ON LONG-TERM FORECASTS OF PROTON FLARES*

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Abstract. 174 proton flares which were observed during the period from 1956 to 1965, occurred in 81 different active regions. It is shown that these active regions formed in complexes of activity, which stayed on the solar surface for many months, and in some cases even for several years. Since the proton-flare regions develop very rapidly and reach the proton-flare active stage within a few days, these complexes of activity represent the areas on the sun, where proton-flare regions can form at any time. Reference is made to contributions by Bumba and Howard, who investigated the birth of active regions and detected some properties of complexes of activity; nevertheless, at the present time, we do not know any method to predict when a proton-flare region begins to develop in such a complex of activity.

On the other hand, there is a chance of predicting the dangerous longitudes on the sun, as soon as such a complex of activity has been well recognized or, from the opposite point of view, to predict the safe proton-flare free periods on the sun. If, however, all the complexes on both the hemispheres are taken into account and every complex is considered 'proton-dangerous' from 2 days before to 7 days after the central meridian passage, one can prove that no proton-flare free periods existed for more than 3 years around the maximum of the last solar cycle. Applying this result to the present cycle, one can conclude that no safe forecasts of proton-flare free periods can be made from the beginning of 1968 to the end of 1970. During the remaining 7 or 8 years of the solar cycle, long-term forecasts of proton flares could be made provided that our knowledge of the formation and development of the complexes of activity is improved.

It is of interest to notice some properties of the complexes formed in the last solar cycle. While the complexes on the Northern solar hemisphere remained at fairly constant heliographic longitudes for many years, the complexes formed on the Southern hemisphere seemed to travel in two rows around the sun, in the direction opposite to the solar rotation. Another interesting fact is a yearly periodicity in the formation of proton-flare regions in the complexes of activity, with a maximum in the summer period and a deep minimum in the winter season. Such a seasonal variation also appears, if one considers the flare activity, type-IV bursts, PCA's, great magnetic storms, and magnetic crochets. Therefore, one can reasonably believe that this yearly variation, even when similar to the seasonal variation at the earth, is of solar origin.

1. Introduction

At the present time we can mostly recognize the active regions which are capable of producing proton flares, according to the sunspot configuration, the complexity and high gradients of the magnetic fields, intensive radio emission, appearance of loop-prominence systems and some other criteria. These typical properties of the proton-flare active regions, however, develop only shortly before the appearance of the proton-flare phenomenon. Forecasts of proton flares based on these criteria, call our attention to the active region only one, two, or three days before the flare appearance, because the development of such active regions is usually extremely fast. Therefore, it is quite clear that these methods cannot be used for long-term proton-flare fore-


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casts, which are necessary for manned space-flights leaving the close neighbourhood of the earth and which need an information on the proton-flare occurrence for a period of at least one week in advance.

To demonstrate this, we can use as a good example the proton flare of July 7, 1966, which has been the subject of study in the Proton-Flare Project. On the first two days of July, there was nothing suspicious on the solar disk. Only on July 3rd a very fast development of an active region began and two days later, on the 5th, the structure of the developing active region indicated that a proton flare might form in it. A proton-flare alert was announced and 1½ days later a proton flare actually appeared. For the purpose of a study of the proton flare, which was the main task of the Proton-Flare Project, this forecast was very successful; but it is quite clear that 5 days earlier, with our present knowledge, nobody could have any slightest idea that a proton flare might appear in that region of the solar surface.

Therefore, long-term forecasts of proton flares need quite different methods. We cannot recognize the dangerous active region a week before. But we can try to investigate what are the conditions in the solar atmosphere, which make the formation of such an active region possible.

2. Complexes of Activity

Let us discuss the period from the beginning of 1956 to the end of 1965. During these 10 years, there appeared 174 flares associated with type-IV radio bursts, which had the characteristics of proton flares (Švestka and Olmr, 1966; Frítzová and Švestka, 1966; Goedeke et al., 1967), in 81 different active regions. We have studied the development of these proton-flare regions, according to the McMath classification as published in the Compilation of Solar-Geophysical data. That is, we have followed each active region from its first appearance on the solar disk, through the subsequent solar rotations, up to its final decay and disappearance and we have plotted this development in a graph, which is shown in Figure 1.

Several interesting conclusions can be drawn from this diagram. First, we observe that the active regions producing proton flares are not randomly distributed on the solar disk, but they tend to occur in complexes of activity, which stay on the solar surface for many months, and in some cases even for several years. Thus, for example, we can see that there appeared 6 proton-flare regions in 1963 and 5 of them formed in one complex of activity lasting for 14 months. One complex which appeared on the Northern hemisphere close to the maximum, can be followed on the solar disk for 2½ years and during that time it produced proton flares or series of proton flares 9 times when passing over the visible solar hemisphere.

This does not mean that an active region producing proton flares is continuously present on the disk in the area of such an activity complex. But the newly born proton-flare regions always form in a similar position on the disk and in this way the proton-flare activity is maintained in a given part of the solar surface for a fairly long time.