Search for Large-Scale Anisotropy of Ultrahigh Energy Cosmic Rays with HiRes Stereo Data

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***Abstract*. We have searched for correlations between the pointing directions of ultrahigh energy cosmic rays in the data of the High Resolution Fly's Eye (HiRes) collaboration, and local large scale structure. The HiRes stereo data set (the same used to search for AGN correlations [1]) was used in the search, and the 2 Micron All-Sky Redshift Survey (2MRS) was used to determine the density of galaxies in right ascension and declination. The two parameters of the search were the minimum energy of the cosmic rays and the typical mean magnetic deflection angle. Previous searches for extragalactic anisotropy used minimum energies of 10, 40, and 57 EeV. We made those energies, plus choosing to quote a 95% confidence level (if no correlations were found), a priori choices of search parameters, and examined deflection angles from 1 to 15 degrees. The results of the search will be reported.**

***Keywords*: HiRes Experiment, UHECR anisotropies, large-scale structure**

I. INTRODUCTION

Since the GZK cutoff [2] has been observed by the HiRes experiment [3], and confirmed by the Auger experiment [4], cosmic rays of extragalactic origin must be largely protons, which suffer energy losses during propagation to the earth from interactions with the cosmic microwave background radiation, and from the expansion of the universe. Hence the highest energy cosmic rays must originate from sources relatively near the earth; i.e., within distances of order 100 Mpc. Since matter is distributed in a very anisotropic way within a sphere of this radius one expects to see anisotropy in the pointing directions of cosmic rays.

To search for this effect we use the stereoscopic data collected by the HiRes experiment. HiRes ran from 1999 through 2006. This data set is the one we used to search for correlations with AGN's [1], and has been adjusted to have the same energy scale as the Auger experiment at the highest energies.

We made a model of what to expect for the distribution of cosmic rays' pointing directions. This model started with the distribution of galaxies within 250 Mpc from the 2 Micron All-Sky Redshift Survey (2MRS) [5]. This distribution traces the matter, and we assume the cosmic ray sources, within this radius. From each galaxy we generated a spectrum of cosmic rays and propagated them to the earth. Since galactic and extragalactic magnetic field strengths, and their correlation lengths, are poorly known, for this study we assumed that all events would suffer a single mean magnetic deflection angle. We will quote our results as a function of this angle. We also calculated what we would expect if the sources of cosmic rays were isotropic.

Previous searches for extragalactic anisotropy used cosmic rays of minimum energy 10 EeV [6], 40 EeV [7], and 57 EeV [8]. We make *a priori* choices of these three energies for our search. In addition we choose *a priori* to quote a 95% confidence level upper limit if our search does not have a positive result.

II. METHOD

The 2MRS survey is a flux-limited survey of galaxies with observed K_s magnitude $m \leq 11.25$ that includes spectroscopic redshifts for almost all galaxies. We removed the galactic plane region by requiring that $\mid b \mid > 10$ degrees, b being the galactic latitude. We used a weighting technique, to be described elsewhere, for each galaxy to transform the catalog into a volume-limited one. The final result consists of 15,508 galaxies within 250 Mpc. Beyond this distance we assume matter is isotropically distributed. At 10 EeV about 40% of cosmic rays originate within the 250 Mpc sphere; at 40 EeV the fraction is about 70%; and at 57 EeV it is 100%.

We assumed that each source had the same flux, and weighted each galaxy's contribution by $1/d^2$, where d is the distance to the galaxy calculated from its red shift. To approximate the effect of galactic and extragalactic magnetic fields we smeared out the pointing directions of cosmic rays in our model by angles between 1 and 15 degrees. We included the aperture of the HiRes stereo events in our model.

The HiRes stereo data set was collected between 1999 and 2006, and contains 6636 events of all energies. Outside the ± 10 degree region about the galactic plane there are 310 events above 10 EeV, 27 above 40 EeV, and 10 above 57 EeV. The typical angular resolution is about 0.8 degrees.

To compare the data with the model, for each event we determined the density of events predicted by the model, and formed an integral distribution of these densities. We compared this distribution with a good-statistics

Monte Carlo set thrown according to the model. We compared the two distributions using a Kolmogorov-Smirnov test. For more information on this process see reference [9]. We repeated this process starting with an isotropic distribution of matter.

III. Results and Conclusions

Results will be presented at the ICRC, together with the conclusions to be drawn from them.

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