SEARCH FOR A PRIMARY COSMIC RAY ANISOTROPY NEAR 1018eV

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ABSTRACT

Air shower data from the Fly's Eye have been used to search for arrival direction anisotropies. The analysis differs from that of air shower arrays because of the irregular pattern of Fly's Eye running times, which are limited to clear moonless nights. The data appear to be free of. major systematic problems. Results include weak support for increased cosmic ray intensities at lower galactic latitudes for showers below 10^{19}eV.

1. Introduction

Large air showers have been detected by the Fly's Eye and successfully analyzed at impact parameters up to 12 km. The Fly's Eye is collecting showers at energies from below 10^{17}eV to above 10^{19}eV and the distribution of shower arrival directions can be compared with isotropic distributions and the results obtained with large arrays. EAS data taken by the completed Fly's Eye during 16 months have been analyzed and have been used in a search for anisotropies in the primary cosmic ray arrival directions. Also, there are an additional 7 months of data taken earlier when the system operated at lower sensitivity and with only 48 of the total 67 mirrors in operation.

The numbers of showers obtained so far are much smaller than the numbers obtained by the Haverah Park array [1]. However, the consistency of our results with other large northern hemisphere measurements can be tested to check our data for undetected systematic effects and to find if our data give weak confirmation of the other results.

2. Method of Analysis

For the anisotropy studies, data were accepted for only those, times which were clear or in which clouds were present only near the horizon. Temperatures were recorded each night and these were' to correct for the temperature dependence of atmospheric fluorescence following the model of Bunner[2]. Showers for-which the uncertai.nty in. direction was greater than 30° were rejected in this analysis.

A maximum likelihood analysis was used to obtain the anisotropy parameters of the first harmonic in right ascension. To minimize

the effects of the slowly changing sensitivity of the Fly's Eye, the expected or trial distribution of shower right ascensions was obtained separately for each monthly operating period. This trial distribution was obtained by folding together an "exposure" distribution with an "acceptance" distribution.- ,The exposure distribution is the length
of time the system was operated during the month as a function of the local sidereal time. For each shower the hour angle (difference between the local sidereal time and the right ascension) was determined. The set of hour angles from the showers observed during a monthly run determined the acceptance distribution.

The trial distribution described above is for the case of isotropic cosmic rays. For the case of an anisotropy, the trial distribution of right ascensions was multiplied by f(á) = 1 + a.cos (á – $á_0$). For each value of a and $á_0$ the likelihood of the observed set of right ascensions was determined, and then the best parameter values and their uncertainties were found. A similar method was used to detect an anisotropy in galactic latitude. In this case the trial distribution was multiplied by f(b) = 1 + s.b, where b is the galactic latitude and s is the slope parameter in inverse degrees. These methods allowed the anisotropy analysis to be done for the complicated pattern of Fly's Eye running times.

3. Results and Discussion.

The results for right ascension anisotropies are shown in Table I. The energy bin above 10^{19}eV does not have sufficient statistics to allow an anisotropy to be determined. With the present statistics all energy ranges are in satisfactory agreement with isotropy. Hillas[3] gave the expected amplitude of the right ascension anisotropy due to random fluctuations in the data. These amplitudes are given in the last column. In our case, in which monthly exposures to different right ascension regions are not uniform, the anisotropy uncertainties are somewhat larger than the ideal values.

Table I. Right Ascension Anisotropies

E range	Anisotropy	$á_0$	# showers	2/ N
$3X10^{16}-10^{17}$	0.15±-23	0.5	84	0.15
$1-3X10^{17}$	0.123±-089	-2.1	564	0.06
$0.3-1X10^{18}$	0.067±-090	10.3	518	0.06
$1-3X10^{18}$	0.10±-13	0.4	185	0.10
$0-3-1X10^{19}$	0.25±-29	-6.0	33	0.25
$>10^{19}$	-	-	14	0.38

Table II. Model of Haverah Park Anisotropy Data

Region	E range $(E/10^{18}eV)$	á (hrs)	# showers
E_1	0.06-0.125	17.7	304
E_2	0.125-0.25	16.2	549
E_3	0.25-0.5	21.6	645
E_4	0.5-1	2.9	386
E_5	1-2	2.9	208
E_6		2.2	70
E_7	4-8	19.8	22
E_8	8-16	20.5	12
E_9	16-32	21 .2	7
E_{10}	>32	10.8	1

For about 30% of the reconstructed showers, the fitting of the shower size to find the shower energy was not successful. In order to include these showers and to maximize our statistics, the anisotropy of all detected showers was determined. As a model of they expected anisotropy for this sample, the results from Haverah Park[4] were used. The right ascensions of the anisotropies for the different energy regions are given in Table II. For intervals E3 and E8 the values were estimated by interpolating between the neighboring intervals. Using a figure from Ref. 4, the amplitudes were estimated to be about $A(\%) = 6.33 \times 10^{-11} \times E_o^{0.61}$. These anisotropies were weighted by the numbers of showers in the energy intervals observed in the Fly's Eye experiment. These numbers are given in the last column. The anisotropy value obtained by this crude model is shown in Figure 1, along with our experimental value and its error circle. We are consistent with the model of the Haverah Park results as well as with isotropy.

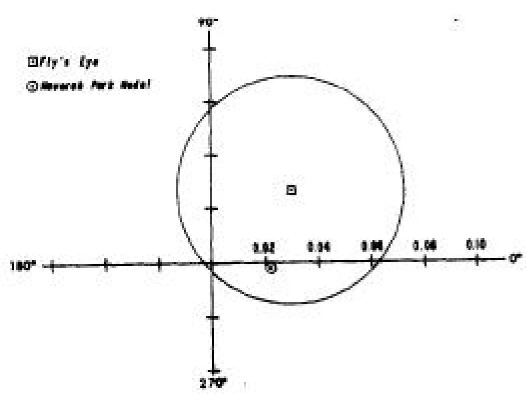

Figure 1. Vector diagram of the first harmonic in right ascension for the Fly's Eye data and for the Haverah Park model.

Showers at energies above 10^{19}eV have been observed to arrive at an enhanced rate at high galactic latitudes Below 10^{19}eV, however, the opposite effect has been observed[1]. Using the slopes obtained by Astley et al.[1] and the numbers of showers observed by us in the different energy intervals, the expected slope parameter s is -5.3 X 10^{-11}per degree of galactic latitude. A fit of the slope of all of our data gives -21 ± 11 X 10^{-4}.

IV. Conclusions.

No major systematic effects have appeared which limit the ability of the Fly's Eye to pursue further anisotropy studies. The first Fly's Eye anisotropy results are consistent with the results from Haverah Park. Although the statistics are small, our data are weakly in favor of an enhancement of showers below 10^{19}eV at lower galactic latitudes. Sensitivity improvements and additional running time are planned for the Fly's Eye to obtain a larger data sample.

V. Acknowledgements.

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References

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