LOOP-PROMINENCE SYSTEMS AND PROTON-FLARE ACTIVE REGIONS

Z. ŠVESTKA
(Astronomical Institute of the Czechoslovak Academy of Sciences, Ondřejov, C.S.S.R.)

ABSTRACT

It is shown that proton flares and loop-prominence systems form in the same type of active regions. Quite often both these phenomena appear simultaneously, but there are also many cases, when only the proton flare or only the loop-prominence system fully develops. The proton-flare active regions 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 even years. Attention is called to the peculiar clustering of proton-flare regions on the Southern hemisphere, where two sources of activity, at a longitudinal distance of about 180°, seemed to move on the solar disk between 1956 and 1962 opposite to the solar rotation, shifting in the longitude at about 70 heliographic degrees per 10 solar rotations.

In my contribution, I would like to discuss very briefly two problems – the occurrence of loop-prominence systems in active regions which produce proton flares, and the occurrence of such proton-flare active regions in complexes of activity.

In 1964, Bruzek called attention to the fact that all loop-prominence systems observed on the disk were associated with proton flares, and he concluded that this association of loop-prominence systems with proton flares was a general characteristic of these two active phenomena (Bruzek, 1964).

We have tried to verify this conclusion of Bruzek using the catalogue of flares associated with type-IV radio bursts prepared by Olmr and myself (1966). This catalogue, containing 174 events, can also be considered for a list of proton flares which appeared on the Sun from 1956 to 1963, and we compared it with 65 loop-prominence system occurrences, taken from lists prepared by Bruzek (1964) and Kleczek (1967). We have verified that all 24 loop-prominence systems observed on the disk were preceded by proton flares listed in the catalogue, in full agreement with Bruzek's results. Of course, one must not forget that Bruzek tried to find loop prominences in this type of flares and, therefore, he might perhaps have missed some other events. For the limb-prominence systems the situation is quite different. Only 9 events of the 40 observed limb systems were clearly preceded by proton flares. It is true that, due to the directional sensitivity at long wavelengths, the classification of type-IV bursts for flares close to the limb is difficult, but one can hardly believe that we could have missed 31 type-IV bursts out of the total number of 40. And this is also supported by the fact that 14 events of these loop-prominence systems were observed on the Western solar limb without any PCA effect, which accompanies the proton flares

Kiepenheuer (ed.), Structure and Development of Solar Active Regions, 287–292.

close to the Western solar limb in about 80% of the cases (Fritzová and Švestka, 1966).

Finally, Figure 1 presents a proof that loop-prominence systems need not be necessarily associated with proton flares. It shows loop prominences accompanying the flare of July 9, 1966, which was no proton flare – no particles were observed in the space – but it formed in the same active region as the proton flare of July 7, studied in detail in the Proton Flare Project.

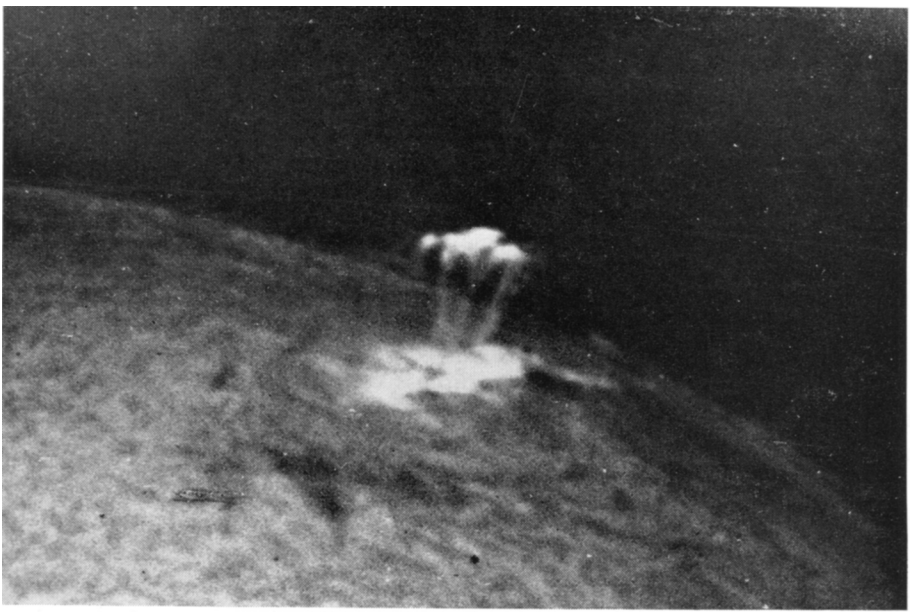

FIG. 1. *Loop prominences following the flare of August 9, 1966 (picture taken by B. Valníček at Ondřejov at 5^h51^m UT).*

Therefore, we have to conclude that, in fact, loop-prominence systems also occur without any simultaneous proton-flare appearance. But we also have found – and this, I think, is important – that the vast majority of limb-prominence systems, even if not directly connected with proton flares, appear in active regions, which produce proton flares on the Sun.

When preparing another report, for the COSPAR meeting in London in July 1967, we have studied the development of these proton-flare regions, according to the McMath classification as published in the Compilation of Solar-Geophysical Data (Švestka, 1968). 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 the development in a graph, which is shown in Figure 2. The left part refers to the Northern, the right part to the Southern solar

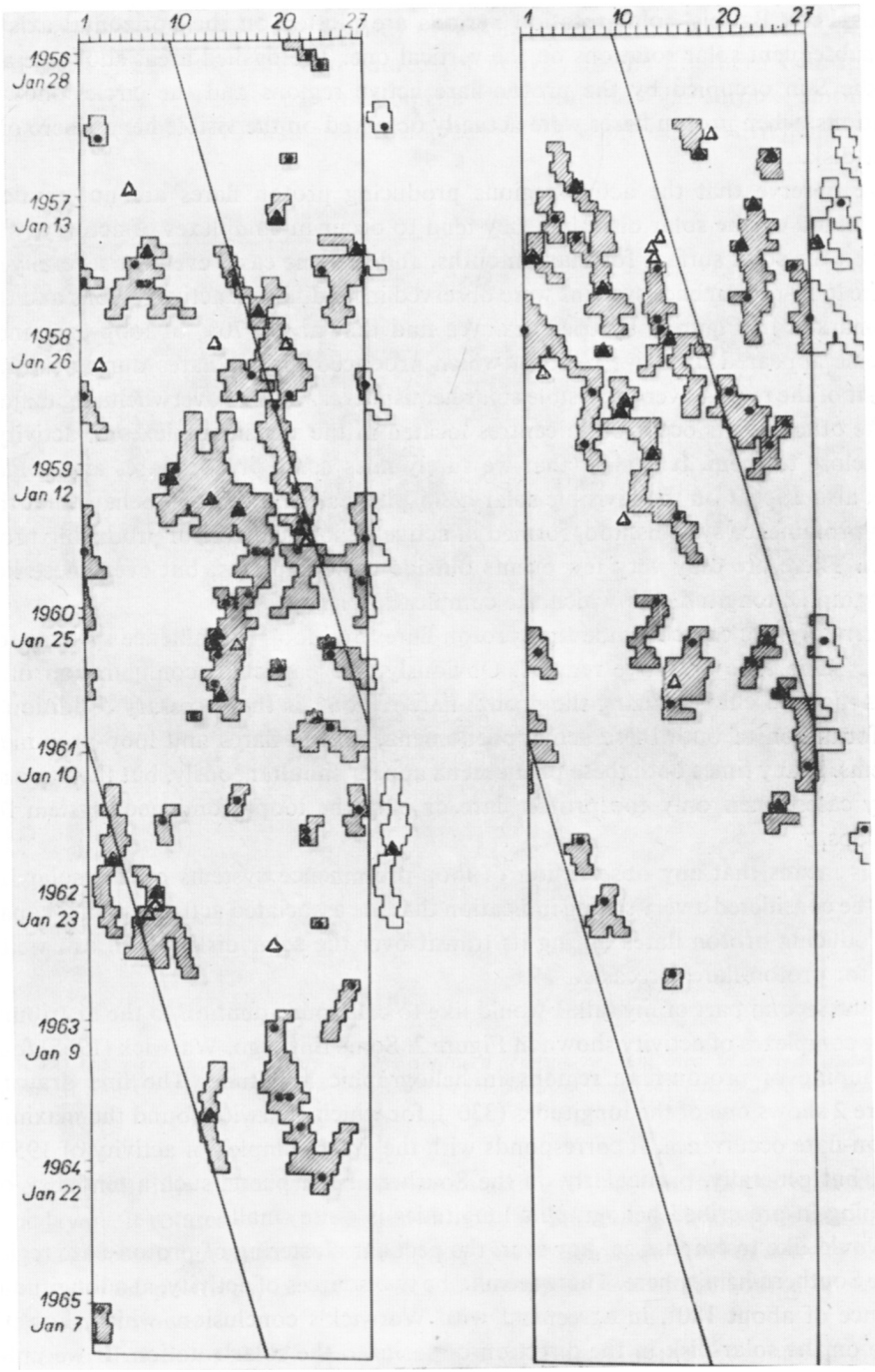

FIG. 2. *Longitudes on the Sun occupied by proton-flare active regions. For details see text.*

https://doi.org/10.1017/S0074180900021677 Published online by Cambridge University Press

hemisphere. Bartels' solar rotation periods are plotted on the horizontal axis and the subsequent solar rotations on the vertical one. The dashed areas show the areas on the Sun occupied by the proton-flare active regions and the circles show the rotations, when proton flares were actually observed on the visible hemisphere of the solar disk.

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.

The loop-prominence systems were observed in 41 different active regions and these are marked in Figure 2 by triangles. We find that about 70% of loop-prominence systems appeared in active regions, which produced proton flares during the same transit of the region over the visible solar hemisphere. And the overwhelming majority of the other events occurred in centres located in the same complexes of activity or very close to them. It is clear that we surely miss some proton flares and some of them also appear on the invisible solar hemisphere so that one can believe that these loop-prominence systems, too, formed in active regions capable of producing proton flares. There are only very few events outside the complexes, but even these lie in heliographic longitudes in which the complexes form.

Therefore, we can conclude that proton flares and loop-prominence systems form in the same type of active regions. Obviously, the particular configuration of the magnetic field characterizing the proton-flare regions, is the necessary condition for the formation of both these active phenomena, proton flares and loop-prominence systems. Many times both these phenomena appear simultaneously, but there are also many cases when only the proton flare or only the loop-prominence system fully develops.

This means that any observation of loop-prominence systems on the solar limb must be considered a very strong indication that the associated active region is capable of producing proton flares during its transit over the solar disk, which can well be used for proton-flare forecasts.

In the second part of my talk I would like to call your attention to the distribution of the complexes of activity shown in Figure 2. Some time ago, Warwick (1965) found a grouping of proton-flare regions in heliographic longitude. The line drawn in Figure 2 shows one of the longitudes (330°), for which Warwick found the maximum proton-flare occurrence. It corresponds with the great complex of activity of 1957 to 1960, but generally, particularly on the Southern hemisphere, such a tendency of a grouping in prescribed heliographic longitudes is quite small.

I would like to emphasize, however, the peculiar clustering of proton-flare regions in the Southern hemisphere. There seem to be two sources of activity, at a longitudinal distance of about 180°, in agreement with Warwick's conclusion, which, however, move on the solar disk in the direction opposite to the solar rotation. If we unfold the diagram in several subsequent rotations, we can follow these two active areas in

the Southern hemisphere from 1956 to 1962 (Figure 3). If this were a real effect, it would show that there were two sources of activity in the Southern hemisphere, which rotated more slowly than phenomena visible on the solar surface, shifting in the longitude at about 70 heliographic degrees per 10 solar rotations. When looking

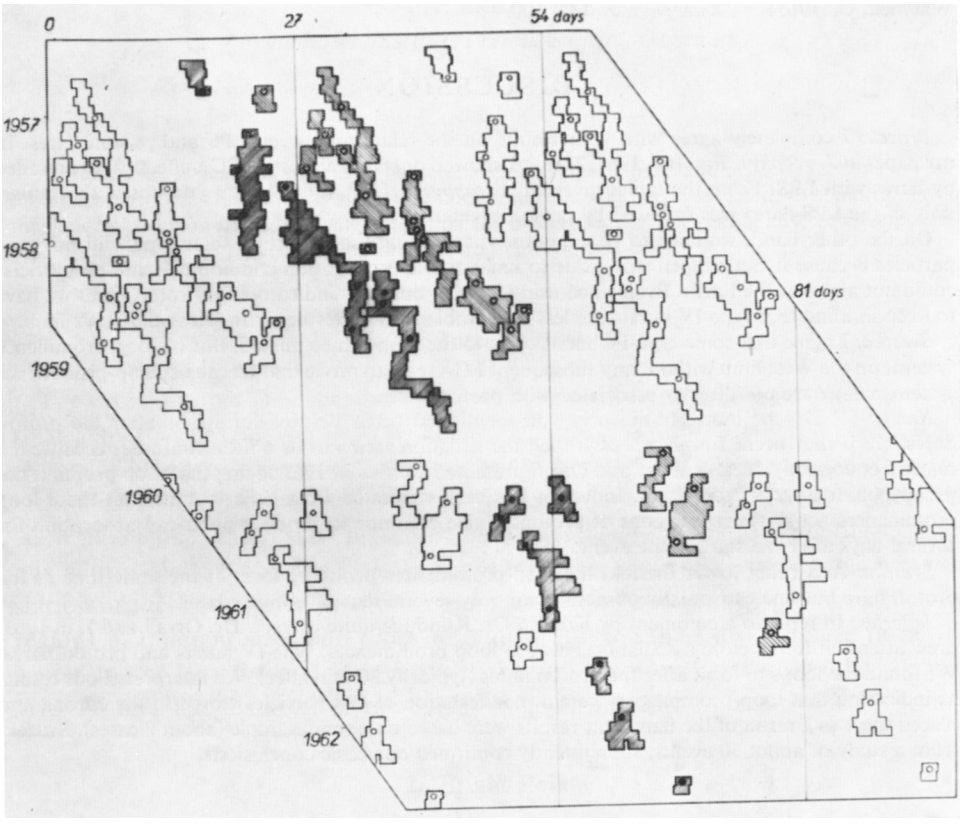

FIG. 3. *The right part of Figure 2 (the Southern hemisphere) unfolded in several subsequent rotations. It shows a shift of two active longitudes in the Southern hemisphere from 1956 to 1962.*

at the diagram, it is clear that as soon as an active region forms in the solar atmospheric layers, it rotates with the normal velocity of the solar rotation (one can see the vertical columns); but entirely new active regions or new complexes of activity always form in shifted positions, in accordance with the position of the source of activity which rotates slower.

It seems that this shift, if proved real, might give us some information on the variation of the rate of solar rotation with the depth.

https://doi.org/10.1017/S0074180900021677 Published online by Cambridge University Press

References

Bruzek, A. (1964) *Astrophys. J.*, **140**, 746.
Fritzová, L., Švestka, Z. (1966) *Bull. astr. Inst. Csl.*, **17**, 249.
Kleczek, J. (1967) private communication.
Švestka, Z. (1968) *Solar Phys.*, **4**, in press.
Švestka, Z., Olmr, J. (1966) *Bull. astr. Inst. Csl.*, **17**, 4.
Warwick, C. (1965) *Astrophys. J.*, **141**, 500.

DISCUSSION

Bruzek: I completely agree with your results on the relation between LPS and proton flares. In my paper in *J. geophys. Res.* (**69**, 1964, 2386)* I showed only that almost all PCA effects were preceded by flares with LPS. From the tables given in *Astrophys. J.* (**140**, 1964, 747)** you notice that a part only of the LPS-flares was followed by proton events.

On the other hand, we have to be cautious when stating that a certain solar event did not emit particles because it can happen that – due to unfavorable propagation conditions – emitted particles could not arrive at the Earth. Even when using type-IV bursts as indicators for proton flares we have to keep in mind that type-IV bursts are less observable from flares occurring near the Sun's limb.

Švestka: I agree that some type-IV bursts close to the limb can be missed. But 14 loop-prominence systems on the West limb without any subsequent PCA seem to prove that there exist loop-prominence systems which are not directly associated with proton flares.

Kundu: (1) Do the loop prominences you mentioned occur before, during, or after the proton flares? (2) If they occur simultaneously, then the situation seems to be a little confused, because if I remember correctly, Drs. Jefferies and Orrall presented a paper in 1963 saying that loop prominences usually occur after proton flares. Indeed it has been suggested from time to time that these loop prominences act as storage regions of protons which continue to produce polar-cap absorption for several days after the start of the event.

Švestka: According to Dr Bruzek, the loop prominences probably form at the same time as the proton flare but one can usually observe them only several tens of minutes later.

Jefferies: In reply to a comment by Kundu, Dr. Kundu is quite correct. Dr. Orrall and I, in 1963, drew attention to the close association between loop prominences, type-IV bursts and proton flares. We found the loops to form after the proton flares (typically 30 min later). We interpreted our results as indicating that loop prominences were a manifestation of fast particles stored in the corona and placed there as a result of the flare. Our results were based on a small sample (about 8 cases). Bruzek, from a study of about 50 events, subsequently confirmed our basic conclusions.

* 'Optical Characteristics of Cosmic Ray and Proton Flares'.
** 'On the Association between Loop Prominences and Flares'.