PROGRESSIVE ROTATION OF COSMIC-RAY DIURNAL VARIATION VECTOR*

S. P. Duggal and M. A. Pomerantz
Bartol Research Foundation of The Franklin Institute, Swarthmore, Pennsylvania
(Received January 29, 1962)

Although the fact that an enhanced diurnal variation of the primary cosmic-ray intensity is associated with geomagnetic disturbances has been recognized for some time, detailed analyses of individual events have heretofore been precluded. Correlation studies involving combined measurements representing a number of storms have been conducted, and qualitative features of the storm-associated anisotropy have been noted.[1] Thus, for example, Yoshida[2] recognized an anticlockwise rotation of the diurnal variation vector during each of 10 cosmic-ray storms, and, on the basis of the average, showed that, 48 hours following commencement, the time of maximum was about 4 hours earlier. Recently, Cattani et al.[3] emphasized the association of a train of enhanced diurnal variation with Forbush decreases.

It is the purpose of the present note to report the direct observation, by means of a large-area high-counting-rate plastic scintillator meson telescope, of a progressive anticlockwise around-the-clock rotation of the anisotropy during a disturbed period extending over 7 days. This phenomenon is relevant to the understanding of the nature of the modulation mechanism which produces the anisotropy.

During July, 1961, a series of solar flares produced appreciable fluctuations in the cosmic-ray intensity. The arrival of solar particles was detected by ground-based detectors at high latitudes on July 18 and July 20. Details of the neutron monitor observations at stations located in the north and south polar regions on these dates,[4] as well as a description of the fine structure characterizing the first of several Forbush decreases recorded by meson telescopes during the period July 11-27,[5] will be given elsewhere. This Letter reports the results of an analysis of meson telescope data recorded at Swarthmore, Pennsylvania (geomagnetic latitude 52°N) during the period July 16-30, 1961.

Figure 1 shows the hourly counting rates, corrected for pressure, during the aforementioned period. Although the fluctuations in intensity were small on July 16 and 17, a Forbush decrease commenced on July 18. The train of enhanced diurnal variation continued even after the Forbush decrease of July 26.

Since the gradual recovery of the mean intensity starting July 18 was superimposed upon the enhanced diurnal variation, a method of removing this effect was applied before subjecting the data to harmonic analysis. The correction for the linear gradient of the mean intensity was accomplished by subtracting moving averages of 12 successive bihourly values from the original readings. The amplitude and time of maximum of the diurnal wave for each day was then determined from the resulting values, expressed as percentage deviations from the daily mean. Figure 2 reveals the progressive anticlockwise rotation of the diurnal variation vector, which, after eight days, has turned completely around the clock.

Although the data were corrected for changes in atmospheric pressure, it was not possible to take into account the distribution of temperatures

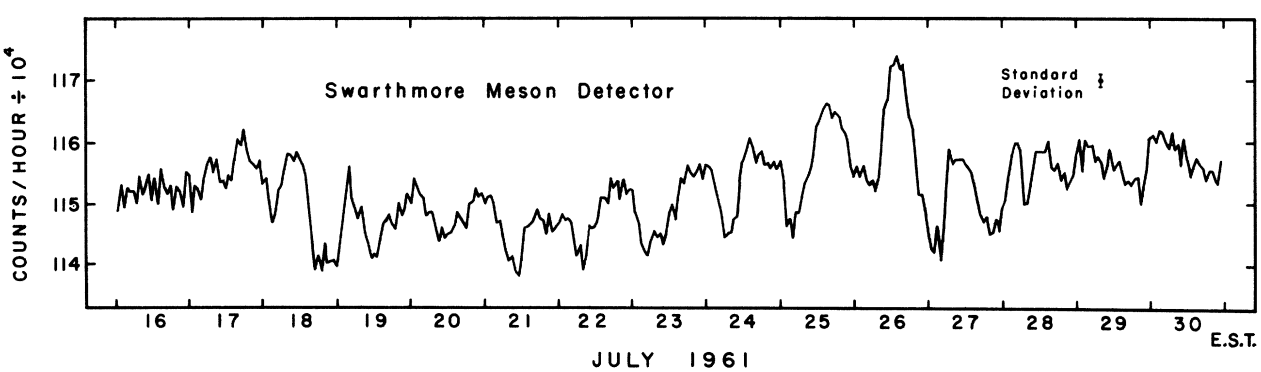

FIG. 1. Hourly counting rates, corrected for pressure, of large-area meson telescope at Swarthmore, Pennsylvania, July 16-30, 1961.

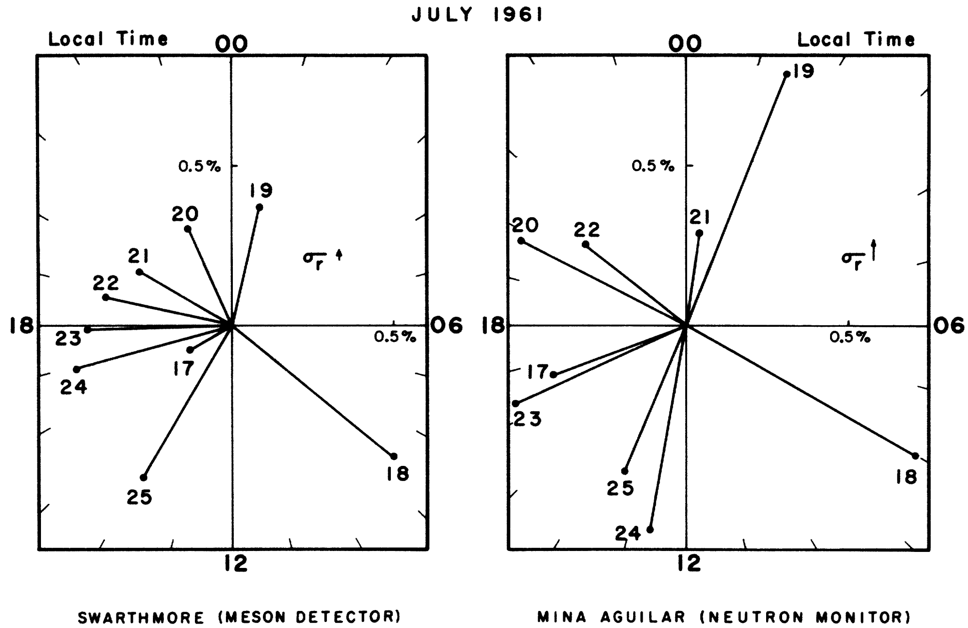

FIG. 2. Harmonic dial representations of the diurnal variation vector on the indicated dates.

throughout the atmosphere. As a first approximation, in order to ascertain whether this meteorological effect could significantly influence the results, corrections for temperature changes up to 2 km altitude (the region where the daily variation of temperature is most significant) were determined, and proved negligible.

Confirmation of the conclusion that the observed diurnal variation was not of local origin was provided by an analysis of neutron monitor data recorded at Mina Aguilar (geomagnetic latitude 11.7 S, altitude 4000 meters). Since the counting rate is sufficiently high for the same type of analysis, and the solar injections on July 18 and July 20 were not recorded by this station, the results may be compared with those based upon the measurements of the meson intensity at Swarthmore. As is seen in Fig. 2, a similar rotation of the diurnal variation vector occurred, although on one day, July 20, the vector is out of sequence. It is probably fortuitous that this is the date of the second solar injection.

The complete around-the-clock rotation of the anisotropy is attributable to one of three mechanisms: (1) the storage of solar particles in the inner solar system, (2) the propagation through interplanetary space of the modulating region which produces the Forbush-type decrease, and (3) the modification of the source of the anisotropy causing the ordinary diurnal variation. The first alternative is untenable on various grounds. With respect to (2), the present result bespeaks the operation of a mechanism whereby the modulating cloud can effectively shield the earth from galactic cosmic radiation even when it is some distance away in interplanetary space. For example, a tongue of magnetic flux which remains attached to the sun, as envisaged by Gold,[6] could, under certain special conditions, produce the 24-hour rotation if appropriate electric fields were associated with the plasma. The final possibility would have to be inherent in the proposed model.

We are grateful to Dr. H. S. Ghielmetti for providing the data from the station at Mina Aguilar, Argentina.

---

*This research was supported in part by the U. S. Air Force Geophysics Research Directorate and the National Science Foundation.

[1]See, for example, V. Sarabhai and N. W. Neruskar, Ann. Rev. Nuclear Sci. 6, 1 (1956).

[2]S. Yoshida, Memoria Del V Congreso Internacional de Radiacion Cosmica, Mexico, 1955 (1958), p. 358.

[3]D. Cattani, M. Galli, and P. Randi, Nuovo cimento 6, 923 (1961).

[4]M. A. Pomerantz and S. P. Duggal, J. Franklin Inst. (to be published).

[5]S. P. Duggal and M. A. Pomerantz, J. Franklin Inst. (to be published).

[6]T. Gold, J. Geophys. Research 64, 1665 (1959).