Interpretation of the spectral inhomogeneity in the 10TV region in terms of a close source

V.Yurovskiy(SINP MSU) F.Gasratov (SINP MSU) I.Kudryashov (SINP MSU) V.Latonov(MSU)

Experimental data show spectral irregularities in 10 TV regions,which can be interpreted as a close source or a special transport feature.

In this paper, we consider the possibility of interpreting the experimental spectral inhomogeneity as the contribution of a single point instantaneous source in the isotropic diffusion approximation.

The emission spectrum of the source is represented by the function:

$$Q(R,t,r)=R^{-\gamma_0}\left(1+\left(R/R_{ref}\right)^{\omega_0}\right)^{-\delta\gamma/\omega_0}\delta(t-t_0)\,\delta(r-r_0)$$

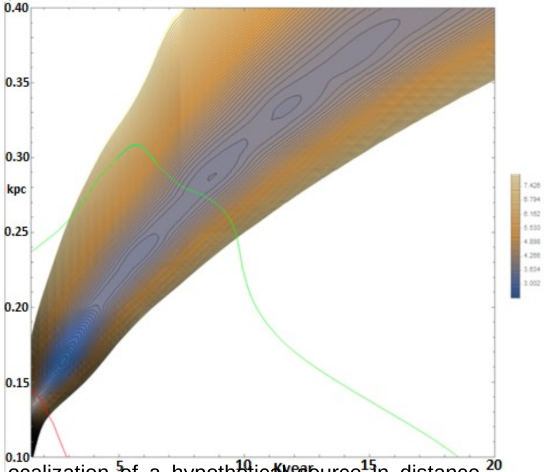
The spectrum of all CR elements in the source has the same shape in terms of rigidity and differs only in the absolute intensity.

Equation describing the evolution of the CL concentration in the diffusion approximation:

$$\frac{\partial N}{\partial t}-\nabla\,(D\nabla\,N)=Q(R,t,r)$$

Where $D[R] = D_0 (R/R_0)^{\delta}$, $D_0 = 4{,}3*10^{28}$ cm^2/s, $\delta = 0{,}395$, $R_0 = 4{,}5$ GV

The model signal represents the sum of the background flux and the flux from the source, obtained as a solution to the diffusion equation $F_{summ} = F_{bgr}(R) + F_{star}(R)$



Localization of a hypothetical source in distance-age coordinates,color denoted xi2 green line power limit 10^51 erg

A feature of this work is the simultaneous consideration of a set of existing direct experiments that measure element-by-element spectra and reveal the elemental structure of inhomogeneity and the spectrum of all particles measured by HAWC.

The HAWC experiment has a significantly higher statistical reliability than direct experiments with high systematic errors. To account for this type of data, the penalty method was applied with a two-dimensional correlation function μ = aR + b

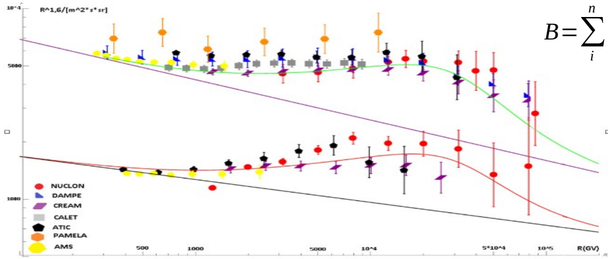
$$\chi^2(\xi,\alpha)=\Sigma_i\frac{\left(F_i\left(1+\Sigma_j\frac{\partial\mu_i}{\partial\alpha_j}\Delta\alpha_j\right)-P_i(\xi)\right)^2}{\delta_i^2\left(1+\Sigma_j\frac{\partial\mu_i}{\partial\alpha_j}\Delta\alpha_j\right)}+\Sigma_i\Sigma_j\Delta\alpha_i\Delta\alpha_j\left(A_s\right)^{-1}_{ij}$$

where ξ are the arguments of the simulated flows Pi (ξ), α is a set of penalty parameters (in our case there are two of them), Fi are experimental flows, δi are experimental errors, As is the correlation matrix

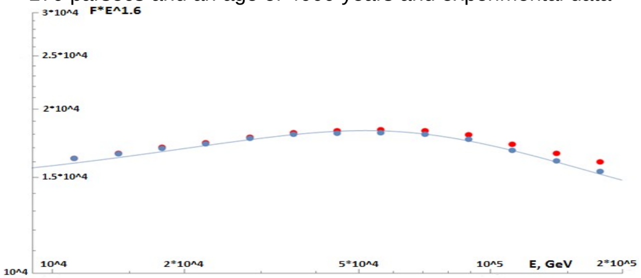
$$A_s=\begin{bmatrix}\sigma 1^2 & \rho\sigma 1\sigma 2\\ \rho\sigma 1\sigma 2 & \sigma 2^2\end{bmatrix}\quad \sigma_1=\frac{B}{(AB-C^2)}\quad \sigma_2=\frac{A}{(AB-C^2)}\quad \rho=\frac{-C}{AB}\quad A=\sum_i^n\frac{E_i^2}{\sigma_i^2}$$

$$B=\sum_i^n\frac{1}{\sigma_i^2}\quad C=\sum_i^n\frac{E_i}{\sigma_i^2}$$

where δ-relative systematic error



Predictive model for a source with minimum Xi2 ~ 3 at a distance o 170 parsecs and an age of 4000 years and experimental data



Predictive model for a source with a minimum Xi2~3 for the HAWC experiment the blue points correspond to the data multiplied by the correlation function

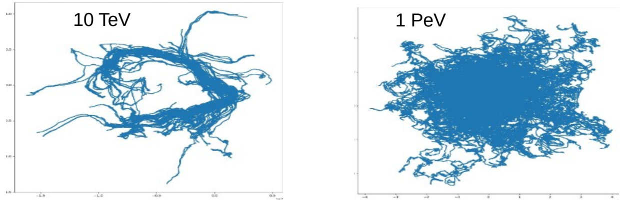
Since the standard methods for calculating the transport coefficients obtained from the ratios of the fluxes of secondary to primary nuclei give estimates only for the coefficients of isotropic diffusion, to study the anisotropy of the transport coefficients, a numerical calculation was performed in a simulated magnetic field B(r)

$$\boldsymbol{B}(\boldsymbol{r})=\boldsymbol{B}_{mean}+\boldsymbol{B}_{random}(\boldsymbol{r})$$

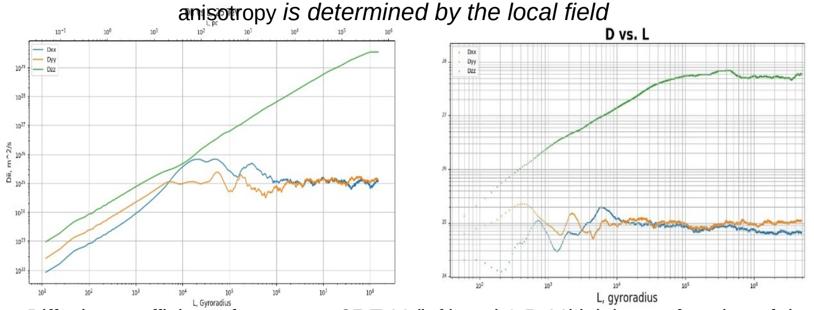
The simulated field is the sum of a regular field with strength B_{mean} and a random turbulent Brandom component with an Brms=6muG, distributed over the Kolmogorov spectrum N=500 modes from 100au to 100 parsec

$$\boldsymbol{B}_{random}(\boldsymbol{r})=\sum_{i=1}^{N}A_i\boldsymbol{p}_i\cos(\boldsymbol{k}_i\cdot\boldsymbol{r}+\psi_i)\qquad A_i=\sqrt{\frac{2\zeta k_i^{-\frac{11}{3}}dk_i}{B_{rms}}}$$

The Kasha-Karp method from the family of Runge-Kutta methods of 4 orders of accuracy was used to numerically solve the equations of motion of a relativisian particle



Trajectories of particles with energies of 10 TeV and 1 PeV in turbulent magnetic field Brandom at Bmean =0. From these trajectories it can be seen that for energies below 10 TeV the anisotropy *is determined by the local field*



Diffusion coefficients for protons 25 TeV (left) and 1 PeV(right) as a function of the path L (in gyroradii), calculated in the configuration Brms = 6muG and Bmean = 6muG (directed along the Z axis). Significant anisotropy of transport coefficients is visible, this will be taken into account in the next work