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The large-scale anisotropy in the PAMELA experiment

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The large-scale anisotropy (or the so-called star-diurnal wave) has been studied in the frame of research carrying out in space with the PAMELA instrument. It was studied during the time period covering 2006-2014 for the Southern and Northern hemispheres simultaneously. The cosmic ray intensity distribution was constructed in the equatorial coordinate system and the anisotropy was obtained. For a dipole approximation its amplitude and phase have been measured for cosmic ray particles with energies 1-20 TeV/n. This result well known from ground based measurements has been obtained in space for the first time.

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[†]A footnote may follow.

1. Introduction

The large scale anisotropy of high energy cosmic rays is observed in many ground-based experiments [1, 2, 3, 4, 5, 6, 7]. In a first approximation it has a dipole form, the amplitude and phase of which depend on energy. In the energy range 1-20 TeV these parameters vary in the different measurements. However, their values have a crucial role for the processes that might be involved for an anisotropy explanation. For example, in the work [8] the anisotropy is explained by a single nearby source. The same source is responsible for the positron and antiproton spectra as they are seen in the PAMELA [9, 10] and AMS [11, 12] experiments. Depending on the amplitude of the dipole there might be different conditions in this source (in the ground measurements such amplitude vary from 0,3 $\times$ 10^{-3} up to 1 $\times$ 10^{-3}). Beside to ground based measurements the satellite ones are able to measure in the both hemispheres and do not undergo by any atmospheric influences. This work is dedicated to the first satellite measurement of the dipole anisotropy in the energy range 1-20 TeV/nuc by PAMELA.

2. The PAMELA experiment

The PAMELA magnetic spectrometer was launched in the summer of 2006 and has been operating since then [13]. The main scientific goals of the experiment are the study of particle and antiparticle fluxes in a wide energy range. PAMELA apparatus consist of several various detectors positioned around a magnetic spectrometer (tracker). While the tracker is able to measure the deflection of particles in the magnetic field up to energies of about 1 TeV, another PAMELA subdetector - a calorimeter, could be used to extend the measured energy range. Furthermore the calorimeter allows to measure particle direction over a wide range of angles. The calorimeter consists of 44 silicon planes, with 96 strip detectors in each one; interleaved with 22 tungsten layers. In neighboring silicon planes, strips are orthogonal providing topological and longitudinal information of the shower development.

3. The data analysis

To measure the particle direction the shower axis inside the calorimeter was reconstructed. The iterative procedure allowed to restore the axis along the primary particle track throughout the 44 planes [14]. This procedure is fit of the center of gravity of energy released in each plane of each view. Events with reconstructed shower axis were further selected by the cut based on the total energy deposition in the calorimeter. A cut threshold was set at the level of 180000 mip corresponds to particles with energy 1-20 TeV/nuc. The obtained statistic allowed the study of anisotropy just in a one dimensional map as a function of right ascension - RA in the equatorial coordinate system. The idea of the method was based on the fact that we can study the anisotropy only using some proposal due to a lack of events. The proposal was that we would search for the dipole anisotropy as it is seen in the ground-based experiments. For this reason 180 degree size bin was chosen for integrating events. Events were grouped by shifting this bin 72 times with 5 degree step in the range from 0 to 360 degree. To create an isotropy map for comparison with the experimental one a shuffling method was used (for details see [15]).

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4. The results

In fig. 1 the obtained dipole anisotropy is shown. The data set covers the time period 2006-2014. The anisotropy is measured in the equatorial coordinate system in terms of relative intensity. The dipole was fitted by a sin function. The result of this fit gives the phase - 27 (8), and the amplitude - 0.0011 (0.0001). The values in brackets represent the fit uncertainties. The amplitude is in an agreement with HAWC[5], Ice-Cube[6] and Bacsan results[7].

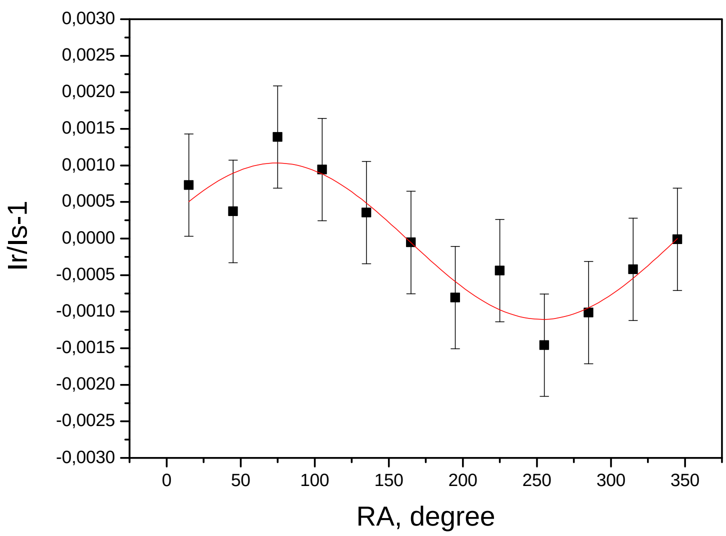

Figure 1: The Ir/Is-1 depending on RA. Ir - the real intensity, Is - the simulated isotropic intensity. The red line is the fit by the sine wave.

5. Acknowledgments

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