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FORECASTING OF SOLAR FLARES

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The magnetic fields of cosmic ray flares and some other flares appearing during 1957 - 1962 have been examined at the Crimean Astrophysical Observatory. Magnetic fields before and after flares determined visually and photographically in groups of sunspots were analyzed in nearly 50 cases. These determinations were carried out during the IGY in a regular program basis at six different observatories. The complete number of observations being three to four per day. During the 1959 - 1962 period, observations made twice a day at the Crimean Observatory were used.

All of the flares were divided into four classes as indicated in table I. The flares, typical for each class, were chosen on the basis of the presence of the reliable data about the field configurations before and after a flare as well as on the data about the generation of cosmic rays and of geophysical effects produced by flare.

Well pronounced changes of configurations of magnetic fields were found when comparing them before and after a flare. Namely, in most cases we found that the magnetic polarities of the opposite sense are approached a little and the 3-d pole is pushed out (see fig. 1). It was found (see table I) that the importance of a flare (and its duration) depend strongly on the gradient of magnetic field near its neutral point. Namely, the more is the gradient, the more is the importance of a flare.

These gradients were obtained by the construction of a laboratory model of the transverse field of the configuration observed (the position of the poles and their strengths) by using the similarity relations for the gradient of transversal field in the region near the neutral point. There were no flares of the importance 3 with the gradient smaller 0.1 gs/km, as well as there were no flares of importance ≤2 with the gradient exceeding this value. (For the detailed description see reference 1).

Table I

The mean gradients of magnetic fields before and after a flare.

Class N of flares	Type of flares	Number of cases	Gradient of field gs/km before a flare	Gradient of field gs/km after a flare	Duration of flares
I	C.R,, Protons (balloons)	13	C.73	0.25	0.17
II	Protons (PCA)	11	0.46	0.27	0.089
III	Imp. 3 without PCA	12	0.18	0.13	0.071
IV	2^+ and 2 (usual)	15	0.054	0.038	0.048

On the fig. 2 - 3 the gradient of magnetic field before and after flares are shown (the values before and after flares are joined by straight line, the part of which corresponding to the duration of flare is thick. The gradients of magnetic fields diminish considerably after a flare and the decrease is the higher the more important is a flare. The biggest chance of the gradient is observed for flares with cosmic ray effects on balloons and for flares producing PCA.

For the forecasts of flare importances with the help of the magnetic fields it is necessary to have the most complete and perfect data about the fields. The experimental forecasts were given during 1961 - 1962. During this period we mainly used the detailed measurements of the absolute magnetic fields made at the Crimean Astrophysical Observatory. Besides that the observations made at Poulkovo Observatory, Mountains Astronomical Station at Kislovodsk and ISMIR (Moscow) were used. The maps of the longitudinal field recorded by magnetograph of the Crimean Astrophysical Observatory were of importance for this work. Our experience shows, that the existence of "invisible spots" - regions of increasing field strength which are not accompanied by any formations in visible light makes it necessary to have even rough map of the field (some hundreds of gauss), while the mean error of the current visual measurements of the field is ± 200 gs.

The data on the magnetic fields near the limb become uncertain. The forecast with the use of magnetic fields is practically impossible during a day after the first appearance of the group at the eastern limb. The same is true for a day before the passage of group into invisible hemisphere at the western limb. Our experience of forecasts also shows that the most rapid serious changes of configurations of the field, as well as the formation of groups, take time in about a day and even less. Therefore the forecast for more than two days can have some error.

We use the following meaning for forecast: 1 - means that no flares are expected or there can be flares of importance 1 -, 1 and 1+; the forecast 2 - means that the flares of the importance 1+, 2 and 2+ are expected. The forecast 3 - has the same meaning as above but for flares of the importance 2+, 3 and 3+. The value 5- means that the forecast is impossible because the lack of data.

The flares of importance 1+ are included simultaneously in the forecasts 1 and 2, (as well as flares of the importance 2+ are present simultaneously in the forecasts 2 and 3) because the lack of clear distinction between the importances of flares and the cosiderable error in the estimates (the error of 0.5 of the scale adopted is quite usual.)

Table II

Forecast of flares for 1962

Number of cases	Correct	Overestimated	Underestimated
102	77	13	12
100%	75.5%	12.7%	11.8%

Fig. 4 contains the numbers of different forecasts of the flare importances for the time interval of 2 days; true forecasts (dots), overestimated (crosses), underestimated - most dangerous (triangles); open circles are the sum of true and overestimated forecasts - it can be considered as the "measure of safety".

It is obvious that forecasts become less reliable with the increase of time interval, and from fig. 4 we see that the flare forecast is effective for time interval no more than 2 - 3 days, when the number of unforeseen flares does not exceed 15 - 20% of total amount. For the bigger time interval the number of underestimated forecasts increases rapidly and for 5 and more days the forecasts are not particularly effective.

The forecasts for the active regions near the limb are not certain when using the magnetic fields only and we should appeal in this case to some other solar phenomena such as the motions of the chromospheric filaments, the appearence of "moustaches" - very broad emission wings of lines, the brightness of the plages, the intensity of the radio-emission and some other.

ref I S. I. Gopasyuk, M. B. Ogir, A. B. Severny, E. F. Shaposhnikova. The structure of magnetic fields and its change in the region of solar flares, Isvestija Crim. Aph. Obs. 29, (in press)

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Figure Captions

1. Typical magnetic field geometry before and after a flare (primes refer to after).
2. Changes in the magnetic field gradient near flare times for flares of class I and II.
3. Changes in the magnetic field gradient near flare times for flares of class III and IV.
4. Is given on figure.

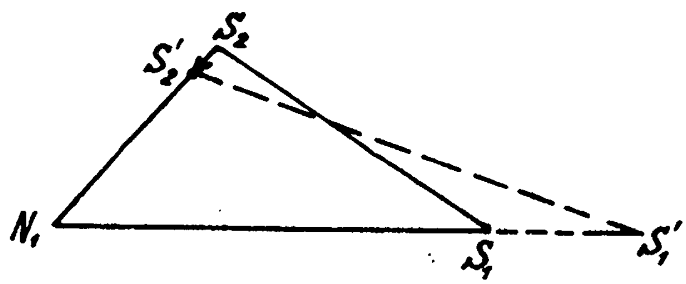


Fig. 1

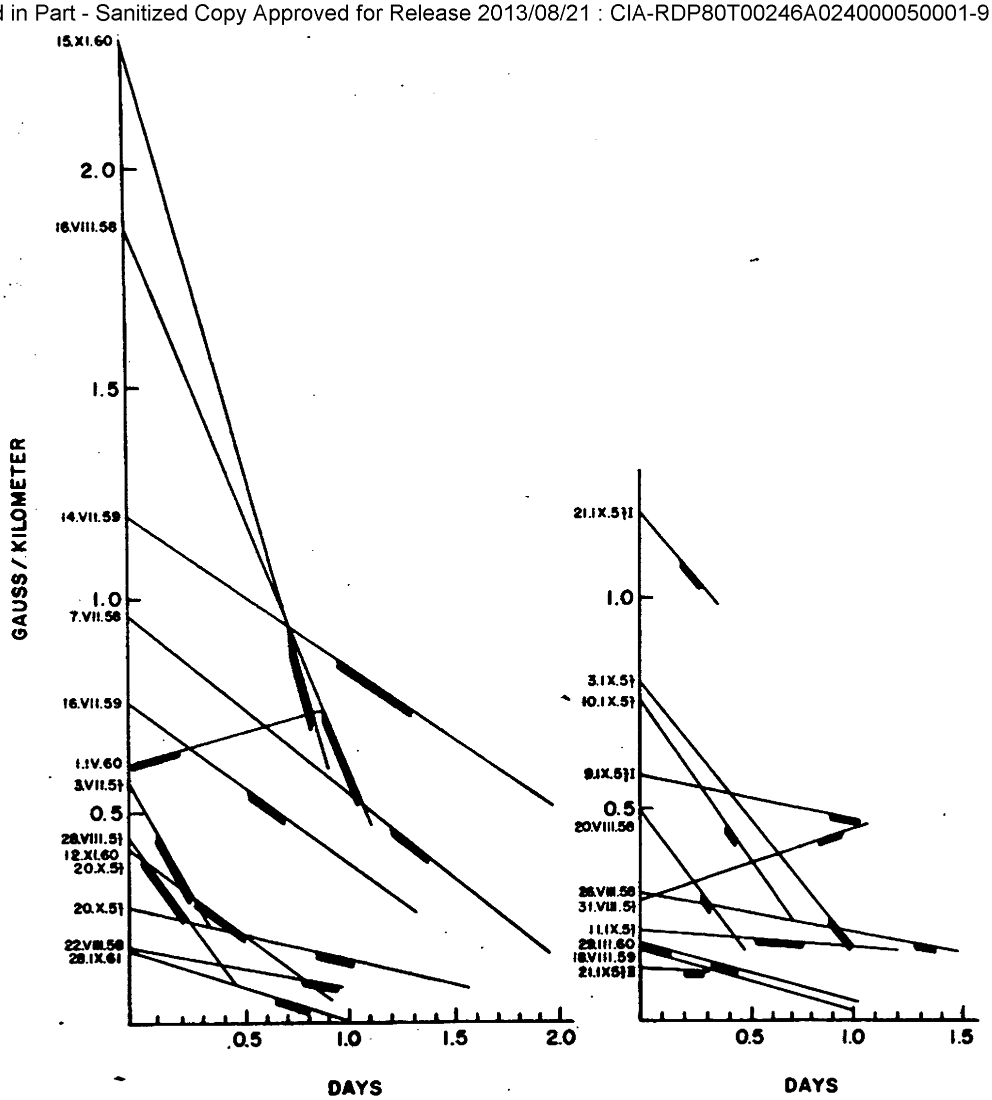

15.XI.60
2.0
16.VIII.58
1.5
GAUSS / KILOMETER
14.VII.59
1.0
7.VII.58
16.VII.59
1.IV.60
3.VII.59
0.5
28.VIII.59
12.XI.60
20.X.59
20.X.59
22.VIII.58
28.IX.61
0.5
1.0
1.5
2.0
DAYS
21.IX.59 II
1.0
3.IX.59
10.IX.59
9.IX.59 II
0.5
20.VIII.58
28.VIII.58
31.VIII.59
11.IX.59
29.III.60
18.VIII.59
21.IX.59 II
0.5
1.0
1.5
DAYS

Fig. 2

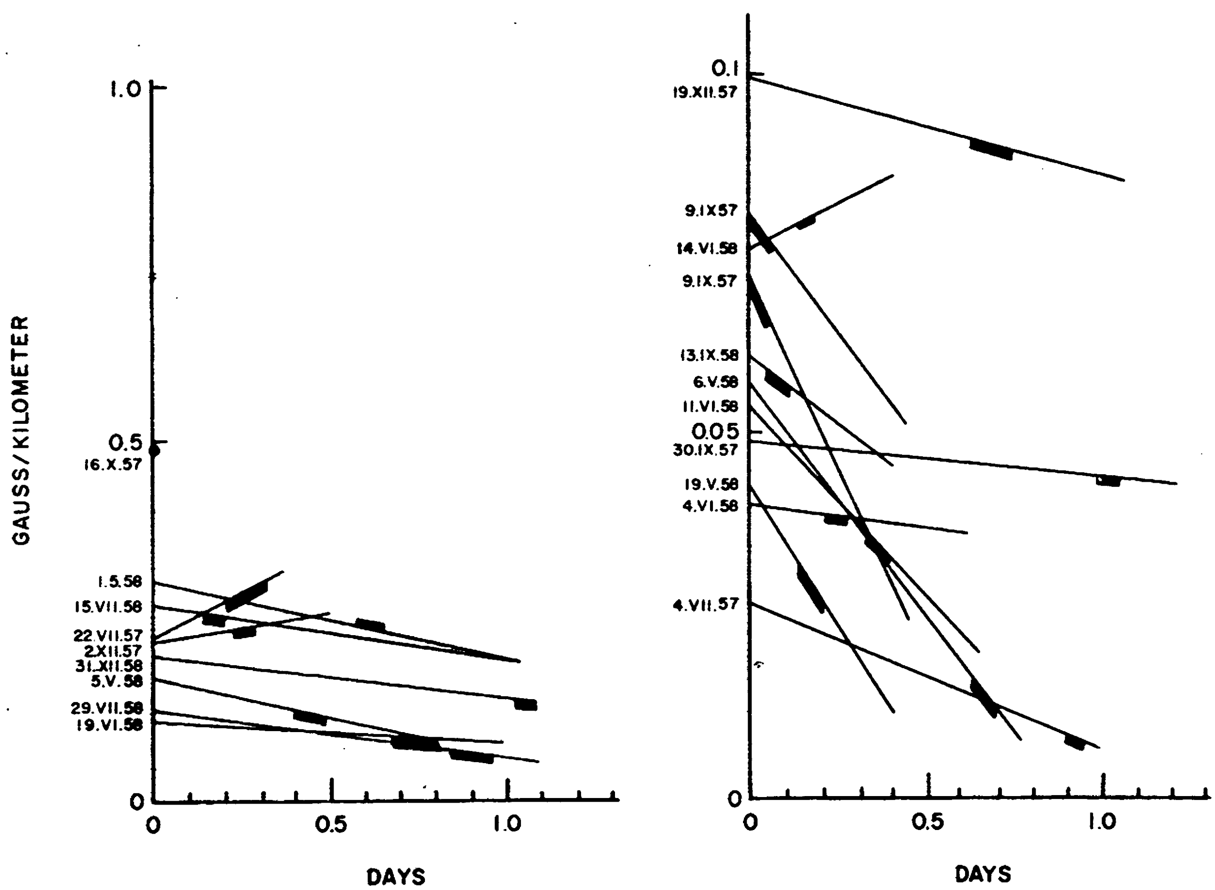
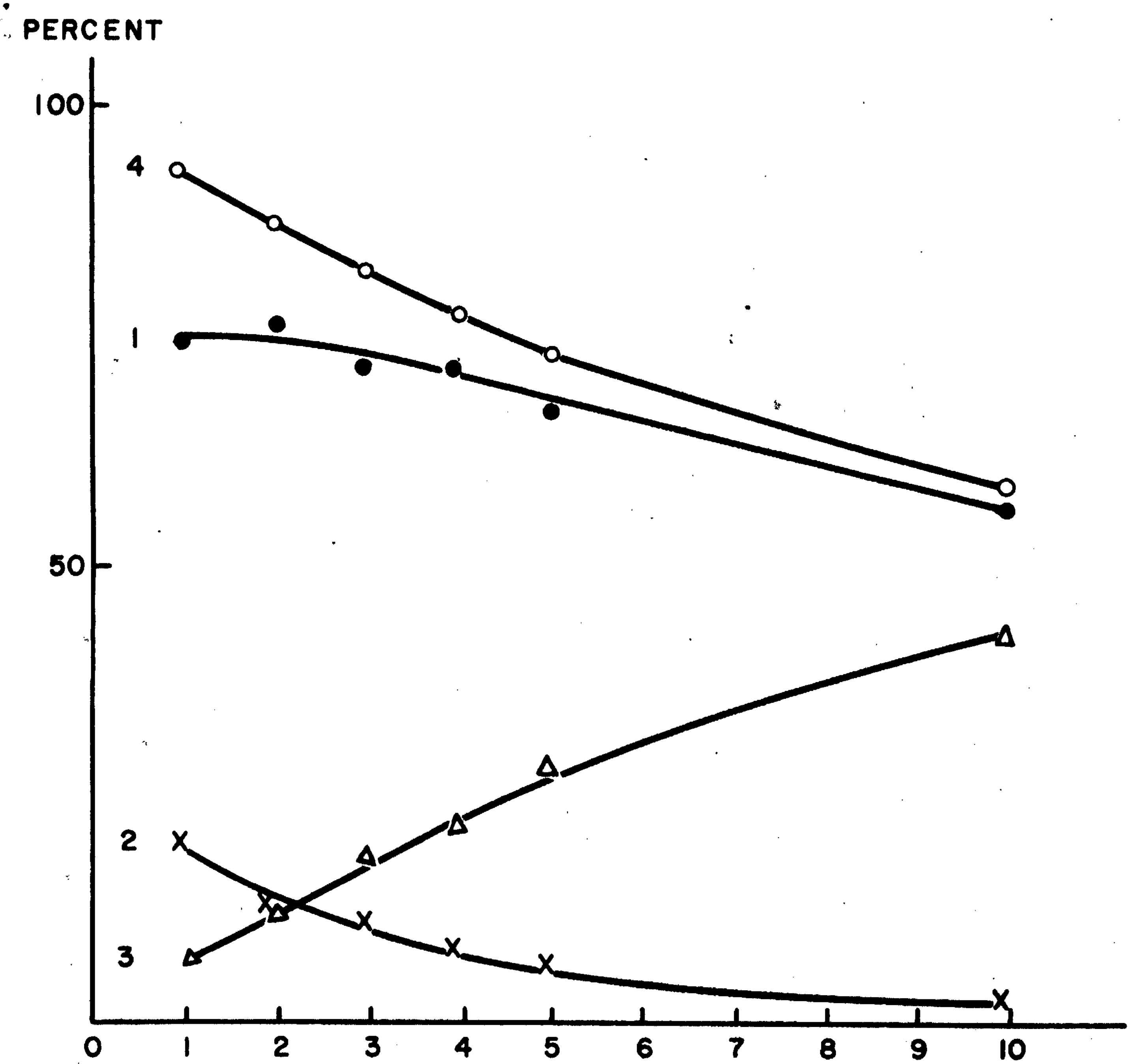

1.0
0.5
16.X.57
GAUSS/KILOMETER
1.5.58
15.VII.58
22.VII.57
2.XII.57
31.XII.58
5.V.58
29.VII.58
19.VI.58
0
0
0.5
1.0
DAYS
0.1
19.XII.57
9.IX.57
14.VI.58
9.IX.57
13.IX.58
6.V.58
11.VI.58
0.05
30.IX.57
19.V.58
4.VI.58
4.VII.57
0
0
0.5
1.0
DAYS

Fig. 3



1 — correct forecasts

2 — overestimated forecasts

3 — underestimated forecasts

4 — Sum or correct and overestimated forecast

Fig.4. Justification of forecasts for 1962