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Cycle of World-Wide Changes in the Daily Variation of Meson Intensity

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The study by Sarabhai and Kane of the world-wide changes in the daily variation of meson intensity has been extended by an analysis of unpublished Carnegie Institution data, kindly supplied by Dr. Forbush. Comparison of Carnegie Institution measurements at Huancayo and Cheltenham for the period 1937 to 1952 reveals high correlation between changes of the times of maxima at the two stations. The changes of amplitudes of the daily variations are not equally consistently related. The change of intensity of the coronal 5303A emission line exhibits the major features seen in the change of the daily variation of meson intensity. Both follow the usual 11-year solar cycle of activity.

Sarabhai and Kane,[1] in a paper later referred to in this article as I, have shown, by an examination of the Carnegie Institution data[2] for the period 1937 to 1946, large world-wide changes in the amplitude and the time of maximum of the daily variation of meson intensity, corrected for barometric pressure. These changes were found to follow the broad pattern of the eleven-year solar cycle. In a later communication, Thambyahpillai and Elliot[3] have drawn attention to the progressive change, from 1940 to 1952, of the time of maximum of the daily variation to earlier hours. They have compared data from different types of instruments at different periods and have suggested a twenty-two-year cycle of change.

Directional studies made at Stockholm and Manchester and recent work at Ahmedabad clearly reveal the dependence of the time of maximum $M\phi^D$ and the amplitude M^D of the diurnal component of the daily variation of mesons on the sensitive cone of the measuring instrument and its orientation. The treatment of results from ionization chambers and counter telescopes on a directly comparable basis therefore appears questionable. A test of this, and further extension of our earlier studies have now been made possible by the supply of unpublished data covering 1946 to 1953 from the Carnegie Institution stations, through the kind generosity of Dr. Forbush.

Figures 1 (a) and (b) show the changes of M^D and $M\phi^D$ computed from the annual mean daily variation centered at successive bimonthly epochs. Unlike the treatment in I the present authors have not smoothed out their results by taking moving averages over three successive bimonthly values. Uninterrupted data are available for Huancayo and Cheltenham from 1936 to 1953, while for Christchurch there is a large gap from 1st July 1942 to 30th April 1946 due to irregular stoppages.

An examination of Fig. 1 reveals that:

(1) The changes in the amplitude M^D at the different stations do not appear to be well correlated except during the period 1940–1946. For Christchurch and Cheltenham which are sea-level stations at comparable latitudes south and north of the equator, respectively, the changes in amplitude are better related than between either station and Huancayo. The prominent disturbance in 1943 followed by a quiet period in 1944 is strikingly revealed in all curves.

(2) The changes in time of maximum $M\phi^D$ at all stations are highly correlated. For the entire fifteen-year period, the correlation between Huancayo and Cheltenham is 0.93.

The change in the annual mean relative sunspot number R, centered at successive bimonthly epochs, is shown in Fig. 1 (c). Alongside are also given corresponding values of the total solar emission of the coronal line 5303 A. These have been computed, after interpolating at bimonthly intervals, from the observations of Waldmeier[4] at different epochs. It is clearly seen that changes of $M\phi^D$ follow the normal solar cycle, there

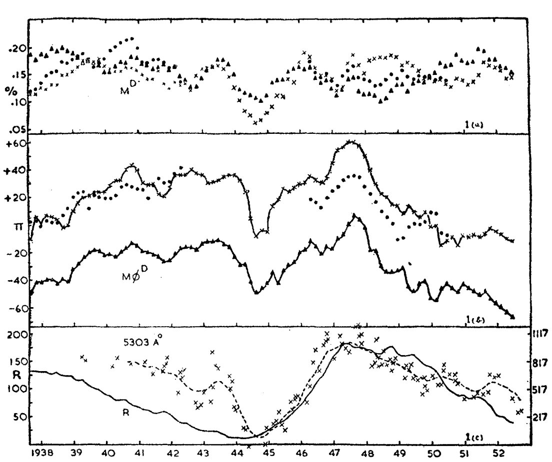

Fig. 1. Time series for annual mean values during 1937–1953 of (a) M^D, meson diurnal amplitude; (b) $M\phi^D$, meson diurnal time of maximum; (c) R, Zurich relative sunspot number and total emission of 5303-A coronal line. In (a) and (b) the results from individual stations are indicated by ▲ for Huancayo, × for Cheltenham, and ● for Christchurch. In (c), × indicate the values of coronal emission reported by Waldmeier. In (b), π in the ordinate relates to 1300 hours instead of noon.

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being no evidence for a twenty-two year period. While the mechanism of solar control is still obscure, we have earlier interpreted the new results as indicative of continuous solar emission of cosmic rays and changes of $M\phi^D$ as caused by magnetic bending of the trajectories of charged solar particles. The consistent world-wide character of changes of $M\phi^D$ is then not surprising.

Coronal emission in 5303 A is the most satisfactory index we know for activity in solar cosmic-ray emission. This is demonstrated strikingly in 1943, and in the pronounced shift of $M\phi^D$ in 1947 to later hours. Therefore, Simpson's observations with neutrons relating to low-energy primaries and the daily variation of mesons related to a more energetic primary component both lead to the same conclusion. They must focus our attention on the solar corona for an understanding of the processes of continuous cosmic-ray emission from the sun.

We are deeply indebted to Dr. S. E. Forbush and to Professor Waldmeier for furnishing the unpublished data, which have made the present study possible. It is a pleasure to acknowledge assistance from Mr. K. A. Gidwani, Mr. Duggal, and Mr. Bhatt, and support from the Atomic Energy Commission of India.

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Precision Measurement of the Negative Pion Mass from Its Radiative Absorption in Hydrogen*†

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The gamma-ray spectrum of the reaction

$$\pi^-+p\rightarrow n+\gamma$$

has been remeasured with an improved design of the high-energy pair spectrometer. This design has taken advantage of one of the focusing properties of a 90-degree wedge-shaped magnetic field to minimize the effect on the resolving power of multiple scattering of the pair fragments in the converter. The theory of the spectrometer is developed in detail. The accuracy of the energy scale depends on magnetic field measurements and the calculation of orbits, aberrations, and resolving power. By the determination of the mesonic absorption gamma-ray energy, a precise mass value for the negative pion has been found:

$$M_{\pi^-}=272.7\pm0.3m_e.$$

From the $\pi^- - \pi^0$ mass differences already obtained by Panofsky, Aamodt, and Hadley (PAH), by Chinowsky, Sachs, and Steinberger (CSS), and the $\pi^- - \mu^-$ mass difference obtained by Lederman, Tinlot, and Booth (LTB), it is possible to improve the mass values for the π^0 and the μ^- mesons.

From $\pi^- - \pi^0$ (PAH): $M_{\pi^0}=262.2\pm2.0\ m_e$;
from $\pi^- - \pi^0$ (CSS): $M_{\pi^0}=263.9\pm0.7\ m_e$;
from $\pi^- - \mu^-$ (LTB): $M_{\mu^-}=206.7\pm3.0\ m_e$.

If one assumes that the positive and negative pions have the same mass, the mass of the positive muon can also be deduced from the work of Birnbaum, Smith, and Barkas:

$$M_{\mu^+}=206.3\pm0.3\ m_e.$$

I. INTRODUCTION

MANY experimenters have in the course of studies both with cosmic rays and artificial sources, measured the pion and muon masses and several relations between them to varying accuracy. This group of experiments is summarized in several review articles.[1–3]

To date only one of these experiments, other than the present work, has been carried to an accuracy better than a half percent (∼1 electron mass). This experiment was started by the late Dr. Eugene Gardner several years ago, and has been carried on by the nuclear emulsion group at Berkeley[4]; results have appeared at various stages of completion.[5]

Since the mass relations obtained in this manner will

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