Search for the sources of Cosmic rays

Dmitri Semikoz

APC , Paris

Overview:

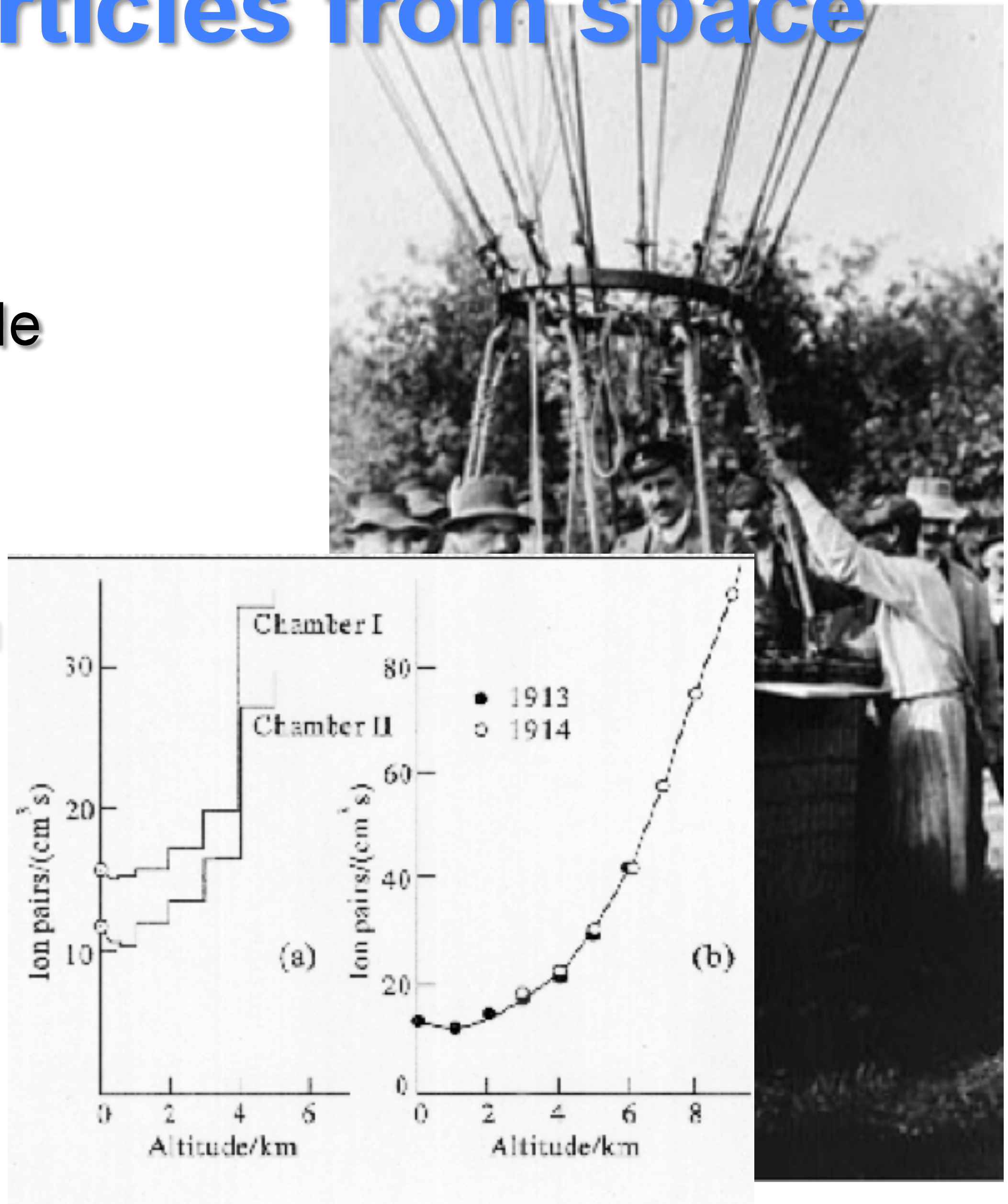
- *Introduction*
- *Acceleration of cosmic rays*
- *Magnetic field of Milky Way*
- *How galactic CR diffuse from their sources*
- *Search for TeV CR sources with Fermi LAT*
- *Extragalactic magnetic fields*
- *Search for UHECR sources*
- *Summary*

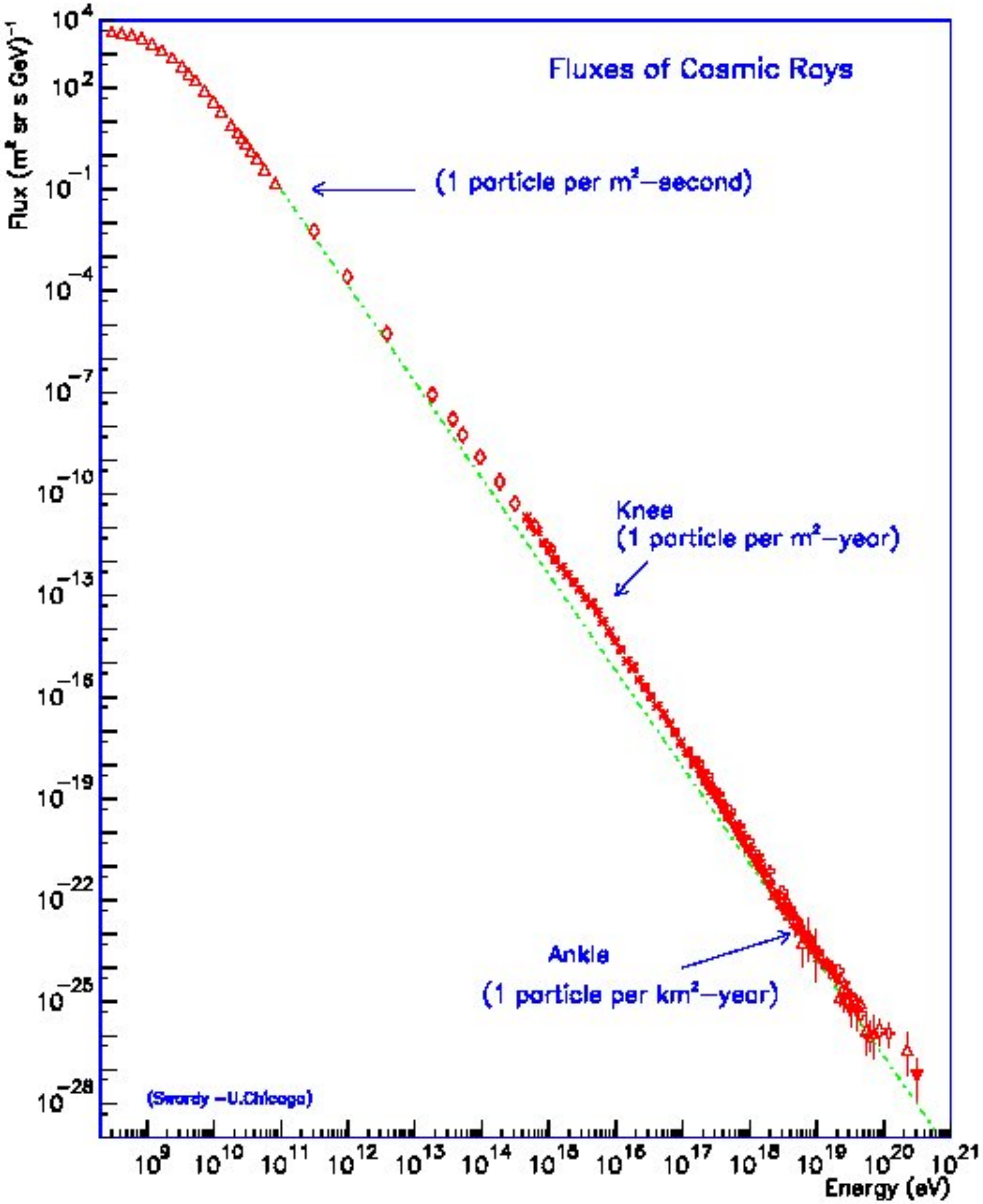
Galactic and extragalactic cosmic rays

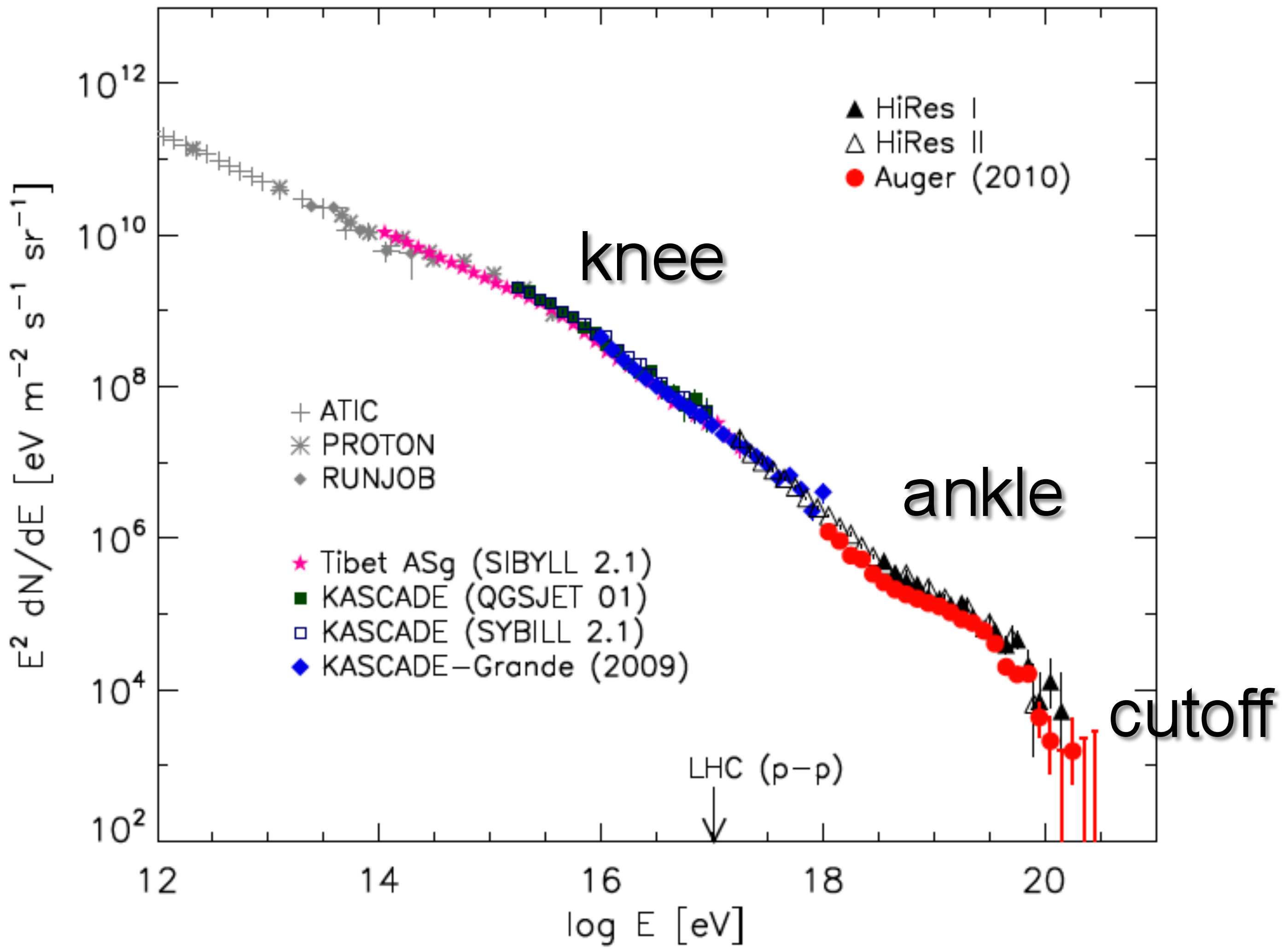
•High-energy particles from space

•Cosmic Rays (CR) are charged high-energy particles coming from outside the atmosphere.

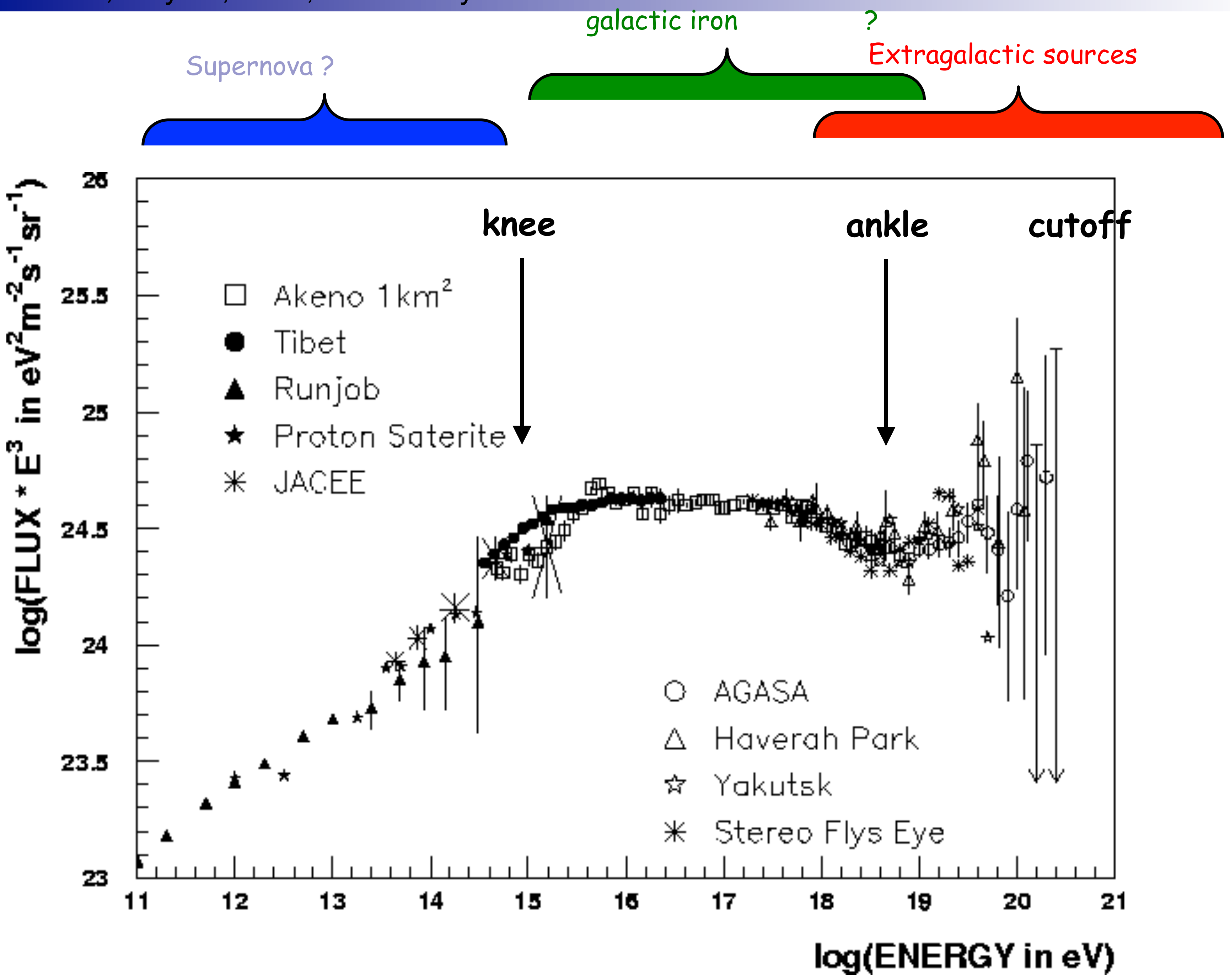
•Discovered 100 yr ago by V.Hess in 1912, via detection of increase of the rate of discharge of an electrometer with increase of the altitude.




Fluxes of Cosmic Rays
(1 particle per m²–second)
Knee
(1 particle per m²–year)
Ankle
(1 particle per km²–year)
(Swordy – U.Chicago)
Flux (m² sr s GeV)⁻¹
Energy (eV)

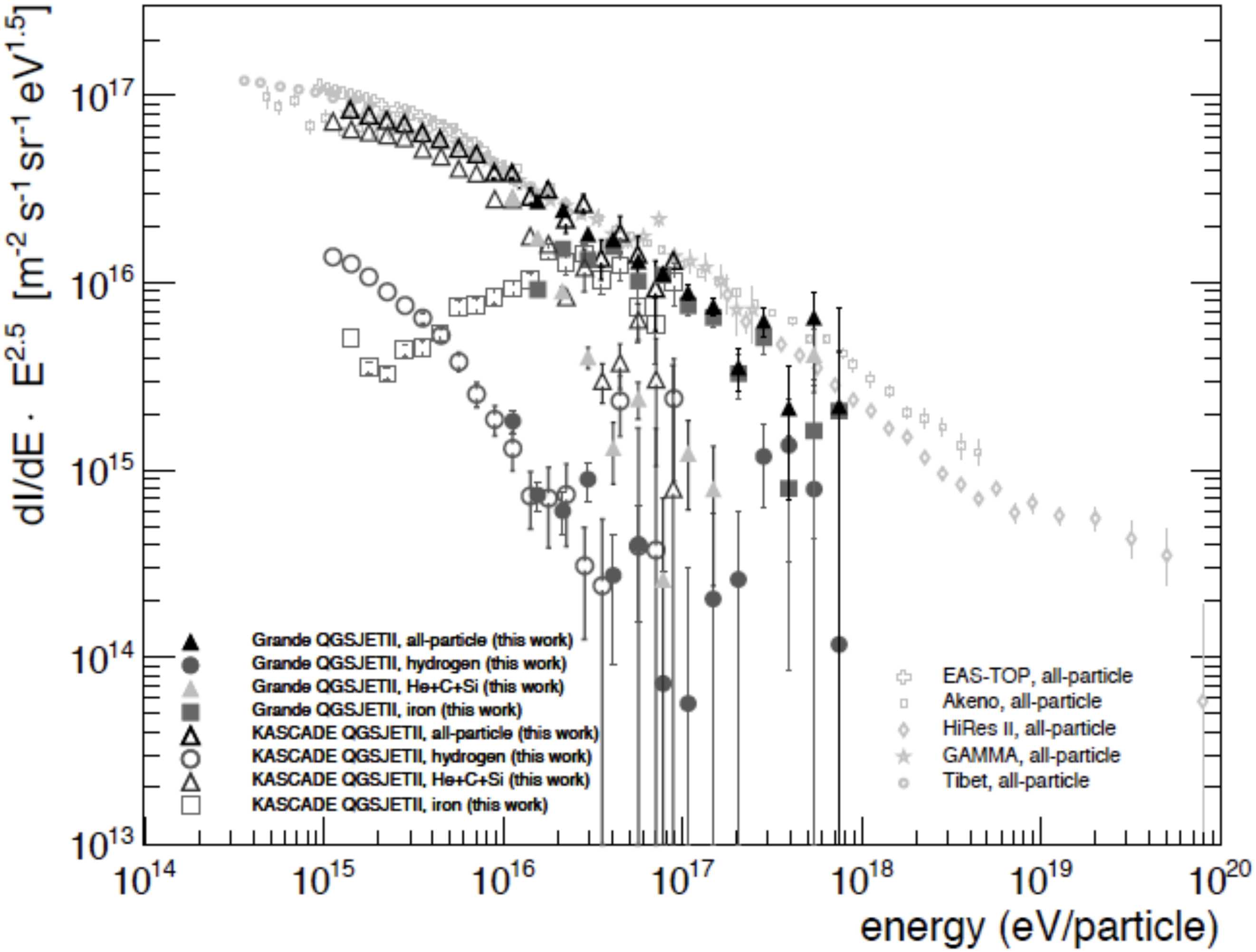


10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
E^2 dN/dE [eV m^{-2} s^{-1} sr^{-1}]
12
14
16
18
20
log E [eV]
HiRes I
HiRes II
Auger (2010)
ATIC
PROTON
RUNJOB
Tibet ASg (SIBYLL 2.1)
KASCADE (QGSJET 01)
KASCADE (SYBILL 2.1)
KASCADE–Grande (2009)
LHC (p–p)
knee
ankle
cutoff



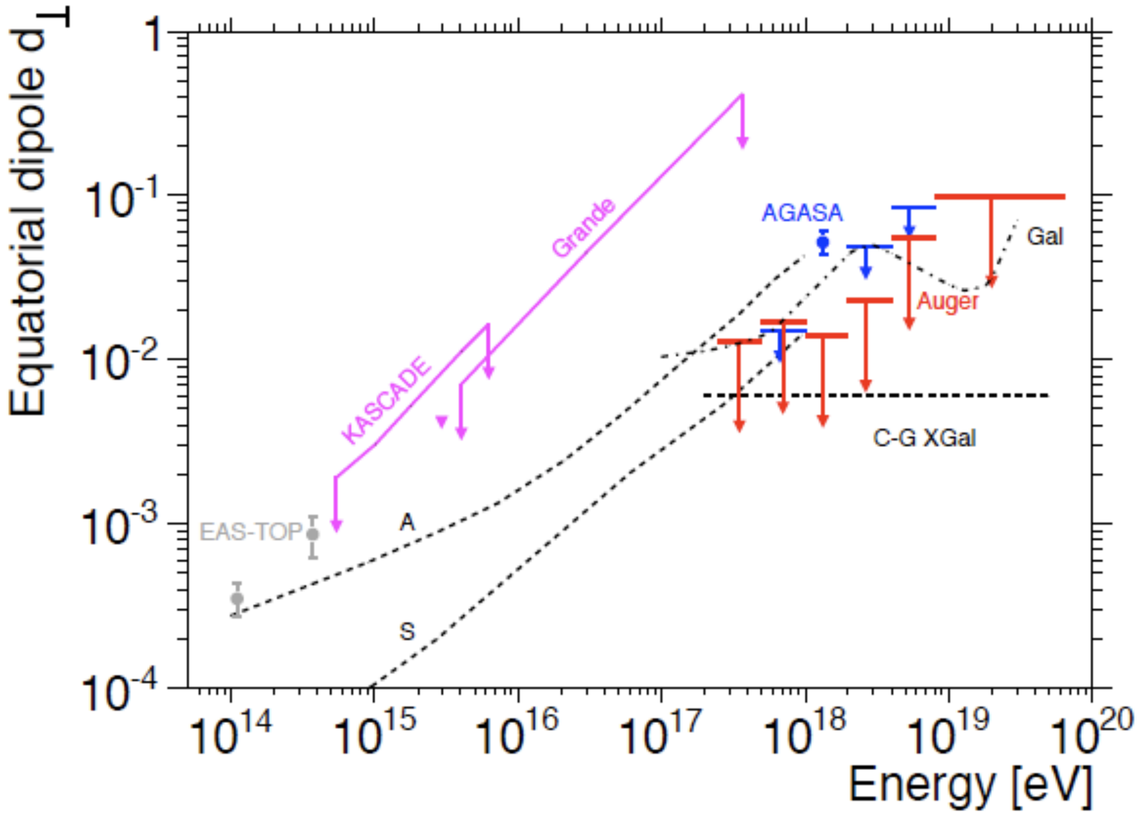
galactic iron
?
Extragalactic sources
Supernova ?
knee
ankle
cutoff
Akeno 1km²
Tibet
Runjob
Proton Saterite
JACEE
AGASA
Haverah Park
Yakutsk
Stereo Flys Eye
log(FLUX * E³ in eV²m⁻²s⁻¹sr⁻¹)
log(ENERGY in eV)

Mass composition knee region



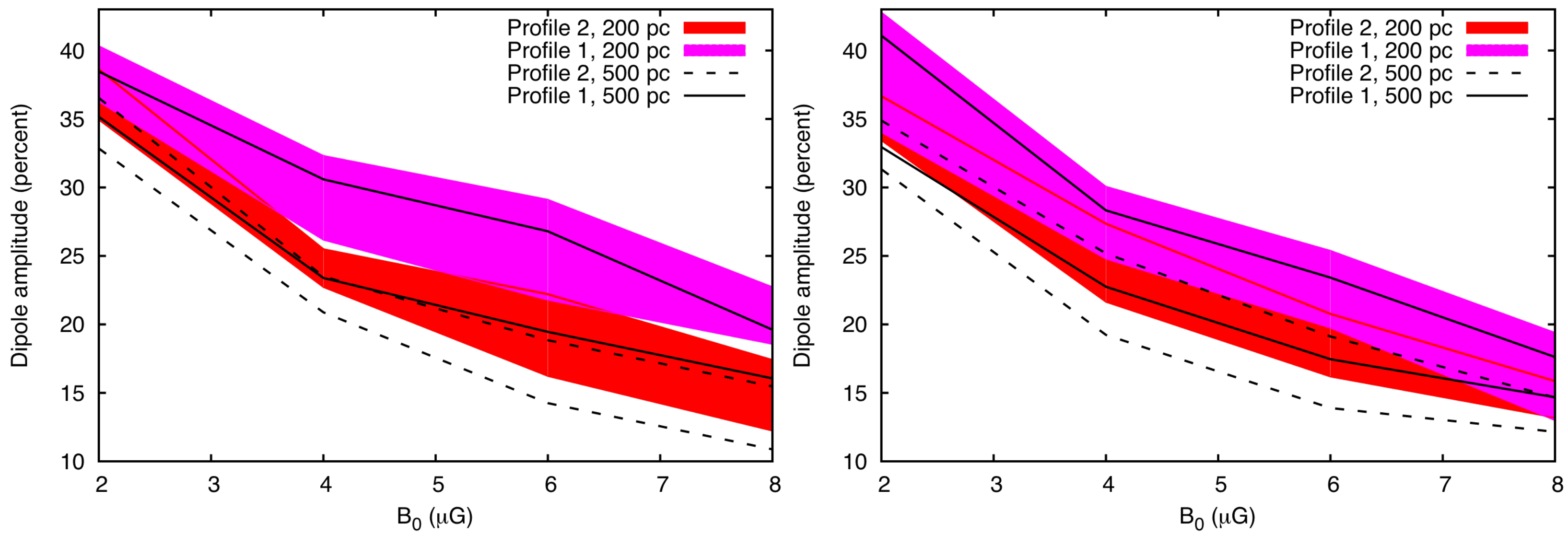
ICRC 2011 arXiv: 1111.5436

Anisotropy in UHECR



Pierre Auger Collaboration, arXiv:1103.2721

1 EeV protons from galactic sources

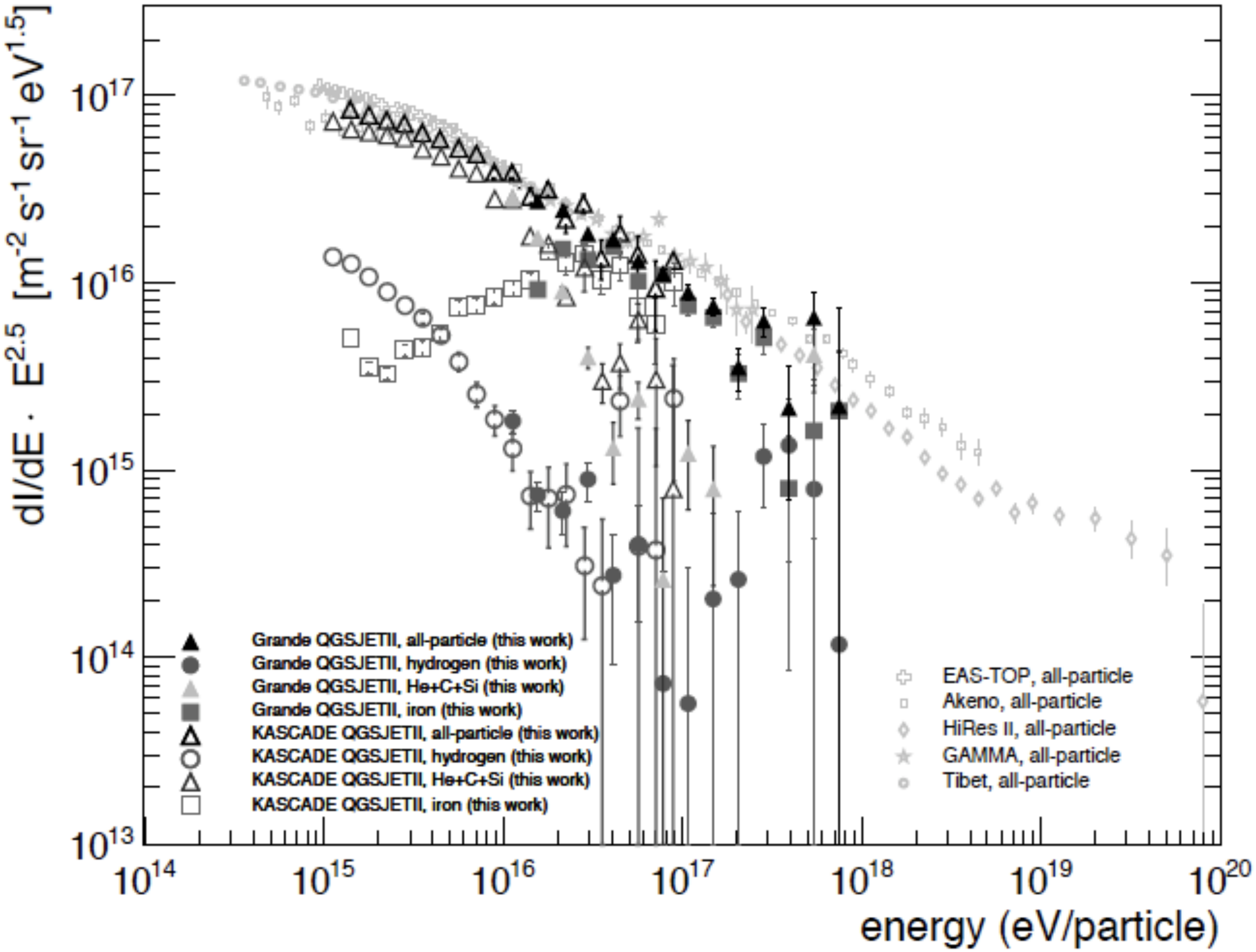


Turb. Magn. Field spectrum Kraichnan

Turb. Magn. Field spectrum Kolmogorov

G.Giacinti et al, arXiv:1112.5599

KASCADE-Grande protons



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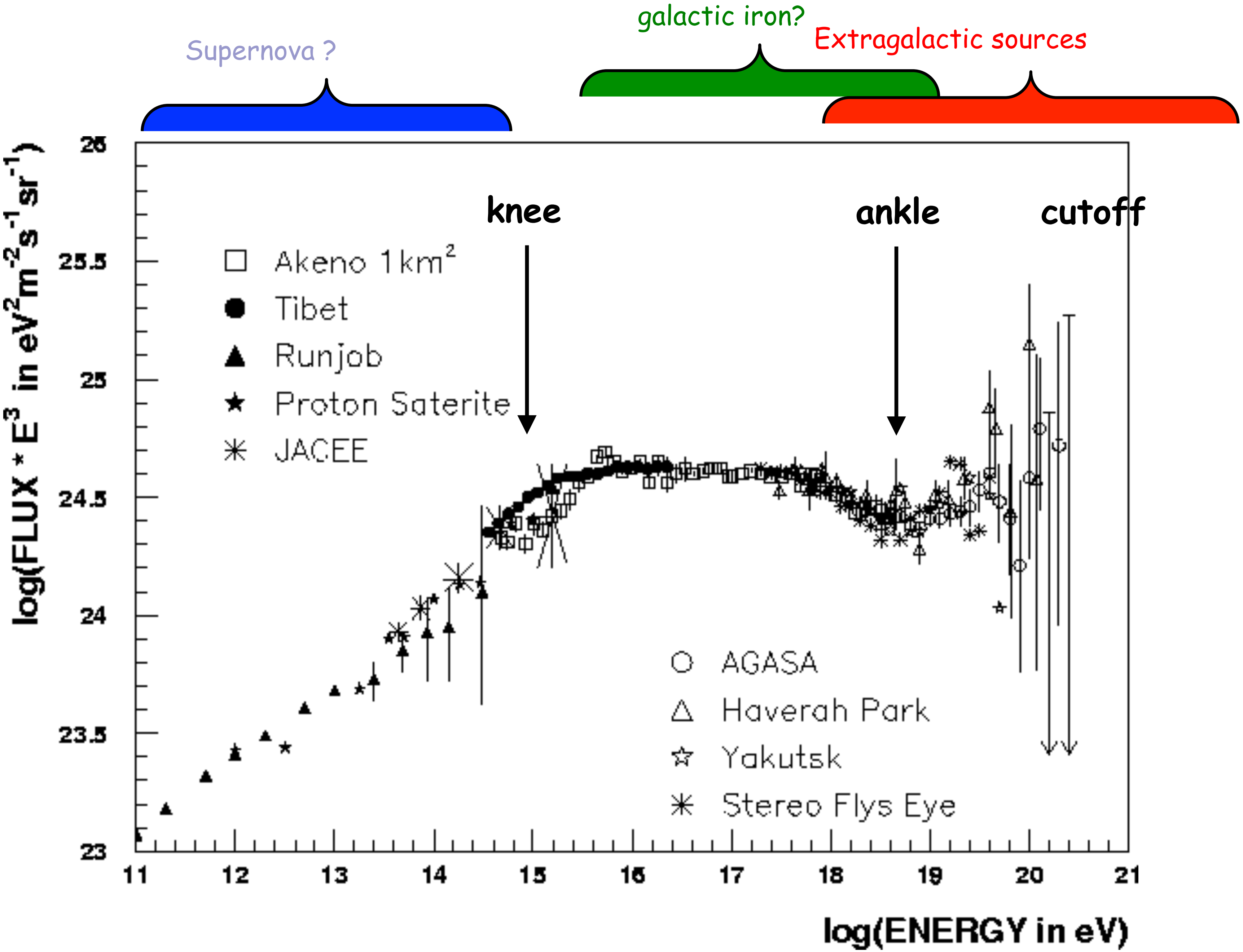


Supernova ?
galactic iron?
Extragalactic sources
knee
ankle
cutoff
Akeno 1 km²
Tibet
Runjob
Proton Saterite
JACEE
AGASA
Haverah Park
Yakutsk
Stereo Flys Eye
log(FLUX * E³ in eV²m⁻²s⁻¹sr⁻¹)
log(ENERGY in eV)
23
23.5
24
24.5
25
25.5
26
11
12
13
14
15
16
17
18
19
20
21

Unresolved questions for search of galactic sources:

- *Detailed structure of galactic magnetic field*
- *What are the sources of Galactic cosmic rays?*
  - *Acceleration problem?*
  - *How good is diffusion approximation? Not good near sources!*
  - *Electrons or hadrons produce observed gamma-rays?*
  - *Can neutrino telescopes observe galactic sources?*

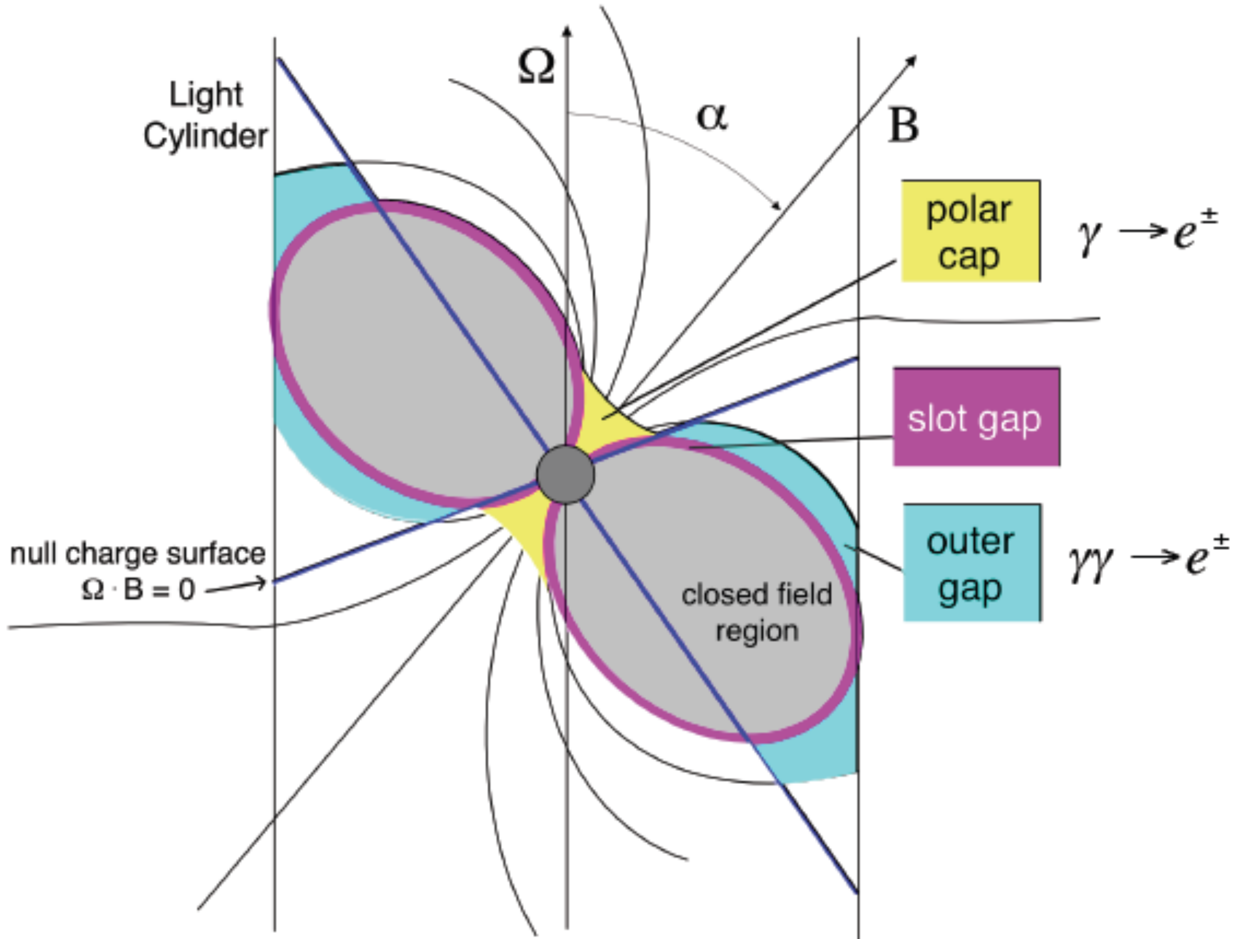
Search for the UHE sources:

- *Mass composition heavy in Auger / light in HiRes/TA: has to be solved*
- *3D structure of extragalactic magnetic fields + remove foregrounds from Galactic magnetic field*
- *What are the sources of extragalactic CR?*
  - *Acceleration to highest energies*
  - *Any real anisotropy at highest energies?*
  - *Search for the source correlations for nuclei?*

Acceleration of cosmic rays

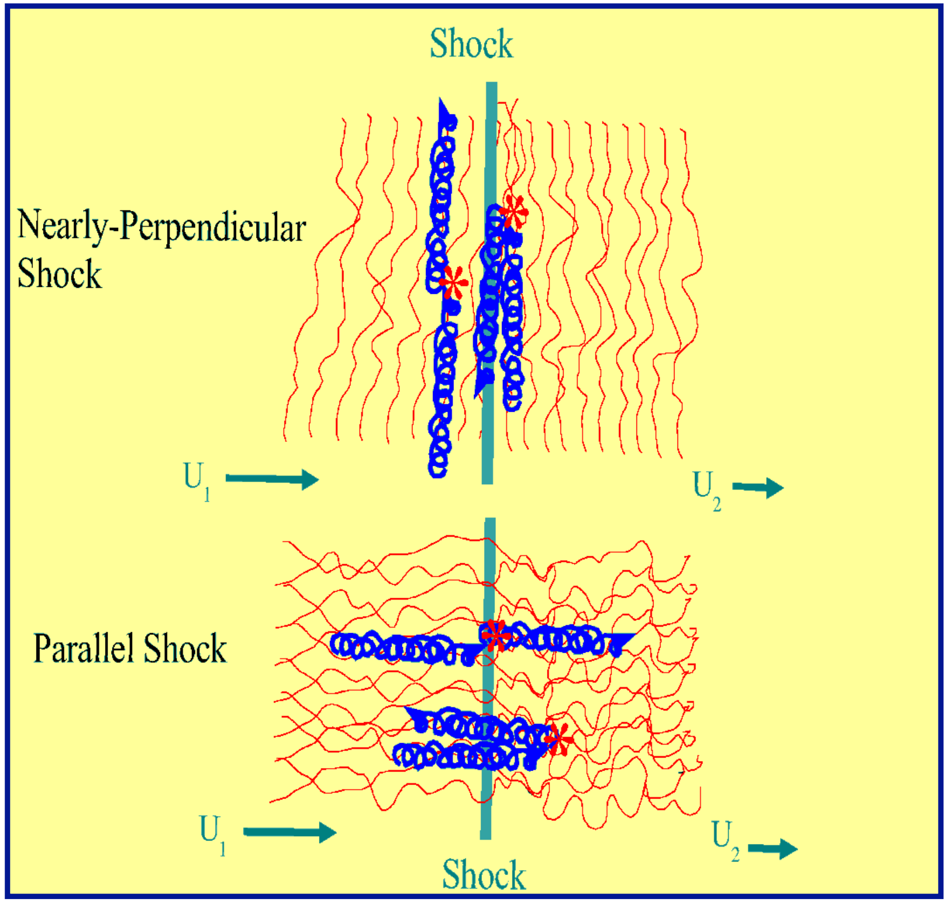
Acceleration by electric field

Pulsar accelerator geometries

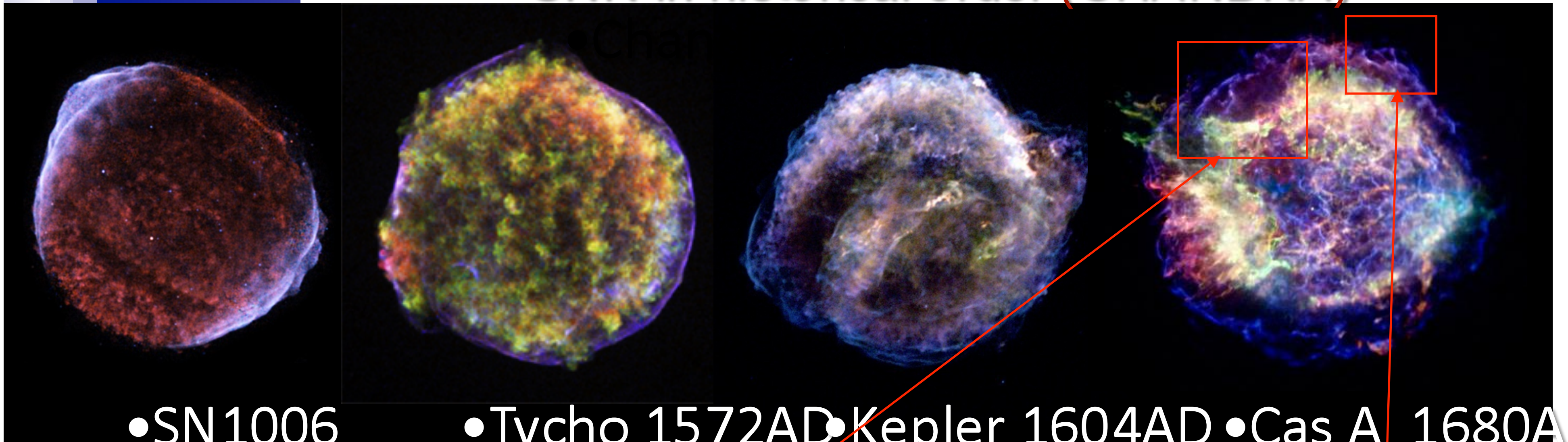


Diffusive Shock Acceleration

- Discovered by four independent teams:
  - *Bell (1978), Krymsky (1977), Axford et al (1977), Blandford & Ostriker (1978)*
- Requires that particles diffuse across a diverging flow (a shock)
- Also requires some form of trapping near the shock



•SNR in historical order (CHANDRA)

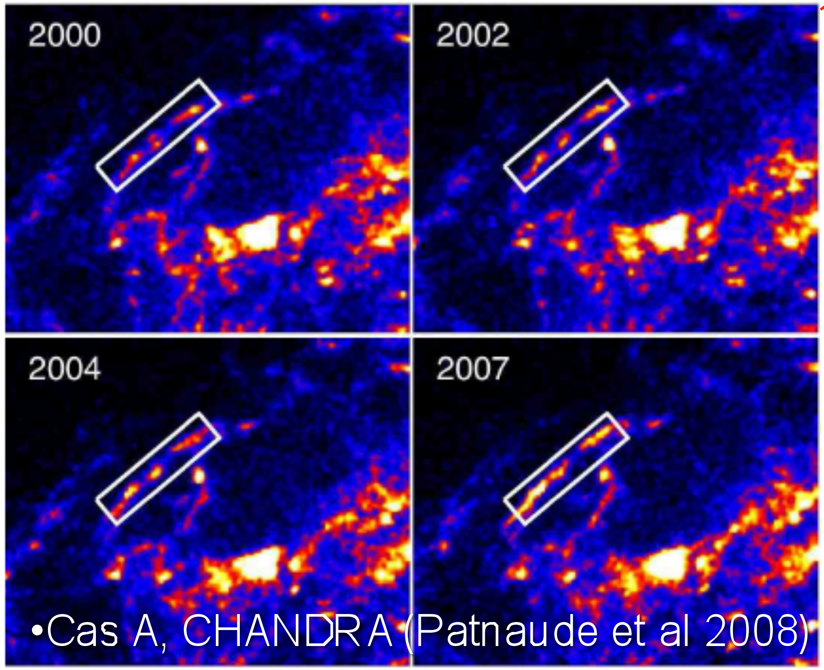


•NASA/CXC/Rutgers/ •J.Hughes et al.

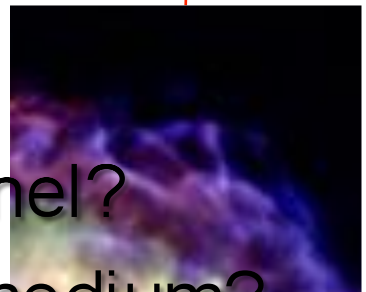
•NASA/CXC/Rutgers/ •J.Warren & J.Hughes et al.

•NASA/CXC/NCSU/ •S.Reynolds et al.

•NASA/CXC/MIT/UMassAmherst/ •M.D.Stage et al.



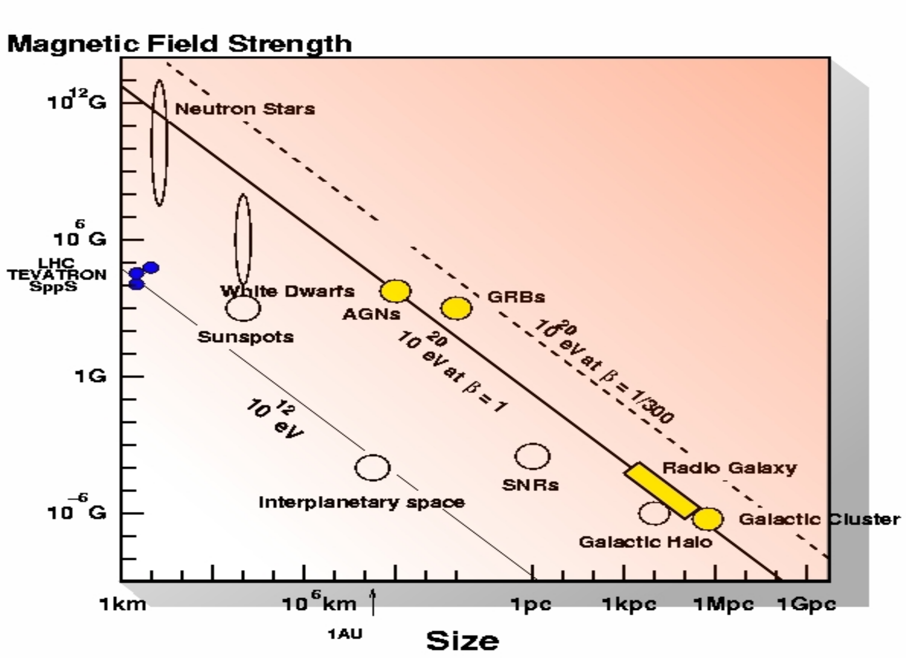
•Cas A, CHANDRA (Patnaude et al 2008)



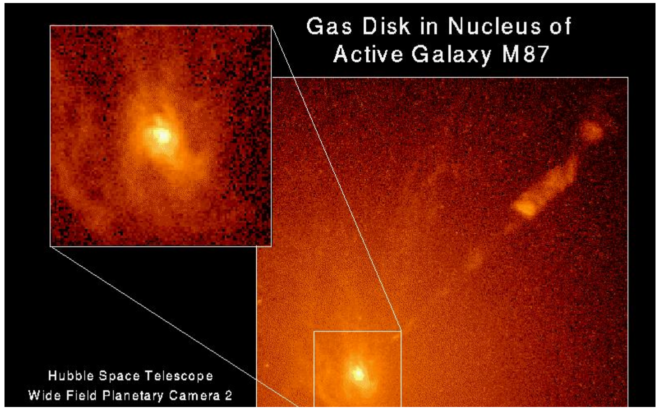
- High speed shrapnel?
- Clumpy ambient medium?
- CR-driven instability?

•Shock structure maps out
•pre-shock features (B, ρ...)

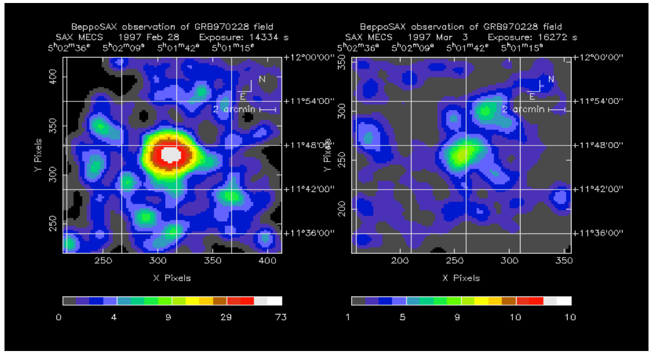
Acceleration of UHECR



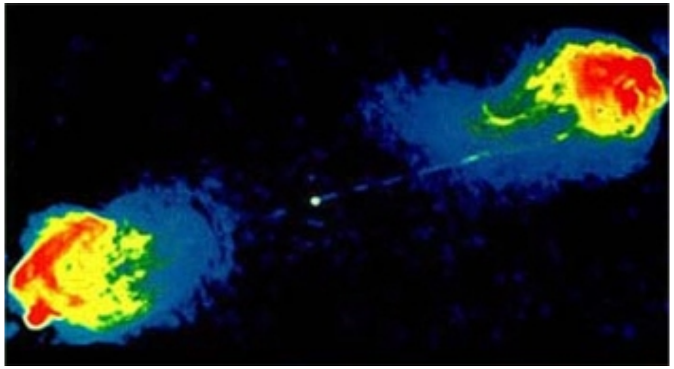
A.G.N.



GRB



Radio Galaxy Lobe



- Hillas 1984
- Shock acceleration $1/E^{\alpha}$ $\alpha>=2$
- Electric field acceleration line at E_{max}
- Many other types

Acceleration with energy losses

- Maximum energy

$$\mathcal{E}_{\max}(B,R) = \begin{cases} \mathcal{E}_{\rm H}(B,R), & B \le B_0(R); \\ \mathcal{E}_{\rm loss}(B,R), & B > B_0(R), \end{cases}$$

- Where

$$B_0(R) = 3.16 \times 10^{-3}\ \mathrm{G}\ \frac{A^{4/3}}{Z^{5/3}} \left(\frac{R}{\mathrm{kpc}}\right)^{-2/3} \eta^{1/3},$$

K.Ptitsina and S.Troitsky, **arXiv:0808.0367**

Acceleration with energy losses

- Hillas maximum energy

$$\mathcal{E}_{\rm H}(B,R) = 9.25 \times 10^{23}\ {\rm eV}\ Z \left(\frac{R}{\rm kpc}\right)\left(\frac{B}{\rm G}\right)$$

- Diffusive acceleration:

$$\mathcal{E}_{\rm loss}(B,R) = \mathcal{E}_{\rm d}(B,R) = 2.91 \times 10^{16}\ {\rm eV}\ \frac{A^4}{Z^4}\left(\frac{R}{\rm kpc}\right)^{-1}\left(\frac{B}{\rm G}\right)^{-2}$$

Acceleration with energy losses

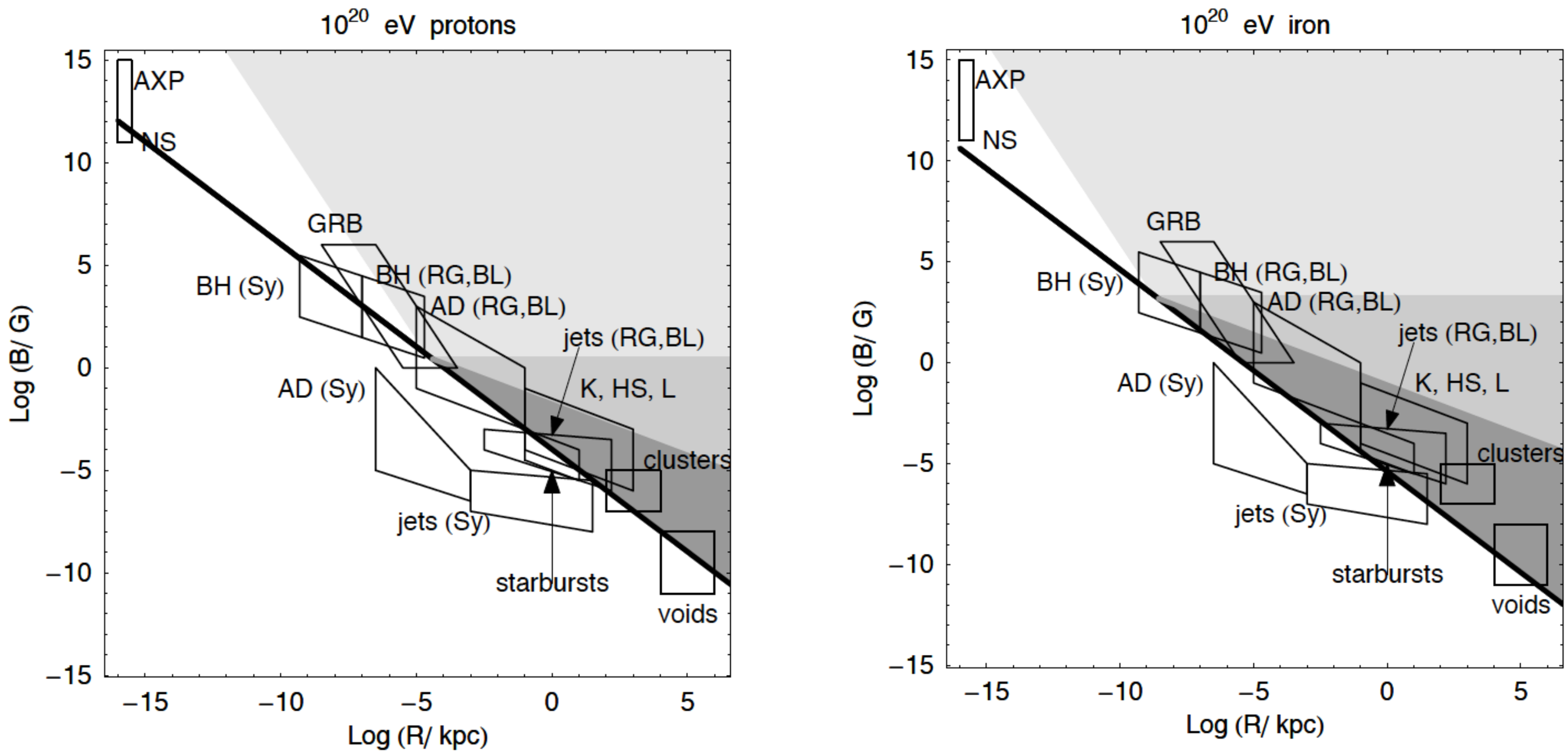
- Inductive with synchrotron loses (jets)

$$\mathcal{E}_{\rm loss}(B,R) = \mathcal{E}_{\rm s}(B,R) = 1.64 \times 10^{20}\ \mathrm{eV}\ \frac{A^2}{Z^{3/2}} \left(\frac{B}{\mathrm{G}}\right)^{-1/2} \eta^{1/2}$$

- Inductive with curvature losses (cores)

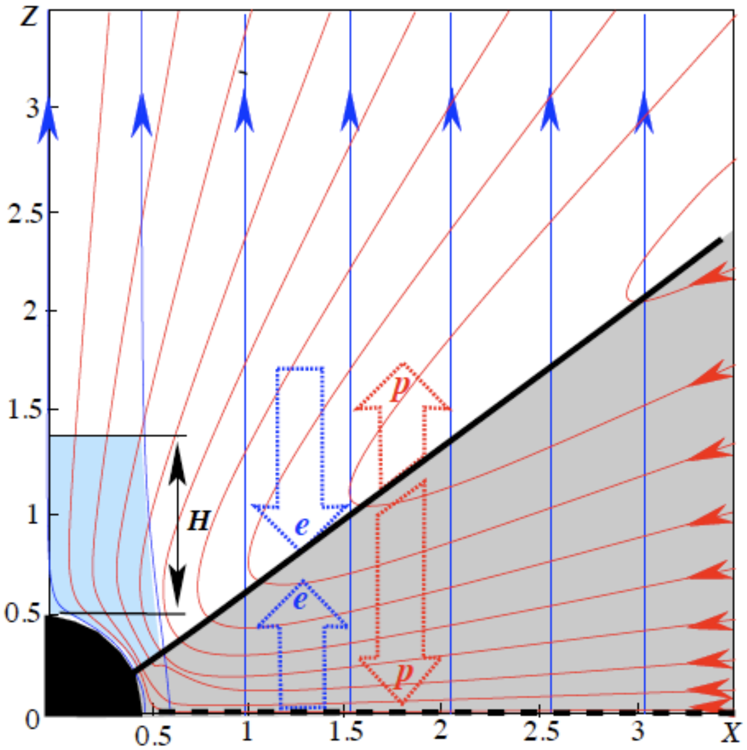
$$\mathcal{E}_{\rm loss}(B,R) = \mathcal{E}_{\rm c}(B,R) = 1.23 \times 10^{22}\ \mathrm{eV}\ \frac{A}{Z^{1/4}} \left(\frac{R}{\mathrm{kpc}}\right)^{1/2} \left(\frac{B}{\mathrm{G}}\right)^{1/4} \eta^{1/4}$$

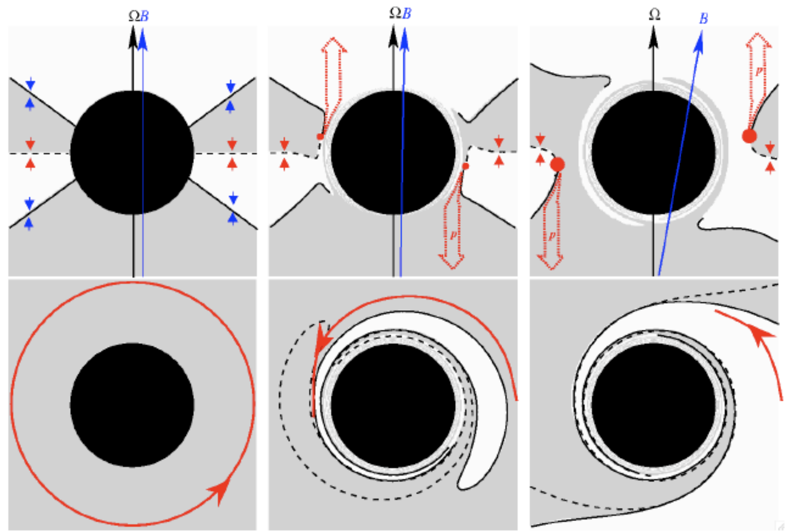
Acceleration with energy losses



K.Ptitsina and S.Troitsky, **arXiv:0808.0367**

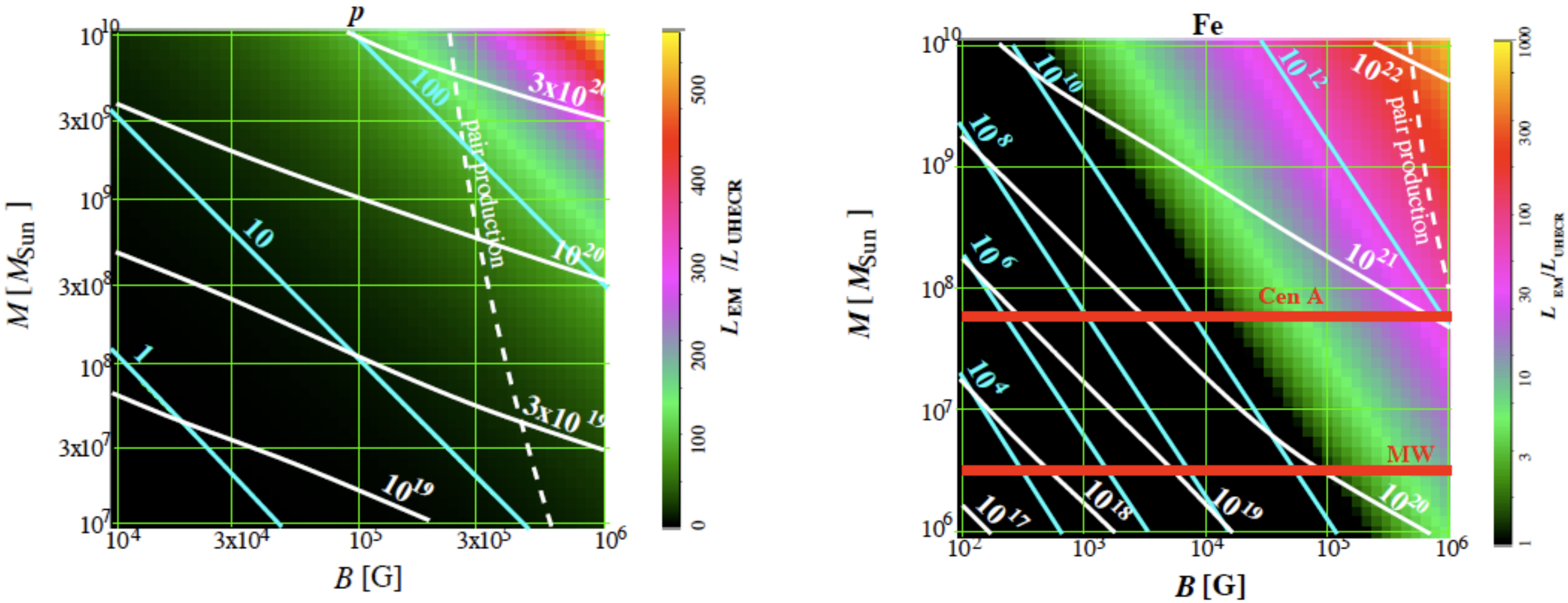
Acceleration near Black Hole in the electric field





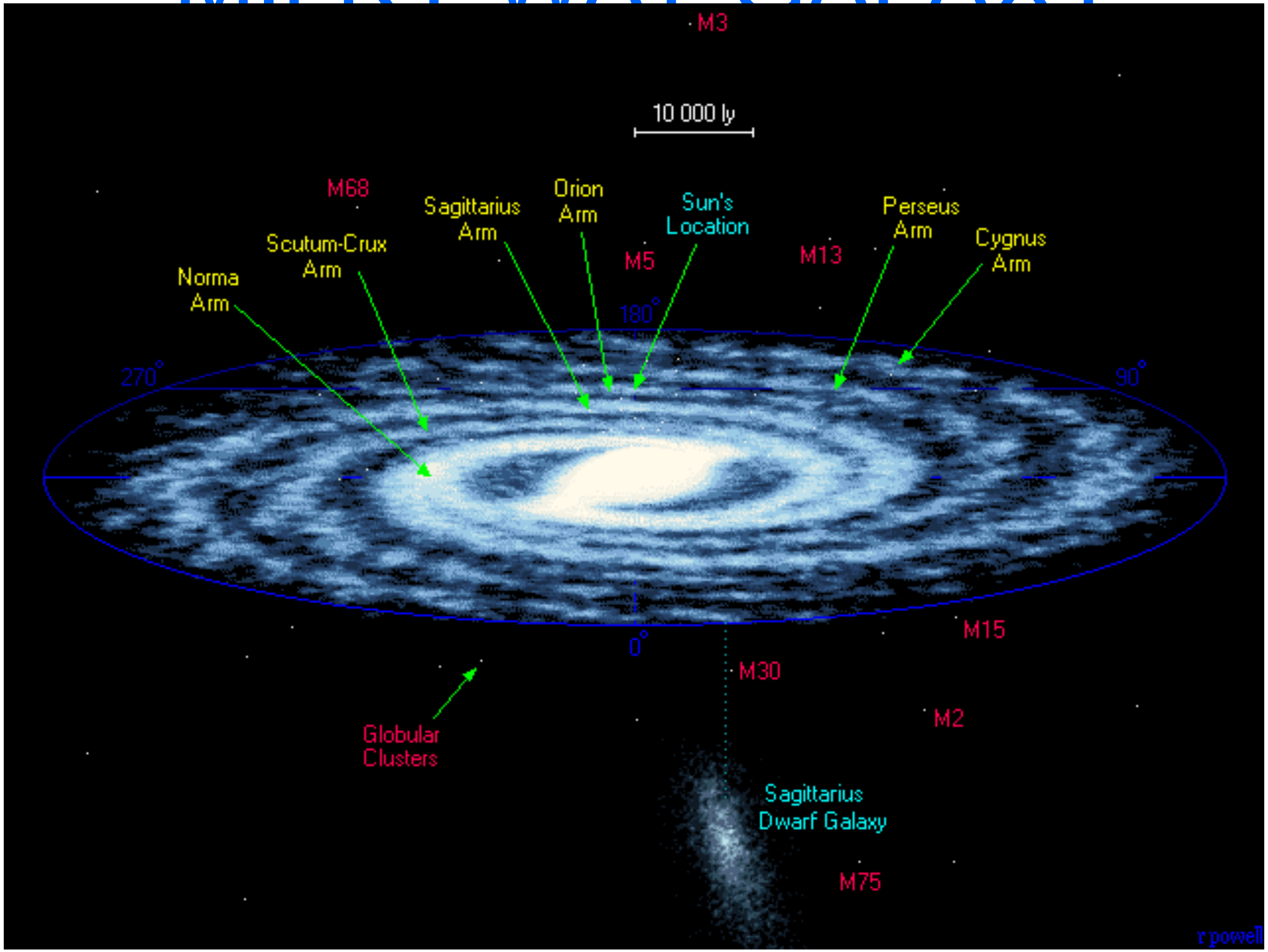
A.Neronov, D.S. and I.Tkachev astro-ph/0712.1737

Acceleration near Black Hole in the electric field

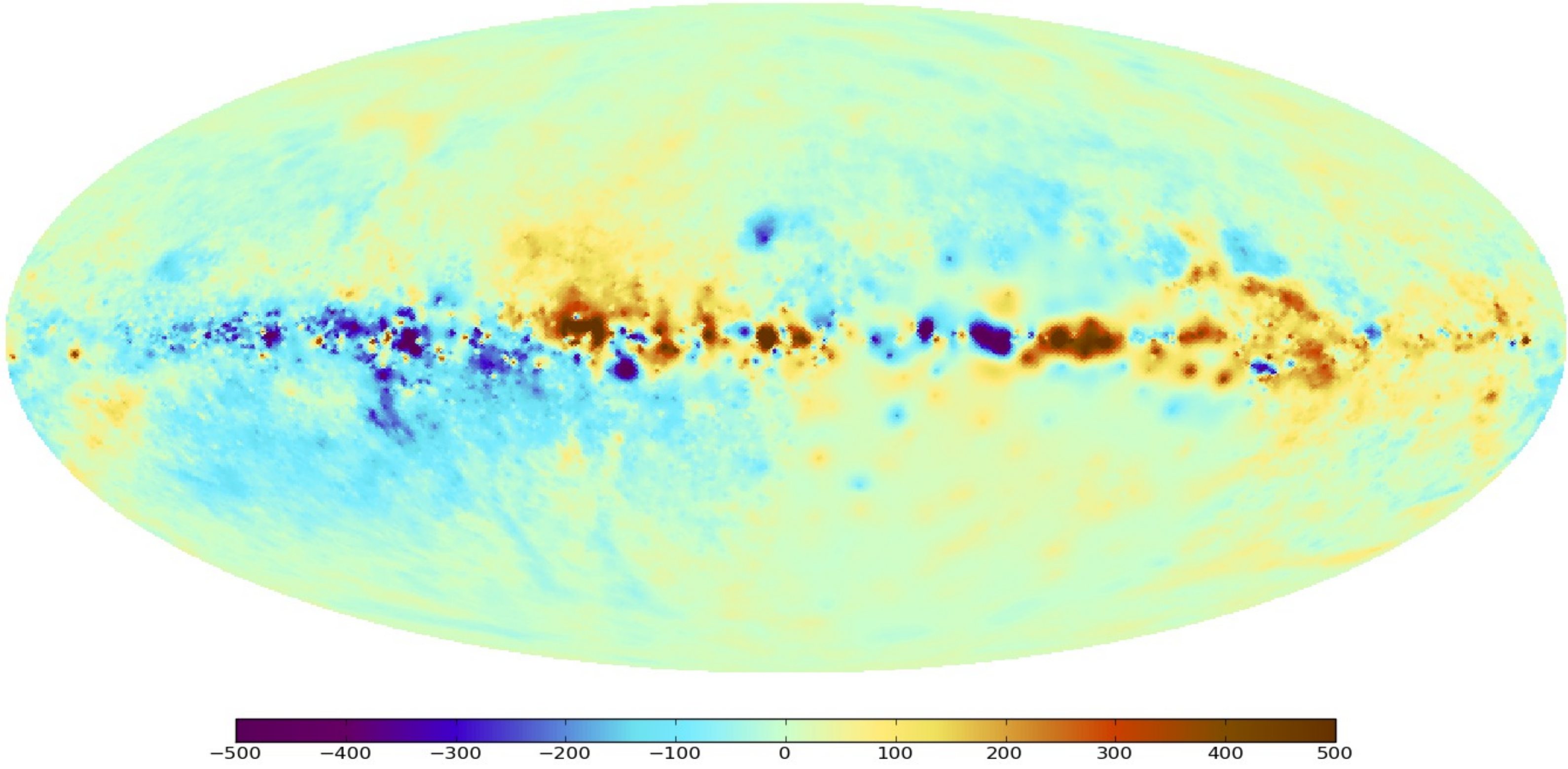


Galactic magnetic field

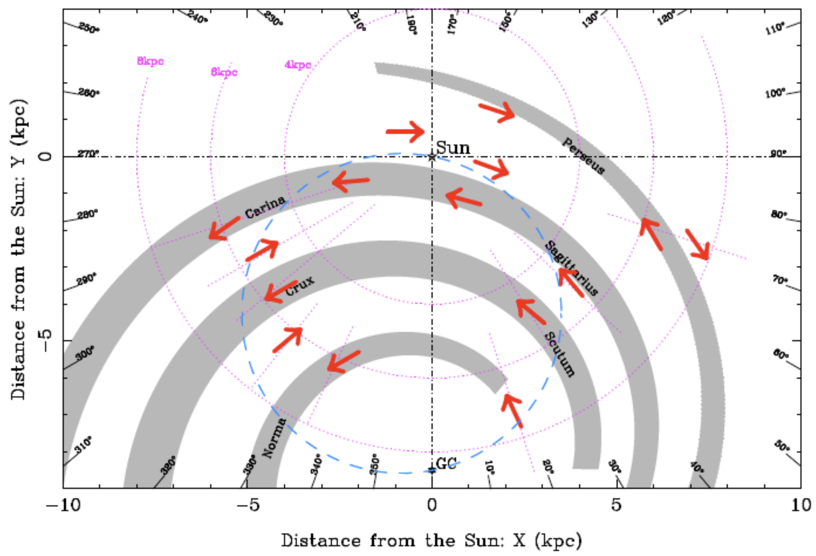
MILKY WAY GALAXY



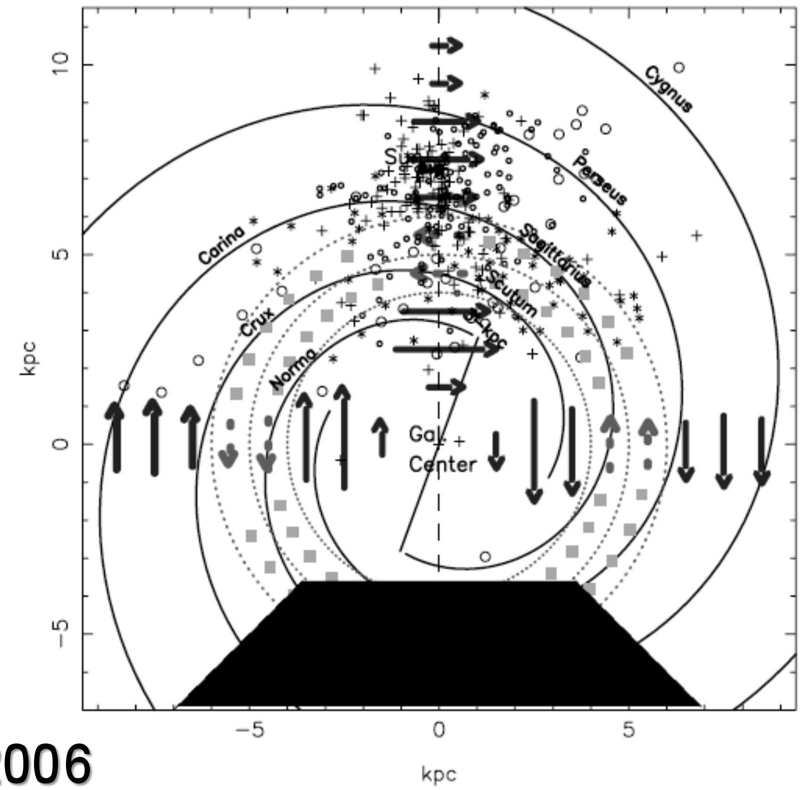
Galactic magnetic field measurement: RM dominated by disk



Galactic magnetic field: disk

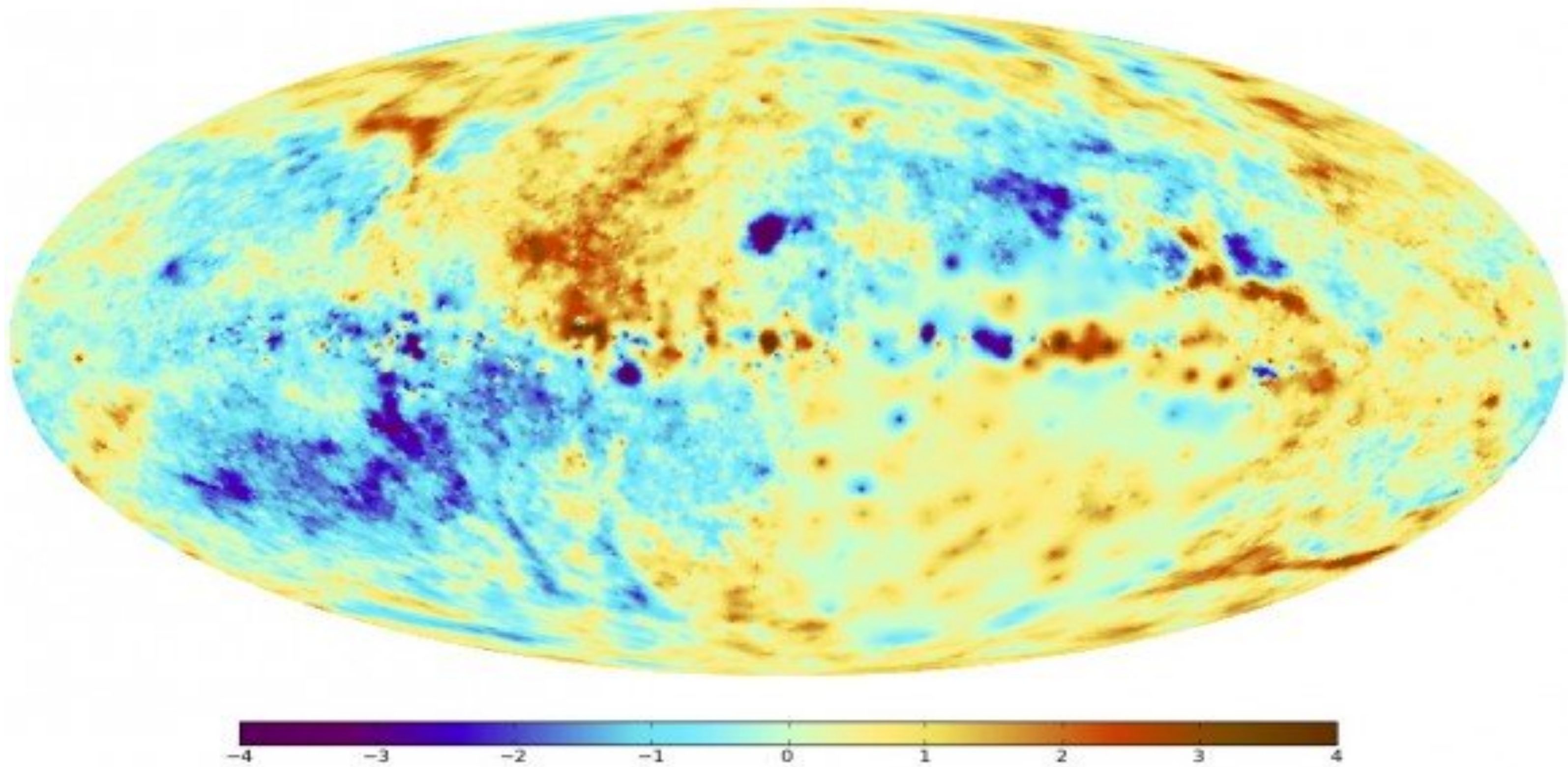


J.L.Han et al, Astrophys.J.642:868-881,2006

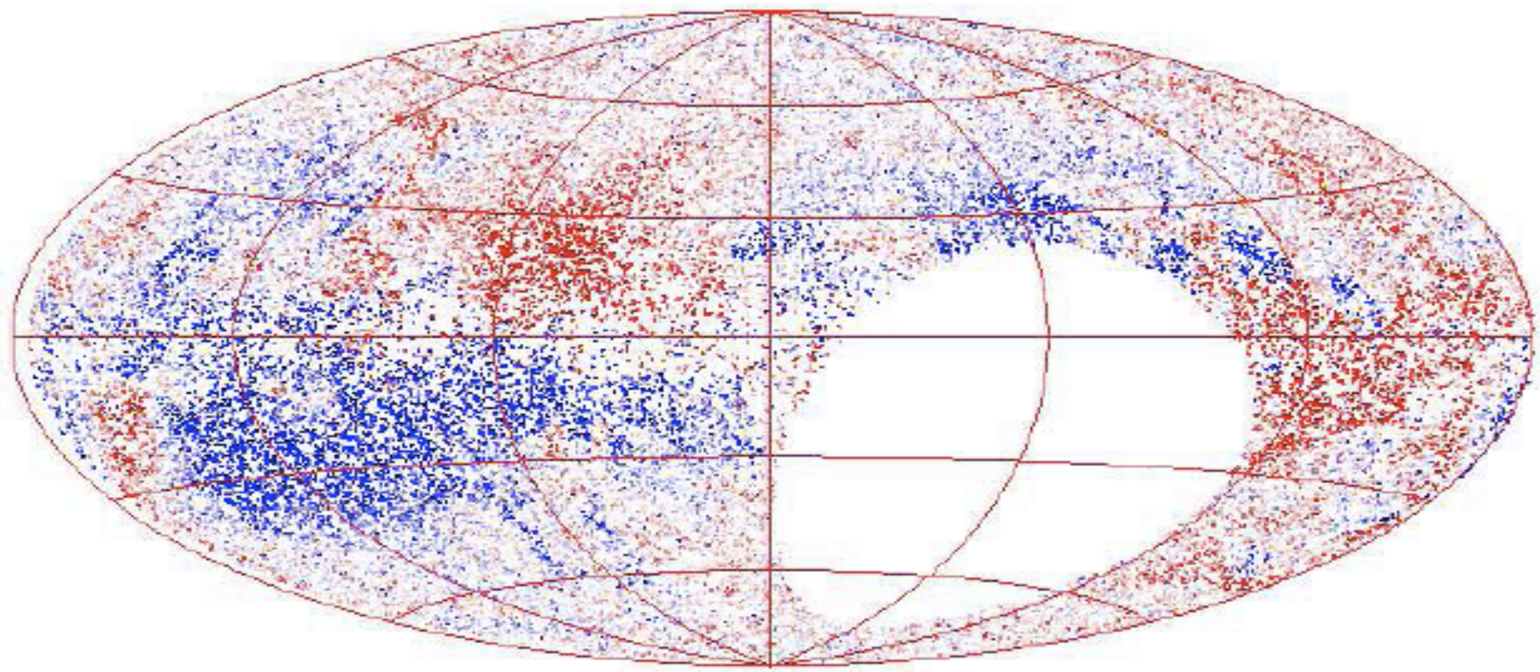


J.Vallee, Astrophys.J. 619:297–305, 2005

Galactic magnetic field halo measurement: RM

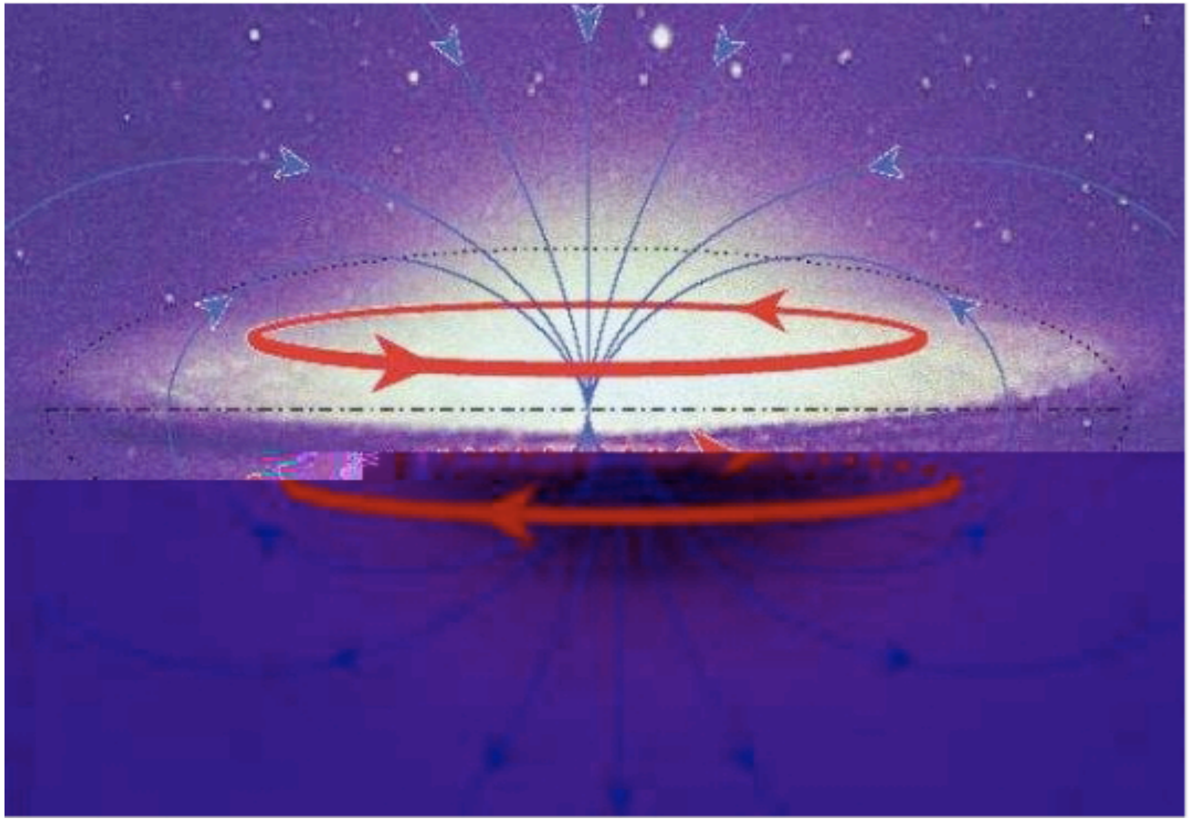


Galactic magnetic field measurement: RM



Pshirkov et al, **arXiv:1103.0814**

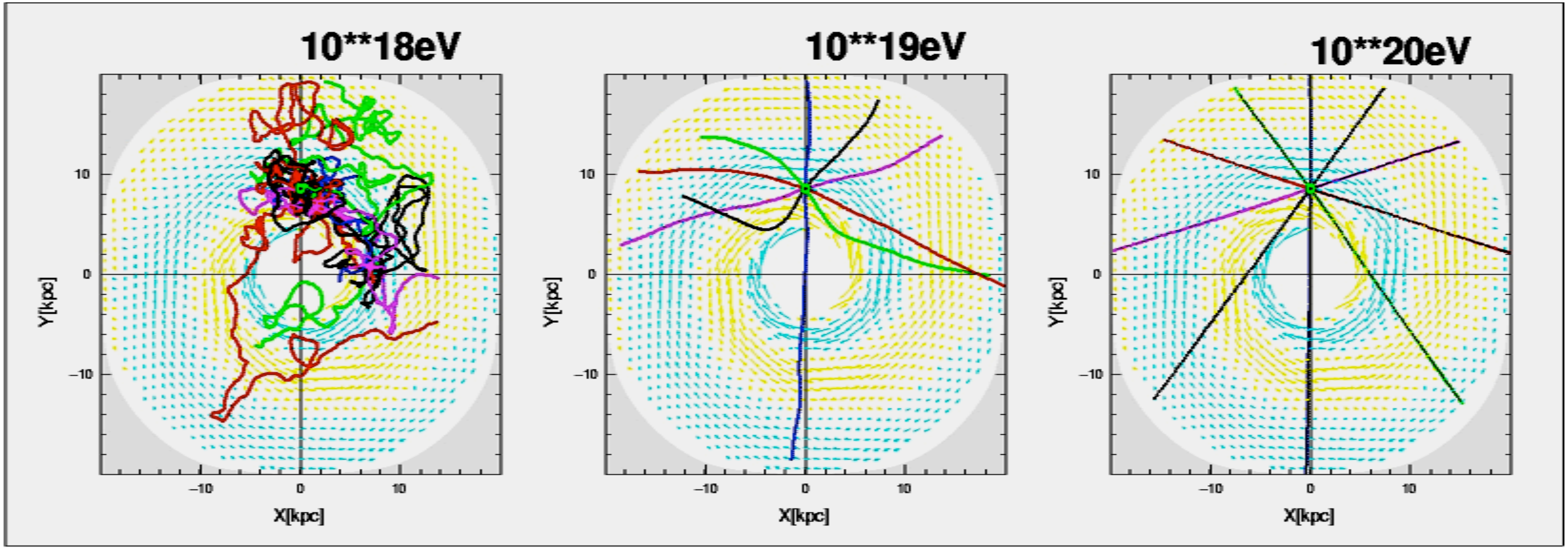
Galactic magnetic field: halo



J-L. Han et al, **arXiv:0901.0040**

UHECR propagation in Milky Way

- Deflection angle ~ 1-2 degrees at 10^{20}eV for protons
  - Astronomy by hadronic particles?



Galactic magnetic field: turbulent component

- Field with $\langle \boldsymbol{B}(\boldsymbol{r}) \rangle = 0 \qquad \langle \boldsymbol{B}(\boldsymbol{r})^2 \rangle \equiv B_{\rm rms}^2 > 0.$
- Power spectrum $\mathcal{P}(k) \propto k^{-\alpha}, \qquad |\boldsymbol{B}(\boldsymbol{k})|^2 \propto k^{-\alpha-2}$
- With index $\alpha = 5/3,\ 3/2$ for Kolmogorov/Kraichnan cases
- Correlation length

$$L_{\rm c} = \frac{L_{\rm max}}{2} \frac{\alpha - 1}{\alpha} \frac{1 - (L_{\rm min}/L_{\rm max})^{\alpha}}{1 - (L_{\rm min}/L_{\rm max})^{\alpha-1}} .$$

- Where
- $L_{\rm min} = 1\,{\rm AU} \qquad L_{\rm max} = 100 - 300\,{\rm pc}.$

Galactic magnetic field: turbulent component

- Profile 1

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

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

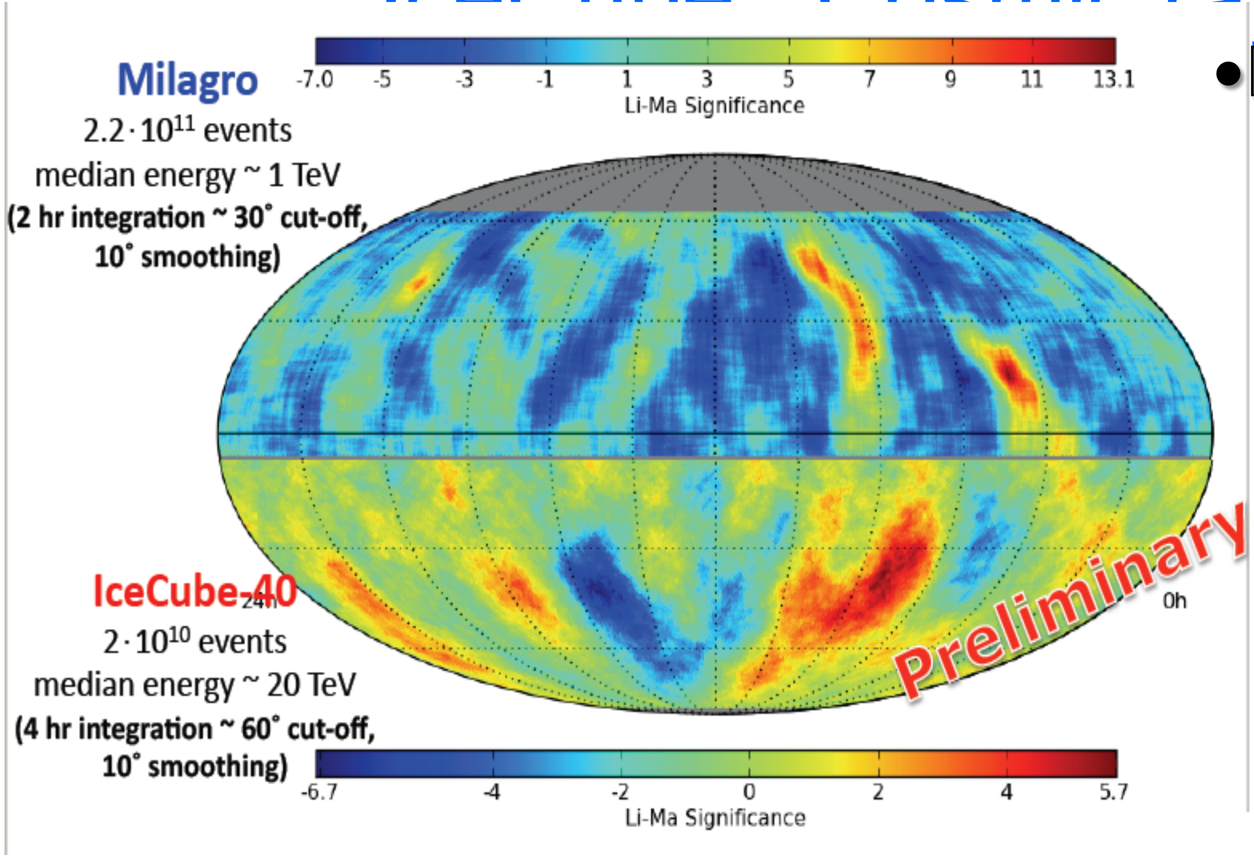
- Profile 2

$$B_{\rm rms}(r,z) = \begin{cases} B_0 & \text{, if } r \leq 20\,\text{kpc and } |z| \leq z_0 \\ 0 & \text{, if } r > 20\,\text{kpc or } |z| > z_0 \end{cases}$$

G.Giacinti et al, arXiv:1112.5599

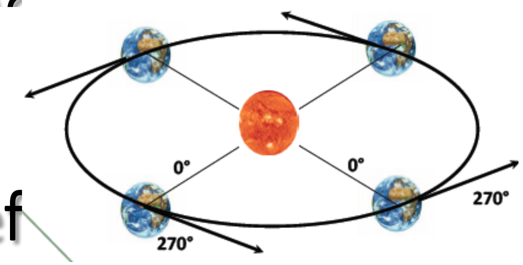
Anisotropy of galactic CR

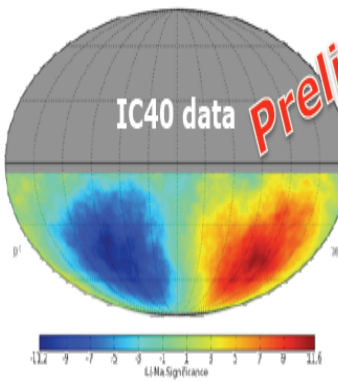
IceCube : Cosmic ray studies

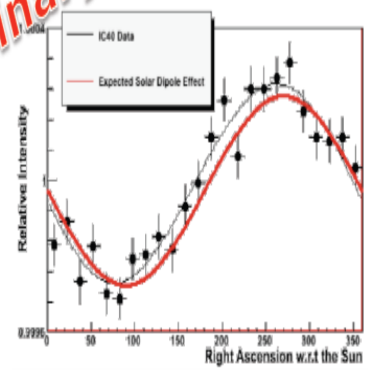


- 🕮 arXiv:1105.2326

- Dipole due to Earth m…
  - around the Sun
- Compton & Getting ef…

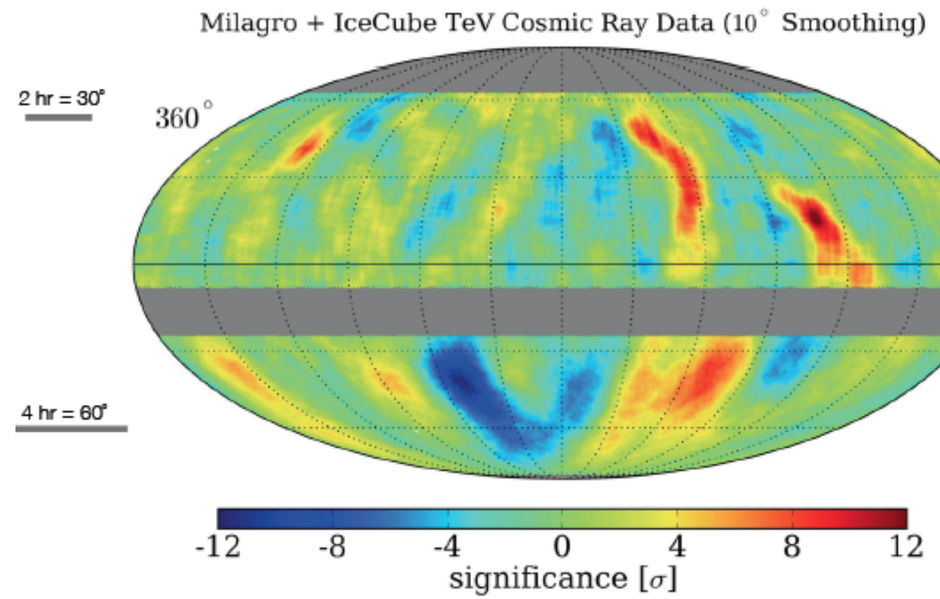






- 🕮 Phys Rev **47** (1935) 817

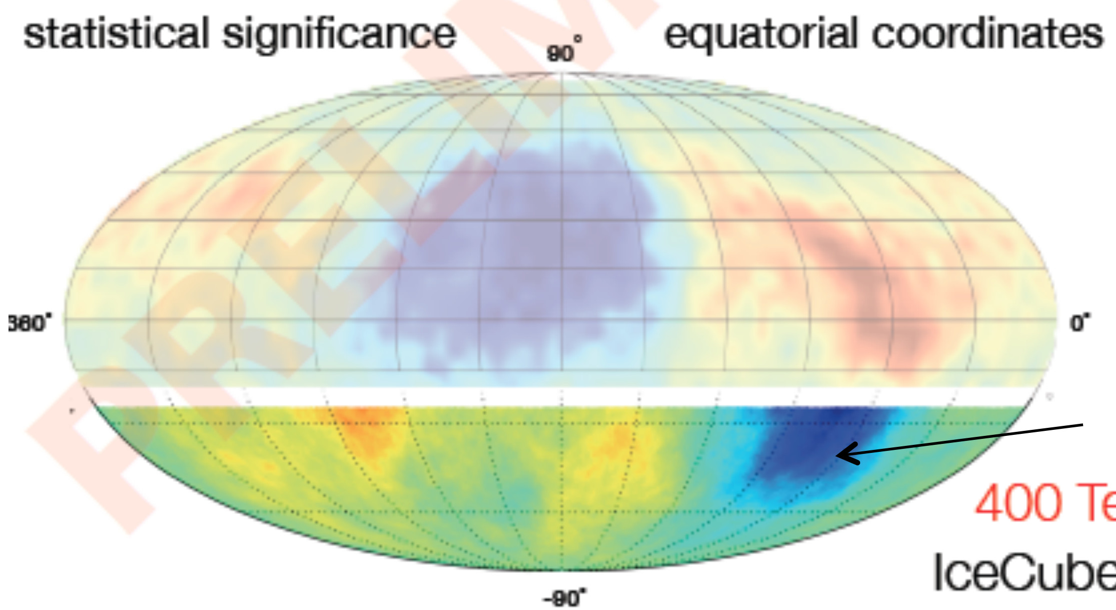
IceCube : Cosmic ray studies



1 TeV

20 TeV

- Anisotropy confirmed
- with IC59



- -6.3σ

400 TeV

IceCube-59

- Evolution with energy
- Différent effect @400 TeV

- 🕮 arXiv1109.101v1

Anisotropy due to local structure of turbulent MF

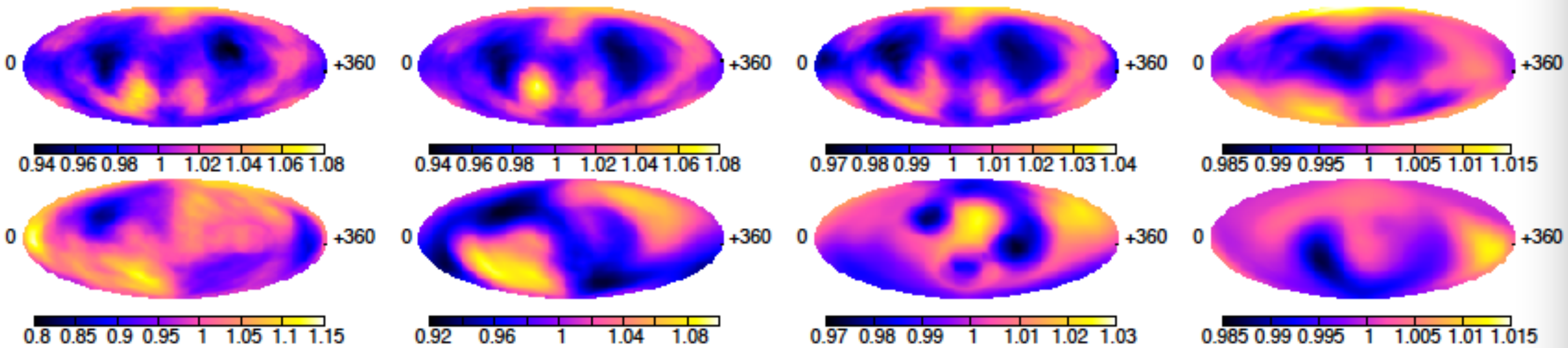
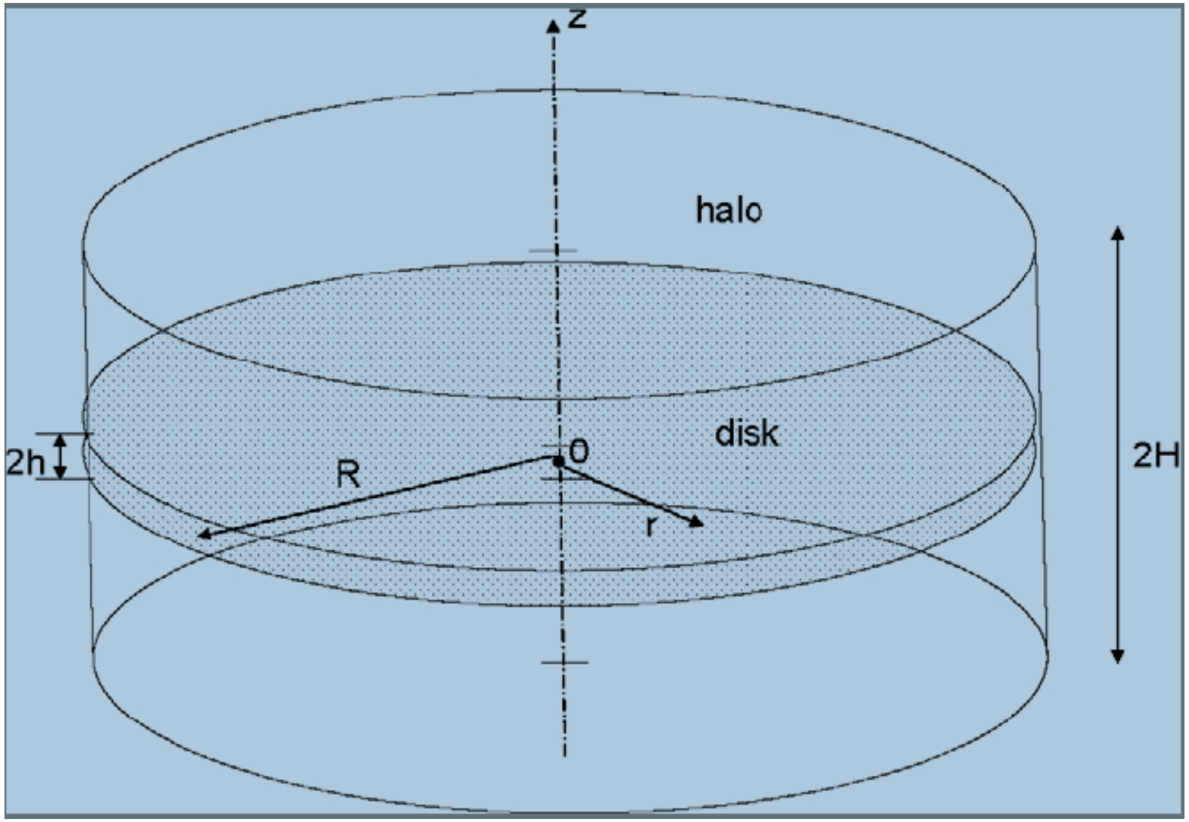


FIG. 2. Same as Fig. 1, for boundary conditions imposed on concentric spheres around Earth with radii $R = 100, 50, 25, 10$ p
(resp. first, second, third and fourth columns). Upper row: $p/Z = 10^{16}$ eV; *Lower row:* $p/Z = 5 \times 10^{16}$ eV.

G.Giacinti and G.Sigl, arXiv:1111.2536

Theoretical models for galactic cosmic rays

Sources and Galactic magnetic field



Ptuskin, **Astropart. Phys. 2011**

Transport Equations ~90 (no. of CR species)

$$\frac{\partial \psi(\vec{r},p,t)}{\partial t} = q(\vec{r},p)$$ •sources (SNR, nuclear reactions…)

•diffusion $$+ \vec{\nabla} \cdot [D_{xx} \vec{\nabla} \psi - \vec{V} \psi]$$

•diffusive reacceleration (diffusion in the momentum space) $$+ \frac{\partial}{\partial p}\left[p^2 D_{pp} \frac{\partial}{\partial p} \frac{\psi}{p^2}\right]$$

•convection (Galactic wind)

•E-loss $$- \frac{\partial}{\partial p}\left[\frac{dp}{dt}\psi - \frac{1}{3} p \vec{\nabla} \cdot \vec{V} \psi\right]$$

•fragmentation $$- \frac{\psi}{\tau_f} - \frac{\psi}{\tau_d}$$ •radioactive decay

- + boundary conditions

$\psi(\mathbf{r},p,t)$ – *density per total momentum*

GALPROP model of CR Propagation in the Galaxy

- Gas distribution (energy losses, π^0, brems)
- Interstellar radiation field (IC, $e^{\pm}$ energy losses)
- Nuclear & particle production cross sections
- Gamma-ray production: brems, IC, π^0
- Energy losses: ionization, Coulomb, brems, IC, synch
- Solve transport equations for all CR species
- Fix propagation parameters
- "Precise" Astrophysics

Cosmic ray propagation from single source

CR interactions in Galaxy

- Cosmic rays interact in galaxy at the rate

$$t_{pp} = (c\sigma_{pp}n_{ISM})^{-1} \simeq 3\times 10^7 \left[\frac{n_{ISM}}{1\ \mathrm{cm}^{-3}}\right]^{-1}\ \mathrm{yr},$$

- where cros-section is

$$\sigma_{pp} \simeq 4\times 10^{-26}\ \mathrm{cm}^2$$

CR from one source

- Local measurements of primary and secondary nuclei give diffusion coeficient:

$$D = D_{28} \times 10^{28} \left[E_{CR}/4\ \mathrm{GeV}\right]^{-\delta}\ \mathrm{cm}^2/\mathrm{s},$$

with

$$\delta = 0.4 \pm 0.1$$

Diffusion region has bound exp(-r^2/r_s^2)

Radius of region around source is

$$r_s \simeq 2\sqrt{DT_s} \simeq 80\ D_{28}^{1/2} \left[\frac{T_s}{10\ \mathrm{kyr}}\right]^{1/2} \left[\frac{E_{CR}}{1\ \mathrm{TeV}}\right]^{\delta/2}\ \mathrm{pc}.$$

Eigenvalues of diffusion tensor

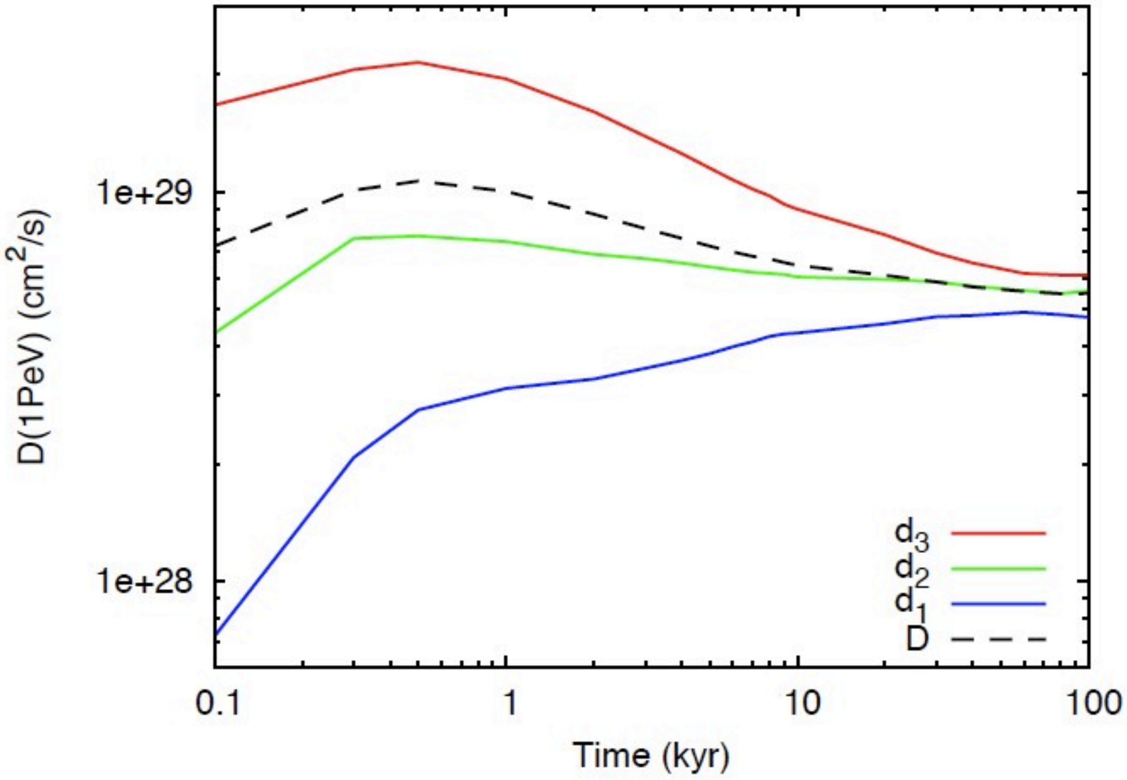
- Diffusion tensor $D_{ij}^{(b)} = \frac{1}{2Nt} \sum_{a=1}^{N} x_i^{(a)} x_j^{(a)}$

  3 eigenvalues $d_1^{(b)} < d_2^{(b)} < d_3^{(b)}$

  Average only after diaganalization $d_i = \frac{1}{M} \sum_{b=1}^{M} d_i^{(b)}$

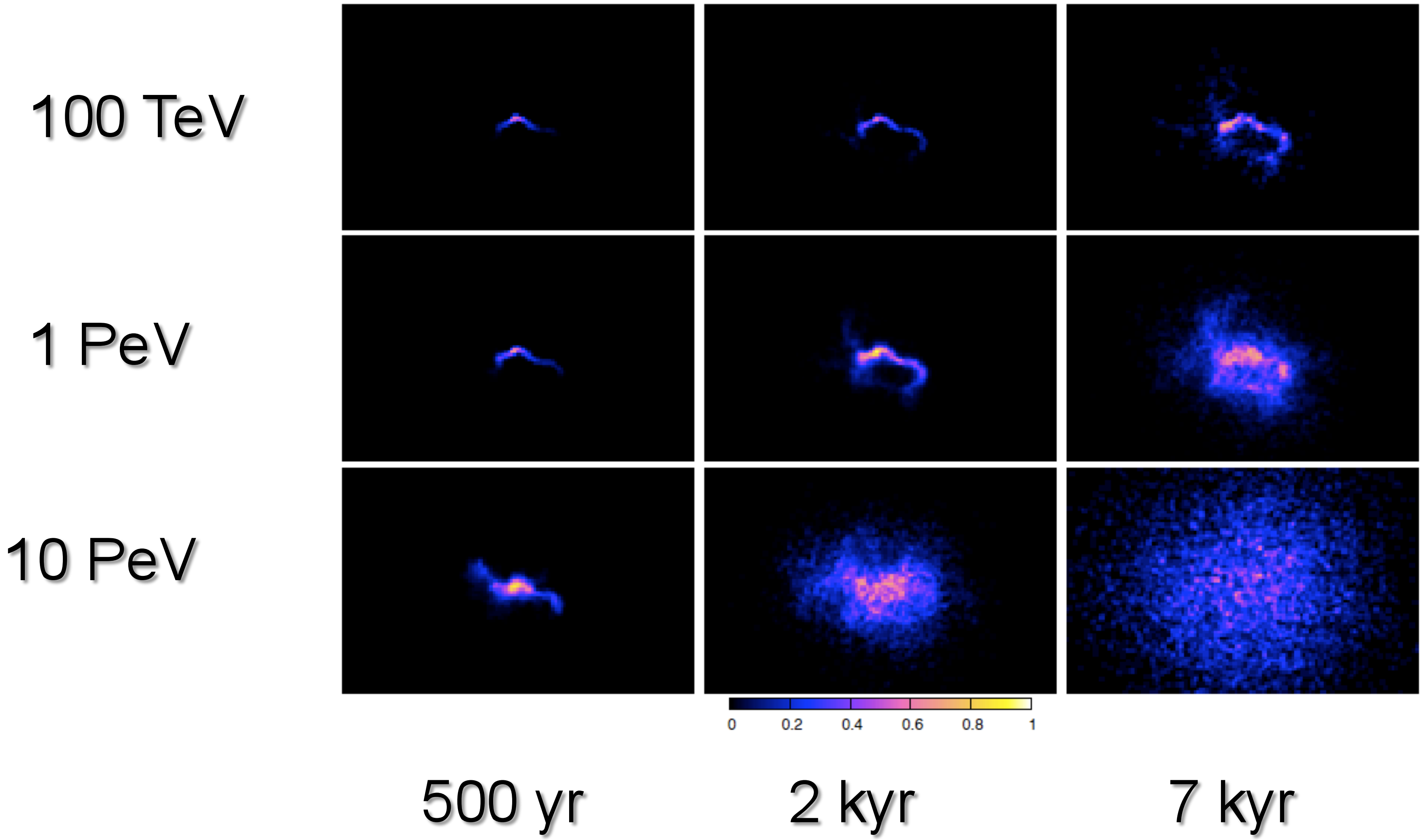
G.Giacinti, M.Kachelriess and D.S., **arXiv:1204.1271**

Evolution of eigenvalues of diffusion tensor at 1 PeV



G.Giacinti, M.Kachelriess and D.S., **arXiv:1204.1271**

Diffusion of protons from single source



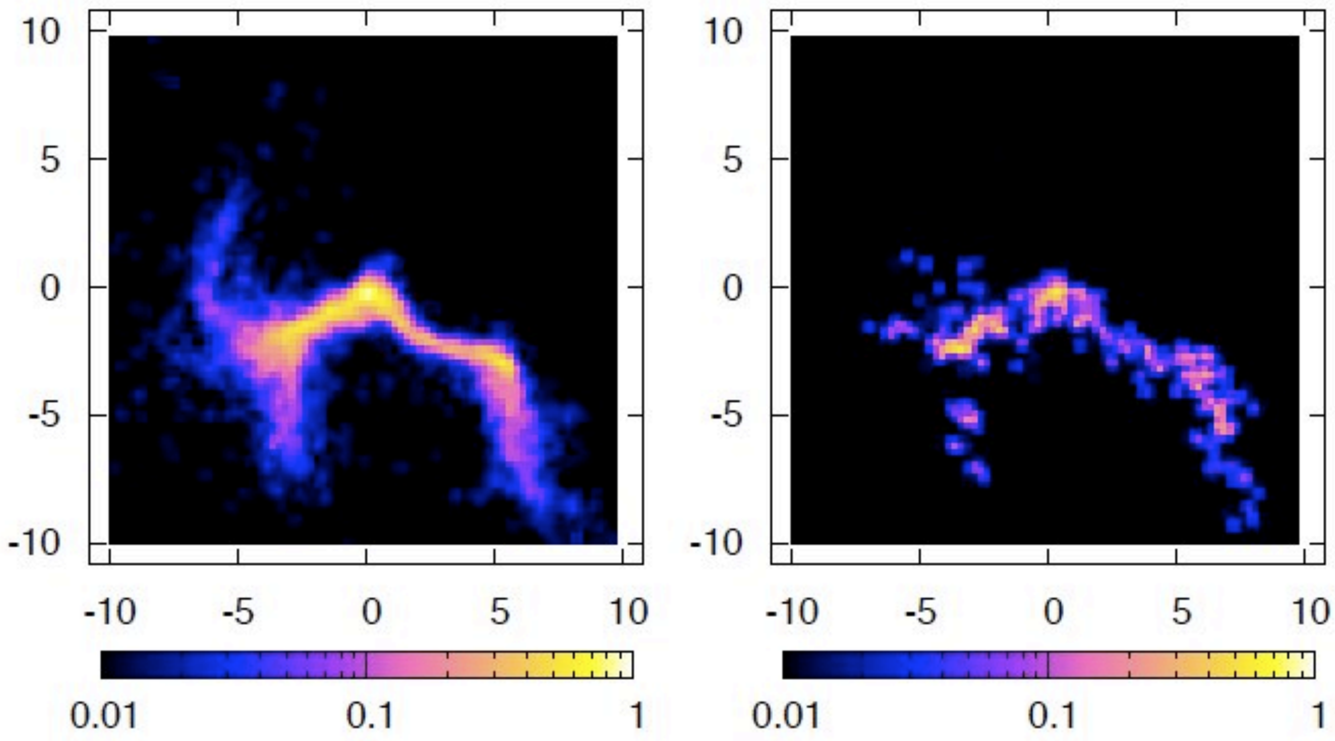
Time needed to come in 3-d diffusion regime

$$t_* \sim 10^4\,\mathrm{yr}\ \ (l_{\max}/150\,\mathrm{pc})^{\beta}\,(E/\mathrm{PeV})^{-\gamma}\,(B_{\mathrm{rms}}/4\,\mu\mathrm{G})^{\gamma}$$

$\beta \simeq 2$ and $\gamma = 0.25$–0.5 for Kolmogorov turbulence

G.Giacinti, M.Kachelriess and D.S., **arXiv:1204.1271**

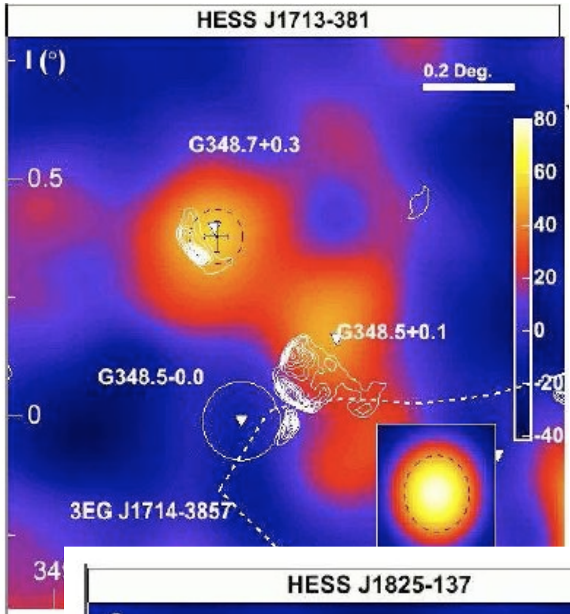
Gamma-rays from CR

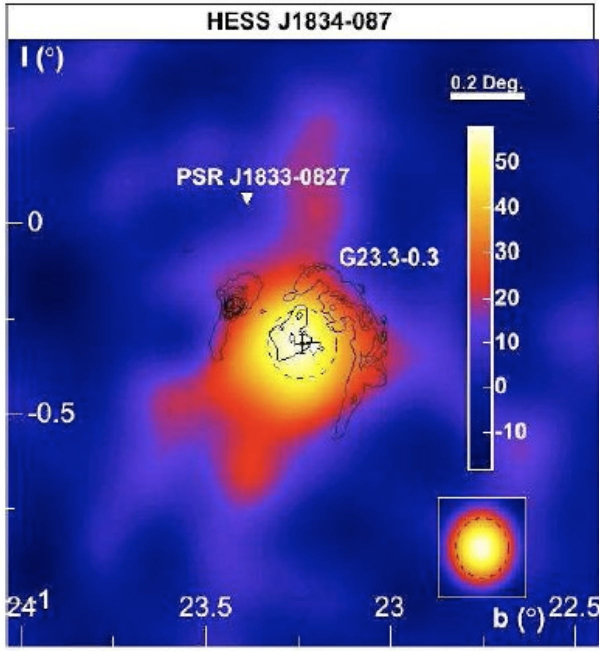


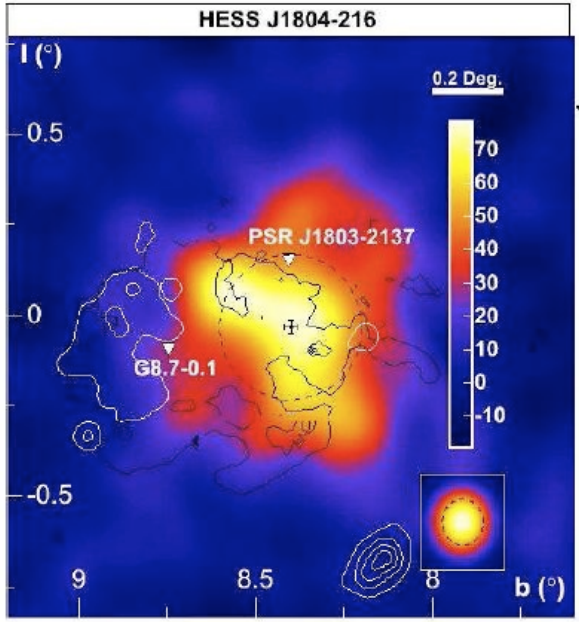
PP interaction simulated with QGSJET-II

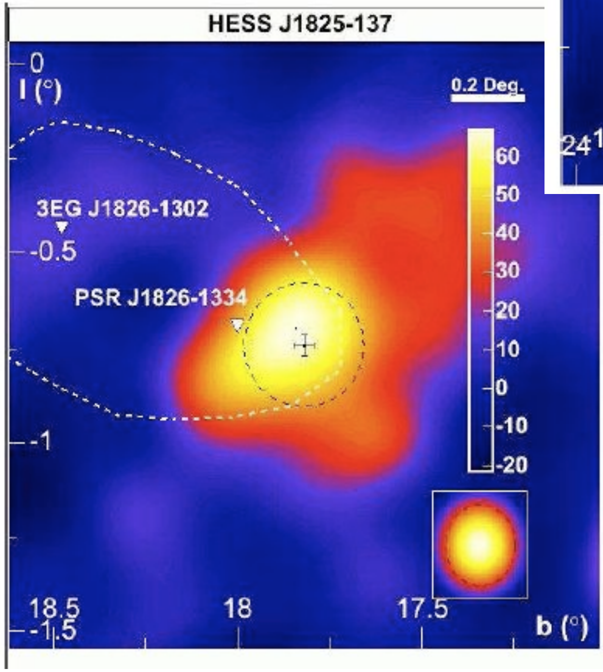
G.Giacinti, M.Kachelriess and D.S., **arXiv:1204.1271**

Examples of observed HESS sources

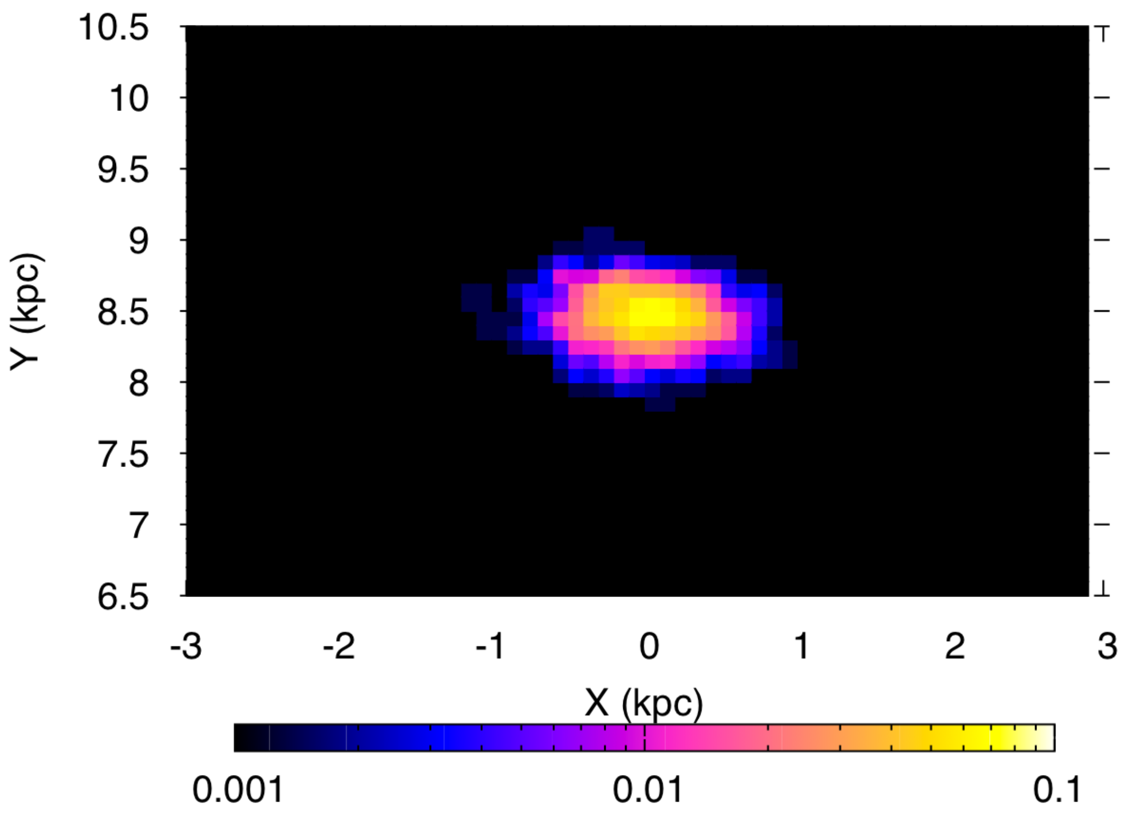




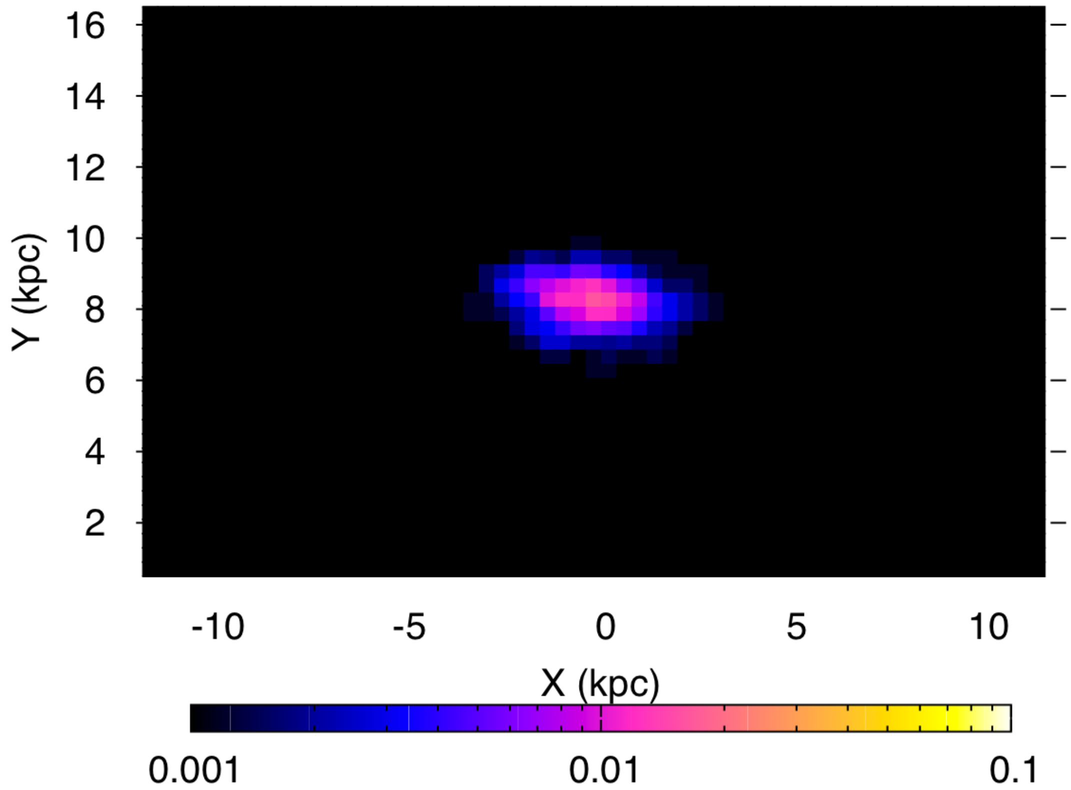




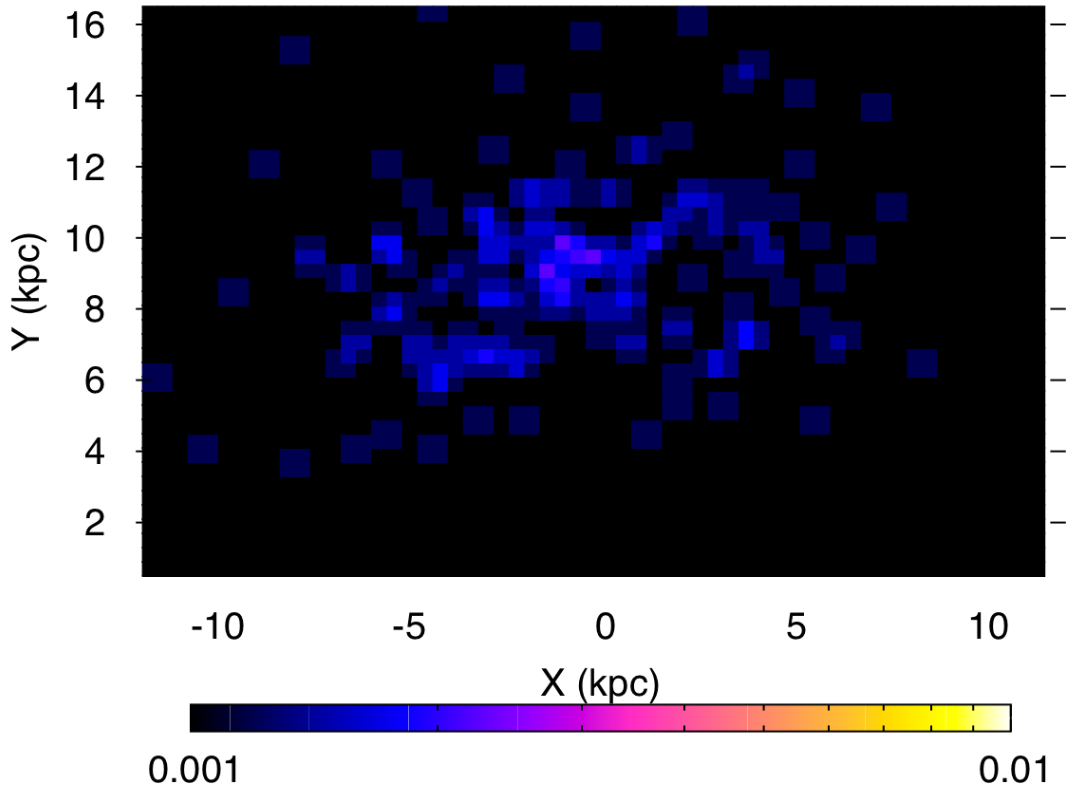
40 PeV protons from single source: 10 kyr (77%)



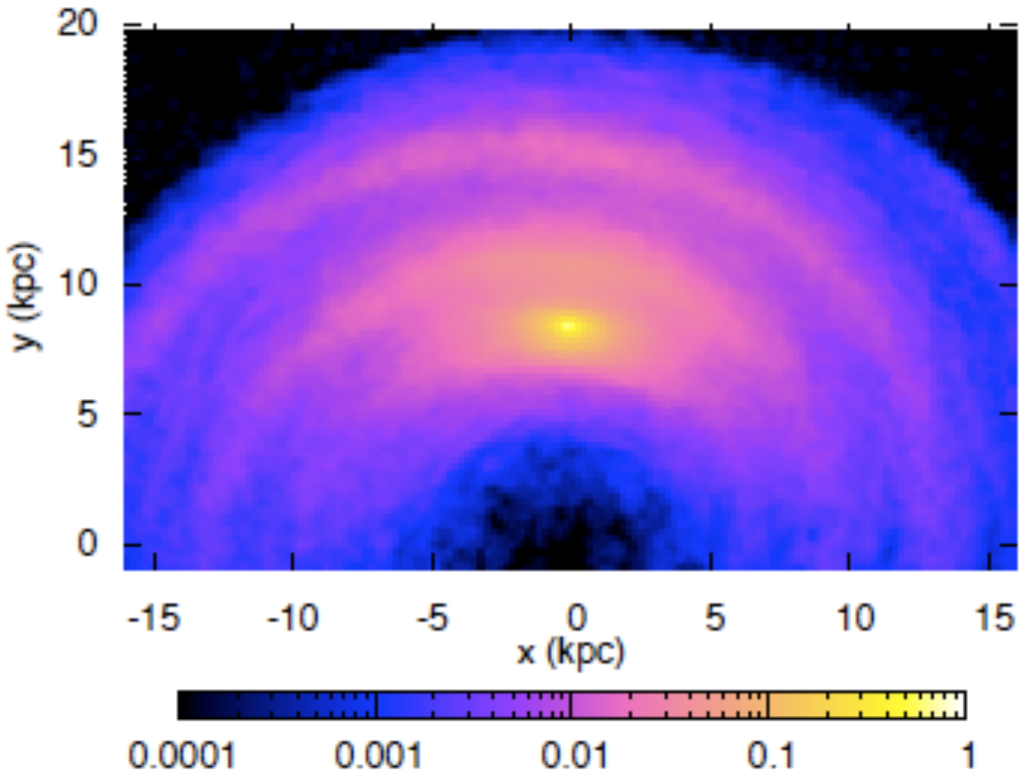
40 PeV protons from single source: 100 kyr (33%)



40 PeV protons from single source: 1 Myr (12%)



40 PeV protons from single source: all times (up to several Myr)



G.Giacinti et al, **arXiv:1112.5599**

Secondary gamma-rays from CR

- To explain observed CR flux each source release

$$E_s \sim 3 \times 10^{50} \left[\mathcal{R}_{SN}/10^{-2}\ \mathrm{yr}\right]$$

In form of cosmic rays

Then luminosity in gamma-rays is

$$L_\gamma \sim \frac{\kappa E_s}{t_{pp}} \sim 2 \times 10^{34} \left[\frac{\kappa}{0.2}\right] \left[\frac{E_s}{10^{50}\ \mathrm{erg}}\right] \left[\frac{n_{ISM}}{1\ \mathrm{cm}^{-3}}\right]\ \mathrm{erg/s},$$

Secondary gamma-rays from one source

- Then flux of gamma-rays from one source is

$$F_s = \frac{L_\gamma}{4\pi R_s^2} \simeq 10^{-11} \left[\frac{R_s}{5\ \mathrm{kpc}}\right]^{-2} \left[\frac{n_{ISM}}{1\ \mathrm{cm}^{-3}}\right] \left[\frac{\kappa}{0.2}\right] \frac{\mathrm{erg}}{\mathrm{cm}^2\mathrm{s}}.$$

and angular size of source is

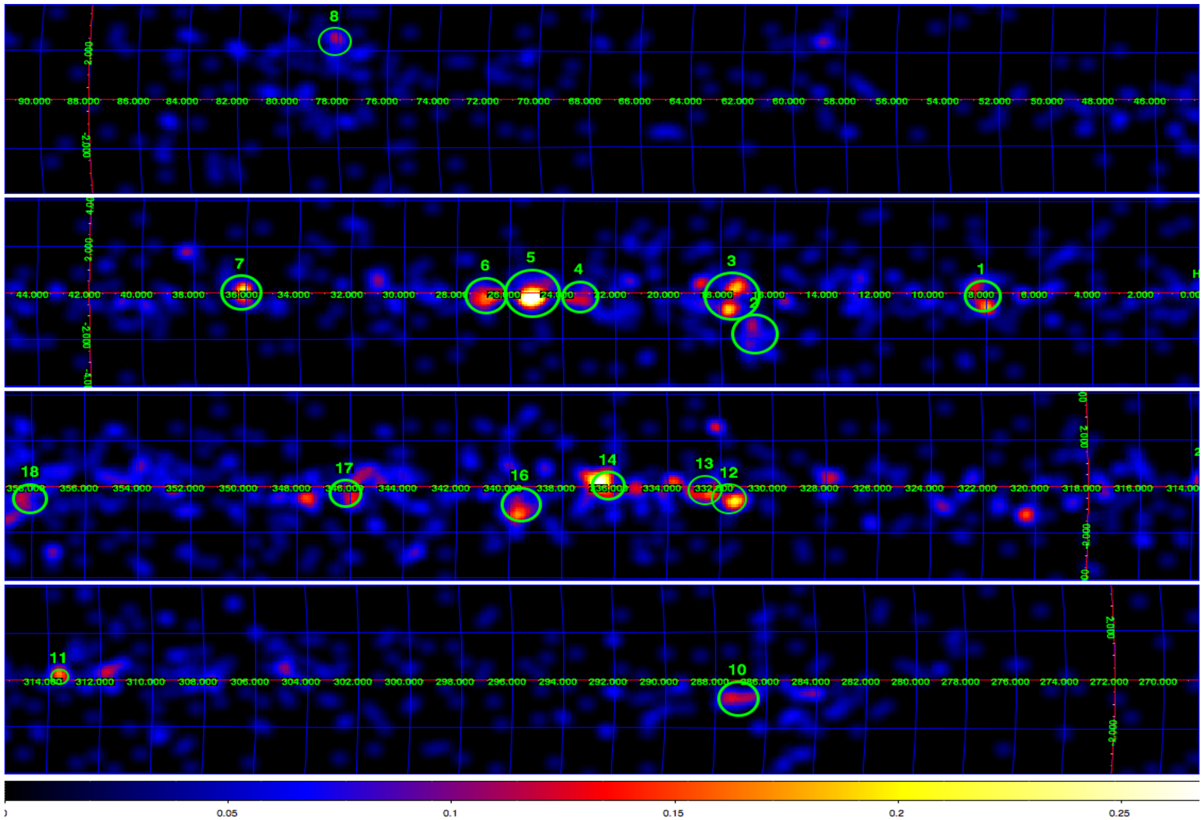
$$\theta_s \sim \frac{r_s}{R_s} \simeq 0.8^\circ D_{28}^{1/2} \left[\frac{R_s}{5\ \mathrm{kpc}}\right]^{-1} \left[\frac{T_s}{10\ \mathrm{kyr}}\right]^{1/2} \left[\frac{E_{CR}}{1\ \mathrm{TeV}}\right]^{0.2}$$

Expected number of sources

- Expected number of sources in the nearby inner part of Galaxy: N_tot* Slocal/Stotal
- N_tot = R_SN *3*10^4 yr = 300
- We should see about 10-20 sources within 5 kpc towards inner galaxy

Fermi LAT observation of Galaxy at E>100 GeV

Fermi LAT Galactic plane at E>100 GeV



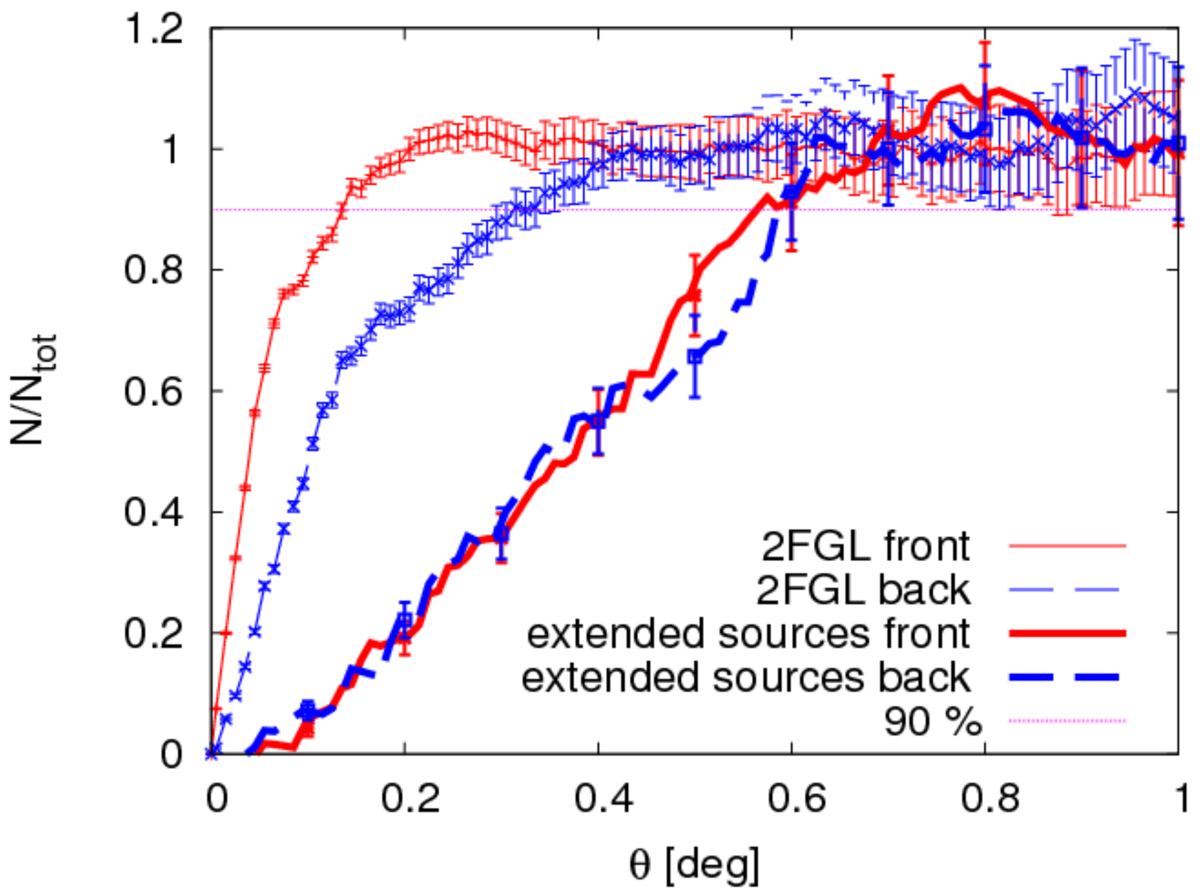
A.Neronov and D.S., **arXiv:1201.1660**

Fermi LAT point sources in Galactic plane at E>100 GeV

	2FGL	l	b	N_{ph}	P	type	Name
1	1837.3-0700c	25.09	-0.08	4	1.e-4		**HESS J1837-069**
2	J2001.1+4352	79.06	-7.12	2	1.e-3	BLZ	**MAGIC J2001+435**
3	J2323.4+5849	111.74	-2.11	2	1.e-3	SNR	**Cas A**
4	J2347.0+5142	112.88	-9.90	4	6.e-8	BLZ	**1ES 2344+514**
5	J0035.8+5951	120.97	-2.96	5	4.e-8	BLZ	**1ES 0033+595**
6	J0110.3+6805	124.70	5.29	2	6.e-4		VCS J0110+6805
7	J0240.5+6113	135.67	1.08	4	2.e-6	GRLB	**LS I+61 303**
8	J0521.7+2113	183.6	-8.70	4	2.e-5	AGU	**VCS J0521+2112**
9	J0534.5+2201	184.55	-5.78	28	0	PWN	**Crab**
10	J0617.2+2234e	189.05	3.03	4	7.e-5	SNR+CCO	**IC443**
11	J0648.9+1516	198.99	6.35	4	4.e-7	AGU	**VER J0648+152**
12	J1030.4-6015	286.28	-2.03	2	1.e-3		
13	J1124.6-5913	292.2	-2.03	2	1.e-3	PWN	PSR J1124-5916
14	J1603.8-4904	332.15	2.56	5	5.e-7		AT20G J160350-49

A.Neronov and D.S., **arXiv:1201.1660**

Fermi LAT point PSF and extended sources at E>100 GeV



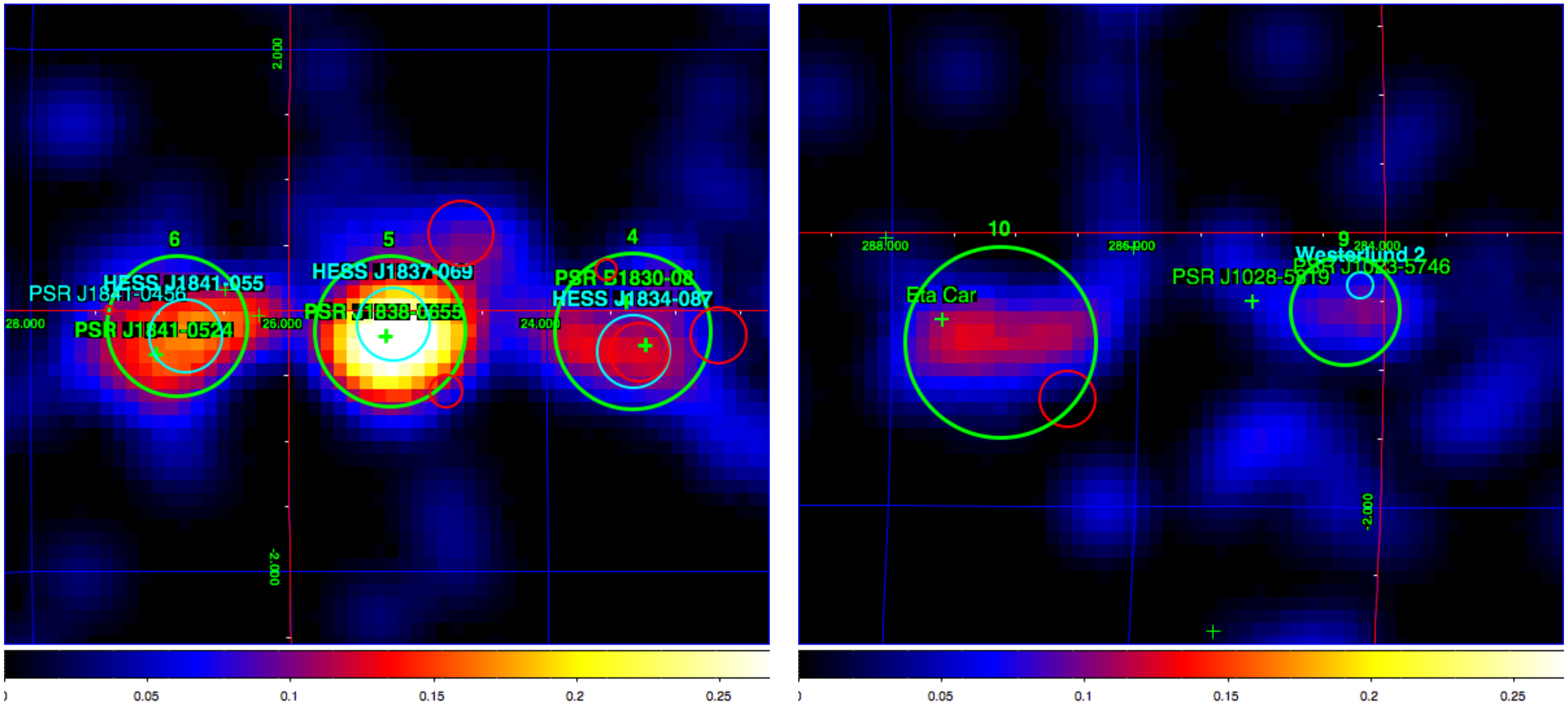
A.Neronov and D.S., **arXiv:1201.1660**

Fermi LAT diffuse sources in Galactic plane at E>100 GeV

	l	b	θ_{50}	θ_{90}	P_{90}	N_{ph}	F	Comments	SNR	PSR	R_s	T_s
1	8.15	-0.14	0.47	0.65	1.e-5	12	4.6 ± 1.3	**HESS 1804-216**	W30	B1800-21	3.9	1.6
2	16.74	-1.79	0.46	0.83	1.e-6	12		**LS 5039**				
3	17.58	-0.14	0.6	1. 0	1.e-3	13	5.2 ± 1.4	**HESS J1825-137**		B1823-13	4.1	2.1
4	23.32	-0.16	0.5	0.6	2.e-2	8	3.4 ± 1.2	**HESS J1834-087**	W41	CXOU J183434.9-084443 B1830-08?	4	~ 10 3.5
5	25.21	-0.16	0.43	0.58	1.e-5	15	6.4 ± 1.5	**HESS J1837-069**		J1838-0655		2.3
6	26.87	-0.12	0.39	0.54	2.e-4	11	4.6 ± 1.4	**HESS J1841-055**		J1841-0524	4.9	3.0
7	36.20	0.02	0.23	0.37	1.e-6	11	4.6 ± 1.4	**HESS J1857+026**		J1856+0245	10.3	2.0
8	78.09	2.54	0.33	0.38	1.e-5	7	2.3 ± 0.9	**VER J2019+407**	γCyg	J2021+4026		7.7
9	284.32	-0.57	0.32	0.42	7.e-3	4	1.3 ± 0.7	**Westerlund 2**		J1023-5746		0.5
10	287.12	-0.80	0.46	0.74	2.e-4	9	2.9 ± 1.0	near Eta Car				
11	313.56	0.11	0.2	0.32	8.e-6	8	2.6 ± 1.0	**Kookaburra**		J1420-6048	7.7	1.3
12	331.66	-0.58	0.27	0.64	7.e-4	11	3.7 ± 1.1	**HESS 1614-518**		J1614-5144		
13	332.57	-0.18	0.34	0.63	1.e-3	10	3.3 ± 1.0	**HESS J1616-508**		J1617-5055	6.5	0.8
14	336.25	0.04	0.37	0.59	1.e-6	16	5.4 ± 1.3	**HESS J1632-478**		J1632-4757	7.0	24
15	339.56	-0.79	0.37	0.72	3.e-3	10	3.4 ± 1.0	**Westerlund 1**		J1648-4611	5.7	11
16	344.90	0.23	0.72	1.05	3.e-2	8	2.8 ± 1.1	**HESS J1702-420**		J1702-4128?	5.2	5.5
17	346.20	-0.31	0.37	0.57	1.e-2	7	2.7 ± 1.0	**HESS 1708-410**		J1706-4009?	3.8	0.9
18	358.06	-0.54	0.57	0.63	1.e-4	10	3.7 ± 1.2	**HESS J1745-303**				

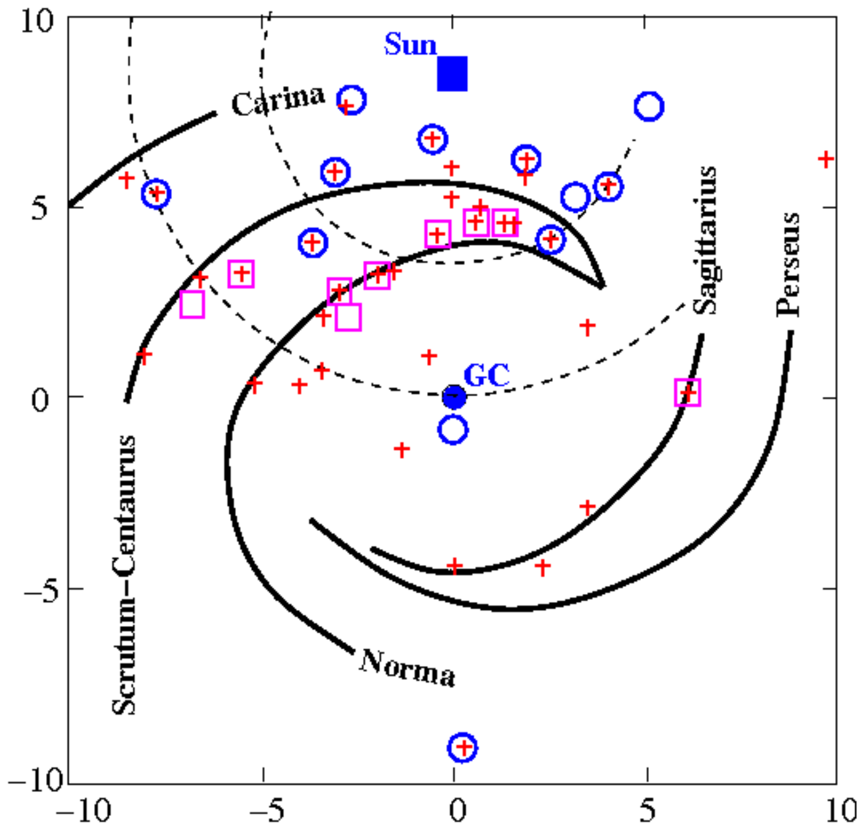
A.Neronov and D.S., **arXiv:1201.1660**

Fermi LAT extended sources at E>100 GeV



A.Neronov and D.S., **arXiv:1201.1660**

Pulsars with T<30 kyr



A.Neronov and D.S., **arXiv:1201.1660**

Pulsars

$$E_{NS} = \frac{I\Omega_{ini}^2}{2} \simeq 3 \times 10^{50} \left[\frac{P_{ini}}{10\ \mathrm{ms}}\right]^{-2}\ \mathrm{erg}$$

$$P \sim t^{1/(n-1)}$$

A.Neronov and D.S., **arXiv:1201.1660**

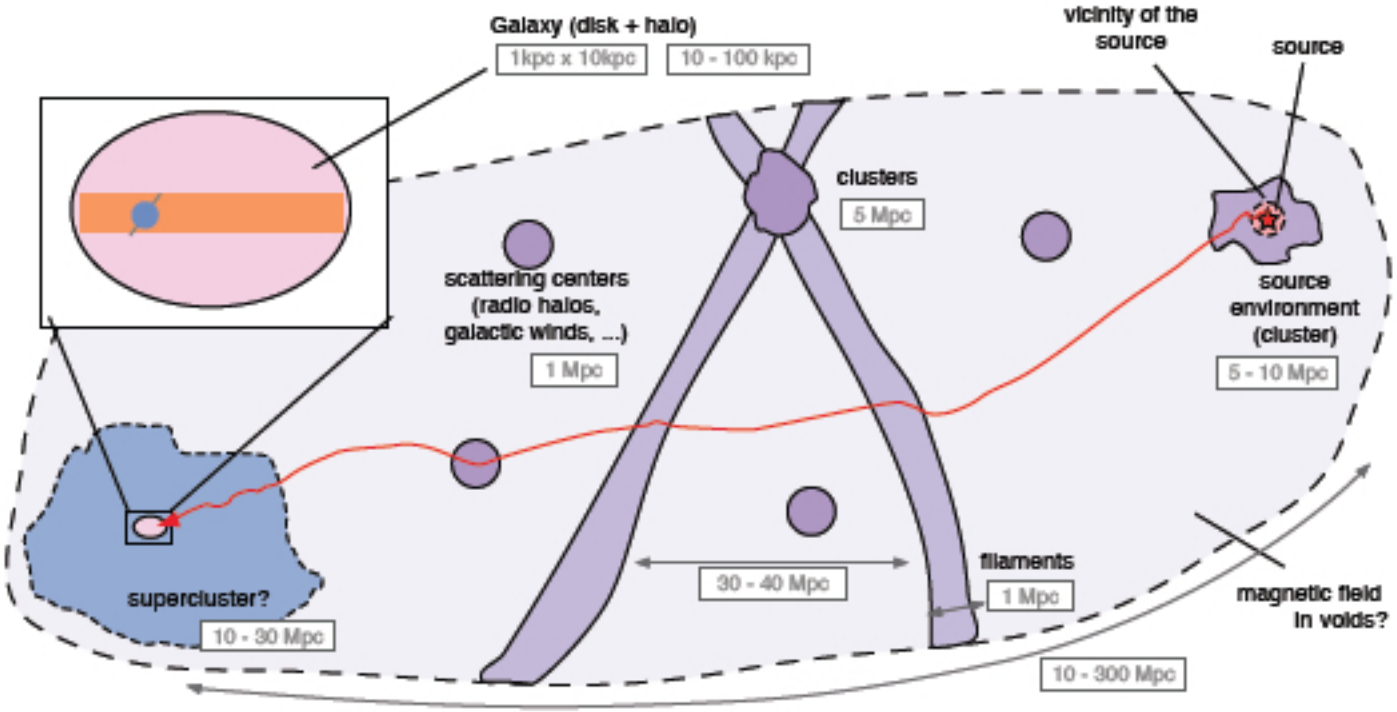
Potential sources

	Name	PSR	R_s	T_s
1	Vela X	B0833-45	0.29	1.1
2	G292.2-0.5	J1119-6127	8.40	0.2
3	HESS J1303-631	J1301-6305	15.84	1.1
4	HESS J1356-645	J1357-6429,	4.09	0.7
5	Rabbit	J1418-6058		1.0
6	MSH 15-52	B1509-58	5.8	0.2
7	HESS J1708-443	B1706-44	1.82	1.8
8	HESS J1741-302	B1737-30	3.28,	2.1
9	G0.9+0.1	J1747-2809	≥ 8	0.5
10	HESS J1809-193	J1809-1943	3.57	1.1
		J1811-1925		2.3
11	HESS J1813-178	J1813-1749		0.5
12	HESS J1833-105	J1833-1034	4.30	0.5
13	HESS J1846-029	J1846-0258	5.10	0.1
14	MGRO J1908+06	J1907+0602	3.01	2.0
15	G54.1+0.3	J1930+1852	5.00	0.3
16	MGRO J2019+37	J2021+3651	18.9	1.7
17	Boomerang	J2229+6114	3.0	1.1

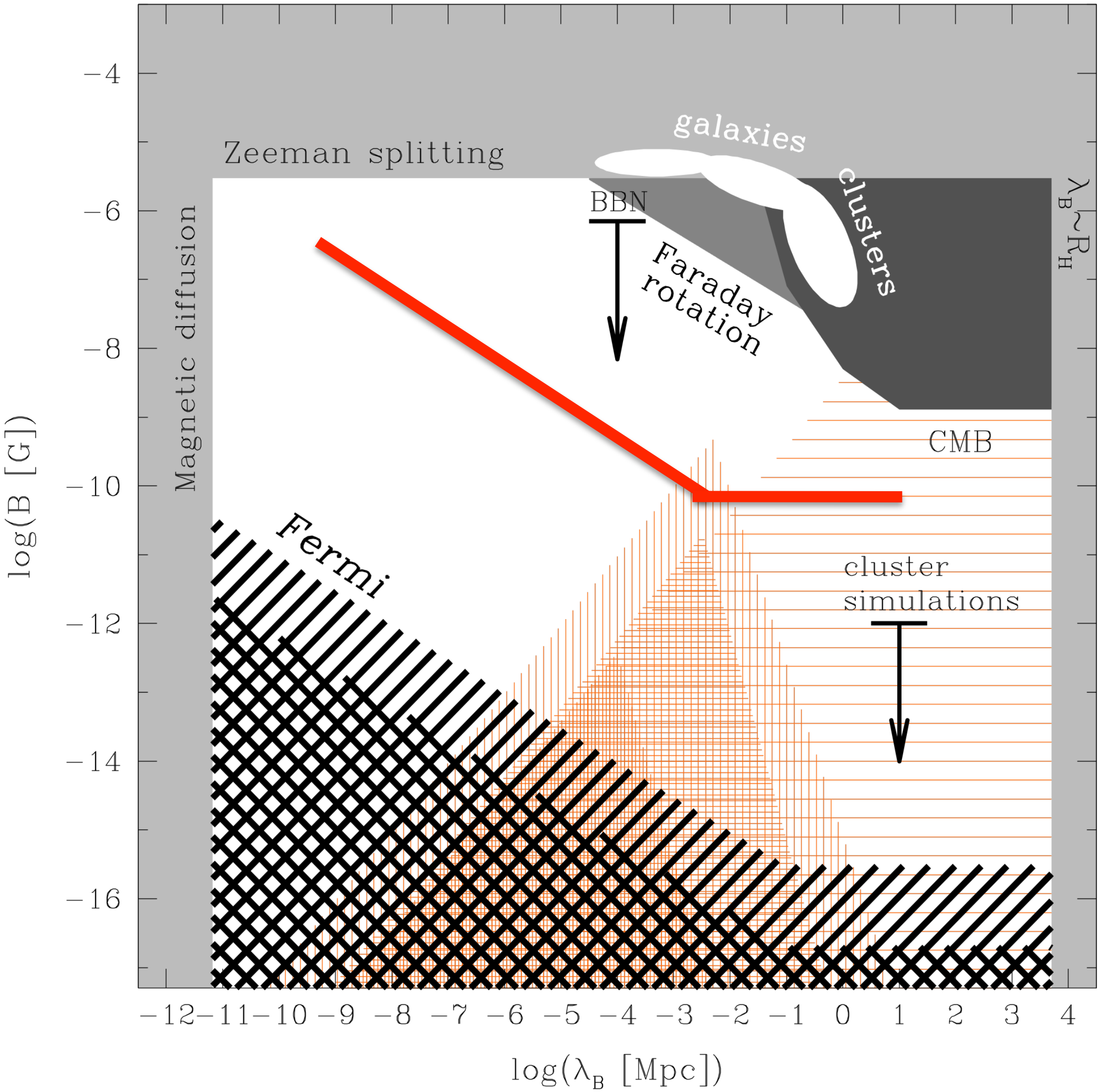
A.Neronov and D.S., **arXiv:1201.1660**

Extragalactic magnetic fields

MF 3d structure



Detection of EGMF



Deflections by EGMF

By K.Dolag, D.Grasso, V.Springel, and I.Tkachev

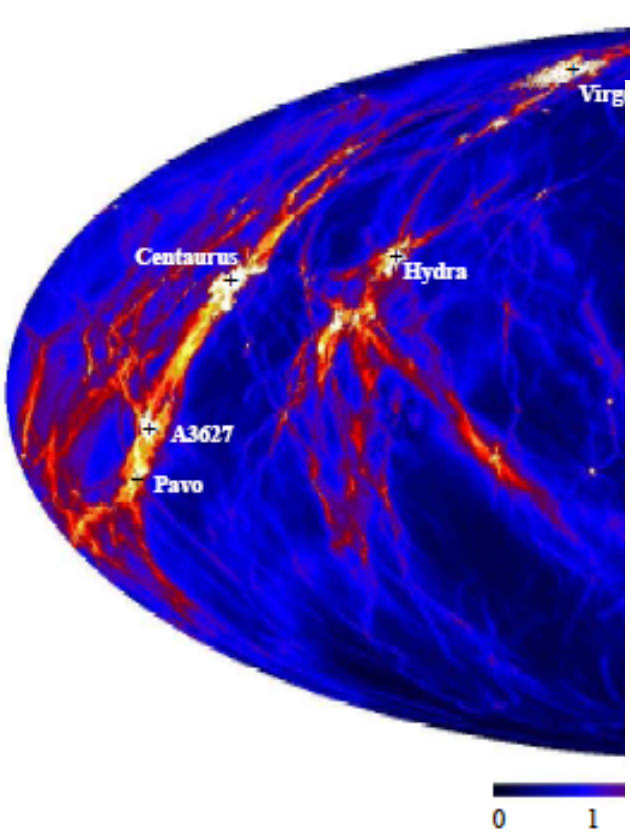


FIG. 1: Full sky map (area preserving projection) of d
scale. All structure within a radius of 107 Mpc aroun
with the galactic anti-center in the middle of the ma
corresponding halos in the simulation.

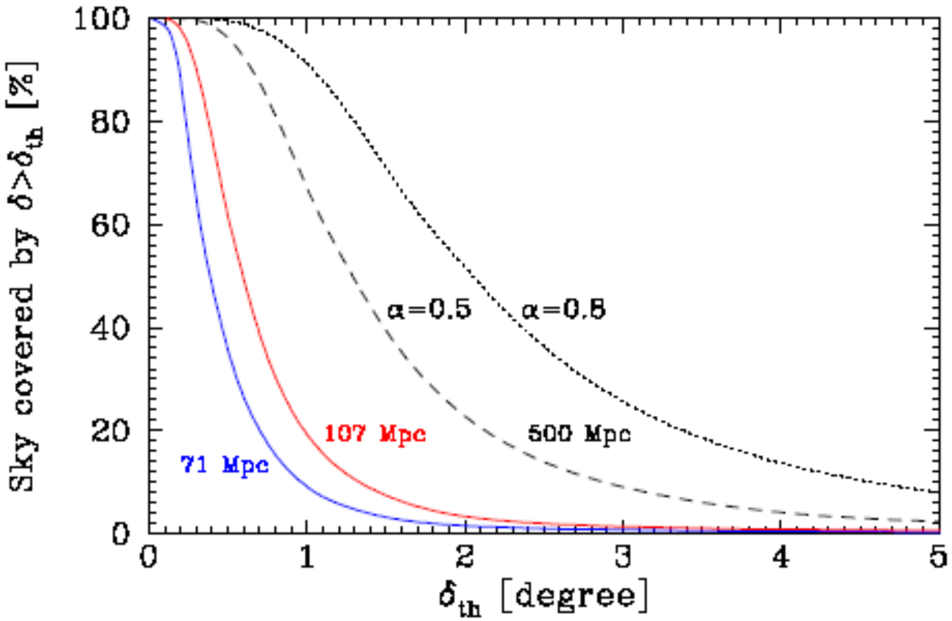
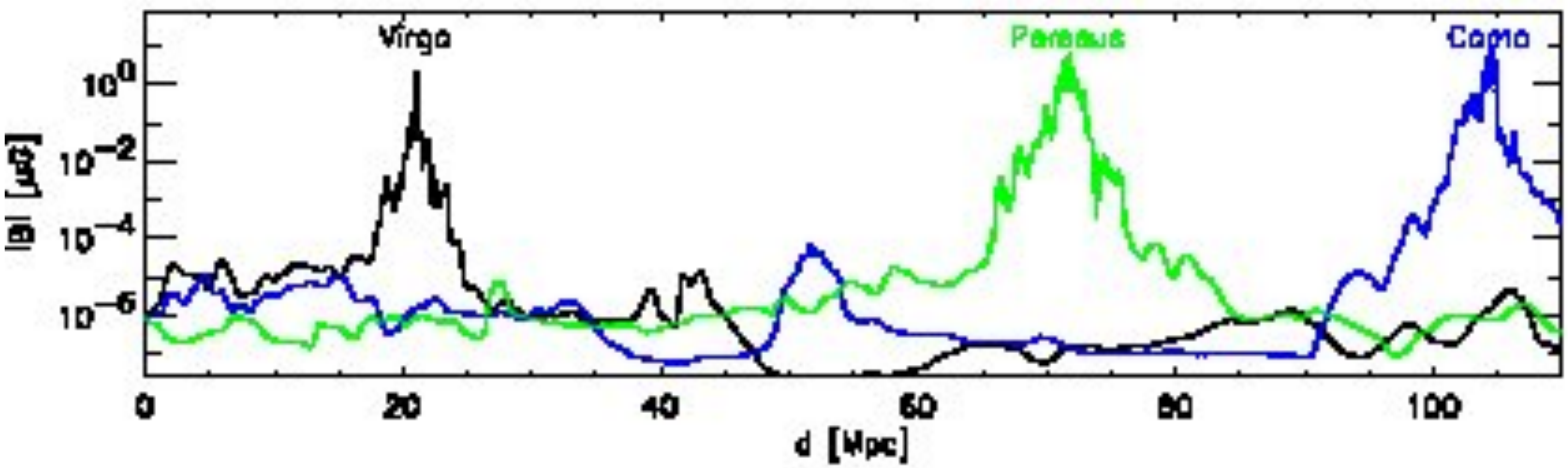


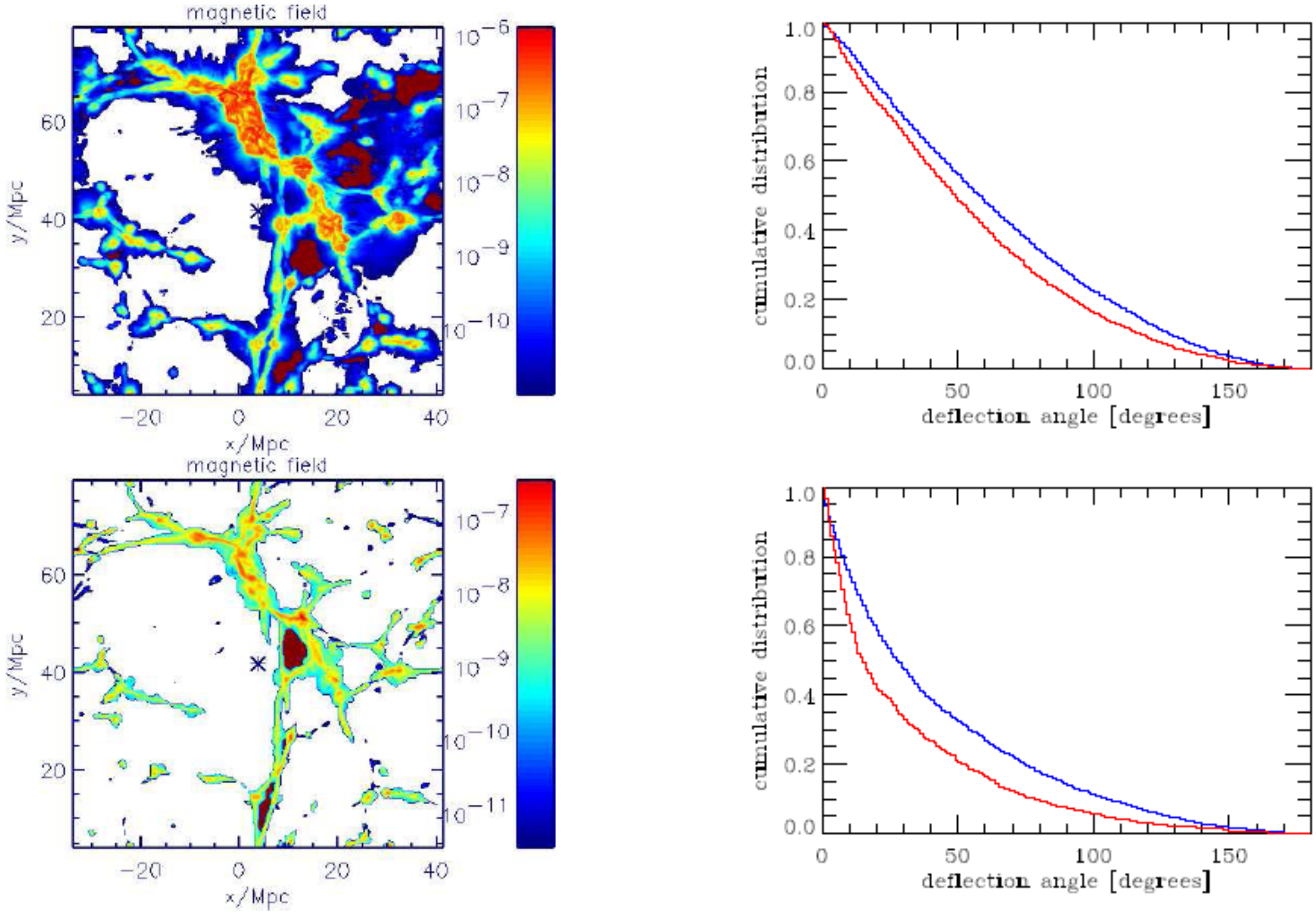
FIG. 2: Cumulative fraction of the sky with deflection angle larger than δ_{th}, for several values of propagation distance (solid lines). We also include an extrapolation to 500 Mpc, assuming self similarity with $\alpha = 0.5$ (dashed line) or $\alpha = 0.8$ (dotted line). The assumed UHECR energy for all lines is 4.0×10^{19} eV.

Magnetic field in several directions from Earth for constrained simulation

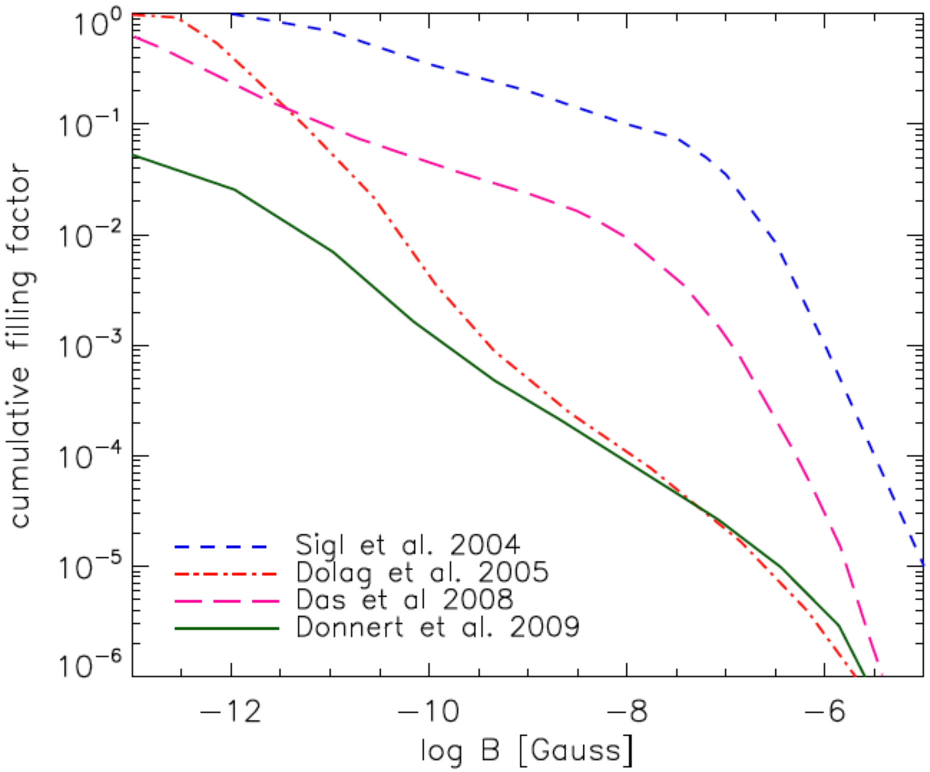


Dolag et al, astro-ph/0410419

EGMF by G. Sigl et al. astro-ph/0401084

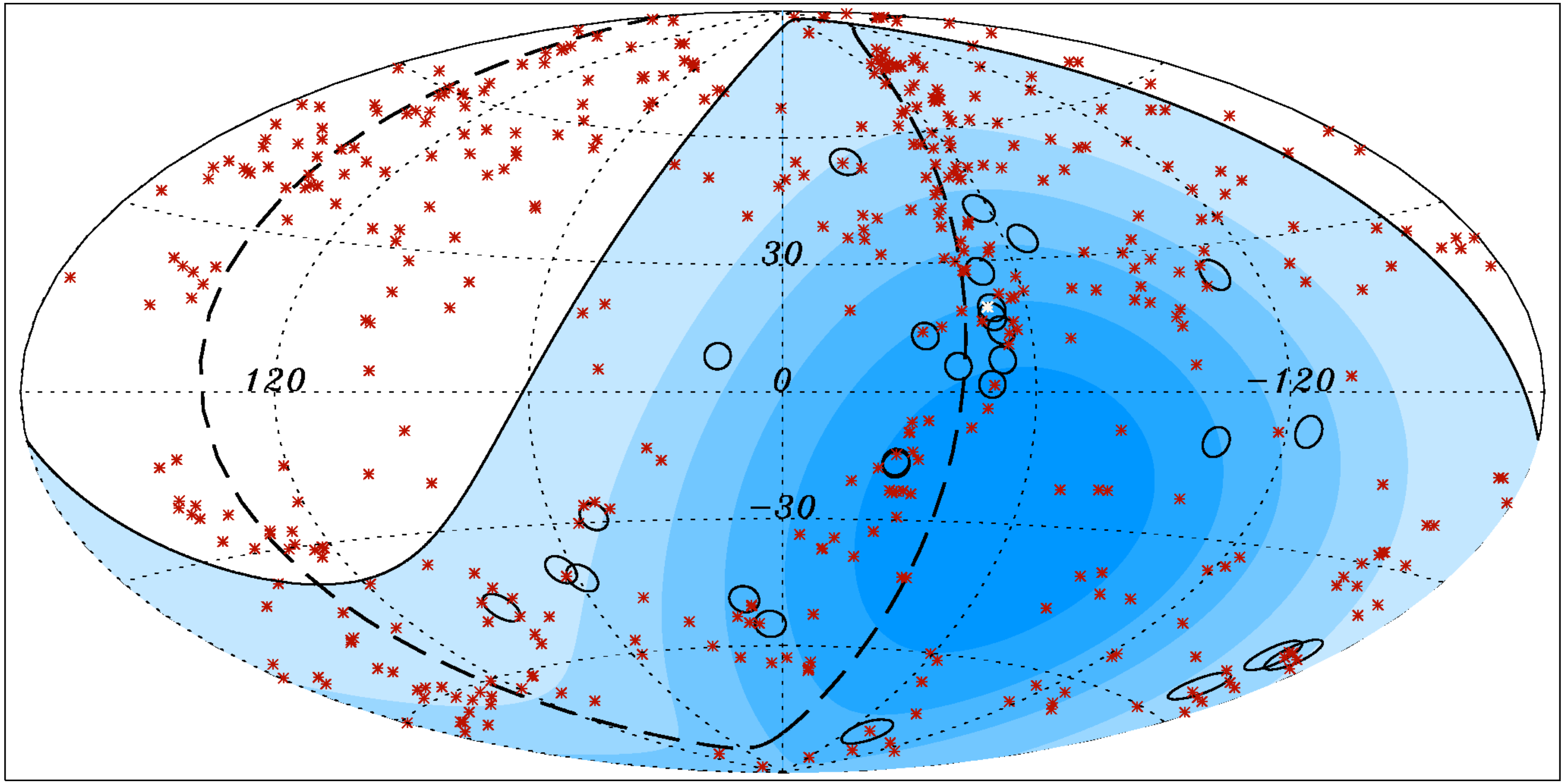


EGMF filling factor

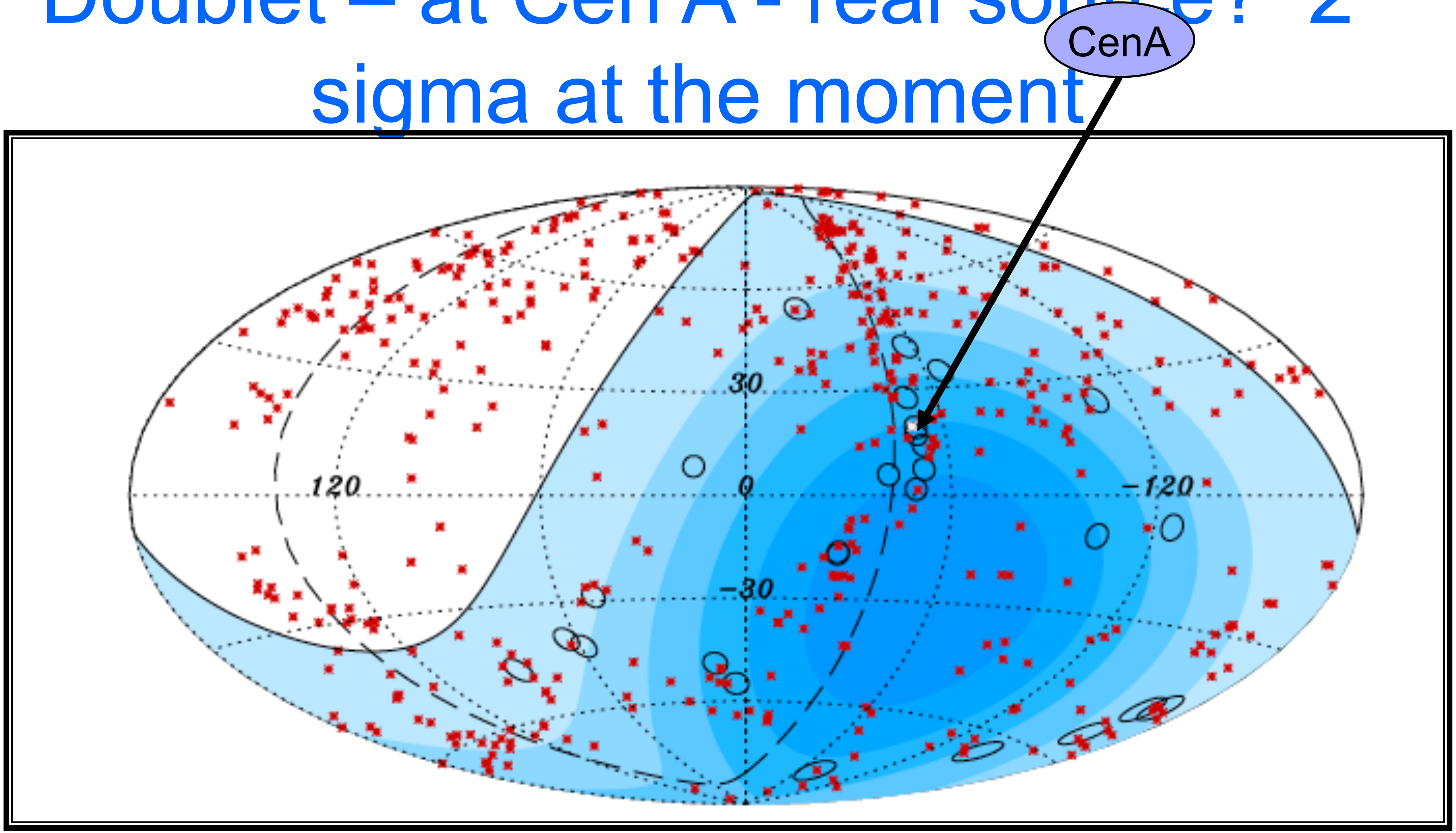


Sources of extragalactic cosmic rays

Arrival directions for E>57 EeV in Auger

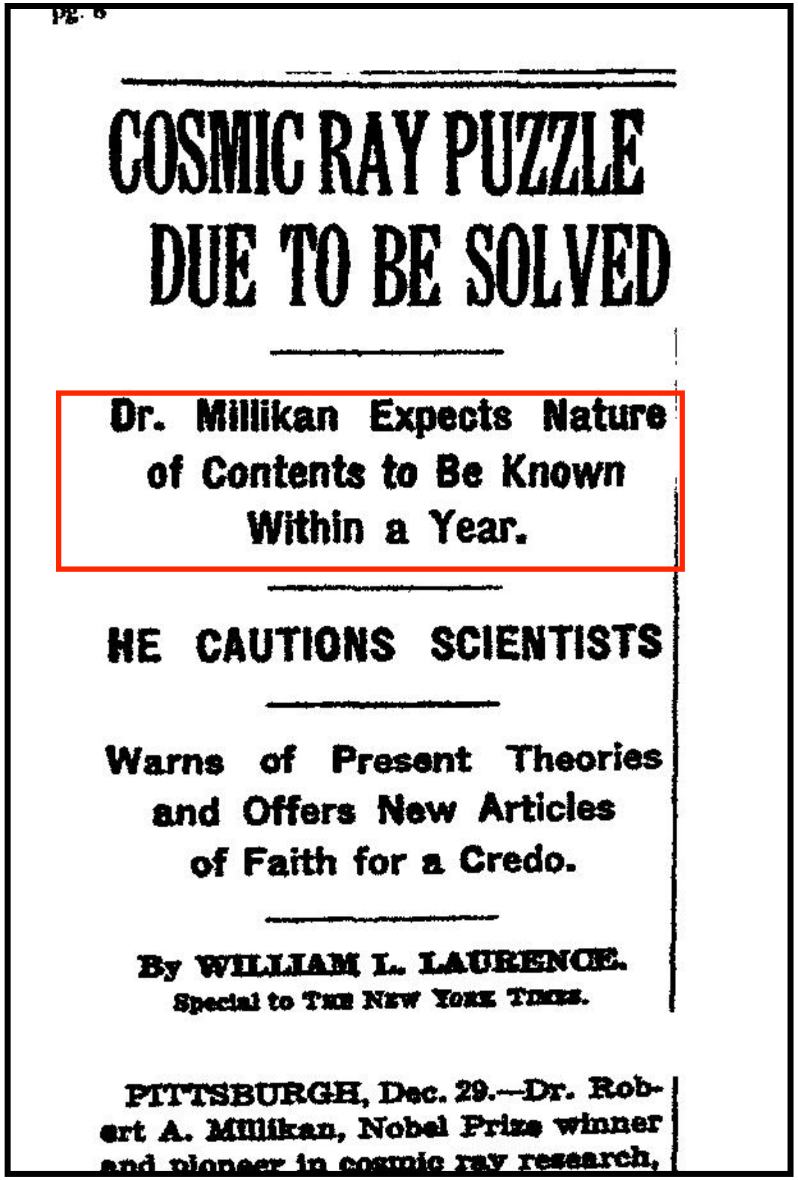


Doublet – at Cen A - real source? 2 sigma at the moment



- New York Times, December 29, 1932

Robert A. Millikan



COSMIC RAY PUZZLE DUE TO BE SOLVED

Dr. Millikan Expects Nature of Contents to Be Known Within a Year.

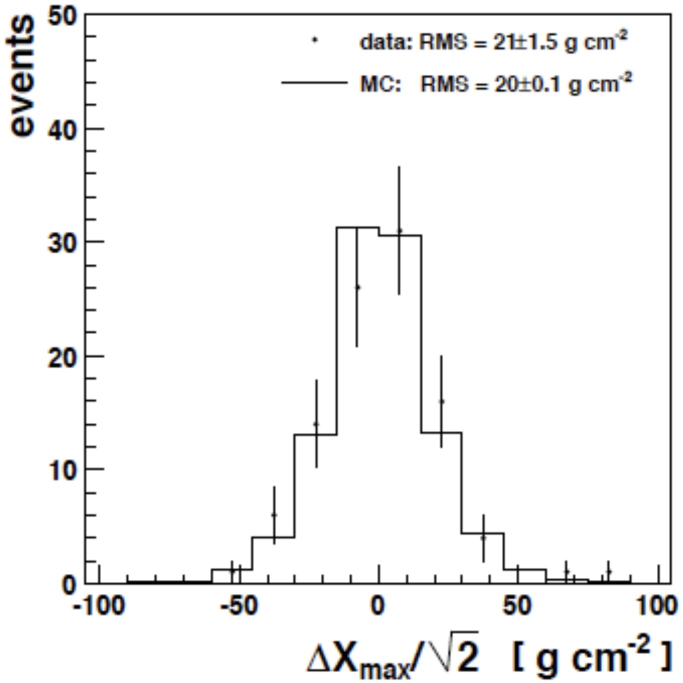
HE CAUTIONS SCIENTISTS

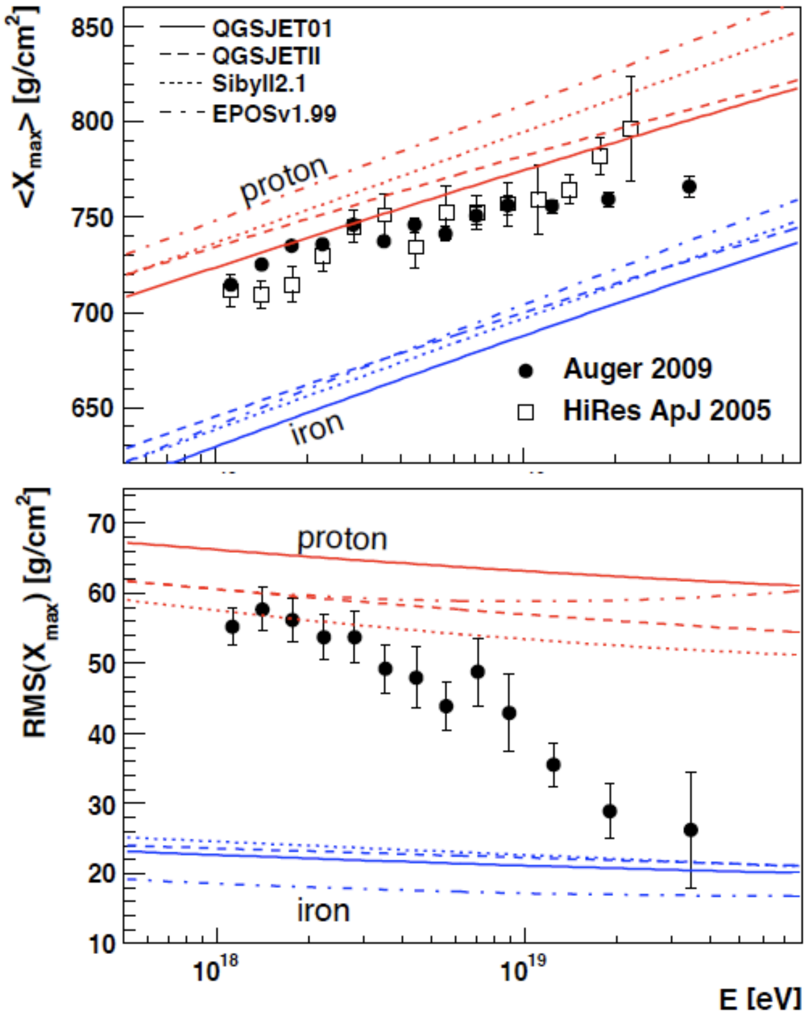
Warns of Present Theories and Offers New Articles of Faith for a Credo.

By WILLIAM L. LAURENCE.
Special to THE NEW YORK TIMES.

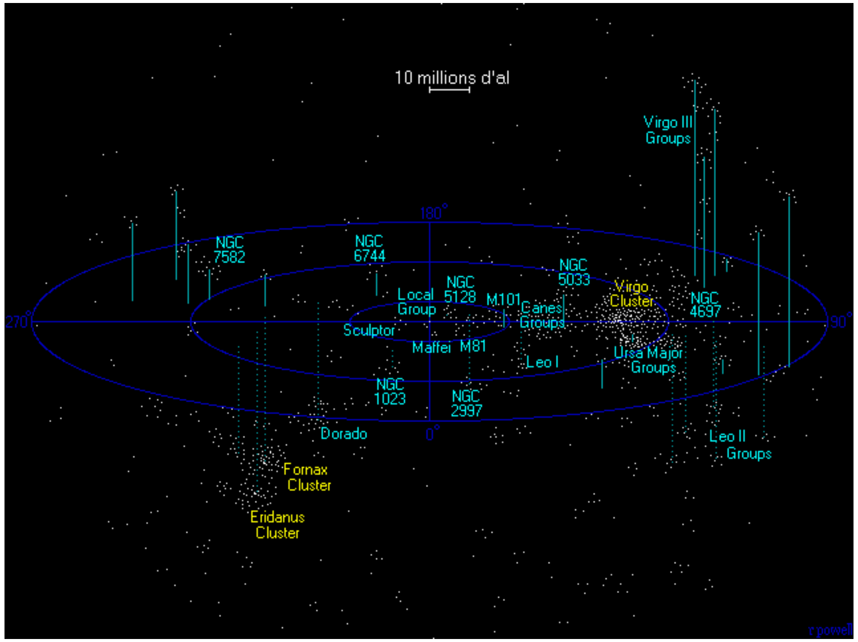
PITTSBURGH, Dec. 29.—Dr. Robert A. Millikan, Nobel Prize winner and pioneer in cosmic ray research,

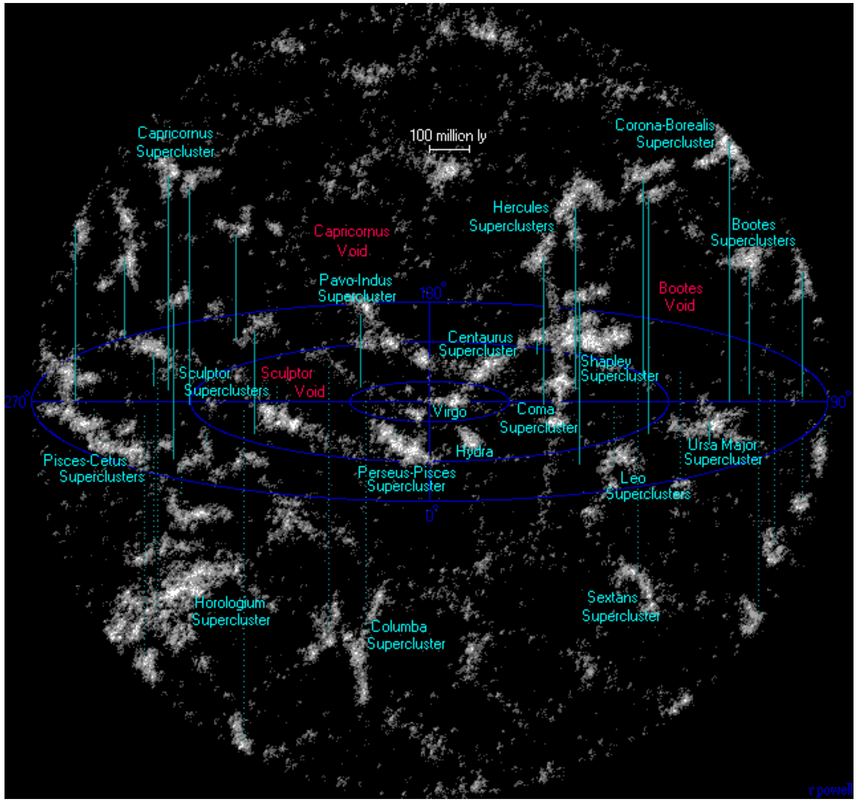
Auger composition 2009: nuclei!



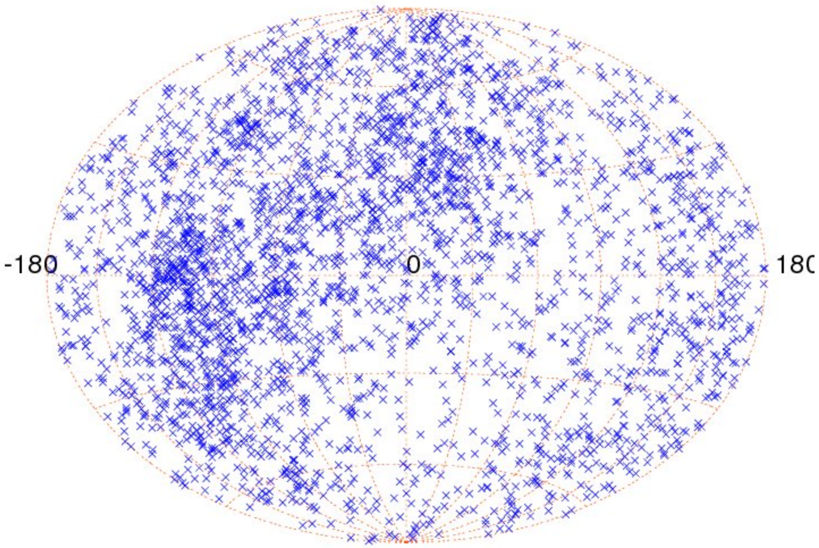


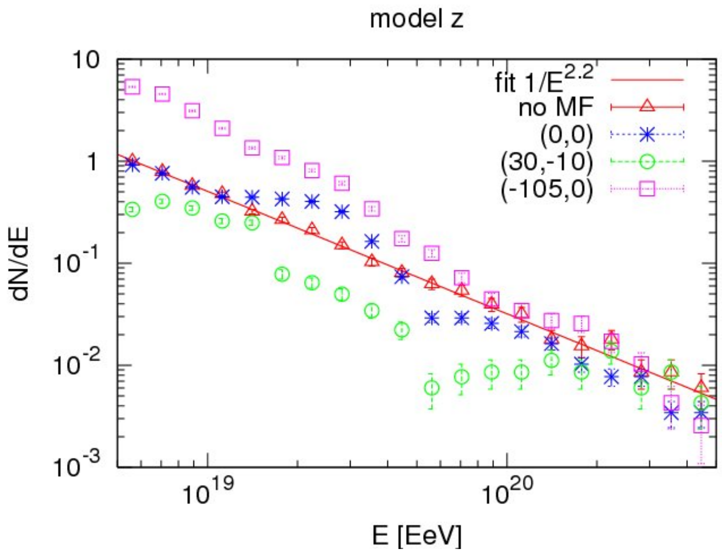
Local LSS


10 millions d'al
Virgo III Groups
NGC 7582
NGC 6744
180°
NGC 5033
Local Group
NGC 5128
M101
Canes Groups
Virgo Cluster
NGC 4697
270°
90°
Sculptor
Maffei
M81
Leo I
Ursa Major Groups
NGC 1023
NGC 2997
Dorado
0°
Leo II Groups
Fornax Cluster
Eridanus Cluster


Capricornus Supercluster
100 million ly
Corona Borealis Supercluster
Hercules Superclusters
Capricornus Void
Bootes Superclusters
Pavo-Indus Supercluster
180°
Bootes Void
Centaurus Supercluster
Sculptor Superclusters
Sculptor Void
Shapley Supercluster
270°
90°
Virgo
Coma Supercluster
Hydra
Pisces-Cetus Superclusters
Perseus-Pisces Supercluster
Ursa Major Supercluster
Leo Superclusters
0°
Horologium Supercluster
Columba Supercluster
Sextans Supercluster

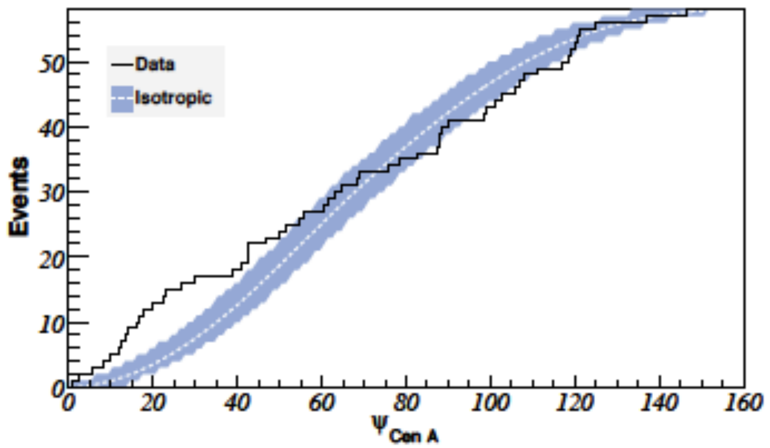
Source in magnetized region





K.Dolag, M.Kachelriess and D.S., **arXiv:0809.5055**

Cen A region: Auger



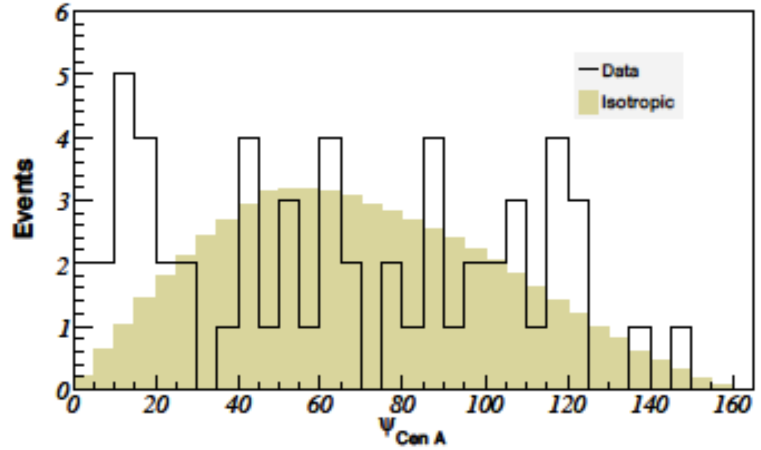
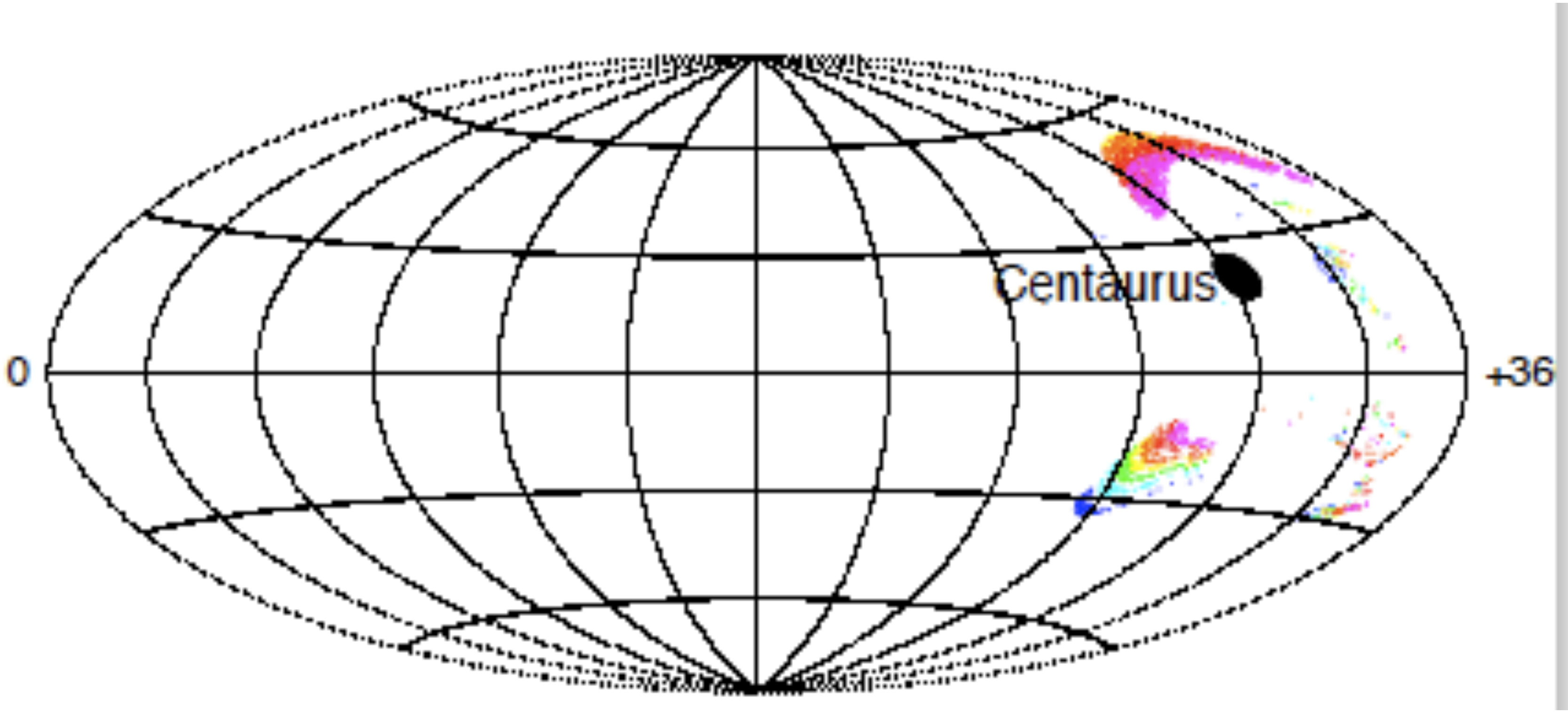


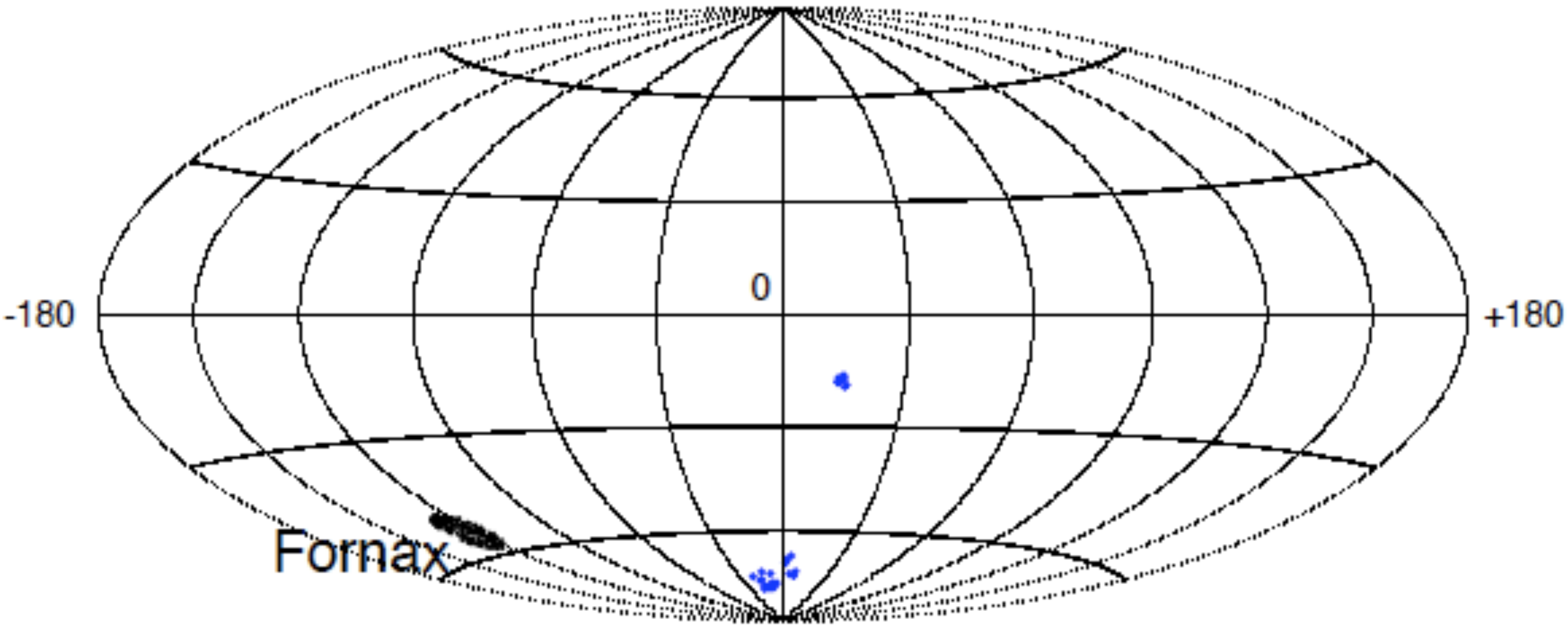
Fig. 3. *Left:* The cumulative number of events with $E \geq 55$ EeV as a function of angular distance from Cen A. The average isotropic expectation with approximate 68% confidence intervals is shaded blue. *Right:* The histogram of events as a function of angular distance from Cen A. The average isotropic expectation is shaded brown.

Image of galaxy cluster: regular field



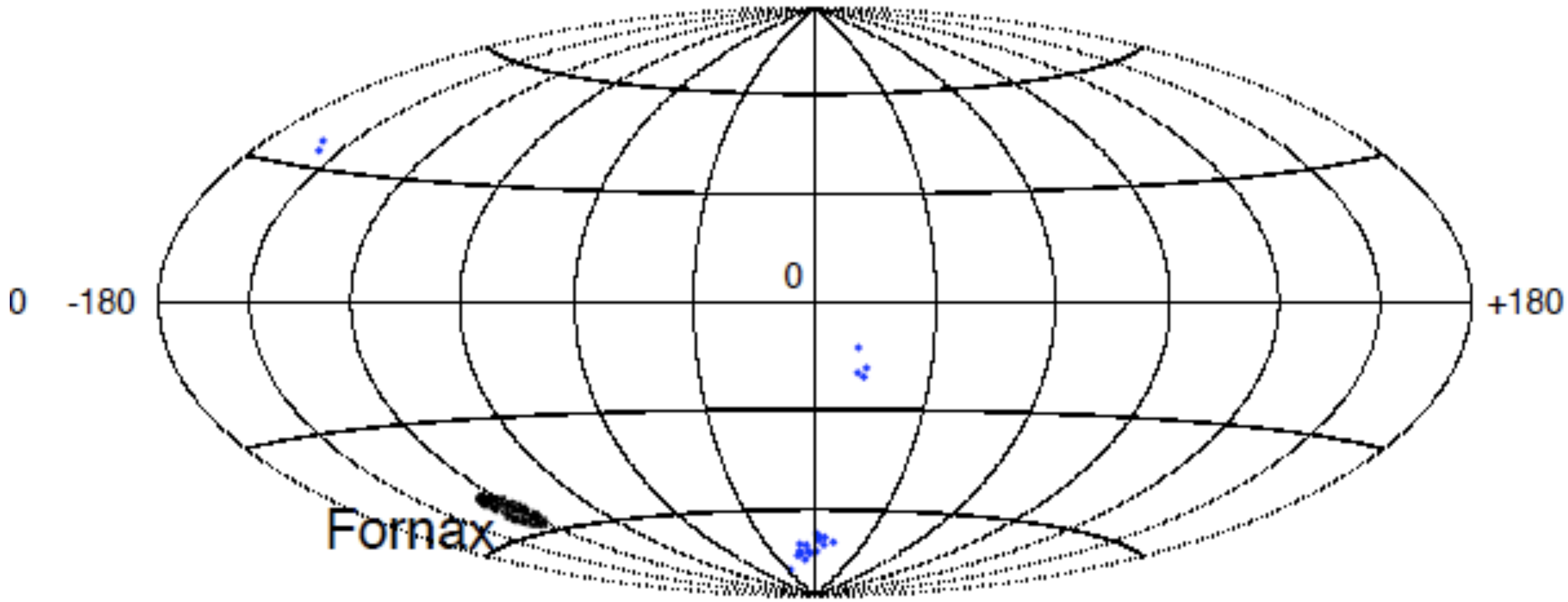
G.Giacinti et al, **arXiv:1006.5416**

Image of galaxy cluster: regular field



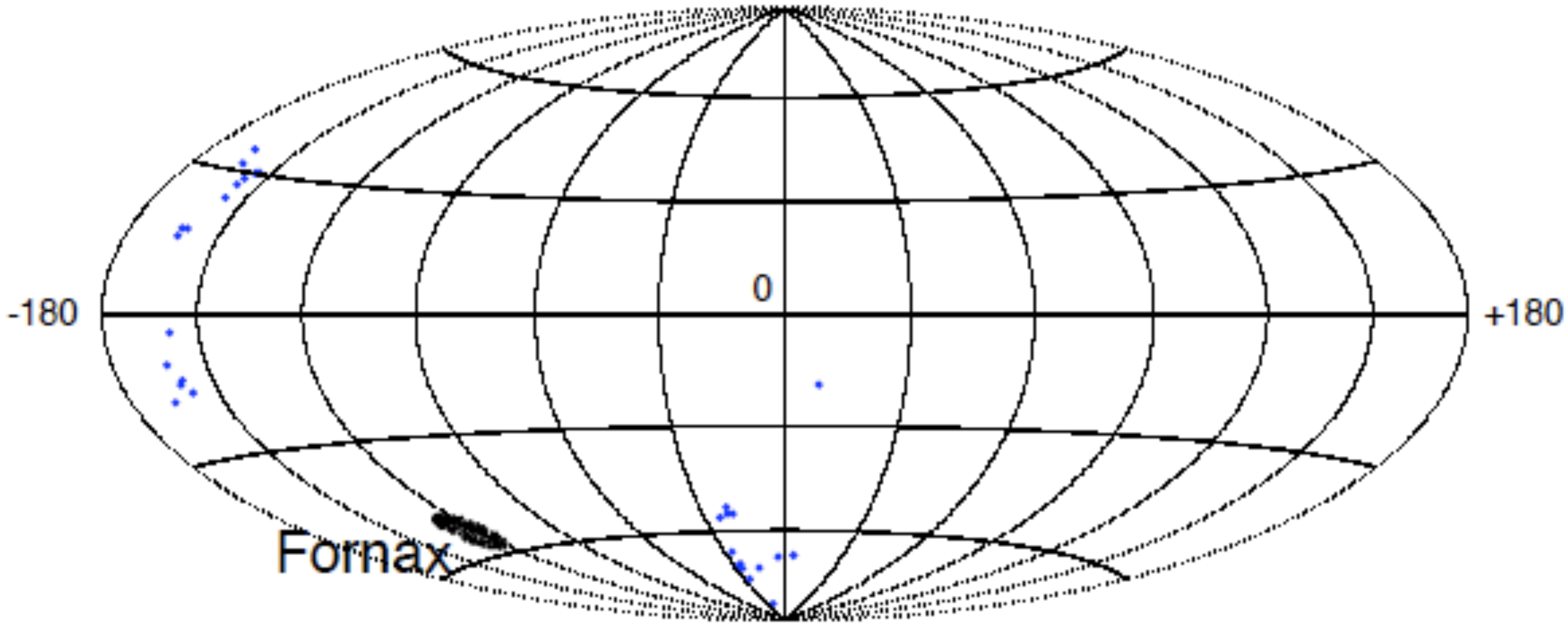
G.Giacinti et al, **arXiv:1104.1141**

Image of galaxy cluster: turbulent field



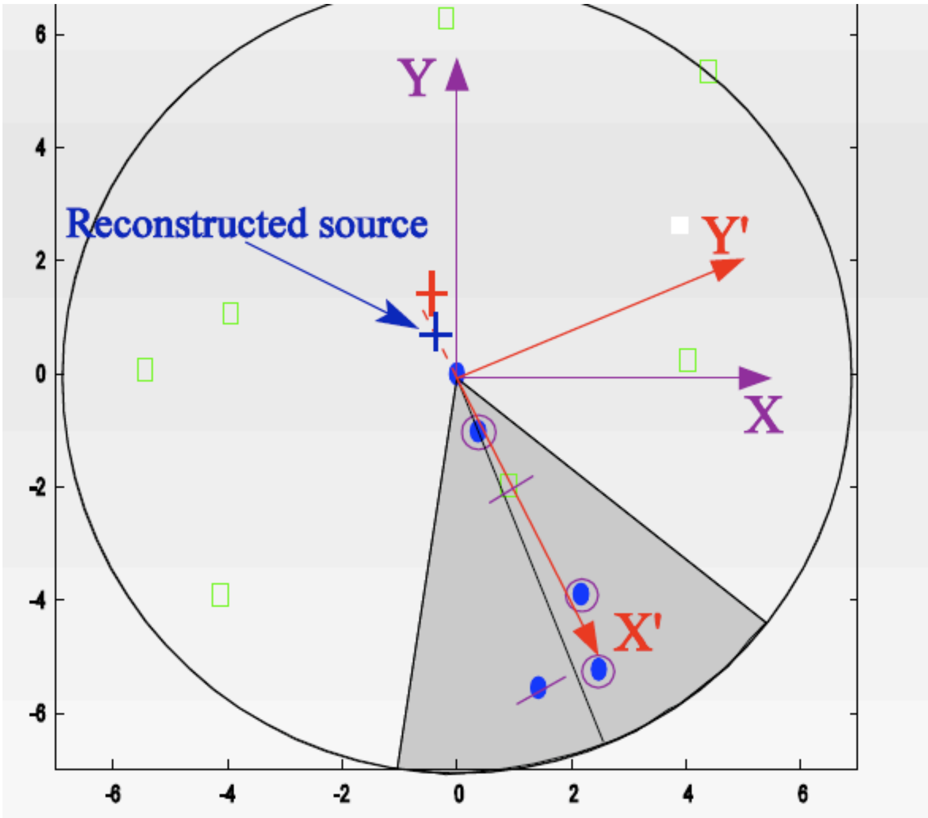
G.Giacinti et al, **arXiv:1104.1141**

Image of galaxy cluster: turbulent field



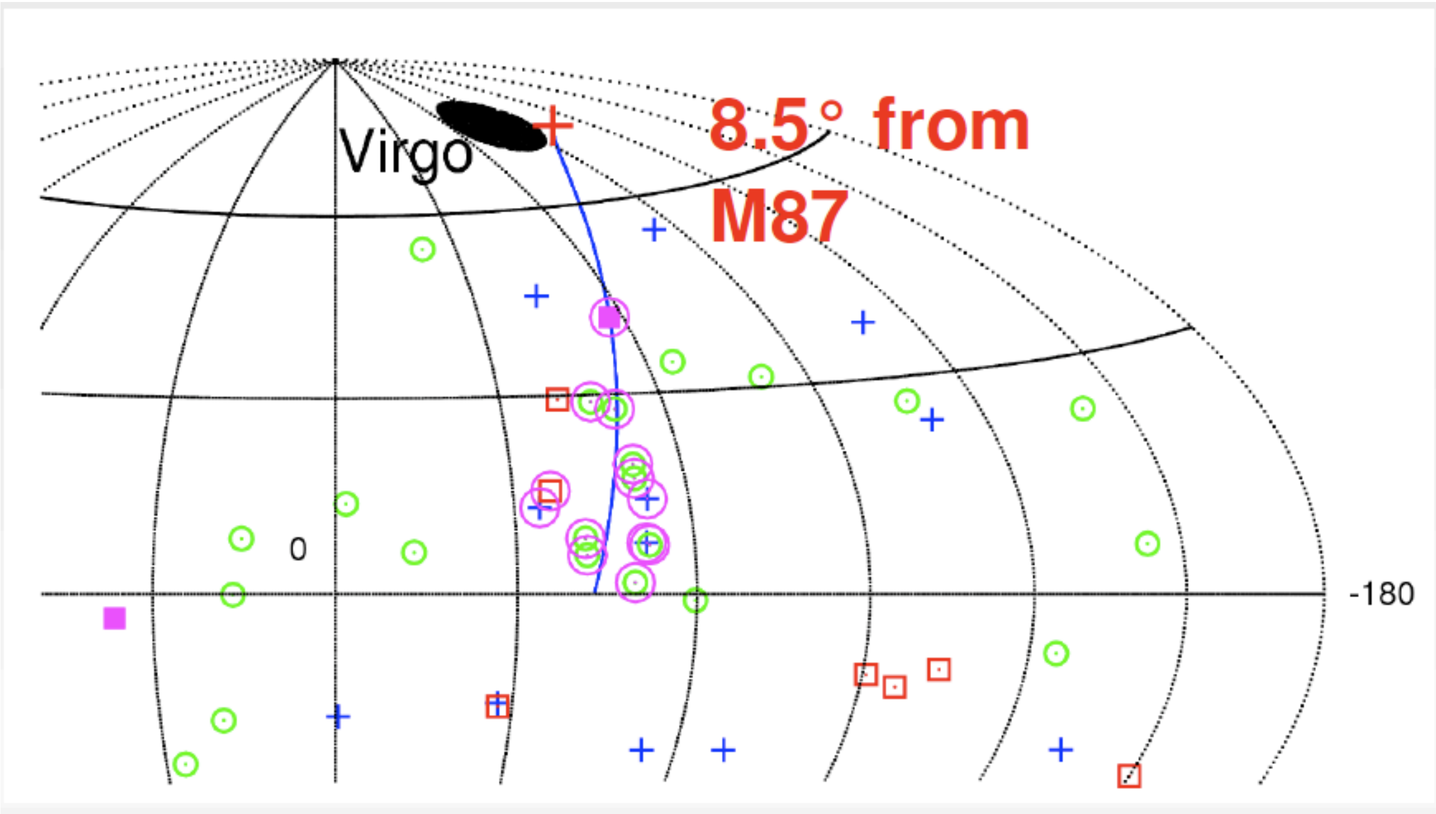
G.Giacinti et al, **arXiv:1104.1141**

Method for search of UHE nuclei source



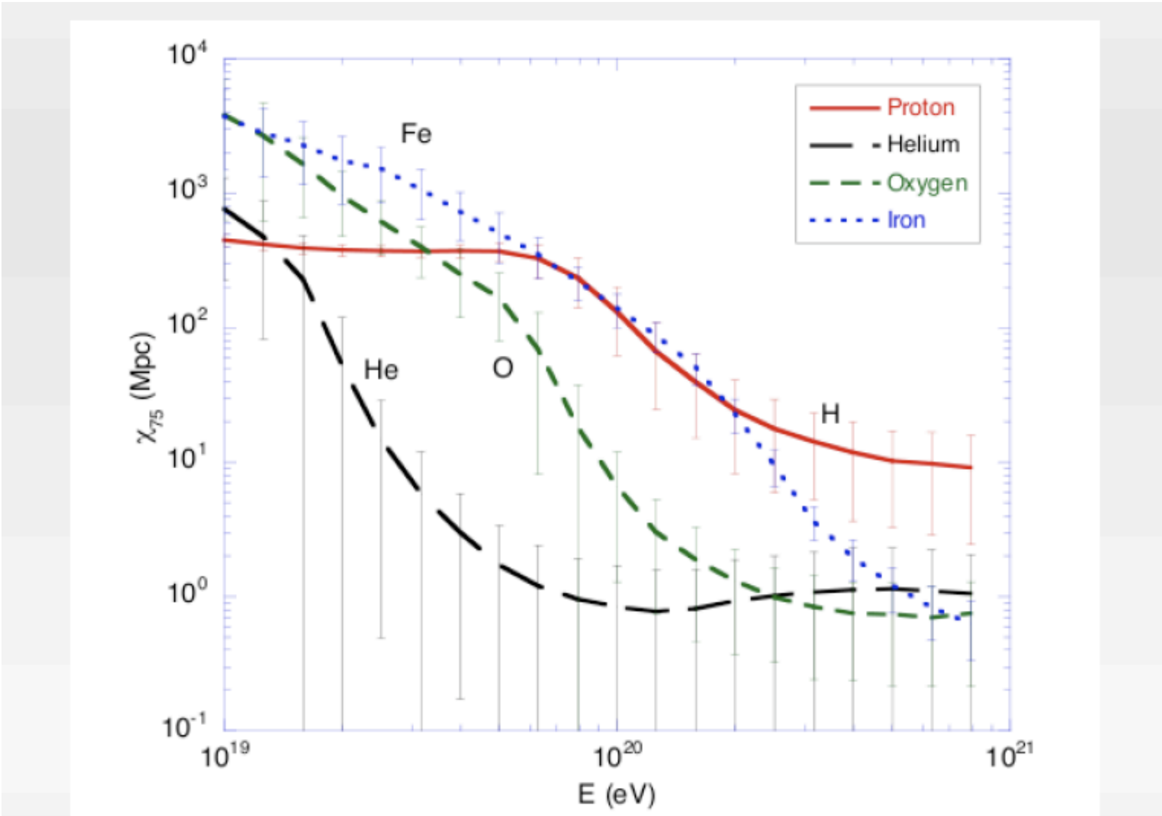
G.Giacinti and D.S., **arXiv:1011.6333**

Application to Auger data



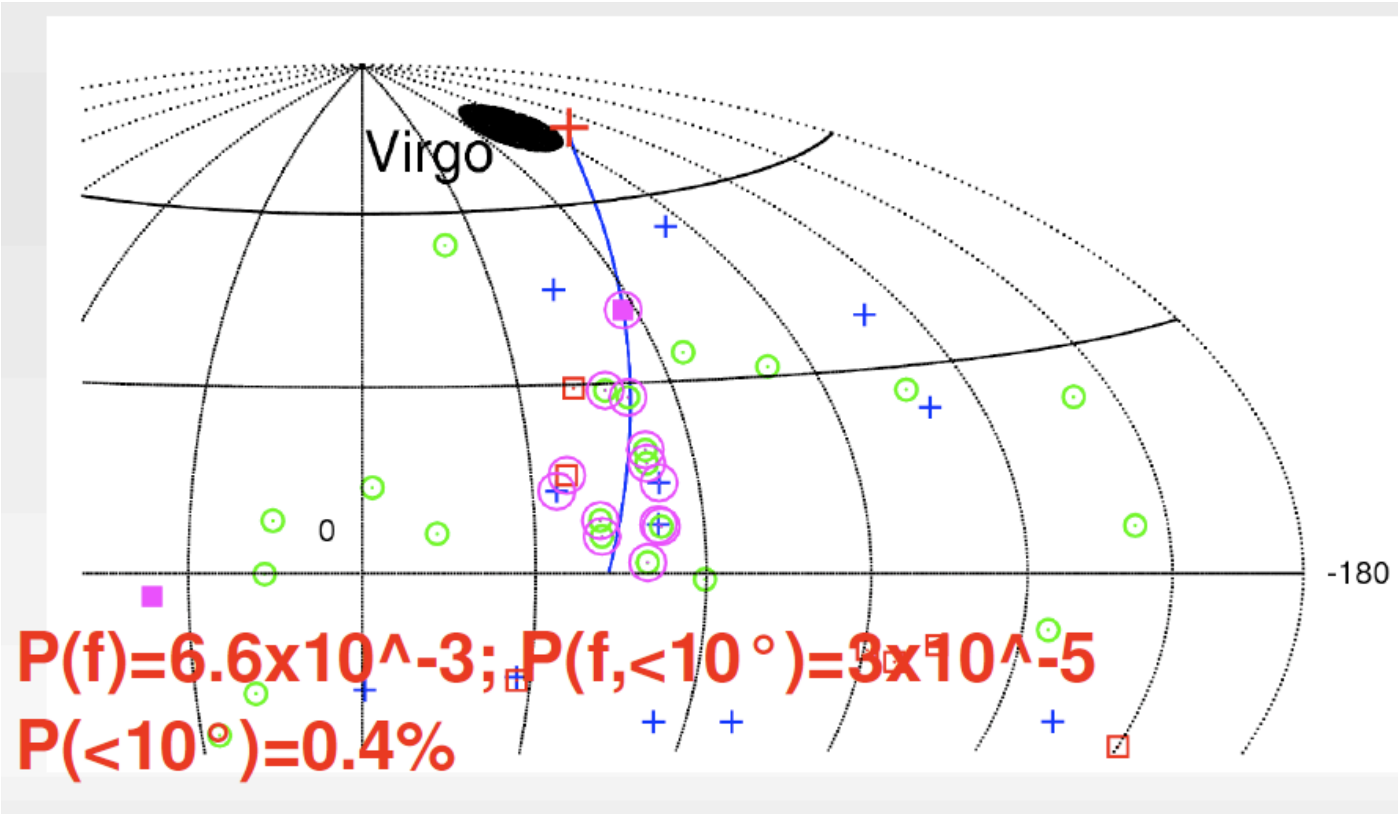
G.Giacinti and D.S., **arXiv:1011.6333**

Application to Auger data



D.Allard et al

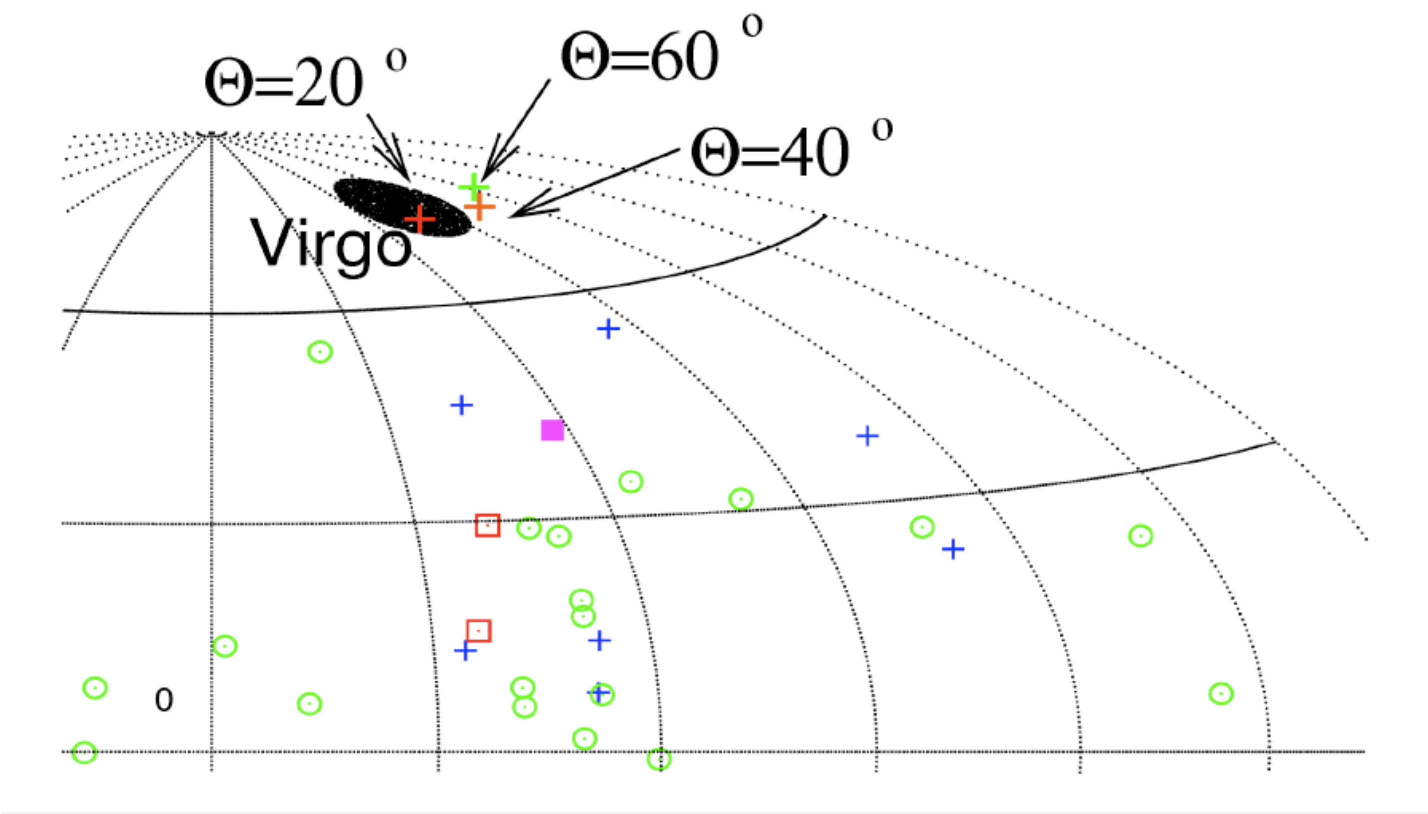
Application to Auger data



P(f)=6.6x10^-3; P(f,<10°)=3x10^-5
P(<10°)=0.4%

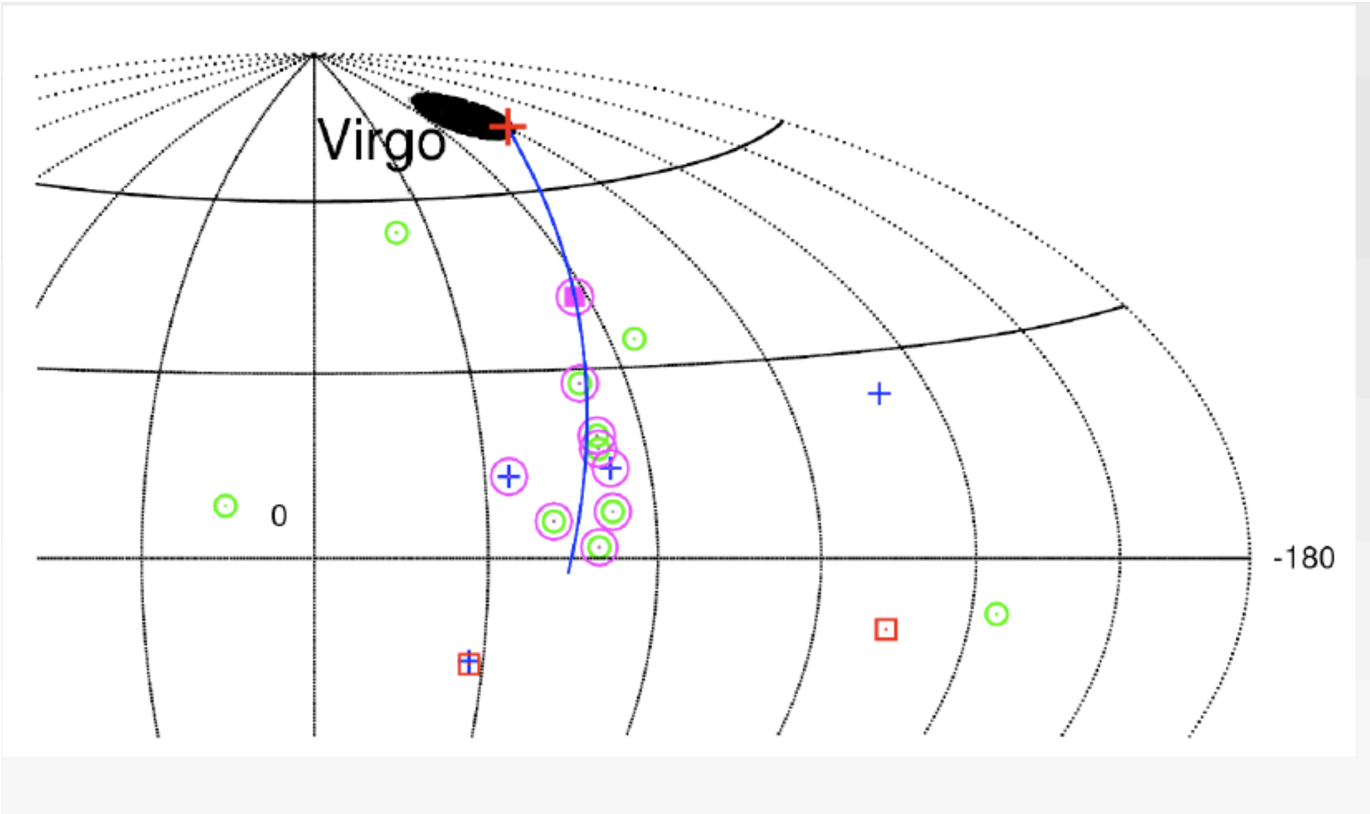
G.Giacinti and D.S., **arXiv:1011.6333**

Application to Auger data



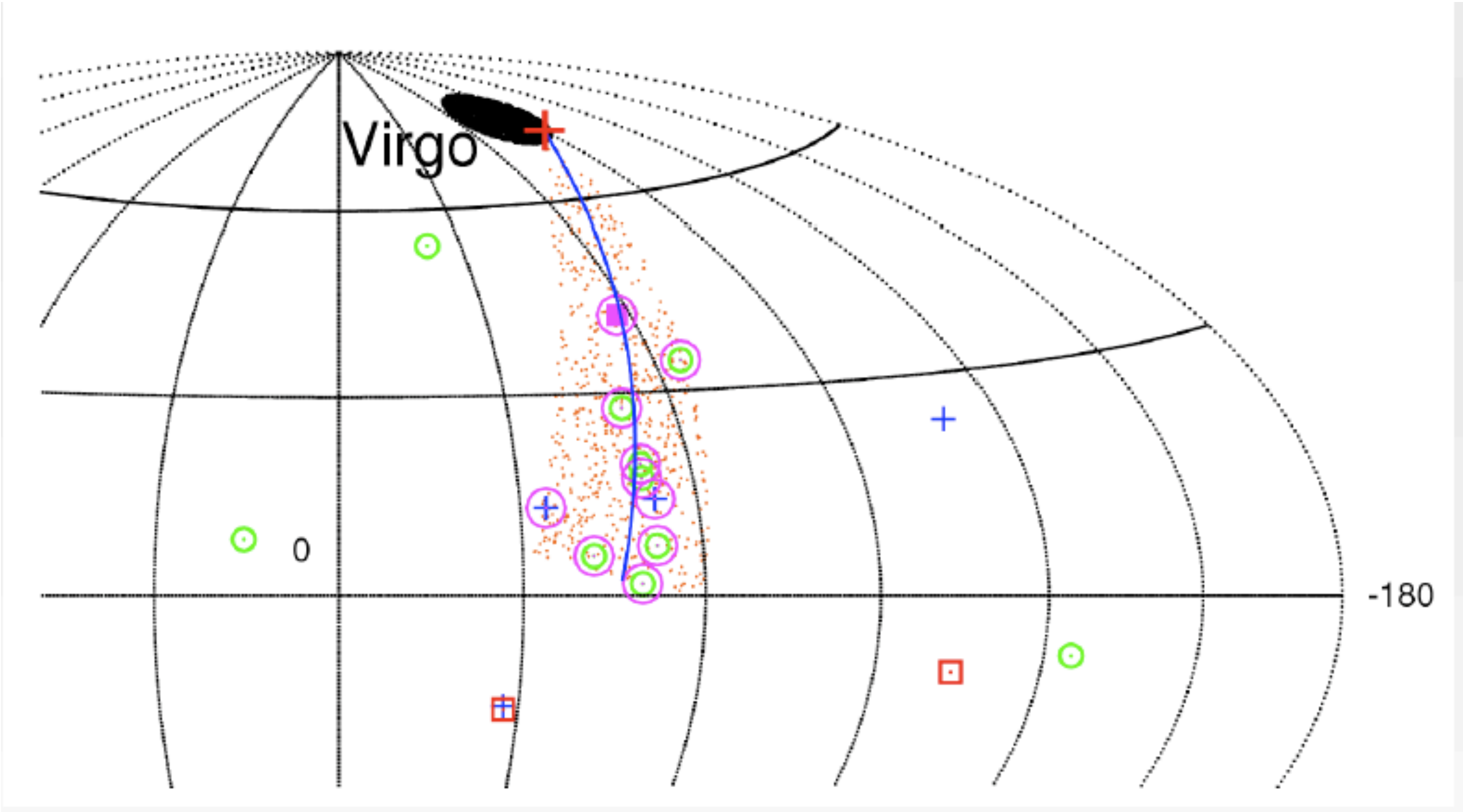
G.Giacinti and D.S., **arXiv:1011.6333**

Application to Auger data: 27 events as first set



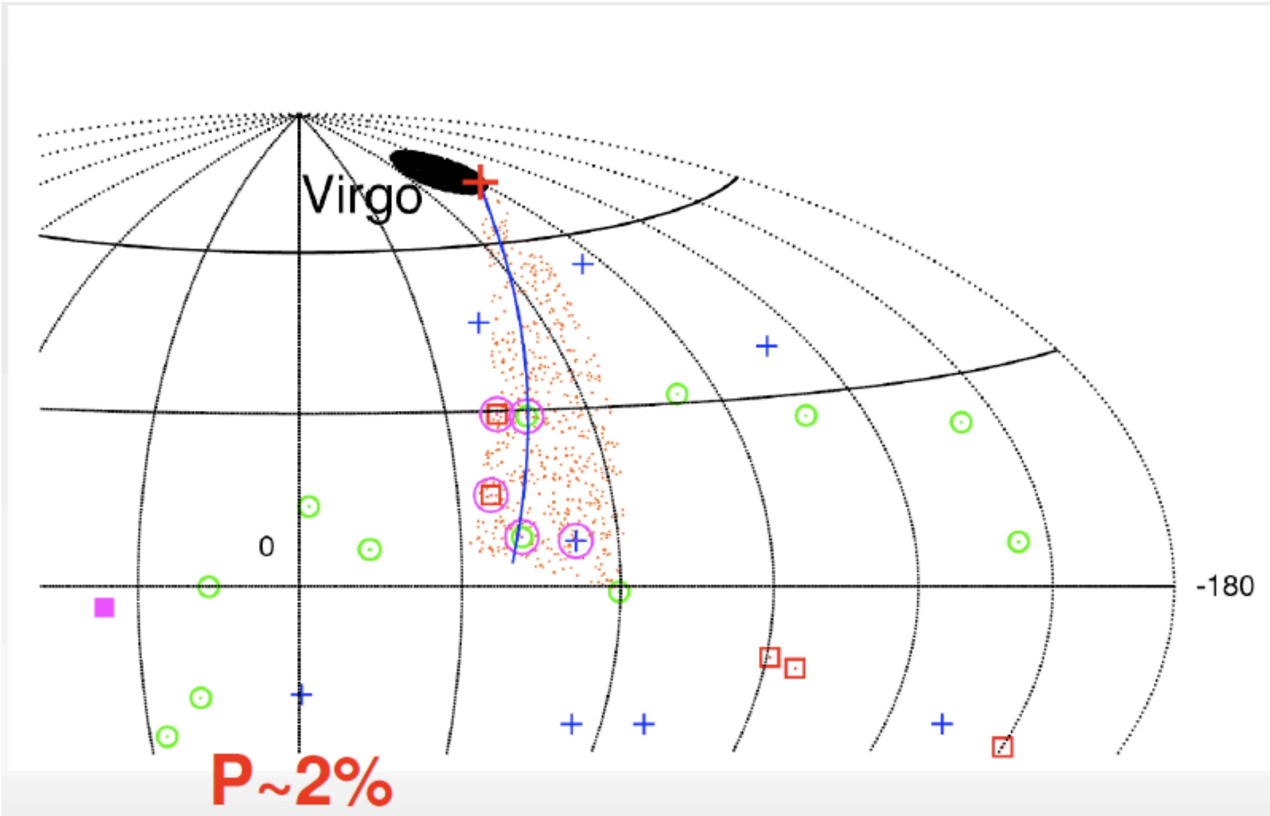
G.Giacinti and D.S., **arXiv:1011.6333**

Application to Auger data: 27 events as first set



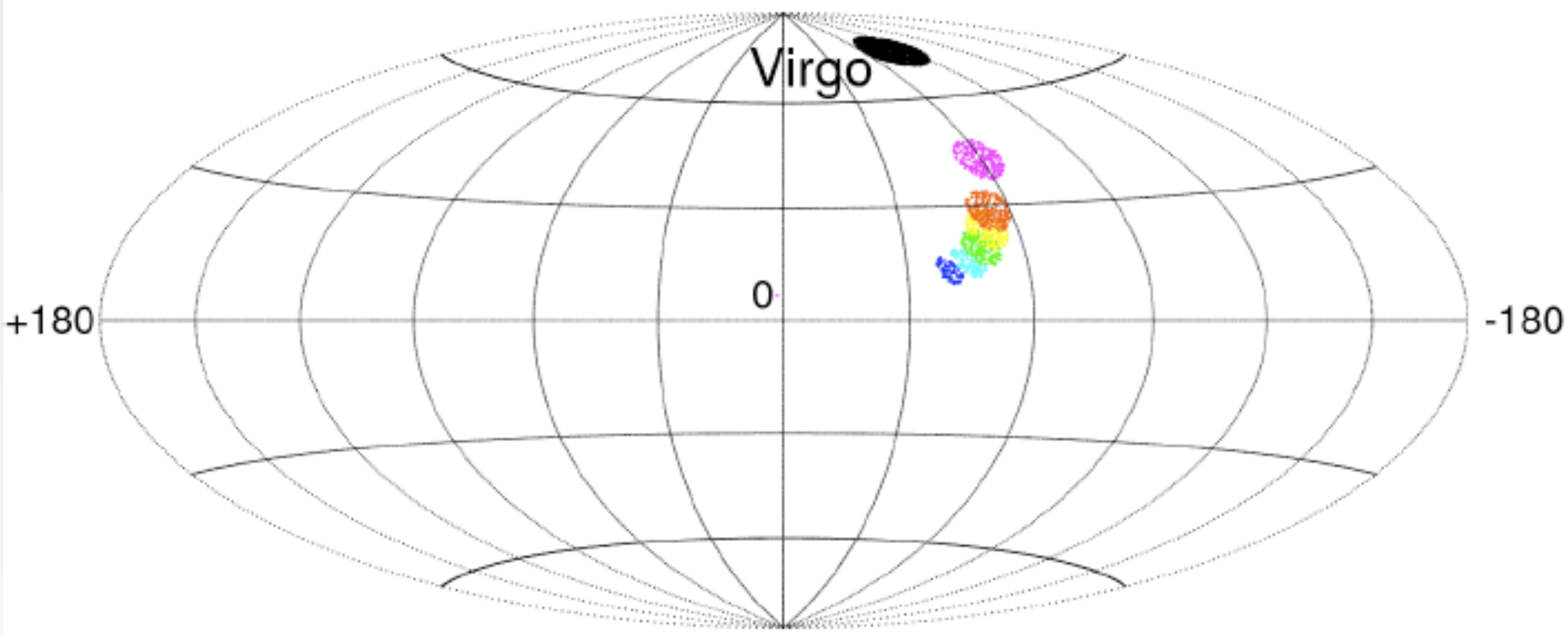
G.Giacinti and D.S., **arXiv:1011.6333**

Application to Auger data: 39 events as second set



G.Giacinti and D.S., **arXiv:1011.6333**

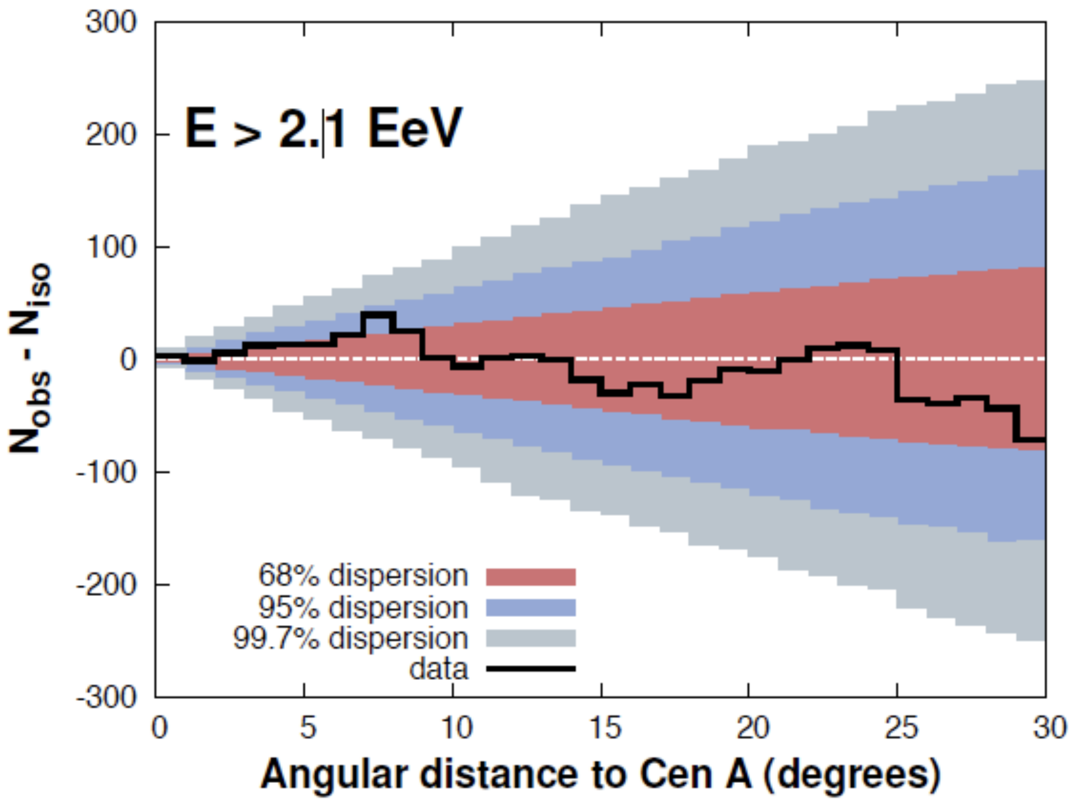
Model simulation of the galactic magnetic field



G.Giacinti and D.S., **arXiv:1011.6333**

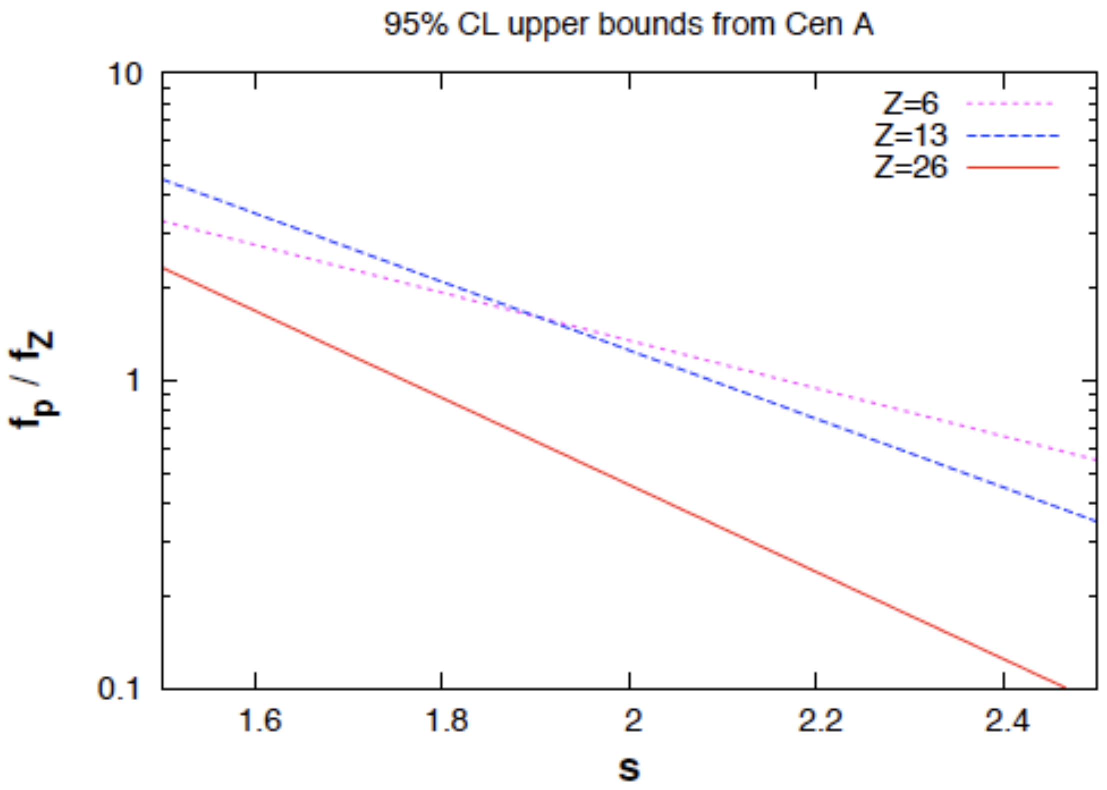
Cen A: check at low energy

M. Lemoine, E. Waxman, JCAP 11 (2009) 009.



Auger 1106.3048: Data = 2887 Back= 2920 +-54

Cen A: Auger 1106.3048



Conclusions

- We expect to see 10th of 100 pc CR sources with 100 GeV gamma-rays if SN are responsible for them. With Fermi LAT we found 18 sources with 90% radius 0.3-1 degree, which give real size about 100 pc. Most of sources associated with pulsars with age T<30 kyr
- Diffusion of CR around sources is very anisotropic, caused by high length (100 pc) modes of turbulent Galactic field.
- Detailed study of source morphology is required for every source to split electron (in center) and CR contributions.
- One can confirm CR origin with observation of neutrinos in 100 TeV range from same sources

Conclusions

- Auger limits on the anisotropy of UHECR does not restrict existence of galactic iron component up to ankle or even up to 10^19 eV, depending on parameters of galactic magnetic fields.

- Existing limits on anisotropy forbid large (conservatively 10% or more) fraction of Galactic protons at 1 EeV. This mean that quickly rising proton fraction below 1 EeV in KASCADE-Grande has extragalactic origin
- Cen A can not be connected to Auger excess in case of heavy nuclei primaries. Contrary Virgo can be a nearest source of UHE nuclei.