NOTAS DE FÍSICA

VOLUME IV

Nº 4

RAPID DECREASE OF COSMIC-RAY INTENSITY

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RO BRASILEIRO DE PESQUISAS FÍSICAS

Av. Wenceslau Bras 71

RIO DE JANEIRO

1958

RAPID DECREASE OF COSMIC-RAY INTENSITY *

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(April 7, 1958)

A remarkable sudden decrease in cosmic-ray mu-meson intensity occurred in connection with the magnetic storm and auroral display of the night of 10 February 1958. We have put in operation a high counting rate, high time-resolution meson monitor which enables detailed study of such events. The instrument employs large disks of plastic scintillator[1], and consists of three telescope units, each of which counts coincidences between two layers of the plastic disks. Figure

* Supported by the joint program of the O.N.R. and the U.S.A.E.C.

*+ On leave from the Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, D. F., at the M. I. T.

1 is a view of one telescope unit; each disk is 107 cm in diameter and 9 cm thick, a layer of four disks is viewed by two Dumont 5" 6364 photomultipliers (only one is shown in the drawing) and two-fold coincidence is made between the upper and lower layers with a resolving time of 0.15 microseconds. The efficiency is over 90%, so that a nearly flat "plateau" is obtained at a counting rate corresponding to the known meson intensity. Each layer has a scintillator area of 3.4m^2 and the two layers are arranged for maximum counting rate: small vertical separation (25. cm) and essentially no absorber between layers. The total absorber thickness, principally the concrete roof of the building is 50 g cm^{-2}. The outputs of the three telescopes can be recorded individually or added electronically to give a total counting rate of nearly 1,000 counts per second. To take advantage of the high resolution which this rate affords, a special recorder has been devised (to be described elsewhere[2]) which accurately registers the number of counts in each 30-second interval; absolute time is known to ± 3 seconds. The monitor is located at Cambridge, Massachusetts, at sea level, latitude 42° 23' N., longitude 71° 08' W.

As the time of the sudden decrease the sum output of two telescopes was being recorded on the count recorder and the third telescope was on a low-precision counting-rate meter. The record of the count recorder, with counts averaged over 8-minute intervals for convenience, is shown in Fig. 2; the 8-minute average counting rates are given in Table I, which includes samples of the recovery of the intensity after the drop. All rates are corrected for barometric changes, the largest correction being 0.46%. The change in height of the upper atmosphere over this period would correspond to a correction of about 0.1%, which has not been made since detailed data are not available. With the exception of the third telescope the instrument has been in operation since August 1957, and has proved to be stable and reliable. A check on the results at the time of the decrease is provided by the third telescope, which has completely independent circuitry, and which showed the same decrease, although with poor precision because of the limitations of the counting-rate meter.

The record (Fig. 2) shows that a small decrease began at about 0100 Universal (Greenwich) Time on 11 February 1958, and the intensity had dropped 0.5% by 0240 U.T. At 0245 ± 5 U.T. the sharp drop began; the intensity dropped 2.1% in about one hour, leveling off at 0340 ± 5 U.T. The intensity remained at this level for a few hours (Table I), then rose gradually to its pre-drop value, the total time from the drop being about 14 hours. The magnetic storm began with a "sudden commencement" at 0121 U.T.[3], and the aurora began a few minutes later. Presumably the three phenomena correspond to the arrival of ionized gas emitted from the sun during the previous day, but the solar activity of that day was so great that it does not seem possible to identify the specific event that was responsible.

The event reported here resembles previously-reported "Forbush" decreases except that the time scale is shorter[4]. Theories of these decreases[5-7] generally assume the arrival of solar gas clouds carrying magnetic fields which somehow exclude a fraction of the cosmic rays from the vicinity of the earth. The median energy of the primaries of the mesons recorded by our apparatus is about 10 Bev; the gyration radius of a 10 Bev proton in a field of B gauss is $3.3 \times 10^7 B^{-1}$ cm; and the minimum time in which a magnetic cloud of velocity v carrying a field B could make its effects felt is greater than $3.3 \times 10^7 (B\ v)^{-1}$ sec. This implies, for a typical gas-cloud velocity of 2,000 km sec^{-1}, and a one-hour decrease a model-independent lower limit for B of 5×10^{-5} gauss. The actual lower limit depends on the model assumed; in the diffusion model[5], for example, fields from two to three orders of magnitude greater than this would be required; in the gravitational-capture model[6] the capture time is longer than one hour, and a more detailed calculation would be required to see whether the model could reproduce the effects reported. The model proposed by Cocconi et al envisions an elongated tongue-shaped magnetic field drawn out from the sun by the outburst of gas, and remaining well-organized out to the earth's orbit. The decrease would then correspond to the tip of this tongue passing over the earth. The three models should give quite different predictions for the anisotropy of the cosmic-ray decreases. It would be very useful to have high-resolution records of these events from different parts of the world.

We are indebted to R. A. D'Arcy for much of the design and successful completion of the monitor; to W. B. Smith for invaluable assistance; to Professor T. Gold for a helpful discussion; and to Professor B. Rossi for his original suggestion and continued support for this work. One of us (R.A.R.P.) is supported by a fellowship of the Conselho Nacional de Pesquisas, Brasil.

TABLE I

Counting rate of the meson monitor in counts per second, averaged over 8-minute intervals, on 11 February, 1958. The standard deviation of each entry is ± 1.2 counts per second.

Universal Time	Counts per second	Universal Time	Counts per second
0002	639.3	0250	634.3
0010	640.0	0258	630.3
0018	640.5	0306	631.5
0026	639.3	0314	629.9
0034	641.8	0322	626.2
0042	640.0	0330	627.4
0050	640.5	0338	621.3
0058	642.9	0346	624.3
0106	638.0	0354	621.6
0114	639.7	0402	623.7
0122	637.7	0410	624.0
0130	634.8	0418	624.1
0138	637.1	0426	620.9
0146	638.1	0434	622.8
0154	637.7	0442	621.7
0202	637.4	0450	623.6
0210	632.7	0448	625.6
0218	637.4		
0226	636.6	0800	625.6
0234	638.8		
0242	637.5	1100	632.4
		1430	633.1
		1700	638.7

1. Clark, Scherb, and Smith, Rev. Sci. Inst. 28 , 433 (1957).

2. R. A. D'Arcy, to be published.

3. Preliminary Report of Solar Activity TR 337, High Altitude Observatory, Univ. of Colorado, Boulder, Colorado.

4. For example, for the widely-noted decrease of August 29, 1957, our monitor recorded a 2.8% decrease in 10 hours, and recovery in another 82 hours.

5. P. Morrison, Phys. Rev. 101, 1397 (1956).

6. E. N. Parker, Phys. Rev. 103, 1518 (1956).

7. Cocconi, Gold, Greisen, Hayakawa, and Morrison, Proceedings of the Varenna Conference, Nuovo Cimento, in press.

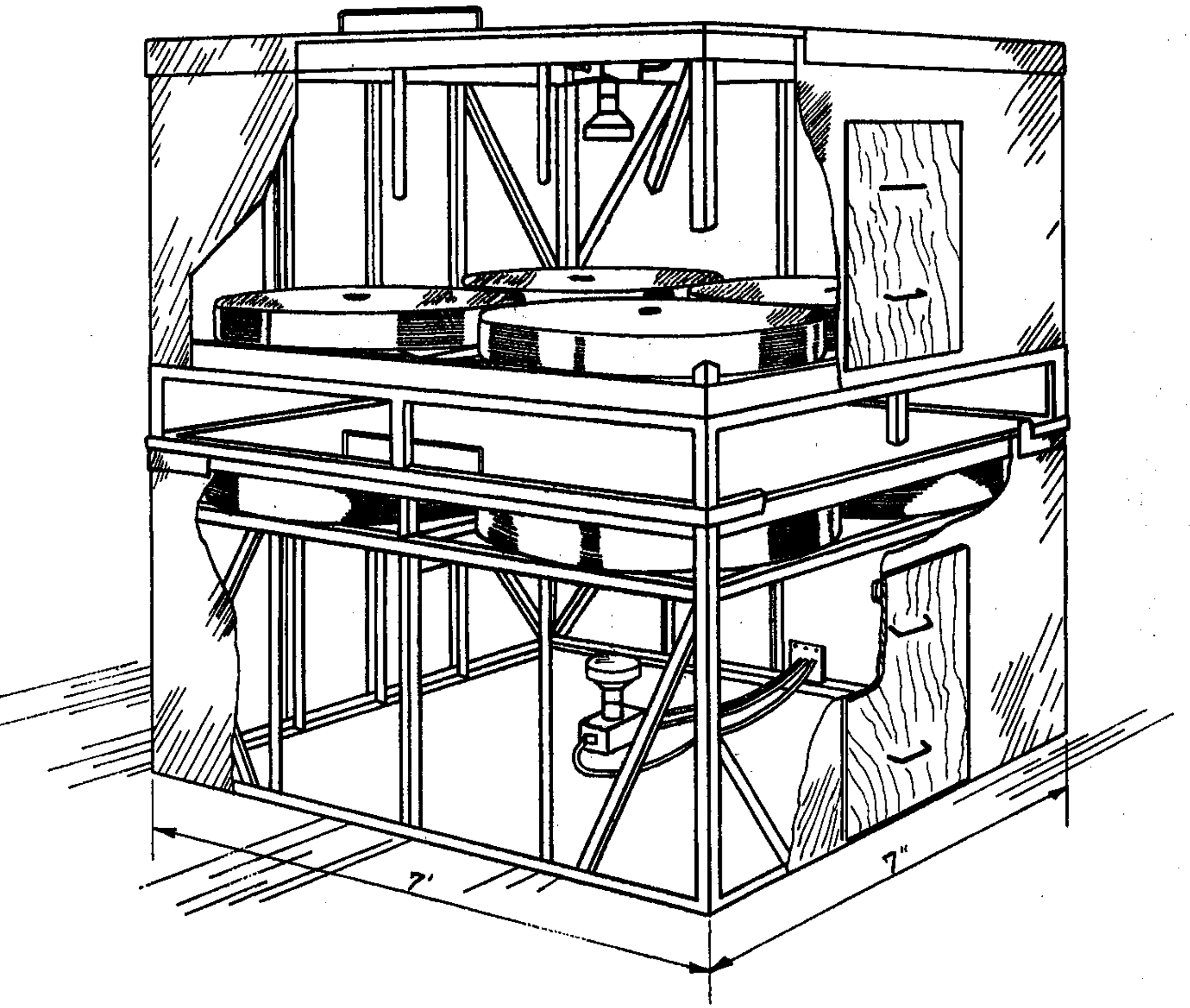

FIG. 1 - CUTAWAY VIEW OF A SCINTILLATOR TELESCOPE UNIT

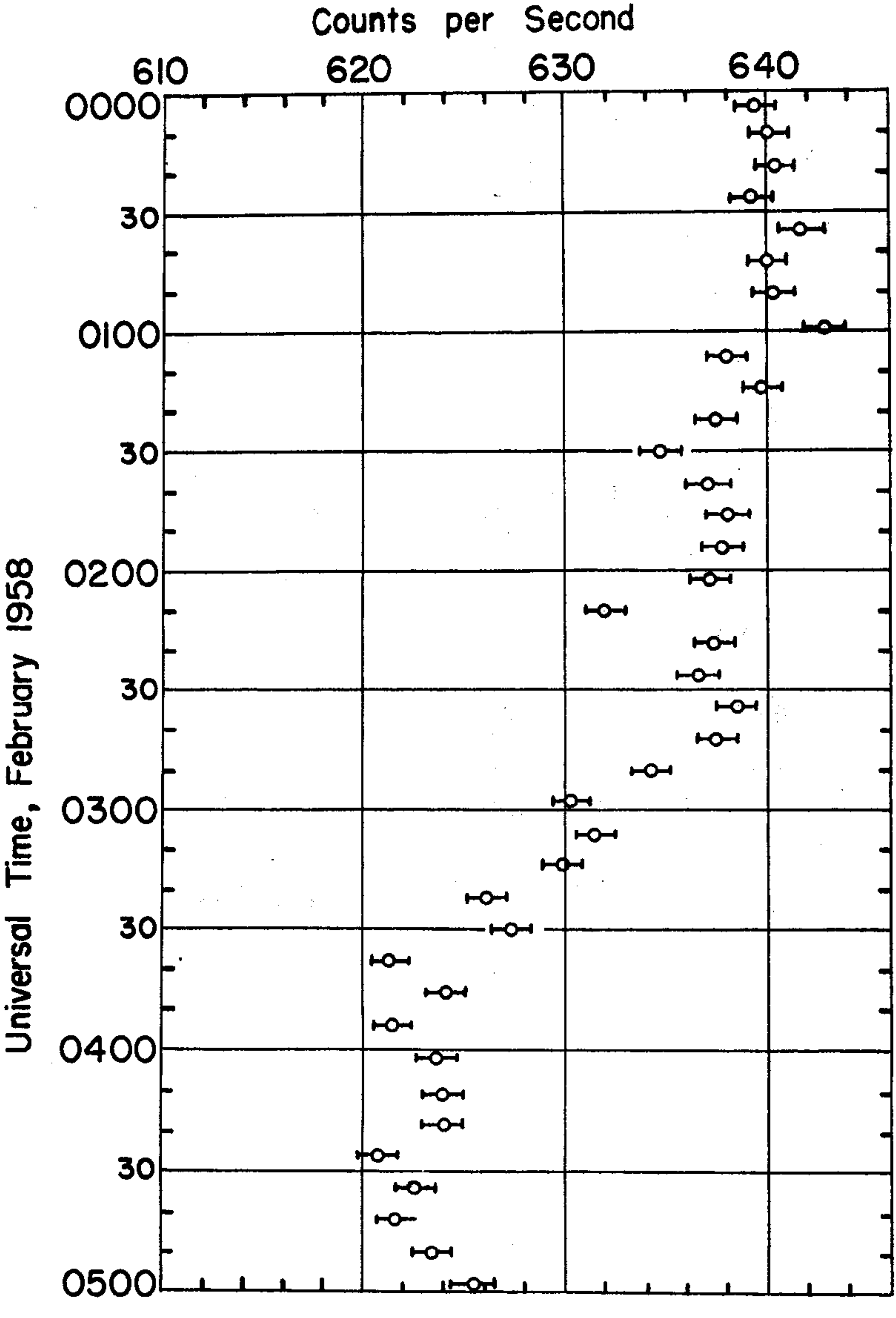
Counts per Second
610
620
630
640
0000
30
0100
30
0200
30
0300
30
0400
30
0500
Universal Time, February 1958

FIG. 2