# PROPAGATION OF UHE HEAVY NUCLEI IN THE GALACTIC MAGNETIC FIELD

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G. SIGL (U. Hamburg, Germany)

arXiv:1006.5416

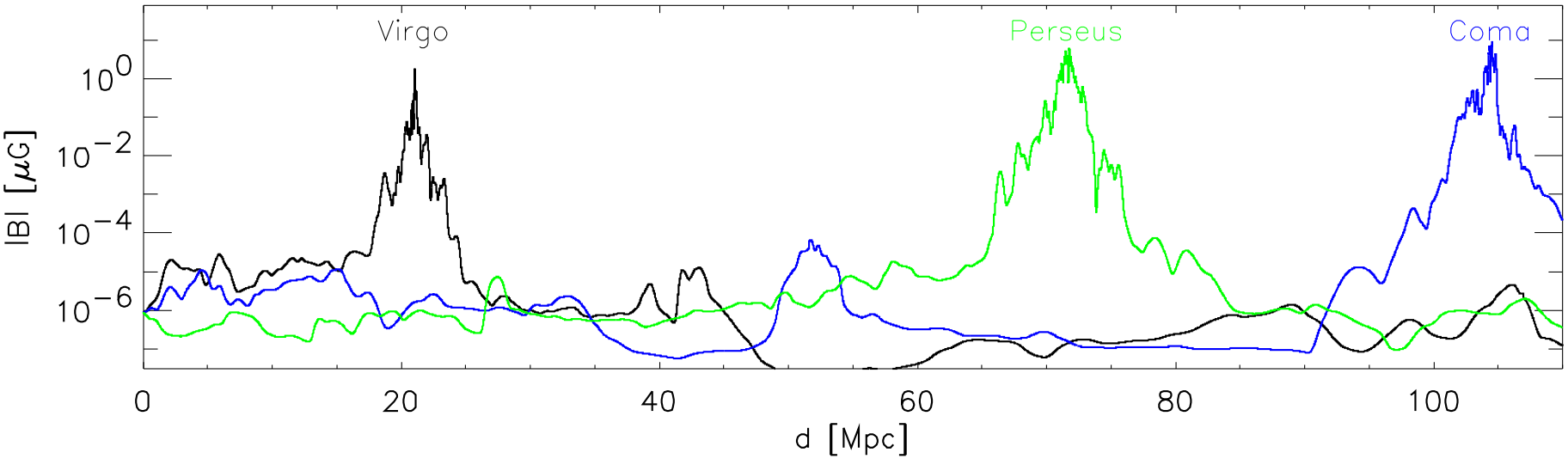
# Goal of the study:

- Composition at the highest energies: Auger, Yakutsk vs HiRes.
-> Study the propagation of UHE heavy nuclei (iron), with **E > 60 EeV**, in the Galactic Magnetic Field.
- Most of the previous works done for protons and light nuclei: search for sources, etc.

# I - Models of the Galactic Magnetic Field

# Extragalactic magnetic field neglected here

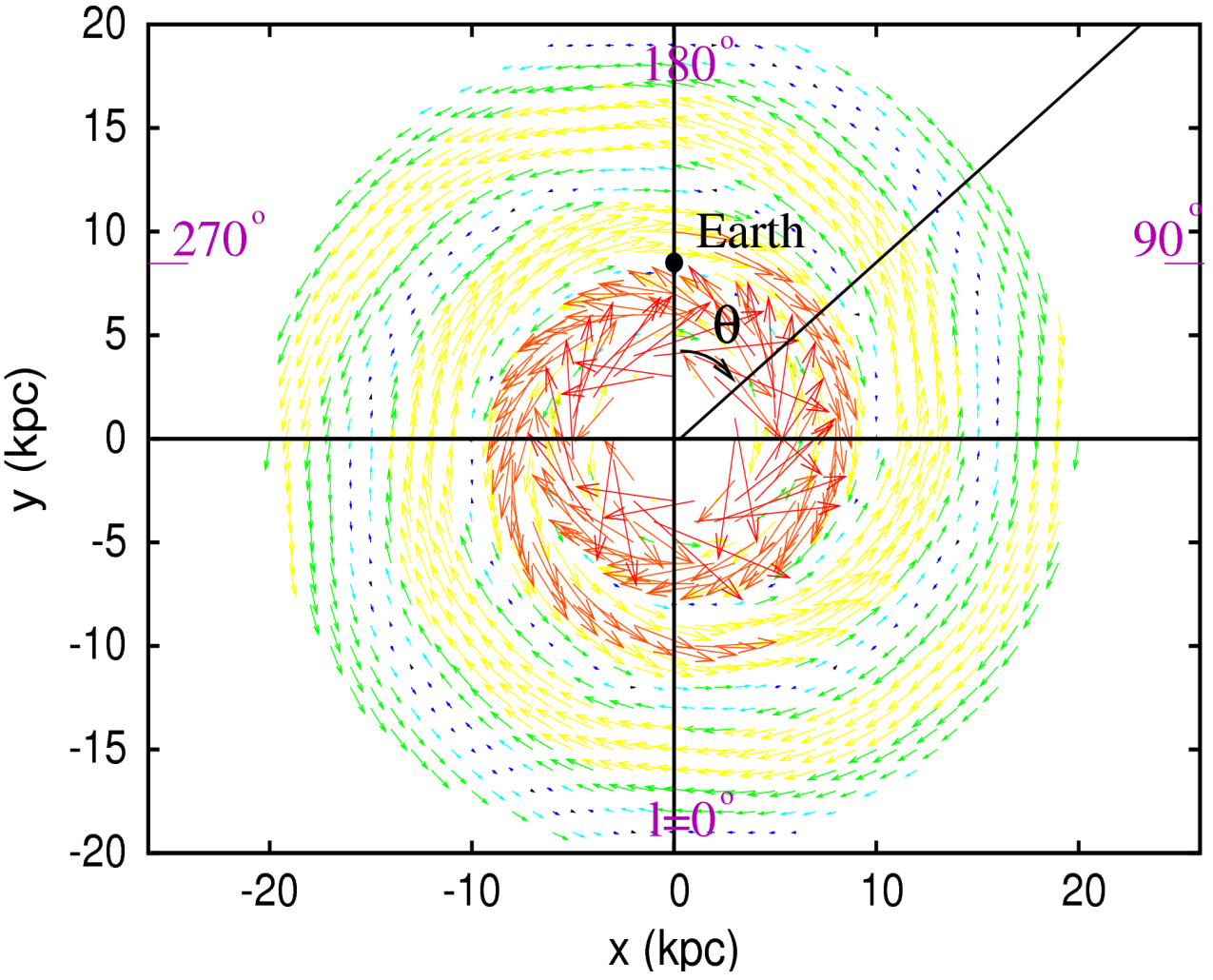
## K. Dolag *et al.* vs G. Sigl et al. (astro-ph/0401084)




K. Dolag *et al.*, astro-ph/0410419

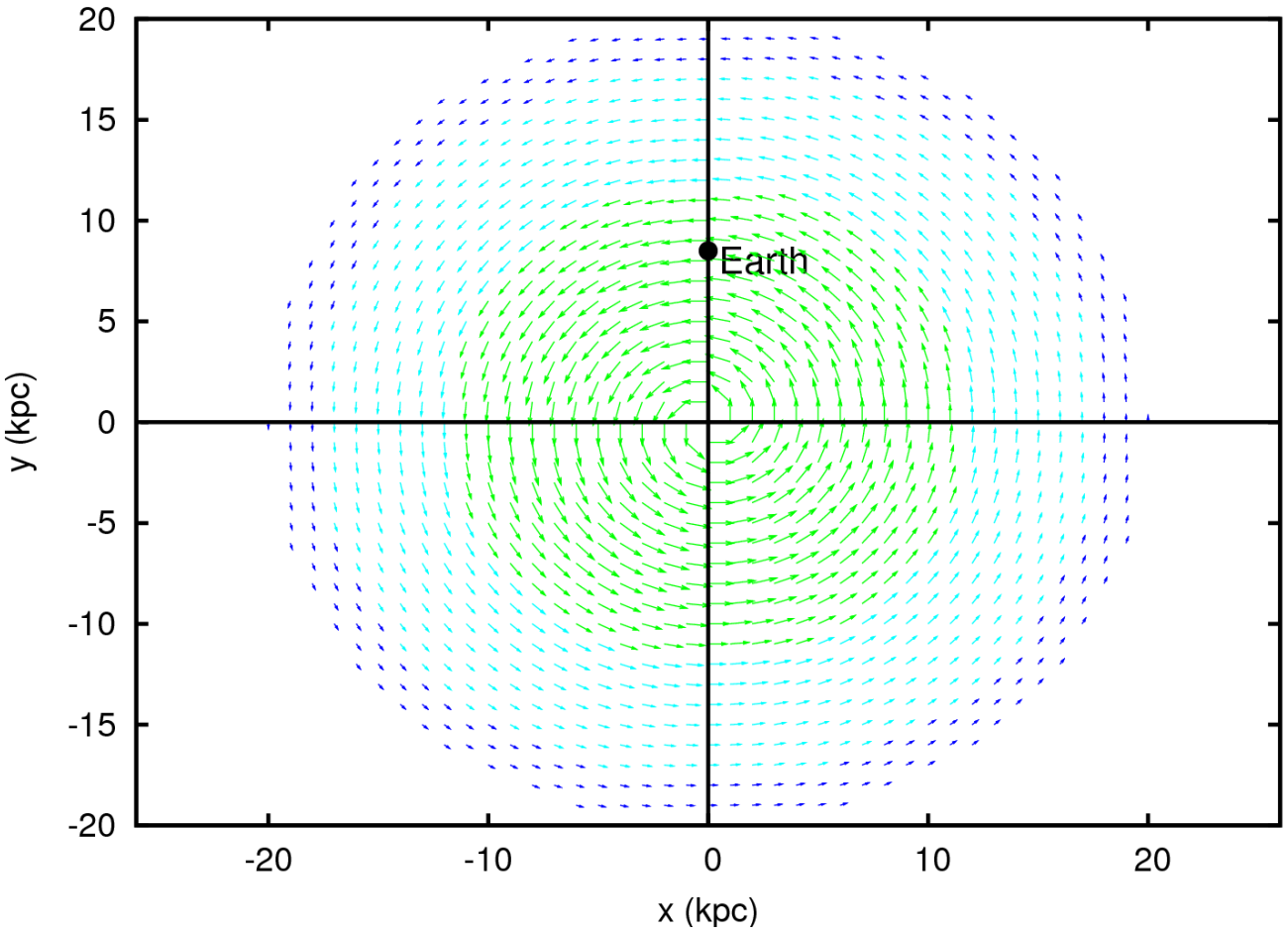
# The regular Galactic MF: disk + toroidal component (+ central dipole)

PS
disk model
astro-ph/
0510444



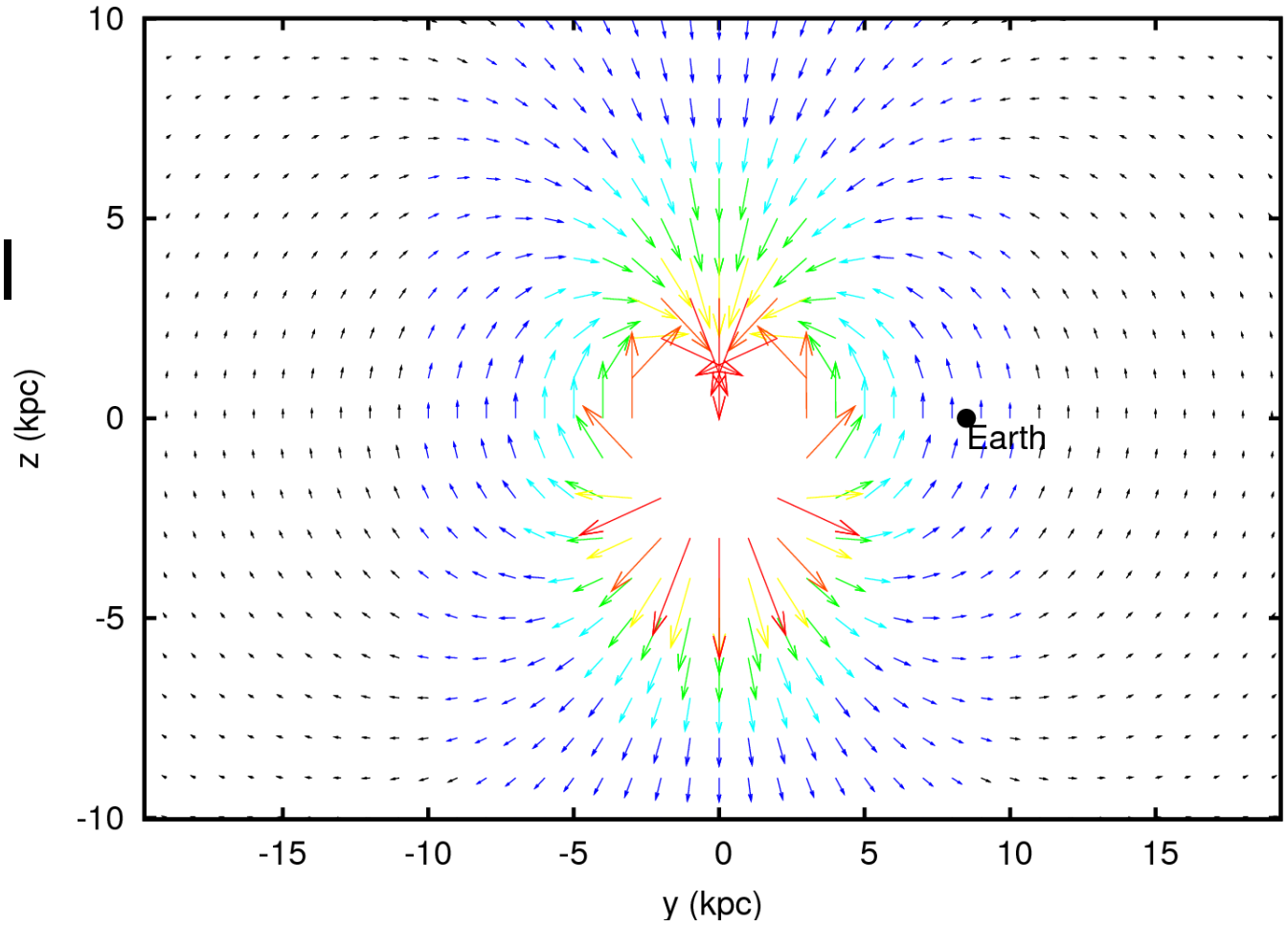
# The regular Galactic MF:

PS
halo model
(here,
z=1.5kpc)



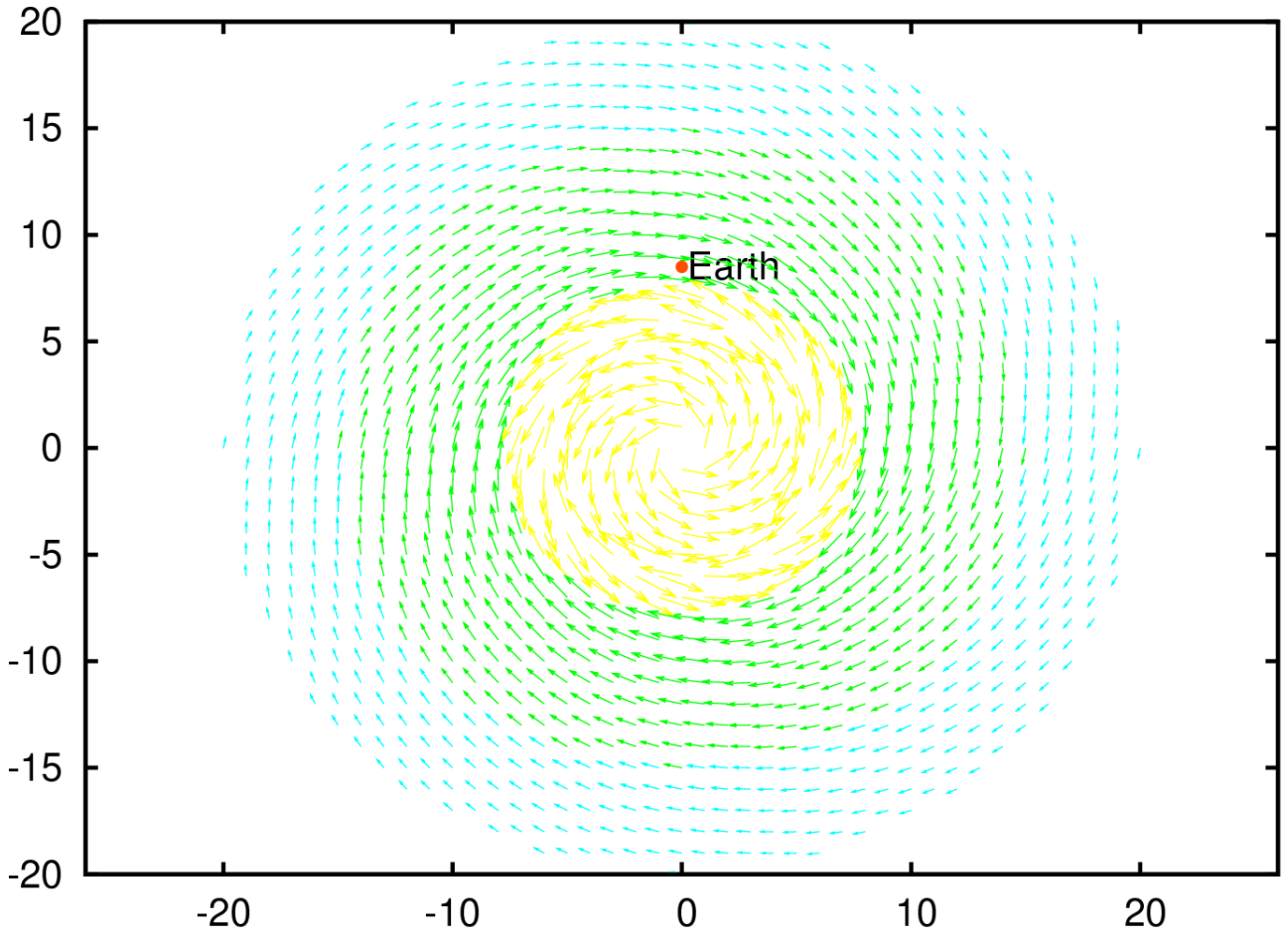
# The regular Galactic MF:

PS
dipole model



# The regular Galactic MF:

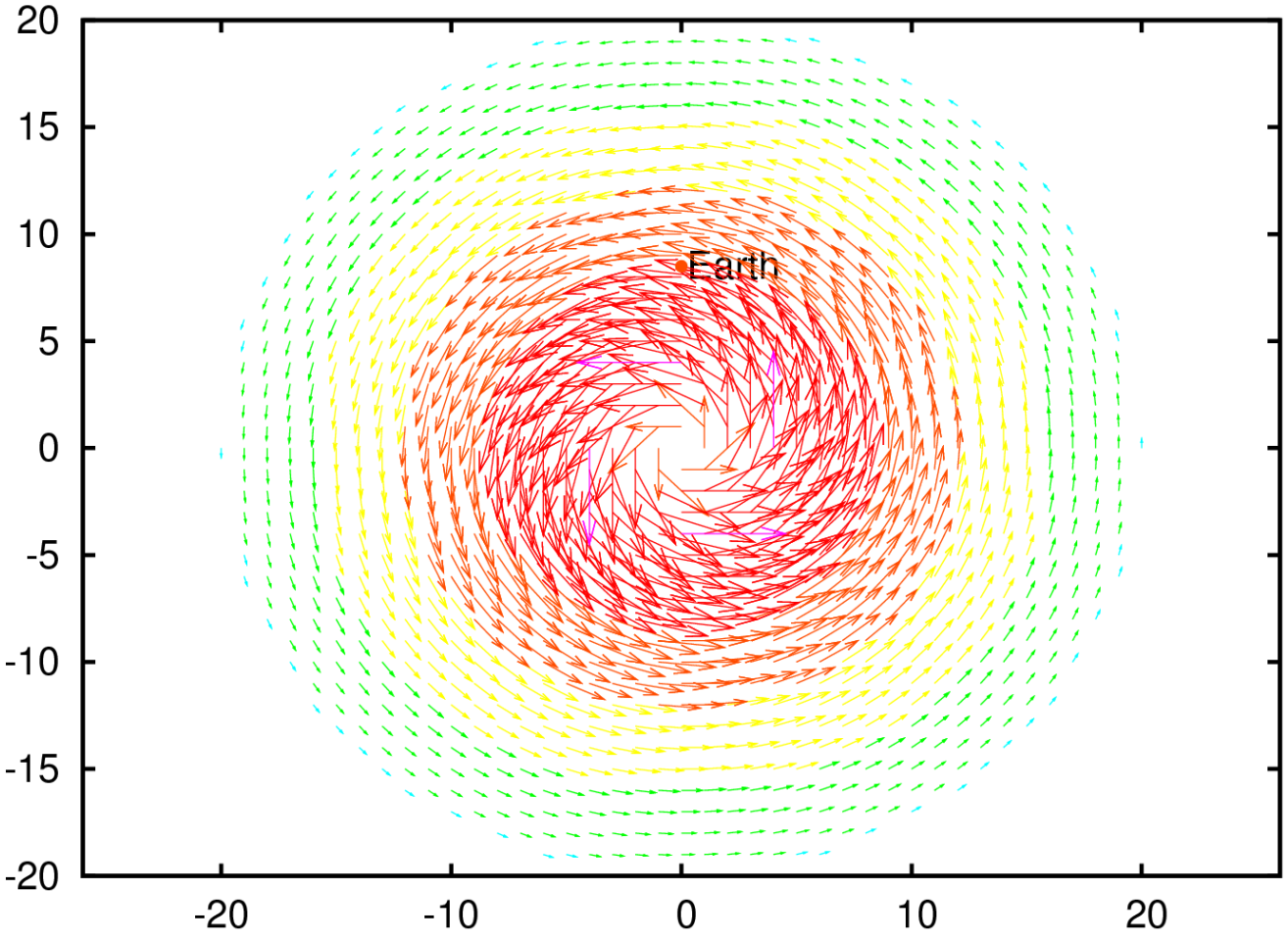
Sun08
disk model




Sun *et al.* astro-ph/0711.1572

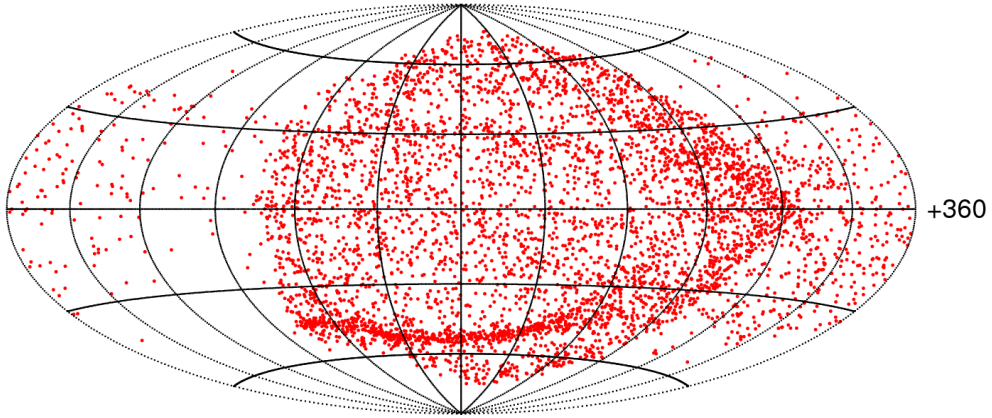
# The regular Galactic MF:

Sun08
halo model



# The turbulent Galactic MF:

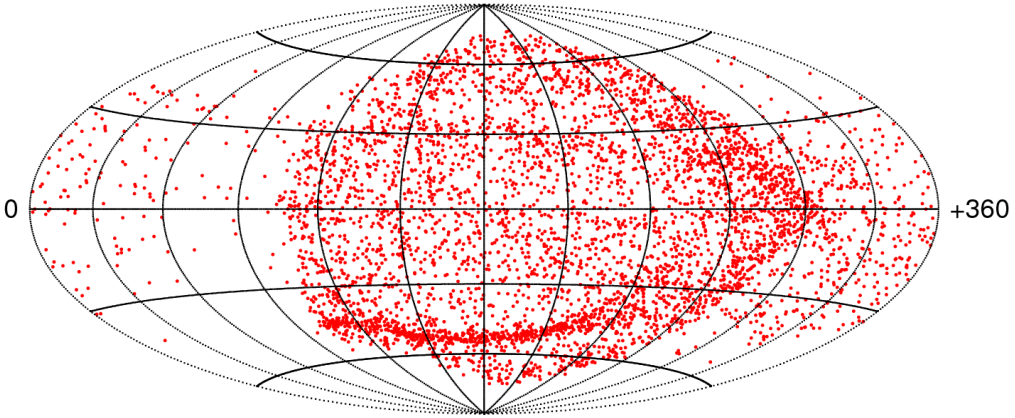
**Regular** GMF




60 EeV iron in the PS model. $\Delta E/E=6\%$.

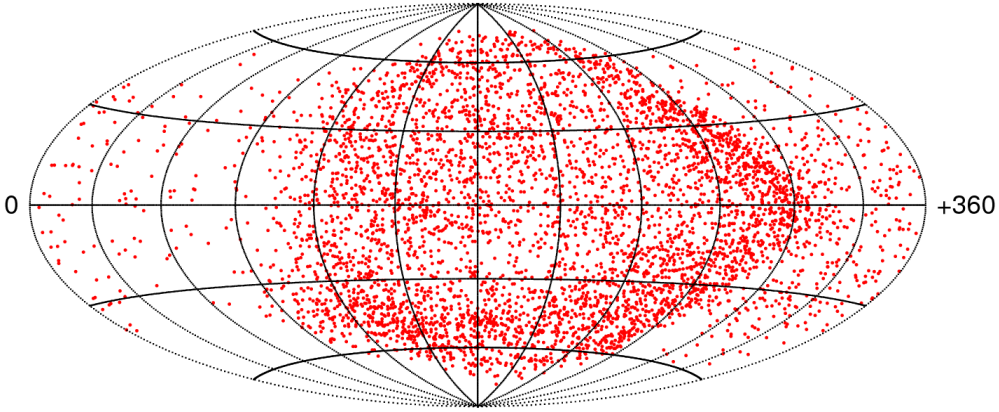
# The turbulent Galactic MF:

**Regular** GMF




60 EeV iron in the PS model. $\Delta E/E=6\%$.

**Regular + turbulent** GMF

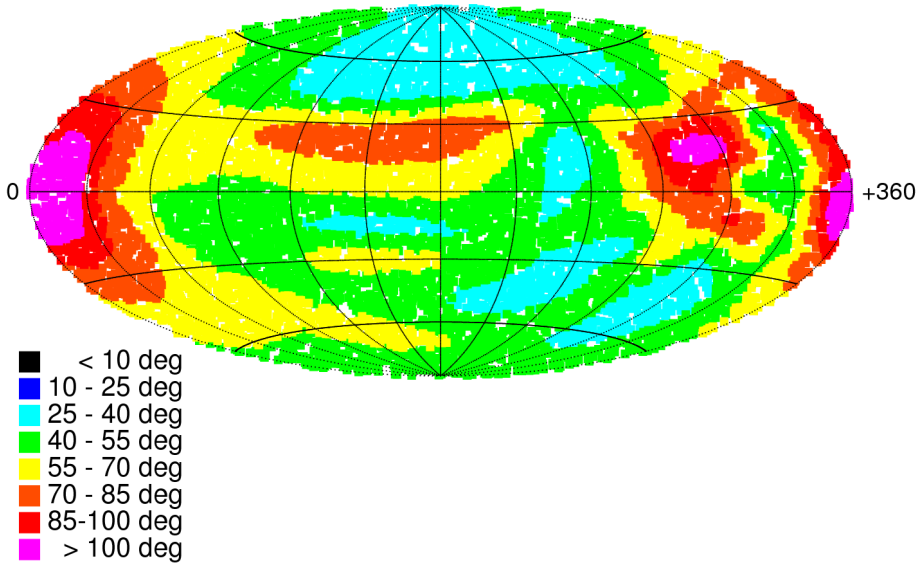



Turbulent field: $B_{rms}(\text{Earth})=4\mu G$, $L_c=50pc$

# II – Backtracing heavy nuclei in the GMF

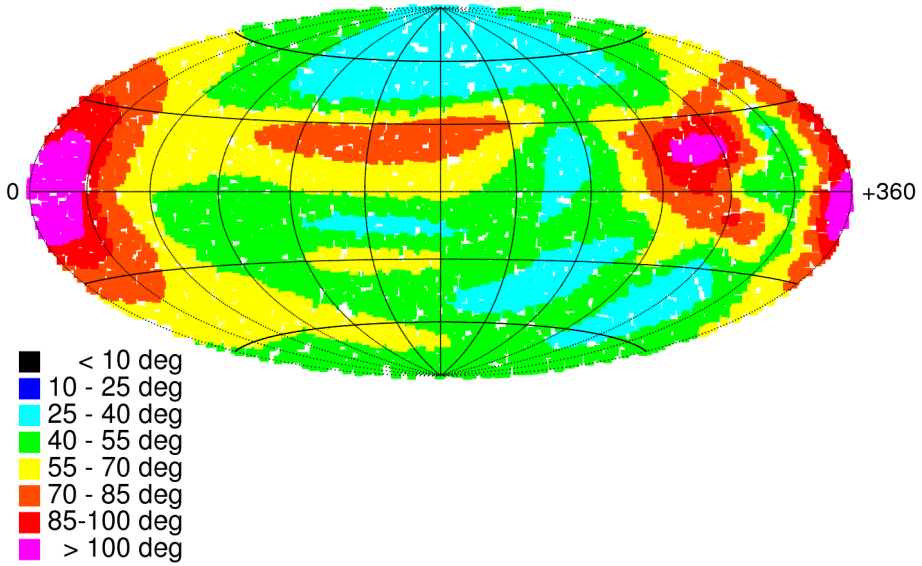
# Deflection angles on the celestial sphere:

PS model - 60 EeV iron



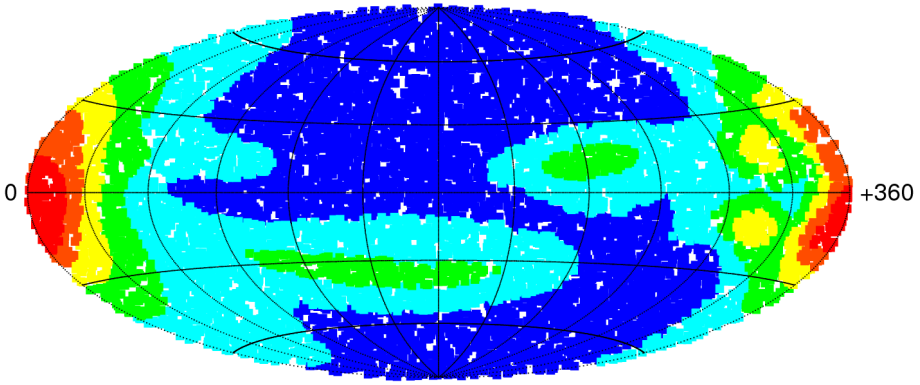
# Deflection angles on the celestial sphere:

PS model - 60 EeV iron



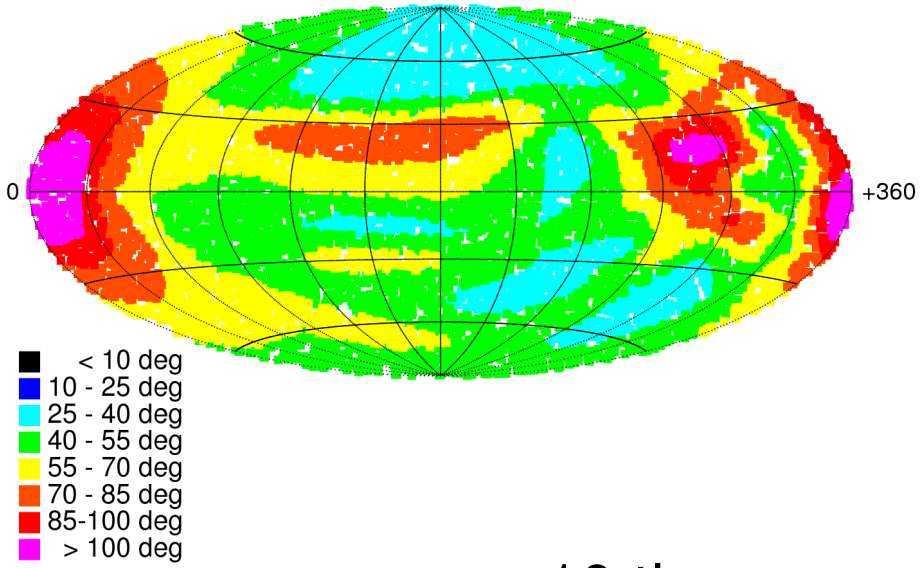

< 10 deg
10 - 25 deg
25 - 40 deg
40 - 55 deg
55 - 70 deg
70 - 85 deg
85-100 deg
> 100 deg

140 EeV

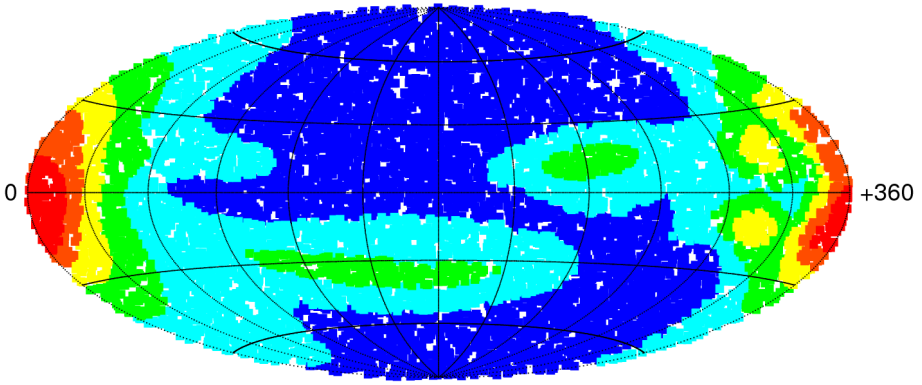


# Deflection angles on the celestial sphere:

PS model - 60 EeV iron

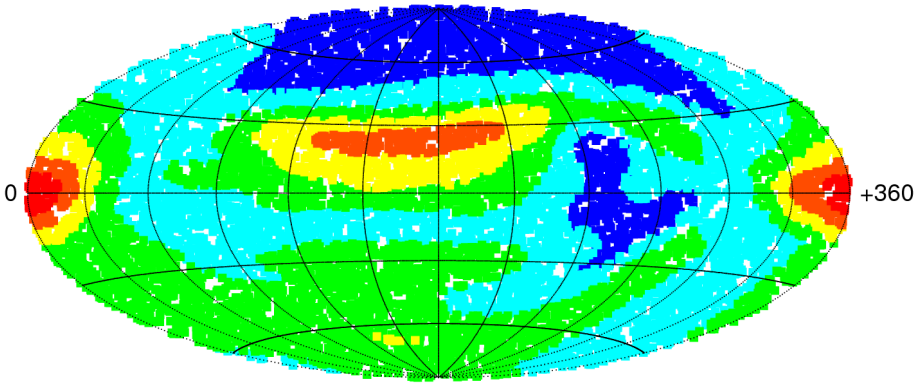


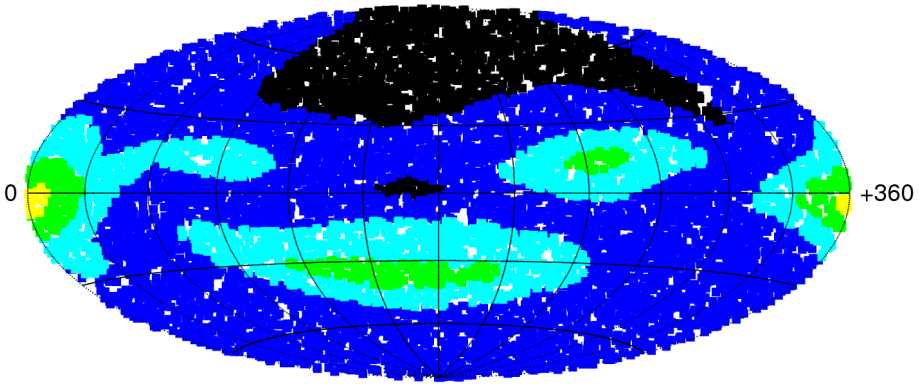

140 EeV



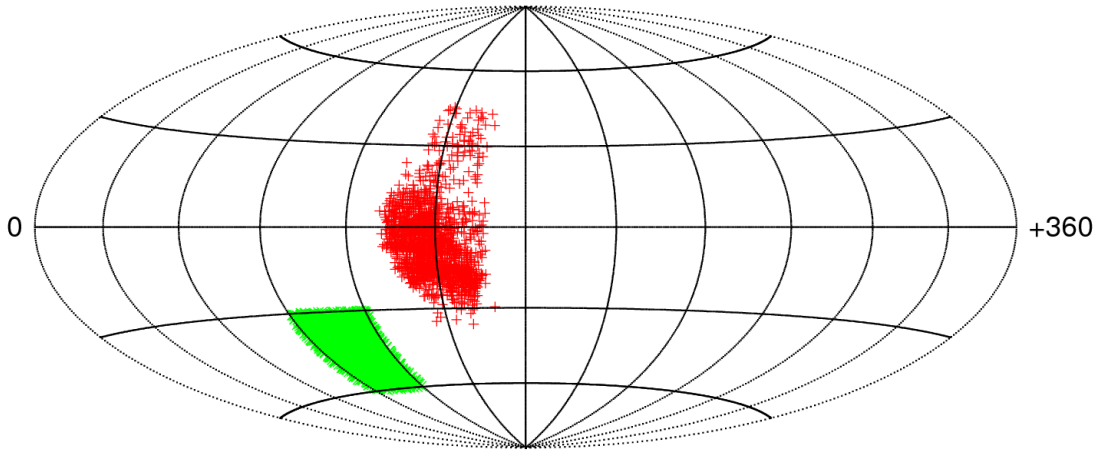

< 10 deg
10 - 25 deg
25 - 40 deg
40 - 55 deg
55 - 70 deg
70 - 85 deg
85-100 deg
> 100 deg

10 times weaker dipole field :

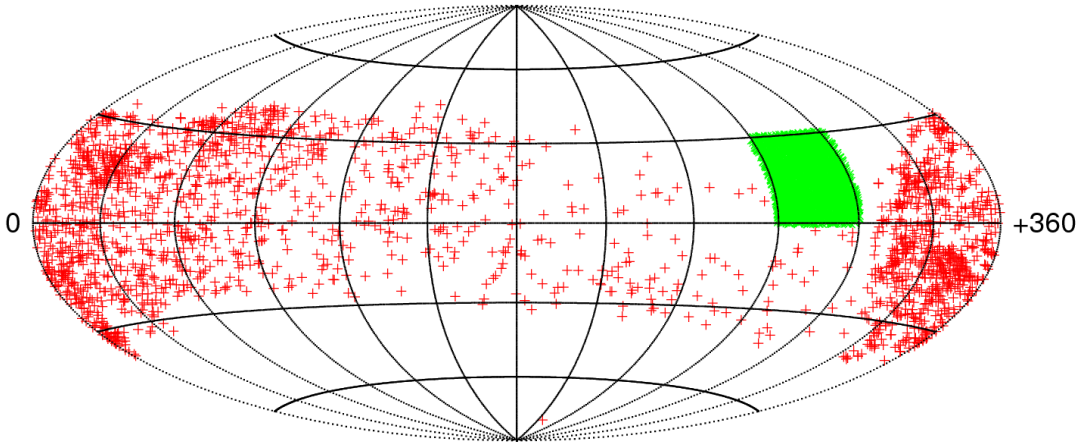


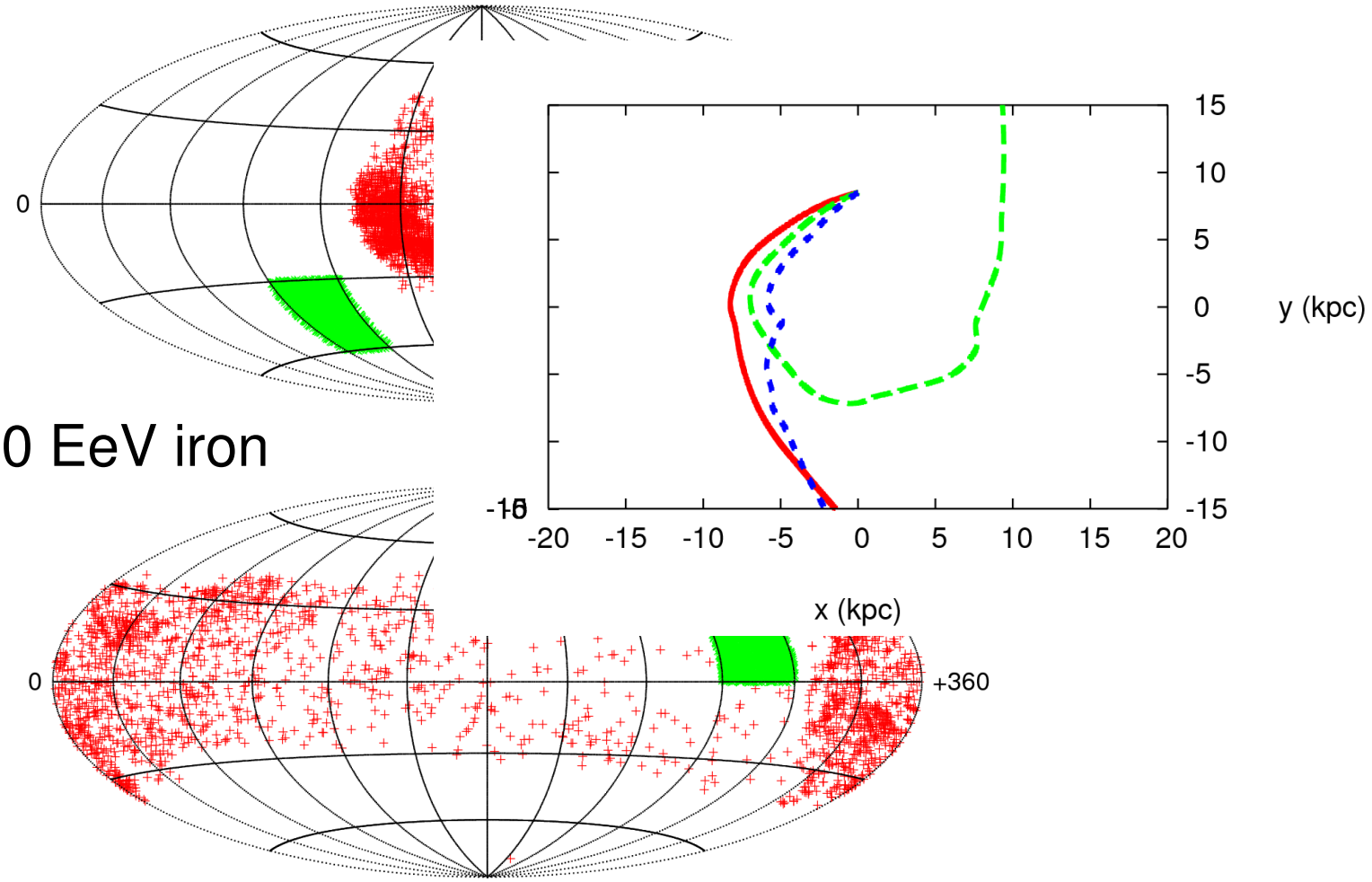
# Extragalactic sources contributing in a part of the sky:




PS model - 60 EeV iron

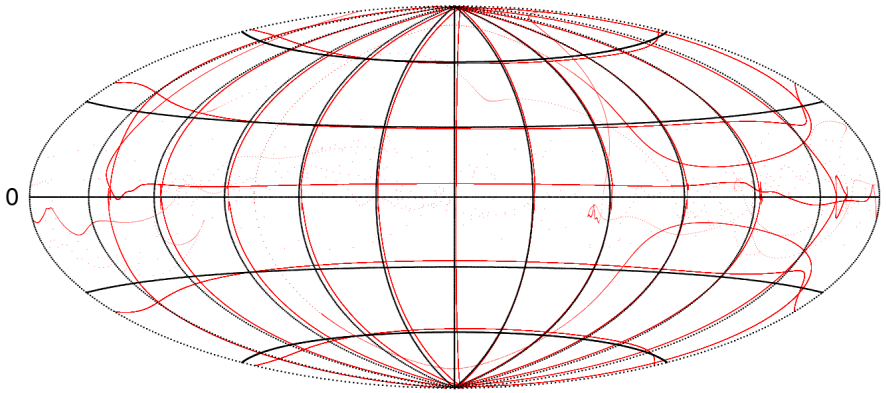


# Extragalactic sources contributing in a part of the sky:

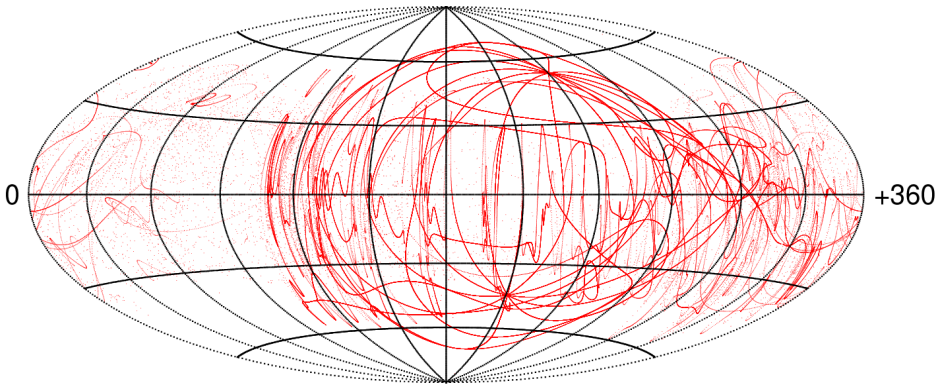



PS model - 60 EeV iron

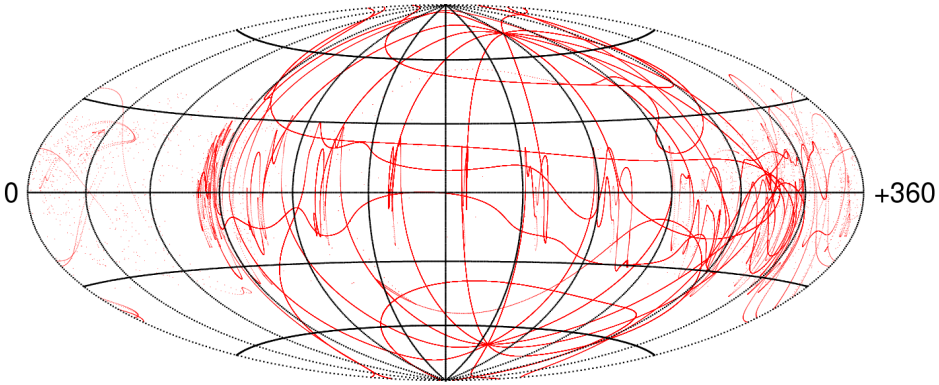
# Grids backtraced in the GMF (PS model):




60 EeV protons



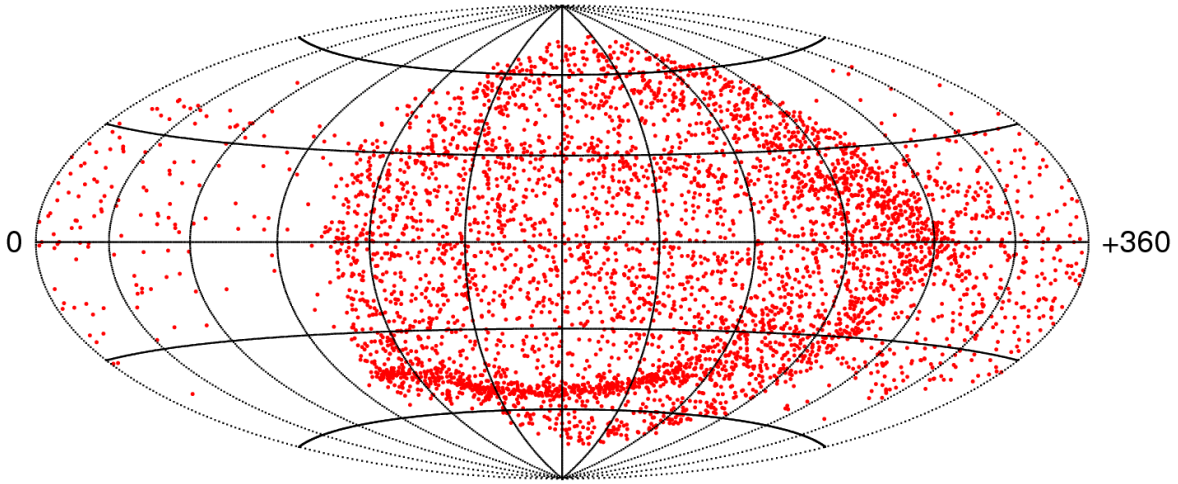

60 EeV iron nuclei




140 EeV iron nuclei

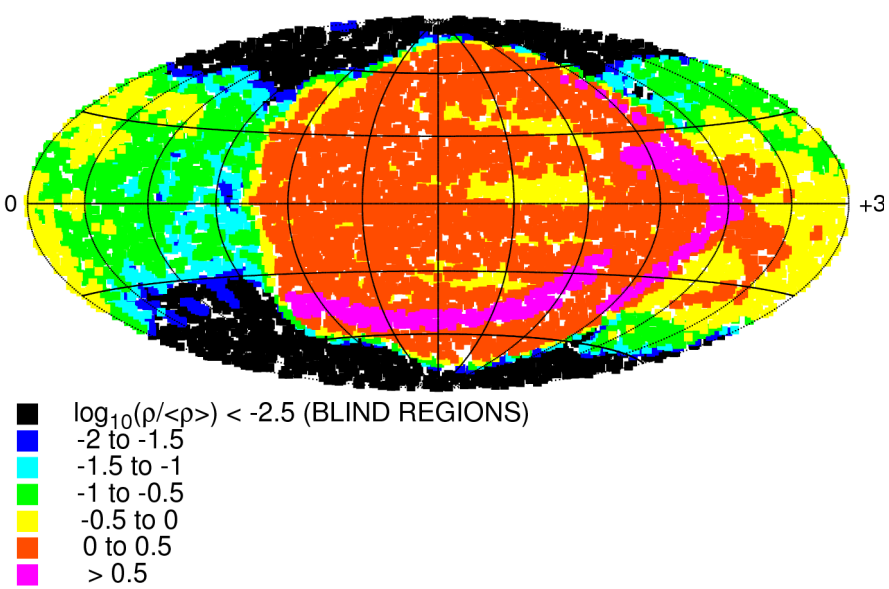
# III – Magnetic lensing: (de)magnification of fluxes

# Densities of outgoing backtraced nuclei and amplification factor:

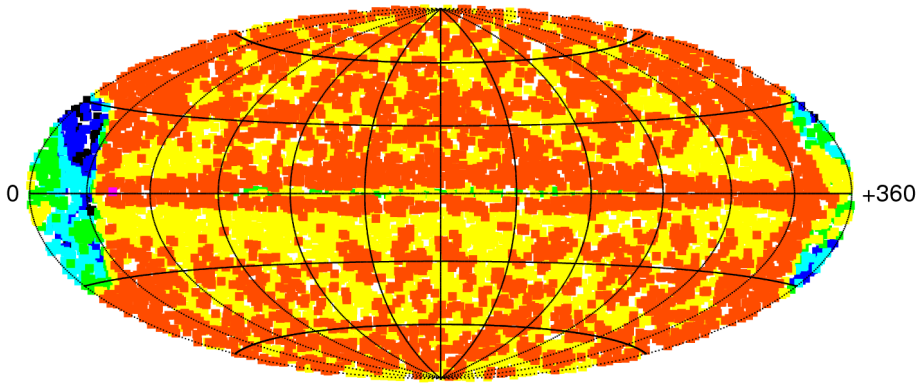



PS model - 60 EeV iron

# (De)magnification of fluxes of individual sources:

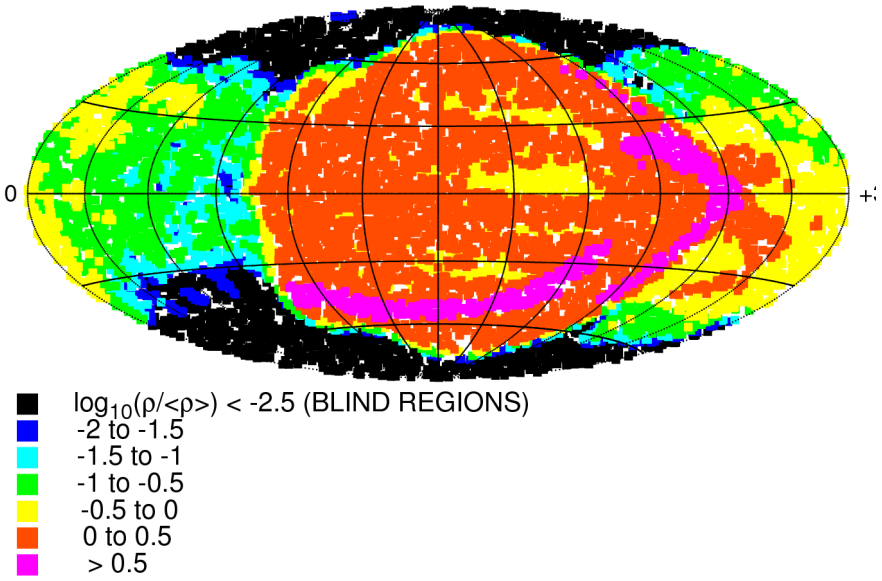



PS model - 60 EeV iron nuclei

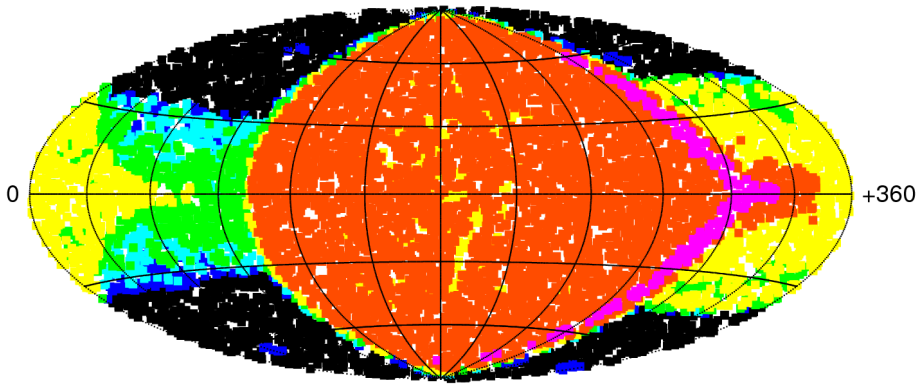



60 EeV protons

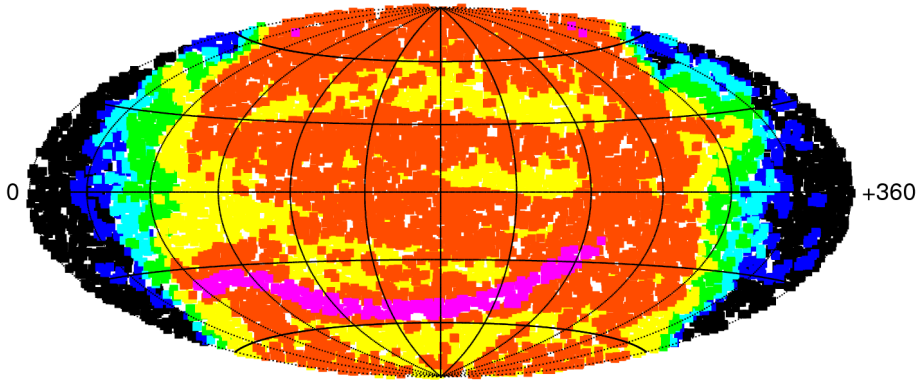
# (De)magnification of fluxes of individual sources:




PS model - 60 EeV iron nuclei

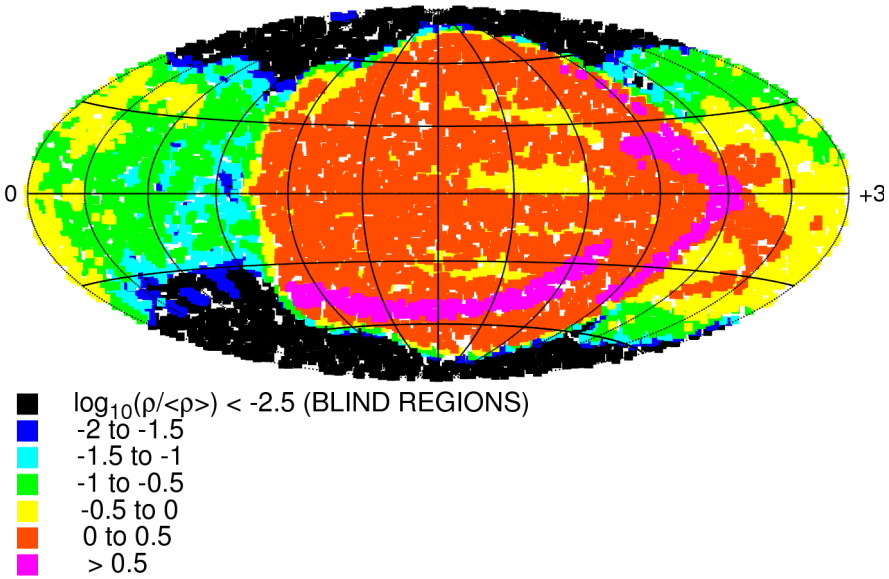


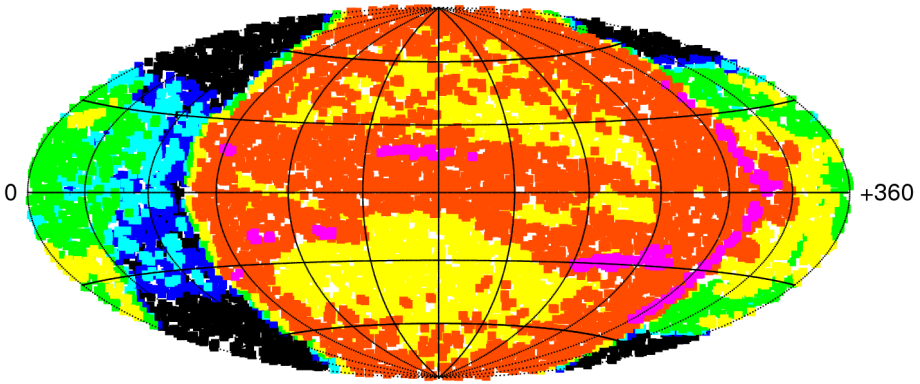

Dipole only




No dipole

# (De)magnification of fluxes of individual sources:

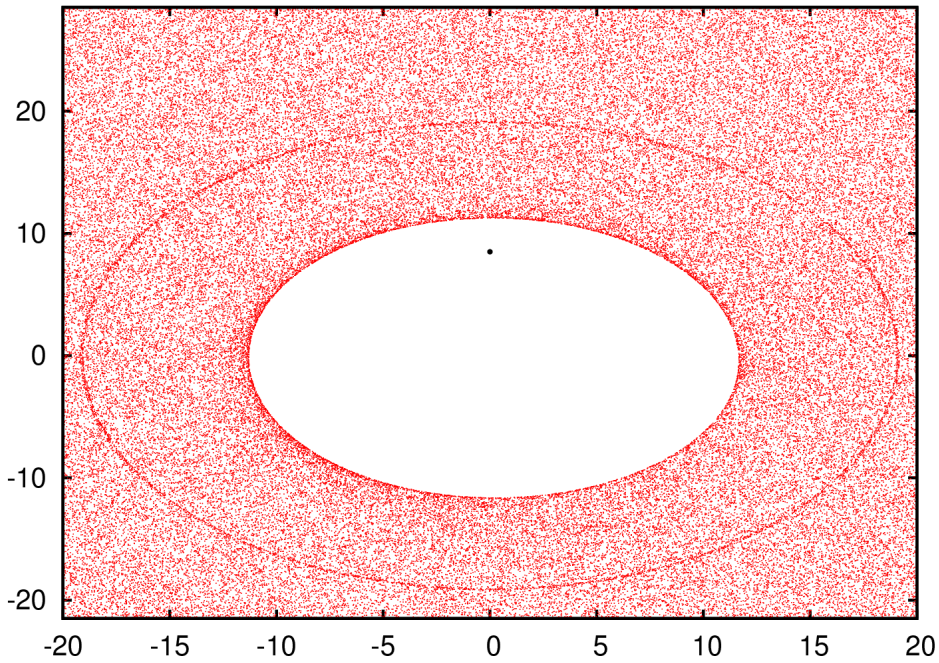



PS model - 60 EeV iron nuclei

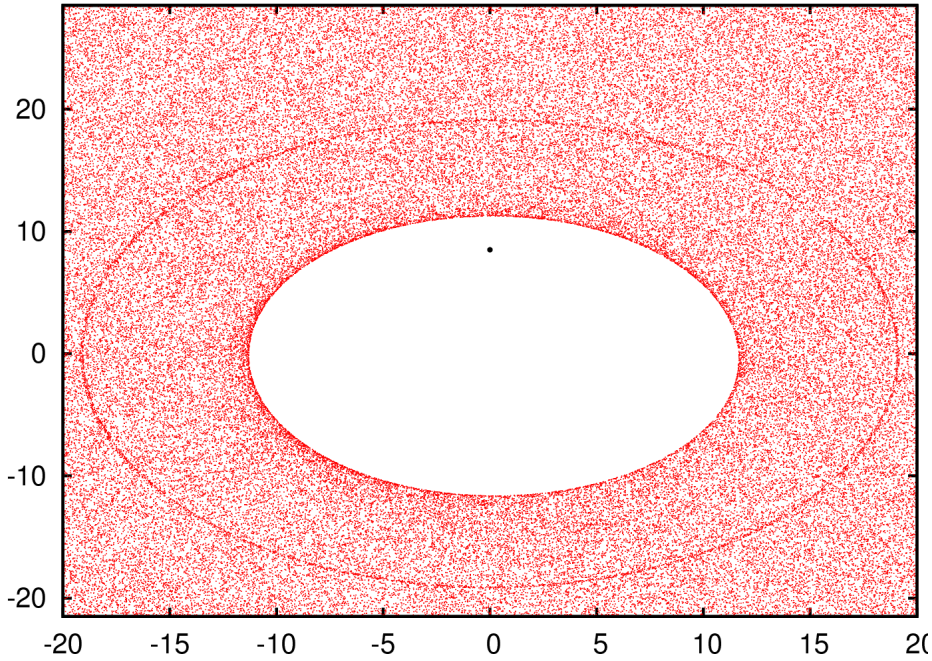
140 EeV

# UHE iron nuclei, from a point source at the Galactic North pole, crossing the Galactic plane:

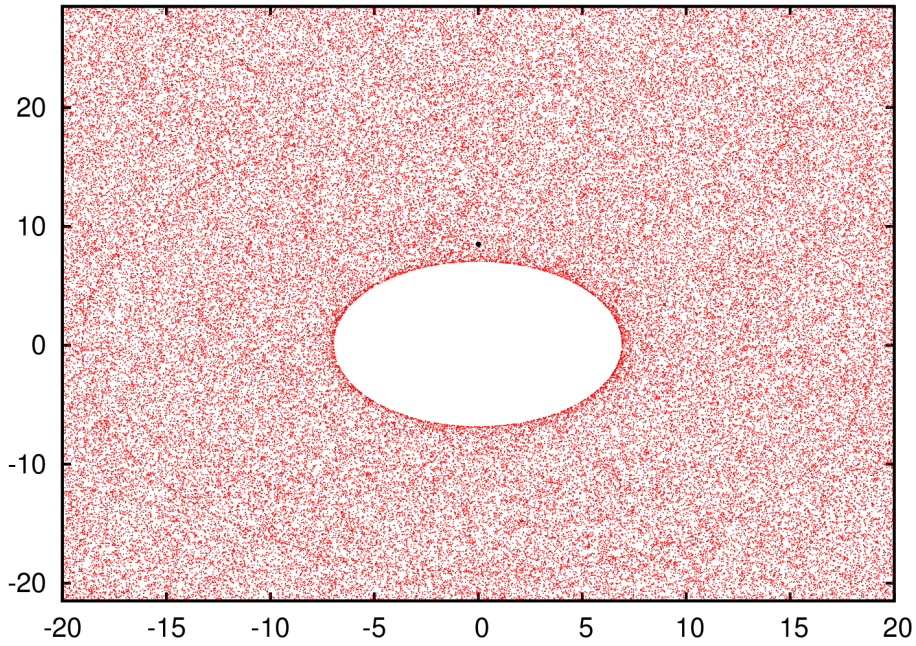



PS model - 60 EeV

# UHE iron nuclei, from a point source at the Galactic North pole, crossing the Galactic plane:

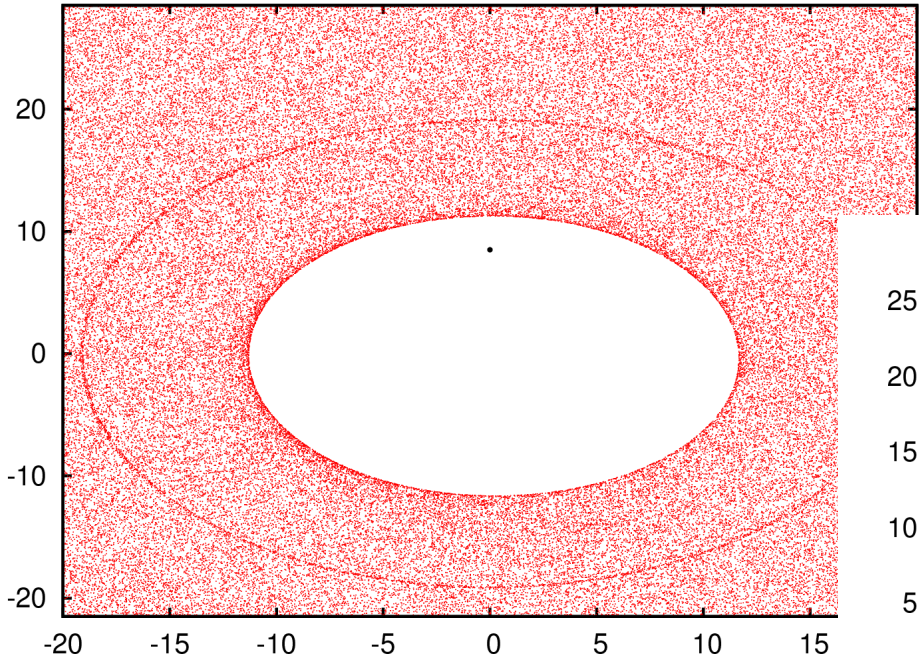



PS model - 60 EeV

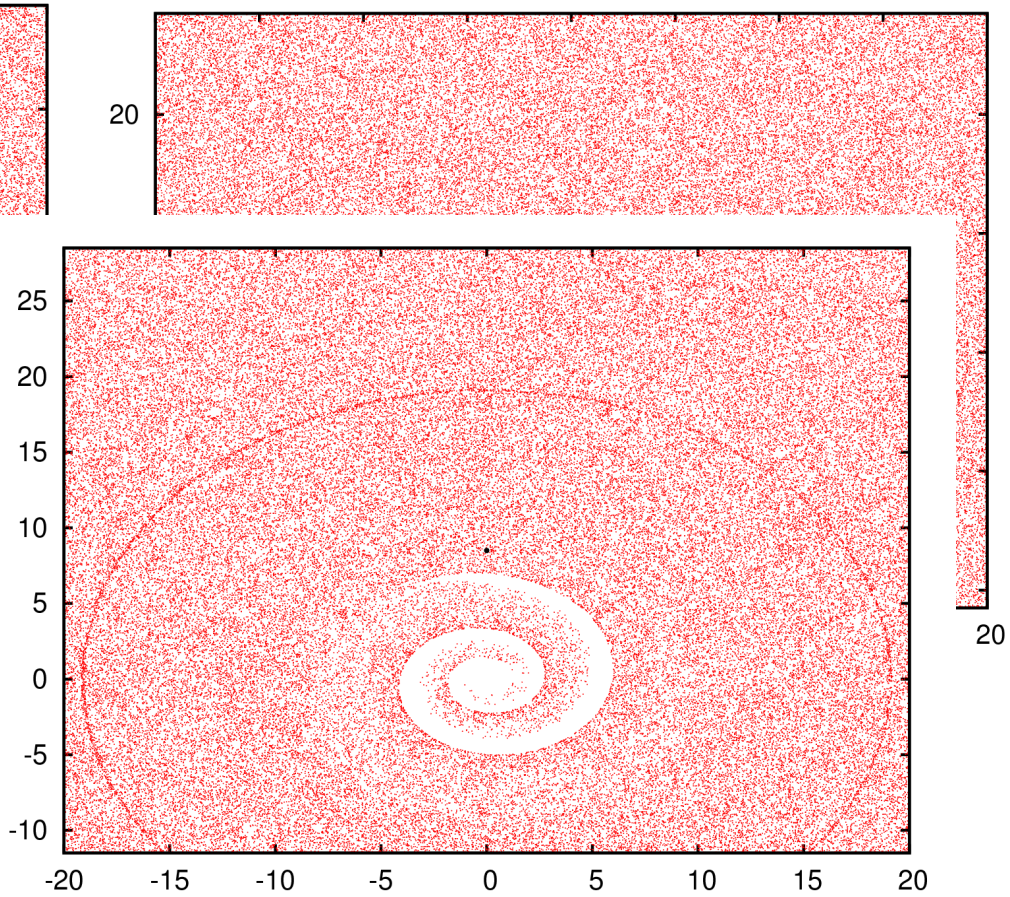



140 EeV

# UHE iron nuclei, from a point source at the Galactic North pole, crossing the Galactic plane:

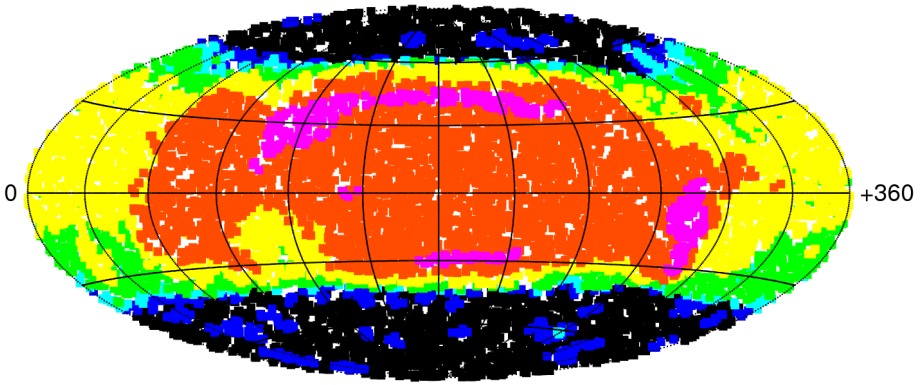



PS model - 60 EeV

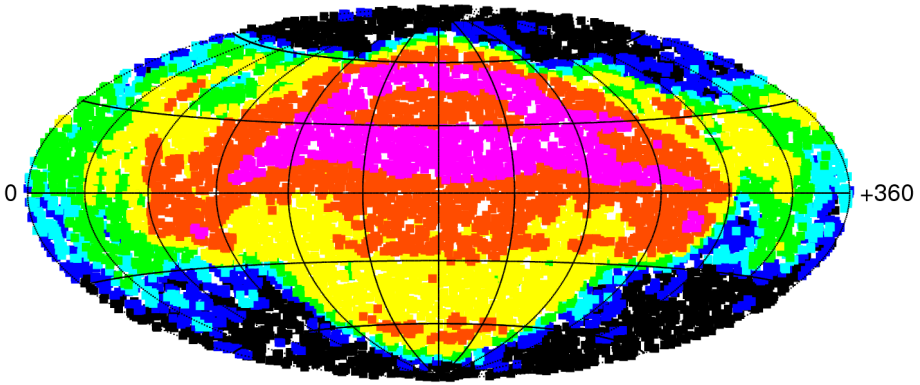



60 EeV – no dipole

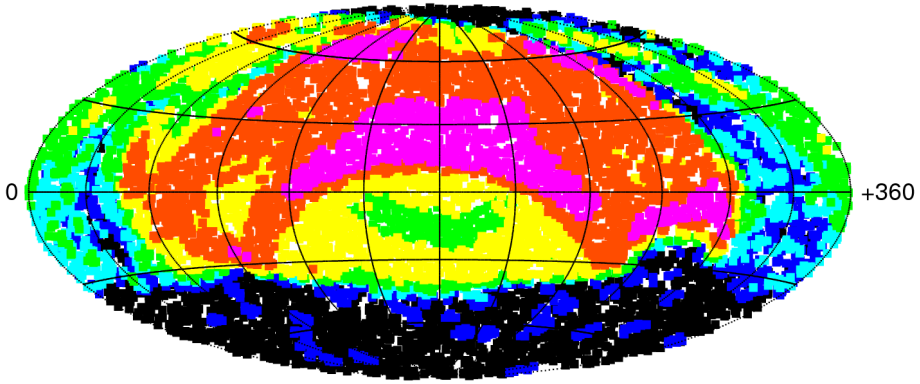
# Model dependence :



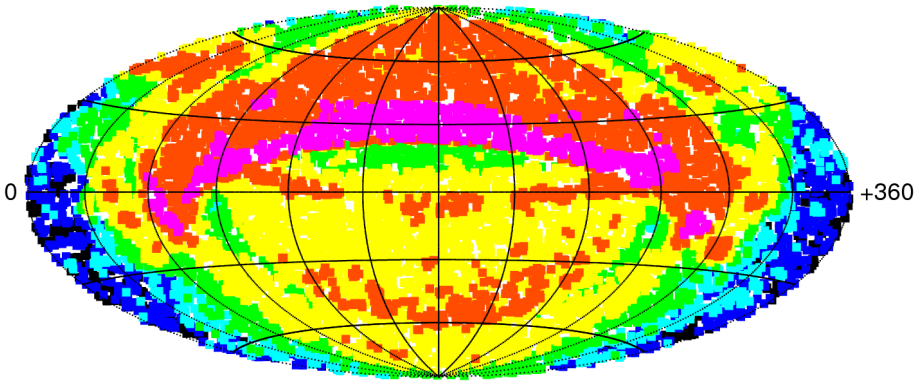

Sun08 - 60 EeV iron nuclei




Sun08 - 140 EeV

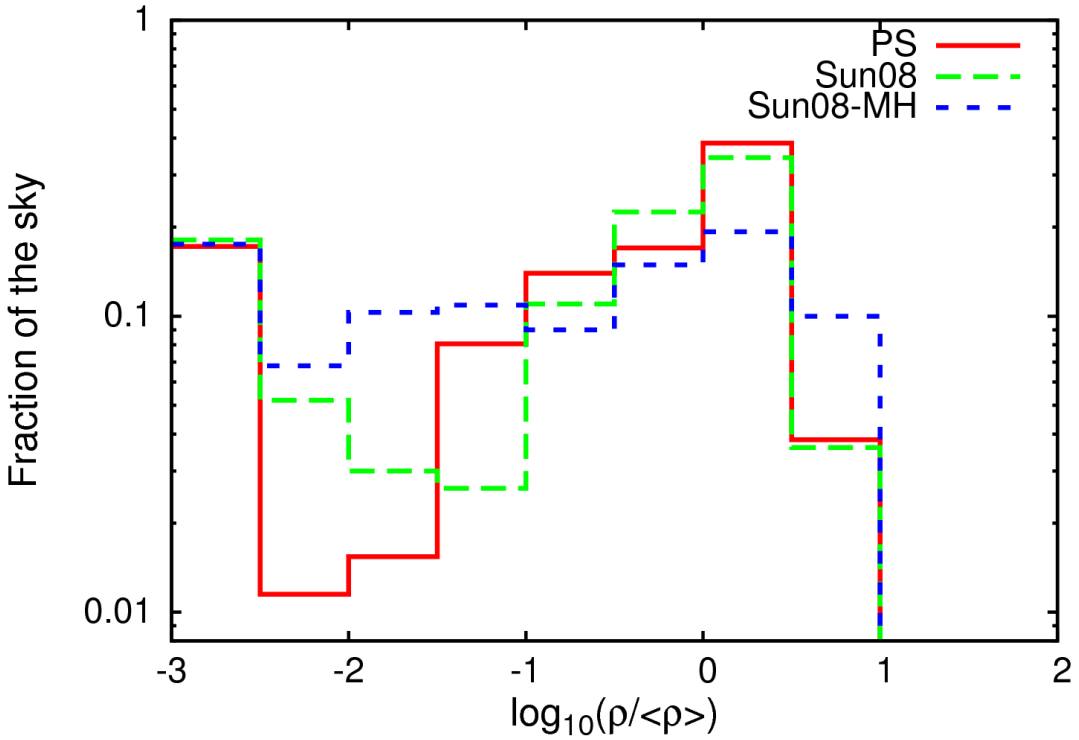



Sun08-MH - 60 EeV

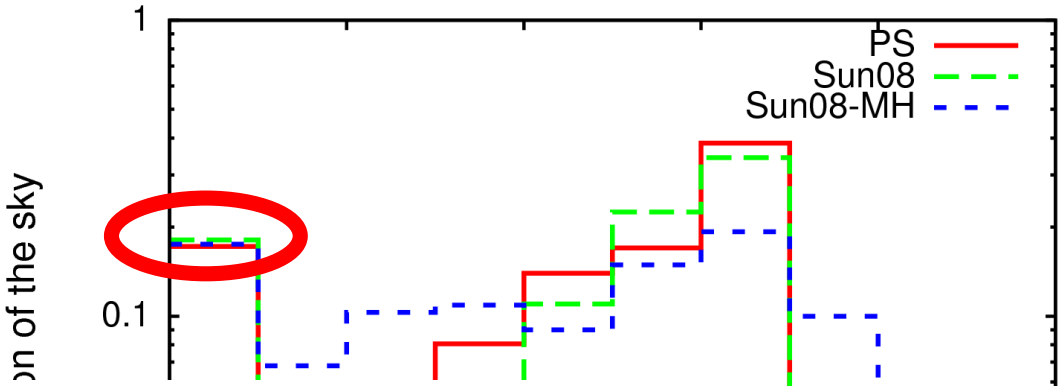


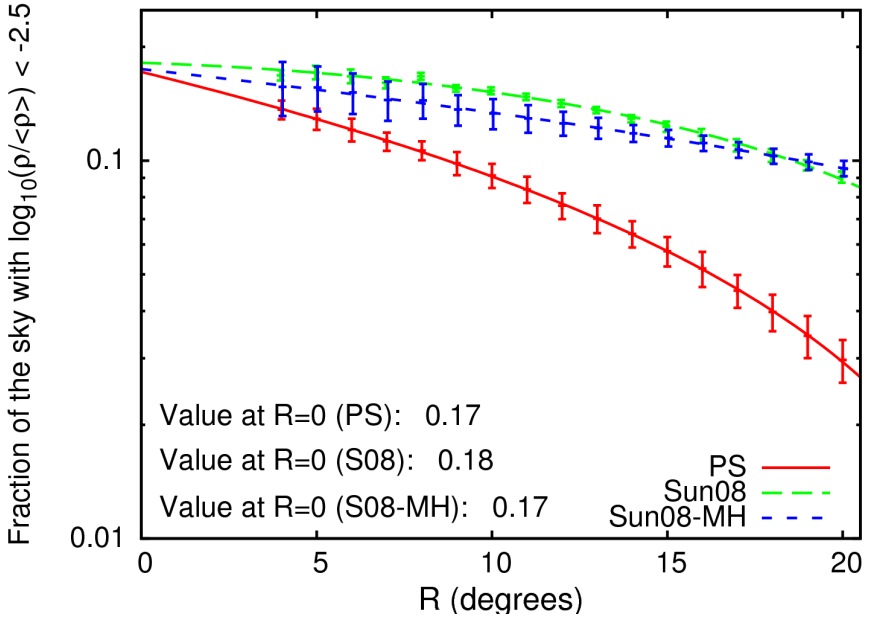

Sun08-MH - 140 EeV

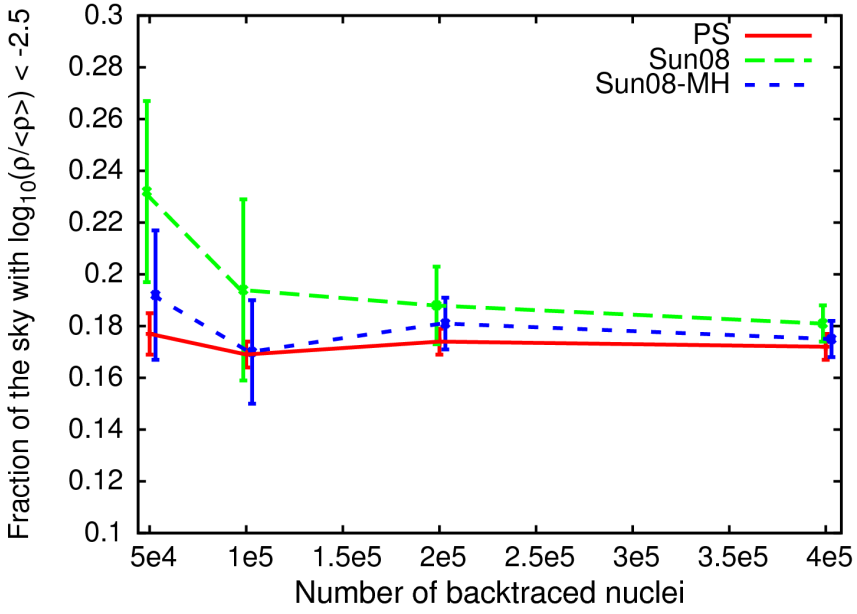
# Histogram of fractions of the sky outside the Galaxy with given (de)magnification (60EeV iron):



# Histogram of fractions of the sky outside the Galaxy with given (de)magnification (60EeV iron):

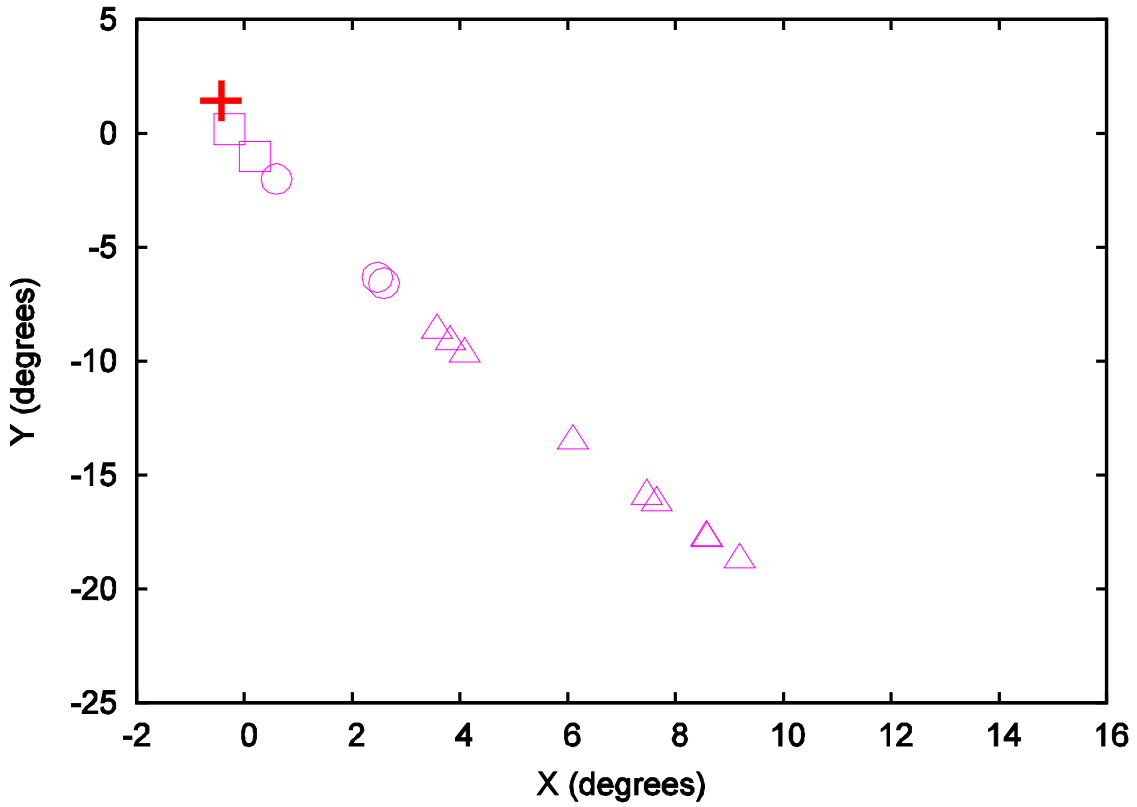


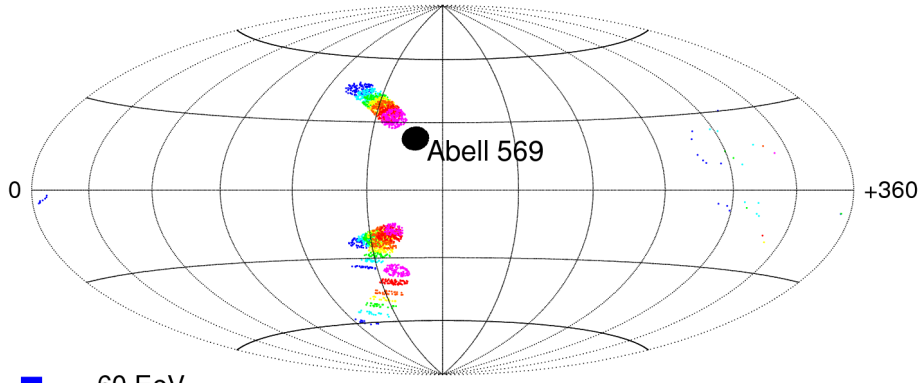
# IV – Search for astrophysical sources of UHE heavy nuclei

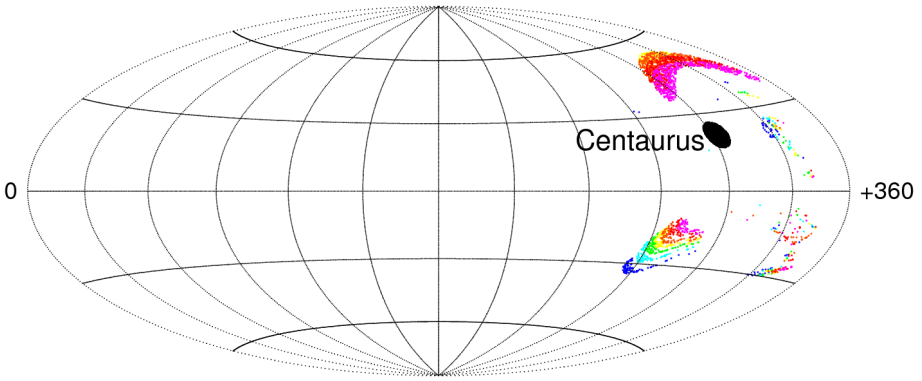
# Search for UHE proton (or light nuclei) sources :




For example: G.G., X.Derkx, D.V.Semikoz, astro-ph/0907.1035

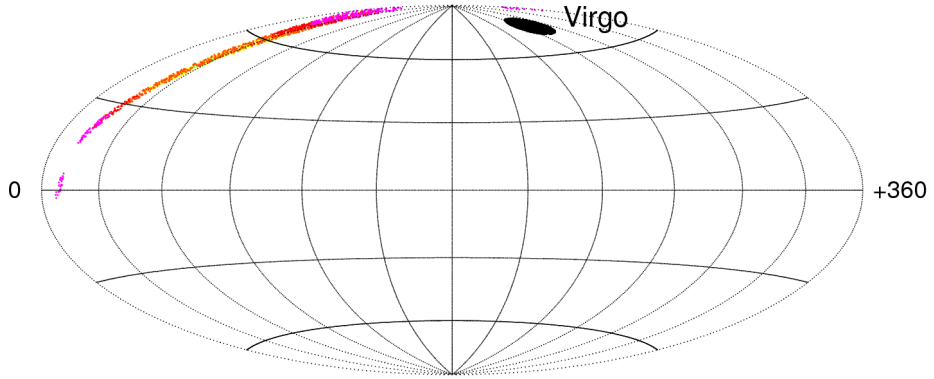
# Search for UHE heavy nuclei sources :

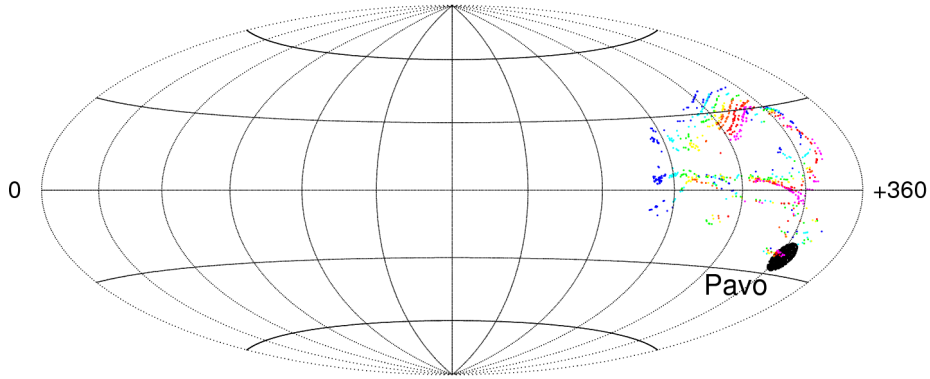


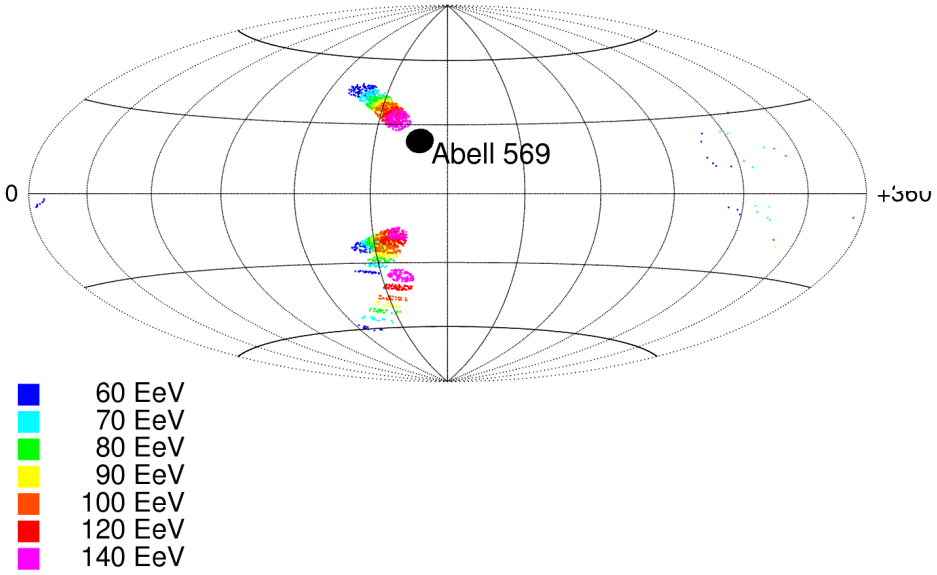

60 EeV
70 EeV
80 EeV
90 EeV
100 EeV
120 EeV
140 EeV

## PS model

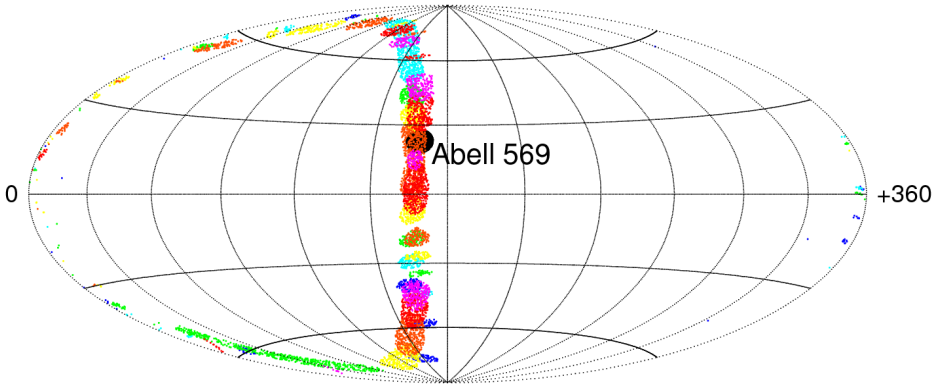


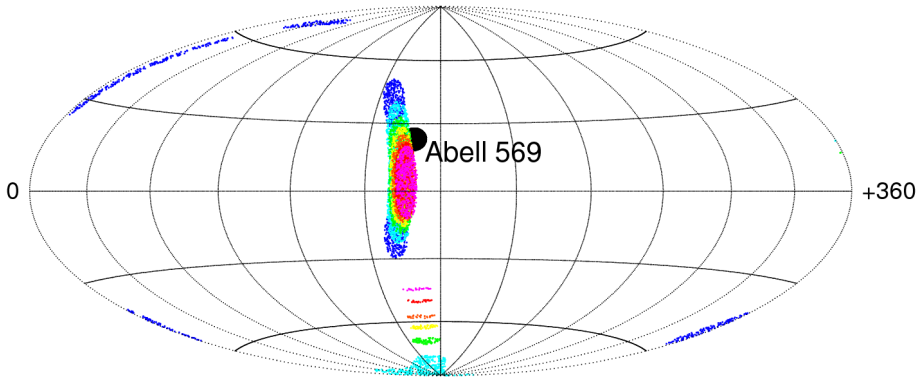
# Model dependence :




PS

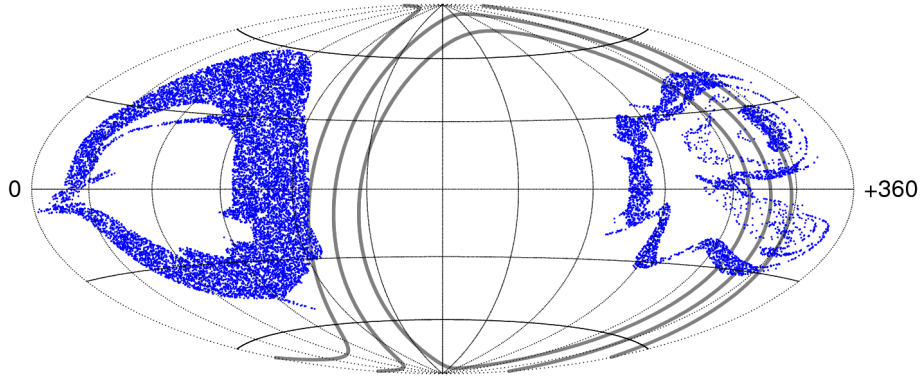



Sun08

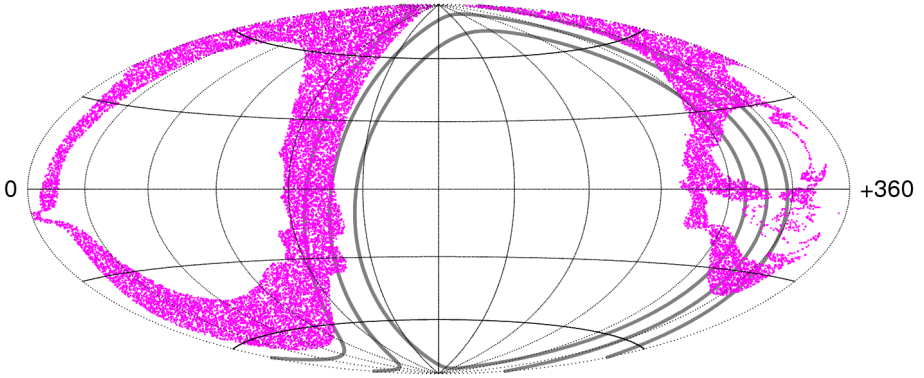



Sun08-MH

# Image of the supergalactic plane (|sgb|<10°) :




60 EeV iron




140 EeV iron

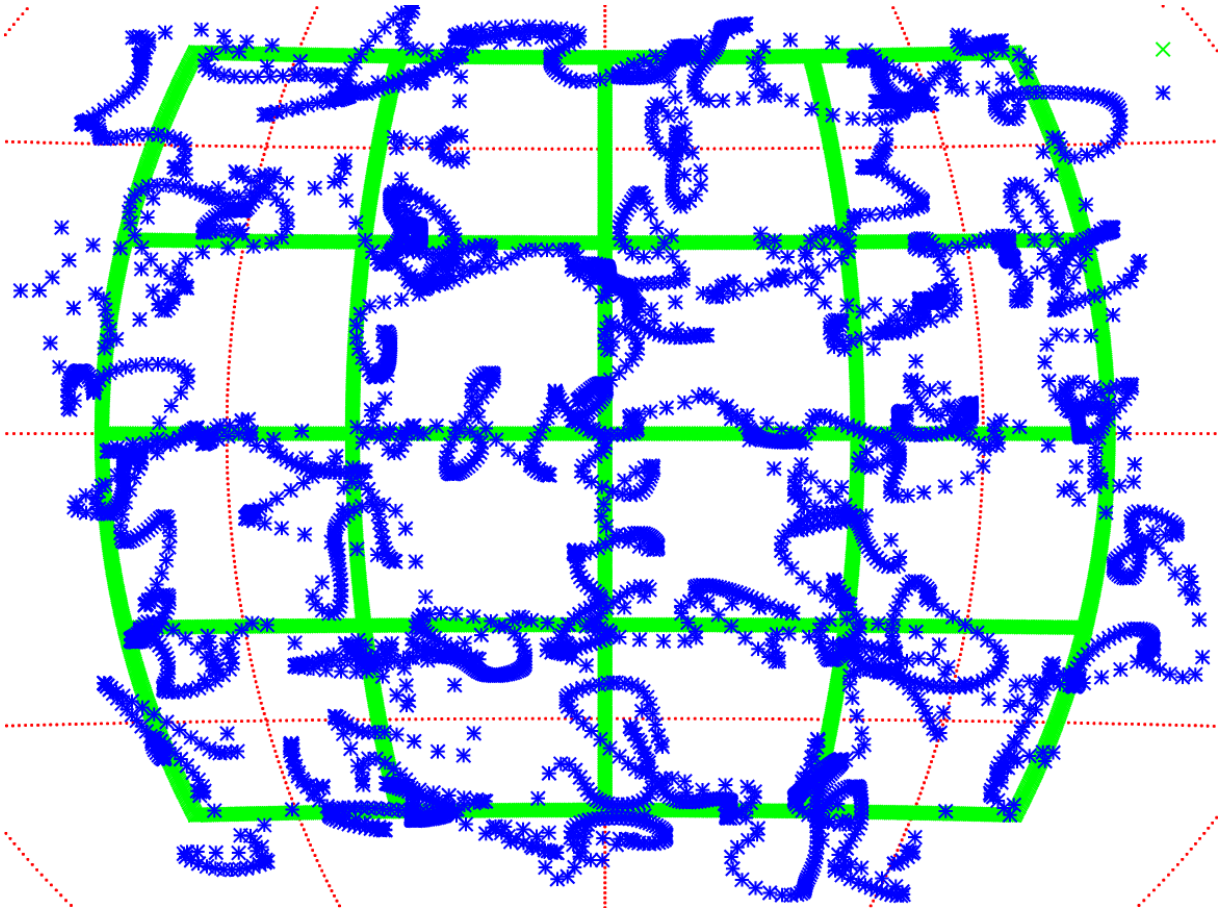
PS model

# Conclusion - perspectives :

- We backtraced iron nuclei with E>60EeV in models of the regular GMF,
- Studied effects of no « one-to-one » correspondance, and of magnetic lensing,
- « Blind regions »: some sources do not contribute to the flux detected at Earth,
- Effects rarely noticeable with proton or light nuclei sources,
- Some sources may be detectable, but a better knowledge on the GMF (SKA, LOFAR,...) would be needed for better algorithms.
- Model dependent results, but general ideas to keep in mind when analysing data.

# Backup

# The turbulent Galactic MF:

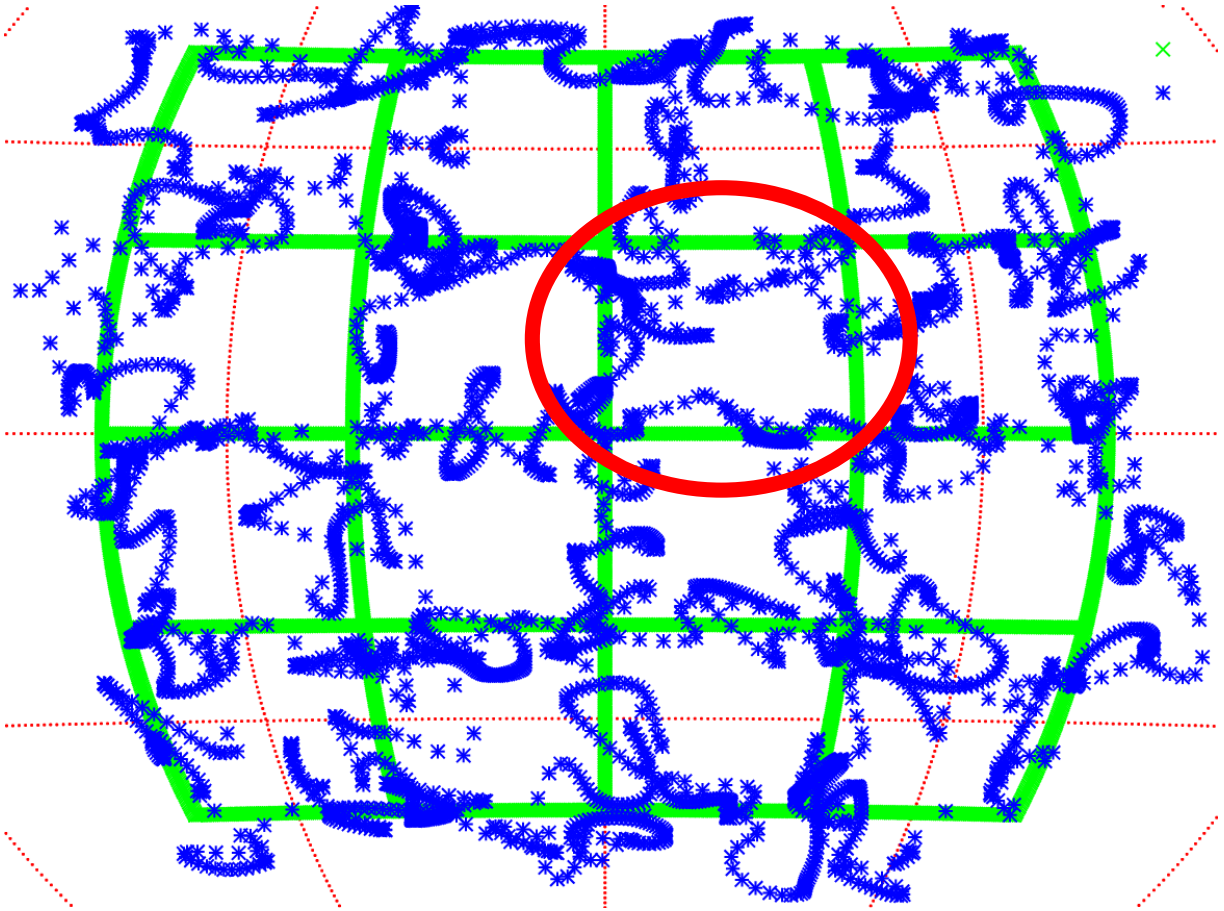


$\Delta l = 20°$

$\Delta b = 20°$

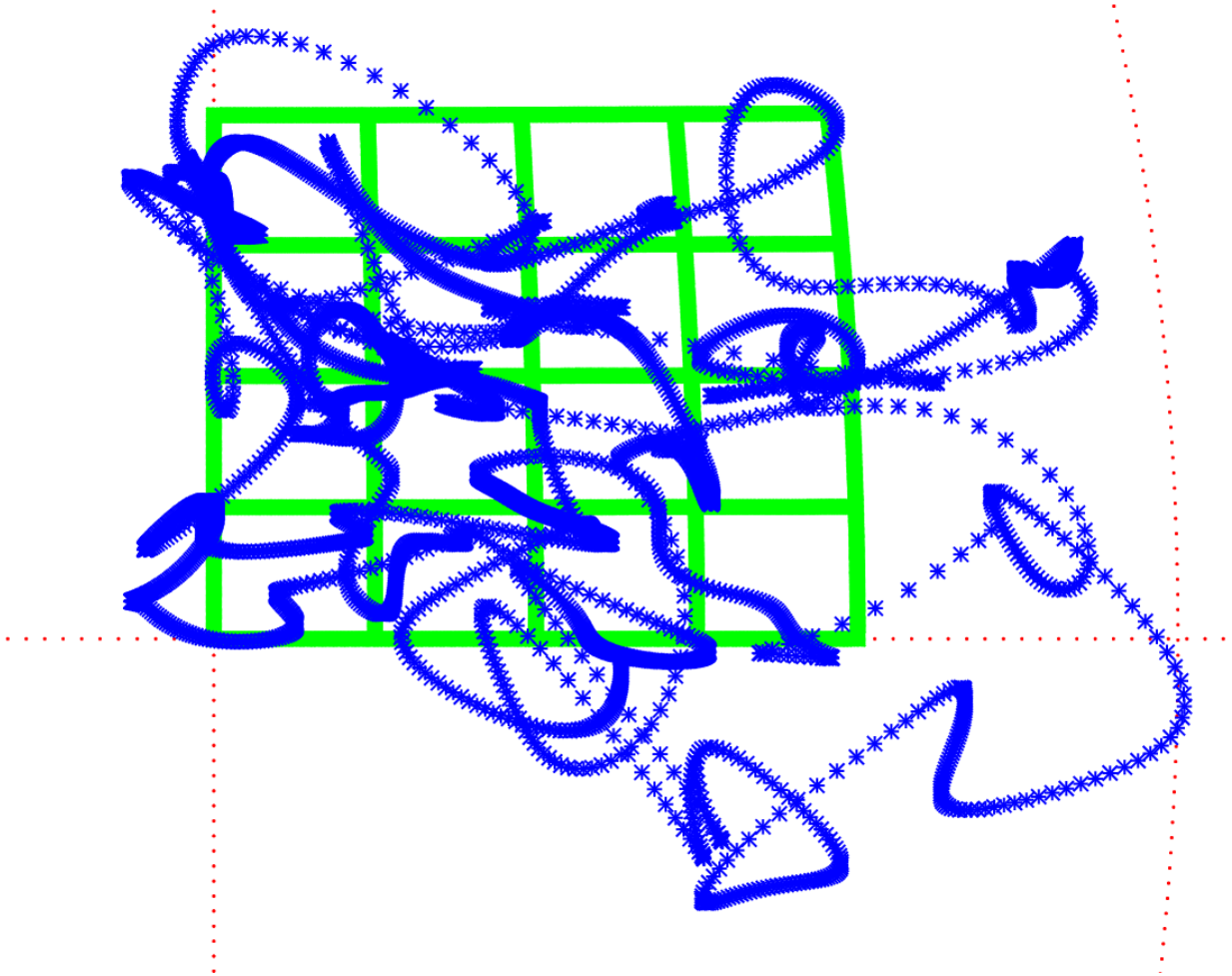
140 EeV iron, $B_{rms}$=4μG, $L_c$=50pc, L=750pc

# The turbulent Galactic MF:



140 EeV iron, $B_{rms}$=4μG, $L_c$=50pc, L=750pc

# The turbulent Galactic MF:



140 EeV iron, $B_{rms}$=4μG, $L_c$=50pc, L=750pc