ON THE DIURNAL VARIATION COEFFICIENTS OF THE NUCLEONIC COMPONENT OF COSMIC RAYS

By

M. F. TOLBA, S. A. WAHAB and A. M. SALEM
COSMIC RAY GROUP, PHYSICS DEPARTMENT, FACULTY OF SCIENCE, AIN SHAMS UNIVERSITY, CAIRO, EGYPT

(Received in revised form 24. X. 1978)

The expected amplitudes, as well as the time shift due to geomagnetic bending, of the diurnal waves have been calculated for 27 cosmic ray neutron monitors for the recent shapes of the diurnal, semidiurnal and tridiurnal anisotropies. The calculations are performed for latitude dependence of the form, \( \cos^\alpha \lambda \) and rigidity dependence of the form \( R^\beta \exp\left[\frac{(1-R)}{R_0}\right] \) where \( \lambda \) is the asymptotic latitude, \( R \) is the rigidity in GV, and \( \alpha, \beta \) and \( R_0 \) are constants.

For the diurnal anisotropy, the calculations are given for \( \alpha = 1, \beta = -0.4, 0.0, +0.4, +0.8, R_0 = \infty \) and maximum cutoff rigidity = 90 GV, while for semidiurnal and tridiurnal anisotropies the results are given for \( \alpha = 1, 2, \beta = 1, 2 \) and \( R_0 = 50, 90 \) GV. Moreover, the calculation of the attenuation due to the latitude effect, the smoothing effect, and the mean latitude and mean cone broadening are given for the different concerned anisotropies. The presently calculated coefficients for diurnal variation are significantly smaller than those calculated previously due to the careful selection of the used parameters. A considerable increase in the time shift due to geomagnetic bending is only found in the wide cone stations. The relation between the mean latitude, the cone broadening, the time shift, and the expected amplitude for all diurnal components and the minimum cutoff rigidity of the different stations are discussed.

1. Introduction

The information about the different modulation mechanisms of cosmic rays in the interplanetary space can be obtained by the investigation of the different components of solar diurnal variations. However, the accurate characteristics of the anisotropies that produce these variations can only be obtained by a careful calculation of the coefficients transforming the shape of the variations recorded on the surface of the earth to the corresponding free space anisotropy. Several calculations have been carried out by different authors for the coefficients of the first and second components of diurnal variation using different methods of calculation and shapes of anisotropy [1, 2, 3, 4, 5].

McCRACKEN et al [2] have calculated the coefficients and the shift in the asymptotic time due to geomagnetic bending for both diurnal and semidiurnal anisotropies, where the rigidity dependence of the anisotropy is used in the form \( R_\alpha \) up to rigidity 500 GV and latitude dependence of the form \( \cos \lambda \). In later investigation, FUJII et al [5] and NAGASHIMA et al [6] showed that the semidiurnal anisotropy is reasonably assumed to have the rigidity dependence of the form \( R^\beta \exp\left(-R/R_0\right) \), where \( R \) is the rigidity in GV, \( \beta \)
and $R_o$ are constants controlling the gradual increase and decrease of the anisotropy with rigidity. Theoretical and experimental investigations of semidiurnal variation show a latitude dependence of the form $\cos^2 \lambda$ rather than $\cos \lambda$ as given by Lietti and Quenby [7] and Rao and Agrawal [8]. For the diurnal variation, Subramanian [9] suggested that the consideration of accurate value of maximum cutoff rigidity, variability of the spectral exponent of the differential primary spectrum, the contribution of high rigidity particles to the counting rate, and the proper selection of the coupling constants would considerably change the expected diurnal waves from those calculated by McCracken et al [2]. On the other hand, the existence of the tridiurnal anisotropy is discovered by Mori et al [10], Fujimoto et al [11] and found to be of almost similar characteristics to those obtained for semidiurnal variation (e.g. Kudo and Wada [12], and Girgis et al [13]).

The change of the predicted characteristics of diurnal and semidiurnal anisotropy from those assumed by McCracken et al [2] together with the discovery of the tridiurnal anisotropy show the great requirement of recent theoretical calculations to the diurnal variation coefficients for the three components of diurnal variation and different cosmic ray stations. In the present work, the expected amplitudes and time shift due to geomagnetic bending are calculated for 27 cosmic ray stations for the diurnal, semidiurnal and tridiurnal anisotropies taking into consideration the different shapes of the rigidity and latitude dependences. Moreover, the mean latitude, mean longitude mean deflection and mean cone broadening of cosmic ray trajectories are approximately calculated for the same stations and for the specified shapes of anisotropy.

2. The expected diurnal waves

The general form of the fractional change in the counting rate $\Delta N(t)/N$ at time $t$ arising from any diurnal anisotropy with harmonic $h$, and amplitude $A$ may be expressed by:

$$\Delta N(t)/N = A \int_{R_{\text{min}}}^{R_{\text{max}}} W(R) \cdot F(R) \cdot T[\lambda(R, a)] \cdot G[\psi(R, a), t, h] \cdot dR,$$

where $W(R)$ is the coupling constant as defined by Dorman [4], $F(R)$ is the function describing the rigidity distribution of the anisotropy, $T[\lambda(R, a)]$ is the declination dependence function of the solar ecliptic latitude $\lambda(R, a)$ for a particle with rigidity $R$ and direction of arrival $(a)$, and $G[\psi(R, a), t, h]$ is the longitude dependence function for solar ecliptic longitude $\psi(R, a)$ at time $t$ for anisotropy of component $h$. $R_{\text{min}}$ and $R_{\text{max}}$ are the minimum and maximum cutoff rigidity of the anisotropy, respectively. The functions $F(R)$,