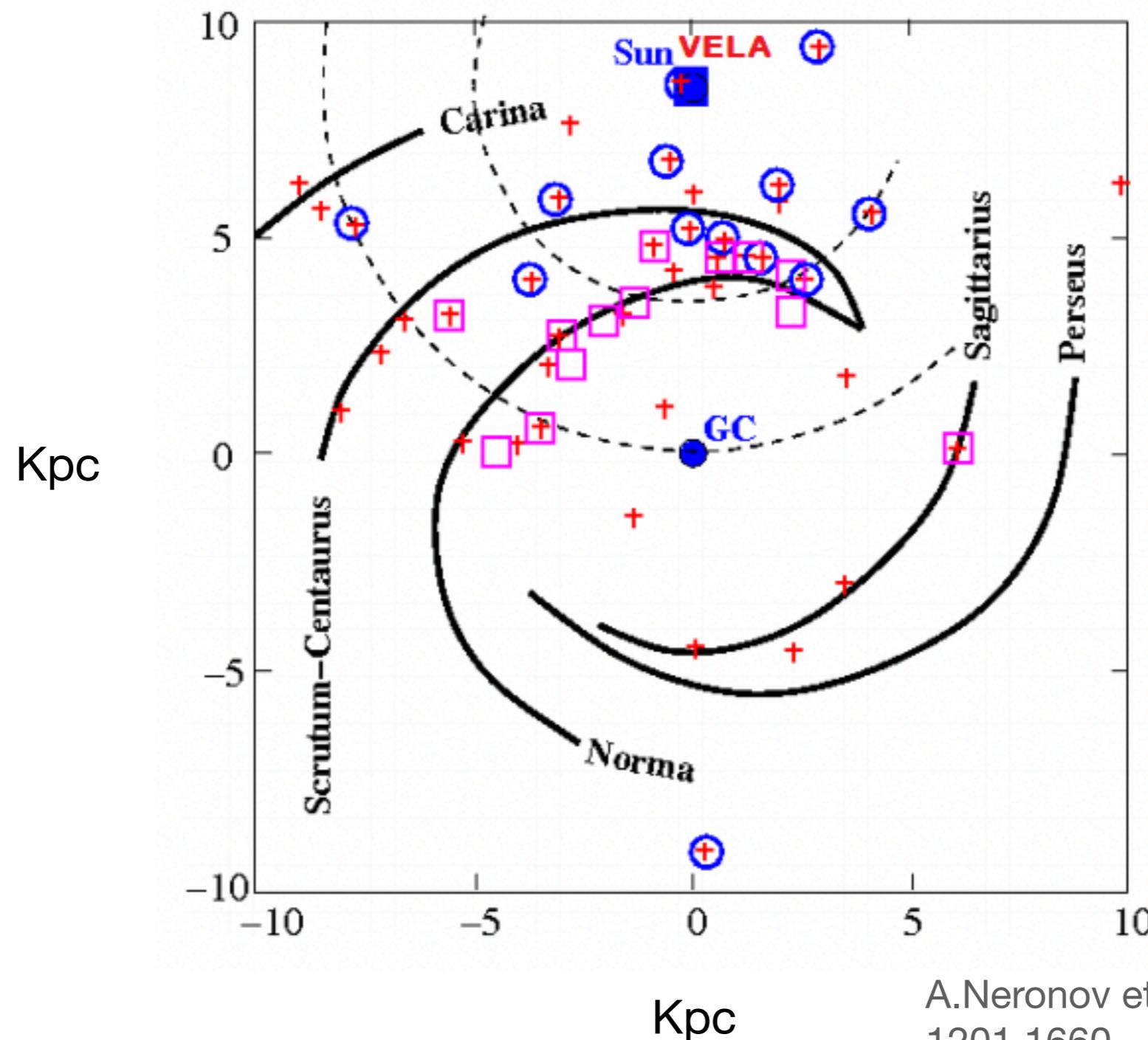
M.Kachelriess, D.Semikoz, B.M 2018 arXiv 1812.03522

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 dependence on the properties of the bubble.

BACK UP

Model of dominant source (Vela SNR)

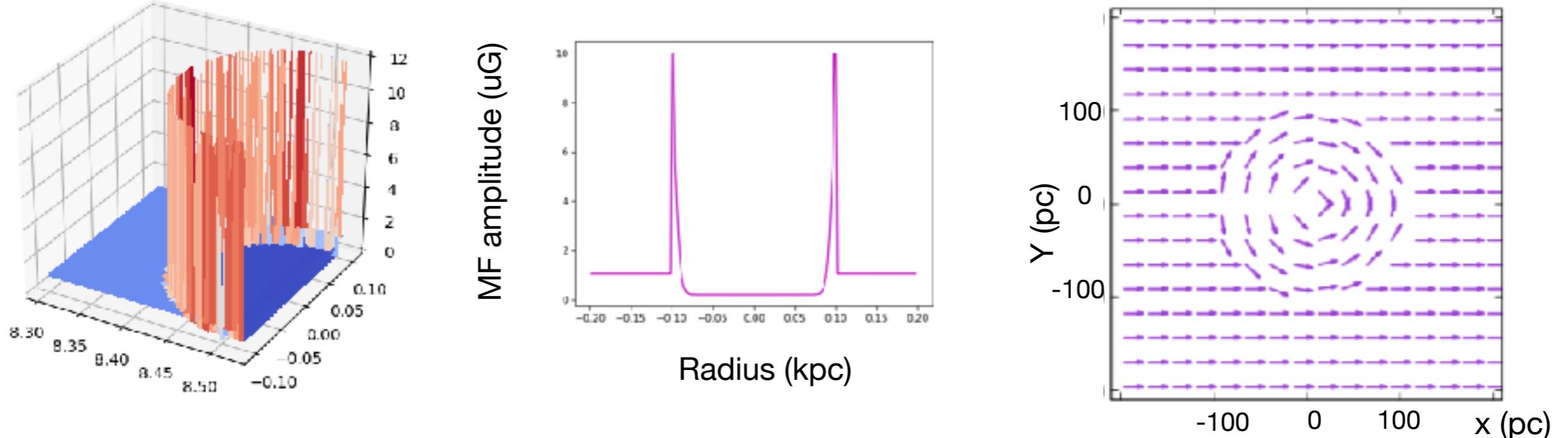


BACK UP

Model (Construction)

- Magnetic field modelisation of the bubble :

K.J Anderson 2017



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

For $r < R$

$$B = B_{\text{in}}(1 - T_1) + B_{\text{sh}}T_1 \begin{pmatrix} s \times \sin(\vartheta) \\ -s \times \cos(\vartheta) \end{pmatrix} \exp(-z^2/z_{\text{bub}}^2) + B_{\text{out}}(1 - \exp(-z^2/z_{\text{bub}}^2)),$$

And for $r > R$

$$B = B_{\text{sh}}(1 - T_2) + B_{\text{out}}T_2 \begin{pmatrix} s \times \sin(\vartheta) \\ -s \times \cos(\vartheta) \end{pmatrix} \exp(-z^2/z_{\text{bub}}^2) + B_{\text{out}}(1 - \exp(-z^2/z_{\text{bub}}^2)),$$

BACK UP

Model (Construction)

$$E_{br} = 1 \text{ PeV} \quad w = 1 \text{ pc}$$

$$E_{max} = 3 \text{ PeV} \quad w_1 = 3 \text{ pc}$$

$$\beta_1 = 2 \quad w_2 = 0.1 \text{ pc}$$

$$\beta_2 = 2.9 \quad |B(r, z)_{in, sh, out}| = 0.1, 10, 1 \mu G$$

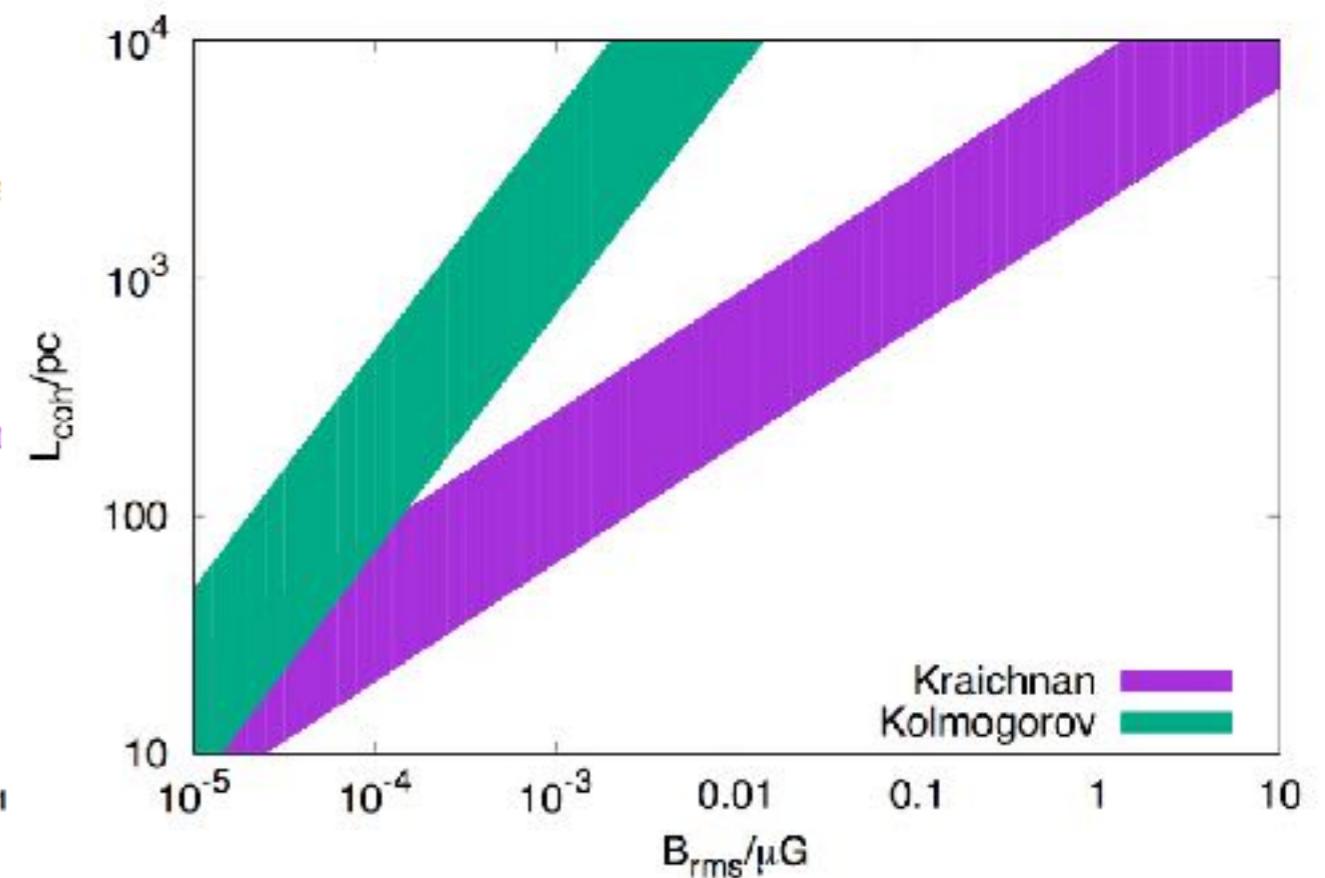
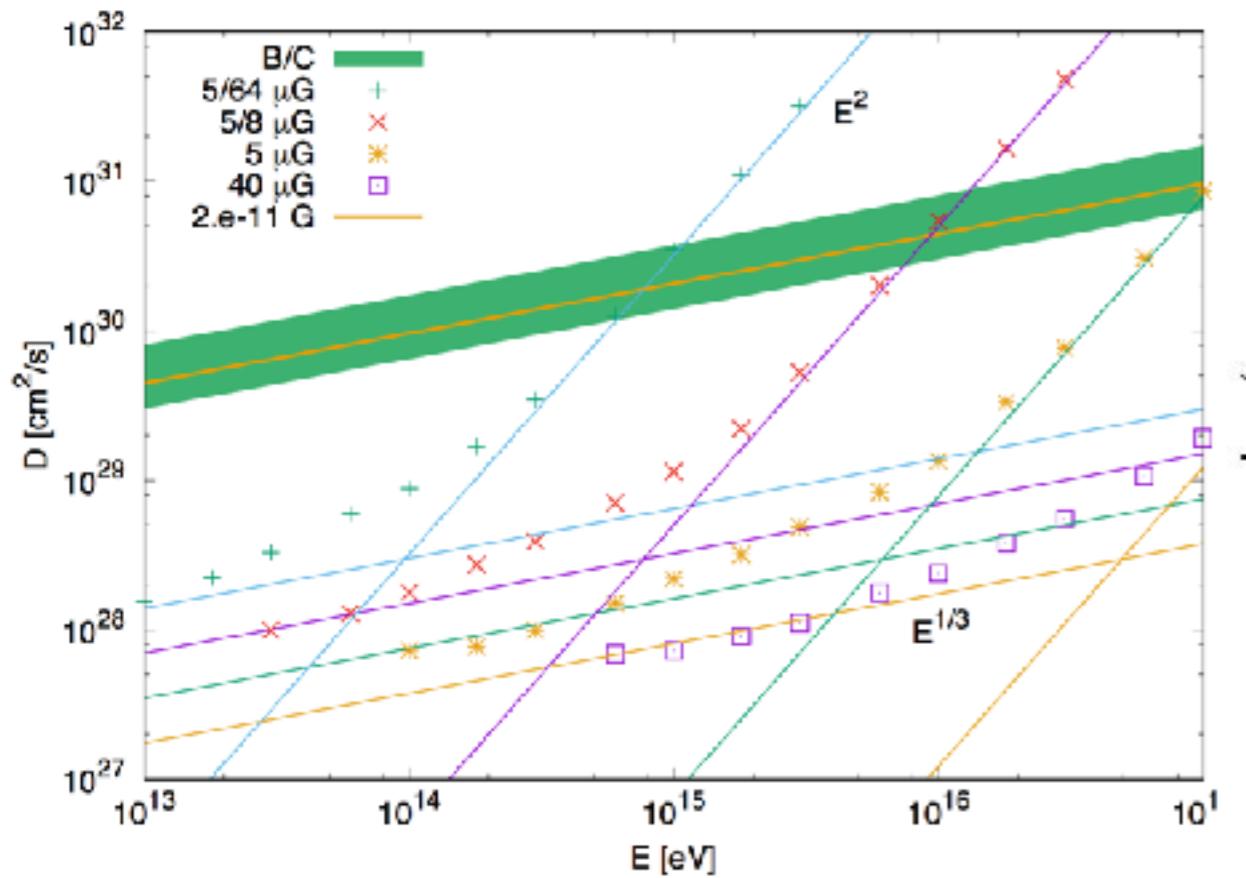
Total luminosity = $3.7 \times 10^{49} \text{ erg}$

Vela kinetic energy = $1.4 \times 10^{50} \text{ erg}$

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

BACK UP

Anisotropic propagation (motivation)



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