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Analysis of Cosmic Ray Intensity Time-Dependence Recorded at Mina Aguilar during July 1959

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Analysis of Cosmic Ray Intensity Time-Dependence Recorded at Mina Aguilar during July 1959.

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Summary. — Intensity variations of nucleonic component at Mina Aguilar (4000 m o.s.l., 12° S geomagnetic latitude) are analyzed as a function of time, for the July 1959 storms. It is suggested that the intensity behaviour is due to a linear addition of three independent Forbush decreases of different amplitudes and relaxation times, but of approximately the same form of primary variation spectrum at high energies. The slow recovery after the third storm is mainly determined by the relaxation time of the second storm.

In a previous report (1), we pointed out the importance of obtaining information upon the degree of linearity of superposition of cosmic ray effects during the overlapping July 1959 Forbush decreases. We stated in the above-mentioned paper, that a linear superposition of modulation effects in two or more successive storms would in general lead to a variation spectrum of functional form constant in time, being the amplitude of decrease the only time-dependent quantity.

As it can be deduced from the results given in the previous paper (2), no change in the variation spectrum takes place until the recovery after the second storm. This strongly suggests that the modulation mechanism responsible for

(1) J. G. ROEDERER, O. R. SANTOCHI, J. C. ANDERSON, J. M. CARDOSO and J. R. MANZANO: *Nuovo Cimento*, **18**, 120 (1960).
(2) Loc. cit. (1), Fig. 6.

the second storm did not interfere the first one, both acting independently. With respect to the third storm, apart of the additional low energy particle flux detected at Ellsworth on July 17th, we conclude from Fig. 9 of the former report that at least until the 19th of July, the variation spectrum did not change appreciably. We therefore suppose all three Forbush decreases to be linearly superposed.

In this paper we will show a further evidence for linear, independent superposition, at least for energies above the Mina Aguilar geomagnetic cut-off (12.7 GeV). To show this, we consider again the simplified form for the primary variation spectrum ([1])

$$\frac{\delta D}{D} = \delta k(t)\, E^{-\gamma}\,.$$

We called the function $\delta k(t)$ the amplitude of the variation spectrum. If no interference between modulation mechanisms of the three storms occurs, γ will be independent of time, and we will have

$$\frac{\delta D}{D} = [\delta k_1(t) + \delta k_2(t) + \delta k_3(t)]\, E^{-\gamma},$$

and for the percentage intensity variations

$$\delta I = \delta I_1 + \delta I_2 + \delta I_3 = \Gamma[\delta k_1(t) + \delta k_2(t) + \delta k_3(t)] \quad (*)$$

where $\delta k_i(t)$ are three independent amplitudes, one function for each storm ($\delta k_i(t) = 0$ for $t <$ time of storm commencement). If we take data from Mina Anguilar, which are less sensitive to low energy flux modulations, and plot δI in logarithmic co-ordinates, Fig. 1, we come to the following conclusions:

i) the recovery to prestorm level after the third storm is exponential ([3]);

ii) this exponential form is not achieved immediately after the third storm, but only two days later, *i.e.* after the 20th;

iii) the extrapolation of this exponential form to earlier days, points accurately to the minimum after the second storm (**);

(*) For the definition of the constant Γ, see formula (4) of ([1]).

(**) This is also true for Ellsworth neutron monitor data, although at this station the intensity fluctuations around the exponential form are much more pronounced. With respect to Buenos Aires records, it has been already mentioned in ([1]) that percentage variations fit within normal fluctuations with those recorded at Mina Aguilar.

([3]) P. MORRISON: *Phys. Rev.*, **101**, 1397 (1956).

iv) the recovery after the first storm may also be fitted by an exponential form.

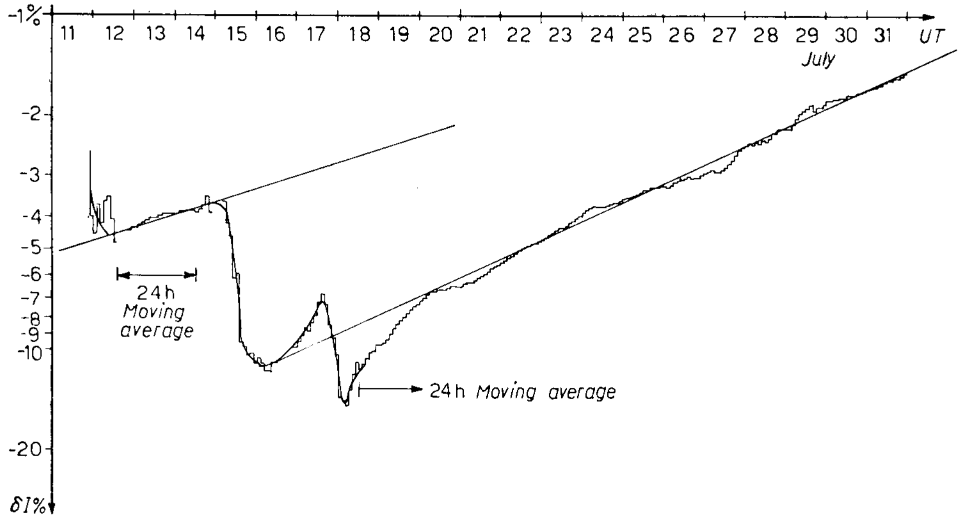

Fig. 1. – Logarithmic plot of percentage variation of nucleon component at Mina Aguilar. The exponential type of recovery is shown. 24 h moving averages are used, except for days in which intensity varies strongly; bihourly data are plotted for these intervals.

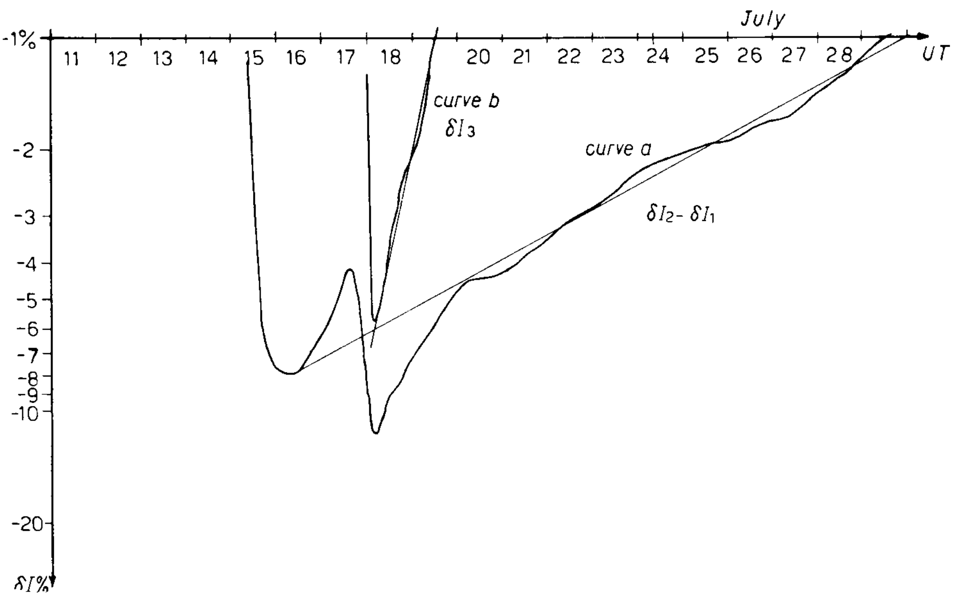

Fig. 2. – Curve a: difference between the intensity variation of Fig. 1 and the exponential contribution δI_1 of the first storm recovery. Curve b: difference between curve a and the exponential contribution δI_2 of the second storm recovery.

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With these results, we proceeded as follows: we supposed $\delta k_1(t)$ and therefore dI_1 to be exponential, of the form (see Fig. 1)

$$\delta I_1 \sim \exp\left[-\frac{t}{274}\right] \qquad (t \text{ in hours}).$$

If we subtract δI_1 from δI, we obtain a curve sketched in Fig. 2-*a*. If we now suppose that the main exponential behaviour after the 20th of July belongs to the *second* storm (*), rather than the third one, we have

$$\delta I_2 \sim \exp\left[-\frac{t}{162}\right]$$

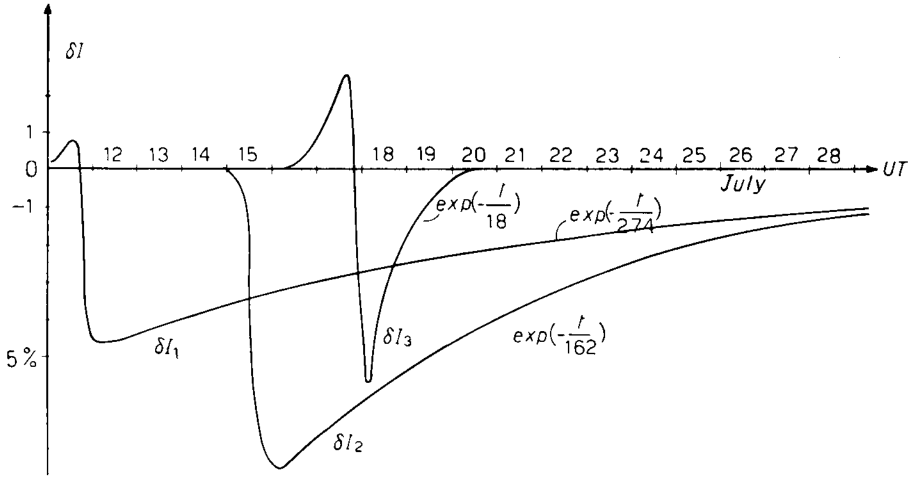

Fig. 3. – Representation of the three independent cosmic ray storms of exponential recovery each, into which the July 1959 intensity variation at Mina Aguilar can be resolved. Total intensity variation (Fig. 1) is given as a linear superposition of these curves.

Subtracting this function from curve *a*), Fig. 2, we are led to δI_3. The negative part of δI_3 represents the decrease and recovery of the third independent storm; it is shown in Fig. 2 curve *b*). Notice the fact that this very fast recovery again comes out to be of exponential form

$$\delta I_3 \sim \exp\left[-\frac{t}{18}\right]$$

In summary, if we make the assumptions, that undisturbed cosmic ray storm recoveries are essentially of exponential type for high energies ($\geqslant$10 GeV),

(*) This of course means that the recovery in Fig. 1 should not be strictly exponential.

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and that cosmic ray effects superpose linearly, we can resolve the July 1959 cosmic ray intensity variations into three single, independently acting Forbush decreases of exponential recovery. These independent cosmic ray storms are shown in Fig. 3. Their sum fits the Mina Aguilar intensity variation curve within normal fluctuations. Characteristic parameters are shown in Table I.

TABLE I.

Storm commencement	Maximum amplitude	Relaxation time for recovery	Prestorm increase
July 11, 16.23 UT	−4.6%	(274 ± 6) h	+0.7%
July 15, 08.02 UT	−8.0%	(162 ± 6) h	none
July 17, 16.38 UT	−5.7%	(18 ± 3) h	+2.5%

* * *

We are deeply indebted to « Compañía Minera Aguilar S.A. » for the efficient co-operation and support given to the High Altitude Cosmic Ray Station Mina Aguilar.

RIASSUNTO (*)

Si analizzano in funzione del tempo le variazioni di intensità della componente nucleonica a Mina Aguilar (4 000 *m* s.l.m., 12° S latitude geomagnetica), per le tempeste del Luglio 1959. Si suggerisce che il comportamento della intensità sia dovuto alla composizione lineare di tre indipendenti decrementi di Forbush di ampiezze e tempi di rilassamento diversi, ma aventi approssimativamente la stessa forma dello spettro di variazione della componente primaria. La lenta ripresa dopo la terza tempesta è dovuta principalmente al tempo di rilassamento della seconda tempesta.

(*) *Traduzione a cura della Redazione.*

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