SHORT-PERIOD VARIATIONS OF COSMIC-RAY INTENSITY*

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Hitherto it has not been possible to establish the occurrence of time variations of galactic cosmic rays with very short periods, of the order of a few minutes, because large detectors that give a really high counting rate were not available. An attempt by Torizuka and Wada,[1] with a counting rate of around 10^5 counts/min, has not yielded conclusive results. However, a large-area scintillation muon detector has been operated for several years by the Bolivian Air Shower Joint Experiment (BASJE) at Chacaltaya at an altitude of 17 200 ft, longitude 68° 10′ W and geomagnetic latitude −5.0°. The authors have been fortunate to have had the opportunity of using the output of the BASJE detector with a counting rate of a million counts/min for conducting an investigation from April 1964 to June 1966. 15 scintillation detectors each of 4 m^2 were used (Suga et al.[2]). The total array of 60 m^2, housed in a cave, was shielded by 3 m water equivalent of galena so that the electron component was absorbed. The outputs of sets of five detectors were combined to provide three independent channels for intercomparison. Accurate time was maintained by using a crystal controlled electronic clock. Cosmic-ray data were recorded every 12 sec while one-minute recordings of barometric pressure were also made using a digital servobarometer. The 12-sec data from the three channels were intercompared and unless one or more channels exhibited erratic behavior, data from the three independent channels were combined for successive one-minute intervals. The constants used for power spectrum analysis were $n = 180$, $m = 30$, and $t = 1$ min, where n is the number of data points in each set, m is the total lag, and t is the averaging interval for each point. This gave us spectral estimates at 31 points equally spaced in frequency from 0 to 30 cycle/h. The significance of spectral-density estimates was evaluated using the method suggested by Blackman and Tucky.[3] For the chi-squared distribution, we have $2(n/m-\frac{1}{3}) \sim 11$ degrees of freedom.

Spectral estimates show variability in individual samples of three-hourly intervals. As more samples are superposed, peaks in the spectral frequency range of 1 to 6 cycle/h get smeared out by superposition. However, persistent peaks at 18 and 25 cycle/h are observed. These appear at 99% confidence limits for the superposition of 487 three-hourly sets during November 1965 to March 1966, as shown in Fig. 1. Records[4] of the magnetic field taken by Mariner IV in the magnetosheath region a year earlier indicate that at 200-sec period (18 cycle/h), there was large spectral activity. Ness, Scearce, and Cantarano[5] have found spectral peaks of 600-, 300-, 180-, and 120-sec periods in the interplanetary magnetic field recorded by Pioneer VI on 16 December 1965 from 1715 to 2015 h. Cosmic-ray data for the same interval show similar periodic fluctuations which are shown in Fig. 2.

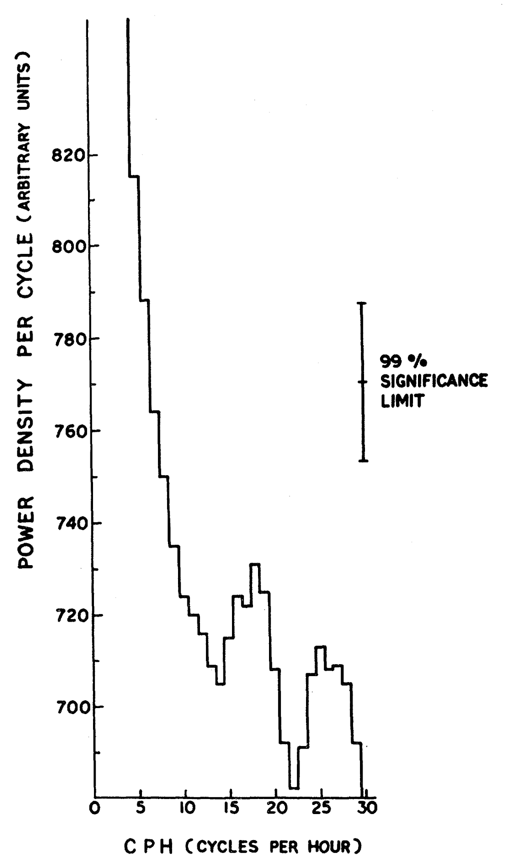

FIG. 1. The superposed spectral density for 487 three-hourly sets (November 1965 to March 1966) indicating peaks at 18 and 25 cycle/h.

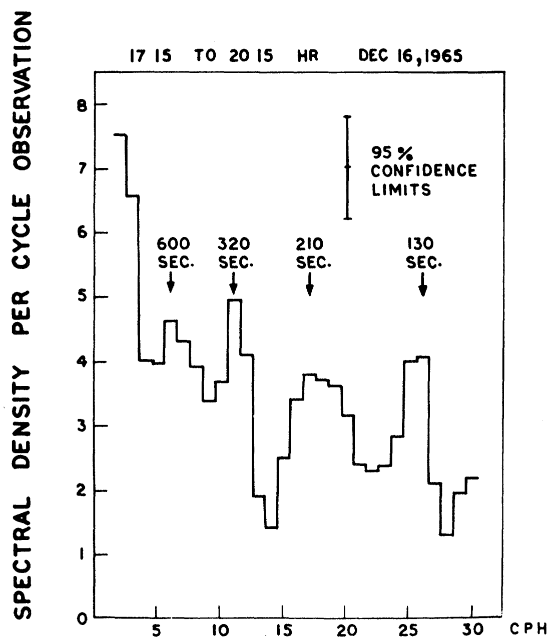

FIG. 2. The spectral density estimates for cosmic rays corresponding to the three-hourly interval when Pioneer VI was simultaneously recording interplanetary magnetic field.

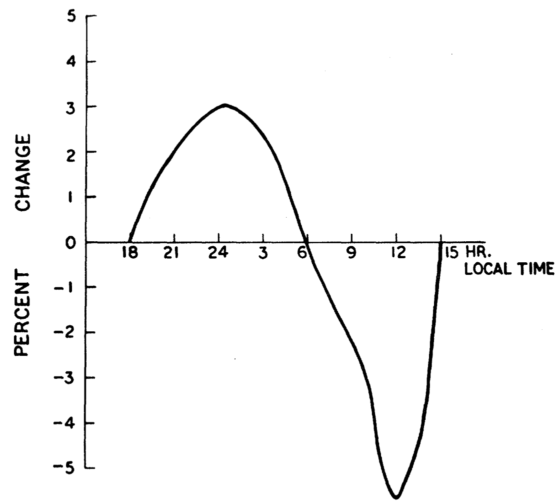

FIG. 3. The percentage change from the average of spectral density in the solar and antisolar directions for 18 cycle/h.

Local time dependence of the spectral density has been studied for 18 cycle/h. Figure 3 corresponding to 487 intervals indicates that the variation has large amplitude when the detector is in the antisolar direction.

The barometric pressure at one-minute intervals has been subjected to power-spectrum analysis. The absence of any peaks of pressure in the region of interest corresponding to cosmic-ray peaks indicates that the cosmic-ray peaks are not due to barometric pressure changes. An attractive possibility of explaining the short-period fluctuation of cosmic rays appears through the periodic change of geomagnetic cutoff rigidities. For 487 three-hourly intervals the average amplitude of the 18-cycle/h periodicity is about $(0.04 \pm 0.01)\%$. To account for these periodic changes, which have been observed for the first time in the present investigation at the geomagnetic equator, we estimate by using the coupling coefficient given by Dorman[6] for the meson component that there need to be periodic changes of about 20γ in the dipole field. Fluctuations of this order of magnitude in the magnetosheath have been observed[4] for 18-cycle/h periodicity.

Related to this interpretation, three interesting points require to be understood: First, the manner in which periodic fluctuations of the interplanetary magnetic field are translated to periodic changes of geomagnetic field relevant to changes in the cutoff rigidity of primary cosmic rays. Interplanetary periodicities measured by magnetometers on space probes are most likely the result of the spatial structure in the plasma wind. For a wind with a radial velocity of 400 km/sec the observed 18-cycle/h fluctuations correspond to a scale length of 0.5×10^{-3} A.U. of the irregularities in the plasma wind. The fluctuations of the energy density impinging on the magnetosphere resulting from these irregularities could be the means through which the periodicities are generated in the geomagnetic field. Second, there is perhaps a difference in the sharpness of the spectral peaks observed in cosmic rays at 18 cycle/h compared to the other peaks. One would like to know whether this is genuine and caused by the inherent resonant and dissipative characteristics of the magnetosheath for energy transmitted through it. Third, the larger amplitude of 18-cycle/h spectral density in the antisolar direction (3%) compared to the solar direction (−5.5%) could probably indicate the variation in the amplitude of the oscillations of the distant geomagnetic field in the tail of the cavity and in the direction of the bow shock. More quantitative analysis with additional data from space craft is necessary to pursue these points.

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NONUNIQUENESS OF MASS-FORMULAS FROM INFINITE-DIMENSIONAL GROUPS AND ALGEBRAS

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The possibility of getting any mass spectrum one desires in the framework of finitely-generated infinite-dimensional associative algebras and unitary groups is discussed. Inevitable consequences for the mass problem are then suggested.

Recently, some authors have tried once more to resolve some difficulties of interpretation concerning the fundamental problem of hadron mass splittings.[1] The authors of this note feel, however, that such an interpretation should not be achieved at any price and no matter how. The aim of this short Letter is to point out that once a suitable algebraic structure is supposed (the only goal and "raison d'être" of which is the justification of the observed mass splittings), any mass formula can be obtained. The connection of this with some no-go theorems is then discussed.

(1) Let H be a separable Hilbert space, and U the group of all unitary operators acting on H (U is an infinite-dimensional Lie group of the Banach type). Denote by $\mathcal{P}$ the universal covering of the connected Poincaré group; if V is any continuous unitary representation of $\mathcal{P}$ on H, we have evidently $V(\mathcal{P}) \subset U$. For simplicity, we shall restrict ourselves to the baryon octet $\frac{1}{2}^+$ (though the suggested construction is easily generalizable to all hadrons and all internal groups, and can easily include discrete symmetries). We thus choose a particular representation

$$V = \bigoplus_{i=1}^{8} V(\tfrac{1}{2}, m_i),$$

the direct sum of eight irreducible unitary continuous representations of $\mathcal{P}$ characterized by $J=\frac{1}{2}$, m_i being the set of the eight $\frac{1}{2}^+$ masses. We identify it with the unitary representation of a "physical Poincaré group" in U. This representation acts on the direct sum of eight (trivially isomorphic) Hilbert spaces $H = \oplus_i H_i$. Let φ_{in} $(n=1,2,3,\cdots)$ be a complete orthonormal basis of H_i $(i=1,\cdots,8)$. For every fixed n, we can define on the vector space generated by the φ_{in} $(i=1,\cdots,8)$ a representation Ad_n of SU(3) isomorphic to the adjoint representation. We thus get a subgroup

$$\bigoplus_{n=1} Ad_n\,(\mathrm{SU}(3))$$

of U, which is the image of SU(3) under a (very reducible) unitary representation on H.

We have therefore suceeded in formulating the octet $\frac{1}{2}^+$ classification and mass splitting (for example!) by mixing unitary reducible representations of SU(3) and $\mathcal{P}$, both contained in our infinite-dimensional Banach-Lie group U. Furthermore, it is of interest to notice that any mass formula can be obtained in the framework of associative algebras.

Indeed, consider the tensor algebra $T(P,S)$ over the vector space $P+S$, where P (S) the Poincaré (internal) Lie algebra. Divide it by the ideal generated (for instance) by the elements $pp'-p'p-[p,p']_P$, $ss'-s's-[s,s']_S$