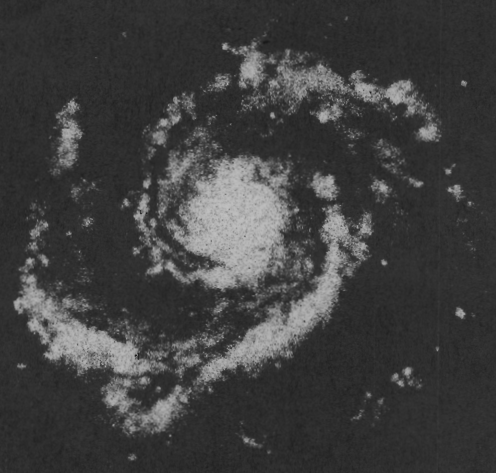

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Is There a Correlation of Single Muon Angles with the Galactic Plane?

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Abstract

We report excesses of single muon angles which are near the galactic plane. The absolute value of the excess is small but the statistics are large enough that the differences are statistically significant (>5 standard deviations), though small in fractional rate [0.0008 / (std dev)]. A two-dimensional plot of muon rate in 10 x 10 deg cells in declination versus right ascension is shown. A possible correlation is noted but shifted ~30 deg relative to the galactic plane. Present and future methods are discussed for handling systematic errors to insure the best use of the high statistics data which are available.

1 Introduction

At UHE, point sources such as Cygnus X-3 and Hercules X-1 [S83, D88] are found to have an anomalously high muon content, and underground experiments have claimed the detection of a muon signal in the direction of Cygnus X-3 [B85,M85]. At HE, experiments such as COSB [M82] and EGRET [B93] have found a general enhancement of gamma ray flux from the galactic plane. Gamma rays have ~1% probability, relative to hadrons, to produce mesons which can subsequently decay to muons. It is thus of interest to examine whether single cosmic ray muons at sea level have a similar angular correlation with the galactic plane in our experiment since GRAND has a high rate of detecting, identifying, and measuring the angles of single muons.

We reported a high statistics histogram of the number of single muon angles in bins of right ascension from 0 to 360 deg [P91]. This histogram was interpreted as showing indications of an excess of muons from the direction of the plane of the Milky Way. We further examine these data. An independent histogram with similar features has been published by a different experiment [B88].

2 Experimental array

A partial array of project GRAND [P91] with 16 stations, located at 86 deg W, 42 deg N, was used to take data in a single track trigger mode; that is, a single trigger from any hut causes the data to be read from all the huts since huts may have useful data stored from an earlier trigger not yet read out. The internal trigger signal from a hut is a triple coincidence of the top 3 PWCs. This coincidence denotes at least one track in that hut with good efficiency and low background. A 5 cm thick plate of steel above a fourth PWC allows us to identify which of the tracks are muons [G91]. From this single trigger, 75% of the tracks are muons. The muon algorithm demands a single hit below the steel aligned with the track above the steel. This simple algorithm loses about 3% of the muon signals and misidentifies about 3% of the electrons as muons and yields a sample of 99% pure muons.

The mean detected muon momentum is ~3 GeV which mainly come from ~100 GeV hadrons incident upon the earth's atmosphere.

The projected angles of each track are measured with a precision of 0.26 degrees in each of the two orthogonal planes; the muon's deflection in the earth's magnetic field before detection degrades this resolution to ~5 degrees. We investigate the angular distribution of these muons at our detection level, 220 m above sea level. Our acceptance extends from 0 to 360 deg in right ascension (RA) and, with reasonably good efficiency, from -10 to +80 deg in declination (Decl). The data candidates which are accepted by the data acquisition system [L91] and an on-line computer [O91] selects data which have the following characteristics: one and only one (or two adjacent) hits in each of the eight planes of the four PWCs of a station. If this selection criteria is satisfied, the coordinates of the hits and the time of the trigger are written on 8mm magnetic tape for later off-line analysis.

3 Data analysis

The algorithm for selecting muon tracks is composed of two parts: the on-line cut discussed above and a cut in the off-line computer program which asks if the hits align on a track in each of the two orthogonal projections. This off-line alignment criteria retains 95% of the data. The slopes of the tracks are obtained in two projections; these slopes and the time are then used to calculate the right ascension (RA) and the declination (Decl) of the track. The presence of the aligned single hit in the fourth PWC satisfies the algorithm for the track's identification as a muon [G91]. The data covered periods of good continuous runs in the interval from Oct. 1990 to Apr. 1991. Only continuous runs of one complete sidereal day were used in the analysis; these distributions are not corrected for pressure and/or temperature variations. To guard against systematic errors which might cause possible angular biases in RA (such as atmospheric pressure and temperature variations or equipment problems causing the data acquisition system to take data non uniformly), we examined each sidereal day for deviations from non-flatness and retained the half of the sidereal days which were the most flat. Although this flatness selection was done by hand, it was not known at that time where the data of an individual sidereal day would appear in the RA plot, thus preventing a possible subjective bias.

The shape of the histogram of our RA data is shown in Fig. 1a ("M" on the ordinate stands for millions of counts per bin). This shape is consistent with a correlation of the data with the galactic plane, since such a positive correlation would yield a decrease in data in the region of RA from 140 to 200 deg when the galactic plane is too far south to be observed in our apparatus and an increase for the other RAs when directions from the galactic plane have good angular acceptance in our apparatus. The effect might also be due to charged primaries spiraling in some orienting magnetic field. Note the suppressed zero used to emphasize the residual non-flatness.

To further check the consistency of the result, we divided the runs of data into two parts; the early and the late half of the sidereal days. Each half was again analyzed in the same fashion as above. The effect was seen in each half in a consistent manner and each showing a similar shift in the phase of the correlation (25 and 30 deg respectively). This asymmetry is reproduced in a similar manner in a previous experiment with similar techniques performed in Italy [B88]; for comparison purposes, their data are reproduced to like scale in Fig 1b. The horizontal line in each plot is an extension of the nearest vertical division shown in the respective plot; in each plot the magnitudes of the non-flatness are about the same fraction of the average counting rate.

A more sensitive test than that of Ref [P91] was devised to study this correlation by looking at the excess in a two-dimensional plot of Decl versus RA (after summing over all Decl values). In order to remove the large Decl dependence of the data, a grid of the following quantities is constructed:

$$[\text{data}(RA,Decl) - \text{ave}(Decl)] \ / \ \text{sqrt}[\text{ave}(Decl)] \qquad (1)$$

to study the deviations of the data in cells of RA and Decl from the average overall RA at that Decl in terms of the number of standard deviations from the average counting rate. These values are summed into a storage grid of 10 deg by 10 deg cells from 0 to 360 deg in RA and -10 to 80 deg in Decl. The duration of summing is arranged to be exactly an integer number of sidereal days so the exposure for each RA region is the same. A total of 273 million muon angles are contained in this grid with 1.4 million muon angles per 10 deg x 10 deg cell for angles near zenith. Thus a one-sigma error-bar on a cell near zenith is 0.0008 that of the absolute counting rate at zenith; five standard deviations corresponds to a fractional deviation of 4 parts per thousand.

The results of this plot are presented in Fig. 2 by a two-dimensional plot of the number of standard deviations versus RA and Decl in 10 deg by 10 deg cells. The number of standard deviations above (or below) the average is indicated by the various degrees of shading with the lightest shade (white) > 5 std dev excess and black denoting < -5 std dev deficiency according to the guide at the right of Fig. 2. The number of standard deviations is obtained from equation (1) above. Near our zenith angle of 42 deg, 5 standard deviations represents a fraction of 4 parts per 1 000 of excess (or deficiency). The galactic plane is indicated by the curve in the figure; the angular shift of the correlation in right ascension is about 30 degrees, too large to be explained by small effects such as the earth's magnetic deflection of positively charged primaries. Cosmic rays interacting with the interstellar material in the galactic plane yield neutral pions which decay to gamma rays; this source is expected to yield a fraction of gamma rays ~1 per 100 000 hadrons from the direction of the galactic plane. These gamma rays would yield ~1% as many single muons as those from hadrons. Thus the expected correlation of single muons with the galactic plane from gamma rays is expected to be ~1 per 10 000 000 of the hadronic background, too small to be a cause of the observed asymmetry.

We propose to expand this study of single muon angles to find these correlations with added precision. Since the full array of 64 stations has recently been completed, the available detector area has been increased by a factor of four over that available for the runs discussed in this paper. A ten-fold increase in statistics would be possible assuming only three times more running time and added on-line computing power to prevent the computing dead time from being increased by the higher data rate. To utilize the full power of these increased statistics of single muons, additional controls will be implemented in order to minimize the systematic sources of error; runs of a year or longer will average out possible solar effects. This research was supported in part by a bequest from Walstine Griffin.

References.

[B85] G. Battistoni et al, *Phys. Lett.* ***155B***, 465.
[B88] G. Battistoni et al, *Il Nuovo Cim* ***11C***, 175.
[B93] D. L. Bertsch et al, *Ap. J,* ***416***, 587.
[D88] B. L. Dingus et al, *Phys. Rev. Lett.* ***61,*** 1906.
[G91] J. Gress et al, *Nucl. Instr. and Methods* ***A302,*** 368.
[L91] Y. Lu et al, *Proc. of the 22nd ICRC, Dublin* ***4***, 421.
[M82] H. Mayer-Hasselwander, *Astron & Astrophys* ***105***, 164.

[M85] M. L. Marshak et al, *Phys. Rev. Lett.* ***54***, 2079.
[O91] ACP68020 CPU Module, *Omnibyte Corporation*, West Chicago, IL USA.
[P90] J. Poirier et al, *Proc. Suppl. Nucl. Phys. B* ***14A***, 143.
[P91] J. Poirier et al, *Proc. of the 22nd ICRC, Dublin* ***1***, 192. [status]
[R90] L. J. Rosenberg et al, *High Energy Gamma Ray Astronomy, Ann Arbor, MI: AIP Proceedings* ***220***, 111.
[S83] M. Samorski and W. Stamm, *Astrophys. J.* ***268***, L17.

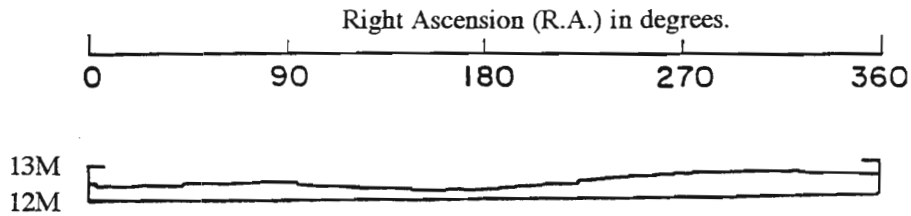

Fig. 1a. Counts per 4°-bins of R.A. when summed over Decl.

Fig. 1b. Similar to Fig. 1a except data are from Ref. [B88].

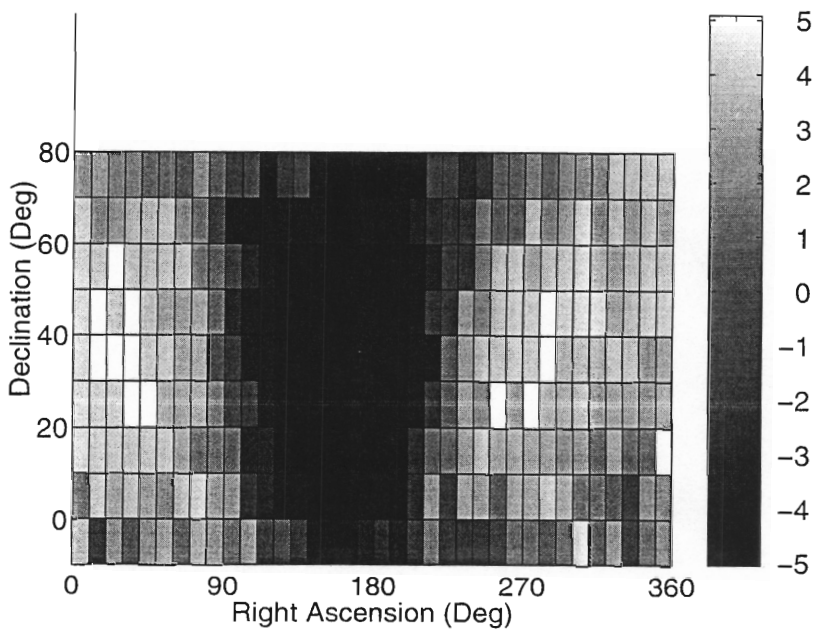

Fig. 2. A two-dimensional display of the number of standard deviations the data is from average behavior as a function of Decl. versus R.A. The curve is the position of the galactic plane in these equatorial coordinates.