

043  
SAS  
1928  
✓

Dissertation

on

A STUDY OF THE TIME VARIATION OF COSMIC RAYS  
AT LOW LATITUDES

presented

by

T. S. G. SASTRY

for

the degree of

DOCTOR OF PHILOSOPHY

of the

GUJARAT UNIVERSITY

043



B1928

August, 1958

PHYSICAL RESEARCH LABORATORY  
AHMEDABAD.

## STATEMENT

1. The daily variation of meson intensity measured with vertical telescopes, having semiangles of  $22^{\circ}$  in the E-W plane and  $37^{\circ}$  in the N-S plane, has been studied by the author during the years 1954, 1955 and 1956 at the equatorial mountain station of Kodaikanal. The 12-month mean daily variation during each year and the daily variation on individual days have been studied. The 12-month mean daily variation has been compared with the daily variation for the years 1952 and 1953 measured with the same instrument at Kodaikanal and with the daily variation of intensity measured by Carnegie Institution ion chambers at Huancayo and Cheltenham. The change of the 12-month mean daily variation has the following noteworthy features:

(a) During 1952 to 1956, changes of the time of maximum of the diurnal component and the amplitude and time of maximum of the semi-diurnal component of the 12-month mean daily variation are well correlated at the two equatorial stations of Kodaikanal and Huancayo.

(b) Change of the time of maximum of the diurnal and the semi-diurnal components at Huancayo over a period of 18 years is most clearly suggestive of a relationship with the 22-year cycle of change of polarity of the magnetic field of sunspot.

A 22-year cycle of change is clearly seen in the form

of the 12-month mean daily variation unresolved into its harmonic components. The change of form takes place principally in relation to a maximum in the early morning or near noon as suggested by Sarabhai et al. The change is large at minimum of solar activity and is gradual at other periods of the solar cycle.

(c) For a proper study of the anisotropy of the primary cosmic radiation and its changes it is necessary, particularly for observations at low latitudes, to take account of the semi-diurnal component of the daily variation in addition to the diurnal component. The change of daily variation unresolved into its harmonic components can be related to a meaningful physical model of change of the anisotropy of primary radiation.

2. A comparison of the form of the 12-month mean daily variation and the distribution of parameters of the diurnal and the semi-diurnal components of the daily variation on individual days does not either confirm or refute the model of change of the 12-month mean daily variation suggested by Sarabhai et al. This model involved the change being produced through alteration of frequency of occurrence from year to year of a "day maximum type" and a "night maximum type" of anisotropy. It appears from the present study that both major states of the primary anisotropy are connected with a diurnal as well as a semi-diurnal component. They differ in relation to different

relative magnitudes of the maxima in the early morning and near noon which are observed in the daily variations produced by them.

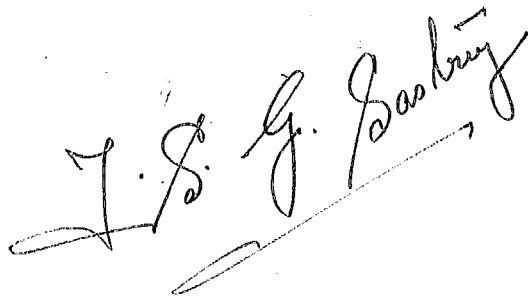
3. A study has also been made by the author of the variation of the meson intensity measured with a narrow angle telescopes of semiangle  $5^\circ$  in the E-W plane and  $19^\circ$  in the N-S plane operated at Kodaikanal during 1956. The daily variation has been compared with the daily variation measured by  $^{22}\text{T}$  telescopes and a neutron monitor at Kodaikanal. The characteristics of the daily variation of the neutron monitor and the  $^{22}\text{T}$  telescopes are very similar. The narrow angle telescopes exhibit or daily variation of larger amplitude than the other two instruments. Identification of the state of the anisotropy on individual days by an examination of only the characteristics of the harmonic components of the daily variation is not in general possible at Kodaikanal. However  $^{5}\text{T}$  and  $^{22}\text{T}$  telescopes confirm the observation of Satya Prakash with a neutron monitor, that on magnetically disturbed days the ratio  $r_1/r_2$  of the amplitudes of the diurnal and the semi-diurnal components respectively of the daily variation, has characteristic values related to the correlated changes of anisotropy and the mean intensity of cosmic rays.

4. The average daily variation on days with different degrees of geomagnetic disturbances, as indicated by the value of  $G_p$  on individual days, suggests that a significant transition

takes place in the range of  $C_p$  from 0.85 to 1.20. The nature of change between groups corresponding to low and high  $C_p$  is not the same in 1954, 1955 and in 1956.

5. A solar flare type of increase of intensity at Kodaikanal, observed on 23rd February 1956, represents one of the first observations of this effect at a station on the geomagnetic equator. It has been interpreted as indicative of the generation on the sun, of cosmic rays in the energy range 35 to 65 Bev. in association with a type 3+ flare.

6. The present dissertation describes in Chapter II the apparatus and in Chapter III, the methods of analysis of data. Chapters IV and V deal with results of the investigations made with vertical telescopes of moderate and narrow angles of opening respectively. In Chapter VI, the principal conclusions of the investigation are discussed. The author has included at the end of his thesis a list of 167 references to original papers published in different parts of the world. The thesis mentions the specific information derived from each of them.



## ACKNOWLEDGEMENTS

I am deeply indebted to Professor Vikram A. Sarabhai for his valuable guidance throughout the period of investigation.

The project under which the present investigation was carried out, has been supported by the Department of Atomic Energy of the Government of India, for which I am extremely grateful.

I take this opportunity to thank my colleagues in the Cosmic Ray and the Electronic research group at Ahmedabad for their kind cooperation during the period of investigation.

It is a pleasure to acknowledge the assistance of the computational staff of the Physical Research Laboratory.

## CONTENTS

	Page
I. INTRODUCTION.	1
1.1 Geomagnetic Effects.	2
1.2 Relationship between measured intensity and primary cosmic radiation.	3
1.3 Variations of atmospheric origin.	7
1.4 Time variations of primary radiation	13
1.41 Variation of intensity with solar cycle.	13
1.42 Change of knee of the latitude effect.	14
1.43 Change of E-W asymmetry.	15
1.44 Magnetic storm type changes.	16
1.45 Day-to-day changes of intensity.	18
1.46 Solar flare effect.	20
1.5 Anisotropy of primary radiation.	24
1.51 Solar anisotropy.	24
1.52 Galactic anisotropy.	30
1.53 Long term changes of solar anisotropy.	32
1.54 Day-to-day changes of anisotropy.	37
1.6 Interpretation of variations.	39
1.61 Relation between solar activity and cosmic ray variations.	39
1.62 Geomagnetic and geoelectric models.	42
1.63 Modulation in interplanetary space.	45
1.7 Statement of the problems.	48

	Page
<b>II. THE APPARATUS.</b>	51
2.1 The experimental technique for time variation studies.	52
2.2 $22^T$ telescopes.	53
2.3 $5^T$ telescopes.	55
2.4 Components of the apparatus.	57
2.41 Geiger-Muller counter.	57
2.42 Electronic units.	62
(A) Quenching unit.	62
(B) Coincidence unit.	64
(C) Scaling and recording circuits.	65
(D) Power supplies.	67
High voltage power supply.	68
Low voltage power supply.	69
(E) Automatic photographic device.	70
<b>III. METHODS OF ANALYSIS.</b>	74
3.1 Cosmic ray data.	74
3.2 Meteorological data.	75
3.3 Correction for meteorological influences.	76
3.4 Normalisation of mean intensity.	78
3.5 Fourier Analysis.	79
3.6 The harmonic dial.	81
3.7 The errors of Fourier coefficients.	82
3.8 The form of the daily variation.	84
3.9 Punch card system of tabulation of data.	86
3.10 Correlation and lines of regression.	88



	Page
IV. EXPERIMENTAL RESULTS OF 22T TELESCOPES.	90
4.1 The 12-month mean daily variation.	90
4.11 Changes of the amplitude $\overline{M}_K^D$ of the diurnal component.	96
4.12 Changes of $\overline{M}_K^S$	101
4.13 Changes of $\overline{M}_{\phi.K}^D$	102
4.14 Changes of $\overline{M}_{\phi.K}^S$	105
4.15 The change of form of the 12-month mean daily variation $^{\circ}\overline{M}$	107
4.2 Daily variation on individual days.	112
4.21 $r_1$ Histograms.	115
4.22 $r_2$ Histograms.	115
4.23 $\phi_1$ Histograms.	116
4.24 $\phi_2$ Histograms.	117
4.25 $r_1/r_2$ Histograms.	118
4.26 $C_p$ Histograms.	118
4.3 Inter-relationship of parameters of the daily variation on individual days.	118
4.31 $r_1$ Sorting.	119
4.32 $r_2$ Sorting.	123
4.33 $\phi_1$ Sorting.	124
4.34 $C_p$ Sorting.	131
4.4 A solar flare type increase of cosmic ray intensity at the geomagnetic equator.	134
4.5 The lunar daily variation in cosmic ray intensity.	135
V. EXPERIMENTAL RESULTS OF 5T TELESCOPES.	136
5.1 The daily variation with narrow angle telescopes.	138
5.2 Types of daily variation observed on individual days with 5T telescopes.	143

	Page
VI. DISCUSSION.	153
6.1 The worldwide characteristics of long term changes of 12-month mean daily variation.	154
6.2 The mechanism of long term change of the daily variation.	158
6.3 Identification of types of daily variations with different states of anisotropy of the primary cosmic radiation.	160
6.4 Conclusion.	162

REFERENCES.

LIST OF FIGURES.

REPRINTS OF PAPERS PUBLISHED.