

The Transition between Galactic and Extragalactic CRs

Gwenael Giacinti

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Based on works with : M. Kachelriess, D. Semikoz and G. Sigl

Based on works in preparation / discussions with : P. Blasi

With thanks to T. Bell and B. Reville for numerous discussions



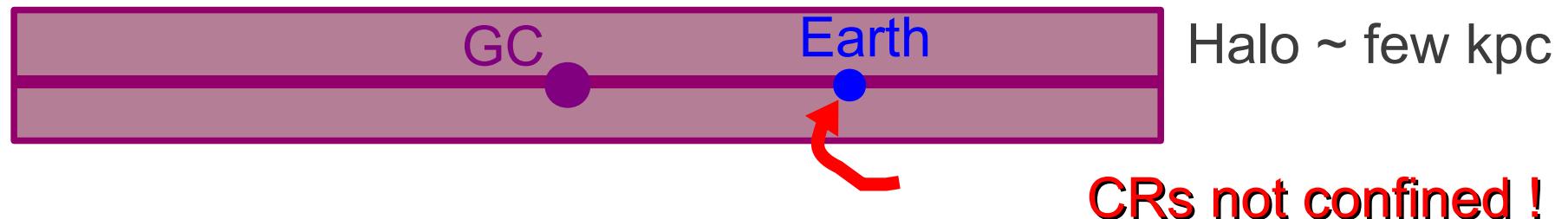
UNIVERSITY OF
OXFORD



A (well) concealed transition...

- CRs with energies up to $\sim 10^{20}$ eV.

10^{19} eV proton : $R_L \sim$ several kpc in a few μG field \rightarrow Extragalactic



- Candidate sources : AGNs, GRBs, magnetars ?



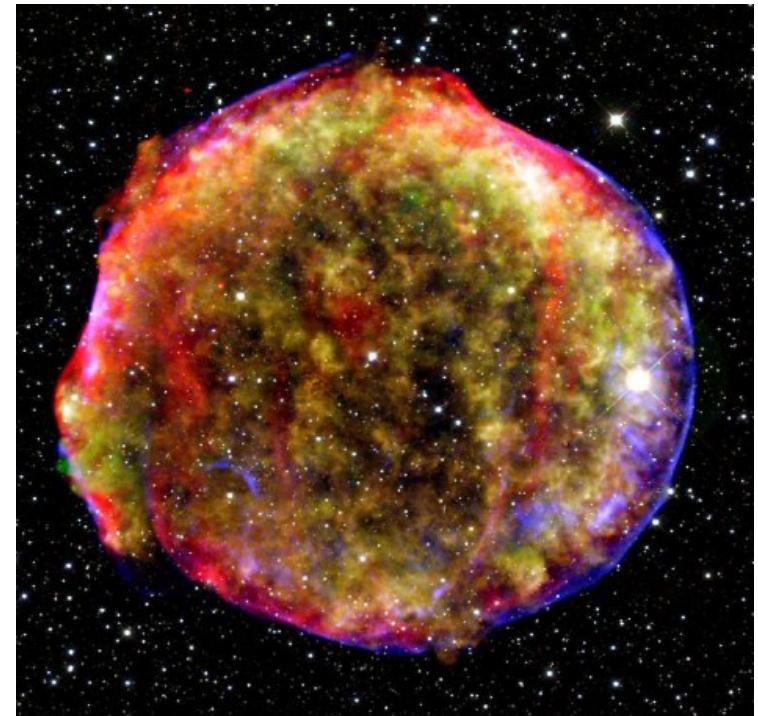
A (well) concealed transition...

- CRs with energies up to $E \sim \text{PeV}$ thanks to diffusive shock acceleration at SNR shocks (See *B. Reville's & D. Caprioli talks*)

CRs confined



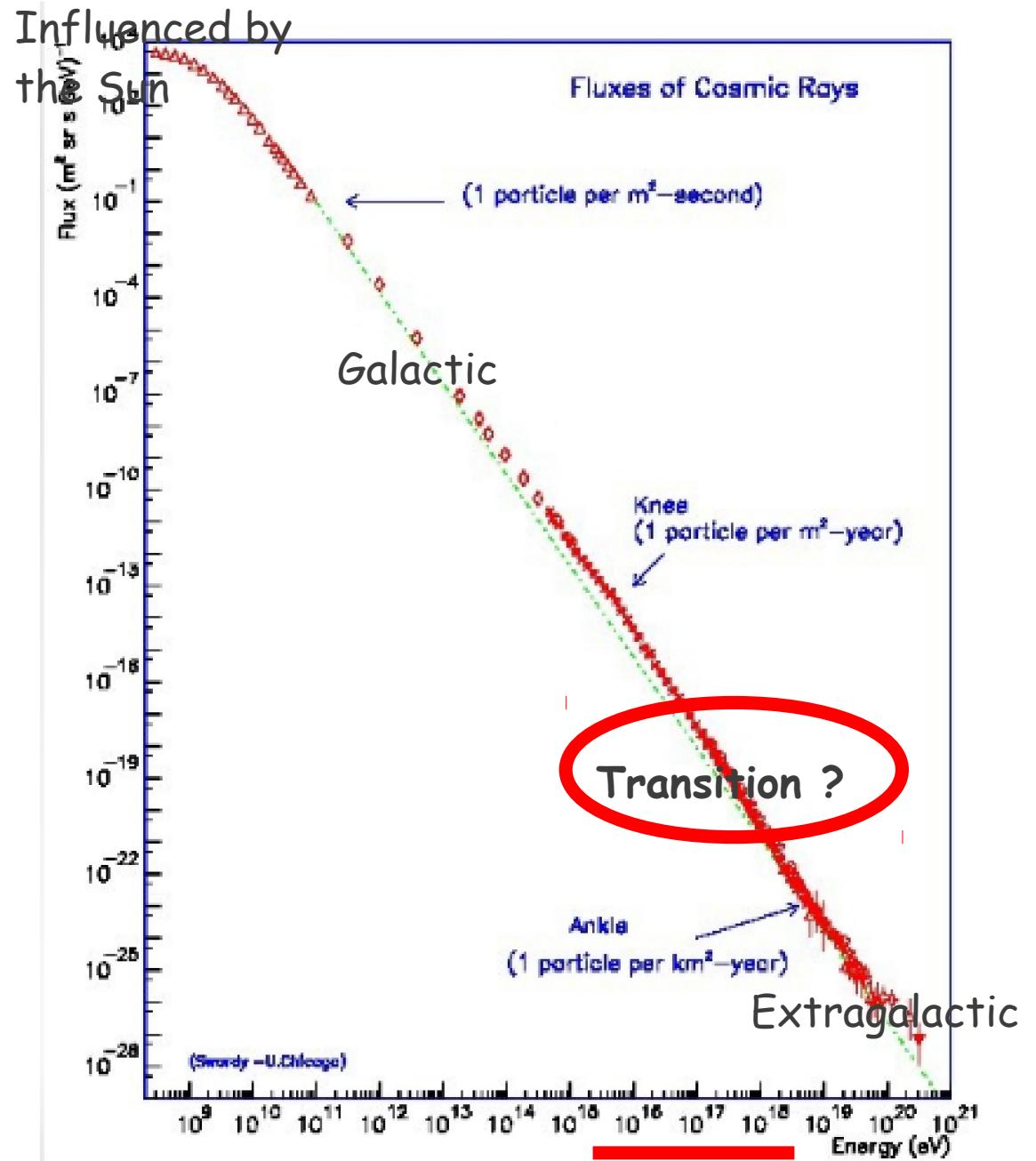
10^{15} eV proton : $R_L \sim$ a fraction of a pc in a few μG field



- Candidate sources : SNe (+?)

A (well) concealed transition...

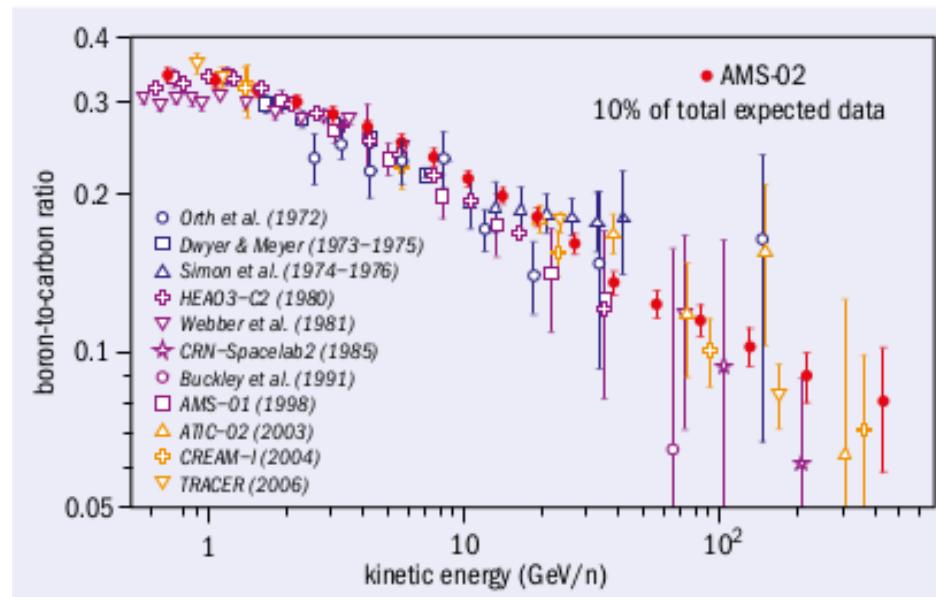
Where is it ?



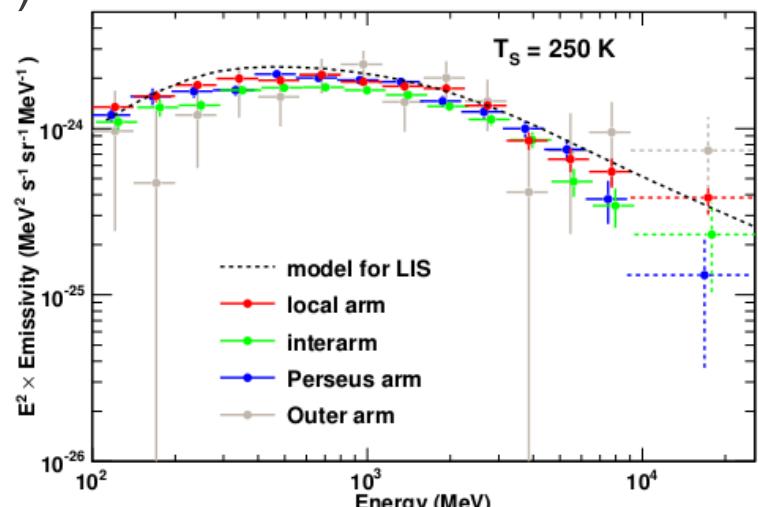
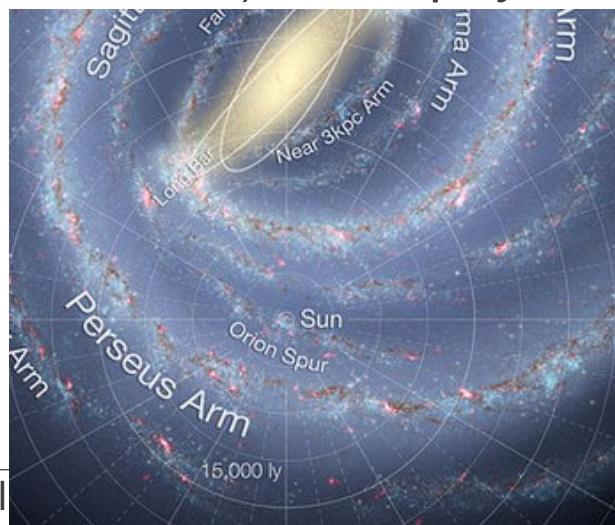
CRs beyond the ankle CANNOT be Galactic

- **Problem** : B/C and confinement time of \sim GeV CRs in the Galactic disk

AMS Coll., ICRC 2013
(CERN Courier)



- + In principle, no strong local variations : Ackermann et al. (FERMI-LAT Coll.), *Astrophys.J.* 726 (2011) 81



Outline

I – Theoretical suggestions and Observations

$\sim 10^{17}$ eV \longleftrightarrow Ankle ($\sim 4 - 5 \times 10^{18}$ eV)

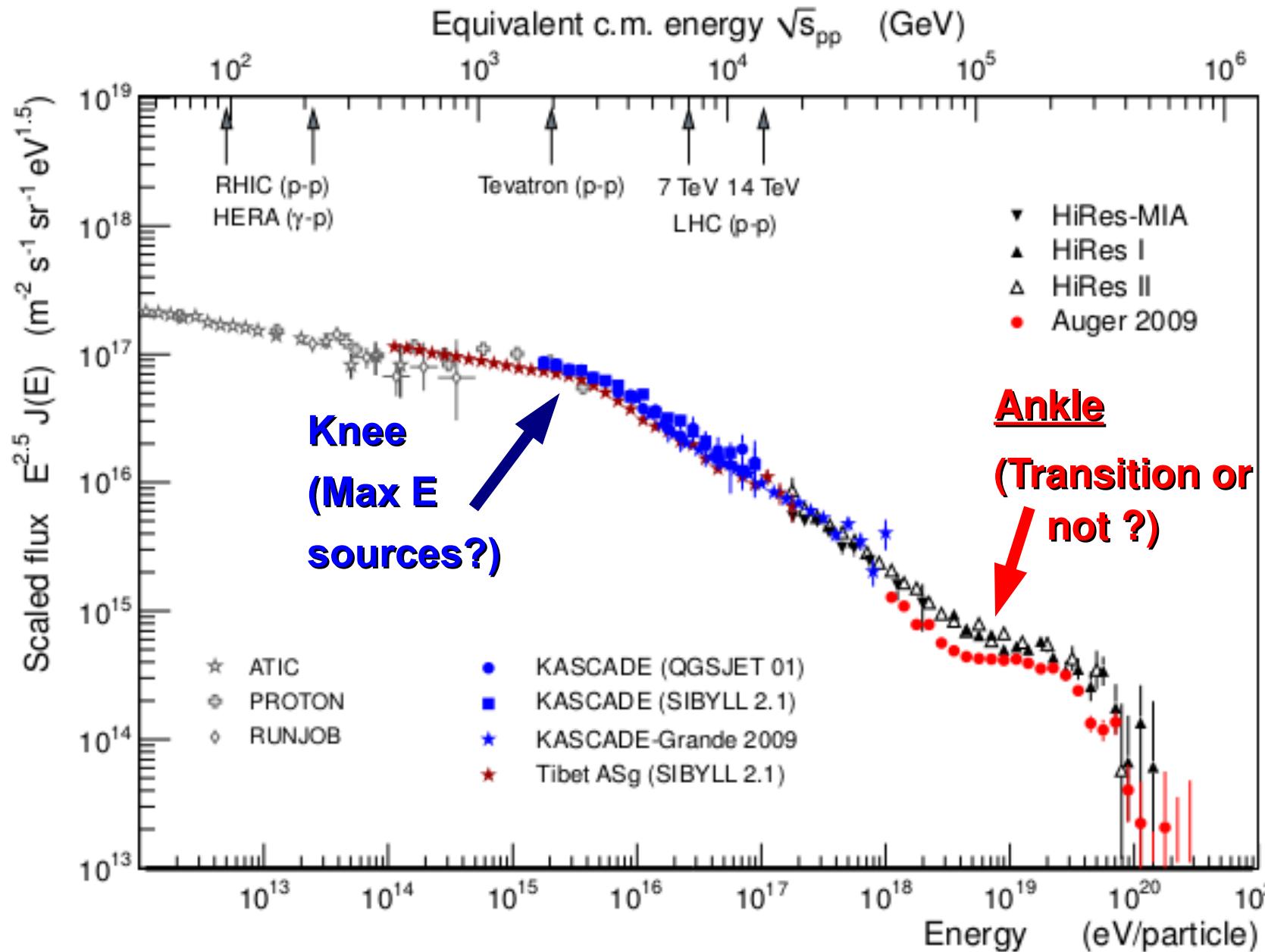
II – Galactic CR propagation in the Galactic magnetic field

III – CR composition vs Anisotropy as a diagnosis

IV – A few words about the knee

V – Conclusion & Directions of interest for future observations

A (well) concealed transition...



The ankle ?

Detection of the ankle by Fly's Eye detector

D. J. Bird et al., *Astrophys. J.* 424, 491-502 (1994)

THE COSMIC-RAY ENERGY SPECTRUM OBSERVED BY THE FLY'S EYE

D. J. BIRD,¹ S. C. CORBATÓ,² H. Y. DAI,² B. R. DAWSON,³ J. W. ELBERT,² B. L. EMERSON,^{2,4} K. D. GREEN,^{2,5} M. A. HUANG,² D. B. KIEDA,² M. LUO,² S. KO,² C. G. LARSEN,² E. C. LOH,² M. H. SALAMON,² J. D. SMITH,² P. SOKOLSKY,² P. SOMMERS,² J. K. K. TANG,² AND S. B. THOMAS²

Received 1993 August 16; accepted 1993 September 24

ABSTRACT

We report on the cosmic-ray energy spectrum above 10^{17} eV as observed by the Fly's Eye detector. The detector has been operated in monocular mode (Fly's Eye I only) since 1981 and in stereo mode (both Fly's Eye I and Fly's Eye II) since 1986. This paper includes data through 1992 July. The cosmic-ray primary energy is measured by integrating over the atmospheric development curve of the extensive air shower produced by the primary particle. The differential monocular energy spectrum above 10^{17} eV is $J(E) = 10^{-29.55} \times (E/10^{18} \text{ eV})^{-3.07 \pm 0.01} \text{ m}^{-2} \text{ s}^{-1} \text{ sr}^{-1} \text{ eV}^{-1}$. We observe a dip in the energy spectrum near $10^{18.5}$ using the higher resolution stereo data. A 3×10^{20} eV shower was detected by the monocular Fly's Eye on 1991 October 15.

Subject headings: cosmic rays — instrumentation: detectors

The ankle ?

Detection of the ankle by Fly's Eye detector

D. J. Bird et al., *Astrophys. J.* 424, 491-502 (1994)

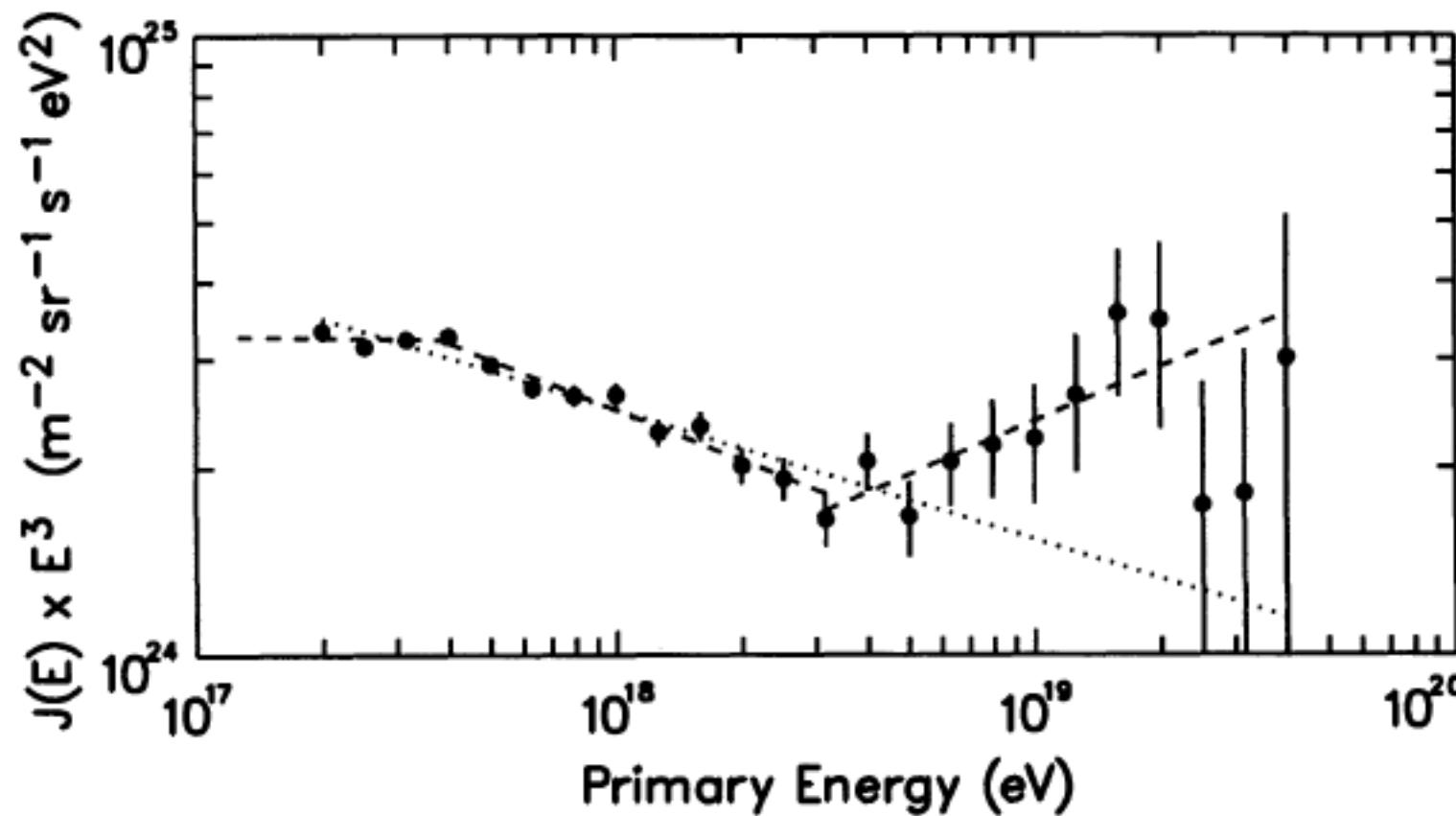


FIG. 5.—Fly's Eye stereo energy spectrum. *Points*: data. *Dashed line*: best fit in each region. *Dotted line*: best fit up to $10^{18.5}$ eV.

tector. The (both Fly's ty primary lower pro- 10^{17} eV is cture near r Fly's Eye

detector has been used by Fly I and II. The energy range covered by Fly II is reproduced by the formula $J(E) = 10^{-10.5} E^{18.5}$ using data taken between 1991 October and 1992 January. The subject has been

The ankle ?

Detection of the ankle by Fly's Eye detector

D. J. Bird et al., *Astrophys. J.* 424, 491-502 (1994)

5.6. *Possible Hint as to the Cosmic-Ray Origins*

What does the structure of the spectrum tell us? One possibility is that the cosmic-ray origin changes with energy. The break between 2 and 5 EeV may indicate the dominance of a new cosmic-ray source. Before the break, the cosmic rays may be mostly of Galactic origin. After the break, an extragalactic component may be taking over. Due to the Galactic confine-

... or *BEFORE* the ankle ?

The suppression of the flux at the ankle may be due to e+e- pair production

V. S. Berezinsky et al.,
Astropart.Phys. 21 (2004) 61

and following works

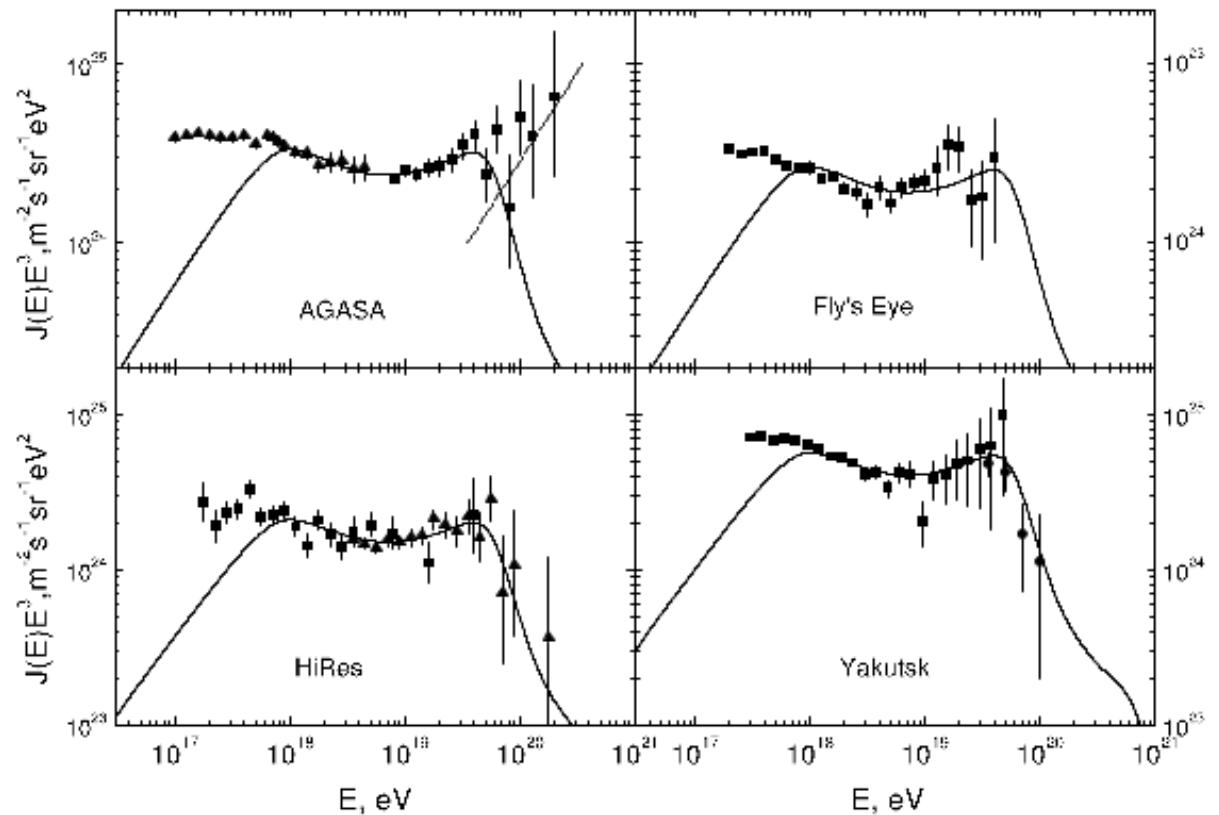


Fig. 2. Comparison of calculated spectra for non-evolutionary model (see the text) with observational data. There is a good agreement of a dip centered at $E \sim 1 \times 10^{19}$ eV with all data. The dip is produced due to pair-production $p + \gamma_{\text{CMB}} \rightarrow p + e^+ + e^-$ on CMB radiation. AGASA excess needs for its explanation another component of UHECR (shown by dashed curve), which can be due to one of the top-down scenarios [14].

... or BEFORE the ankle ?

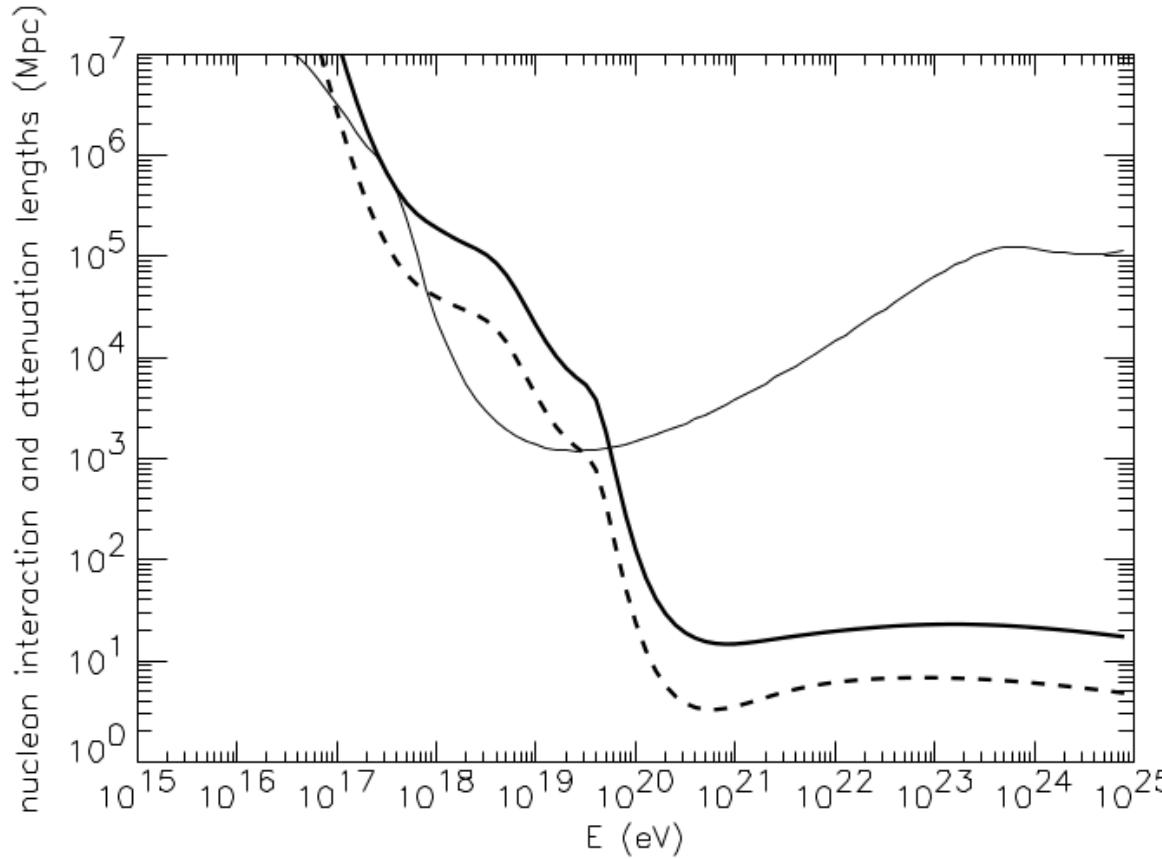
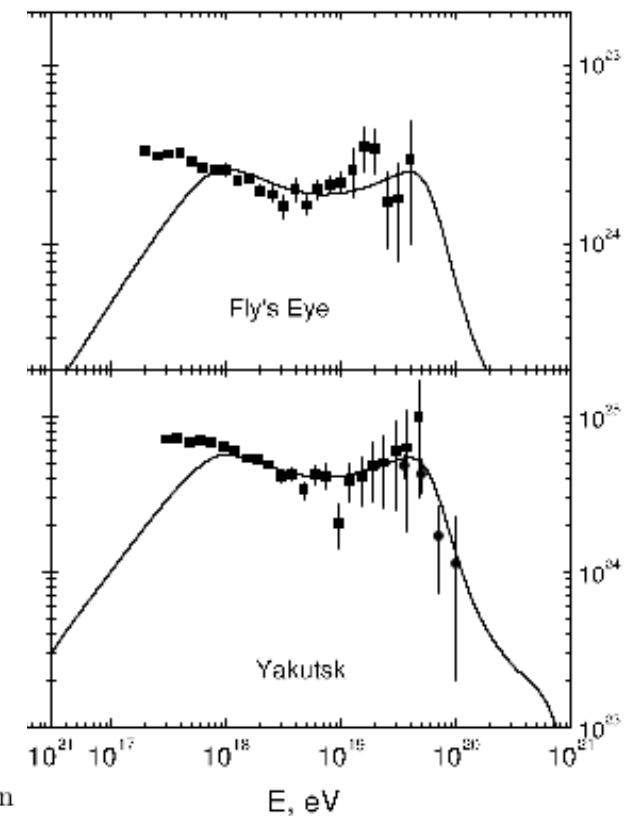


Figure 9: The nucleon interaction length (dashed line) and attenuation length (solid line) for photo-pion production and the proton attenuation length for pair production (thin solid line) in the combined CMB and the estimated total extragalactic radio background intensity shown in Fig. 10 below.

ie to e^+e^-



ra for non-evolutionary model (see the

text) with observational data. There is a good agreement of a dip centered at $E \sim 1 \times 10^{19}$ eV with all data. The dip is produced due to pair-production $p + \gamma_{\text{CMB}} \rightarrow p + e^+ + e^-$ on CMB radiation. AGASA excess needs for its explanation another component of UHECR (shown by dashed curve), which can be due to one of the top-down scenarios [14].

**P. Bhattacharjee, G. Sigl,
Phys. Rept. 327, 109-247 (2000)**

... or *BEFORE* the ankle ?

The suppression of the flux at the ankle may be due to e+e- pair production

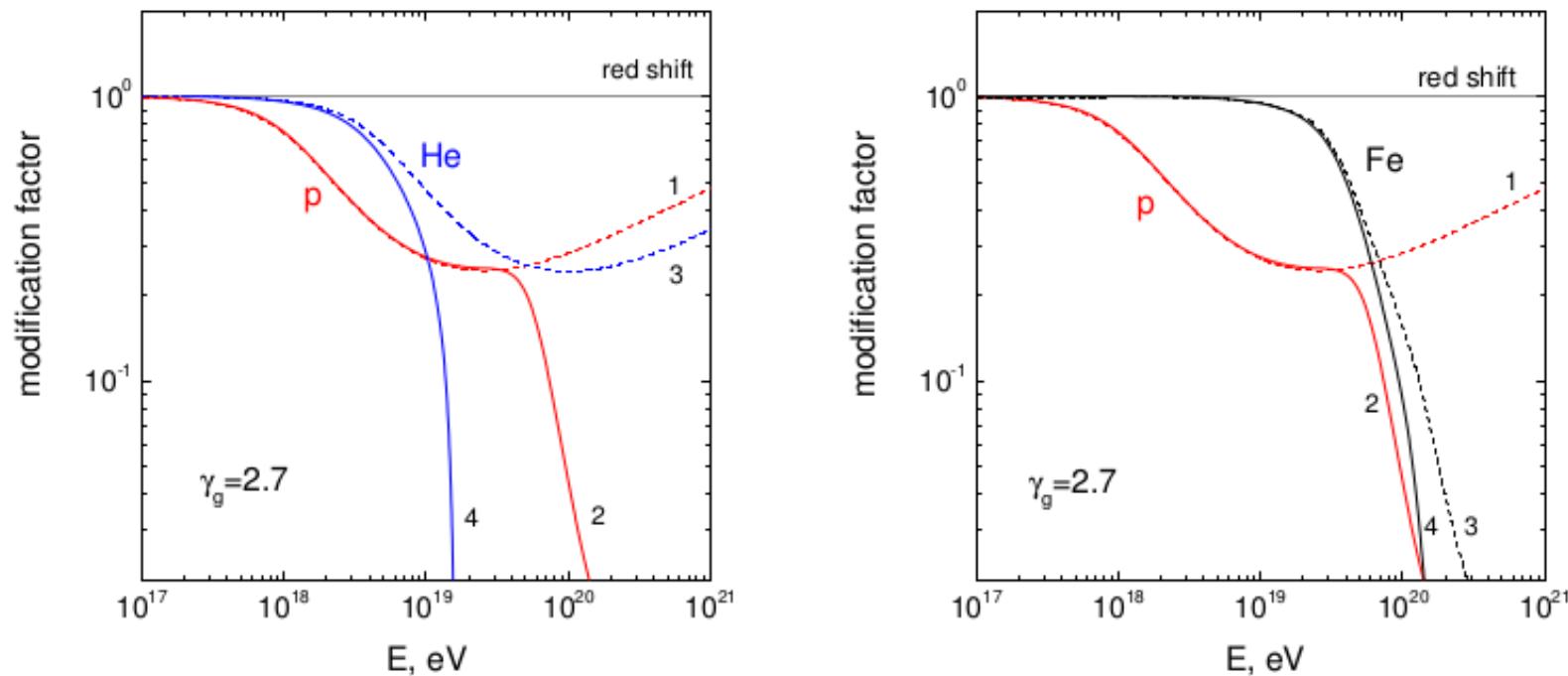


Fig. 4. Modification factors for helium and iron nuclei in comparison with that for protons. Proton modification factors are given by curves 1 and 2. Nuclei modification factors are given by curves 3 (adiabatic and pair production energy losses) and by curves 4 (with photodisintegration included).

V. S. Berezinsky et al.

Mixed composition and the ankle

No e+e- pair production dip (except if large fraction of protons)

On the transition from Galactic to extragalactic cosmic-rays: spectral and composition features from two opposite scenarios

D. Allard^{a,b} E. Parizot^c A. V. Olinto^{a,b}

Abstract

**D. Allard et al.,
Astropart. Phys.
27, 61-75 (2007)**

We study the phenomenology of cosmic-rays (CRs) at the galactic/extragalactic transition, focusing on two opposite models for the composition of the extragalactic (EG) component. Model A assumes a mixed source composition, with nuclear abundances similar to that of the low-energy CRs, while model B assumes that EG sources accelerate only protons. We study the limits within which both scenarios can reproduce the observed high-energy CR spectrum and composition. The ankle in model A is interpreted as the GCR/EGCR transition, while in model B it is the pair-production dip. Model A has a source spectrum $\propto E^{-x}$ with $x \sim 2.2 - 2.3$, while model B requires $x \sim 2.6 - 2.7$. We compare the predictions of both models with the available data on the energy evolution of the high-energy CR composition using the two main composition-related observables: X_{\max} and $\langle \ln A \rangle$. We conclude that model A is currently favoured. Uncertainties are discussed and distinctive features of the two models are identified, which should allow one to distinguish between the models in the near future when more precise measurements are available with higher-statistics experiments.

Key words: cosmic rays, ultra-high energy, composition

Mixed composition and the ankle

No e^+e^- pair production dip (except if large fraction of protons)

D. Allard et al.,
Astropart. Phys.
27, 61-75 (2007)

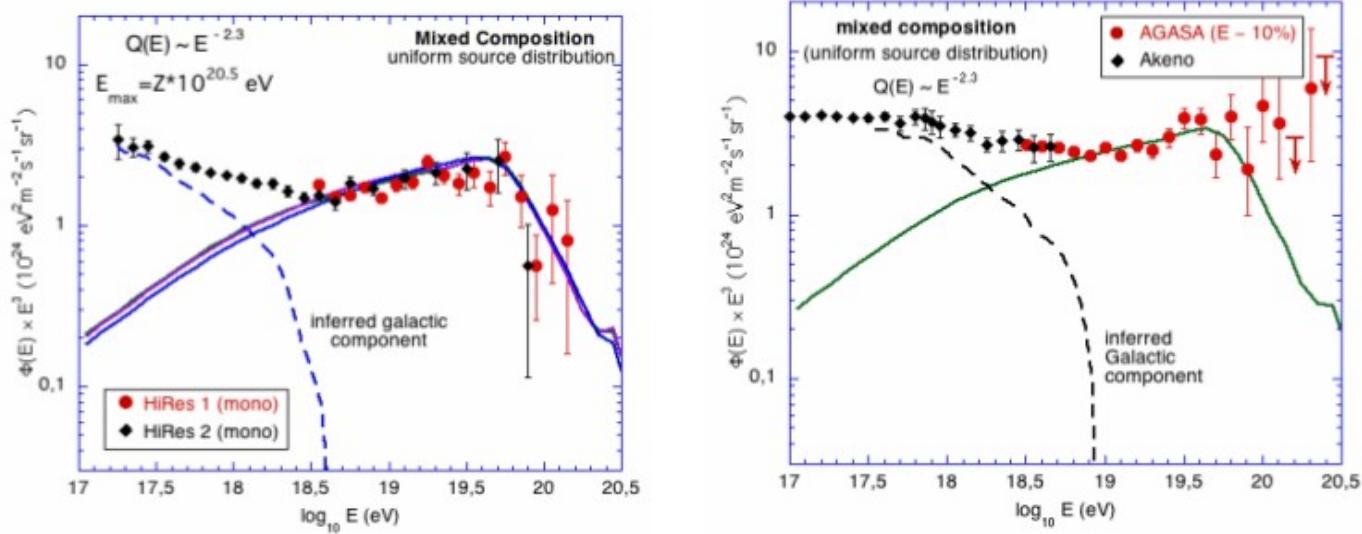


Fig. 1. Propagated spectra, $\Phi(E) E^3$, for model A (mixed EGCR source composition), compared with the HiRes data (left) and the Akeno/AGASA data (right). The dashed line corresponds to the inferred GCR component, obtained by subtraction of the EGCR component from the total CR flux (data points). In both cases the source spectrum has a logarithmic index of $x = 2.3$, and the ankle corresponds to the GCR/EGCR transition. On the left, the three propagated spectra correspond to three different compositions (see text), with essentially identical results.

Mixed composition and the ankle

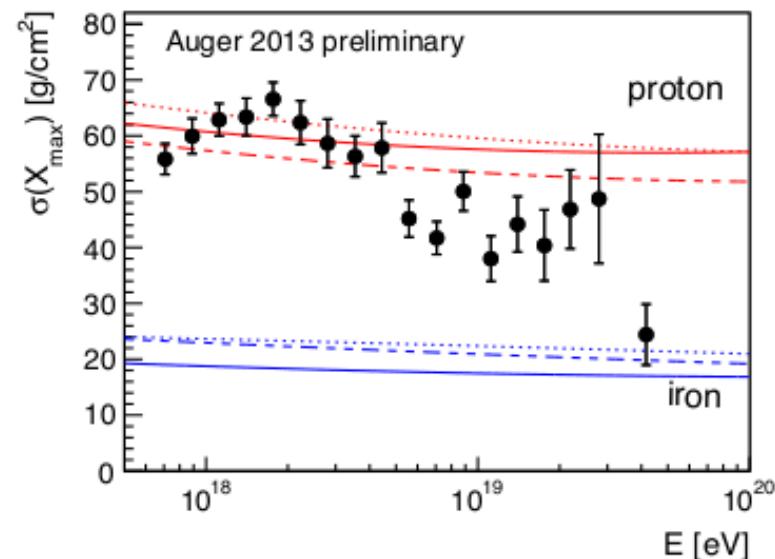
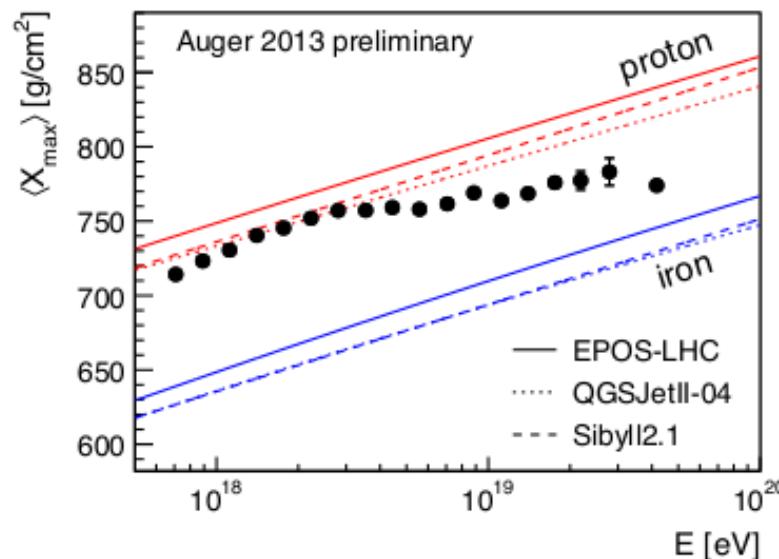
... Is then the ankle the mark of the transition ? Not necessarily ?

Warning on EGMFs : e.g. G. Sigl, E. Armengaud, JCAP 0510, 016 (2005)

But 'large' EGMFs + Composition at the highest energies

* The results from Auger (2009 to now) disfavour a large fraction of protons above a few 10s of EeV :

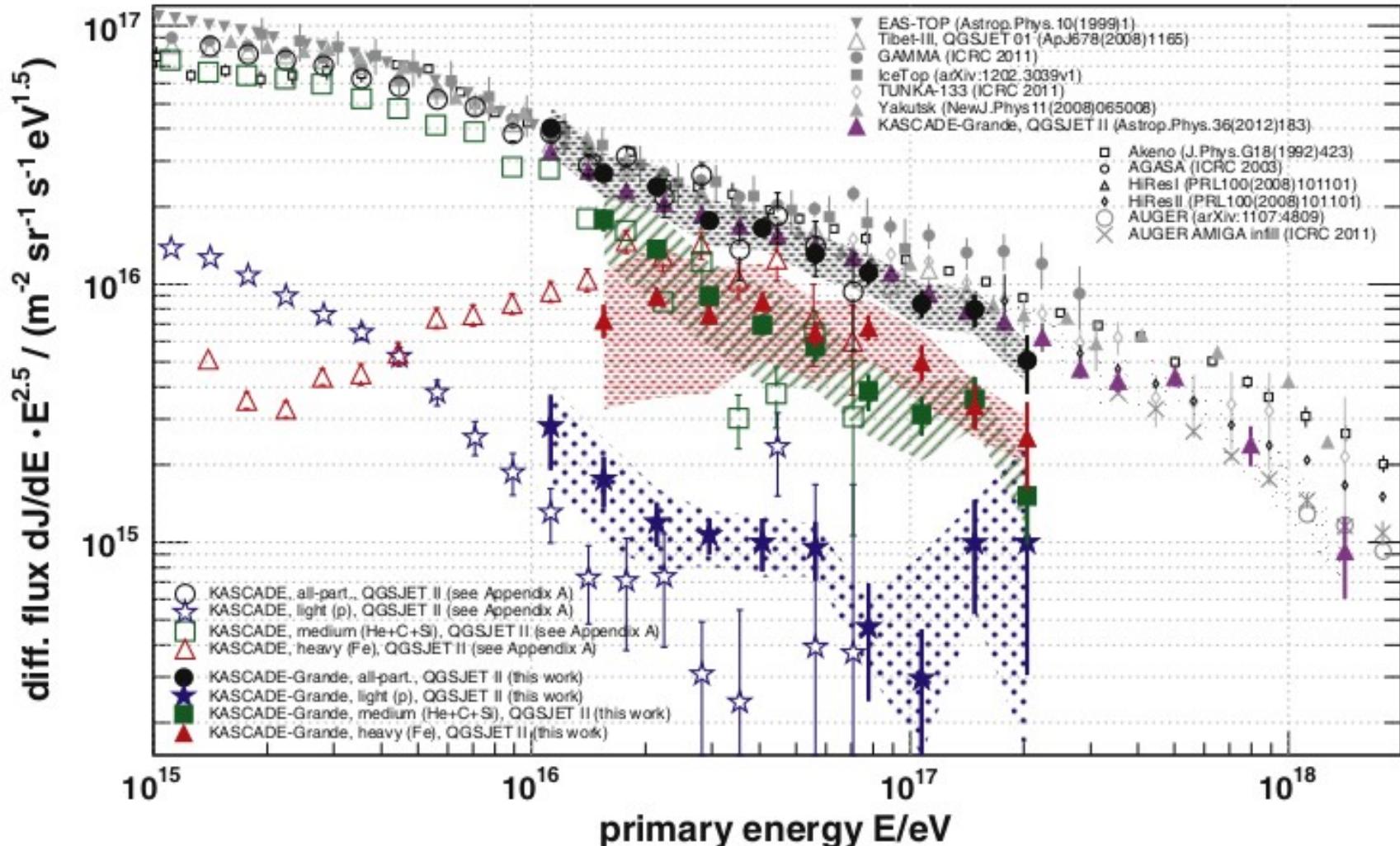
J. Abraham et al. [Pierre Auger Collaboration], Phys. Rev. Lett. 104, 091101 (2010)



Auger collaboration, proc. ICRC 2013

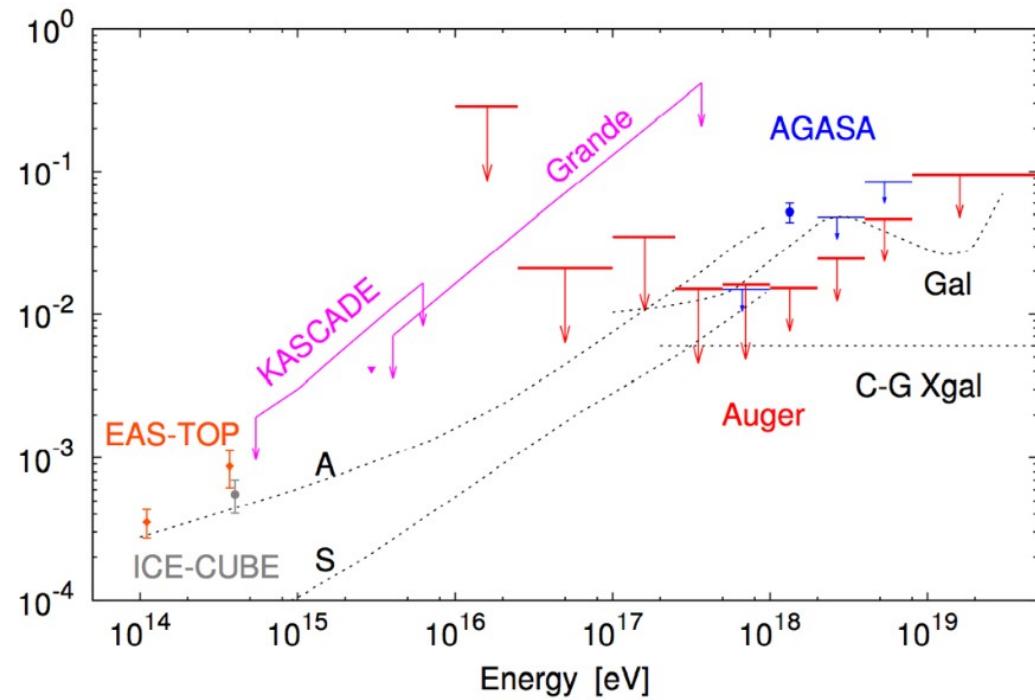
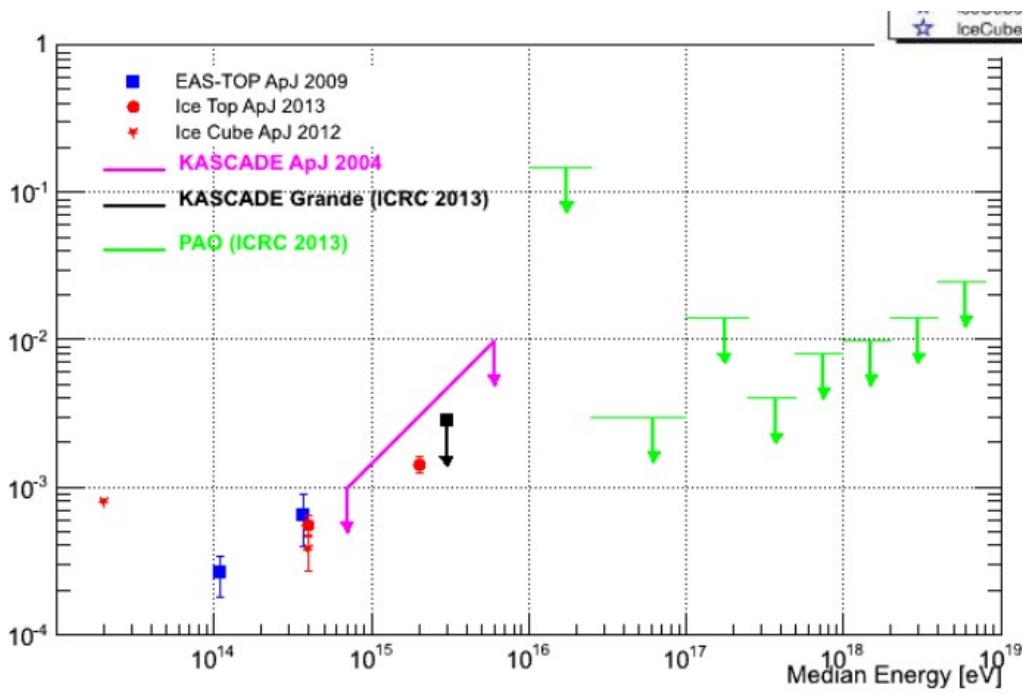
Composition, anisotropy and the transition

W.D. Apel et al / Astroparticle Physics 47 (2013) 54–66



Composition, anisotropy and the transition

Limits on / Measurements of the dipole amplitude :

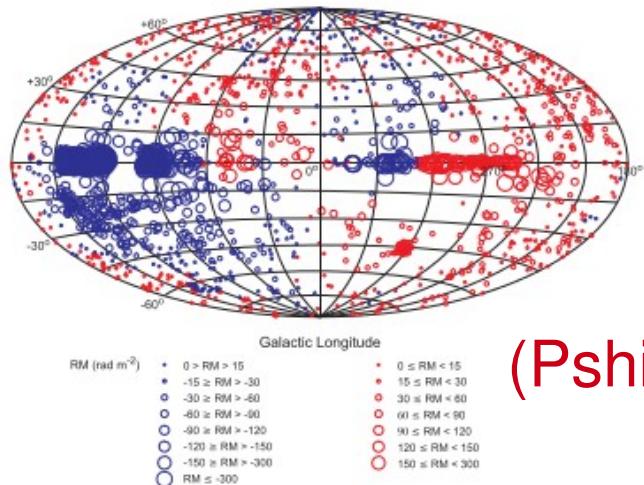


(Pierre Auger Coll.)

Galactic magnetic fields

- Faraday rotation measurements:

$$\Delta\theta = \text{RM} \cdot \lambda^2 ,$$

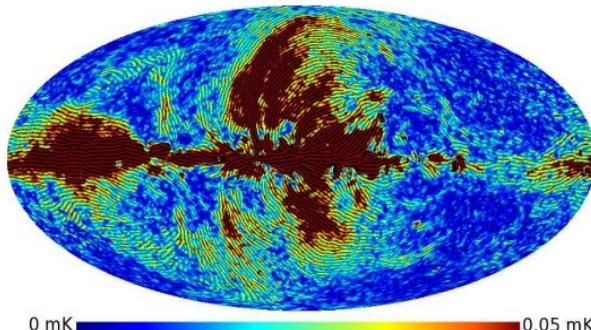


(Pshirkov *et al* '13)

$$\text{RM} = \frac{e^3}{2\pi m_e^2 c^4} \int_0^{l_s} n_{\text{te}}(l) B_{\parallel}(l) dl$$

Large scale component ~ in the Galactic disk ($B_{\text{reg}} \sim 2 \mu\text{G loc.}$)

- Synchrotron emission:



(Farrar *et al*)

Magnetic turbulence

$B_{\text{rms}} \sim 4 \mu\text{G locally} > B_{\text{reg}}$

The Galactic turbulent magnetic field

Satisfies : $\langle \mathbf{B}(\mathbf{x}) \rangle = 0$, $\langle \mathbf{B}(\mathbf{x})^2 \rangle = B_{\text{rms}}^2$, and $\text{div } \mathbf{B} = 0$

Fourier transform : $B_i(\mathbf{x}) = \int \frac{d^3k}{(2\pi)^3} B_i(\mathbf{k}) e^{i(\mathbf{k} \cdot \mathbf{x} + \phi_i(\mathbf{k}))}$

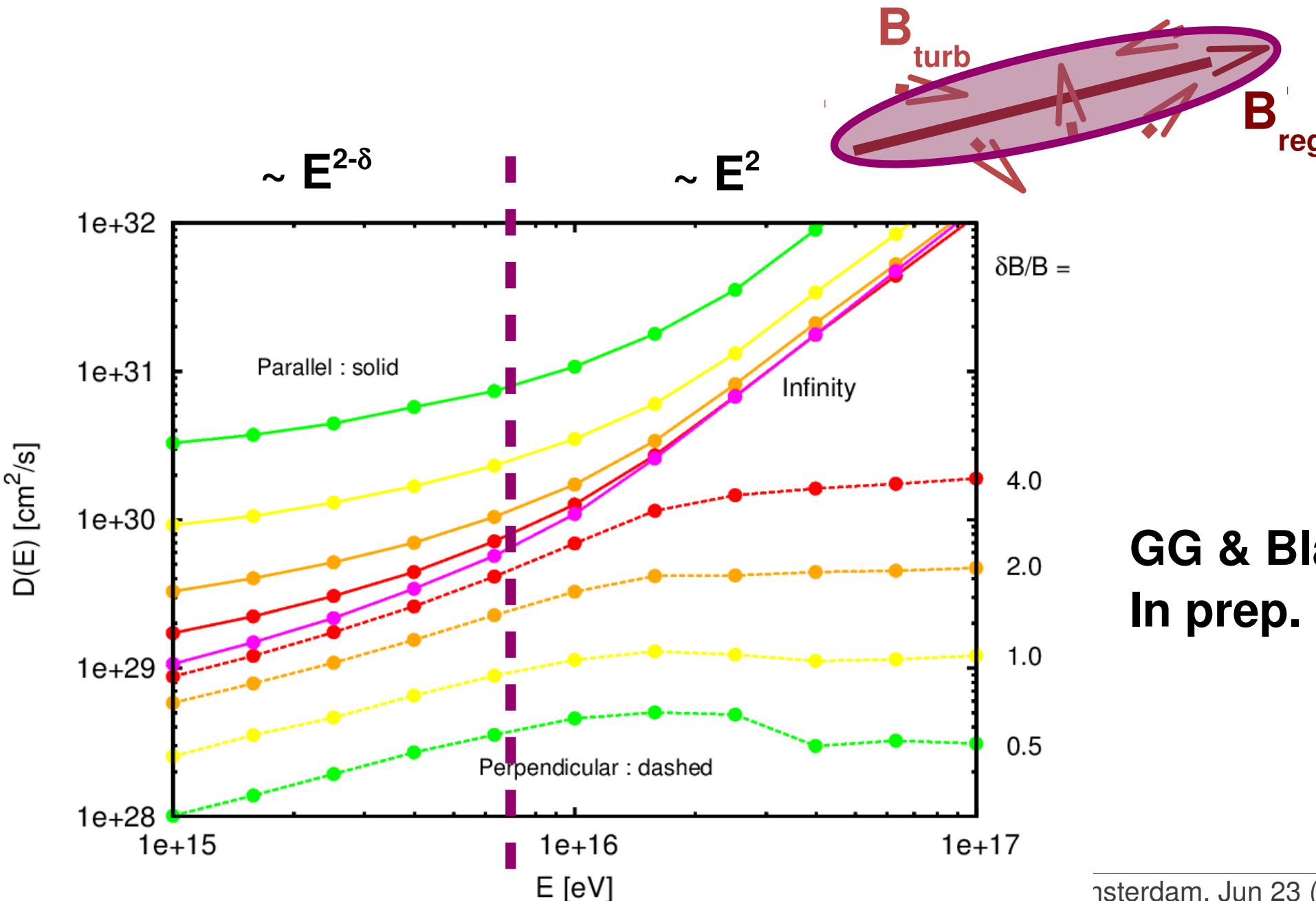
$$\text{with } |B(\mathbf{k})|^2 \propto k^{-\alpha-2}$$

Power spectrum : $\mathcal{P}(k) \propto k^{-\alpha}$ ($\alpha = 5/3, 3/2$ plausible)

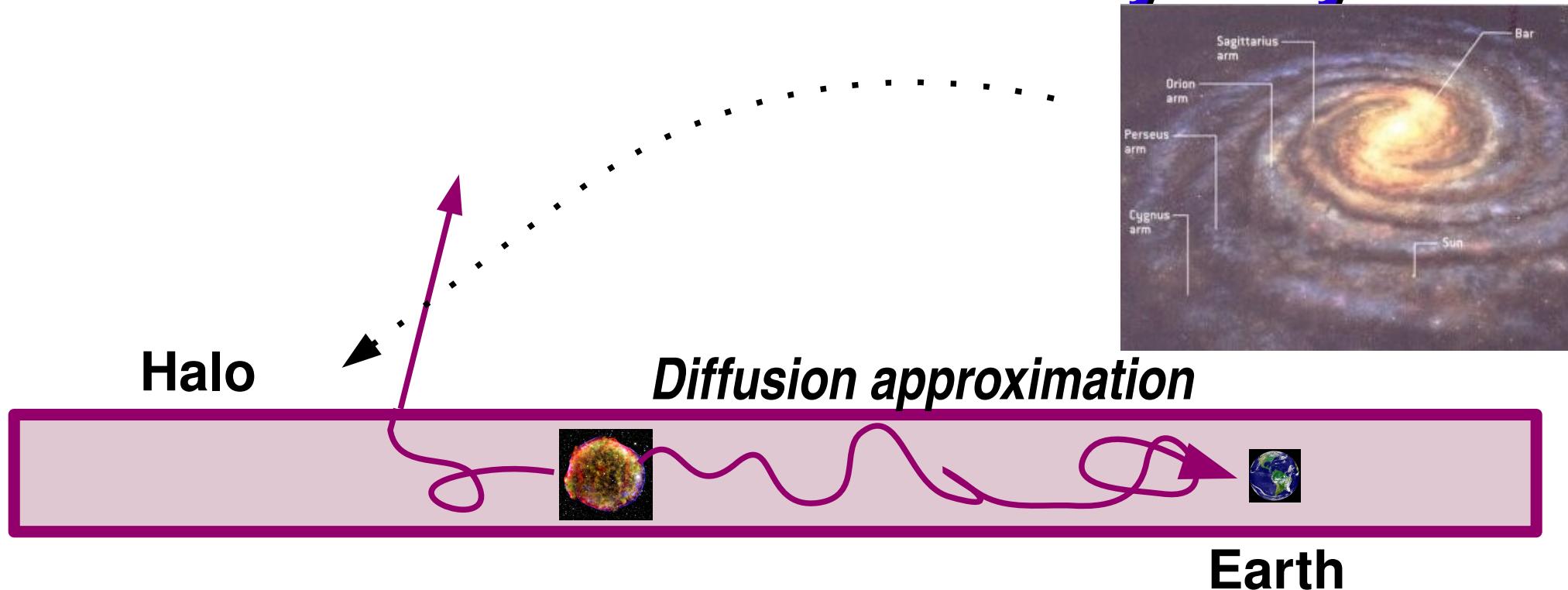
for $2\pi/L_{max} \leq k \leq 2\pi/L_{min}$ with $L_{min} < 1$ AU, $L_{max} \sim 10$ pc -
100 pc

Coherence length : $L_c \sim$ few 10s pc locally
(e.g. works of P. Frisch)

Perpendicular/Parallel diffusion coeffs.



CR diffusion in the Milky Way

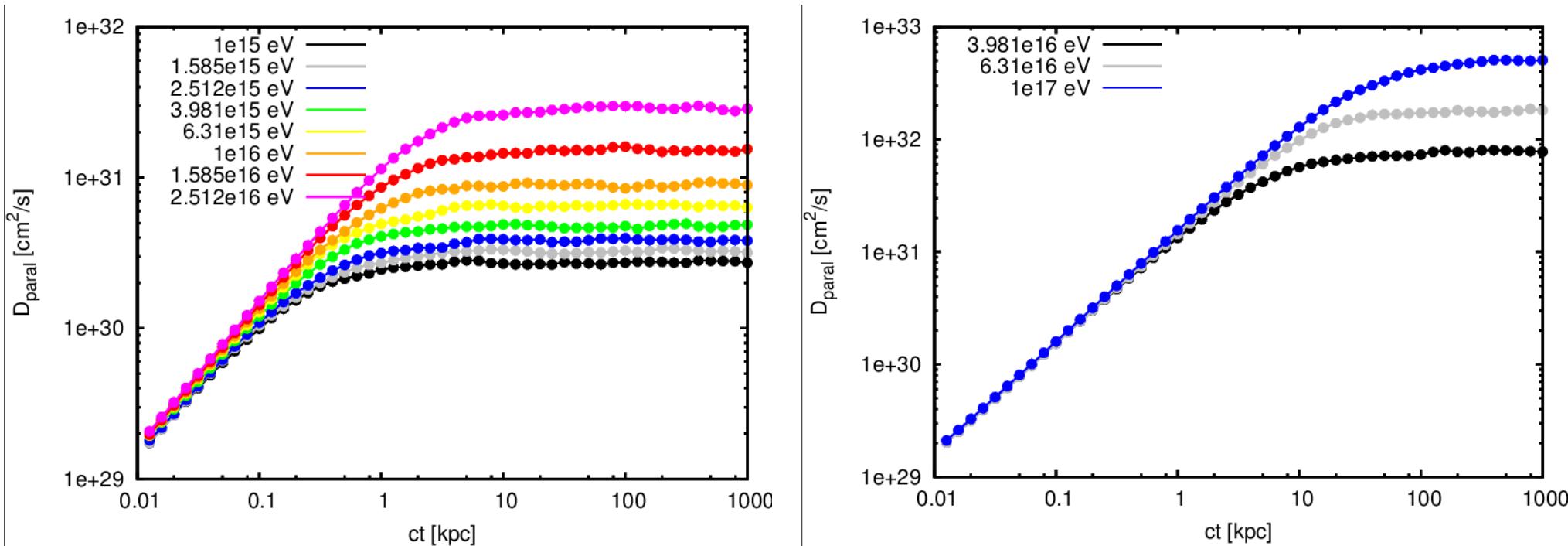


$$D(p) \simeq 10^{28} \left(\frac{p/Z}{3 \text{ GeV}} \right)^\delta \left(\frac{z_0}{\text{kpc}} \right) \text{ cm}^2 \text{ s}^{-1}$$

G. Di Bernardo, C. Evoli, D. Gaggero, D. Grasso,
and L. Maccione, Astropart. Phys. 34, 274 (2010)

Limitations ; Need for individual trajectories

- Drift – Antisymmetric term in the diffusion tensor
(but see also DRAGON code; De Marco et al.)
- Diffusion approximation breaks down at high energies



→ NEED FOR INDIVIDUAL CR TRAJECTORIES

Individual CR trajectories in GMF models

Cosmic ray anisotropy as signature for the transition from galactic to extragalactic cosmic rays

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Trondheim, Norway

^bII. Institut für Theoretische Physik, Universität Hamburg,
Hamburg, Germany

^cAstroParticle and Cosmology (APC),
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^dInstitute for Nuclear Research of the Russian Academy of Sciences,
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Abstract. We constrain the energy at which the transition from Galactic to extragalactic

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G. Giacinti,^{a,b} M. Kachelrieß,^a D.V. Semikoz^{c,d} and G. Sigl^b

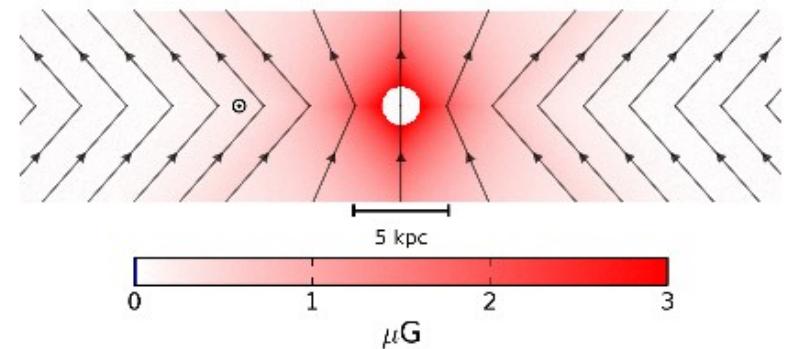
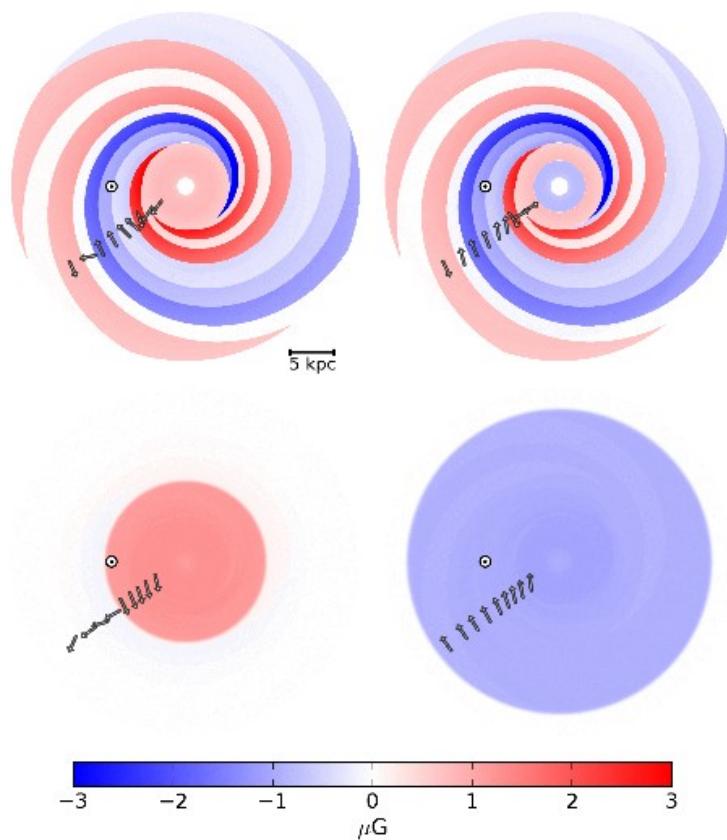
JCAE

Abstract. We constrain the energy at which the transition from Galactic to extragalactic cosmic rays occurs by computing the anisotropy at Earth of cosmic rays emitted by Galactic sources. Since the diffusion approximation starts to lose its validity for $E/Z \gtrsim 10^{16-17}$ eV, we propagate individual cosmic rays using Galactic magnetic field models and taking into account both their regular and turbulent components. The turbulent field is generated on a nested grid which allows spatial resolution down to fractions of a parsec. Assuming sufficiently frequent Galactic CR sources, the dipole amplitude computed for a mostly light or intermediate primary composition exceeds the dipole bounds measured by the Auger collaboration around $E \approx 10^{18}$ eV. Therefore, a transition at the ankle or above would require a heavy composition or a rather extreme Galactic magnetic field with strength $\gtrsim 10 \mu\text{G}$. Moreover, the fast rising proton contribution suggested by KASCADE-Grande data between 10^{17} eV and 10^{18} eV should be of extragalactic origin. In case heavy nuclei dominate the flux at $E \gtrsim 10^{18}$ eV, the transition energy can be close to the ankle, if Galactic CRs are produced by sufficiently frequent transients as e.g. magnetars.

Recent Galactic magnetic field models

Jansson & Farrar

R. Jansson and G. R. Farrar, Astrophys. J. 757, 14 (2012)



Regular

Recent Galactic magnetic field models

Jansson & Farrar

Astrophys. J. 761, L11 (2012)

Halo component	$B_0 = 4.68 \pm 1.39 \mu\text{G}$ $r_0 = 10.97 \pm 3.80 \text{ kpc}$ $z_0 = 2.84 \pm 1.30 \text{ kpc}$	field strength exponential scale length Gaussian scale height
Striation	$\beta = 1.36 \pm 0.36$	striated field $B_{\text{stri}}^2 \equiv \beta B_{\text{reg}}^2$

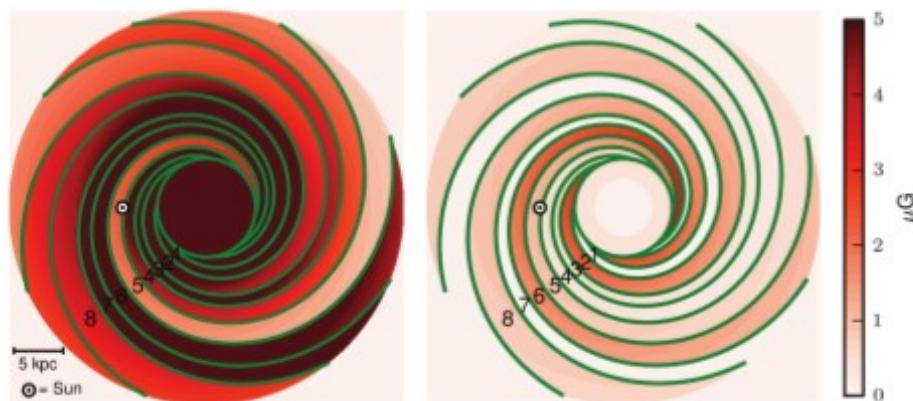


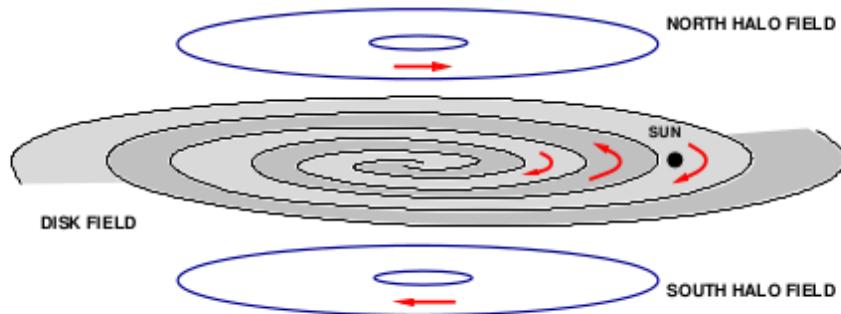
Figure 3. Left panel: The random field in the disk. Right panel: The disk component of the JF12 coherent field model for comparison; it is clockwise in rings 3-6 and counterclockwise in 1,2,7, and 8.

Turbulent

Recent Galactic magnetic field models

Pshirkov et al.

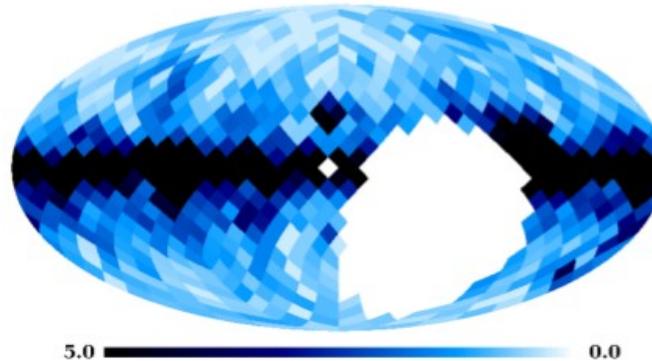
*M. S. Pshirkov, P. G. Tinyakov, P. P. Kronberg and
K. J. Newton-McGee, Astrophys. J. 738, 192 (2011)*



Regular

FIG. 4.— Sketch of the structure of the galactic magnetic field.

M. S. Pshirkov et al., Mon. Not. Roy. Astron. Soc. 436, 2326 (2013)



Turbulent

Recent Galactic magnetic field models

Turbulent field profile (except for Jansson & Farrar)

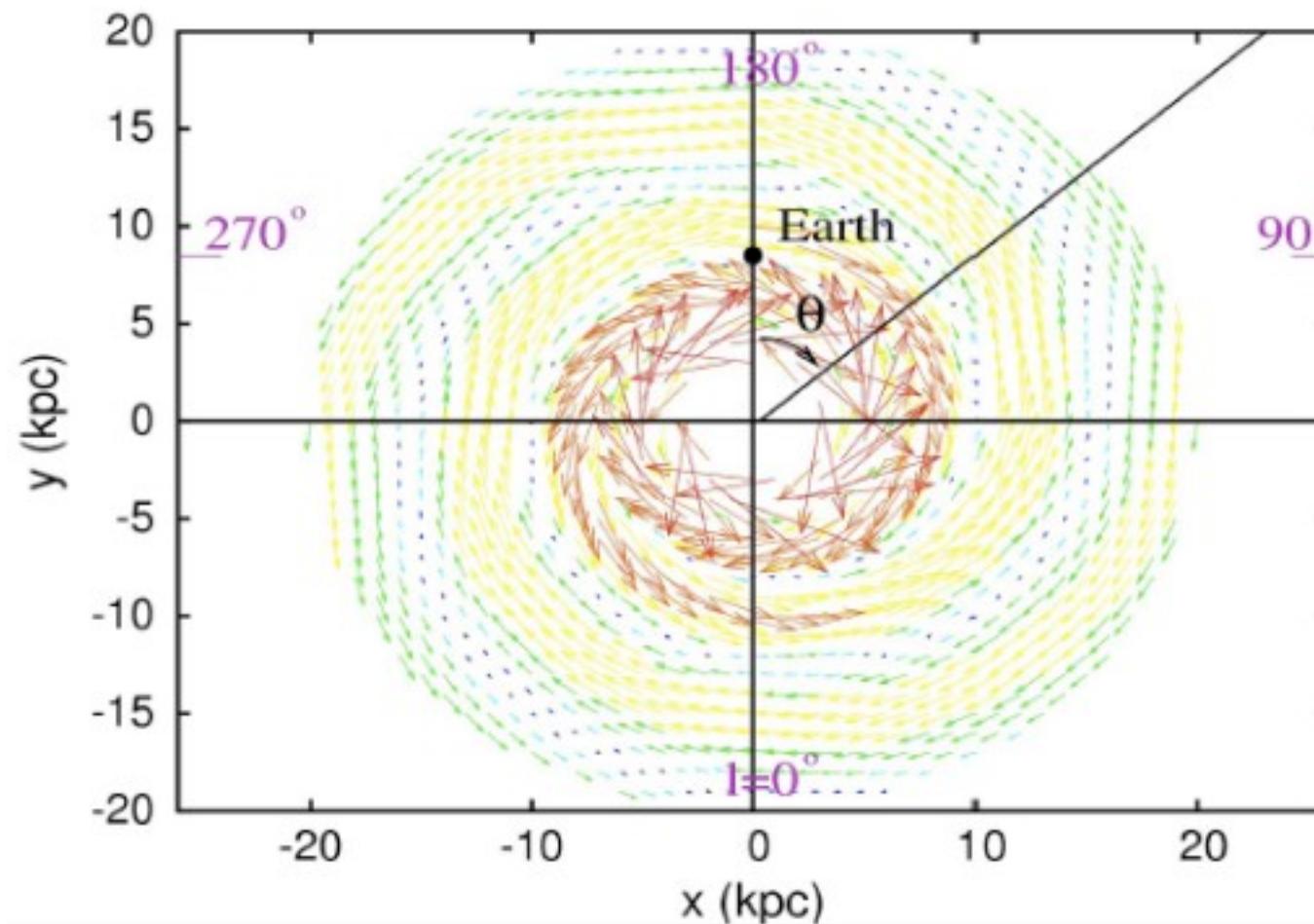
$$B_{\text{rms}}(r, z) = B(r) \exp\left(-\frac{|z|}{z_0}\right)$$

$$B(r) = \begin{cases} B_0 \exp\left(\frac{5.5}{8.5}\right) & , \text{ if } r \leq 3 \text{ kpc (bulge)} \\ B_0 \exp\left(\frac{-(r-8.5 \text{ kpc})}{8.5 \text{ kpc}}\right) & , \text{ if } r > 3 \text{ kpc} \end{cases}$$

... or a cylindrical box of height z_0

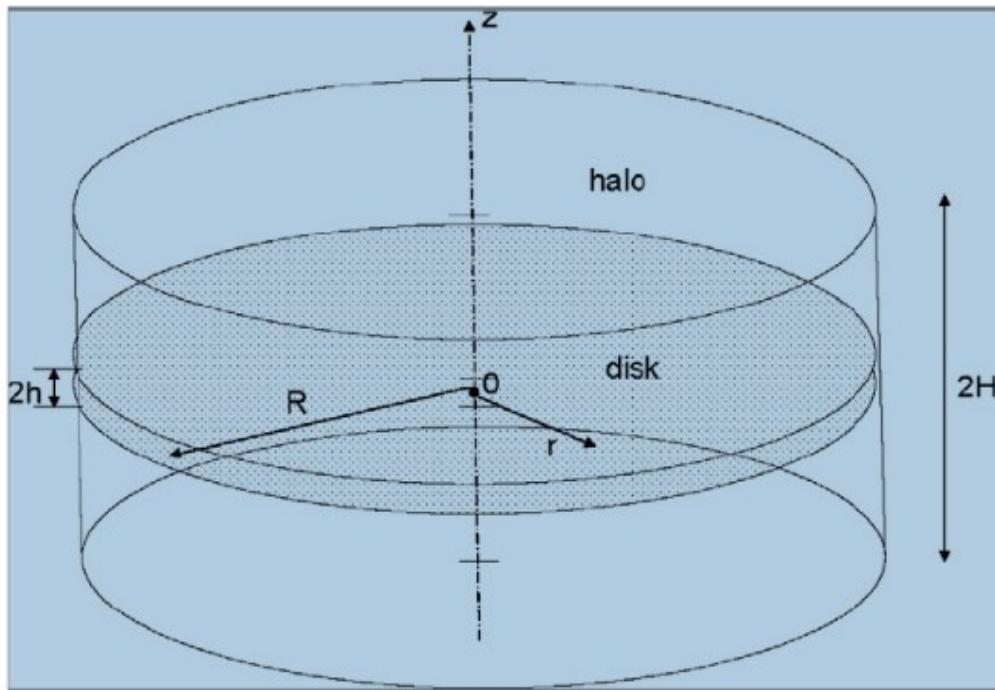
(Recent) Galactic magnetic field models

Prouza & Smida



M. Prouza and R. Smida astro-ph/0307165

Individual CR trajectories in GMF models



(Ptuskin Astropart Phys '11)

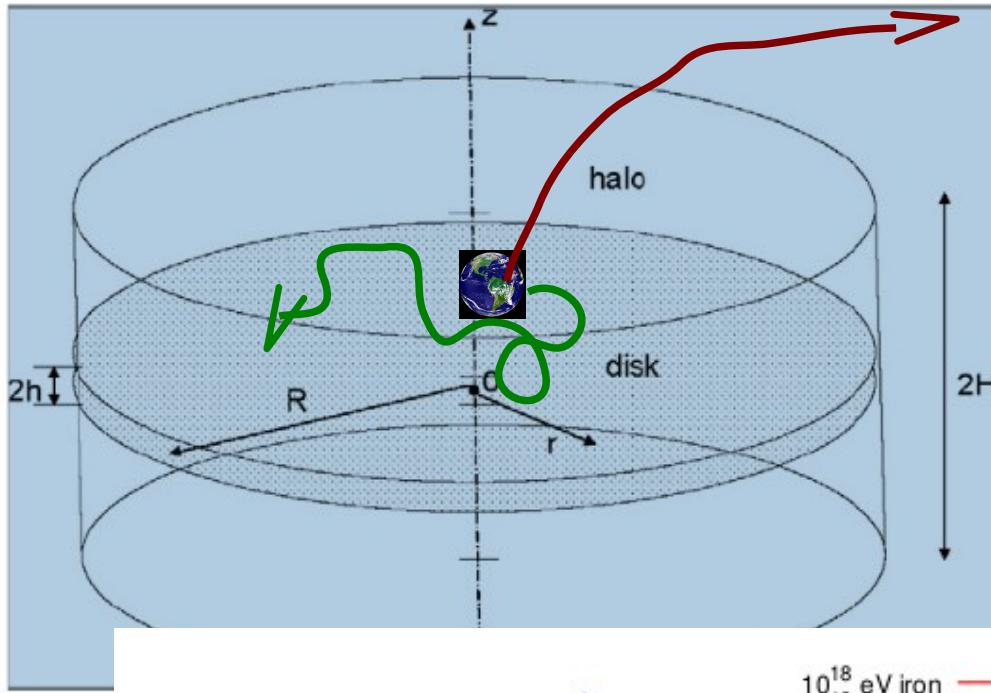
- Sources assumed to be uniformly distributed in the Galactic disk - width $h=200-500$ pc ; up to a radius $r=15-20$ kpc
- Method of S K Karakula et al 1972 J. Phys. A:Gen. Phys. 5 904. See also A A Lee and R W Clay 1995 J. Phys. G: Nucl. Part. Phys. 21 1743

$$\mathcal{D} = \frac{3}{NL} \left| \sum_{i=1}^N \mathbf{v}_i \right|$$

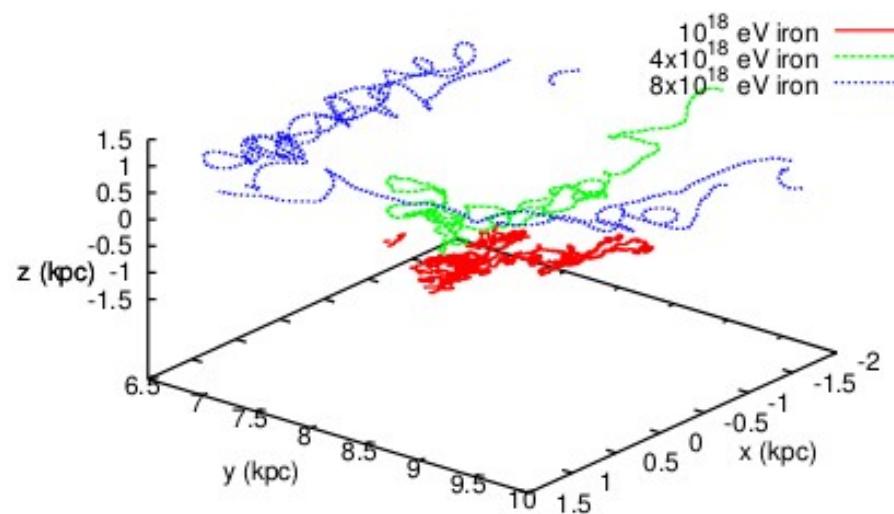
Traj. lengths in disk

Giacinti et al., JCAP 07, 31 (2012)

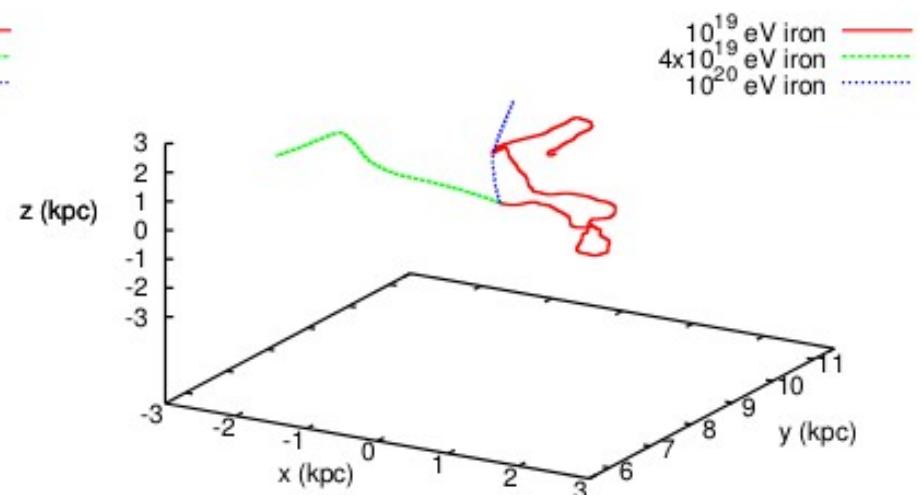
Individual CR trajectories in GMF models



(Ptus)



- Sources assumed to be uniformly distributed in the Galactic disk - width $h=200-500$ pc ; up to a radius $r=15-20$ kpc
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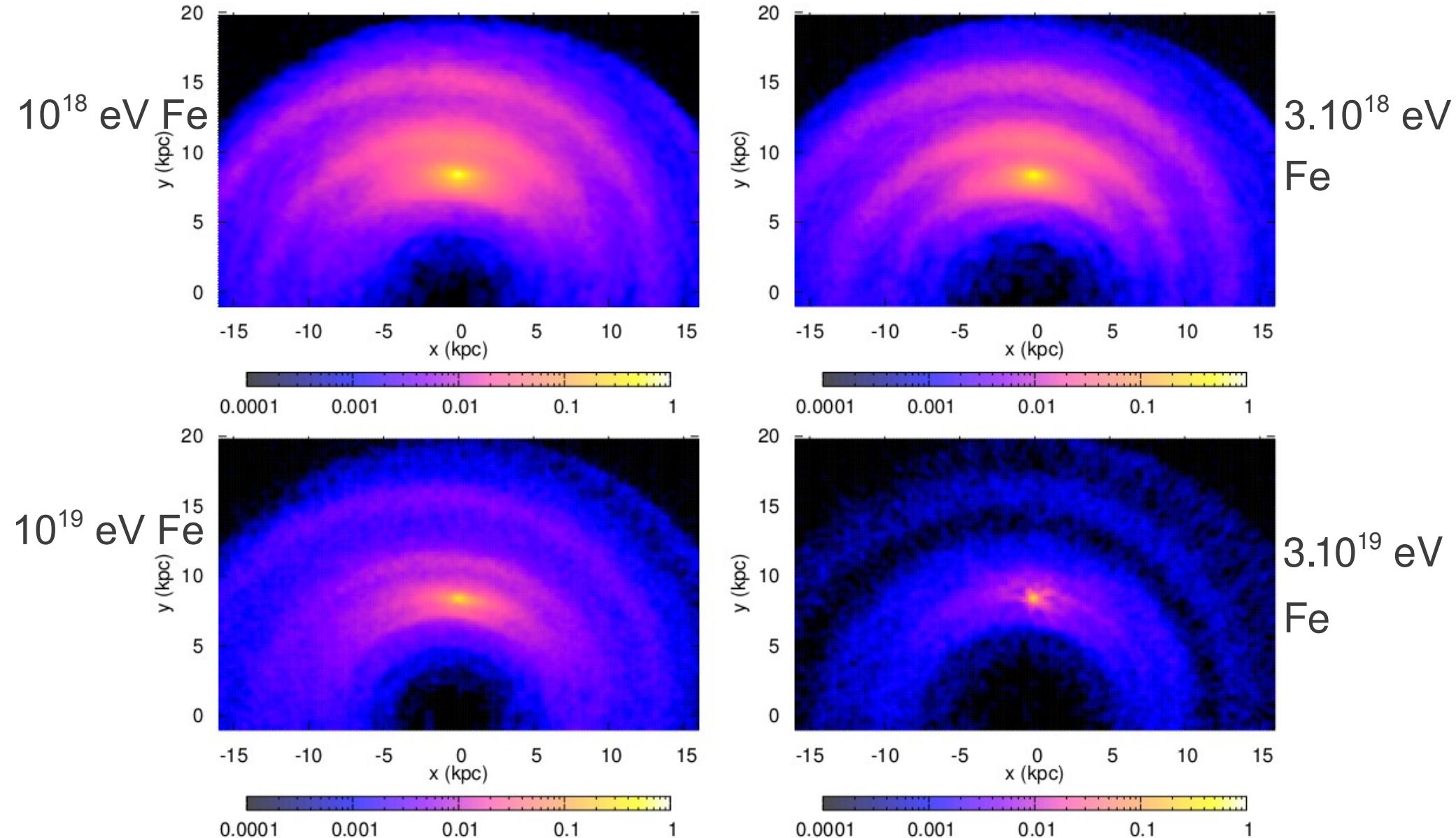
Giacinti et al., JCAP 07, 31 (2012)

Individual CR trajectories in GMF models

QUESTIONS :

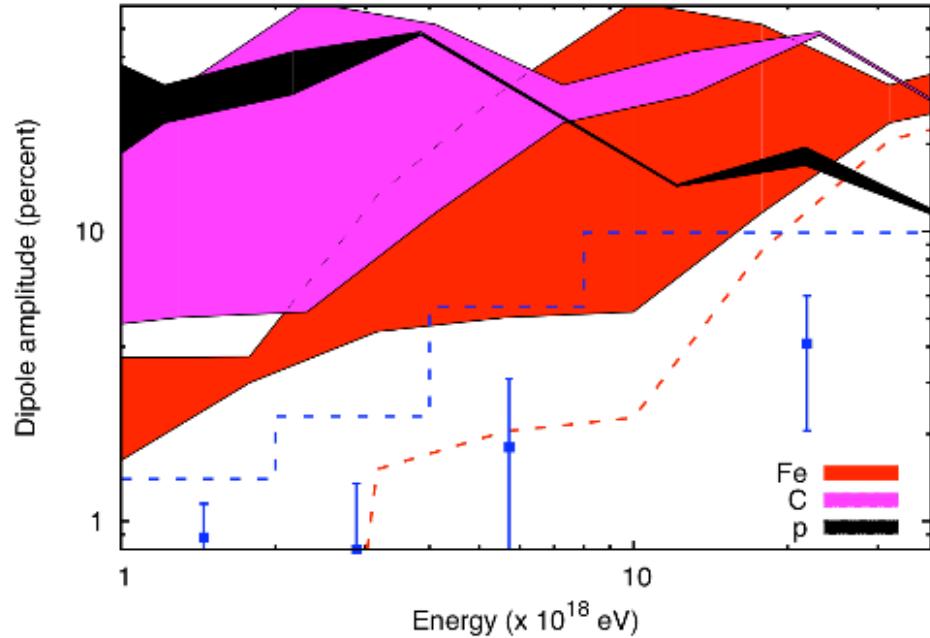
- Can iron from potential Galactic sources be isotropic up to the ankle ?
- Can any light component around 1 EeV (sub-ankle region) be Galactic ?

Individual CR trajectories in GMF models

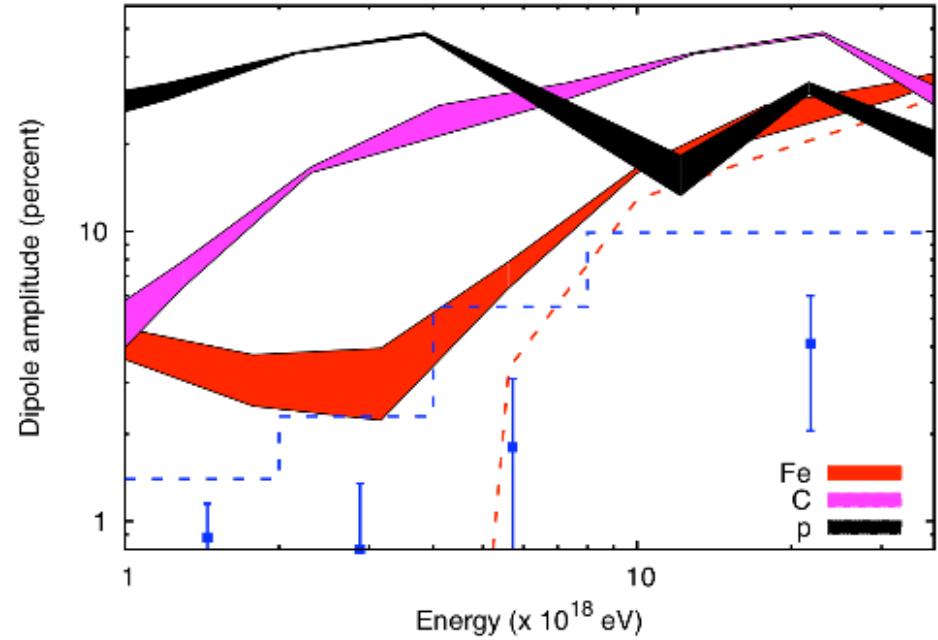


Giacinti et al., JCAP 07, 31 (2012)

Individual CR trajectories in GMF models



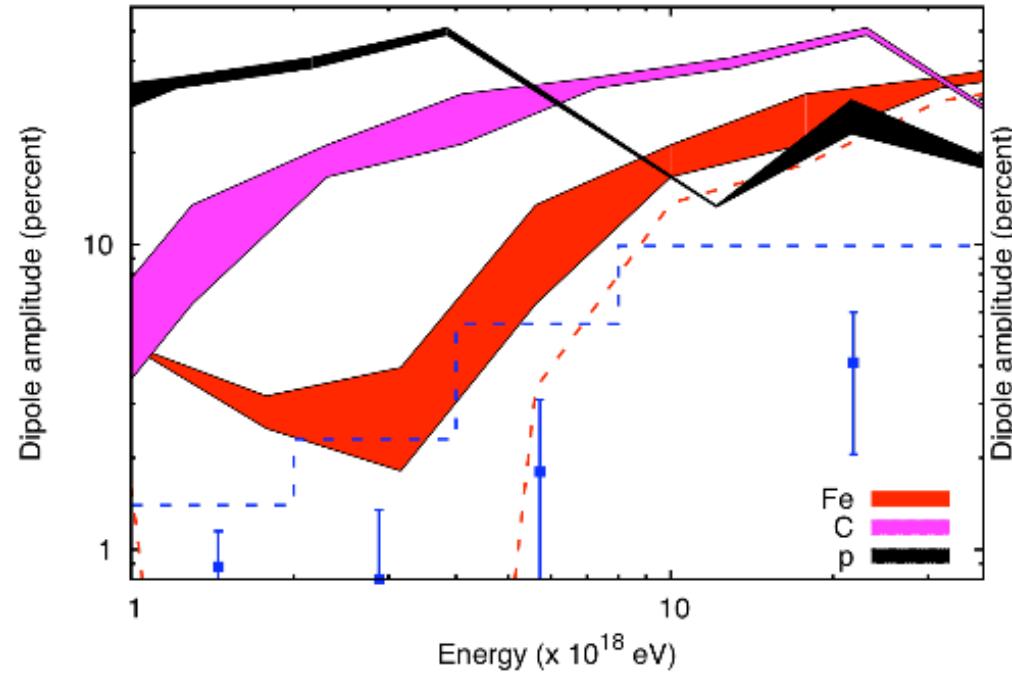
Magnetic field strength 2-8 μG



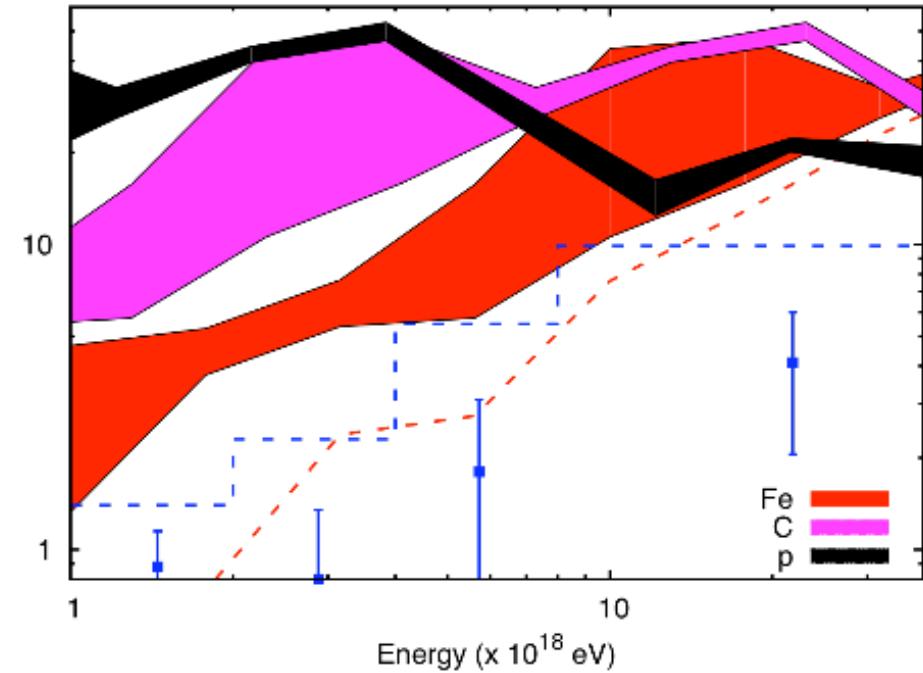
Halo width $z_0 = 1-8$ kpc

Giacinti et al., JCAP 07, 31 (2012)

Individual CR trajectories in GMF models



Turb. Magn. Field spectrum
Kolmogorov/Kraichnan



$L_{\text{max}} = 100\text{-}300 \text{ pc}$

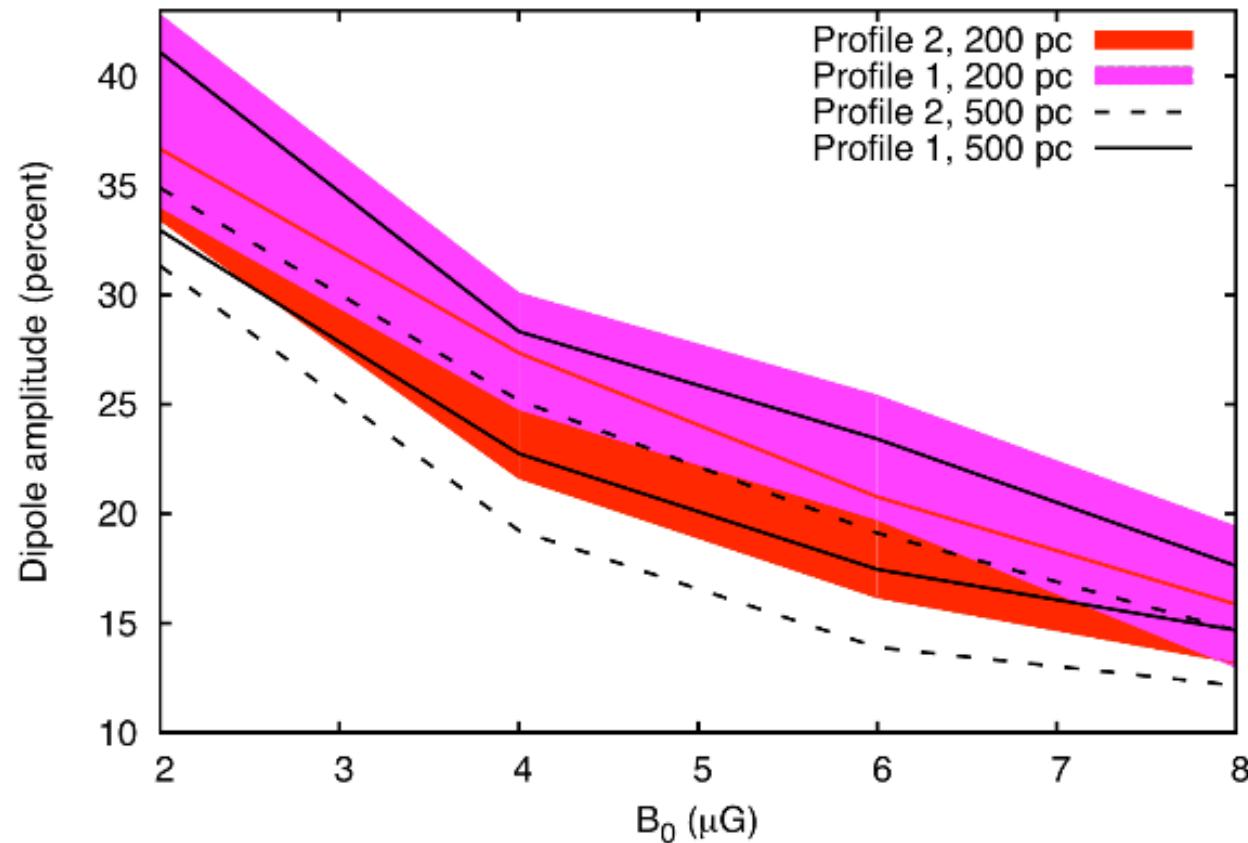
Giacinti et al., JCAP 07, 31 (2012)

Individual CR trajectories in GMF models

1 EeV protons in Kolmogorov turb.

Reg. GMF : PS , Pshirkov et al.

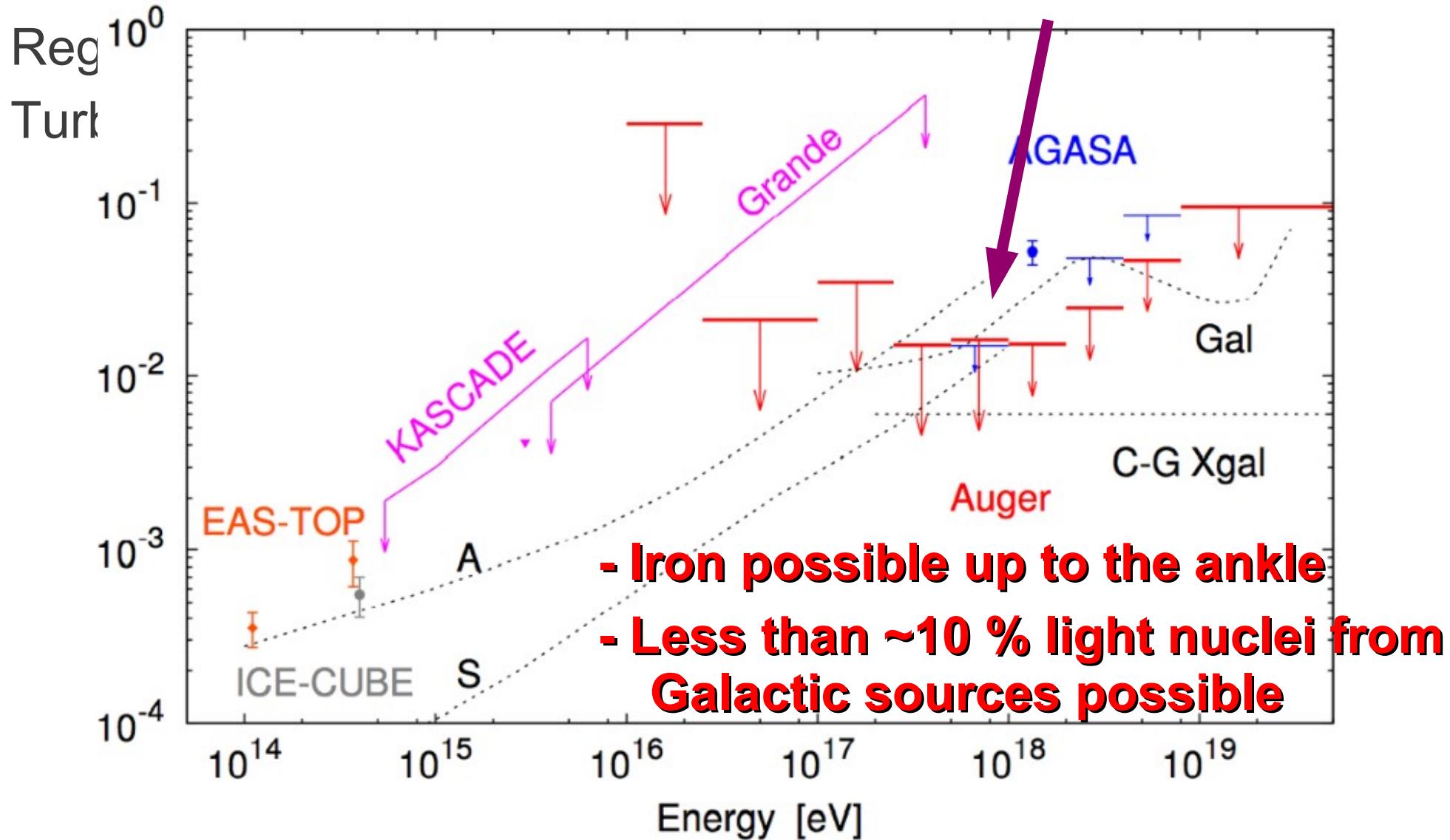
Turbulent GMF : Profile 1 or box ; $z_0 \sim 1$ to 8 kpc



Giacinti et al., JCAP 07, 31 (2012)

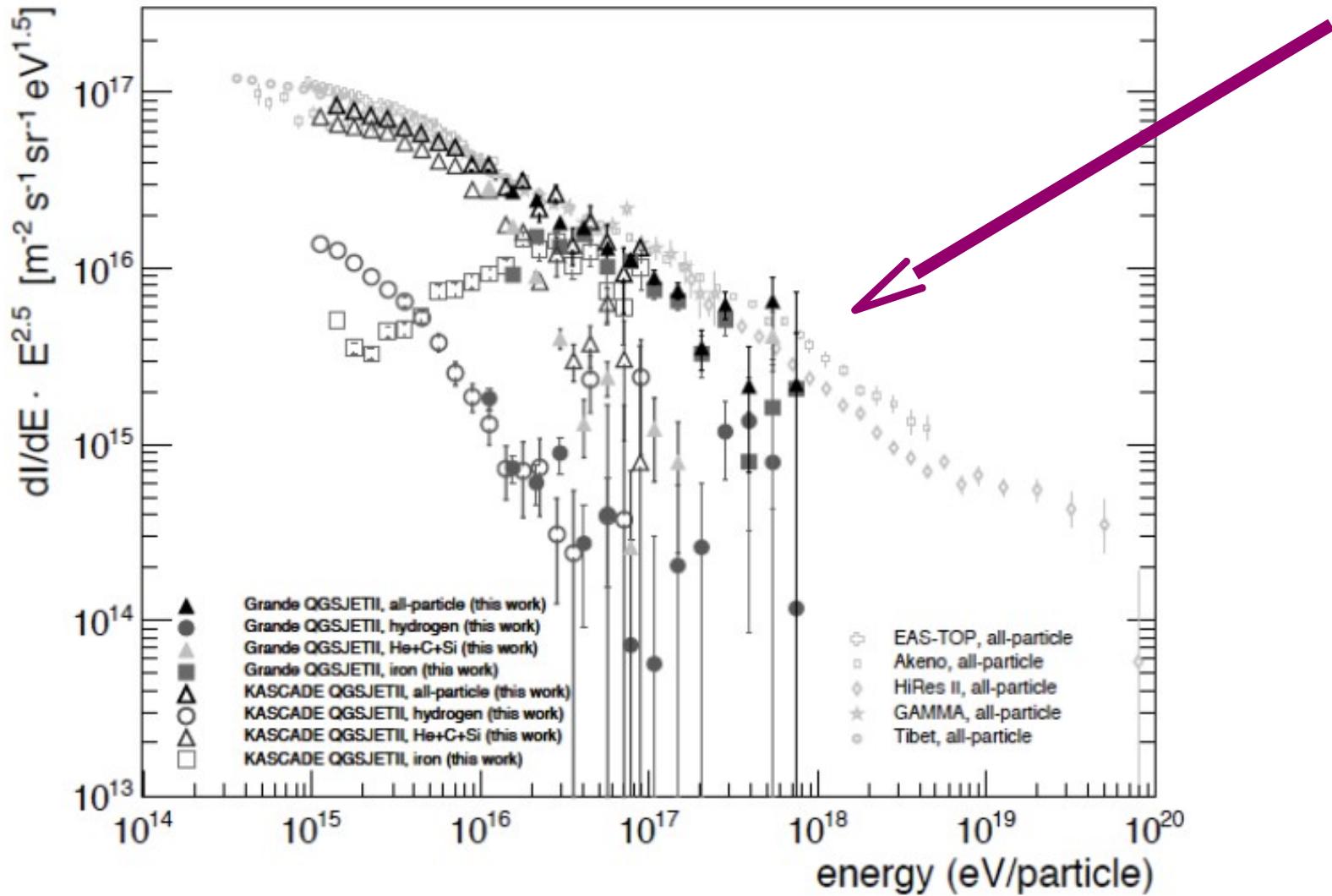
Individual CR trajectories in GMF models

1 EeV protons in Kolmogorov turb.



Giacinti et al., JCAP 07, 31 (2012)

KASKADE-GRANDE protons



ICRC 2011 arXiv: 1111.5436

KASKADE-GRANDE protons

PHYSICAL REVIEW D 87, 081101(R) (2013)

Ankle-like feature in the energy spectrum of light elements of cosmic rays observed with KASCADE-Grande

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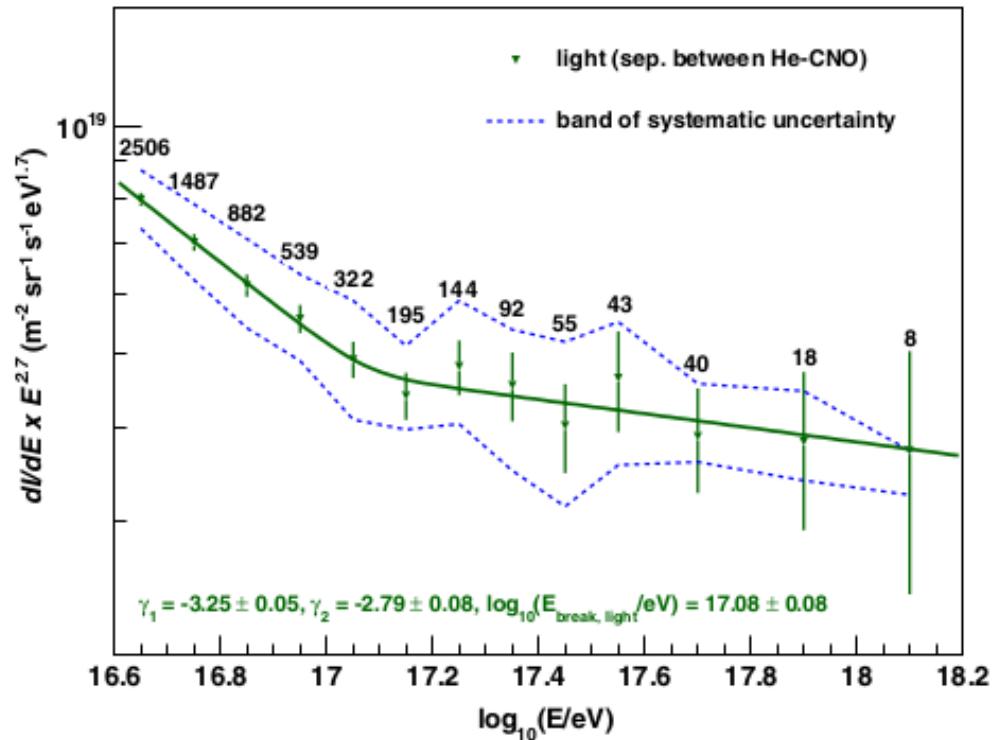


FIG. 5 (color online). The reconstructed energy spectrum of the light mass component of cosmic rays. The number of events per energy bin is indicated as well as the range of systematic uncertainty. The error bars show the statistical uncertainties.

Auger composition and the ankle

Astroparticle Physics 34 (2011) 620–626

Ultra high energy cosmic rays: The disappointing model

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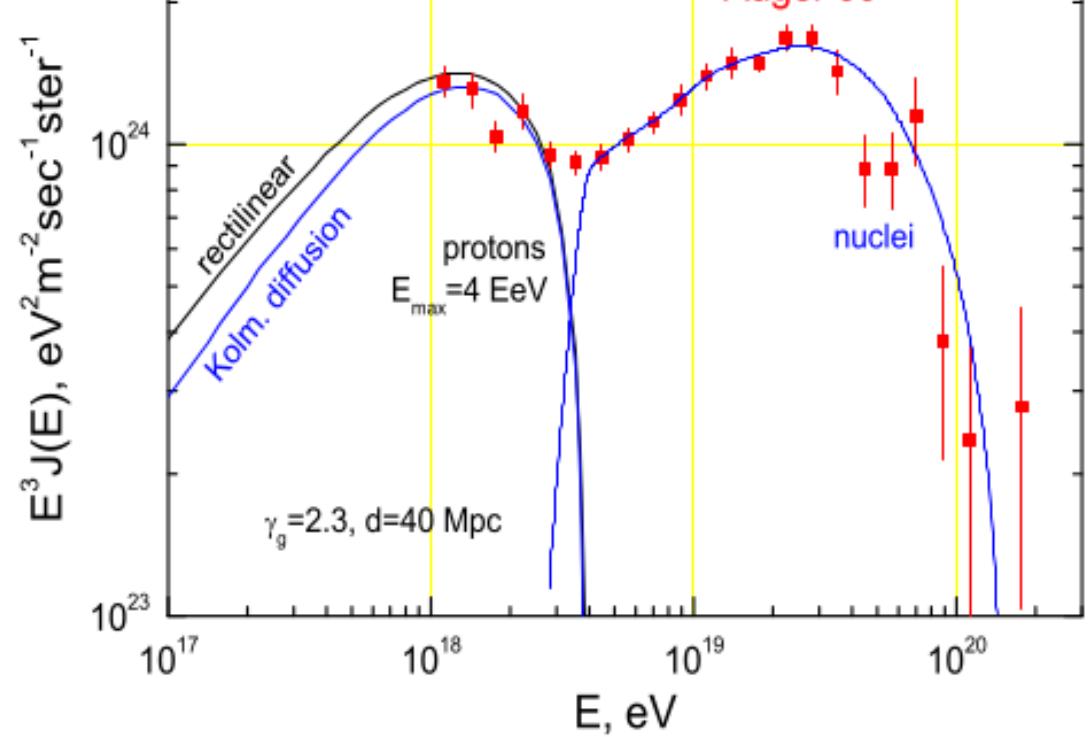
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ABSTRACT

We develop a model for the spectrum of ultra high energy cosmic rays (UHECR) in the range 3 EeV to 35 EeV. The model is based on the assumption that the spectrum observed in both proton and nuclei fluxes is the same. We argue that it must be



Auger composition and the ankle

Could it be a transition between 2 populations of extragalactic CRs ?

Ultra high energy cosmic rays: implications of Auger data for source spectra and chemical composition

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Abstract. We use a kinetic-equation approach to propagation of ultra high energy protons and nuclei to infer possible implications of the data on source composition collected by the Pierre Auger Observatory. Using a histogram fit, we show that a simultaneous fit to the spectrum, elongated dispersion $\sigma(X_{max})$ implies the injection of nuclei with very hard spectra. To underestimate the flux at energies $E \leq 5 \times 10^{18}$ eV, thereby implying a primary component is required, which needs to be of extragalactic nature of this additional component in terms of the recent findings on fluxes and chemical composition, which allows to describe the transition between Galactic and extragalactic cosmic rays.

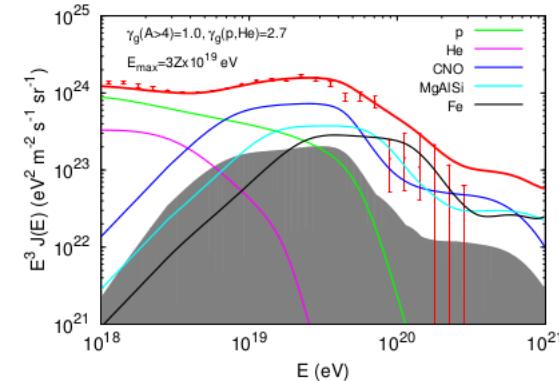


Figure 7. Fluxes of protons and nuclei in the case of two populations of extragalactic sources with an injection power law index $\gamma_g = 2.7$ for proton and helium and $\gamma_g = 1$ for heavier nuclei. Curves with different colors show the sum of the flux of primaries with given mass number A_0 and all secondaries produced by the same nuclear species. The shadowed area shows the flux of all secondaries alone.

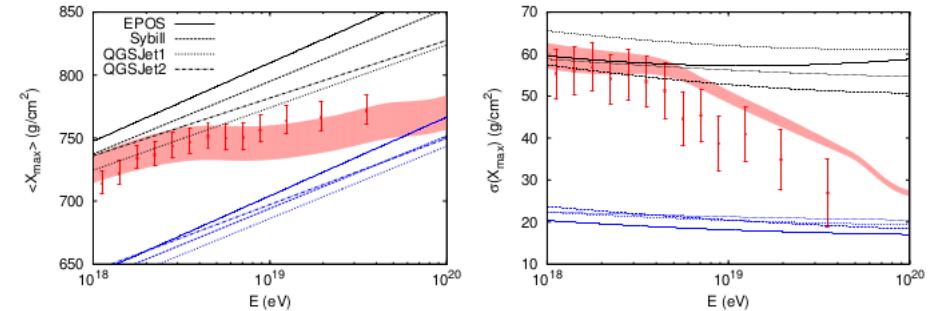


Figure 8. Mean value of the depth of shower maximum $\langle X_{max} \rangle$ and its dispersion $\sigma(X_{max})$ as measured by Auger [20] and in our calculations with the same choice of parameters as in figure 7.

The knee

Explaining the Spectra of Cosmic Ray Groups above the Knee by Escape

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We investigate the possibility that the cosmic ray (CR) knee is entirely explained by the energy-dependent CR leakage from the Milky Way. We test this hypothesis calculating the trajectories of individual CRs with energies between $E/Z = 10^{14}$ eV and 10^{17} eV propagating them in the regular and turbulent Galactic magnetic field. We find a knee-like structure of the CR escape time $\tau_{\text{esc}}(E)$ around $E/Z = \text{few} \times 10^{15}$ eV for a coherence length $l_c \simeq 2\text{pc}$ of the turbulent field, while the decrease of $\tau_{\text{esc}}(E)$ slows down around $E/Z \simeq 10^{16}$ eV in models with a weak turbulent magnetic field. Assuming that the injection spectra of CR nuclei are power-laws, the resulting CR intensities in such a turbulence are consistent with the energy spectra of CR nuclei determined by KASCADE and KASCADE-Grande. We calculate the resulting CR dipole anisotropy as well as the source rate in this model.

Giacinti et al., Submitted, 1403.3380

The knee

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**Astronomy
&
Astrophysics**

Studying Galactic interstellar turbulence through fluctuations in synchrotron emission

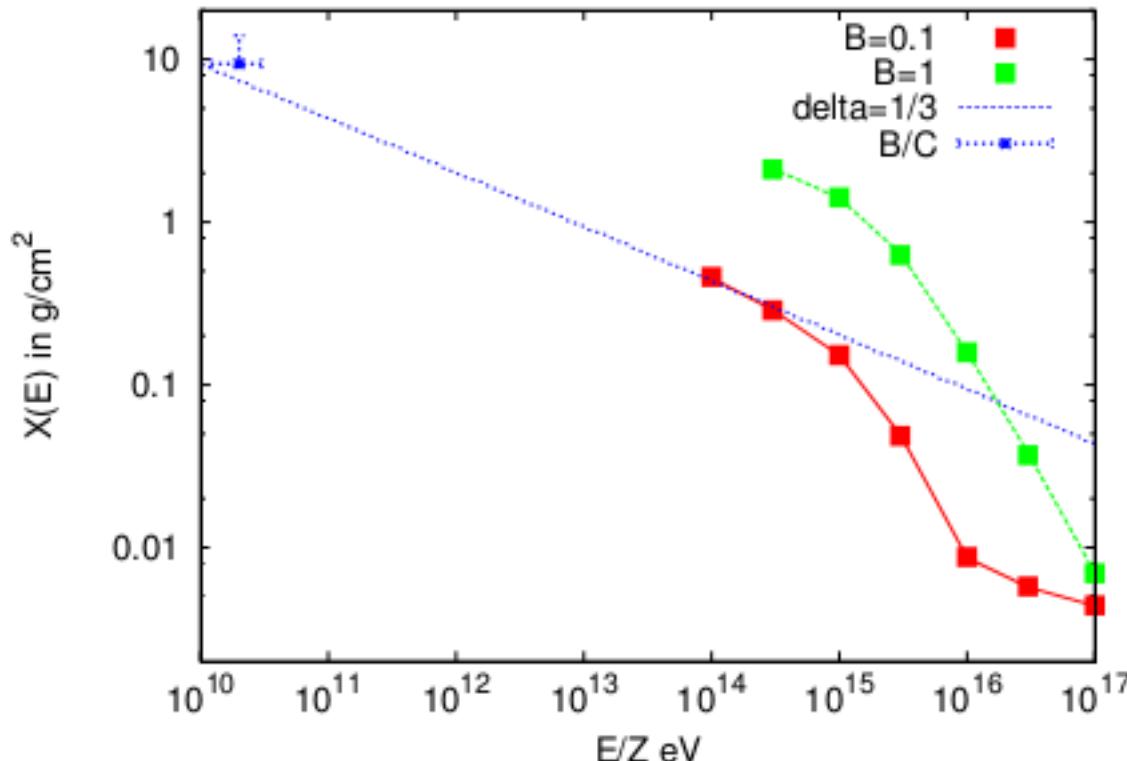
First LOFAR Galactic foreground detection

M. Iacobelli^{1,2}, M. Haverkorn^{3,1}, E. Orrú^{2,3}, R. F. Pizzo², J. Anderson⁴, R. Beck⁴, M. R. Bell⁵, A. Bonafede⁶, K. Chyzy⁷, R.-J. Dettmar⁸, T. A. Enßlin⁹, G. Heald², C. Horellou¹⁰, A. Horneffer⁴, W. Jurusik⁷, H. Junklewitz⁹, M. Kunivoshi⁴, D. D. Mulcahy⁴, R. Paladino³⁵, W. Reich⁴, A. Scaife¹¹, C. Sobey⁴, C. Sotomayor-Beltran¹²

a variation of the ratio of random to ordered field as a function of Galactic coordinates, supporting different turbulent regimes.

Conclusions. We present the first LOFAR detection and imaging of the Galactic diffuse synchrotron emission around 160 MHz from the highly polarized Fan region. The power spectrum of the foreground synchrotron fluctuations is approximately a power law with a slope $\alpha \approx -1.84$ up to angular multipoles of $\lesssim 1300$, corresponding to an angular scale of ~ 8 arcmin. We use power spectra fluctuations from LOFAR as well as earlier GMRT and WSRT observations to constrain the outer scale of turbulence (L_{out}) of the Galactic synchrotron foreground, finding a range of plausible values of 10–20 pc. Then, we use this information to deduce lower limits of the ratio of ordered to random magnetic field strength. These are found to be 0.3, 0.3, and 0.5 for the LOFAR, WSRT and GMRT fields considered respectively. Both these constraints are in agreement with previous estimates.

The knee



Giacinti et al.,
Submitted, 1403.3380

FIG. 1: Grammage $X(E)$ traversed by CR protons as a function of energy E/Z for two different levels of magnetic turbulence in the GMF model of Ref. [10], with $l_c = 2 \text{ pc}$.

Gaz
distribution :

$$n(z) = n_0 \exp(-(z/z_{1/2})^2) \text{ with } n_0 = 0.3/\text{cm}^3 \text{ at } R_\odot \text{ and } z_{1/2} = 0.21 \text{ kpc}$$

$$n = 10^{-4} \text{ g}/\text{cm}^3 \quad \text{Minimum, up to } z = +/- 10 \text{ kpc}$$

The knee

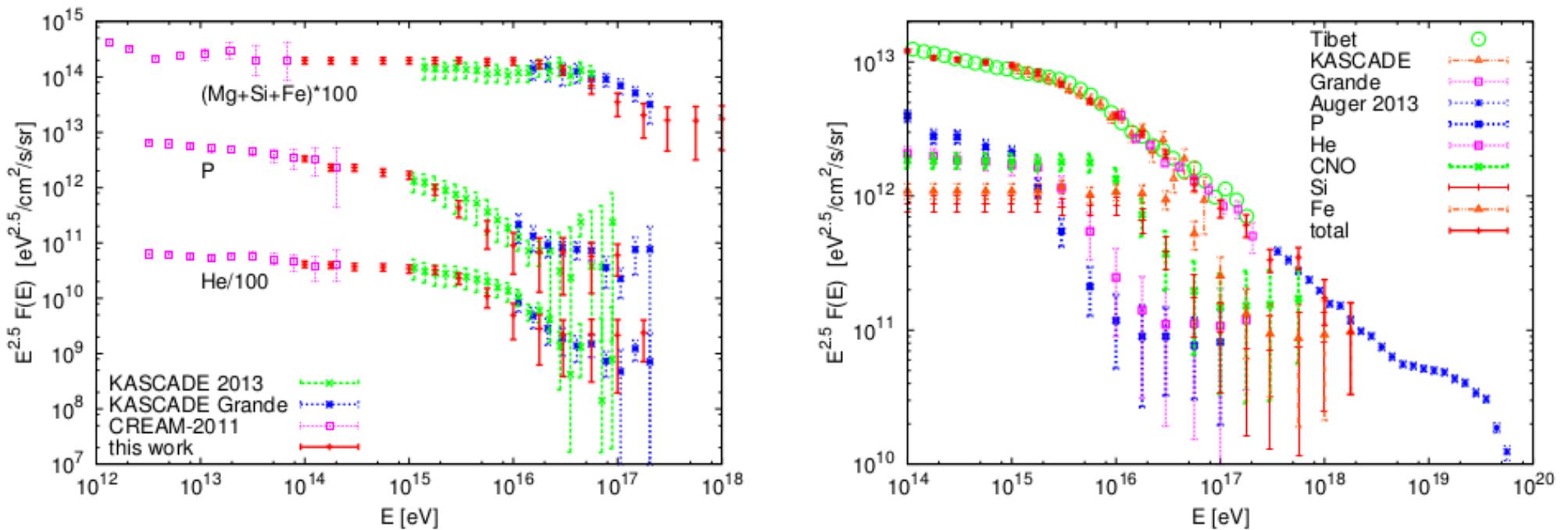


FIG. 3: Left: The (rescaled) intensity $I(E)$ of CR protons, He and Fe nuclei compared to the experimental data from KASCADE [2], KASCADE-Grande [2] and CREAM [24], using the rescaled turbulent GMF. Right: Intensity $I(E)$ of CR protons, He, CNO, MgSi and Fe nuclei as a function of energy E per nucleus, obtained using the same GMF.

Giacinti et al., Submitted, 1403.3380

The knee

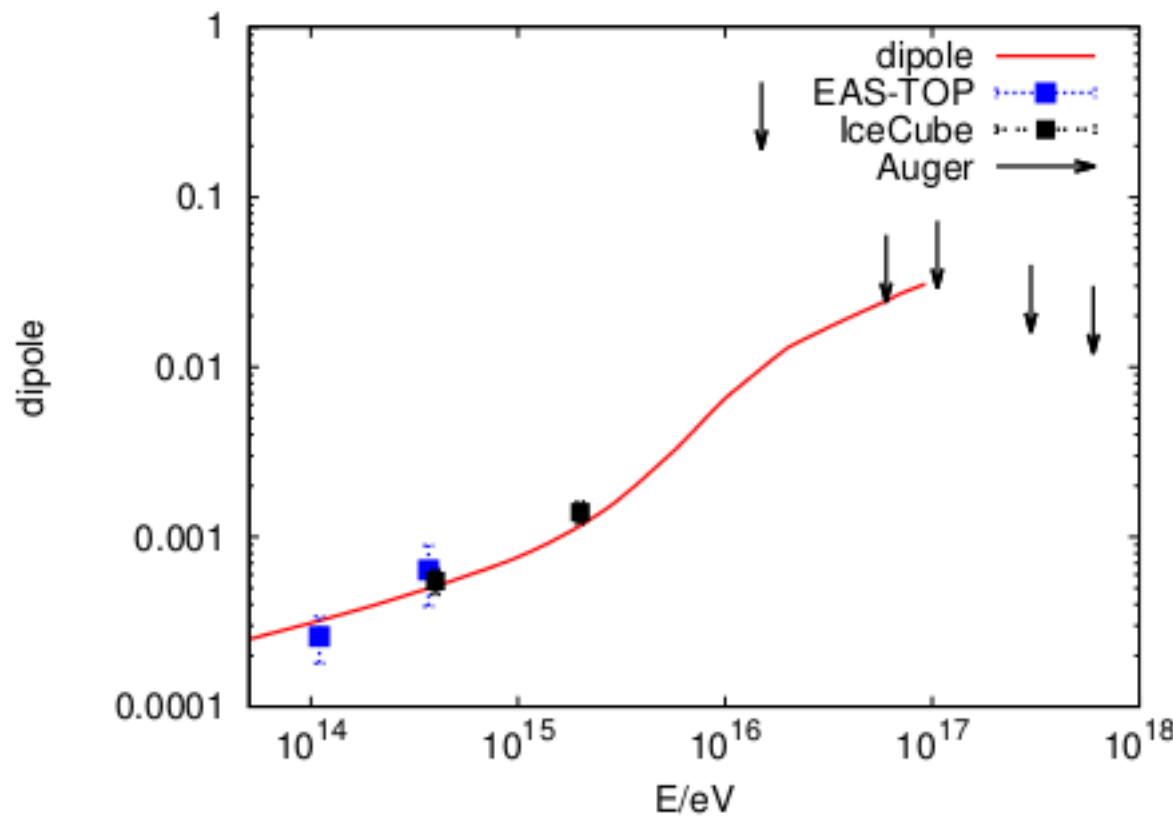


FIG. 2: Dipole amplitude $d(E)$ as a function of energy E/Z in the GMF model of Ref. [10] with reduced turbulent field and $l_c = 2$ pc.

Giacinti et al., Submitted, 1403.3380

Conclusions and perspectives

- Short review on where the transition may happen
- Limitations of the diff. approx. at the highest energies
 - + Make use of the recent knowledge of the GMFs
- Have propagated individual CRs in recent GMF models
- Composition vs anisotropy allow for a few conclusions :
 - If sub-ankle mostly light => Extragalactic
 - Remaining Fe ? May still be Galactic
 - > Composition vs Anisotropy between knee and ankle can solve this question (KASKADE-GRANDE + Low extensions of Auger and TA)
- Knee as a signature from CR escape from the Galaxy ? Still allowed. Can be tested in the relatively near future by constraining the CR anisotropy above a few 10s of PeV.