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Abstract

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SOLAR CORPUSCULAR STREAMS

AND FAMILIES OF GEOMAGNETIC STORMS

(Presented by Academician D. I. Shcherbakov, 29 VI 1960)

It is generally recognized that geomagnetic storms arise as a result of the interaction of solar corpuscular streams and the geomagnetic field. As early as 1957 we expressed the idea that solar corpuscular streams produce not only storms, during which the stream envelops the Earth, but also magnetic disturbances weaker than storms, during which the stream passes "by" the Earth without enveloping it ([1]). Observational material from 1957-1959 under the program of the International Geophysical Year made it possible to confirm and refine this idea. At present we believe that each corpuscular stream producing a magnetic storm, as a rule, causes geomagnetic disturbances on the days preceding and following the storm. (For brevity, we shall agree to call these disturbances, together with the magnetic storm produced by the stream, the family of geomagnetic storms of the given stream, or, more briefly, the family of storms.) This conclusion was reached by us on the basis of an examination of magnetograms from three observatories far distant from one another: Srednikan (USSR), Eskdalemuir (Great Britain), and Little America (Antarctica, U.S. observatory) (Fig. 1). The principal material consisted of the Srednikan magnetograms.

Figure 2 gives an example of a family of storms. For a considerable number of storm families it is characteristic that the magnitude of the magnetic disturbance (measured by its amplitude R) first increases monotonically from day to day to a maximum, and then decreases monotonically. In some storm families other forms of dependence of R on time t are also encountered (Table 1). Changes in R

Table 1

Various types of distribution of R within a family of storms*

Fig. 1. Variations of the vertical component of the geomagnetic field in Eskdalemuir (E), Srednikan (S), and Little America (LA) on 26 XI 1957. Universal time is plotted horizontally.

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Fig. 2. Variations of the vertical component of the geomagnetic field in Srednikan on 25–30 XI 1957. Universal time is plotted horizontally.

Figure 2: Fig. 2. Variations of the vertical component of the geomagnetic field in Srednikan on 25–30 XI 1957. Universal time is plotted horizontally.

Date	Day in family	R	Date	Day in family	R	Date	Day in family	R
23 IX 1957	0	422	29 IX 1957	0	>624	3 II 1957	−1	22
24 IX	+1	187	30 IX	+1	254	4 II	0	187
25 IX	+2	38	1 X	+2	86	5 II	+1	91
						6 II	+2	14

* R is the amplitude of the vertical component (in gammas) at Srednikan.
0 is the day of greatest R; day −1 is the preceding day; days +1, +2 are the following days.

within a family of storms are due to the day-to-day change in the shortest distance d from the Earth to the stream that produced the family of storms. The magnitude R is proportional to d^{-2}. One cannot assume that disturbances and storms are directly the magnetic field of corpuscles moving in the stream.

The magnetic field of the corpuscular stream would have had to exist continuously, throughout the entire time that the corpuscular stream interacts with the geomagnetic field. In fact, however, each member of a family of storms is separated from its neighbors

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by a period of relative calm of the field. Therefore it must be assumed that a family of storms is produced by corpuscles ejected as a stream into the vicinity of the Earth, and that the density of these corpuscles is proportional to d^{-2}. The corpus-

···corpuscles, upon entering the Earth' s radiation belt, slip out of it into the terrestrial atmosphere not at any hours of the day, but only at certain ones. The separation of families of storms was aided by the fact that Srednikan is located not far from the line AK, connecting the two greatest world anomalies of the northern hemisphere: the Asiatic (A) and the Canadian (K). Apparently, these world anomalies are responsible for the fact that corpuscles from the Earth' s radiation belt can enter the terrestrial atmosphere only within a certain range of angles of the line AK relative to the corpuscular stream. The concept set forth above concerning the nature of the dependence of R on d agrees with the following concept concerning the nature of the dependence of the duration, in days, of the disturbed period (the duration of one member of a family of storms), Δt, on d. One may assume that Δt is proportional to the angle ω, at which the radius ρ of the circular cross section of the stream is seen from the Earth, the stream being a cylinder constructed on the Earth' s orbit as a directrix and with a generatrix perpendicular to the plane of the ecliptic. In this case it is obvious that

Table 2

Intensities R and durations Δt in a family of storms, in %, relative to R and Δt on day 0*

$\Delta\varphi$		−3	−2	−1	0	+1	+2	+3
5°	R	2	3	12	100	12	3	2
5°	Δt	10	15	25	100	25	15	10
10°	R	6	13	37	100	37	13	6
10°	Δt	20	30	50	100	50	30	20
30°	R	36	56	83	100	83	56	36
30°	Δt	45	60	82	100	82	60	45

* See the footnote to Table 1.

$$\sin\frac{\omega}{2} = \frac{\rho}{\sqrt{d_{\min}^2 - (vt)^2}},$$

where $d_{\min}$ is the minimum value of d for the given family of storms; v is the velocity of the stream along the Earth' s orbit, and t is time. Comparison of the actual R and Δt with R and Δt calculated from the views presented above (see Table 2) makes it possible, for each family of storms, to determine the quantity $\Delta\varphi$–the difference between the heliographic latitudes of the stream and of the Earth. Taking, in accordance with our estimates ([2]), the radial velocity of the corpuscles from the Sun to be 10^3 km/sec, one can assign each family of storms to a definite active region on the Sun. The results of such determinations are quite plausible. Families of storms with the maximum value of R at the "center" of the family correspond to streams that reached the distance of the Earth's orbit from the Sun long before coming close to the Earth. Families of storms in which the largest R belongs to the first member of the family correspond to streams that appeared at the Earth' s orbit near the Earth and rapidly moved ahead of it. Finally, families consisting of only one member (of one storm or one disturbed period) correspond to streams that passed by the Earth and quickly ceased to exist. Consideration of the values of $\Delta\varphi$, taking into account generally accepted estimates of stream widths, leads to the conclusion that the Earth very rarely finds itself inside a stream, and that most storms, not to mention disturbances, arise when streams pass by the Earth without encompassing it.

Everything said above does not negate the dependence of R on other characteristics of the streams, such as the mean radial velocity of the corpuscles from the Sun, their density in the principal axial part of the streams, etc. However, the parameter that makes it possible to relate both geomagnetic storms and weaker geomagnetic disturbance into a single phenomenon should be regarded as the quantity $d_{\min}$ or $\Delta\varphi$.

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CITED LITERATURE

1. V. I. Afanas' eva, *Tr. N.-i. inst. zemnogo magnetizma, ionosfery i rasprostraneniya radiovoln AN SSSR*, **12**(22), 59 (1957).

2. V. I. Afanas' eva, *Tr. Mezhdunarodn. geofiz. goda*, **3**, 1, 15 (1959).

Note: Figure translations are in progress. See original paper for figures.