uncertain ones, into 3 groups, namely L, M, and H groups, which represent 4 masses from 54 to $105m_e$, 10 masses from 135 to $364m_e$, and 7 masses from 465 to $649m_e$, respectively. The M group contains μ mesons, for which the number estimated by using the data of Merkle *et al.* is about 2, that estimated from the number of decay electron is about 3, and that expected from the measured mass is about 5. It is uncertain whether the remaining particles in the M group are π mesons or mesons of a new type. The L and H groups, in which the average masses are 86 and 592, respectively, are free from π and μ mesons, thus implying mesons of a new type. Concerning the decay of the new mesons, there is doubt whether they are a "non-decaying type" or a "long-lived type," or whether they produce a decay particle of such short range as to be undetectable, or whether they are negatively charged particles and are captured by nuclei before their spontaneous decay.

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Diurnal Variations of the Intensity of Cosmic Rays Far Underground*

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In the analysis of 249 762 coincidences due to cosmic rays at a depth of 1600 m.w.e. underground, no diurnal variation of the rate with respect to solar or sidereal time was found. With high confidence the amplitudes of such variations may be said to be less than one percent of the average intensity. The average energy of the primary cosmic rays responsible for the particles recorded was about 4×10^{13} ev.

IN 1950 a series of measurements of the intensity of cosmic rays reaching a depth of 1600 meters water equivalent (m.w.e.) was begun in a salt mine near Ithaca, New York (geographical latitude $\lambda=42.5°$N). Analyses of the intensity-time variations, based on part of the results, have already been published.[1,2] Now these measurements have been completed, and the results we publish here supersede the previous ones.

Other experiments performed in the same mine[3] have shown that the observed particles are mu mesons created with an average energy of about 10^{12} ev by primary cosmic rays having an average energy of about 4×10^{13} ev.

The intensity was measured by several vertical telescopes, each containing two trays of G.M. counters (30 in.×40 in.) separated by four inches of lead, and shielded above and below by two inches of lead. The number of coincidences in each telescope was recorded hourly. A total of 249 762 coincidences have been recorded during the period July, 1951 to August, 1953, with an average rate per telescope of 10.7 per hour. The accidental coincidences, which have not been subtracted, were about five percent of the total.

The data have been assembled according to the hour of solar time (Eastern Standard Time), or of local sidereal time in which the counts were recorded. Small corrections were applied for slight differences of running time in the different intervals. The results are plotted in Fig. 1, showing the apparent variation of intensity as a function of the solar time and as a function of the sidereal time. The errors indicated are standard errors.

On the solar time scale, the deviations from the mean have a quite normal distribution, with an rms value just equal to that which is expected from statistical fluctuations of the numbers of counts recorded. Fitting these data to a sinusoidal diurnal intensity variation can reduce the residual mean square deviation, the best fit occurring for an assumed amplitude equal to 0.5 percent of the mean counting rate, with 5.9 hours E.S.T. as the time of the maximum. However, the fit is

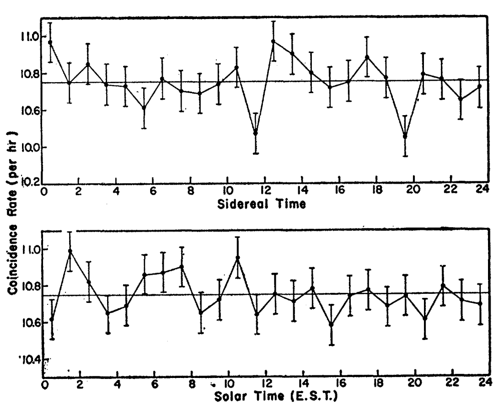

FIG. 1. Average coincidence rate of the three counter telescopes, as a function of local sidereal time and Eastern Standard solar time. The indicated errors are standard errors.

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hardly better than that which is expected from normal data involving the same number of counts in the absence of any real intensity variation. With high confidence, the true amplitude can be said to be less than one percent of the average intensity.

On the sidereal time scale, several of the deviations are a little large for a normal distribution, the mean square deviation being 1.4 times the most probable value. But in view of the angular resolution of the apparatus (effective aperture $\approx 60°$, determined mainly by the zenith-angle distribution of the mesons), and the fact that neighboring points on the graph do not show similar deviations in the same direction, we infer that the large deviations were more probably caused by random flucutations than real intensity changes. Indeed, fitting the data to a sinusoidal intensity variation hardly reduces the residual deviations at all, the fit being poorer than that expected on the average if the deviations are random. One may confidently infer that the amplitude of any sinusoidal diurnal intensity variation with respect to sidereal time is less than 0.7 percent of the average intensity. The best fit is for an amplitude of 0.1 percent, with maximum at 16.5 hours local sidereal time, but there is no evidence that the effect is real.

Our results contradict those of Sekido *et al.*[4] who, at a similar latitude and similar energy, seemed to observe a large intensity variation with respect to sidereal time. However, our analysis of their data indicates that their results were not significant statistically. On the other hand, our results are in good agreement with those of Sherman[5] who, at 846 m.w.e. underground, found diurnal amplitudes less than one percent, the data being consistent with zero amplitude.

Our results are not inconsistent with those of Daudin and Daudin,[6] who at a similar latitude, but at a higher primary energy (by detecting air showers of energy $\sim 2\times 10^{15}$ ev) and with better statistics than ours, found a sidereal variation with amplitude a few tenths of a percent, barely significant statistically; the maximum occurring at 22 hours local sidereal time.

In sharp contrast to the measurements at northern latitudes stand the results of Farley and Storey[7] obtained in Auckland, New Zealand, where the central region of the galaxy passes overhead at 18 hours local sidereal time. A very significant maximum was found to occur at this time in the air shower intensity (primary energy $\sim 10^{15}$ ev); on the assumption of a sinusoidal variation, the amplitude was about 1.5 percent.

It may be mentioned that these results, both the positive and the negative ones, have a bearing on theories of the origin of cosmic rays.[8] The positive results from New Zealand lend encouragement to a continuation of these studies. In retrospect, however, it is clear that it is better to look for the primary asymmetries by measuring variations of air shower intensities than by measuring variations in the meson intensity far underground. It is true that the latter method has an advantage, in that the meson intensity is comparatively insensitive to atmospheric changes, and therefore would not contain a spurious sidereal time variation due to solar and seasonal effects. But this is more than compensated for by the improved statistics that are obtainable in the air shower measurements, owing to the large effective area over which the showers can be detected. Thus, one can count events of primary energy around 10^{15} ev, as air showers at ground level, with about the same frequency as one can count primary events of 10^{13} ev by detection of the mesons underground. If events of equal primary energy are selected, the air shower counting rates can exceed the underground rates by a factor of about 1000.

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