Propagation of galactic cosmic rays

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Introduction

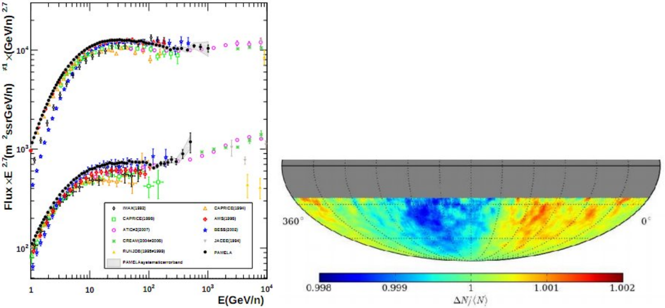

Figure: Proton Flux as observed by PAMELA Colaboration. arxiv:1103.4055,Cosmic rays anisotropy as observed by IceCube. arxiv:1110.207

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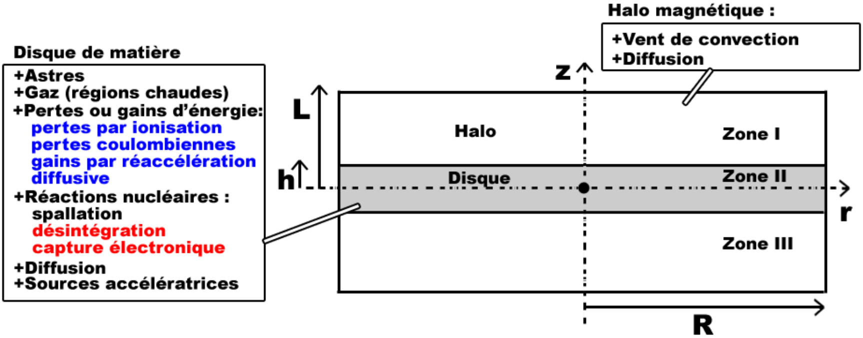
Galaxy model

Cylindrical symmetry, large disk



Diffusion Model

Magnetic Halo : It keeps charged particles inside the galaxy
2 components :

- Regular one (around 2μgauss)
- Turbulent component

$\rightarrow$Decomposition of the turbulence in power spectra $\rightarrow$ **multi size turbulences**

Turbulence $\sim$ Larmor Radius

Slightly turbulent

On each little turbulence : the particle is slightly deflected in a random direction.

$\rightarrow$ **Diffusion process**

Defined by a diffusion coefficient $K = K_0 \beta R^{\delta}$.

Stationary diffusion equation :

$$\frac{\partial^2 N(r,z)}{\partial z^2} + \frac{1}{r}\frac{\partial}{\partial r}(r\frac{\partial}{\partial r})N(r,z) - \frac{V_c}{K}\frac{\partial N(r,z)}{\partial z} = \left(-\frac{q_0(r,z)}{K} + \frac{h\Gamma}{K}N(r,z) + 2\frac{V_c}{K}N(r,z)\right)\delta(z) \quad (1)$$

Anisotropy of cosmic rays

Origins of anisotropy

- Compton-getting effect : motion of the solar system into the galaxy
- Heliosphere effects
- Large scale anisotropy

Anisotropy

Previous works :
δ_{dip} dipole anisotropy
I flux of cosmic rays in a given direction on earth

Definitions of anisotropy in the literature

$$I = \langle I \rangle (1 + \delta_{dip} \cos\theta) \quad \text{or} \quad \delta_{dip} = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}} \quad \text{or} \quad \delta_{dip} = \frac{3K}{c}\frac{1}{N}\left|\frac{dN}{dr}\right| \tag{2}$$

The anisotropy holds 2 informations :

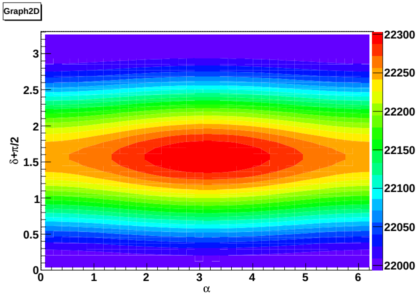
- The absolute value of δ_{dip} : constrain K0 and δ_s
- The direction of the maximum (the phase) : constrain the model of anisotropy

Experiments

Principle of the experiments :

- Scanning each declination band in the sky
- Harmonic decomposition of each dec band signal

$\rightarrow$ One loses the correlation between each dec band.



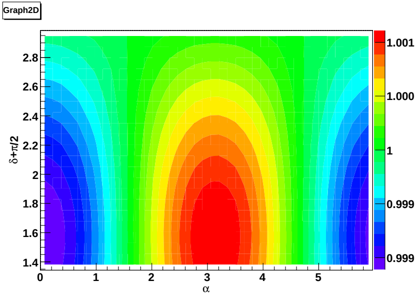


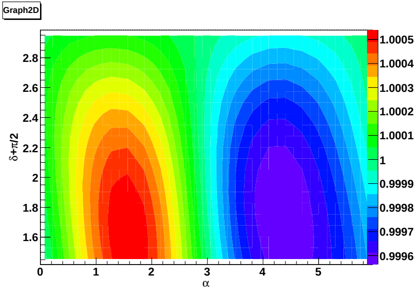
Figure: Signal in equatorial coordinates - Signal as viewed by experiments

different models of anisotropy

- Distribution of sources
- Local bubble
- Real sources

Large scale anisotropy

Thanks to the diffusion model we can build our own maps of anistropy
Anisotropy induced by source distribution in the galaxy



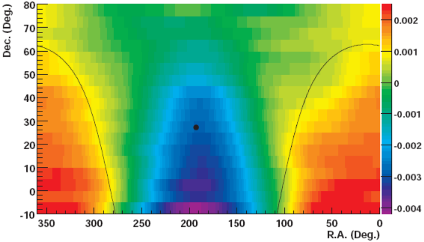


Figure: Signal using pulsar distribution - Signal detected by milagro

→ The positions of the maximum don't match !

constraining K0 and δ_s

Using the results of milagro ($\delta = 2.49 \pm 0.09$) one can manage to constrain K0 and δ_s

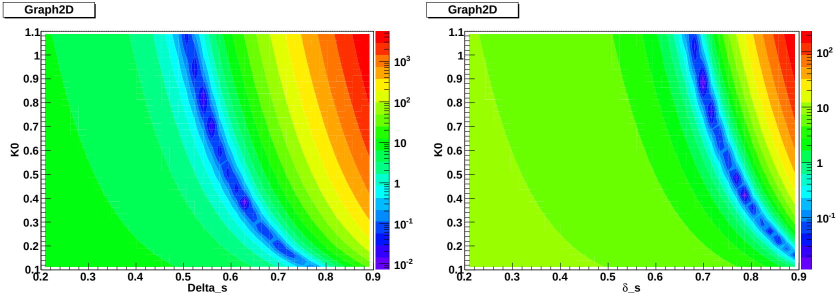


Figure: Chi2 test computed with milagro data and with a pulsar distribution - and a SNR distribution

$\rightarrow$ very sensitive to the source distribution
$\rightarrow$ cannot fit the energy dependance of anisotropy

Local bubble

Solar system is located in a low density zone
Possibility of two diffusion coefficients

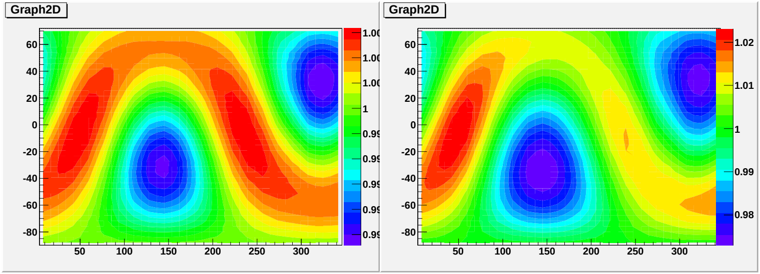


Figure: $K_{bubble} = K$, $K_{bubble} = 10 * K$

$\rightarrow$ Hard to conclude, possible reason for anisotropies but introduction of a new parameter

Real sources

Anisotropy is highly sensitive to local effects. We may be sensitive to time dependant effects.
We consider now time dependant solutions of diffusion equation.
$\rightarrow$ Sources are now considered as beeing pointlike in space and time
Sources are choosen in a catalog of SNR and Pulsar for close ones (distance $<$ $2kpc$) and randomly for other ones

Real sources

We choose sources from a Pulsar and a SNR catalog in a 2kpc radius

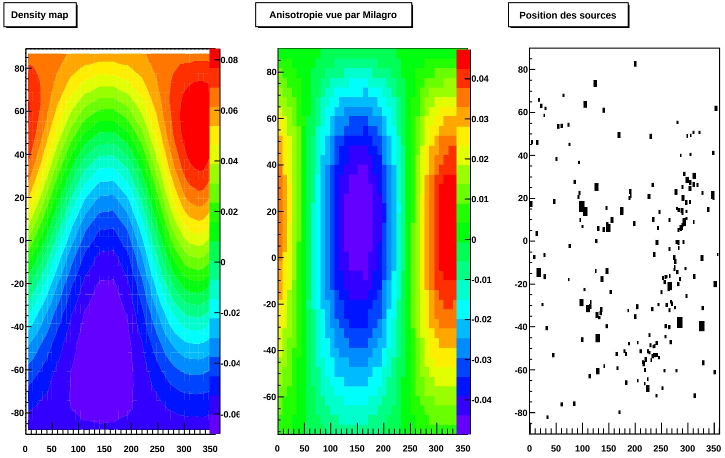


Figure: Anisotropie àt 6TeV

Real sources

Comparison with milagro measurements

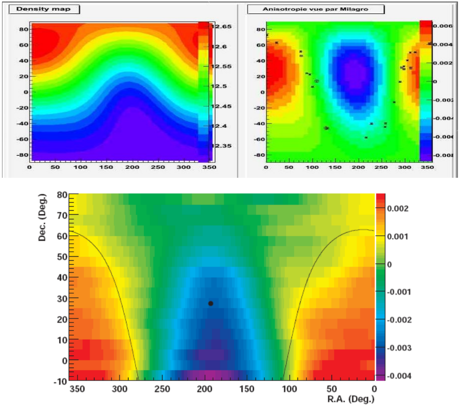


Figure: δ =0.8 and δ = 0.86

$\rightarrow$ The maximum and minimum begin to fit

Real sources

We compute the anisotropy for two different parameters set

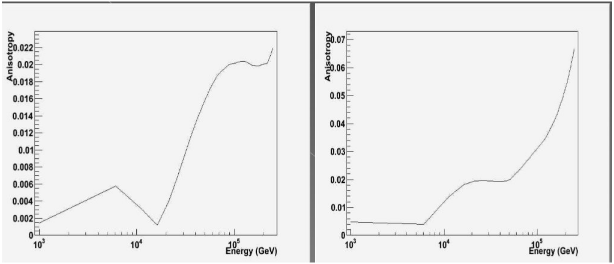


Figure: δ =0.8 and $\delta = 0.86$

$\rightarrow$ We can manage to have a good agreement with measurements

Proton Flux

Aim : Try to explain the anomaly observed by PAMELA CREAM and ATIC in the proton flux

Ideas : As we are choosing sources from a catalog and randomly, this should induce a variance in the flux, so that a slight change in the flux is not forbidden by the model

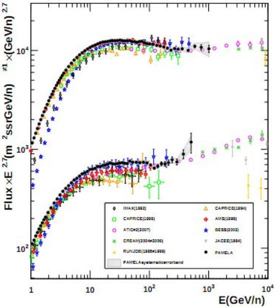


Figure: Proton Flux as observed by PAMELA Colaboration. arxiv:1103.4055

Conclusion and prospects

- The model can constrain δ_s but still need to check the energy dependance
- We need to do the calculations with Heliums and electrons
- Influence of the local bubble
- Influence of sources witch are not pointlike in time
- Need to think of the limit of the models (mean free path $>$ distance of the sources)