Some Remarks on the Sudden Cosmic Ray Increase on Februari 23, 1956

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(Manuscript received June 8, 1956)

Abstract

The north and south pointing GM-telescopes at Stockholm measured different cosmic ray increases during the solar flare on Feb. 23. It is shown that this difference is due to particles of momenta greater than 10 GeV/c which could not have travelled along straight line paths from the sun.

A first report of the Swedish registrations of the large cosmic ray increase on February 23, 1956, has been given by SANDSTRÖM (1956) and ECKHARTT (1956). This increase was associated with a solar flare which was observed to have started at 3.30 h GMT (FORBUSH, 1956). A few important conclusions could be drawn from the Stockholm registrations measured with GM-telescopes in different zenith angles in the north—south plane. These conclusions are supported by the results of the directional telescopes at Rome (BACHELET a. CONFORTO, 1956).

In the following discussion we have used the data from the unshielded four-channel directional telescopes at Stockholm (magn. latitude $\lambda_m = 58°$ N). The telescope measuring in zenith direction will be denoted by Sthlm_Z. The north and south pointing telescopes measure in directions inclined 30° to the zenith and are denoted in an analogous way by the subscripts N and S. The station is situated at an elevation of 46 m above sea level. The total amount of absorber above the instrument is 1047 g/cm^2 which is composed of 1039 g/cm^2 of air mass (equivalent to a mean air pressure of 1023 mb during the flare) and 8 g/cm^2 of material of the roof.

It must be pointed out that a check of the pulse rates of the individual channels revealed that one group of GM-counters changed and increased its sensitivity between 19 h and 20 h GMT on the 22nd. This group is common to one of the four channels for both the north and the zenith directions. After 20 h the particular group remained on the new and constant level of sensitivity. Consequently only the data after 20 h have been used. Before this time, the sum of the three properly working channels of Sthlm_N has been taken and multiplied by 4/3.

The pulse rates of the different telescopes are given in Fig. 1.

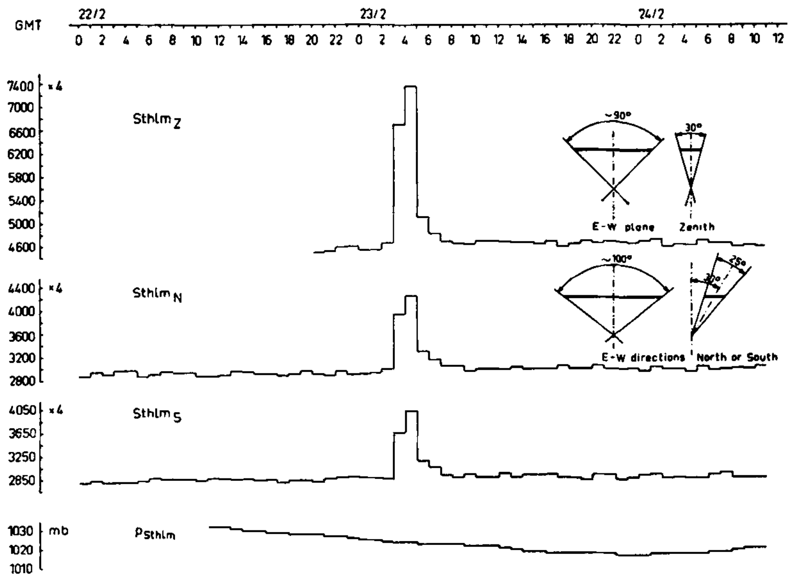

Fig. 1. The uncorrected hourly pulse rates measured by the directional telescopes at Stockholm together with the mean air pressure during the corresponding hours. Small figures indicate opening angles of the different telescopes.

The North—South Asymmetry

The pulse rates from $Sthlm_N$ and $Sthlm_S$, uncorrected for pressure, are compared. Since particles arriving from these inclined directions have traversed atmospheric layers which have approximately the same structure, we assume that the absorption effects are the same for the two directions. Comparing the pulse rates of the two telescopes therefore means comparing the flux of primaries above the atmosphere.

In Fig. 2a the ratio between the pulse rates of $Sthlm_N$ and $Sthlm_S$ together with their probable errors are plotted. Dots represent values derived from all the four northern channels, crosses represent values computed from the three properly working channels times 4/3, as mentioned above. It is seen that before the 20—21 h interval on the 22nd there are differences between dots and crosses due to the difference in sensitivity of one group of counters, as mentioned above. Using the values corresponding to crosses before the particular time, we get the same value of the ratio before and after the flare.

Fig. 2a shows that during the hours following the solar outburst more particles were recorded by $Sthlm_N$ than by $Sthlm_S$. The

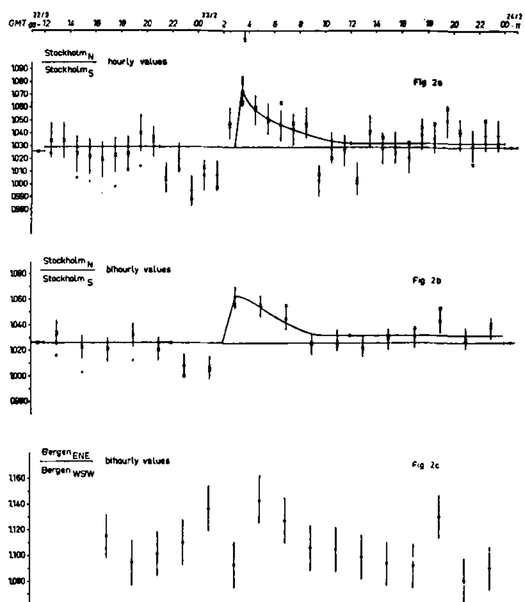

Fig. 2 a. The ratio between the hourly pulse rates of the north and south pointing telescopes at Stockholm.

Fig. 2 b. The ratio between the bi-hourly pulse rates of the north and south pointing telescopes at Stockholm.

Fig. 2 c. The ratio between the bi-hourly pulse rates of the directional telescopes at Bergen, Norway. These telescopes are preferably orientated in the east—west plane. (See text.)

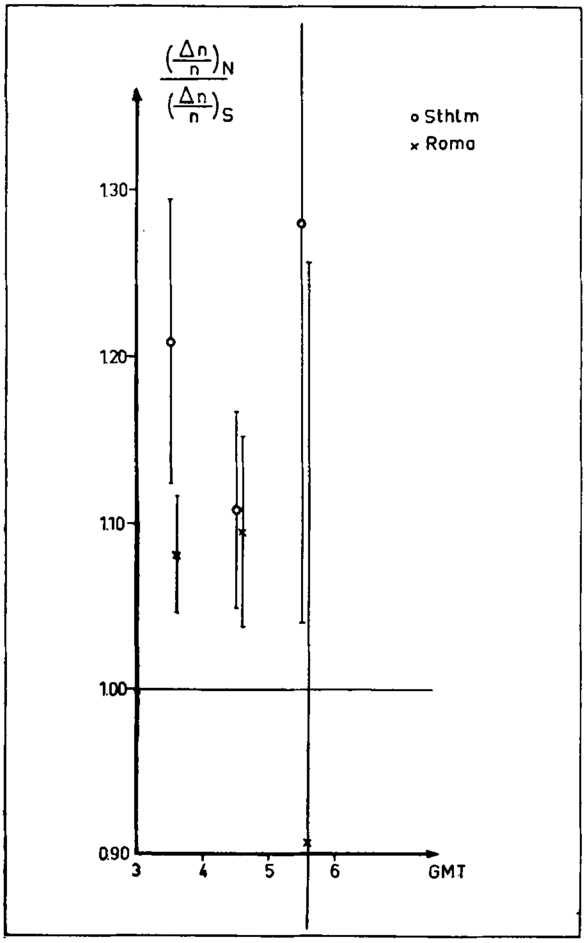

Fig. 3. The ratio between the relative increases in pulse rates of the north and south pointing telescopes at Stockholm and Rome.

slight decrease immediately before the onset of the flare is not outside the statistical errors.

In Fig. 2b the ratios between Sthlm_N and Sthlm_S, computed from bi-hourly values of the pulse rates, are given which allow a comparison with the values measured at Bergen, Norway, ($\lambda_m = 61.5°$ N), Fig. 2c. The Bergen telescopes are orientated in the ENE—WSW plane below about 28 cm of lead. This is essentially an orientation in the east—west plane (TREFALL a. TRUMPY, 1956). While the Stockholm bi-hourly values clearly show the asymmetry in the north—south direction, no such definite conclusions can be drawn from the Bergen values concerning the east—west direction, as has already been pointed out by Trumpy and Trefall.

In Fig. 3 we show the ratio between the relative increases of pulse rates for the two directions with respect to the mean value of the two hours preceding the event. The ratios for the Rome telescopes ($\lambda_m = 42.5°$ N) are computed from the published 15-minute records. These telescopes are inclined 30° to the zenith and have slightly larger apertures than the Stockholm telescopes. It is clearly seen that during the two hours after the beginning of the event, relatively more particles are measured by the north pointing telescope at both the stations.

Discussing this north—south asymmetry one must take into account the deflection of the primary particles in the earth's magnetic field. The initial direction of the primary particles far away from the earth will be called the asymptotic direction in the following. In Fig. 4 the asymptotic directions for those primary particles which are measured by the north, south, and zenith pointing telescopes in Stockholm are given. Let us represent the asymptotic direction by a vector. The end point of this vector coincides with the center of a globe.

Each curve on the globe is then the locus of the foot points of the afore-mentioned vector, which gives the asymptotic direction for different particle momenta (BRUNBERG, 1956). The zenith angles of arrival are denoted on each curve (32° N, 32° S . . .) and the numbers indicate the momenta in GeV/c. As an example take the point 18 GeV/c on the curve 32° S. This point has in the geographic system the coordinates $\Psi = 30° + 18° = 48°$ E, $\Phi = 38°$ N. (The longitude of Stockholm is 18° E.) This means that a particle with a momentum of 18 GeV/c which is approaching the earth from an asymptotic direction, defined by the two angles Ψ and Φ, will arrive at Stockholm from the 32° S direction.

It is seen from Fig. 4 that Sthlm_N and Sthlm_S, the asymptotic directions of which are represented by the curves 32° N and 32° S for primary momenta higher than 12 GeV/c, scan considerably different directions in space. Particles with momenta around and below 10 GeV/c, however, come from nearly the same directions independent of the measuring directions of the telescopes. This depends on the focusing effect of the geomagnetic field which has been discussed by ÅSTRÖM (1956). Below 10 GeV/c the asymptotic directions of 32° N and 32° S are still nearer each other than are 48° N and 48° S, which are plotted in the figure. Note that on the 32° N curve even momenta up to 20 GeV/c lie within the main bulk of asymptotic directions for lower momenta, whereas the 32° S curve runs away to the west.

Hence, the fact that Sthlm_N records more particles than Sthlm_S indicates firstly, that there are particles with momenta higher than 10 GeV/c in the spectrum of the extra flare particles. Secondly, either the intensity (i.e. the number of particles) or the energy of the extra flare primaries, or both, are different in the different asymptotic directions. The same conclusion is arrived at when considering the geomagnetic deflection for the telescopes at Rome.

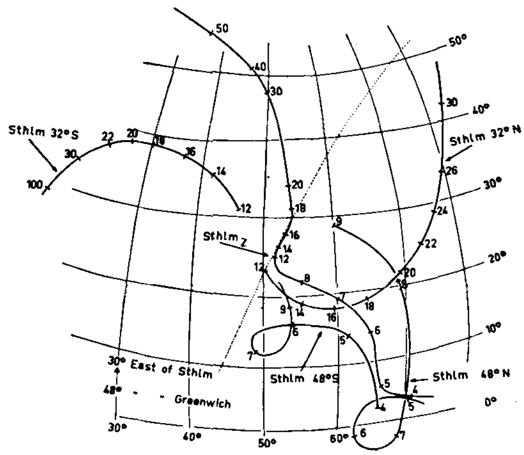

Fig. 4. Photograph of a part of the globe on which the angular coordinates of the asymptotic directions for the Stockholm telescopes are drawn. The dotted line defines asymptotic directions that have a 70° distance in angle from the direction towards the sun.

The conclusion that there are particles with momenta higher than 10 GeV/c in the spectrum of the solar flare primaries is supported by the observed increases at the equatorial stations of Huancayo (MEYER a. SIMPSON, 1956) and Ahmadabad (SARABHAI et al., 1956) where the cut-off momentum is around 10 GeV/c.

Another important conclusion that could be drawn from the observed north—south asymmetry is, that the flare primary particles did not travel in straight line paths from the sun to the earth as has usually been assumed (FIROR, 1954, SARABHAI et al., 1956). Consider Fig. 5 in which the position of the earth and the asymptotic directions for the Stockholm station are given in relation to the sun at the beginning of the flare. From this picture it is evident that particles with momenta 10 (20) GeV/c and measured by the Stockholm north pointing telescope have arrived at an angle of about 70° (55°) to the earth—sun direction. Particles with momenta higher than 10 GeV/c and measured by Sthlm_S have been deflected still more (compare Fig. 4). Considering the telescopes at Rome, one finds the angular distances between the asymptotic directions and the direction towards the sun generally

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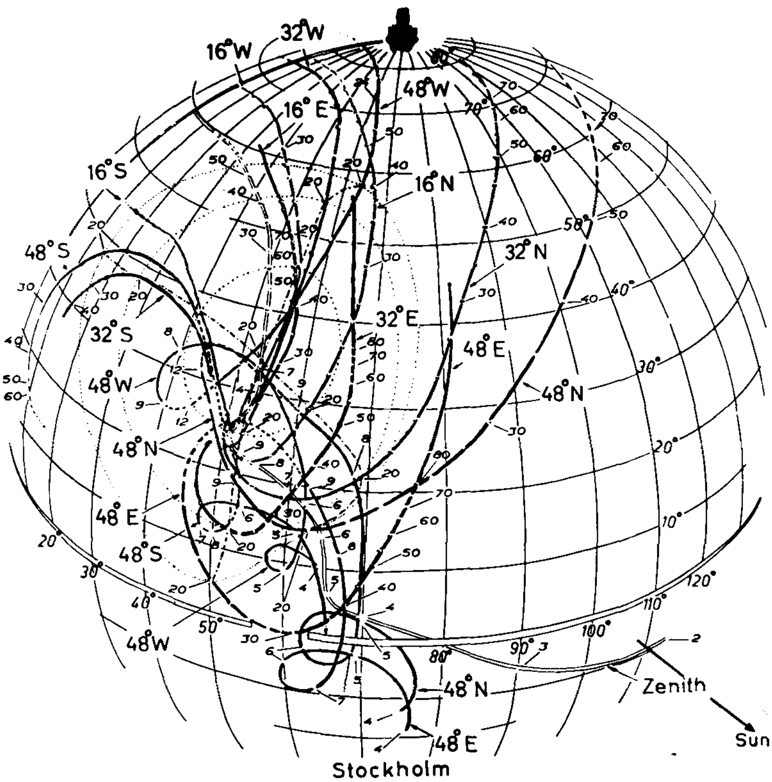

Fig. 5. The angular coordinates of the asymptotic directions for arrival at Stockholm together with the directions towards the sun at the beginning of the flare.

smaller except for those particles of higher momenta that are measured by the south pointing telescope.

This deflection is of particular interest as it shows the existence of magnetic fields in the interplanetary space. From the above mentioned values for deflection angles and corresponding momenta, a value of $0.6 \cdot 10^{-5}$ gauss is computed for the mean magnetic field through which the particles must have passed in order to be measured by Sthlm_N if emitted from the vicinity of the sun.

The authors are indebted to Prof. H. Alfvén for many valuable discussions.

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