3D Modeling of CR propagation

"Dark side of the Universe"
SISSA, Trieste
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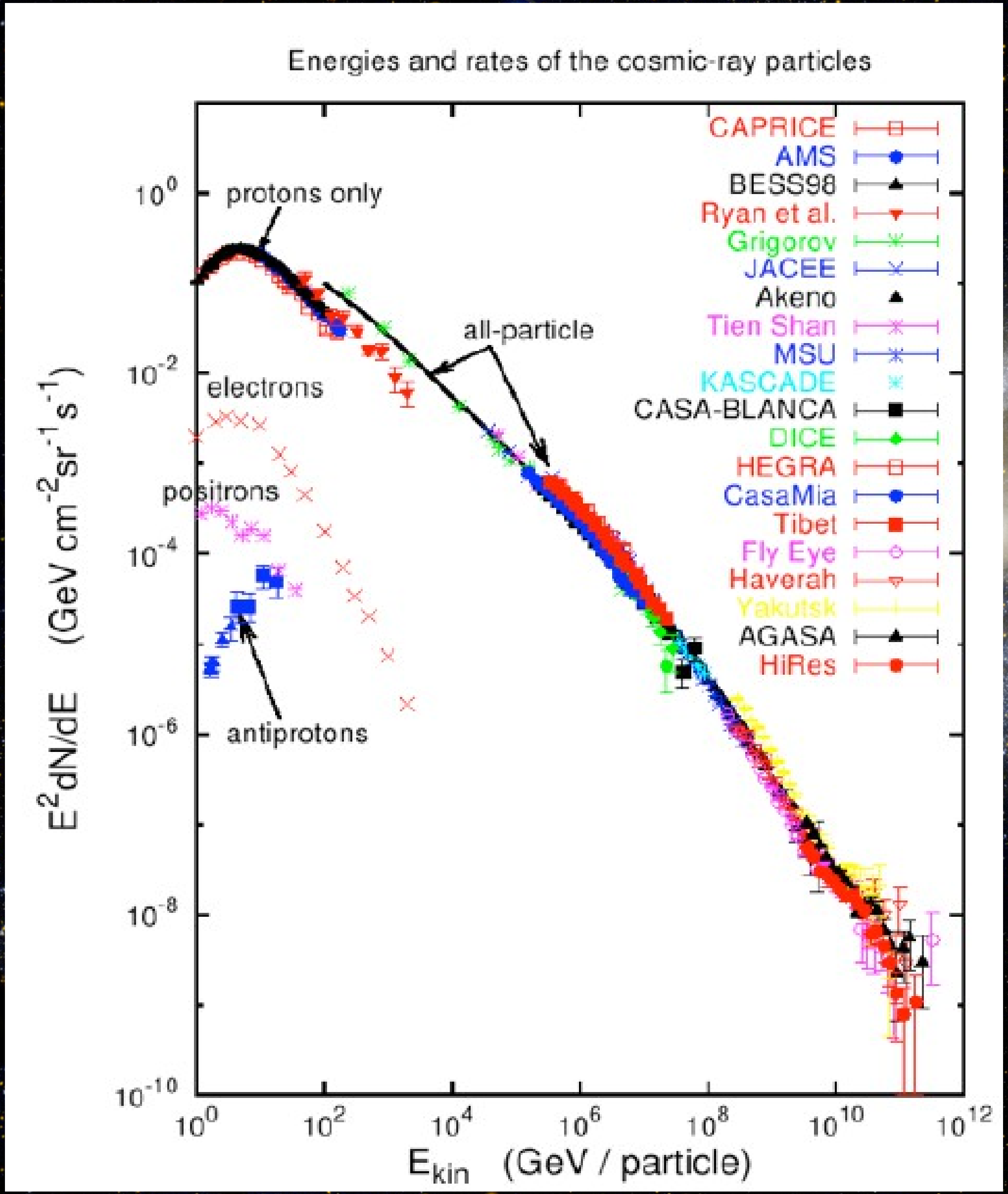
Cosmic ray diffusion in the Galaxy. A short introduction.



CR spectrum extends over a very wide energy range.
The spectrum is well approximated by a broken power law

Protons are the most abundant particles in CRs

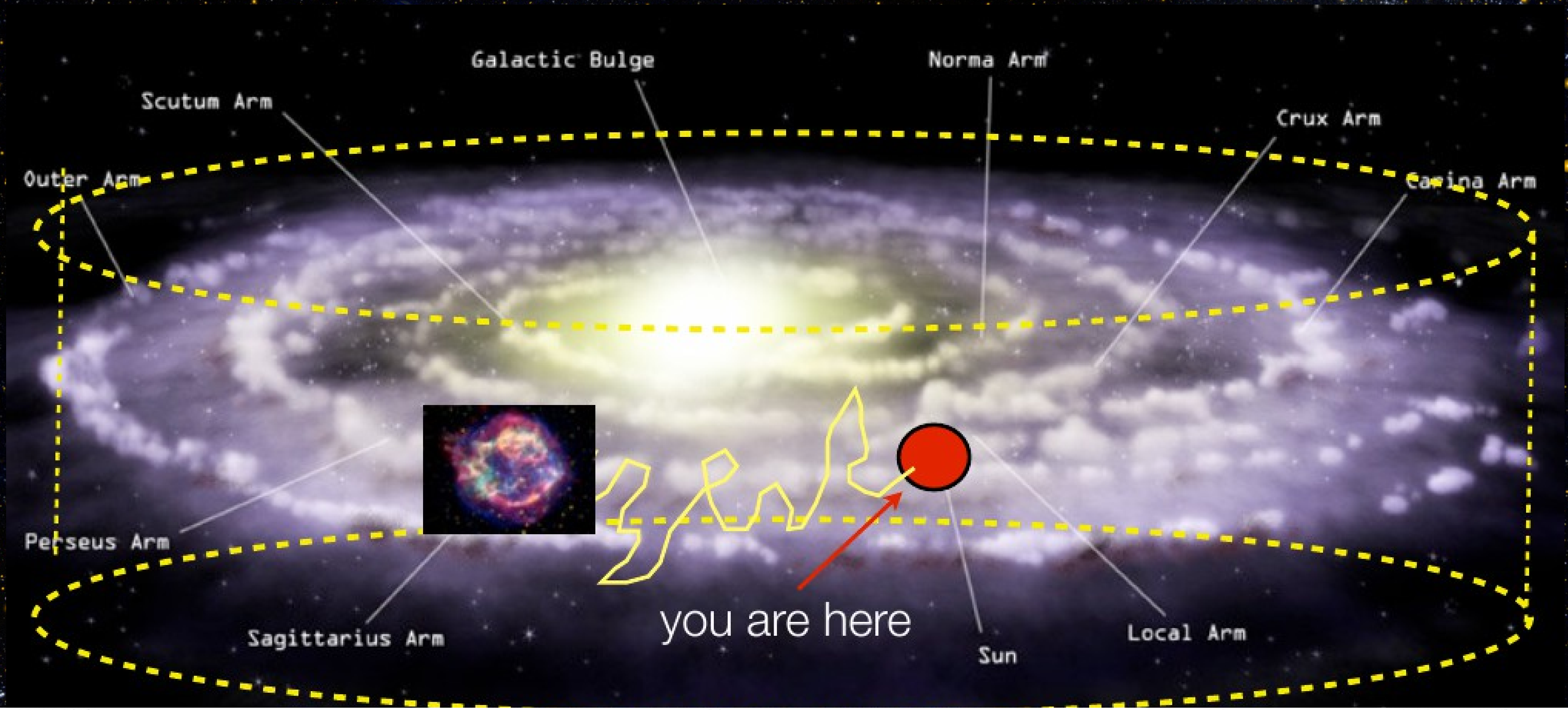
Rate:
~1/cm^2/s at GeV
<1/km^2/century at the highest energies.

A significant amount of antiparticles (positrons, antiprotons) is present.

I will concentrate on the GeV-TeV region!

Cosmic ray diffusion in the Galaxy.

The diffusion equation

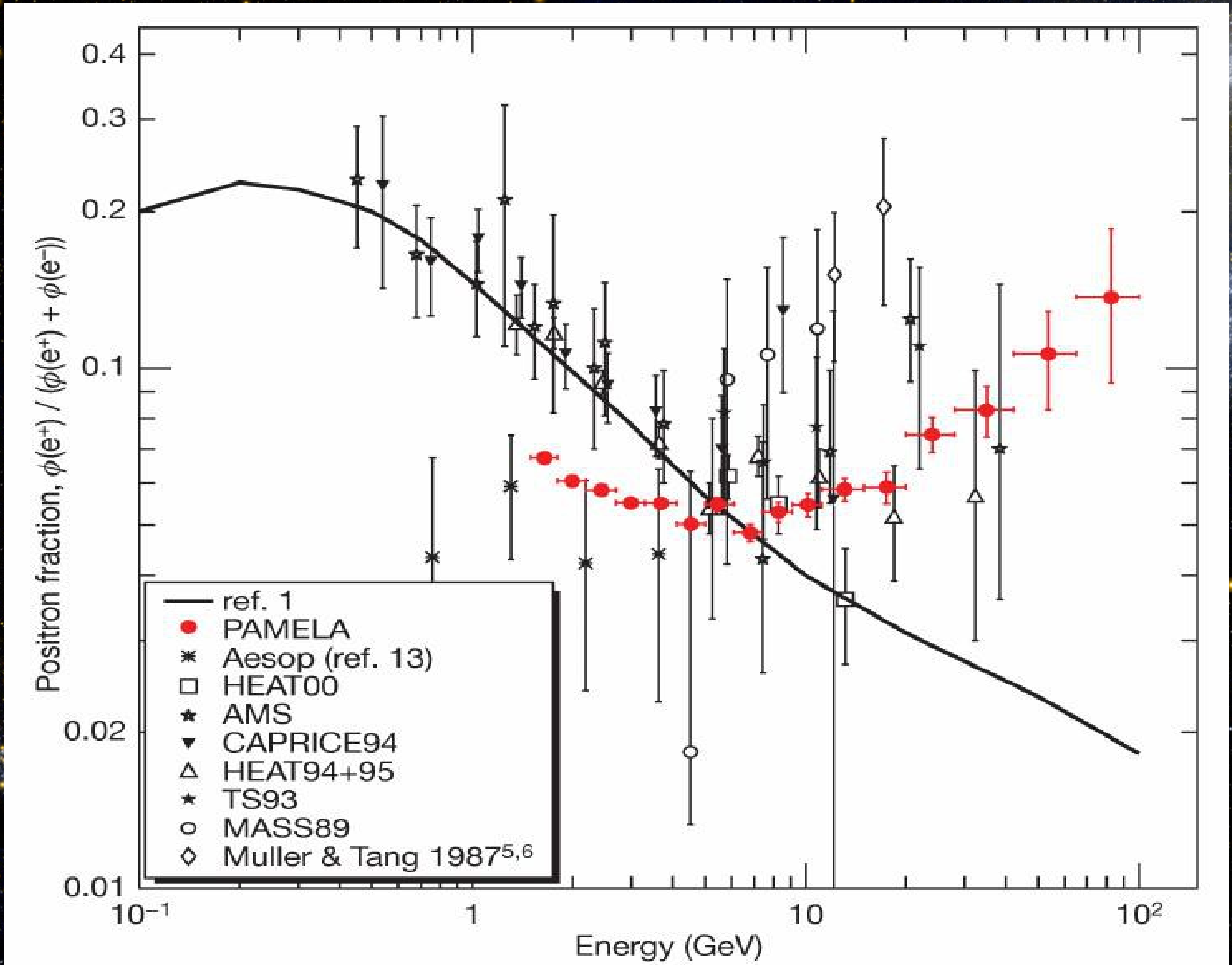


$$\frac{\partial N^i}{\partial t} - \nabla \cdot (D\nabla - v_c)N^i + \frac{\partial}{\partial p}\left(\dot{p} - \frac{p}{3}\nabla \cdot v_c\right)N^i - \frac{\partial}{\partial p}p^2 D_{pp}\frac{\partial}{\partial p}\frac{N^i}{p^2} =$$

$$= Q^i(p,r,z) + \sum_{j>i} c\beta n_{\rm gas}(r,z)\sigma_{ji}N^j - c\beta n_{\rm gas}\sigma_{\rm in}(E_k)N^i$$

Cosmic ray diffusion in the Galaxy.

The positron anomaly

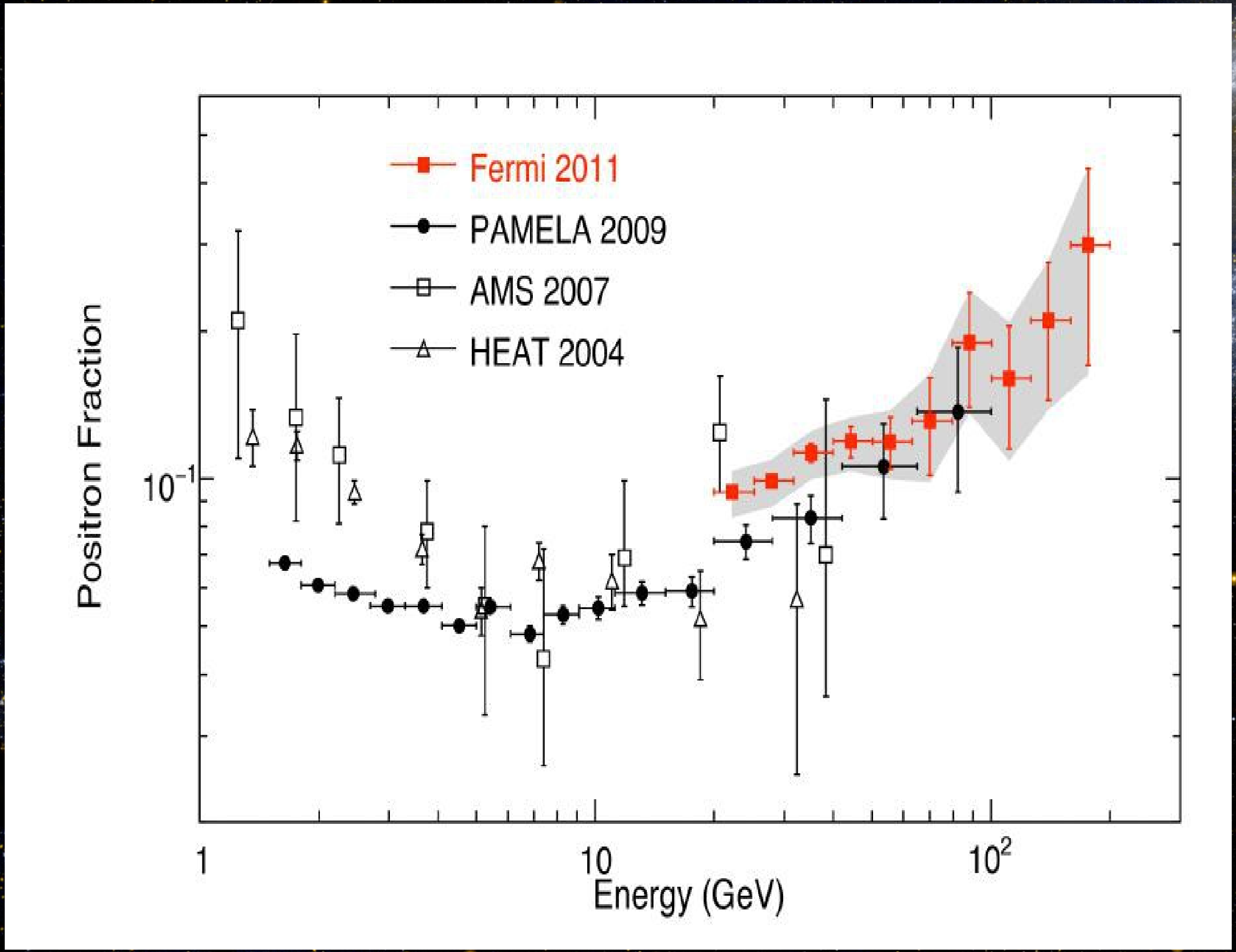


The first clear indication of a rising in the position fraction came in 2008 from PAMELA collaboration.

This behaviour is in strong tension with what expected from conventional simulations in which positrons are entirely secondary!!

Cosmic ray diffusion in the Galaxy.

The positron anomaly

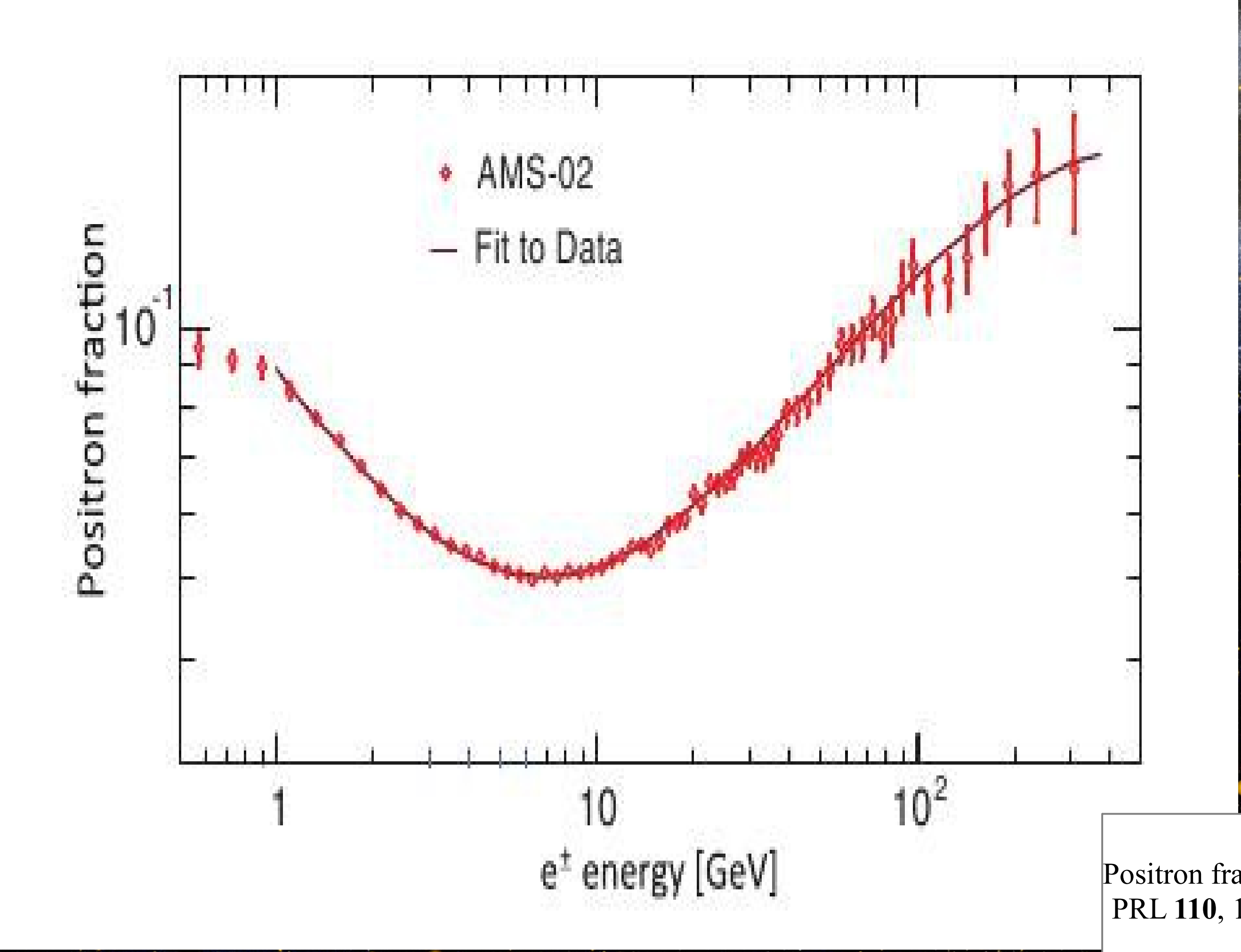


The release of the all-electron flux from Fermi-LAT in 2009 confirmed that the excess was real and not due to a very steep electron spectrum.

Fermi-LAT independently confirmed the position fraction rising using the Earth magnetic field to discriminate electrons from positrons

Cosmic ray diffusion in the Galaxy.

The positron anomaly



Recently AMS confirmed the anomaly and provided a new dataset with unprecedented accuracy.

Positron fraction (official)
PRL **110**, 141102 (2013)

The DRAGON code

DRAGON is a public code available at
dragon.hepforge.org

The DRAGON team:

- Luca Maccione (MPP & LMU, Muenchen)
- Daniele Gaggero (SISSA & INFN Trieste)
- Dario Grasso (INFN Pisa)
- Carmelo Evoli (DESY, Hamburg)
- Giuseppe Di Bernardo (Gothenburg University)

Contributions from KIT (Karlsruhe)

- Iris Gebauer
- Simon Kunz
- Matthias Weinreuter
- Florian Keller

The DRAGON code

DRAGON solves the diffusion-reacceleration-loss equation describing Cosmic Ray propagation in the Galaxy for all relevant species.

Hadronic species: all nuclei starting from the heavier one are propagated, and for each of them the contribution coming from spallation from heavier ones is computed

Leptonic species: Primary and secondary electrons, secondary positrons, plus possibly an extra primary component of electrons and positrons (e.g. originating from pulsars)

Exotic sector: Particles coming from DM annihilation or decay can be propagated. DRAGON can be coupled to DarkSUSY for the computation of the injection spectrum

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Why DRAGON is an appropriate tool for these investigations.
Recent and planned developments of the code.

<u>3 different modes</u>

<u>a) 2D mode</u> [arXiv:0807.4730, published on JCAP]:

Assumes cylindrical symmetry.
Propagation in (R,z,p)
---> Very fast, perfect for large parameter scans.
Diffusion coefficient is a position and rigidity dependent scalar D(R,z,p)
---> This allows to investigate how properties of diffusion change through the Galaxy; we found that the CR gradient and anisotropy and the gamma ray profile are much better reproduced exploting this feature (see later)

<u>b) 3D isotropic mode</u> [arXiv:1304.6718, published on PRL]:

Propagation in (x,y,z,p)
Diffusion coefficient is a position and rigidity dependent scalar D(x,y,z,p)
--->This mode allows to investigate, e.g., the impact of large scale structures (such as the spiral arm pattern) in the source, gas or ISRF distribution.

The DRAGON code

3 different modes

c) 3D ANISOTROPIC mode

[arXiv:1306.6850]:

Full equation (spatial part):

$$\alpha_{xx}(x,y,z) = (D_{||} - D_{\perp})b_x^2 + D_{\perp}$$
$$\alpha_{yy}(x,y,z) = (D_{||} - D_{\perp})b_y^2 + D_{\perp}$$
$$\alpha_{zz}(x,y,z) = (D_{||} - D_{\perp})b_z^2 + D_{\perp}$$
$$\delta_{xy}(x,y,z) = (D_{||} - D_{\perp})b_x b_y + D_{\perp}$$
$$\delta_{xz}(x,y,z) = (D_{||} - D_{\perp})b_x b_z + D_{\perp}$$
$$\delta_{yz}(x,y,z) = (D_{||} - D_{\perp})b_y b_z + D_{\perp}$$
$$u_x(x,y,z) = \partial_x \alpha_{xx} + \partial_y \delta_{xy} + \partial_z \delta_{xz}$$
$$u_y(x,y,z) = \partial_x \delta_{xy} + \partial_y \alpha_{yy} + \partial_z \delta_{yz}$$
$$u_z(x,y,z) = \partial_x \delta_{xz} + \partial_y \delta_{yz} + \partial_z \alpha_{zz}$$

$$\frac{\partial f}{\partial t} = Q + \alpha_{xx}\partial_x^2 f + \alpha_{yy}\partial_y^2 f + \alpha_{zz}\partial_z^2 f$$
$$+2\delta_{xy}\partial_x\partial_y f + 2\delta_{xz}\partial_x\partial_z f + 2\delta_{yz}\partial_y\partial_z f$$
$$+u_x\partial_x f + u_y\partial_y f + u_z\partial_z f$$

The DRAGON code

3 different modes

In each mode it is possible to set a non-equidistant binning
(thanks to the KIT group!)

--> this feature is very useful if one wants to have a more detailed modeling of a particular region, e.g. the local environment

--> Local bubble studies (ongoing work at KIT)

The DRAGON code

3 different modes

In 3D mode it is possible to propagate particles originating from a moving source!!

--> this feature is very useful if one wants to model, e.g., a moving DM clump

see later for some preliminary results on that, in collab. With Hani N. Santosa, P. Ullio

And now let's use the code to do some physics!

Some issues we can investigate with the 3D code:

1) where do the extra positrons come from? Pulsars? Dark Matter? ***from the DM halo or from a very luminous clump?*** Enhanced production in SNRs?

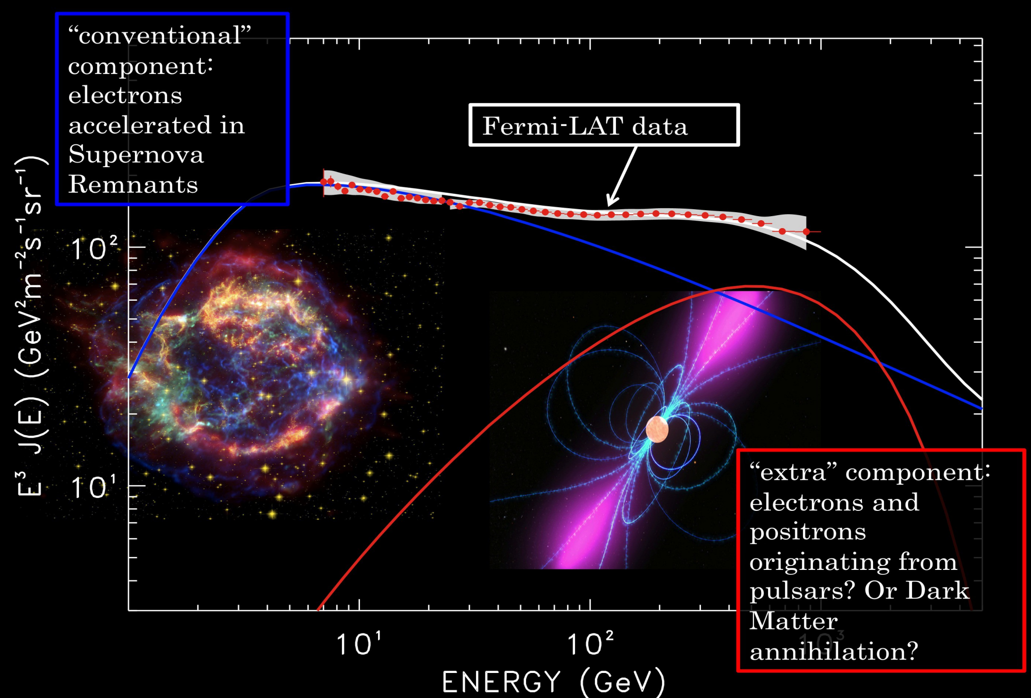
2) how do the large scale structures (in particular the spiral arm structure) influence the observables, *in particular the leptonic fluxes* that are very sensitive to energy losses and trace smaller and smaller regions as the energy increases

Where do the extra positrons come from? Pulsars? Dark Matter? Enhanced production in SNRs?

It is well known that the e^+ excess was interpreted in several ways.

1) A previously unaccounted population of primary electron and positrons with hard spectrum is present, coming from a local source (e.g. a pulsar)?

2) An exotic population of primary electron and positions is present, coming from Dark Matter annihilation or decay?



Where do the extra positrons come from? Pulsars? Dark Matter? Enhanced production in SNRs?

It is well known that the e^+ excess was interpreted in several ways.

3) No extra component is present, but an enhanced production of secondary near the accelerator is taking place?

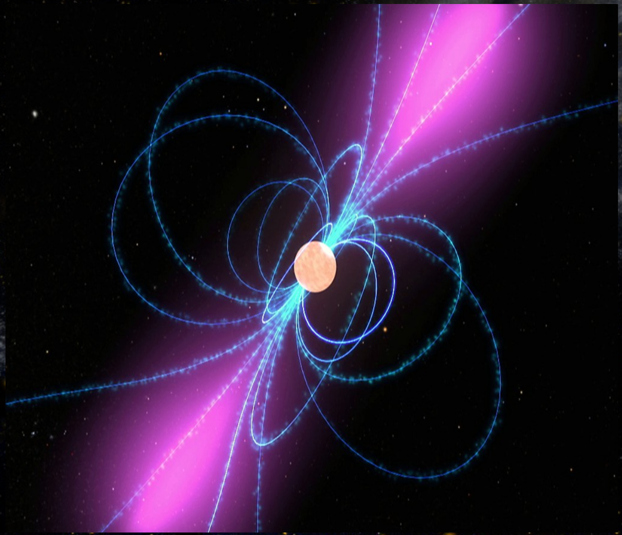
Where do the extra positrons come from? Pulsars? Dark Matter? Enhanced production in SNRs?

Summary of different interpreatations with pros and cons

Pulsar interpretation.

Quite natural: the energetic of observed nearby pulsars is compatible with observed fluxes.
Might be confirmed by the detection of a dipole anisotropy pointing towards a known pulsar..
No anisotropy detected so far, but the interpretation is fine with current upper limits.

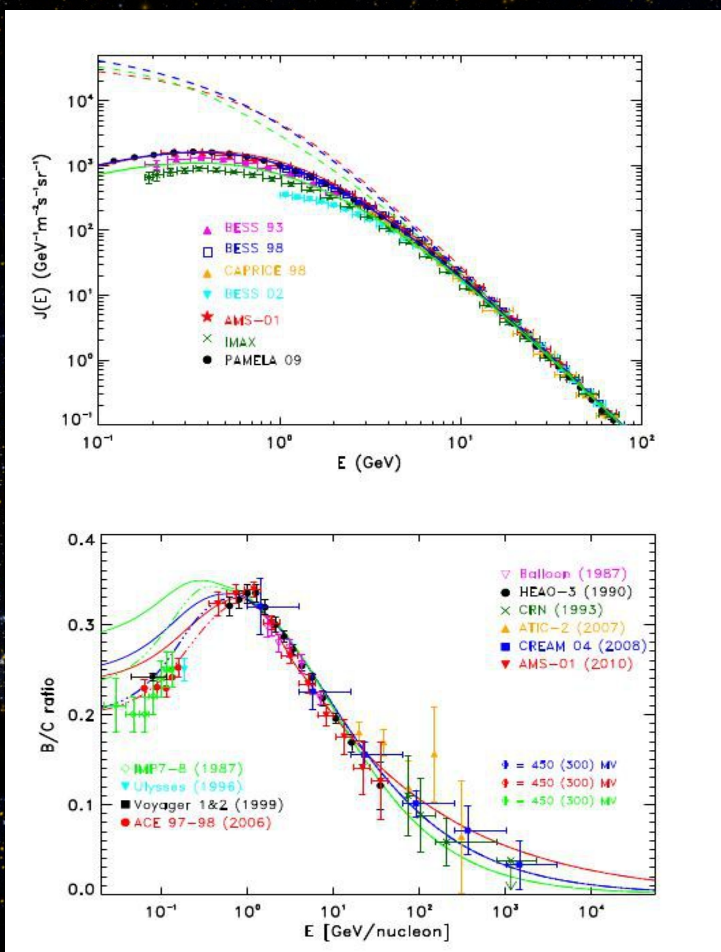
Very incomplete list of papers:
P.D.Serpico arXiv:0810.4846, D. Hooper et al. ArXiv:0810.4846, S.Profumo arXiv:0812.4457, I. Buesching et al. ArXiv:0804.0220, D. Grasso et al. ArXiv:0905.0636, T.Delahaye et al. ArXiv:1002.1910, G. Di Bernardo et al. ArXiv:1010.0174, **and many others...**



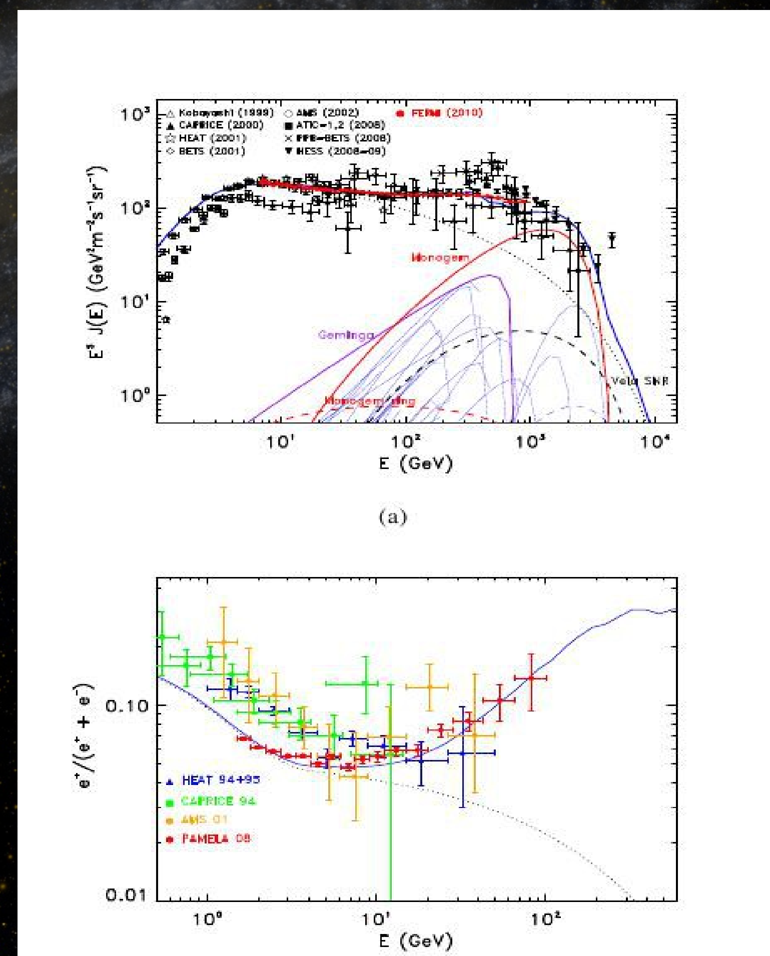
Where do the extra positrons come from? Pulsars? Dark Matter? Enhanced production in SNRs?

Results from the DRAGON team regarding the PULSAR scenario.

Using diffusion setups that consistently reproduce the protons, antiprotons, B/C and other nuclei ratio, we were able to fit the positron fraction rising as well as absolute leptonic fluxes with a conventional component + local sources (pulsars, SNRs)

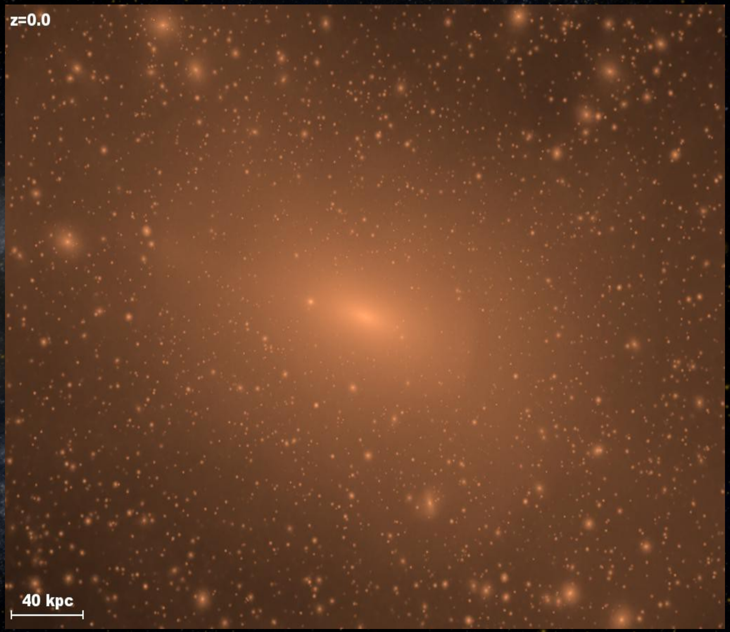


G. Di Bernardo, C.Evoli, D.Gaggero, D.Grasso, L.Maccione, M.N.Mazziotta, arXiv:1010.0174



Where do the extra positrons come from? Pulsars? Dark Matter? Enhanced production in SNRs?

Summary of different interpreatations with pros and cons



Dark Matter interpretation.

Not so natural for many reasons. Very challenging for model builders:
- DM particle should be heavy
- it requires very high cross section (boost factor)
- it requires a “leptophilic” behaviour (no annihilation into hadrons)

(See e.g. Arkani-Hamed arXiv:0810.0713 for a model with Sommerfeld enhancement that includes all these features)

Might be strongly constrained or ruled out by antiproton measurements, gamma rays and other observables.
(See e.g. Evoli et al. ArXiv:1108.0664)

Very popular in the literature! (list taken from a slide by M.Cirelli)

M.Pospelov and A.Ritz, 0810.1502: Secluded DM - A.Nelson and C.Spitzer, 0810.5167: Slightly Non-Minimal DM - Y.Nomura and J.Thaler, 0810.5397: DM through the Axion Portal - R.Harnik and G.Kribs, 0810.5557: Dirac DM - D.Feldman, Z.Liu, P.Nath, 0810.5762: Hidden Sector - T.Hambye, 0811.0172: Hidden Vector – Yin, Yuan, Liu, Zhang, Bi, Zhu, 0811.0176: Leptonically decaying DM - K.Ishiwata, S.Matsumoto, T.Moroi, 0811.0250: Superparticle DM - Y.Bai and Z.Han, 0811.0387: sUED DM - P.Fox, E.Poppitz, 0811.0399: Leptophilic DM - C.Chen, F.Takahashi, T.T.Yanagida, 0811.0477: Hidden-Gauge-Boson DM – K.Hamaguchi, E.Nakamura, S.Shirai, T.T.Yanagida, 0811.0737: Decaying DM in Composite Messenger – E.Ponton, L.Randall, 0811.1029: Singlet DM - A.Ibarra, D.Tran, 0811.1555: Decaying DM - S.Baek, P.Ko, 0811.1646: U(1) Lmu-Ltau DM - C.Chen, F.Takahashi, T.T.Yanagida, 0811.3357: Decaying Hidden-Gauge-Boson DM - I.Cholis, G.Dobler, D.Finkbeiner, L.Goodenough, N.Weiner, 0811.3641: 700+ GeV WIMP - E.Nardi, F.Sannino, A.Strumia, 0811.4153: Decaying DM in TechniColor - K.Zurek, 0811.4429: Multicomponent DM – M.Ibe, H.Murayama, T.T.Yanagida, 0812.0072: Breit-Wigner enhancement of DM annihilation - E.Chun, J.-C.Park, 0812.0308: sub-GeV hidden U(1) in GMSB - M.Lattanzi, J.Silk, 0812.0360: Sommerfeld enhancement in cold substructures - M.Pospelov, M.Trott, 0812.0432: super-WIMPs decays DM - Zhang, Bi, Liu, Liu, Yin, Yuan, Zhu, 0812.0522: Discrimination with SR and IC - Liu, Yin, Zhu, 0812.0964: DMnu from GC – M.Pohl, 0812.1174: electrons from DM - J.Hisano, M.Kawasaki, K.Kohri, K.Nakayama, 0812.0219: DMnu from GC - A.Arvanitaki, S.Dimopoulos, S.Dubovsky, P.Graham, R.Harnik, S.Rajendran, 0812.2075: Decaying DM in GUTs - R.Allahverdi, B.Dutta, K.Richardson-McDaniel, Y.Santoso, 0812.2196: SuSy B-L DM- S.Hamaguchi, K.Shirai, T.T.Yanagida, 0812.2374: Hidden-Fermion DM decays - D.Hooper, A.Stebbins, K.Zurek, 0812.3202: Nearby DM clump - C.Delaunay, P.Fox, G.Perez, 0812.3331: DMnu from Earth - Park, Shu, 0901.0720: Split- UED DM - .Gogoladze, R.Khalid, Q.Shafi, H.Yuksel, 0901.0923: cMSSM DM with additions - Q.H.Cao, E.Ma, G.Shaughnessy, 0901.1334: Dark Matter: the leptonic connection - E.Nezri, M.Tytgat, G.Vertongen, 0901.2556: Inert Doublet DM - C.-H.Chen, C.-Q.Geng, D.Zhuridov, 0901.2681: Fermionic decaying DM - J.Mardon, Y.Nomura, D.Stolarski, J.Thaler, 0901.2926: Cascade annihilations (light non-abelian new bosons) - P.Meade, M.Papucci, T.Volansky, 0901.2925: DM sees the light - D.Phalen, A.Pierce, N.Weiner, 0901.3165: New Heavy Lepton - T.Banks, J.-F.Fortin, 0901.3578: Pyrma baryons - Goh, Hall, Kumar, 0902.0814: Leptonic Higgs - K.Bae, J.-H. Huh, J.Kim, B.Kyae, R.Viollier, 0812.3511: electrophilic axion from flipped-SU(5) with extra spontaneously broken symmetries and a two component DM with Z2 parity – and others...

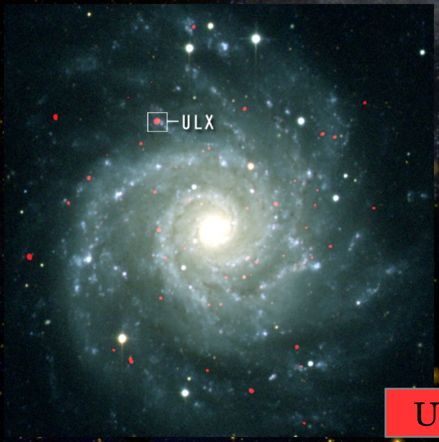
The possible role of a moving DM clump on the positron excess

A Dark clump

In `Koushiappas et al. 2003 [astro-ph/0311487]` a cosmological scenario is discussed in which **intermediate mass black holes (IMBHs) with M = [100 ...10^6] solar masses** (higher than stellar BHs and lower than SMBHs that are expected to be found in the center of the galaxies) **originate in massive objects formed during the collapse of gas in early forming halos.**

Hints of existence of IMBH come from:

--> detection of ultra-high-luminosity X-ray sources (ULXs) in several galaxies



ULX in M74

The possible role of a moving DM clump on the positron excess

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Hints of existence of IMBH come from:

--> studies of stellar kinematics of globular clusters

— Frank, J., & Rees, M. J. 1976, Mon. Not. Roy. Astron. Soc. , 176, 633
— Gebhardt, K., Rich, R. M., & Ho, L. C. 2002, Astrophys. J. Lett. 578, L41
— van der Marel, R. et al. 2002, Astron. J. 124, 3255

The possible role of a moving DM clump on the positron excess

A Dark clump

If the IMBH grows adiabatically (growth time scale >> orbital time scale of DM particles) then the DM profile in halos hosting a IMBH show a very sharp spike around the center.

- The DM density is saturated at Rs < R(spike) due to the annihilation into SM particles (see e.g. `Bertone et al. astro-ph/0509565`).

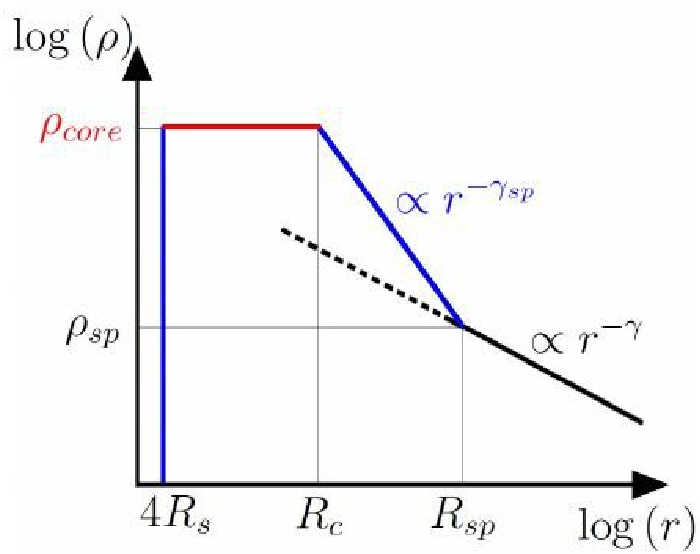
$$\rho_{core} \approx m_{DM}/(\langle\sigma v\rangle t_{BH})$$

$$\rho_i(r) = \rho_0 (r/r_0)^{-\gamma}$$

$$\rho_{DM}(r) = \frac{\rho_{core}\rho'(r)}{\rho'(r) + \rho_{core}}$$

$$\rho'(r) = \rho_{sp}\left(1 - \frac{4R_s}{r}\right)^3 \left(\frac{R_{sp}}{r}\right)^{\gamma_{sp}}, \gamma_{sp} = \frac{9-2\gamma}{4-\gamma}$$

$$L_{sp} = \frac{12}{5}\pi R_{sp}^3 \rho_{sp}^2 \left\{ \frac{14}{9}\left(\frac{\rho_{max}}{\rho_{sp}}\right)^{5/7} - 1 \right\}, \gamma = 1$$



The possible role of a moving DM clump on the positron excess

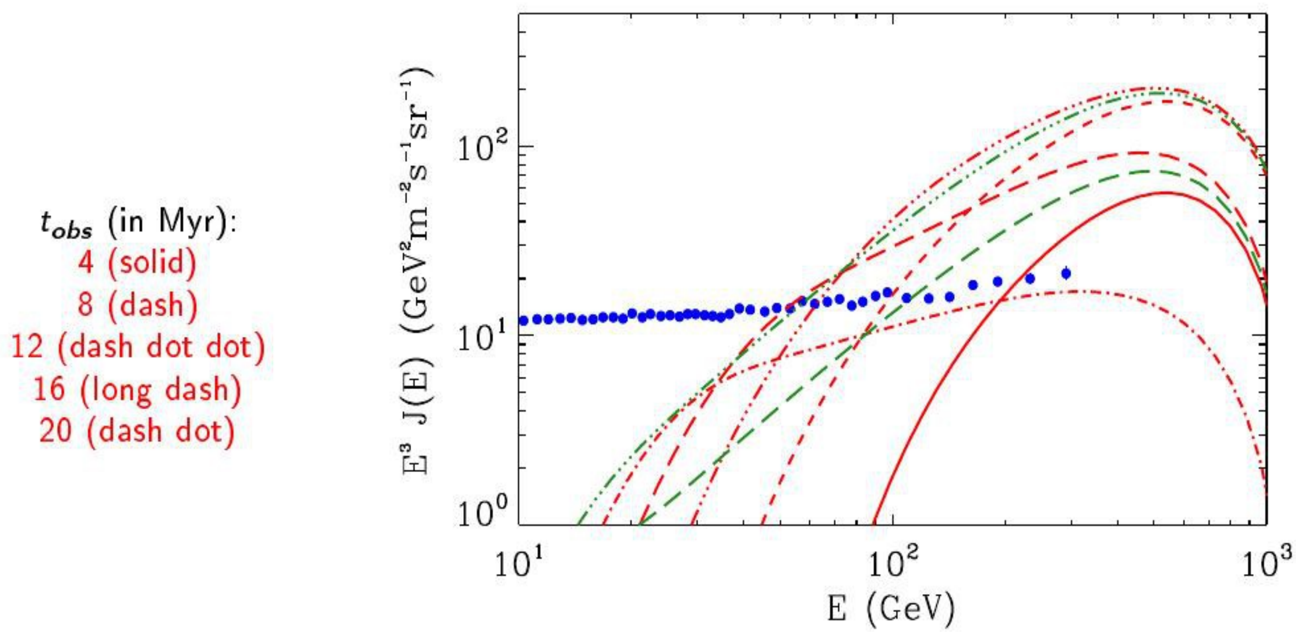
A Dark clump

The SM particle flux originating from DM annihilation in a mini-spike surrounding a IMBH moving through the Galaxy can be high enough to sustain, e.g., the positron excess observed by PAMELA, Fermi-LAT and AMS!

With DRAGON 3D it is now possible to simulate the propagation of particles originating from a moving source (or set of sources)

In the following I will show some preliminary results

The possible role of a moving DM clump on the positron excess



Blue dots are AMS-02 positron data. Red lines indicate local positron spectrums from a moving subhalo, with $L_{sp} = 1.2 \times 10^{20} M_{\odot}^2 kpc^{-3}$, $\{x_0, y_0, z_0\} = \{5.5, 0, -4\}$ in kpc, and $\{v_x, v_y, v_z\} = \{0, 0, 0.4\}$ in kpc/Myr. Different line styles correspond to different observation times. Green lines indicate local positron spectrums from *stationary* subhalos, at the same positions as the corresponding red lines with the same line styles.

Preliminary results from:

Hani N. Santosa, PhD thesis

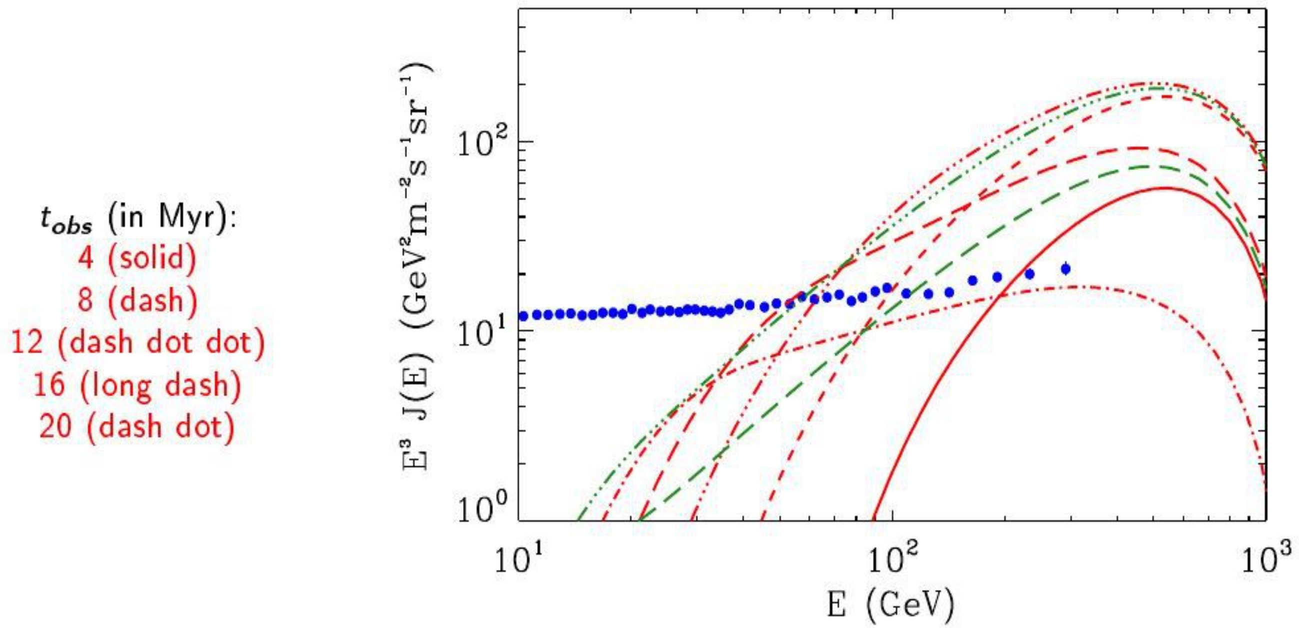
A moving DM clump powered by IMBH emitting electrons and positrons is simulated using DRAGON 3D

The luminosity of such clump is high enough to sustain the positron flux measured by AMS!

According to Bertone et al. Astro-ph/0509565 **several clumps of such a luminosity are expected to be found within 3 kpc from us!**

Paper in preparation by
Hani Santosa, Daniele Gaggero,
Piero Ullio

The possible role of a moving DM clump on the positron excess



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According to
`Bertone et al. Astro-ph/0509565`

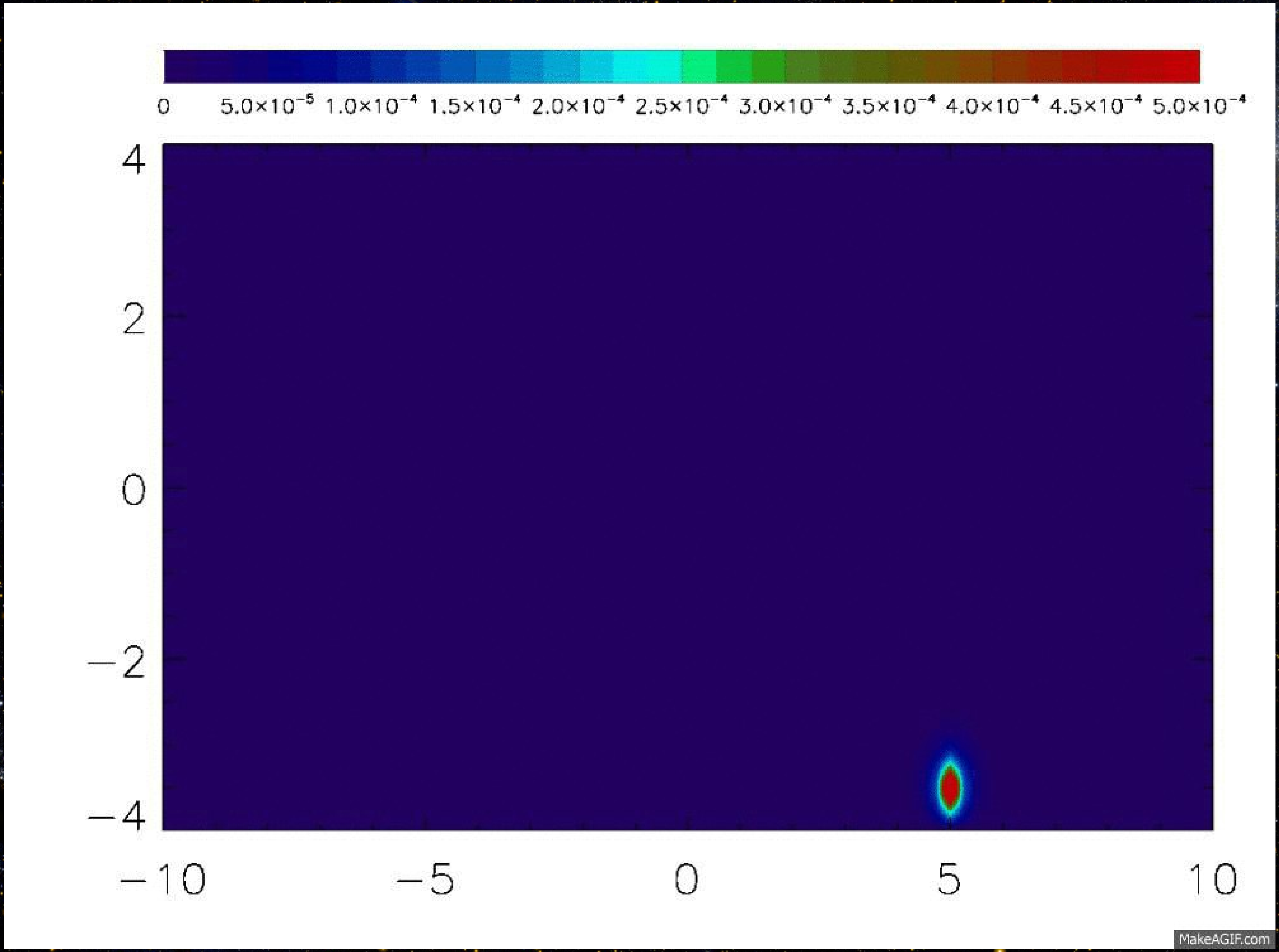
from 200 MonteCarlo realitazions of IMBH distributions in Miky-Way sized DM halos,

→ 100 IMBH per realizations are present, and among them

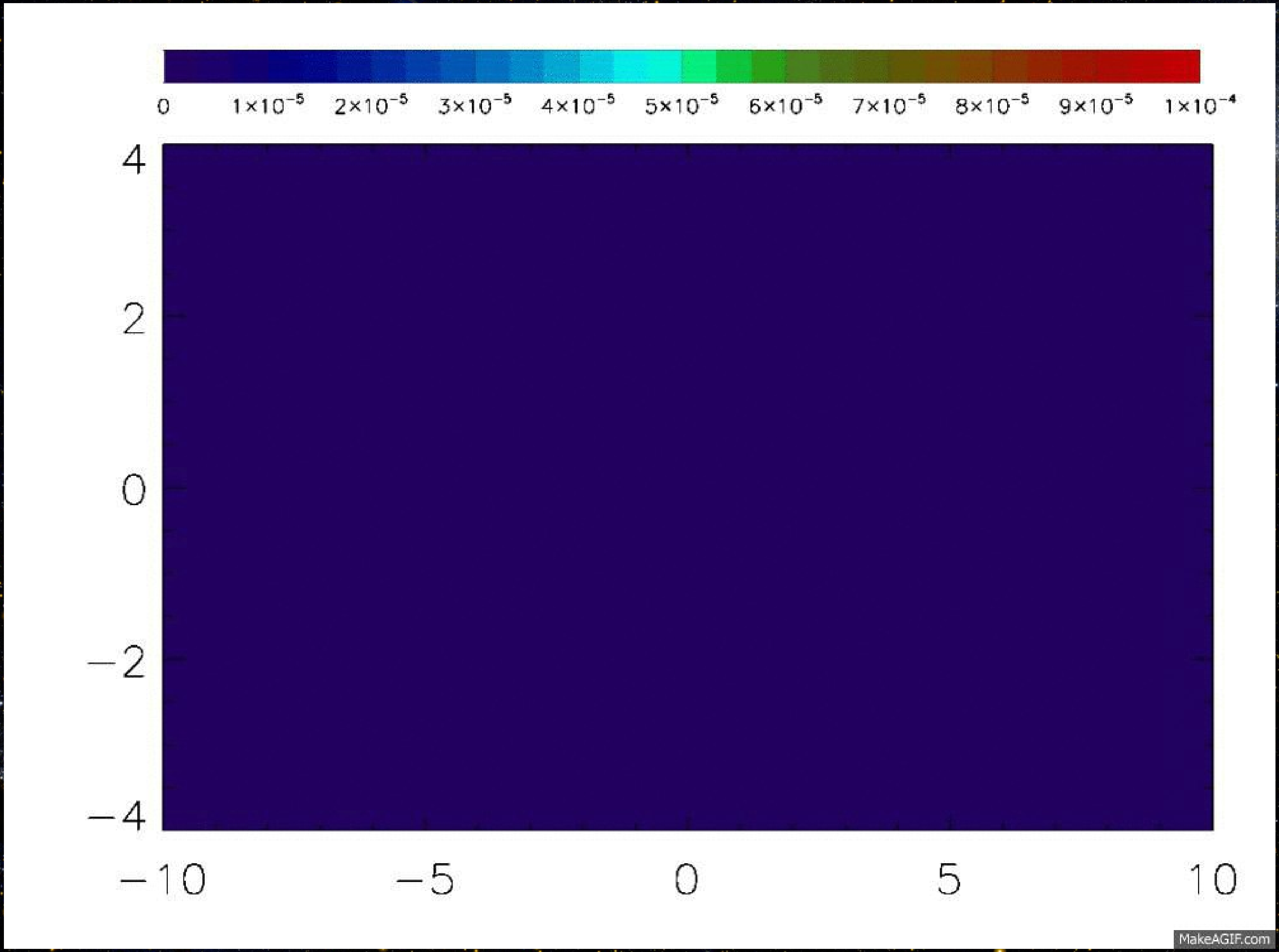
→ **0.9 IMBH are nearby** (within 4 kpc from us)

Paper in preparation by Hani Santosa, Daniele Gaggero, Piero Ullio

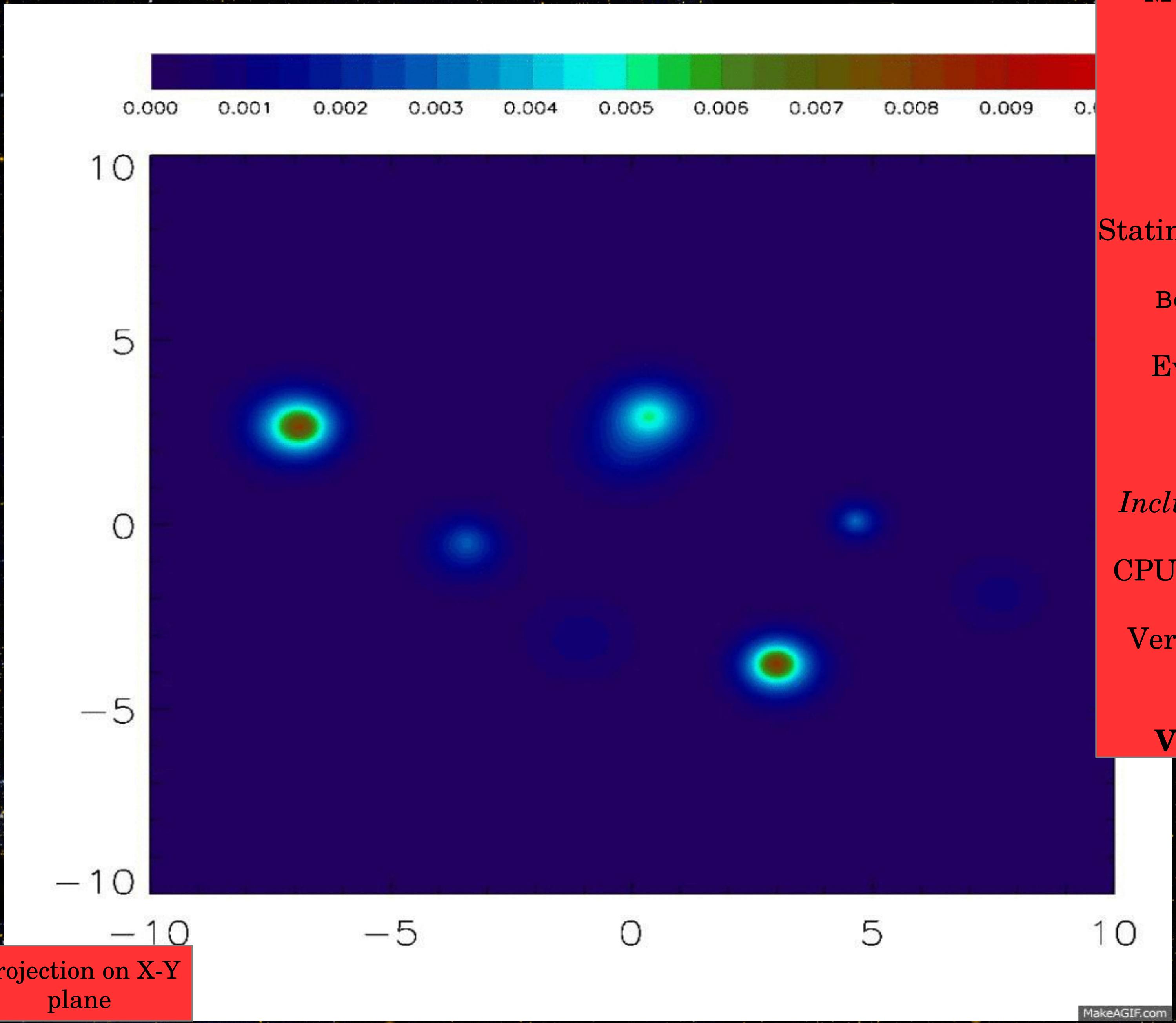
The possible role of a moving DM clump on the positron excess – DRAGON movies (*1 TeV*)



The possible role of a moving DM clump on the positron excess – DRAGON movies (***100 GeV***)



The possible role of a moving DM clump on the positron excess



Projection on X-Y plane

Multiple clump animation

Injection @1TeV
Plot @500GeV

dt = 50 kyr

Stating configuration taken from datafile by
`Bertone et al. 2005`

Evolution computed with
`DRAGON_3D`

Including the effect of gravity!

CPU time: 2 days on a 64-core machine;
Very high spatial resolution 161x161x161pixels

VERY PRELIMINARY

How do the large scale structures (in particular the spiral arm structure) influence the observables?

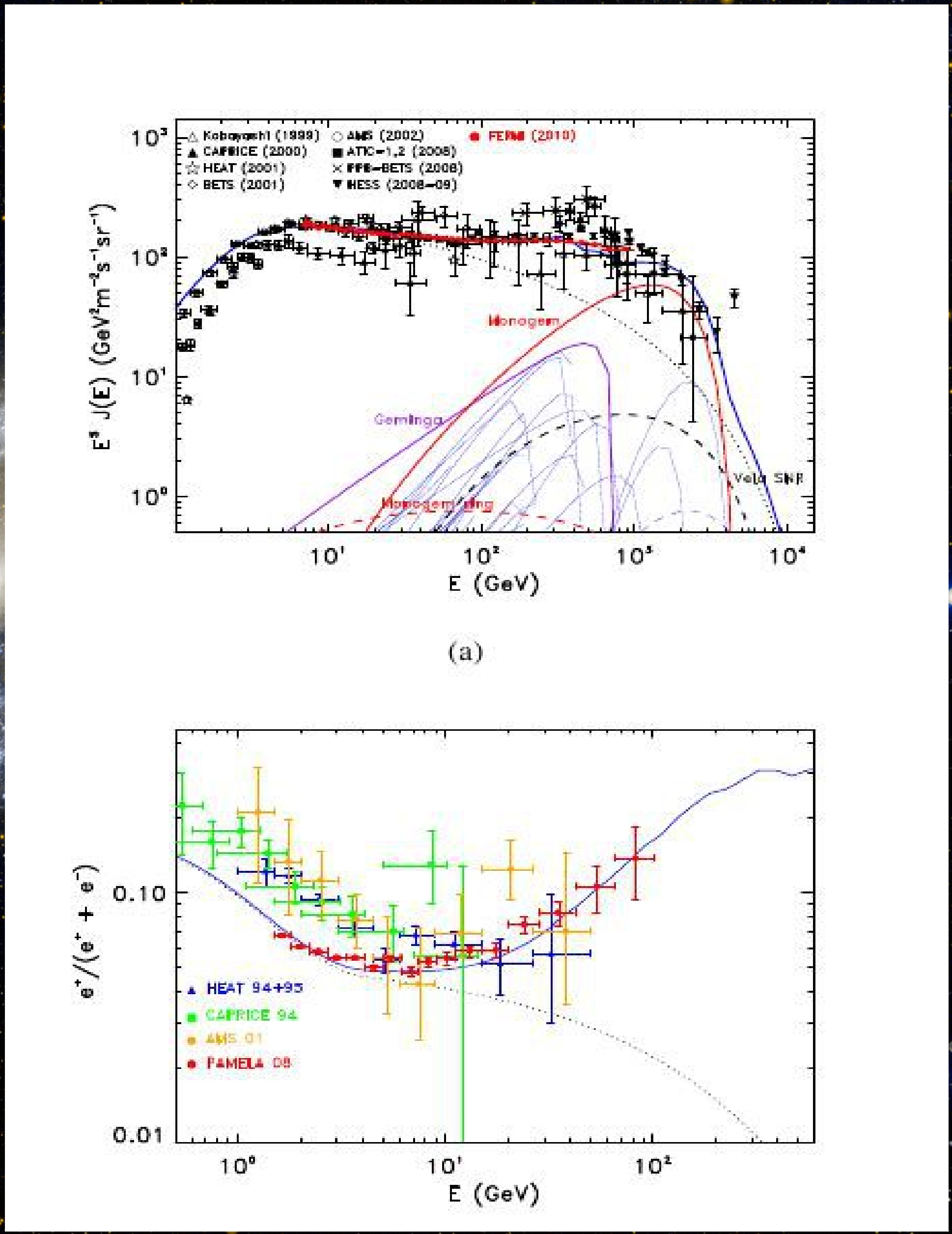
How do the large scale structures (in particular the spiral arm structure) influence the observables?

An important flaw of most two-component interpretations of the leptonic fluxes is that they require the “conventional” component to have a steep injection spectrum in order to leave room for the extra component in the high energy range.

We found an injection around (-2.65 -- -2.70) depending on the propagation setup.

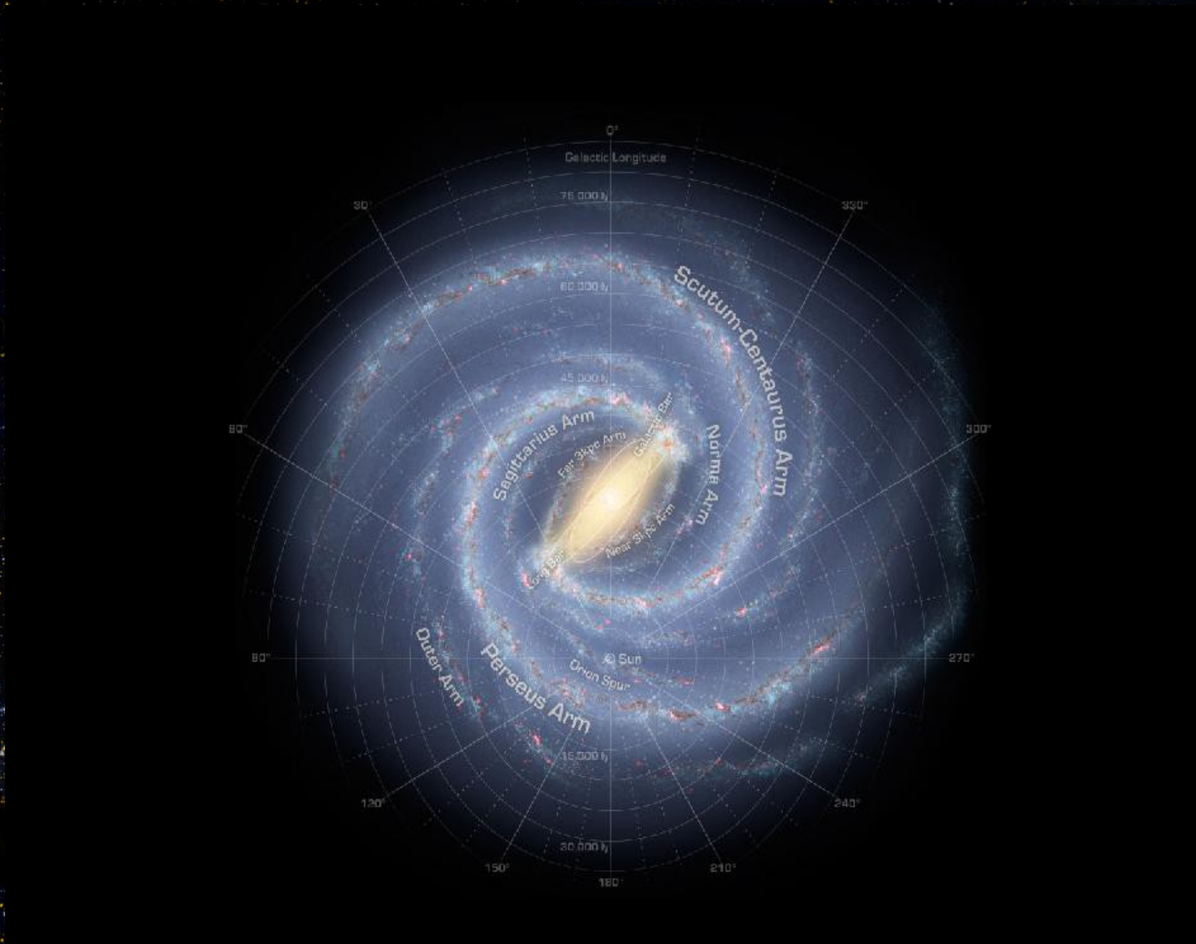
These values are *clearly inconsistent* with shock acceleration theory and simulations and also with electron spectra inferred from observations of SNRs (see e.g. `Caprioli, arXiv:1103.4798`) --> those arguments point towards slopes around (-2 -- -2.30)

--> “STEEPNESS problem”



How do the large scale structures (in particular the spiral arm structure) influence the observables?

A possible solution to the steepness problem may come from the spiral arm structure of the Galaxy



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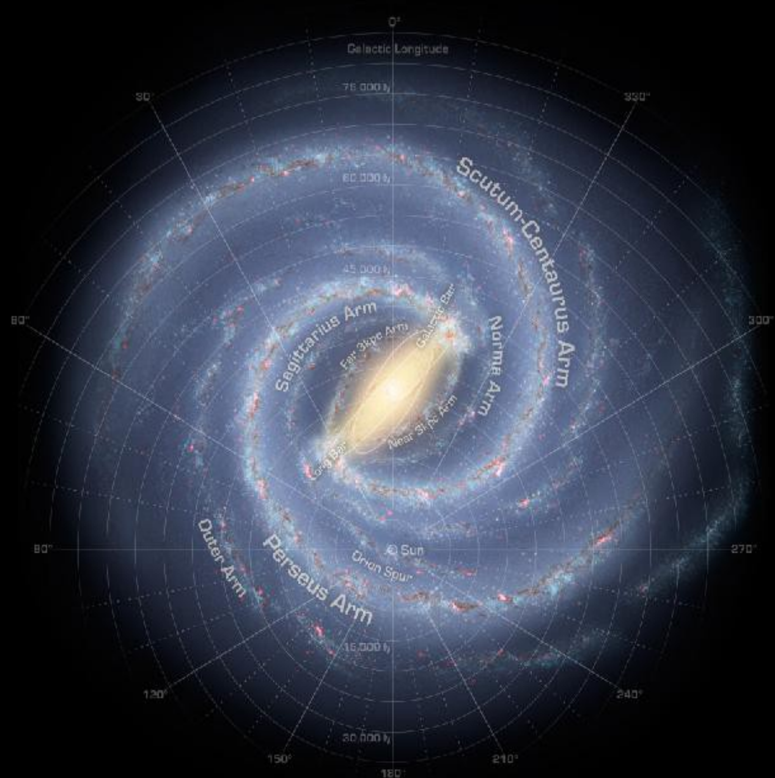


Since we live in an interarm region, and most CR sources are expected to be located in the arms, the high energy electrons come from a larger distance than what expected in a smooth model where no spiral arm structure is taken into account.

This results in more severe energy losses (the electrons take a long time to travel from the arm to us and lose energy via IC and Synchrotron emission), hence in a steepening of the spectrum

So it is possible to get a steep propagated spectrum (needed to leave room for the extra component) even with a not so steep injection, compatible with Fermi acceleration!

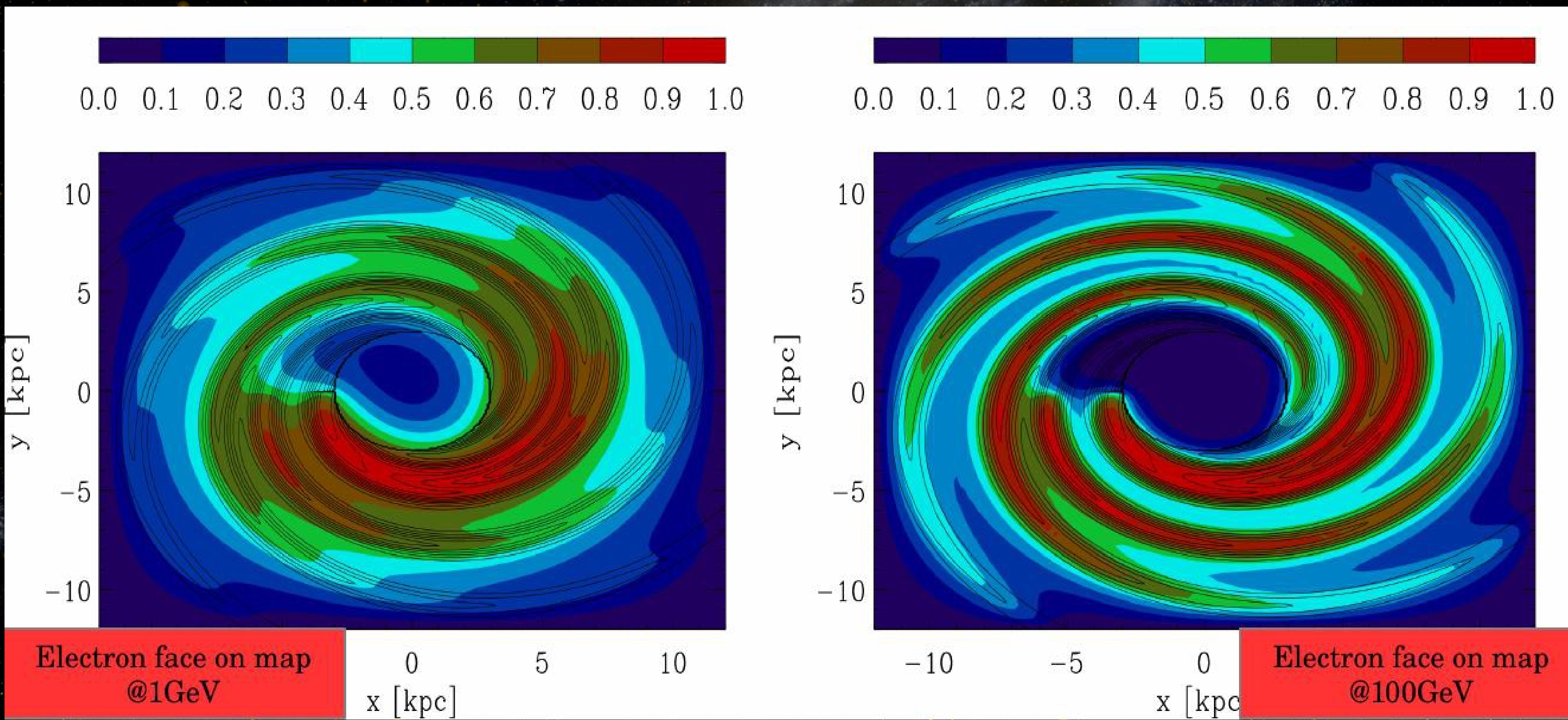
How do the large scale structures (in particular the spiral arm structure) influence the observables?

Our implementation in DRAGON

We considered a spiral arm model from `Blasi&Amato, arXiv:1105.4529`

We used the 3D isotropic version of the code putting the sources within the spiral arms.

RESULTS:

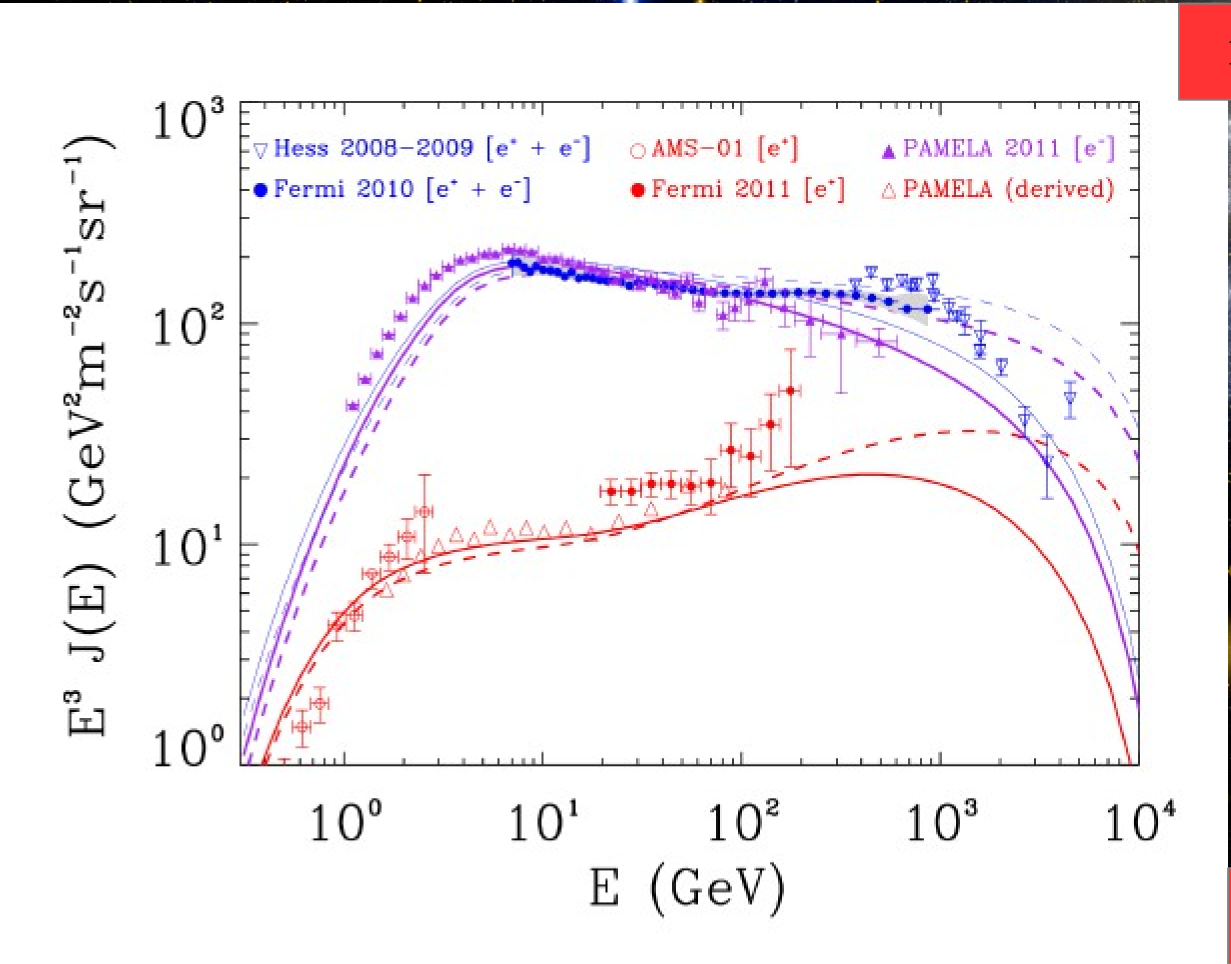


Electron face on map @1GeV

Electron face on map @100GeV

How do the large scale structures (in particular the spiral arm structure) influence the observables?

Our model with spiral arm patter allows to reproduce the data with an injection index γ = -2.38, similar to the one used for the nuclei (-2.28)!



NoSpiral VS Spiral

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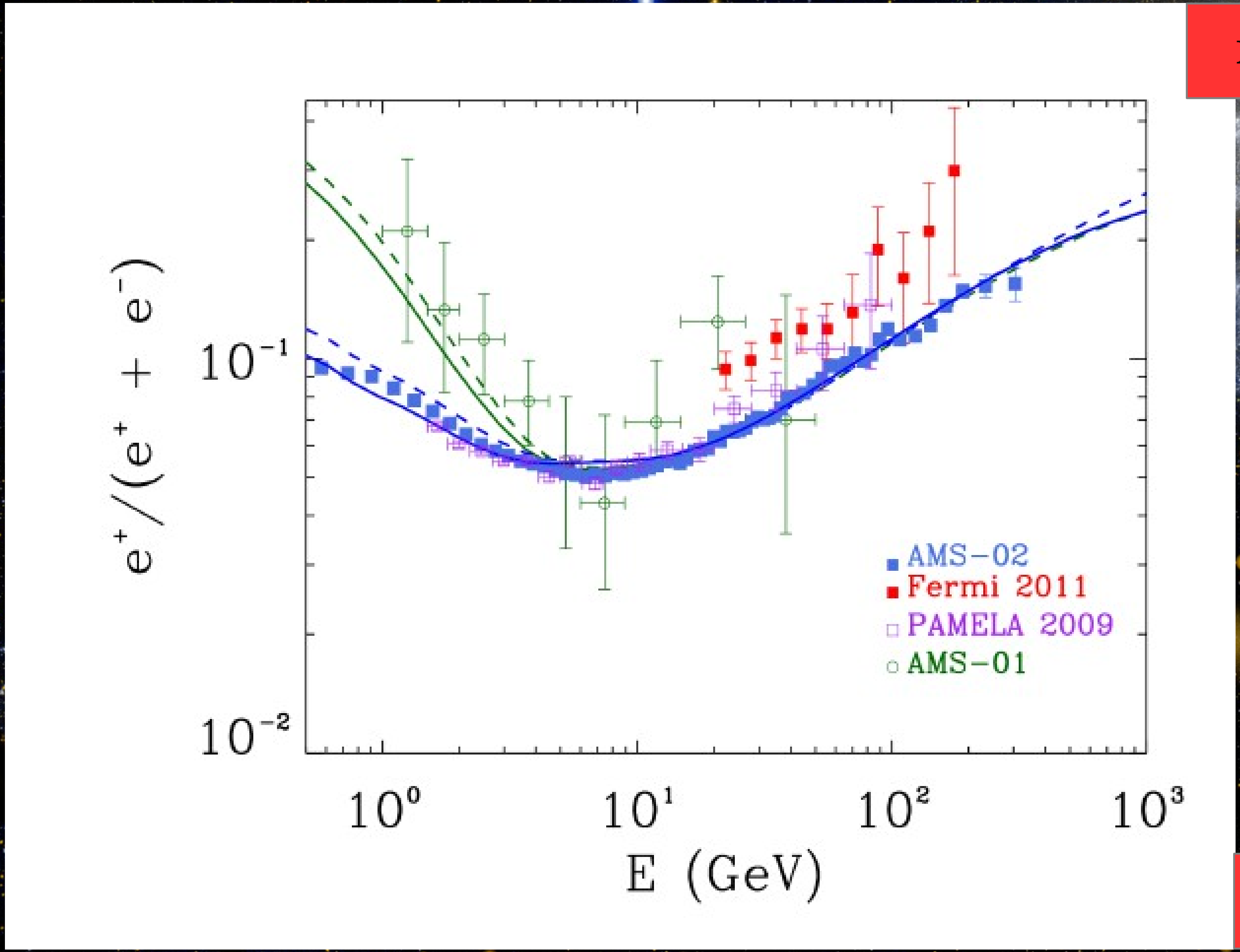

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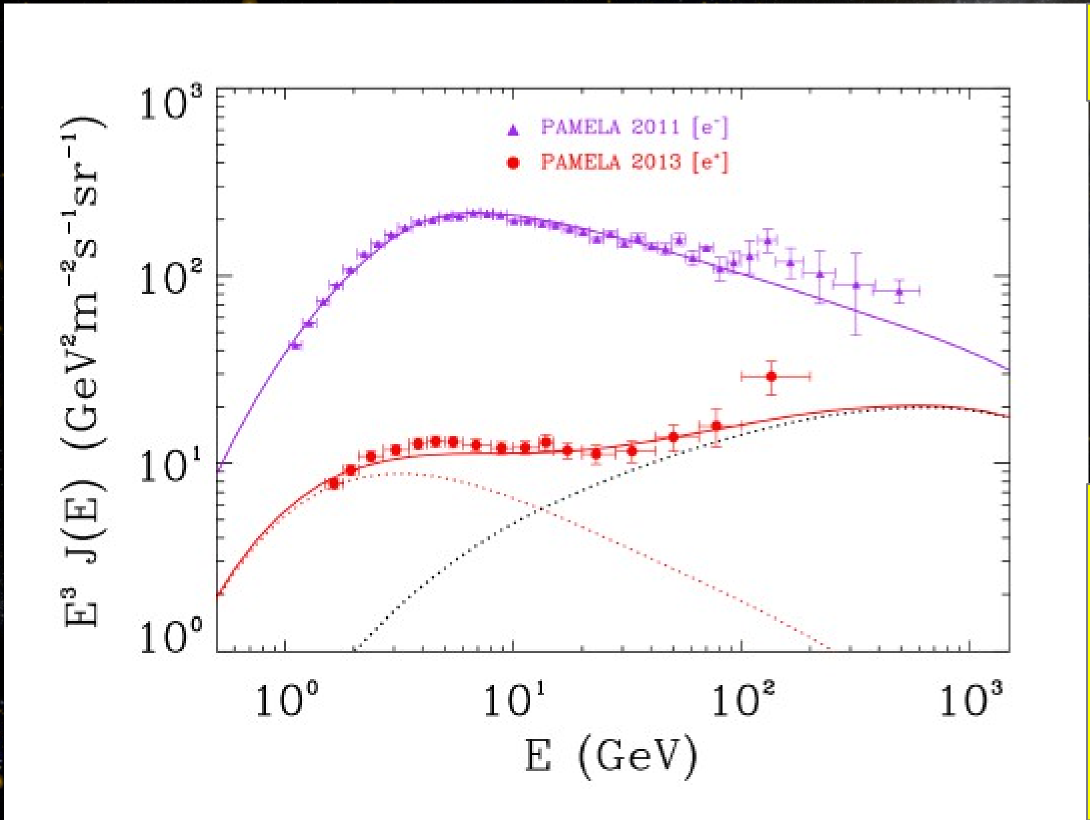
There is some work in progress to tune our 3D models in order to reproduce the new AMS preliminary data... both the data and the models are very preliminary!

Hints that the new AMS and PAMELA data on electrons and positrons require a steeper electron injection spectrum? And maybe an electronly only component (a SNR)?

With these ingredients it is possible to achieve a very good fit!

Fermi-LAT all electron data (not shown here) and AMS all electron are in tension – it looks like it is not possible to have a model compatible with both within systematic errors – still under investigation, and waiting for final data!



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Tuned on PAMELA data!
Paper in preparation from the DRAGON team....

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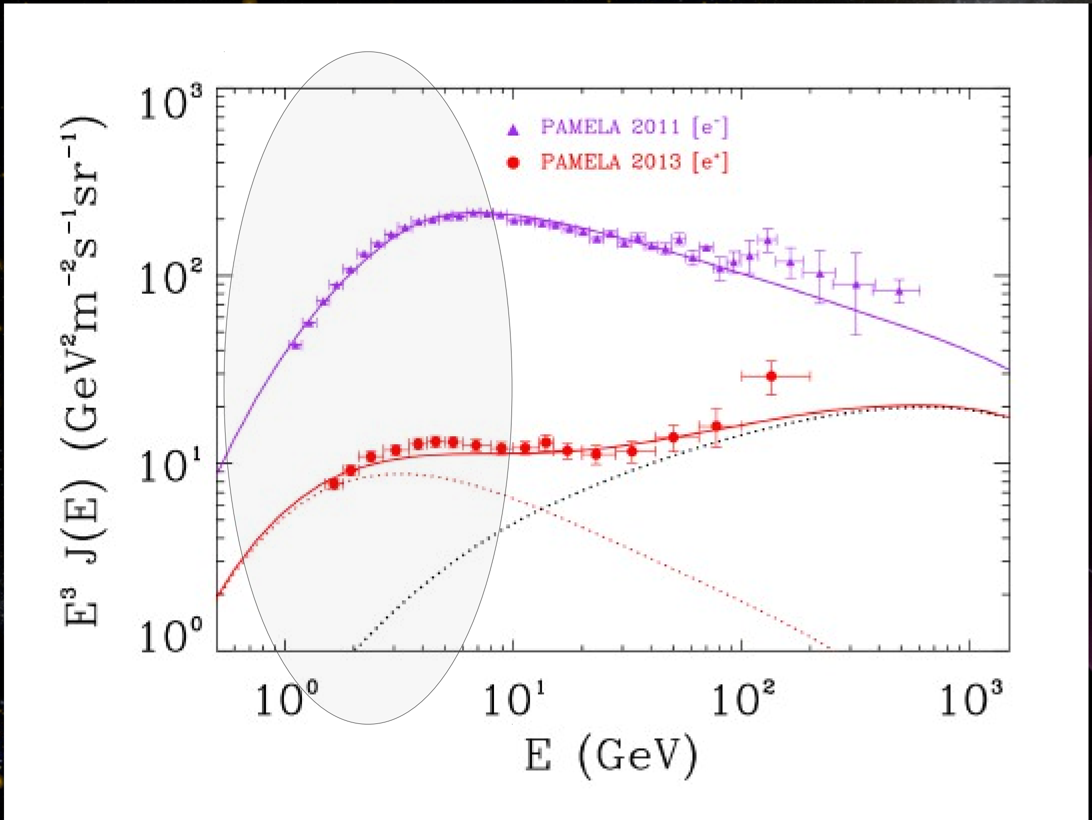

The low energy spectrum is modulated applying Charge-Dependent modulation.

The CD modulation is computed making use of the numerical package `HelioProp` (`Maccione, 2012`)

The relevant parameters (helioshperic magnetic field polarity, current sheet tilt angle, mean free path) are compatible with PAMELA data taking period

Negative polarity
Tilt angle 10°
Mean free path 0.4 AU

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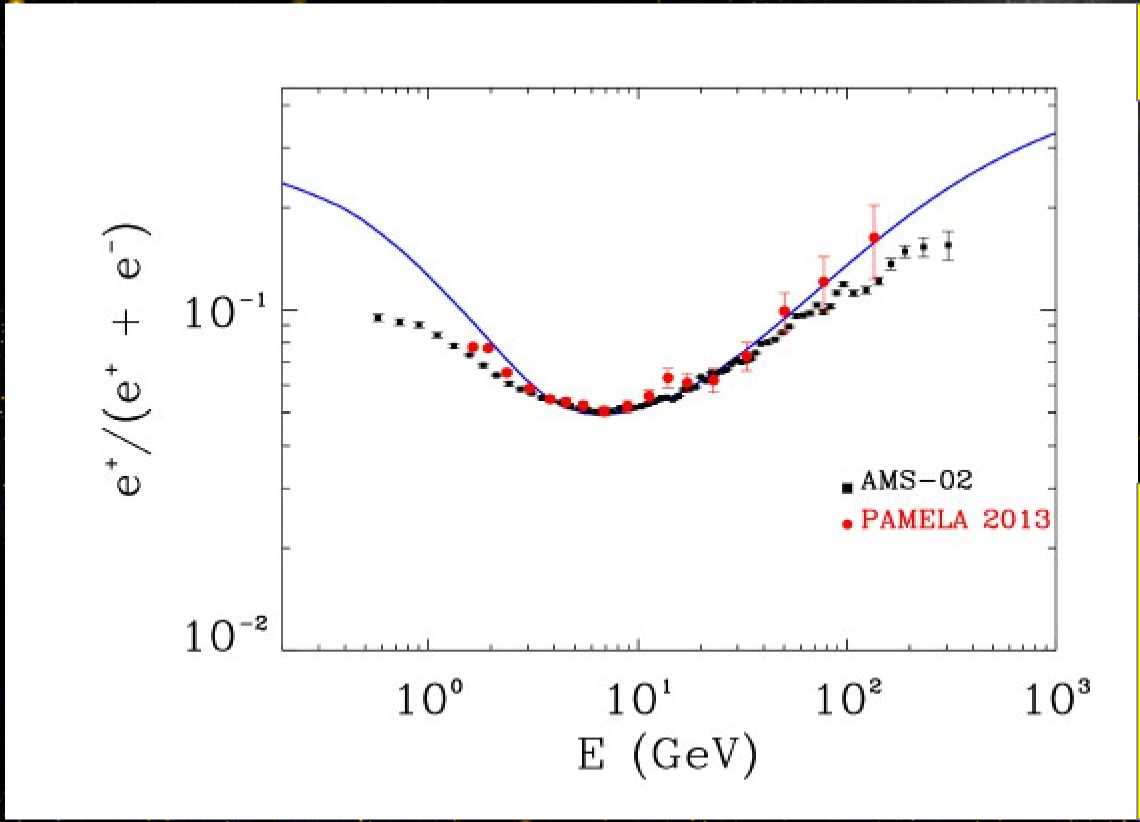

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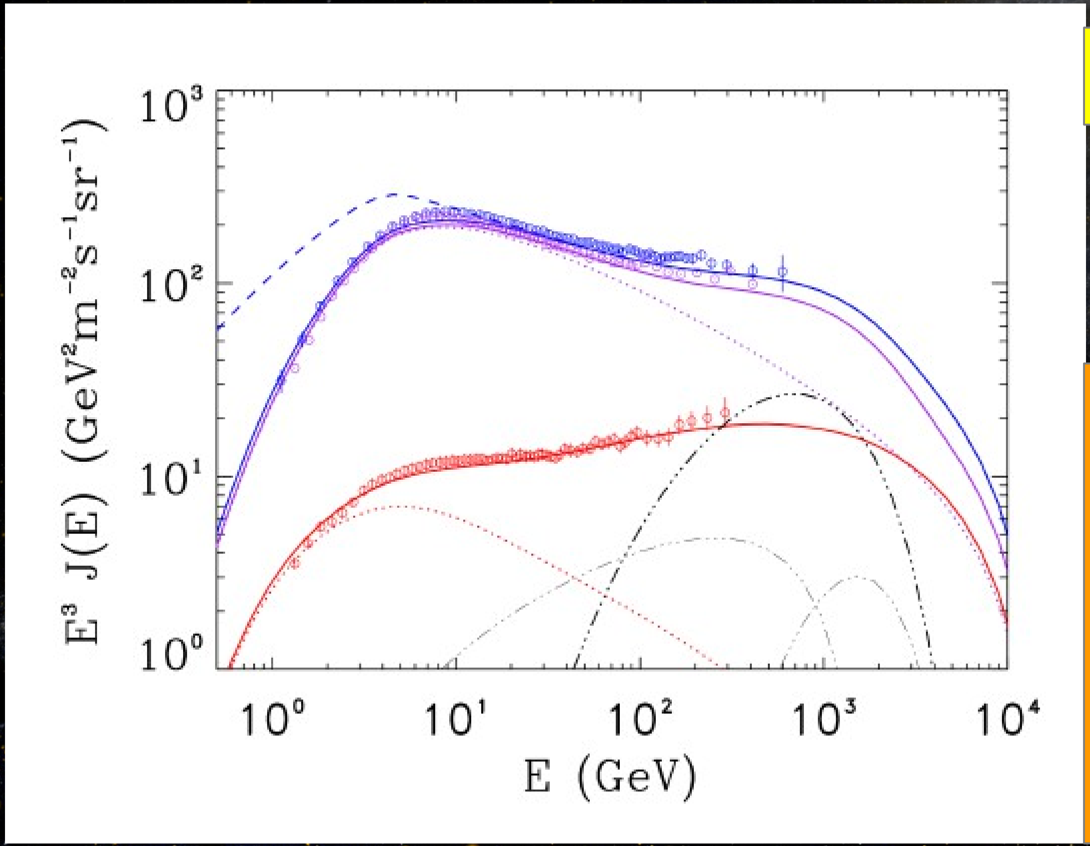

...PRELIMINARY...

Tuned on preliminary AMS data!
A local SNR as electron-only source is considered at high energy!

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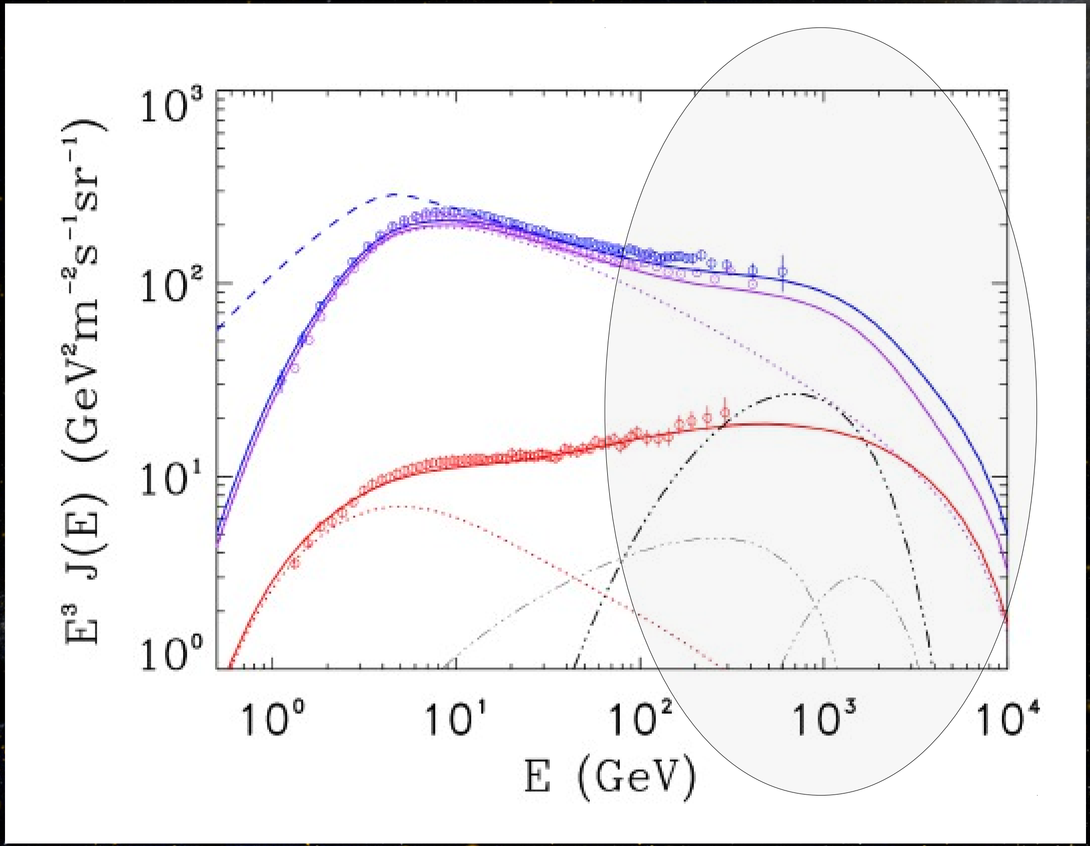


The low energy spectrum is modulated applying Charge-Dependent modulation.

At high energy the electronic emission from nearby SNRs is considered in order to reproduce the flattening observed in AMS electron spectrum (which is not present in the positron-only spectrum)

Conclusions

1) We have many new high accuracy data. AMS provided a lot of interesting preliminary results. We need to be more accurate in modeling as well.

2) DRAGON is a suitable tool for most CR analyses. The 2D mode is fast and useful for large parameter scans on diffusion setup. The 3D mode allows to study the impact of structures (both large scale and small scale) on the observables. The 3D anisotropic mode allows to start studying the unexplored world of anisotropic diffusion.

3) The "moving source" feature allows to study the emission from moving Dark Matter clumps. A IMBH-powered nearby clump may explain the rising positron fraction observed by PAMELA, AMS and Fermi-LAT

4) The spiral arm structure has a strong impact on the electron spectrum. Models including 3D spiral arm structure can fit the data with a realistic electron injection slope compatible with observation and theory

The origin of the rising fraction is still a mystery. Several hypotheses need to be confirmed or ruled out. Anisotropy data will be very important and also accurate antiproton data to constrain DM models

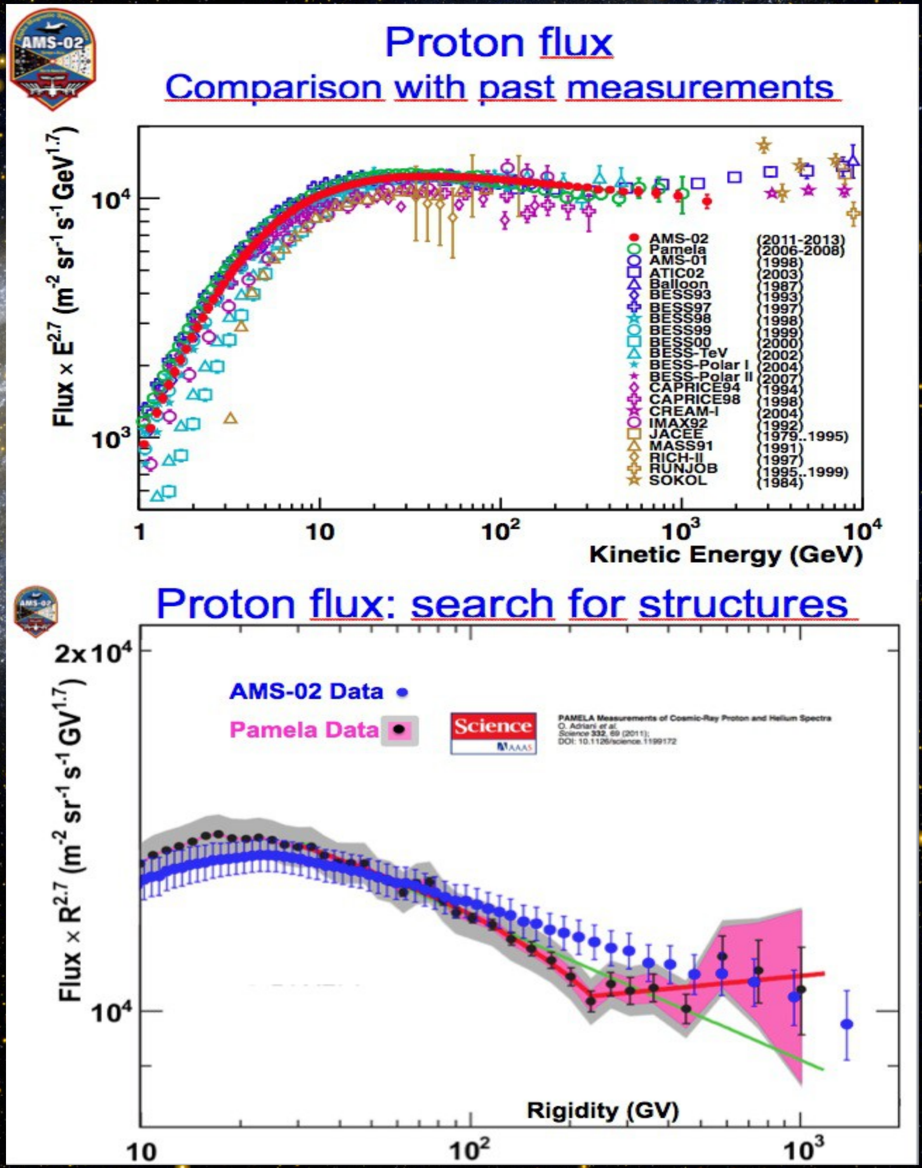
Backup slides

What can we learn from the high-precision measurements we are getting in this period?

From proton spectrum:

--- we can not constrain the properties of diffusion in the ISM: there is a **degeneracy** between **the source slope** γ and the **diffusion coefficient slope** δ

--- maybe **hints of new phenomena** if some break is found at high energy (see e.g. R.Aloisio&P.Blasi arXiv:1306.2018), however this feature is **not confirmed by AMS** at least in preliminary release

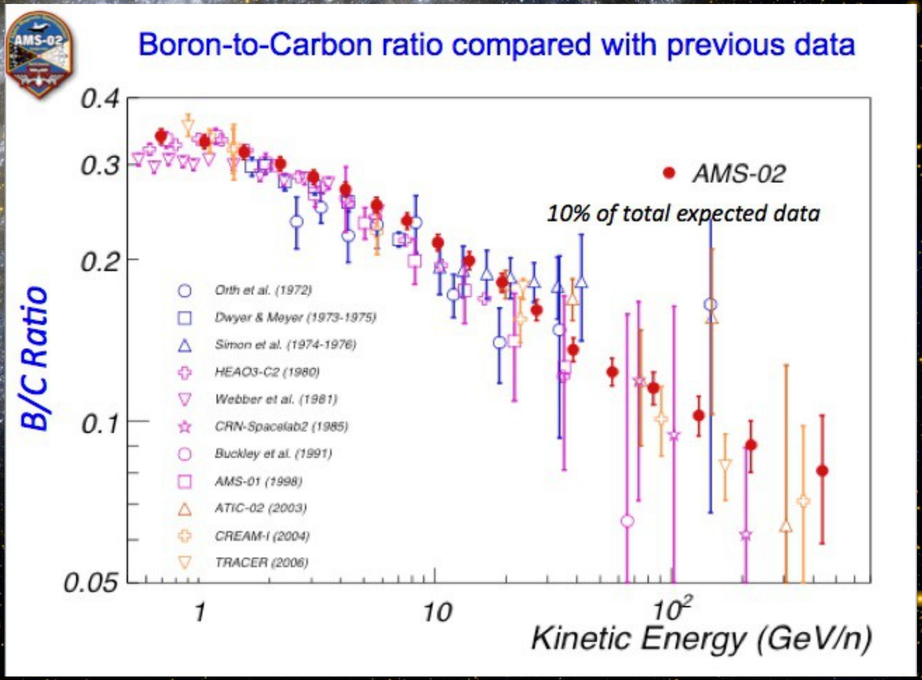


What can we learn from the high-precision measurements we are getting in this period?

From B/C:

--- since it is a secondary/primary ratio, it is one of the most important observables to constrain the diffusion parameters.

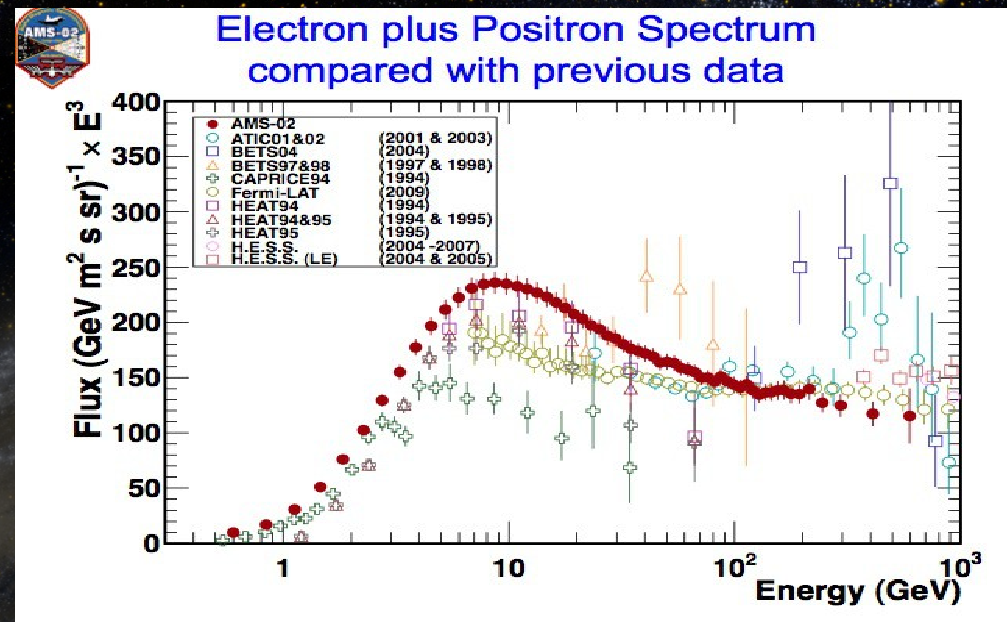
--- especially the high energy part is important, because above 20 GeV reacceleration and convection are amost negligible, and so is solar modulation, so only rigidity-dependent diffusion shapes the B/C spectrum

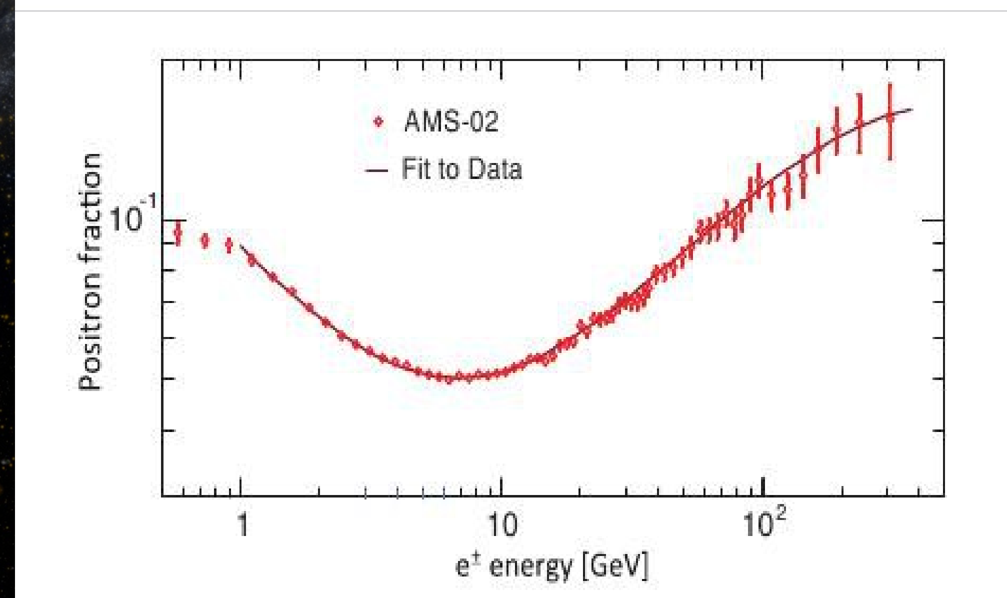


What can we learn from the high-precision measurements we are getting in this period?

From leptons:
The LOCAL environment.
New sources?? signature of DM??

--- the high energy electron flux is very local due to severe energy losses --> so it **probes the nearby interstellar medium** --> we can learn about the presence of local sources (or underdensities of sources)
--- the **famous position fraction rising** may be the hint of the presence of one or few nearby accelerators of electrons and positrons, or maybe a signal of DM particle annihilation or decay (maybe from a nearby clump?)

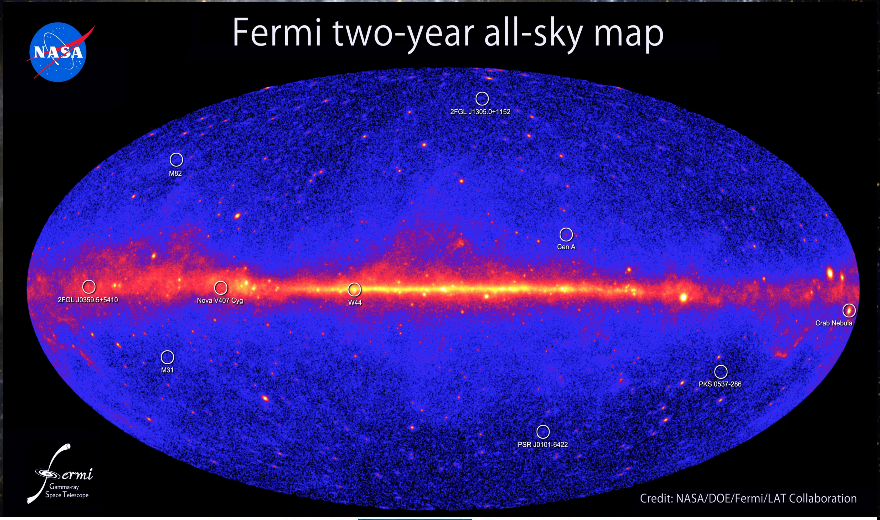




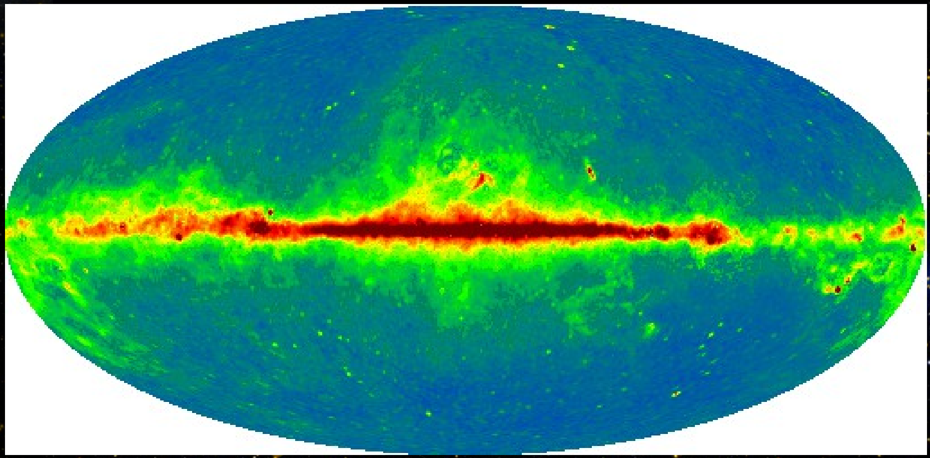
What can we learn from the high-precision measurements we are getting in this period?

From gamma rays and synchrotron:
The GLOBAL environment.

--- the **high resolution γ-ray maps** from Fermi-LAT are useful because *they trace the CRs all through the Galaxy*
---> they can show different diffusion properties in different regions of the Galaxy (see later)



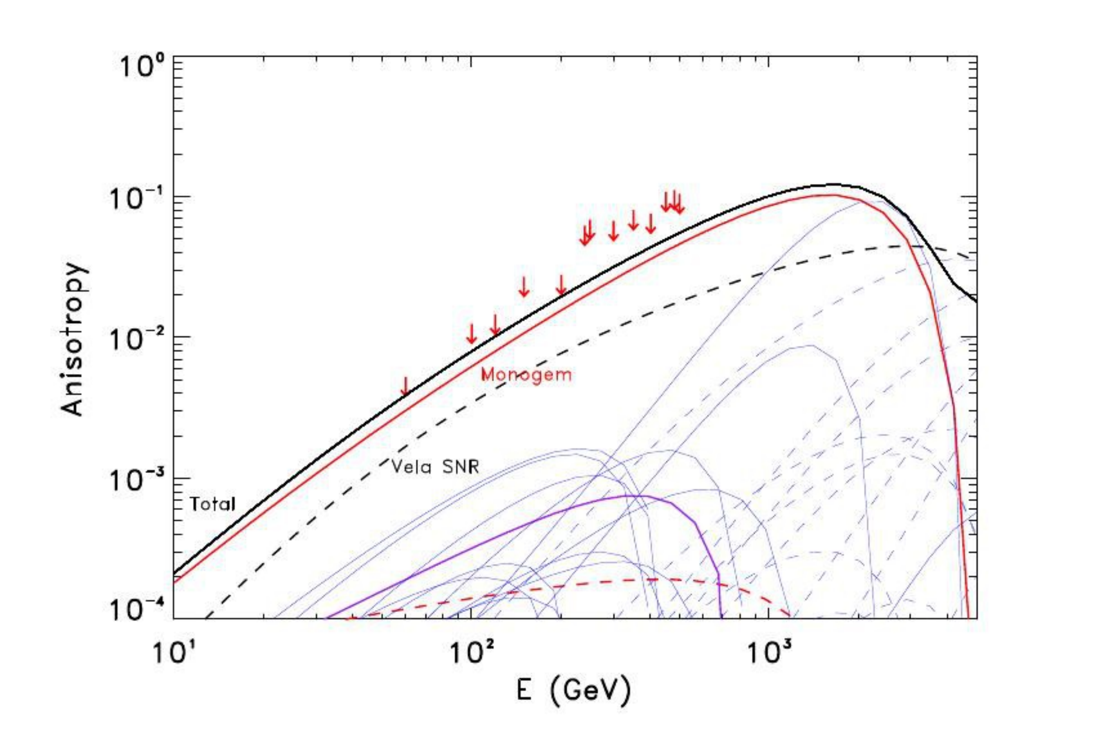
--- the **synchrotron maps** are very useful because *they trace the leptonic component of CRs*
---> they can be used to constrain the heigth of the diffusion halo
(see e.g. Di Bernardo et al., 1210.4546)



What can we learn from the high-precision measurements we are getting in this period?

From the electron anisotropy:

--- Upper limits on lepton anisotropy provided by Fermi-LAT and AMS can provide useful constraints to models which include local sources of leptons.

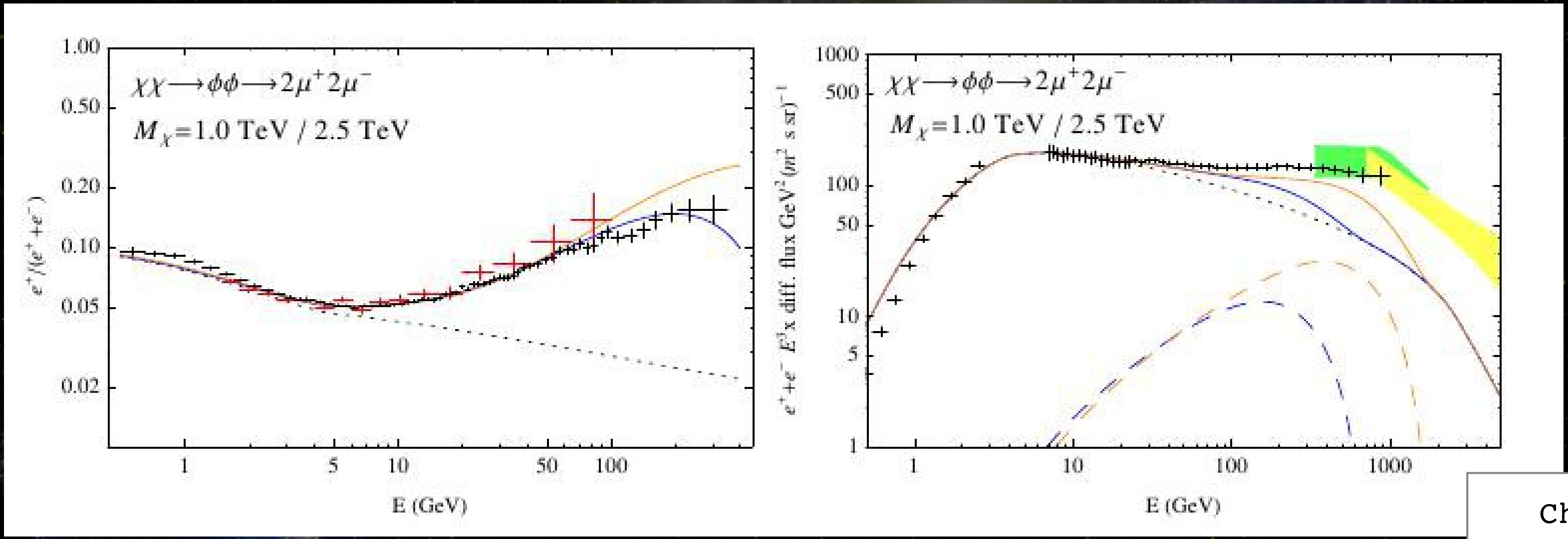


Do AMS data imply a charge asimmetry in the extra component?

First interpretations of AMS PF data. *A charge asymmetry?*

A problem reconciling AMS and Fermi was pointed out by several authors
[Yuan et al., arXiv:1304.1482]; [Yin et al., arXiv:1304.1997] ;
[Cholis et al., arXiv:1304.1840]

Fermi-LAT all electron dataset and AMS positron fraction require an electron-only primary extra component to be reconciled? Charge asymmetry in the extra component?



Cholis and Hooper, 1304.1840

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The issue of the compatibility between those two datasets can be investigated in a very simple and model independent way.

If only high energies are considered, where only diffusion and energy losses are relevant, the propagated leptonic fluxes can be approximated as power laws. So we parametrized the problem in term of 2 components:

Component *A* a primary electron component with spectrum $J_A = A\times(E/E_0)^{-\alpha}\exp(-E/E_{\mathrm{cut},A})$

Component *B* an extra component of electrons and positron with spectrum $J_B^{e^-} = J_B^{e^+} = J_B = B\times(E/E_0)^{-\beta}\exp(-E/E_{\mathrm{cut},B})$,

Then, we consider the possibility of a charge asimmetry in two different ways: introducing a deviation (1+ε) and (1-ε) around the normalization factor B for the extra electrons and positrons respectively, or introducing an extra electron-only component C.

Do AMS data imply a charge asimmetry in the extra component?

First interpretations of AMS PF data. ***A charge asymmetry?***

The main result of this analysis is that ***Fermi-LAT all electron dataset and AMS positron fraction are compatible within the systematic error.***
The improvement of the fit achieved by introducing a charge asymmetry is not significant.

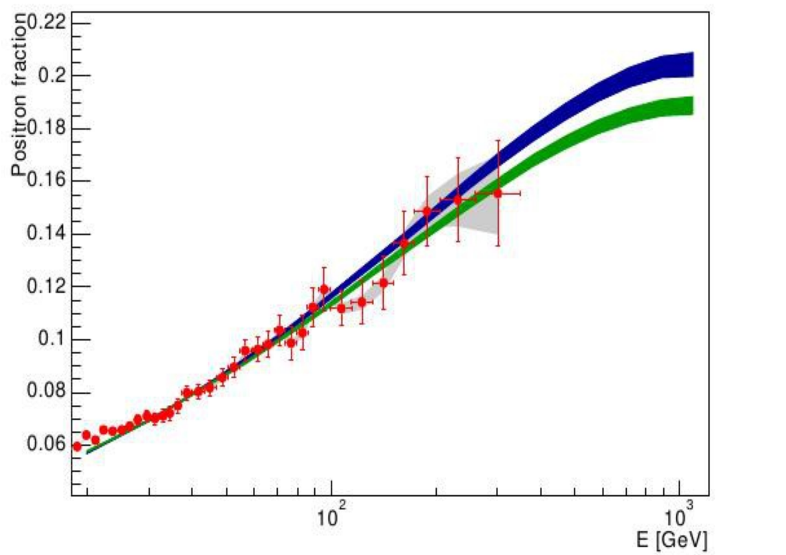
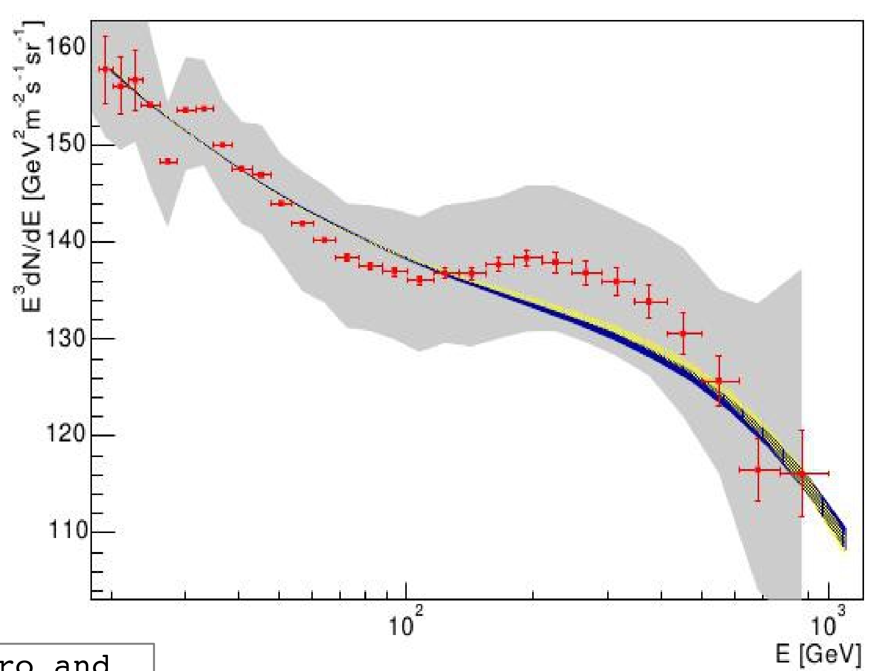


Figure 7. Positron fraction for the best fit model derived combining AMS-02 and Fermi-LAT data. Red points are AMS-02 experimental data. The blue area represents our best-fit model, with its 68% uncertainty band. The green area is instead for the best fit model assuming charge asymmetry. Error bars are statistical errors, while systematic errors correspond to the grey band.



D.Gaggero and L.Maccione, arXiv:1307.0271

How the small scale structures (e.g. the local bubble) can influence some observables, e.g. the leptonic anisotropy.

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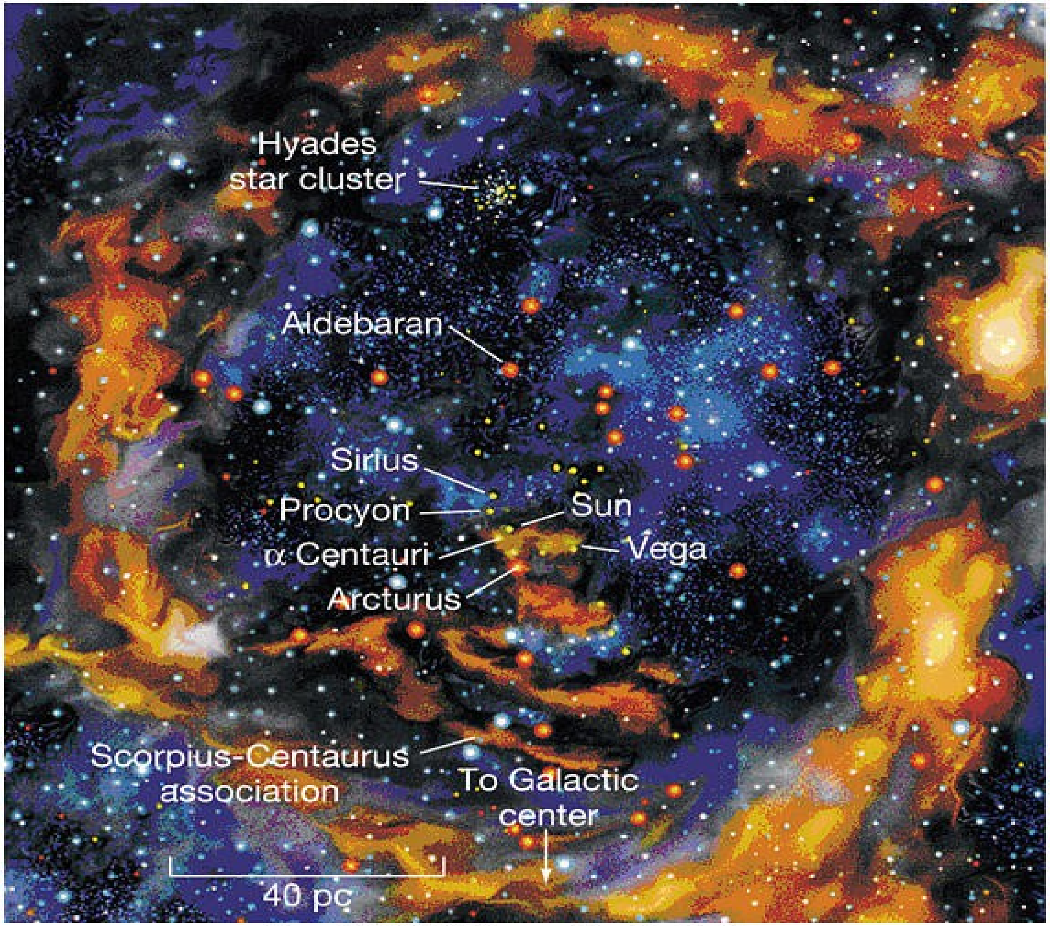


The local bubble is a cavity in the interstellar medium where the Solar System is located.

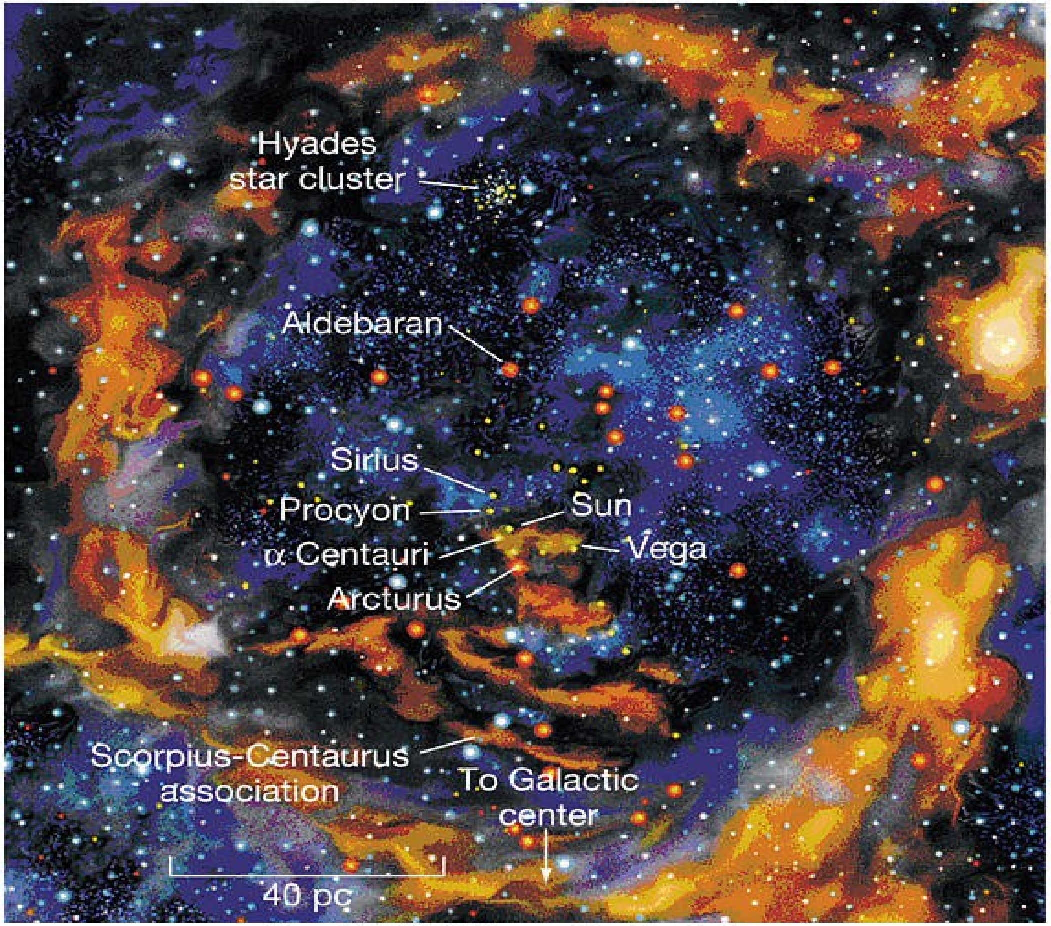
The neutral hydrogen density in the bubble ($0.05\ cm^{-3}$) is approximately one tenth of the average for the ISM in the Milky Way.
The bubble is filled with hot ionized gas that emits X rays.

There is ongoing work at KIT on the impact of the local bubble on CR observables

See e.g. some preliminary results in ICRC proceeding:

`www.cbpf.br/~icrc2013/papers/icrc2013-1115.pdf`

How the small scale structures (e.g. the local bubble) can influence some observables, e.g. the leptonic anisotropy.



An interesting effect might be observable in the **leptonic anisotropy**.

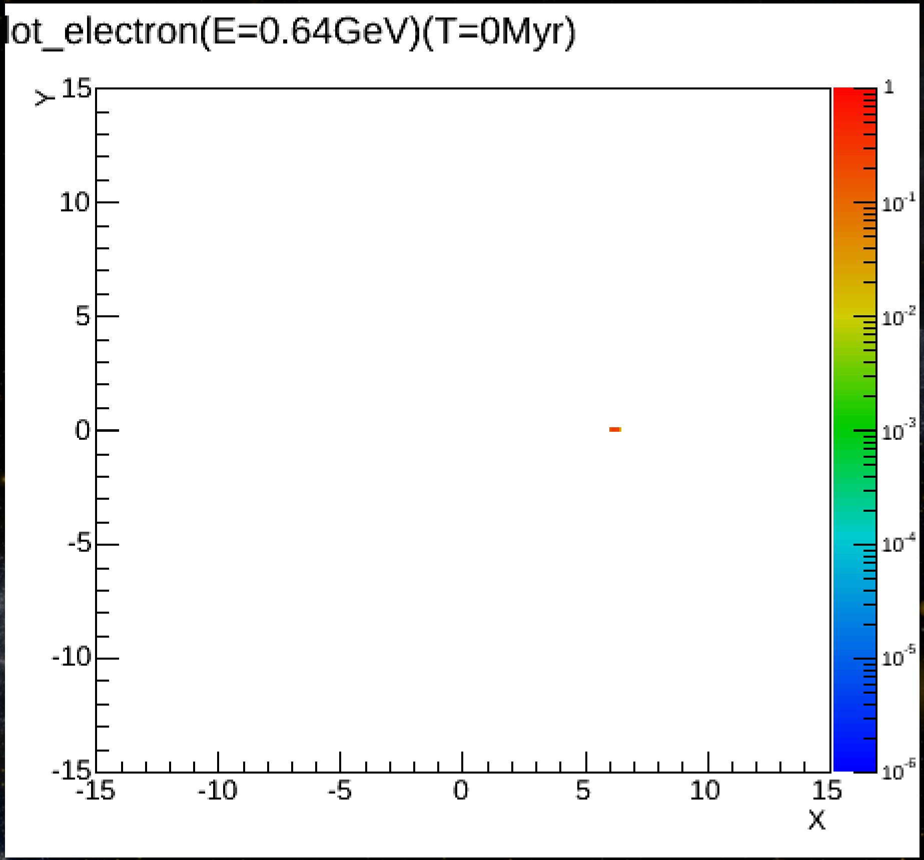
If a nearby source situated outside the bubble, e.g. a pulsar, emits electrons and positrons, their propagation may be highly influenced by the change in the diffusion properties inside the bubble.
For examples the CRs should be more confined in the outer part (where many molecular clouds are located) and diffuse more quickly in the inner part

---> Effect on the anisotropy? The flux should be more isotropized

This is very important to investigate because Fermi-LAT and AMS are providing more stringent upper limits and the pulsar scenario may be seriously challenged!

How the small scale structures (e.g. the local bubble) can influence some observables, e.g. the leptonic anisotropy.

Preliminary results (thanks to Matthias Weinreiter, KIT):



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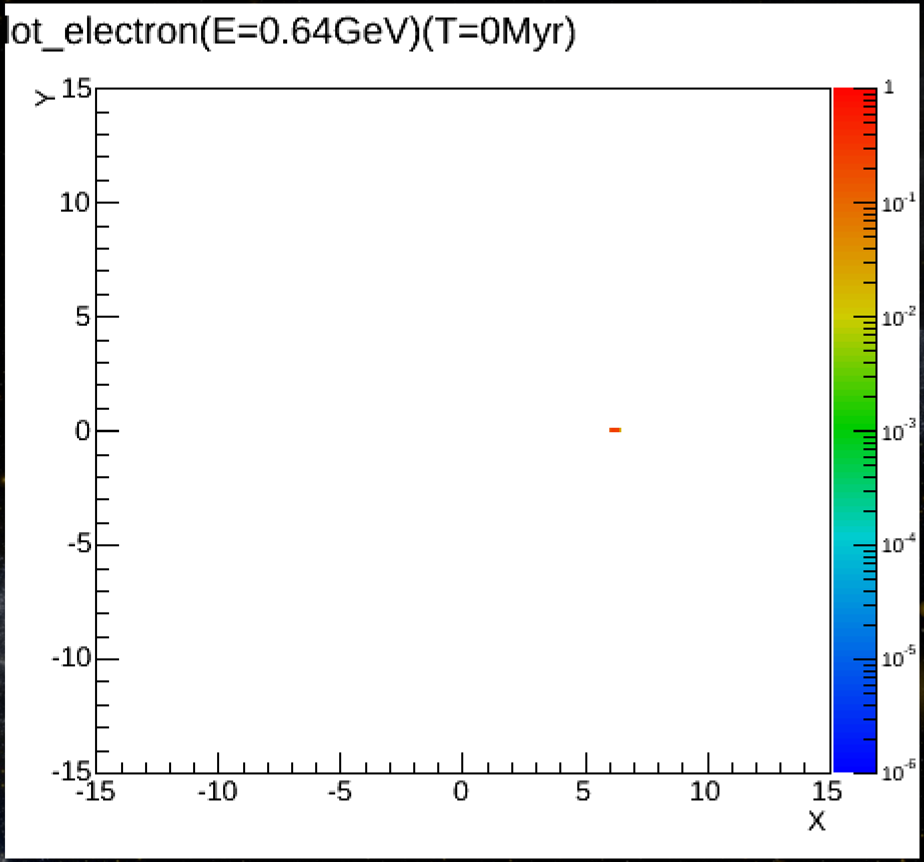

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