JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN Vol. 17, SUPPLEMENT A-II, 1962
INTERNATIONAL CONFERENCE ON COSMIC RAYS AND THE EARTH STORM Part II

II-5-3. Ejection of Plasma with the Magnetic Field and Low-Energy Solar Cosmic Rays from the Region* of Chromospheric Flares

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During the period of 1957–1960 the relationship between the polar-cap absorption ($f_{\min}$) and magnetic storms with sudden commencement (SC) was examined in connection with solar flares accompanied by the type IV solar radio outburst. From the analyses of observed data conclusions were made about the generation of the high-energy protons (~10–100 Mev) on the sun. It is supposed that the ejection of high-energy protons from active region takes place simultaneously with the ejection of the plasma which causes magnetic storm with sudden commencement[1,2]. From the considerable time-delay in the arrival of high-energy protons, the duration and isotropy of the precipitation of the protons in the polar cap conclusions were made about the existence of an approximately radial magnetic field with irregularities in the interplanetary space.

It is supposed that the source of this field is the local magnetic field of the active regions and the general magnetic field of the sun, carried away by the motion of ejected plasma. This conclusion is supposed by the fact that the more rapid arrival of protons from a flare is observed, if another flare has occurred in this region earlier, to cause a magnetic storm. This means that the protons are injected in an approximately radial magnetic field. Such a field is produced by the plasma which has earlier been ejected from this active region[1,2].

While the magnetic field remains rooted in the active region of the sun, the rotation of the sun causes it to become twisted as far as at the distance of 1 a.u. The difference between the time-delays of the arrivals of high-energy protons ejected by the flares occurring on the eastern and western hemisphere of the sun, supports this conclusion.

It is established that solar flares, which generate high-energy protons ("proton" flares), cause also sudden commencement magnetic storms with small time-delay (Fig. 1) and large amplitude SC. These magnetic storms are accompanied by a sharp and deep Forbush decrease (Table I). The precipita-

Table I. The Forbush decrease's amplitude in the intensity of the galactic cosmic rays for two groups of magnetic storms.

The magnetic storms associated with flares which development was accompanied by generation of protons with energy 10–100 Mev.	The magnetic storms associated with flares which development was not accompanied by generation of protons with energy 10–100 Mev.
$\bar{A}_N=4.5\pm0.75\%$ (14 storms)	$\bar{A}_N=3.5\pm0.45\%$ (14 storms)
$\bar{A}_N^{\dagger}=7.2\pm0.77\%$ (17 storms)	$\bar{A}_N^{\dagger}=4.5\pm0.38\%$ (20 storms)
For the flares and storms with a large number of protons.	For the magnetic storms with SC which are not identified with flares.
$\bar{A}_N=5.2\pm1.0\%$ (7 storms)	$\bar{A}_N=3.0\pm0.5\%$ (10 storms)
$\bar{A}_N^{\dagger}=8.6\pm0.33\%$ (10 storms)	$\bar{A}_N^{\dagger}=4.3\pm0.4\%$ (16 storms)

$\bar{A}_N$=Forbush decrease's amplitude for IGY period averaged along 50° geomagnetic parallel's station.

$\bar{A}_N^{\dagger}$=Forbush decrease's amplitude for 1957–1959 period averaged on the station: Moscow, Herstmonceux, Crimean Observatory.

* This paper was read by A. I. Lebedinsky.

tion of high-energy protons in the polar cap simultaneously with the onset of a sharp Forbush decrease account for the arrival of the high-energy protons together with the plasma carrying away the magnetic field.

The above facts, as well as the very important circumstance that the energy carried away by high-energy protons is more than (or equal to) the energy of ejected plasma (corpuscular stream), allow to consider the high-energy protons (as well as a component of very hot gas accelerated to less values of energy) as the agent of the pressure which pushes out the field and plasma from the active region. It is pointed out that intensive (up to 500 gauss) magnetic fields penetrate into the chromosphere in the regions of sunspots[3]. Magnetic fields with strengths $\sim$300 gauss transported by the movement of the plasma of limb flares have been found at heights 20000–30000 km above the limb[4]. Radioastronomical observations show that intensive magnetic fields may penetrate into the chromosphere and corona. For the duration of type IV radio outbursts (which is approximately several hours long) points out, that it is during this time that the electrons with $E \sim 10^8$ ev energy must be trapped in the local region of the corona having linear size $L \sim 5 \times 10^{10}$ cm. The appearance of large type IV radio outbursts, after which the precipitation of high-energy protons in the polar cap is observed, is closely associated with the occurrence of large solar flares as well as type II radio bursts which are characterized by drift to lower frequencies.

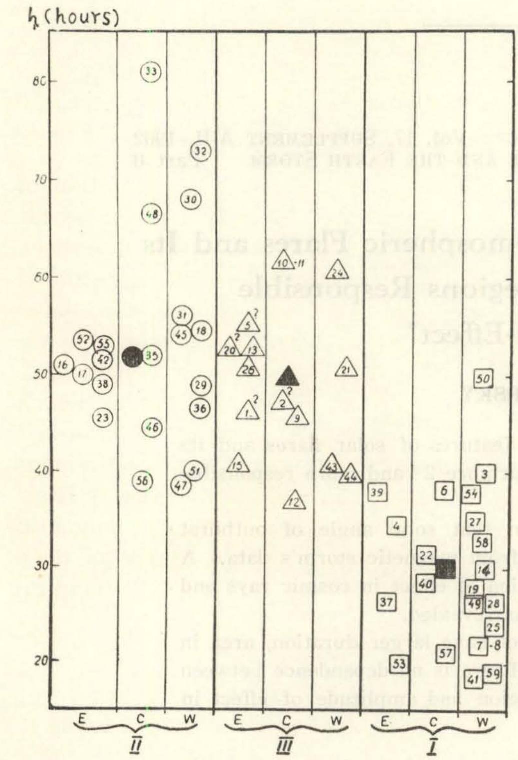

Fig. 1. The time-delay of magnetic storms (in y-direction) was plotted for three groups of chromospheric flares (in x-direction). The time-delay of *SC* magnetic storms identifying with flares development of which is accompanied by generation of large number of protons with energy 10–100 Mev denoted by the squares. A position of circle corresponds to the time-delay of magnetic storms associated with flares which development are not accompanied by generation of protons. The time-delay of magnetic storms of the intermediate group meaned by the triangle. The quantity in each sign correspond to the number of flare in Table I and from Refs. (1) and (2).

If one assumes that acceleration of high-energy protons and electrons ($E \sim 10^8$ ev) takes place as early as during the flash phase of the development of the flare, the delay of the type IV radio outburst in relation to the onset of the flare and type II radio outburst, as well as a gradual increase of intensity of the type IV radio outburst may bear evidence out that the radiating cloud of plasma in time ascends into the higher layers of the corona. During the development of the solar limb flares[5,6] causing the increases of cosmic ray intensity at earth, bright loops, expanding with high, $\sim 10^8$ cm/sec, transverse velocities, were observed in the coronal region. Thus, optical and radioastronomical observations allow to suppose that the pressure of accelerated particles (and very hot gas) forces out the magnetic field and plasma from the active region.

As can be seen from flares[10], Ref. 10, flares the development of which is accompanied by the generation of high-energy protons and an ejection of plasma with magnetic field, appear in active regions with magnetic field of very complicated structure. Photoelectric recordings show the presence in these regions of large gradients of field[7]. As it was pointed out by A. B. Severny[8,9] instability of plasma in such conditions must lead to the appearance of flares accompanying by the generation of high-energy protons up to relativistic energies.

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II-5-4. Some Features of Chromospheric Flares and Its Corresponding Active Regions Responsible for Forbush-Effect*

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An attempt was made to reveal some features of solar flares and its active regions by analysing flares of importance 2^+ and more responsible for Forbush decrease.

Data of IGY are used. It was shown that solid angle of outburst exciting Forbush-effect is the same as from magnetic storm's data. A dependence between amplitude and duration of effect in cosmic rays and longitude of corresponding solar flare was revealed.

The flares connected with Forbush-effect have larger duration, area in the maxima and larger intensity in H_α. There is no dependence between strengths of magnetic field in active region and amplitude of effect in cosmic rays.

1. It is very important to study a connection between the parameters of Forbush-effects and those of corresponding solar flares (and its active regions) for clearing up some features of a corpuscular streams (responsible for SC magnetic storms) and understanding the mechanism of its outburst.

The parameters of Forbush-effects found in Refs. 1, 2 and 3 were compared with some parameters of solar flares and their active regions on the day of the flare. The data for the comparison were Refs. 4, 5 and 6, and "Catalogue of solar magnetic fields" prepared at the Crimean Astrophysical Observatory.

2. First of all it was interesting to know whether there is a connection between an importance of the flare and its heliographical co-ordinates on one side effectivity of the flare in exciting of Forbush-effect on the other side. The data about the flares of the importance more than 2^+ were used. It was found that among 7 flares of the importance 3^+ six were effective, and among 31 flares of the importance 3 and 82 of the importance 2^+ there were accordingly 8 and 7 effective ones.

A dependence between a number of the

* This paper was read by A. I. Lebedinsky.