The 24-Hrs Averages of Cosmic Ray Intensity in Stockholm 1947—48 and 1954

By ARNE ELD SANDSTRÖM, Fysiska Institutionen, University of Uppsala

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Abstract

Curves are given showing the variation of the 24-hrs averages of the C.R. intensity as measured by means of directional counter telescopes during two registration periods separated by six years. During both periods the maximum deviations were 2—3 per cent. In accordance with the view expressed by SIMPSON (1954) the periods of maximum are to be regarded as recurrent rather than being a harmonic function of time. There are some traces of a 27-day component having an amplitude of $\pm$ 0.4 per cent. The C.R. intensity as a function of time is compared to the solar cycles, the relative sun-spot number, the sun-spot area and the K_p-index.

The cosmic ray registrations in Stockholm Oct. 1947 to May 1950 (MALMFORS 1949, SANDSTRÖM 1955) offer possibilities for a study of the 24-hrs averages as a function of time. That as yet no such study has been made is partly due to the fact that these averages are affected by some systematic influence, easily eliminated as regards the diurnal variations, but becoming serious as soon as absolute intensities are concerned. For part of the registrations, however, these difficulties can be overcome.

The 24-hrs averages were derived from the sum of twelve bihourly values corrected for the barometer effect (LINDHOLM 1950). As a function of time these averages display a trend due to a systematic change of counting rate. After correcting for this trend the variations of the 24-hrs values were computed in per cent of the average intensity.

The intensity was registered in the N-, Z-, and S-directions by means of four two-fold coincidence channels in each direction (MALMFORS 1949). Rather frequently it happened, however, that one or several channels were out of order. Owing to the individual characteristics of the counters the counting rate varies with the combination of channels. As a result the present study had to be confined to the period Oct. 1, '47 to July 10, '48. Only 4-channel registrations were considered except as regards the N-direction from March 27 until May 20 1948 for which interval comparatively homogeneous 3-channel registrations are available. The 24-hrs average is approximately 10^5 impulses derived from a total of 12×10^5. The corresponding statistical fluctuations are of the order of magnitude of 0.1 per cent.

The curves in Fig. 1 representing the three directions agree even as to detail. A slight difference ought to be expected as the diurnal variation has a phase difference of 2.5 hours between the N- and S-directions, and 1.8 hours between the Z- and S-directions (BRUNBERG 1953, BRUNBERG and DATTNER 1954). The influence on the 24-hrs values is obviously too small to be recognizable.

A certain periodicity related to the 27-day cycles is easily perceived. Such a variation

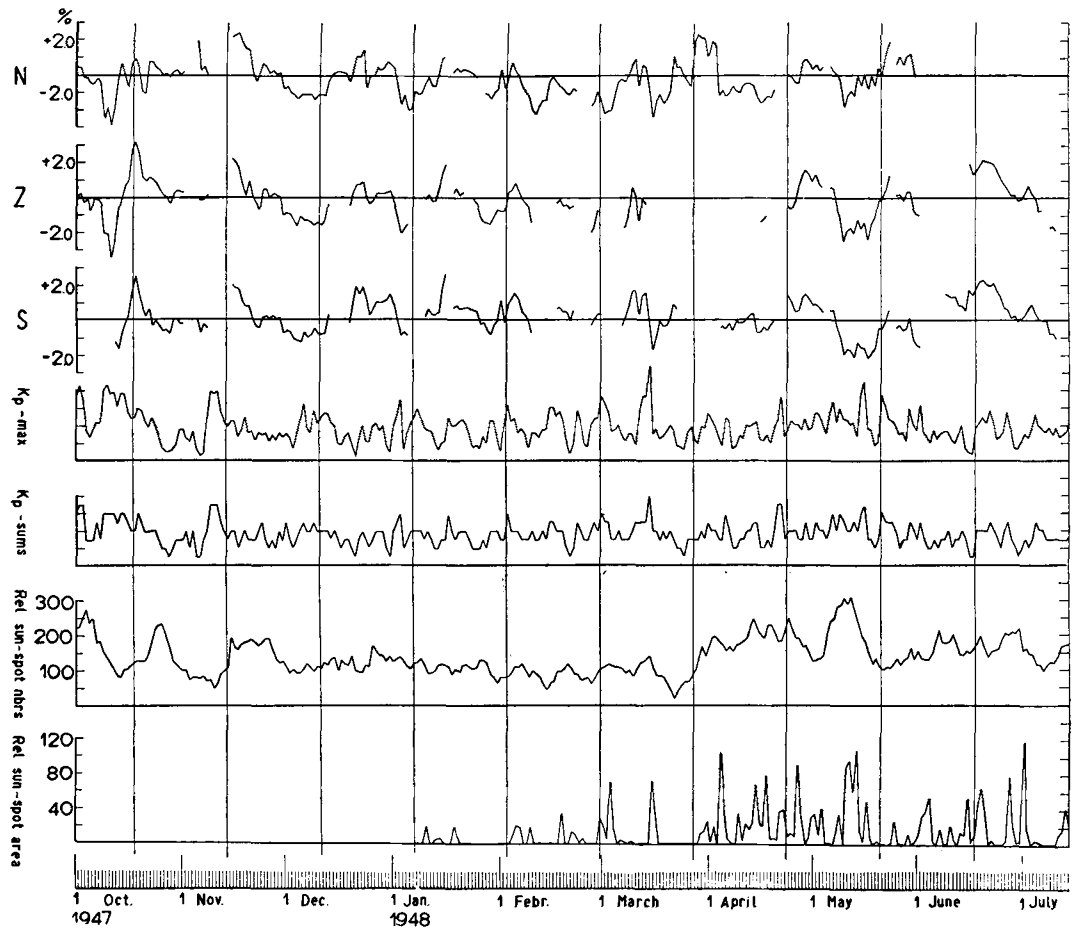

Fig. 1. The three uppermost curves represent the variation of the daily averages in the N-, Z-, and S-directions. The fourth curve represents the daily sums of the K_p-indices and the fifth curve the daily maximum values of these indices. Below is the relative sun-spot number and (from Jan. 1, 1948) the sun-spot area as functions of time. The vertical lines divide the diagram into 27-day cycles.

has often been reported (HEISENBERG 1953, p. 39, SIMPSON, FIROR, FONGER, and TREIMAN 1953, ELLIOTT 1953, EHMERT 1953) but probably the present issue is the first time it was observed by simultaneous measurements in three directions. Through the experimental studies of BRUNBERG (1953) it is now possible to determine the directional coordinates of the incident primary particles. The angle φ_N between the direction of the primaries and the equatorial plane did not differ very much for the three sets of telescopes. This is illustrated in Fig. 2, where P represents the point of observation. The north-south aperture of the telescopes was big enough to make all the three sets of telescopes measure practically the same beam of primaries integrated over 24 hours.

A comparison between the three curves offers some means of control as to the reliability of the registrations. As an example the N-direction differs from the other two directions on Oct. 15 to 19. The close correspondence elsewhere indicates that something was wrong with the N-telescopes and, as a matter of fact, the daily averages were calculated from less than 12 bihourly values. Incidentally, these days were never included in the studies of the diurnal variation.

After having been adjourned for more than three years registrations were resumed in 1954. The new telescopes differ from the

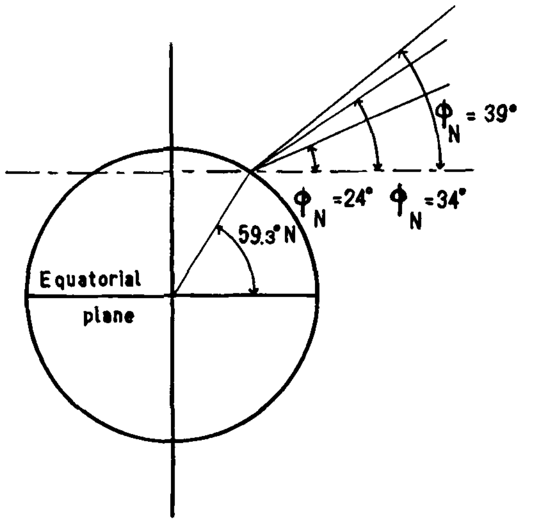

Fig. 2. The directions in the geographical meridian of the beams registered by the three sets of counter telescopes.

former set only as regards aperture and counting rate. They do not display any trend of the kind that is so disturbing in the '47—'48 measurements. Therefore a comparison between the two intervals is doubly valuable. The effect of the changed aperture can be seen from Fig. 2. Days with one or more channels out of order were excluded.

As expected the three directions give closely corresponding records. (Fig. 3). We find the same variations related to the 27-day cycles as in the former case except during Oct. and Nov. They reappear at the end of the period of registration.

The variations average ± 0.8 per cent for Oct. '47 to July '48 as well as for April to Dec. '54, although the first interval coincides with a period of comparatively high solar activity and the second with one of minimum activity. The maximum deviations from the average intensity is between 2 and 3 per cent.

Although in general one maximum and one minimum of C. R. intensity are related to each solar cycle a phase shift apparently exists. Sometimes the registrations display a distribution of maximum and minimum regions even suggesting a period of twice the length of the 27-day cycle. There is really no reason for the existence of such a period and a scrutiny of Fig. 1 reveals that the position of the intensity maximum moves through the 27-day cycles in a comparatively continuous way. Incidentally SIMPSON (1954) prefers to speak of recurring periods of maximum intensity instead of associating them with the 27-day cycles.

Comparing all three directions the averages of the 24-hrs values of corresponding days in all the available 27-day cycles were calculated. Finally the first harmonic was derived and found to have an amplitude of ± 0.4 per cent. This is little as compared to the superimposed recurring variations.

The diffusion of particles outwards from the sun (ALFVÉN 1954) ought to display variations related to the solar cycles. The occasional corpuscular radiation, originating from disturb-

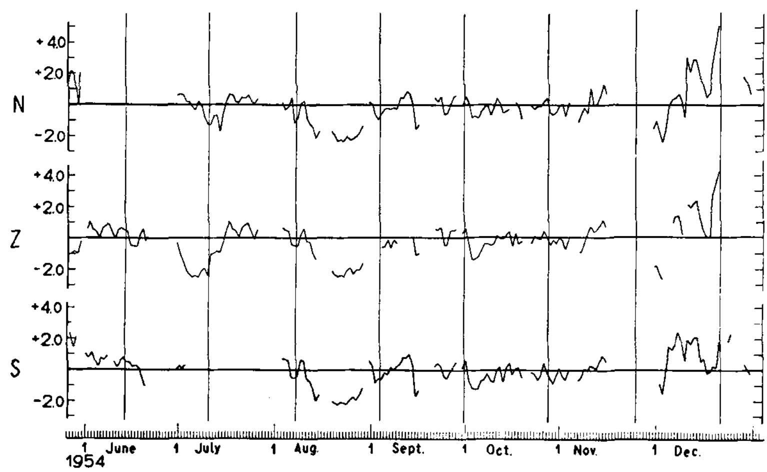

Fig. 3. The variations of the 24-hrs averages in Stockholm during 1954.

ances in the sun, will cause irregular changes of the C.R. intensity partly depending on the position of the earth relative to the emitted beam. However, if the latter lasts for more than one solar cycle it will cause a 27-day periodicity (BRUNBERG and DATTNER 1954). It follows that quite regular variations are not to be expected. The nature of those observed appears to be in accordance with this theory. Apparently the $\pm$ 0.4 per cent variation is a characteristic of the diffusion of particles from the sun outwards, while the less regular but much larger variations are due to the action of direct beams. The intermixture of the two effects makes any calculation of the true periodic variation difficult. In addition, very probably both the amplitude and the phase of the latter vary with conditions on the sun.

It is therefore especially interesting to compare the C. R. intensities with the variations in relative sun-spot number (Fig. 1). Another noteworthy fact is that the regions of high relative sun-spot numbers in Oct. '47 and in April and May '48 seem to be related to regions of low C. R. intensity. To try to advance one step further an attempt was made to correlate the C. R. variations with the total sun-spot area. Data on the latter are available from Jan. '48 (ÖHMAN 1950). We find that the period of low C. R. intensity in April and May '48 coincides with a sequence of days with large sun-spot areas. However, for the N-direction the correlation coefficient is only 0.22 (not significant).

As regards 1954 there are as yet no data available either on relative sun-spot numbers or on sun-spot areas. Data on geomagnetic character figures are also lacking. Once again we have to resort to the period Oct. '47 to June '48. One of the curves in Fig. 1 represents the sums of all the eight K_p-indices of each day (HOWE and WEISMAN 1949), while the one below shows the daily maximum of the same indices. The differences between these two curves are very small, the regions of maximum values being more marked as regards the K_p-sums. As was mentioned in a previous paper (SANDSTRÖM 1955) it does not matter, with regard to the present degree of accuracy, which of these two values is selected for classifying the days geomagnetically. Comparing the curves we find that, even if a cosmic ray minimum does not exactly coincide with a maximum of geomagnetic activity, the former succeeds the latter in a way indicating a common origin. In this case it is impossible, however, to recognize the rule given by SIMPSON (1954) that the geomagnetic maximum appears two days later than the end of the cosmic ray maximum. This discrepancy may be due to the fact that the present material is statistically small.

The change from day to day of the 24-hrs average constitutes a trend which certainly affects the observed time of maximum of the diurnal variation. However, the phase difference between the C. R. intensity and the geomagnetic variations has a remarkable effect. Given a sufficiently large number of days of the same geomagnetic activity, positive and negative trends will be randomly distributed (SANDSTRÖM 1955) even as regards magnitudes. As a result the average daily trend will become insignificant as soon as the number of days is sufficiently large. The periodicity of the general diffusion of particles explains the fact that negative as well as positive trends are to be found even on magnetically quiet days.

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REFERENCES

ALFVÉN, H., 1954: On the Origin of Cosmic Radiation. *Tellus*, **6**, p. 232.

BRUNBERG, E. Å., 1953: Experimental Determination of Electron Orbits in the Field of a Magnetic Dipole. *Tellus*, **5**, p. 135.

BRUNBERG, E. Å. and DATTNER, A., 1954: On the Interpretation of the Diurnal Variation of Cosmic Rays. *Tellus*, **6**, p. 73.

BRUNBERG, E. Å. and DATTNER, A., 1954: Variations of the Cosmic Ray Intensity During Magnetic Storms. *Tellus*, **6**, p. 254.

EHMERT, A., 1953: On the Small Variations of the Primary Intensity of Cosmic Radiation. *Recueil des Travaux de l'Observatoire de Pic-du-Midi. Série Rayons Cosmique*, No 1. Congrès International sur le Rayonnement Cosmique 1953. Session annexe sur les variations du rayonnement cosmique.

ELLIOTT, H., 1953: Time Variations of the Neutron Intensity. *Recueil des Travaux de l'Observatoire du Pic-du-Midi. Série Rayons Cosmique*, No 1. Congrès International sur le Rayonnement Cosmique 1953. Session annexe sur les variations de rayonnement cosmique.

FONGER, W. H., 1953: Cosmic Radiation Intensity—Time Variations and Their Origin. *Phys. Rev.*, **91**, p. 351.

HEISENBERG, W., 1953: *Kosmische Strahlung*, Berlin-Göttingen-Heidelberg.

HOWE, H. H. and WEISMAN, E. K., 1949: Geomagnetic Indices, K and C, 1948. *International Union of Geodesy and Geophysics.*
Association of Terrestrial Magnetism and Electricity. Bulletin No. 12 b, pp. 118—120.

LINDHOLM, F., 1950: Atmospheric Effects on Cosmic Radiation Airmass Absorption and Meson Decay. *Tellus*, **2**, p. 63.

MALMFORS, K.-G., 1949: Recordings of Cosmic Radiation. *Tellus*, **1**, No. 2, p. 54.

SANDSTRÖM, A. E., 1955: On the Correlation between Geomagnetic Activity and the Diurnal Variation of Cosmic Rays. *Tellus*. **7**, p. 204.

SIMPSON, J. A., 1954: Cosmic Radiation Intensity Time Variations. *Phys. Rev*. **94**, p. 426.

SIMPSON, J. A., FIROR, J., FONGER. V., and TREIMAN, S. B., 1953: Properties of Primary Intensity—Time Variations. *Recueil des Travaux de l'Observatoire du Pic-du-Midi. Série Rayons Cosmique*, No 1. Congrès International sur le Rayonnement Cosmique 1953. Session annexe sur les variations du rayonnement cosmique.

ÖHMAN, Y., 1950: On the Solar Work of the Stockholm Observatory. *Tellus*, **2**, p. 255.