ISSN 0010-9525, Cosmic Research, 2011, Vol. 49, No. 4, pp. 308–318. © Pleiades Publishing, Ltd., 2011.
Original Russian Text © V.I. Sidorov, Yu.V. Kuzminykh, S.A. Yazev, 2011, published in Kosmicheskie Issledovaniya, 2011, Vol. 49, No. 4, pp. 318–328.

Solar Flare with a Surge: Scenario, Energy Budget, and Forecast

V. I. Sidorov[1, 2], Yu. V. Kuzminykh[1], and S. A. Yazev[1, 2]

[1] *Institute of Solar-Terrestrial Physics, Siberian Branch of Russian Academy of Sciences, Irkutsk, Russia*
[2] *Astronomical Observatory of Irkutsk State University, Irkutsk, Russia*

Received June 2, 2009

Abstract—Based on the analysis of solar events on August 18, 1995 (SN/C1.9 limb event) and September 23, 1998 (3B/M6.9 disk event) we suggest a new scenario of a solar flare with a surge in which the return motion of a surge is a cause of additional energy release and formation of a second system of solar flare ribbons. Observations in H_α line and data on x-ray emission fluxes in the range 1–8 Å and 0.5–4 Å are supplemented for the second case by the data in line 1550 Å. The scenario specifies two stages of development. During the first one the energy release proceeds in the current layer, which makes provisions both for acceleration of eruption upward from the solar surface and for the flare itself, including flare region heating, and radiation and thermal conductance losses. The second stage of the flare is supplied with energy due to a fall of the surge substance onto the chromosphere. The second pair of flare ribbons observed at this stage is suggested as a chromospheric criterion of realization of this scenario for disk flares. The energy released during the first stage of the flare on September 23, 1998 was equal to $\sim 3 \cdot 10^{31}$ erg. Its part consumed on flare processes is about $\sim 0.5 \cdot 10^{31}$ erg. The remaining part representing the eruption energy is consistent in order of magnitude with a calculated value of the flare energy on the second stage, which does not contradict the suggested scenario. Early recognition of such a scenario for flares on the disk can be used for prompt space weather forecast. In particular, a flare with a surge allows one to predict the absence of a bright core in a coronal mass ejection.

DOI: 10.1134/S0010952511030099

INTRODUCTION

In paper [1] a topological model is presented that provides for a common mechanism of formation of a strong solar flare and a coronal mass ejection. This model is based on the analysis of chromospheric phenomena observed during powerful flares in active complexes and large active regions on the Sun. In particular, such types of flare active structures as ring-like bright structures on the ends of flare ribbons (SEFR) and dynamic emission peripheral structures (PS) [2] were found, described, and explained in the context of the above model. According to the model, SEFR and PS represent the bases of an arc large-scale magnetic flux rope at different stages of its evolution. In the process of eruption this rope is elevated to the corona forming there a coronal mass ejection (CME).

In this paper, which is a continuation of the first one, it is shown that the phenomenon of so-called surges can be explained using the same approach. As is known, the surge phenomenon observed on the limb in light of chromospheric lines consists in the following. Quick eruption of prominence matter is observed during a limb flare, which is well seen in the picture plane as lifting (expansion) of the prominence upwards, away from the Sun. Further on, this motion is slowed down with subsequent passage to back relocation of ejected matter along magnetic field lines downwards to the chromosphere. Apparently, similar phenomena are observed on the disk as well. However, it is difficult to reveal them due to overlapping of different directions of motion of matter in a flare along the line of sight and because of ambiguous interpretation of concomitant manifestations of the Doppler effect.

It is shown in this paper that some types of flare chromospheric phenomena observed on the solar disk can be interpreted as eruption of prominences with subsequent fall of ejected matter back on the chromosphere. The observed phenomena find their explanation in the concept of a powerful solar event developed by the authors. According to it, every such event includes a flare and mass ejection. The concept admits realization of at least two variants of the event scenario. In the first variant the matter is thrown away into the interplanetary space forming a CME with a bright core [3]. In the second variant the matter of an eruptive prominence falls back on the Sun and, hence, even if a CME is formed, most likely, it has no core [3]. The analysis of complex data of observations allows one to suggest that, based on the character of development of bright chromospheric structures (flare ribbons FR, SEFR, and PS), one can perform early diagnostics of an event and draw conclusion whether the event will be accompanied by a coronal mass ejection or by a surge. Usually, it is difficult to observe such phenomena on the disk: if an event occurs on the disk, in this case both CME and surge move to an observer. On the background of bright solar disk, because of quick changes of temperature and due to a small variable density of the ejected matter, the development of eruptions can be hidden from an observer. If growing CME has no bright core and its angle of divergence is small, it enters the field of view of a coronagraph beyond the central mask when the CME density is already insufficient for precise diagnostics. In another variant of ejection development the eruptive surge also can be masked by bright details of a flare event on the disk. Unambiguous interpretation of such phenomena turns out to be a difficult task, especially when there are no observations made by coronagraphs LASCO onboard the *SOHO* spacecraft and in some other ranges of wavelengths. The results of this paper allow one to determine observational criteria according to which identification of the event type at observations on the disk is simplified.

FLARE WITH SURGE ON AUGUST 18, 1995

In order to study the scenario of the type 'flare – surge' we have made a sufficiently comprehensive analysis of the limb event on August 18, 1995. Though this event included a flare of small power, it clearly demonstrates typical features of this class of phenomena.

We have used observations of the BBSO observatory made in line H_α. Simultaneous development of the flare and eruptive prominence was well seen on the east limb. The flare SN/C1.9 was observed from 17:17 UT (here and below the universal time is used) up to 18:02 with a maximum of development at 17:22 (Fig. 1) [4]. The maximum of the X-ray burst was recorded at 17:11.

One of the bases of the arc prominence was compact and located immediately near the flare arcade, another base was located at a considerable distance from the flare region. A spiral spin-up of lengthwise strands of the magnetic rope along the arc clearly reveals itself in the prominence structure. While there were no discernible changes in first base during the flare, the second base was significantly elongated at the phase of maximum of the flare. The first (compact) base became wider with height and resembled an inverted truncated cone. In the second (remote) base the process of untwisting of curled structure of the prominence above the chromosphere was observed. It should be noted (Fig. 1) that chromospheric flare emission in the remote base was stronger at its ends in comparison with the situation in the center. If this situation were observed at another aspect angle (flare on the disk), chromospheric emission at this base, apparently, would look as a bright ring on the chromospheric background, similar to SERF.

Variations of the height of several characteristic elements of the prominence are presented in Fig. 2, as well as the plot of soft X-ray emission (1–8 Å) according to the data of *GOES* spacecraft. Unfortunately, the interval of observations of the prominence does not cover the onset of the X-ray flare. However, retrospective projection of positions of characteristic details of the prominence onto the surface of the Sun convince that the flare onset and eruption of the prominence have occurred simultaneously, which indicates to a possibility of existence of a common source of energy for the flare and for the prominence eruption.

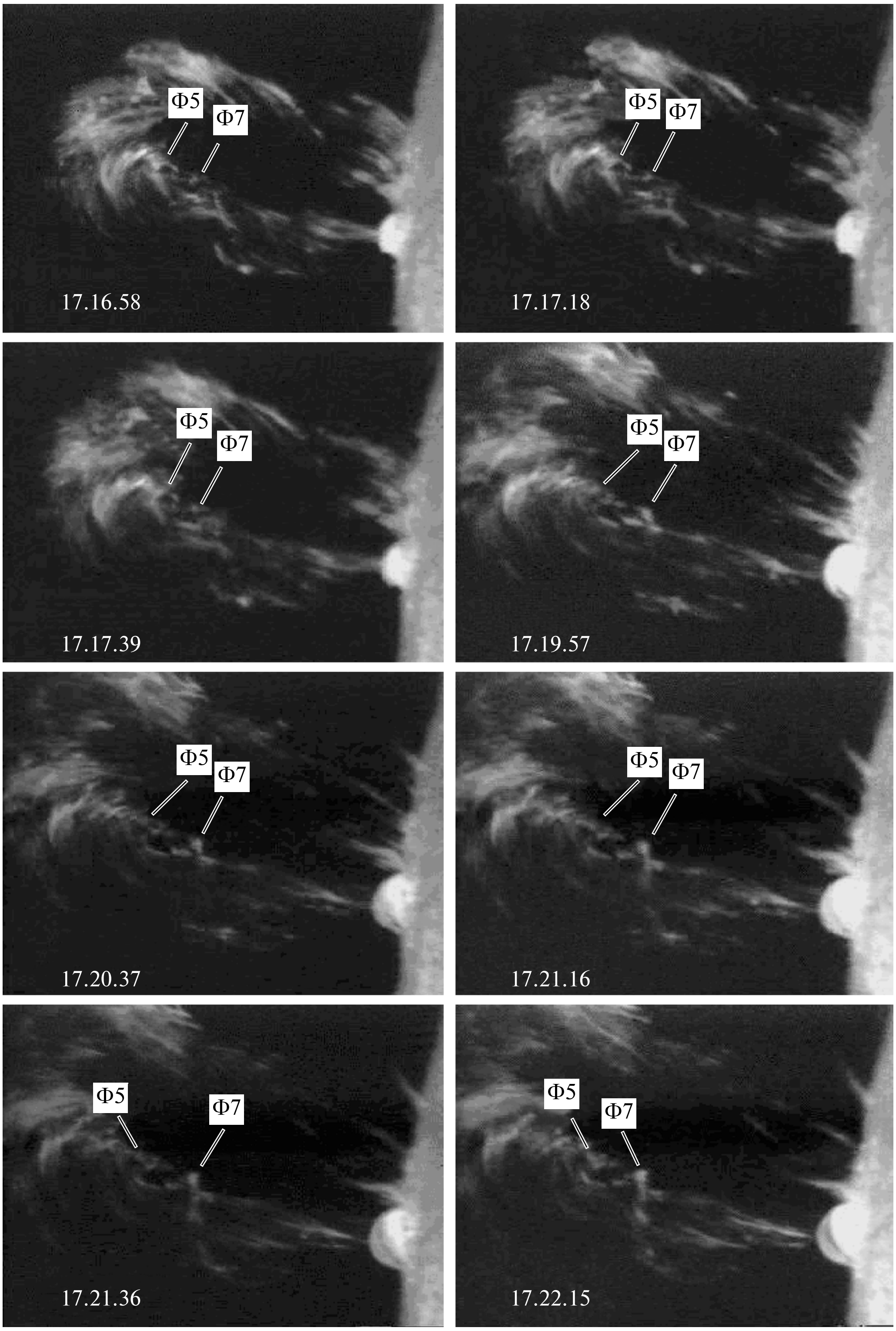
At the second stage of the event a weakening of emission of the flare arcade was observed. Matter of the prominence was falling down, which was accompanied by chromospheric emission at its bases. The second, relatively small maximum of X-ray burst near 17:50 can be interpreted as an evidence of additional flare energy release due to falling matter of the prominence. Magnetic strands of the prominence, which at the maximum exceeded the height of flare loops by an order of magnitude, descended by a factor of 1.5–2. Their structure has become essentially simpler, strands of the magnetic rope of the prominence has formed the upper layer of loops above the decaying flare. The above-described processes of evolution of the limb event of August 18, 1995 allow us to suggest a new scenario of development of the flare accompanied by a surge phenomenon.

ENERGY BUDGET OF THE FLARE WITH A SURGE

The proposed scenario includes two stages of development of the event.

The first stage lasts from the event onset until maximum elevation of the prominence into the corona. An important element of this scenario is insufficient boost of the ejection (in order to overcome attraction of the Sun). It motion upwards is slowed down and stopped at an altitude close a value of the solar radius above the photosphere level [3]. The ejection is observed in the form of a system of twisted filaments (magnetic rope) rooted in one base near flare ribbons. The contact of helical magnetic loops of the ejection with flare loops [1] (see Fig. 1 in [1]) determines the place of primary energy release. The fact of coinciding time intervals of ejection boost and increasing flare emission observed in H_α line seems to be very important.

Energy processes at the first stage of the event can be represented as follows. The primary energy release (flare power flux in the current layer) supplies with energy both the flare located below (including heating of the flare region together with losses through emission and thermal conductance) and the ascending prominence. Leaving the issue of a mechanism of ejection acceleration beyond this study, one can suggest that a part of the magnetic energy of electric current that is released in the process of reconnection is transformed into kinetic energy of ascending matter. Upon reaching the maximum height of elevation this energy is converted into potential energy of the matter contained in the ejection. It is natural to suppose that a store of non-potential energy of the magnetic field is



2 **Fig. 1.** The flare with a surge on August 18, 1995 (the data of BBSO). Arrows on filtrograms show characteristic long-living plasma blobs Φ5 and Φ7.

spent in the event nonuniformly, and its part responsible for elevation of the prominence decreases with time, which is a main cause of its slowing down and stopping. Accordingly, the flux of released non-potential magnetic energy supplying the flare also drops down to the end of this stage. One can suggest that the

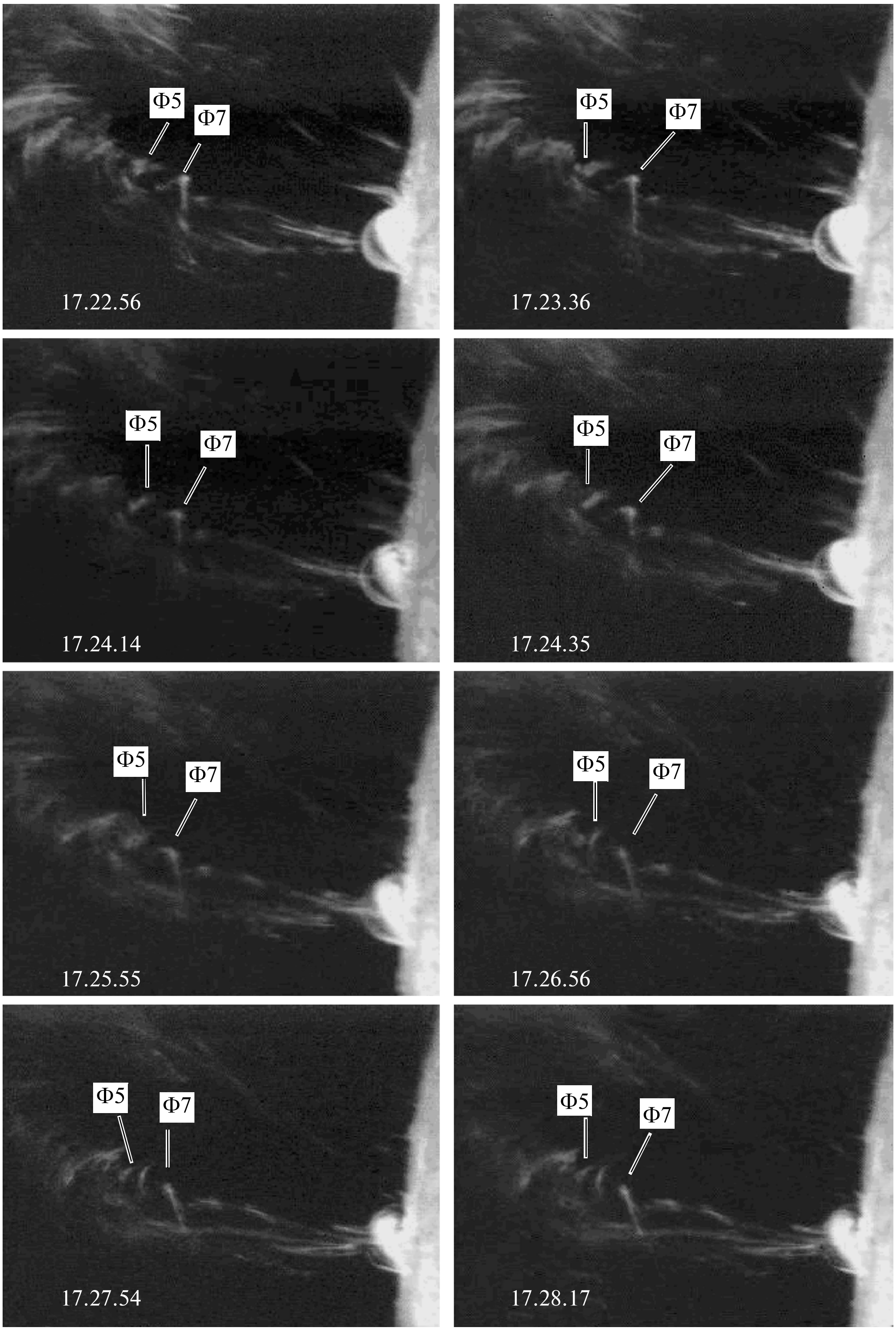


Fig. 1. Contd.

prominence energy is equal to the total energy of the event minus the energy spent during the first stage for the flare. A method of corresponding calculations is described in [5].

At the second stage emission of flare ribbons decreases, as well as the velocity of their divergence. Matter of the prominence falls back onto the chromosphere moving along its helical magnetic field lines.

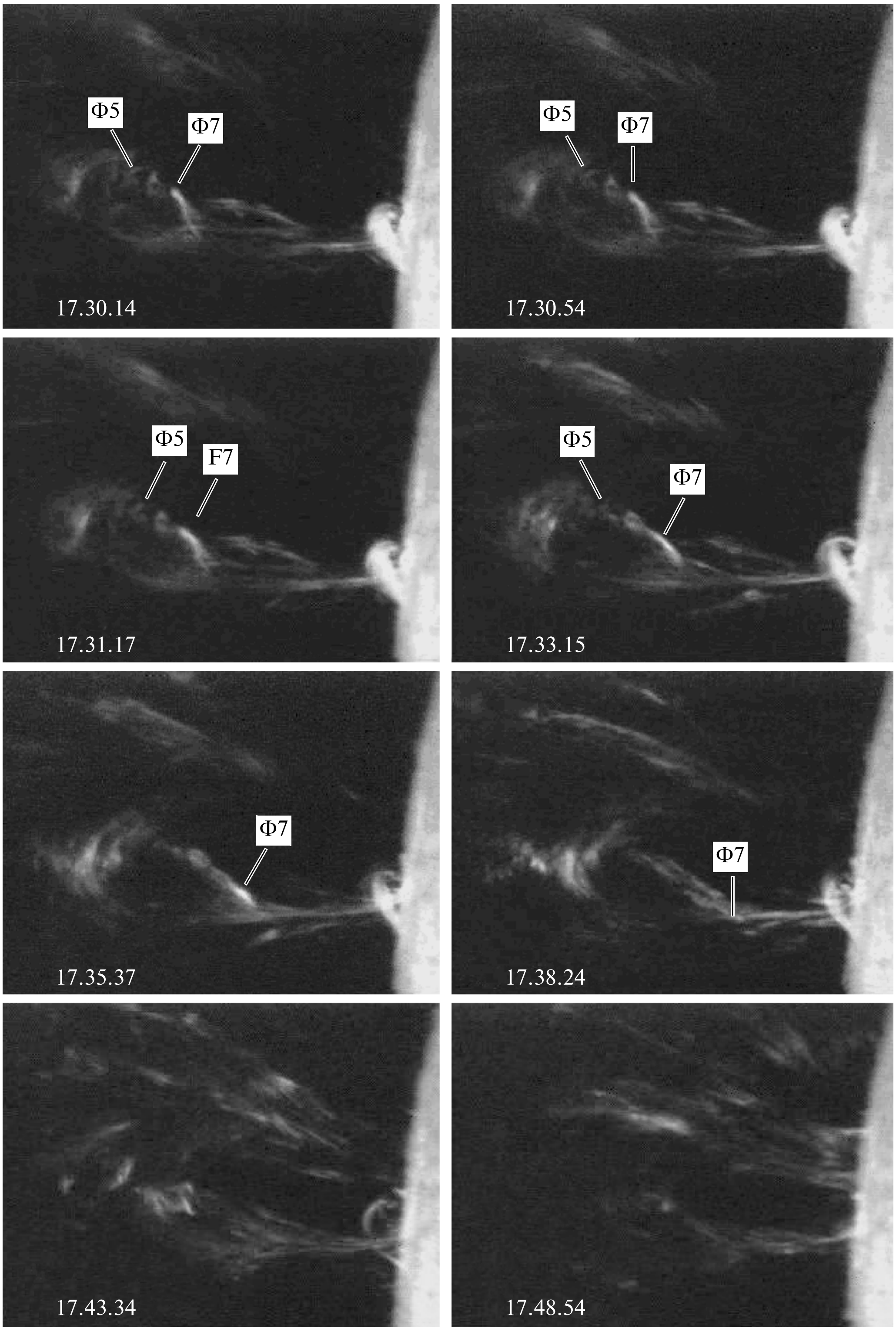


Fig. 1. Contd.

The prominence itself as a system of twisted filaments descends (falls down), and chromospheric emission at the places where the matter falls (bases of the prominence) is intensified. The zone of emission is close to position of fading flare ribbons only at that place where the compact base of the magnetic rope is adjacent to the ribbons. Another (considerable) part of the emission zone is located far from primordial ribbons, where a wide base of the magnetic rope is located. Magnetic loops of the prominence are located above the flare arcs leaning on the flare ribbons.

Original energy release at the second stage is close to zero. This follows from termination of hard X-ray emission observed for most flares to the moment of maximum development in H_α line. It is suggested [6] that the intensity of hard X-ray emission is proportional to the rate of energy release whose origin is a magnetic reconnection.

The sum of kinetic and potential energies of the prominence does not increase at this stage.

Potential energy of elevated matter of the prominence is transformed into kinetic energy during its fall onto the chromosphere. Accordingly, the energy of falling matter is converted into energy of the chromospheric flare localized near the prominence bases.

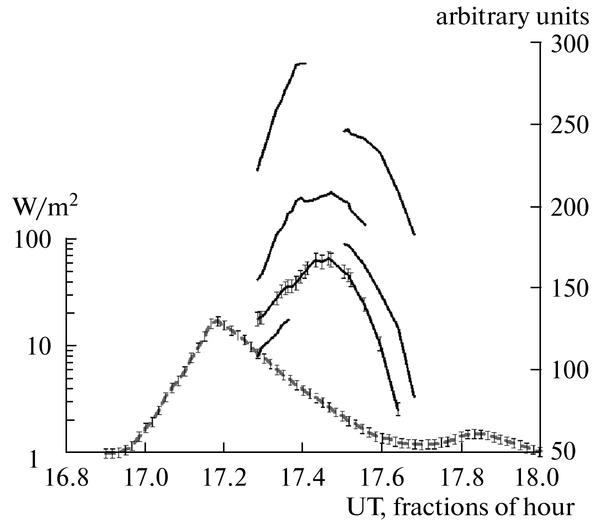


Fig. 2. Temporal changes in the flux of X-ray emission (the lower plot, the soft channel of *GOES* spacecraft, left scale) and in heights of some typical fragments of the prominence (the upper plots, right scale) in the course of development of the flare on August 18, 1995. The abscissa axis is UT in fractions of an hour. Explanations are given in the text.

FLARE DISK EVENT ON SEPTEMBER 23, 1998

Let us consider the solar disk event observed on September 23, 1998 (3B/M6.9). The event included a chromospheric flare with successive development of two pair of quasi-orthogonal flare ribbons. Researchers of this flare [7–10] have analyzed its evolution in the chromosphere and corona, as well as specific features of development in different ranges of the spectrum of electromagnetic waves. Nevertheless, the possible role of a surge in development of the second pair of flare ribbons was not discussed in these papers.

During the even of September 23, 1998 no observations were made by coronagraphs LASCO/SOHO, and this circumstance brings in a certain intrigue. Two different variants of interpretation of the event are possible. The flare could be accompanied by a CME of the halo type. In this case, energy release in the current layer (CL) should supply both the flare and CME acceleration [1]. On the other hand, if the eruptive prominence, having returned back to the solar surface, took place, the energy budget of the event is complicated.

For this analysis we added the data in H_α line provided by the Ondrzejov observatory, the data of the *TRACE* spacecraft in line 1550 Å, and the data on X-ray fluxes of the *GOES* spacecraft in the ranges 1–8 Å and 0.5–4 Å. Eruption of the prominence occurring simultaneously with flare development is well presented in Fig. 3 (line 1550 Å).

Unfortunately, no observational data pointing to return of the prominence were found for this event. Nevertheless, one can indicate the following experimental facts that are interpretable in favor of the prominence return.

1. The system of filaments observed in line 1550 Å (Fig. 3) is rooted by one of its bases at the place of chromospheric brightenings to the west of the first pair of flare ribbons, where later a region of powerful chromospheric emission has emerged.

2. Appearance of the second cupola of flare arcs leaning on the outer pair of flare ribbons [8]. This cupola was formed above the lower arcade of flare arcs leaning on the first inner pair of the flare ribbons.

3. Almost simultaneously with the onset of the second stage of the flare one observed in the wing of H_α line the downward motion of plasma with a velocity of 80 km/s [8].

Thus, the entire set of available data of observations does not contradict the suggested scenario. Moreover, it rather supports this scenario. The development of chromospheric bases of the magnetic rope, considered in the context of topological model [1], gives convincing arguments in favor of a return of the eruptive prominence observed in the event of September 23, 1998 and testifies its substantial role in the flare evolution.

The flare stages were determined based on the scenario described above. For example, from the flare onset at 06:47 until the beginning of development of the second pair of flare ribbons the first stage continues (Fig. 4 in line H_α). In the same period the first pair of flare ribbons (FR1) is developing together with small emission structures on the ends of flare ribbons, or SEFR [1], presumably at places of rooting of the bases of the arc prominence.

The first stage of the event is illustrated in Fig. 3, where a pair of flare ribbons FR1 is well discernible, as well as eruptive ascending matter of the prominence in the form of a system of twisted filaments. One base of the eruptive prominence is compact, while the second base is more extended. The compact base is tightly adjacent to the southern flare ribbon of pair FR1.

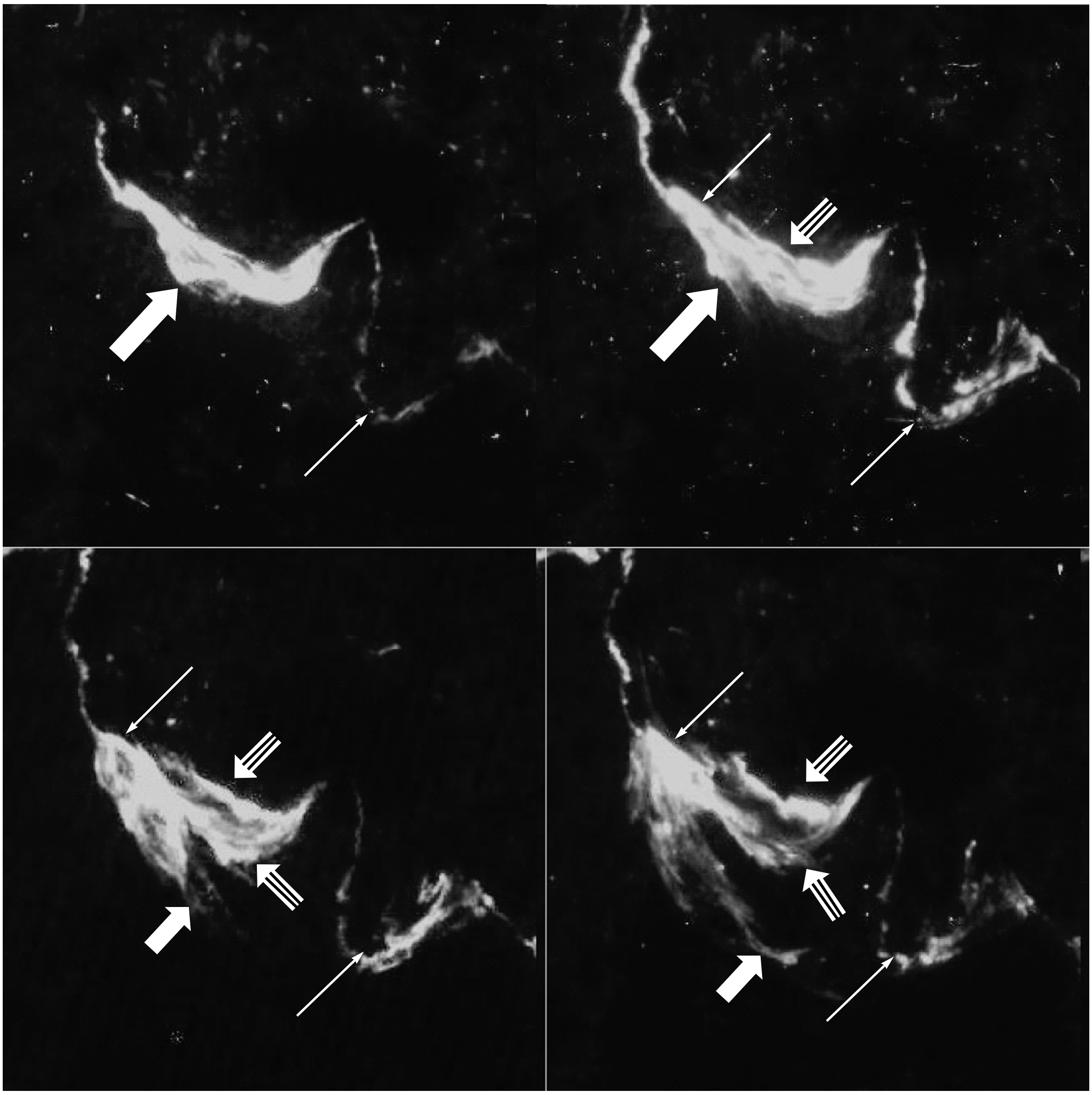


Fig. 3. The onset of the flare on September 23, 1998 in line 1550 Å according to TRACE data. Thick arrows show eruption of a filament (prominence). The fine structure of filaments in the form of fibres is well discernable. Divergent flare ribbons (FR1) are designated by thick double arrows, and the prominent bases (SEFR) are indicated by thin arrows.

From this base (SEFR) the system of twisted filaments diverges in fan-shaped pattern upward and in the direction of the other base. Thus described SEFR is distinct from the southern flare ribbon by only one feature: it serves as a base for higher helical loops of ejection whose topology differs from that of low flare loops of the flare arcade. Making observations of the chromosphere, it is impossible to distinguish this SEFR from the southern ribbon of pair FR1 without special observations of the loops.

The second base of the ejection (system of twisted filaments) has a distinct structure. It is remote from FR1 ribbons. The structure of emission resembles an oblate oval. There is no emission inside this oval.

The beginning of the second stage of flare development is determined to occur at 06:58 based on a corresponding increase of the ratio of fluxes of X-ray emission measured by the *GOES* spacecraft (ranges 0.5–4 Å and 1–8 Å, respectively). According to [7], the impulsive stage was terminated also at 06:58.

The second stage of the event is shown in Fig. 4. Small segments remained from the original flare ribbons FR1. One of them, near the shadow of a large sunspot is in contact with emission region that was called SEFR at the first stage of the flare. This SEFR

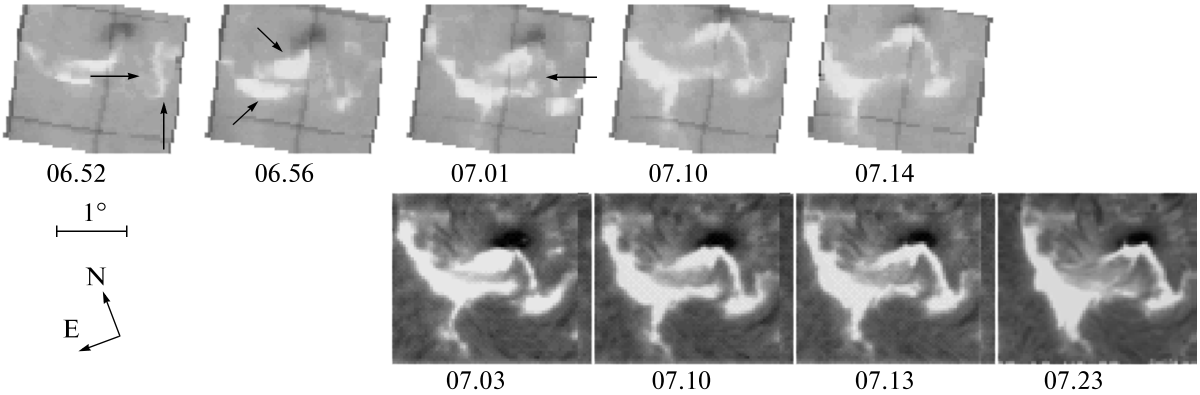


Fig. 4. Images of the flare on September 23, 1998 in H_α line (Ondrejov, Czech Republic): images of the upper layer are of poor
2 quality, obtained with a multichannel spectrograph; the lower layer contains high-quality filtrograms. Inclined arrows at 06:56 show the first flare ribbons (FR1). The vertical arrow designates emission of the western structure at the ends of flare ribbons (SEFR), more intense from the outer side of the oblate oval. At 07:23 one can see a powerful second pair of flare ribbons (FR2) quasi-orthogonal pair FR1 which has almost disappeared to this moment. Using characteristic invariable features of emission, one can demonstrate that the western FR2 pair is localized at the place of inner emission of SEFR oval (designated by horizontal arrows).

has been transformed into the western ribbon of the outer second pair of flare ribbons FR2. Emission on the inner side of the oblate oval has increased.

Another SEFR, which on the first stage could be separated from the southern flare ribbon FR1 only due to topology of magnetic loops, has become even more indistinguishable for southern FR1. Moreover, these structures have merged, and together they formed the eastern ribbon of the second pair of flare ribbons FR2 rotated with respect to the southern FR1 by an angle of about 60°. The former SEFR were transformed into spatially separated powerful emission structures FR2. The flares loops, which were bright and adjoined FR1 at the first stage of the flare, seem to be covered with prominence loops descending from above. The latter have lost their helical twisting [11] and connect the second pair of flare ribbons FR2 at the second stage of the flare.

As it has been demonstrated earlier, the cause of FR2 emission on the second stage of the event is the fall of prominence substance along the same magnetic field lines, along which at the first flare stage the substance evaporated from the chromosphere in the SEFR region moved with acceleration upward.

CALCULATION OF ENERGY IN EVENT OF SEPTEMBER 23, 1998

According to the method adapted by one of authors [5] and published in [12], the rate of energy release in the CL during the fist stage of the event can be described as a flux of Pointing vector, $B_{cor}^2 \cdot V_{in}/(4\pi)$, to the region S of reconnection:

$$dE/dt = 2B_{cor}^2 V_{in} S/(4\pi), \qquad (1)$$

where B_{cor} is the average magnetic field in the corona above the AR in which the flare under study has occurred, V_{in} is the velocity of inflow into the reconnection region, and S is the area of the reconnection region. According to [12] the following expression is true:

$$B_{cor}V_{in} = B_{phot}V_{H\alpha}, \qquad (2)$$

where $B_{phot} \sim 300$ G is the mean intensity of the magnetic field on the AR photosphere at places of localization of flare ribbons FR1 (estimated using a magnetogram of the Kitt Peak observatory, see Fig. 2 in [7]), $V_{H\alpha}$ is the mean rate of divergence of the bases of flare loops as measured by the data in H_α line. Following to the scenario described above, only the area of the first flare ribbons FR1 is used when we calculate the energy balance at the first stage of the event. The value of parameter $V_{H\alpha}$ was measured using filtrograms in H_α 2
lined and equaled $5 \cdot 10^4$ m/s.

Transformed expression (1) takes on the form:

$$dE/dt = 2B_{cor}B_{phot}V_{H\alpha}S/(4\pi). \qquad (3)$$

We assume that the unknown value $B_{cor} \sim 1/4\ B_{phot}$. The magnetic reconnection area S at the first stage of the event can be estimated in order of magnitude as 1/2 of the mean area of flare ribbons, which is approximately a half of maximum area of the first pair of flare ribbons FR1, $S_{ВЛ1} \approx 10^{15}$ m^2. Then, on the time interval from the onset of the flare to its maximum the rate of magnetic energy release can be determined from the expression:

$$dE/dt = 1/2B_{ph}^2 V_{H\alpha} 1/2 S_{H\alpha}/(4\pi). \qquad (4)$$

As a result of integration of expression (4) over the first stage interval (from 06:47 to 06:58) we get $\sim 3 \cdot 10^{31}$ erg.

The time behavior of energy consumption of the source for heating the flare region, and for radiation and heat conductivity is calculated as [13]:

$$Q = \dot{E}_{cond} + \dot{E}_{rad} + \dot{E}_{th}, \tag{5}$$

where $\dot{E}_{cond}$ is the energy flux from the tops of flare loops down to their bases propagating due to heat conductivity, $\dot{E}_{rad}$ is the flux of radiated energy, $\dot{E}_{th}$ is the flux of energy expended for heating the flare region, and Q is the total energy flux.

Losses due to heat conductance were calculated according to the expression:

$$\dot{E}_{cond} = k_0 T^{7/2} S_{loop}/l, \tag{6}$$

where $k_0 = 10^{-6}$ erg s^{-1} cm^{-1} K$^{-7/2}$ according to [14], T is effective temperature, S_{loop} is the cross section area for flare loops estimated as $1/2S_{\mathrm{H}\alpha}$, and l is the mean length of flare loops.

The energy flux consumed for heating the flare region is determined from the expression:

$$\dot{E}_{th} = \{E_{th}(t + \Delta t) - E_{th}(t)\}/\Delta t, \tag{7}$$

where $\Delta t = 60$ s.

The thermal energy E_{th} contained in the volume occupied by the flare is calculated approximately using one-minute data of the *GOES* satellite according to the formula [15]:

$$E_{th} = 3kT\sqrt{EM^{flare}V^{flare}}, \tag{8}$$

where k is the Boltzmann coefficient, V^{flare} is the flare region volume, T is the effective temperature of the flare, and EM^{flare} is its corresponding emission measure according to [16].

The flux of radiated energy is calculated according to the expression:

$$\dot{E}_{rad} = EM^{flare}\Lambda(T), \tag{9}$$

where $\Lambda(T)$ is the function of radiation losses [17].

The flare volume at every time moment was determined from the expression:

$$V^{flare} = (S_2)^{3/2}, \tag{10}$$

where S_2 is the area between the outer boundaries of flare ribbons FR1.

The value of integral Q of the energy flux spent for flare manifestations at the first stage of the event (06:47–06:58) turned out to be equal to $0.5 \cdot 10^{31}$ erg to a factor of 2.

Calculation of the energy budget of the event at its second stage included only the flare part. The flare energy is calculated using formulas (5)–(10). The cross section area of flare loops S_{loop} was estimated as $1/2S_{\text{ВЛ2}}$. S_2 is the area between the outer boundaries of the flare emission zone in H_α line. The duration of the second stage of the event is determined as 06:58–07:30 from the character of changes in X-ray emission measured by the *GOES* spacecraft. As a result, it is obtained that with the same accuracy the energy consumed by the flare at the second stage is about $3 \cdot 10^{31}$ erg.

Thus, the energy released in the CL at the first stage of the event was $\sim 3 \cdot 10^{31}$ erg, including the energy of $\sim 0.5 \cdot 10^{31}$ erg spent for supporting the flare processes. According to out original hypothesis, kinetic energy of ejection (of surge in this particular case) should be equal to the difference of these values. The calculated value of flare energy during the second stage, $\sim 2.7 \cdot 10^{31}$ erg, turned out to be close to the expected value. Thus, performed calculations do not contradict the statement that the bulk of flare energy at the second stage of the event can be the transformed energy of falling matter of the prominence.

At least two scenarios can be realized in the process of development of powerful solar events: either a flare accompanied by a coronal mass ejection [1] or a flare accompanied by eruption of a surge. Early identification of the event (determination of a scenario which has been realized) can be quite useful for prompt forecast of the space weather state. In the case of realization of the second scenario with a surge one can, as a minimum, predict the absence of a bright core of the coronal mass ejection in a given event. In this scenario the second pair of flare ribbons caused by falling of the prominence matter onto the chromosphere turns out to have substantially larger area than the first pair of ribbons.

RESULTS AND DISCUSSION

An attempt has been made in this paper to solve the problem which is distinct at the first sight by a considerable ambiguity. By determining the topological correspondence of emission flare structures to different types of flare magnetic loops, according to the topological model [1] developed by the authors, we have succeeded in substantiating different variants of the scenario of development of the event accompanying the chromosphere flare. In one variant of the scenario a flare is accompanied by CME with a bright core, another case is accompanied by a surge. For example, characteristic development of SEFR with their subsequent transformation into the second pair of flare ribbons at the second stage of the flare gives a direct evidence of downfall of the matter of eruptive prominence onto the chromosphere. In this situation SEFR are chromospheric bases of the ascending magnetic rope forming a backbone of the arc eruptive prominence. The second pair of flare ribbons formed at the second stage of the event on the place of SEFR represents the bases of the same magnetic rope, but already on the stage of falling matter of the eruptive prominence.

Under these conditions the probability for CME not to be formed or to be formed without a bright core is high. In the first case the plasma cloud thrown away to the interplanetary space cannot reach the Earth's orbit, since both matter and field return back to the Sun. In the second case one can expect that CME will be essentially less geoeffective due to smaller density of matter and lower magnetic field strength. In addition, we emphasize that this variant of scenario allows one to explain the phenomenon of 'four-ribbon flares' observed and described long ago [10].

If the total energy of an event or the power of a flare are estimated [18–20] based on the area of chromospheric flare ribbons and on the local photospheric magnetic field of an active region, then it is fair to make such estimates for this class of events only analyzing the development of the first, relatively small flare ribbons at the first stage of the flare. The total energy of the event, as has been demonstrated above, correlates with the area of first flare ribbons with small dimensions.

The flare power calculated in such a way is not high. It is comparable to typical power of optical flares with importance 1–S. Accordingly, it is unlikely that the event will be accompanied by solar energetic protons. In addition, in this situation there is knowingly no such source of proton generation as localized in the flare maximum on the front of a fast CME [21].

Thus, the event of the class under consideration (a flare with a surge) is shown to have essentially local character and the total energy that ranks below the energy of the strongest flares. Hence, its influence on the space weather is insignificant.

Another result allowing one to make conclusions (from the standpoint of suggested topological model) about the processes of energy release in the corona at different stages of an event is the interpretation of emission evolution SEFR–FR2.

During the first stage of an event, when ejection of matter is coming up, the emission turns out to be stronger on the outer side of the SEFR oval. To the moment of the end of the flare's first stage the region of maximum brightness of emission has traveled to the oval bend. At the second stage of the event the region of maximum emission of SEFR, as was demonstrated earlier, is shifted to the inner side of the oval, nearest to the first flare ribbons FR1, thus forming powerful FR2. A logical suggestion arises that the emission is an indicator of active processes taking place in those magnetic loops which rest on particular segments of the chromosphere. Hence, it follows that in the volume of a system of twisted filaments (magnetic rope) of the prominence the processes of magnetic reconnection occur during a quick increase in the ejection height on the upper surface of this volume, while during the fall of matter they occur on the lower surface. When matter goes upward the processes of magnetic reconnection take place on the upper surface of the system of twisted filaments. At backward motion of the prominence the lower part of its loops undergoes collisions with lower flare loops connecting FR1. At the place of their contact and stop of falling magnetic loops of the prominence there occur active processes accelerating particles. The latter precipitate onto the chromosphere along magnetic field loops. Then, the next portion of descending loops stops falling higher than the preceding part. The particles accelerated in this process move away along magnetic field lines precipitating onto the chromosphere and thus providing for the effect of visible divergence of flare ribbons FR2. Thus, the topological model of the event of development SEFR–FR2 unambiguously determines localization of magnetic reconnections and energy releases in the corona at different stages of an event of this class.

Summarizing all said above, let us list the basic results of the paper.

1. Based on the topological model of a large solar event 'flare–CME' [1] a new scenario is suggested for development of the event 'flare with eruptive surge' including two stages corresponding to elevation and fall of a prominence, the backward motion of the prominence being a cause of additional energy release and formation of a second system of flare ribbons.

2. A realization of this scenario is demonstrated using as examples the limb event on August 18, 1995 and the disk event on September 23, 1998.

3. For the disk event on September 23, 1998 it is shown that the energy of a surge, whose origin is the primary energy release on the first stage of a flare, can provide for energy release on the second stage.

4. An observational chromospheric criterion is suggested for an eruptive surge in a solar event including a strong flare on the disk. The criterion uses the development of structures on the ends of flare ribbons SEFR, namely: SEFR observed at the first stage are transformed into the second pair of flare ribbons FR2 on the second stage of the event.

5. Weak influence of solar flare events satisfying the above-mentioned observational criterion on space weather is substantiated (a consequence of the absence of a bright core of CME and, hence, lesser CME mass and lower probability of the fluxes of solar protons).

ACKNOWLEDGMENTS

The work is supported by the Ministry of Education and Science (a part of the project RNP.2.3.1/198) by the State Program of Support of Leading Scientific Schools, grant NSh-4741.2006.2 "Physics of solar processes and phenomena and development of new methods for their study".

REFERENCES

1. Sidorov, V.I. and Yazev, S.A., Topological Model of the Solar Event Including a Flare and Coronal Mass Ejection on October 19, 2001, *Kosm. Issled.*, 2008, vol. 46, no. 4, pp. 329–335. [*Cosmic Research*, pp. 320–326].
2. Banin, V.G. and Fedorova, A.S., Strong Chromosphere Flare on November 5, 1970, in *Issledovaniya po geomagnetizmu, aeronomii i fizike Solntsa* (Investigations in

Geomagnetism, Aeronomy, and Physics of the Sun), Irkutsk: SibIZMIR AN SSSR, 1971, issue 2, pp. 73–85.

3. Filippov, B.P., *Eruptivnye protsessy na Solntse* (Eruptive Processes on the Sun), Moscow: Fizmatlit, 2007, p. 134.

4. Solar Geophysical Data Prompt Reports, no. 613, Part 1, 1995, p. 28.

5. Sidorov, V.I., Relation of Energies in the Flare and Coronal Mass Ejection on October 19, 2001, in *Solar-Terrestrial Physics*, issue 8 (121) of Institute of Solar-Terrestrial Physics, Novosibirsk: Izd. SO RAN, 2004, pp. 71–72.

1 6. Asai, A., Masuda, S., Yokoyama, T., et al., Difference between Spatial Distributions of the H_α Kernels and Hard X-Ray Sources in a Solar Flare, *Astrophys. J.*, 2002, vol. 578, pp. L91–L94.

7. Altyntsev, A.T., Sych, R.A., Grechnev, V.V., et al., Flare of September 23, 1998: Relation between Temporal and Spatial Structure, *Solar Physics*, 2002, vol. 206, pp. 155–176.

8. Kotrč, P., Karlicky, M., Kupryakov, Y.A., et al., Physical Characteristics of the September 23, 1998 Solar Flare, in *Magnetic Fields and Solar Processes*, Wilson, A., Ed., Noordwijk, ESA Publications Division, 1999, pp. 841–845. [Ninth European Meeting on Solar Physics, Florence (Italy), September 12–18, 1999].

9. Kulagin, E.S., Papushev, P.G., and Chuprakov, S.A., An Analysis of Phenomena Observed in the Process of Development of a Flare with Importance 3B on Sep-
2 tember 23, 1998 Using Filtrograms in Line *HeI* 10830, in *Investigations in Geomagnetism, Aeronomy, and Physics of the Sun*, 2001, issue 113, *Proceed. of Conference Dedicared to the Memory of G.V. Kuklin*, pp. 109–118.

10. Mishin, V.M., Sidorov, V.I., Grigoriev, V.M., et al., Flare on September 23, 1998: New Arguments in Favor of CSHKP Model, in *Investigations in Geomagnetism, Aeronomy, and Physics of the Sun*, 2001, issue 113, *Proceed. of Conference Dedicared to the Memory of G.V. Kuklin*, pp. 120–126.

11. Portier-Fozzani, F. and Inhester, B., 3D Coronal 3
Structures and Their Evolutions Measured by Spectroscopy, Consequences for Space Weather and the Stereo Mission, *Space. Sci. Rev.*, 2001, vol. 97, pp. 51–54.

12. Isobe, H., Yokoyama, T., Shimojo, M., et al., Reconnection Rate in the Decay Phase of a Long Duration Event Flare on 1997 May 12, *Astrophys. J.,* 2002, vol. 566, p. 528.

13. Ohyama, M. and Shibata, K., Preflare Heating and Mass Motion in a Solar Flare Associated with Hot Plasma Ejection: 1993 November 11 C9.7 Flare, *Publ. Astron. Soc. Japan*, 1997 vol. 49, pp. 249–261.

14. Spitzer, L., Physics of Fully Ionized Gases, New York: Interscience, 1962, p. 144.

15. Sylwester, J., Garcia, H.A., and Sylwester, B., Quantitative Interpretation of GOES Soft X-Ray Measurements. I. The Isothermal Approximation: Application of Various Atomic Data, *Astron. Astrophys.*, 1995, vol. 293, pp. 577–585.

16. Thomas, R.G., Starr, R., and Cranell, C.J., Expressions to Determine Temperatures and Emission Measures for Solar X-Ray Events from GOES Measurements, *Solar Physics*, 1985, vol. 95, pp. 323–329.

17. Priest, ER., *Solar Magnetohydrodynamics*, Dordrecht, Holland: D. Reidel, 1981. Translated under the title *Solnechnaya magnitogidrodinamika*, Moscow: Mir, 1985, p. 99.

18. Sidorov, V.I., Mishin, V.I., Kovalenko V.A., et al., Calculations of Power of Solar Flares and Their Heliophysical Manifestations, in *Topical Problems of Physics of Solar and Star Activity, Proc. of Conf. of FSU and Baltic States, 2–7 June, 2003*, Nizhni Novgorod, 2003, pp. 422–425.

19. Sidorov, V.I., Sedukh, P.A., and Mishin, V.I., Estimating the Power of Magnetospheric Substorms and Solar Flares in the Context of Their Unified Scenario, *Proc. ICS-5, St. Petersburg, Russia, 16–20 May 2000,* ESA SP-433, pp. 573–576.

20. Mishin, V.M., Sidorov. V.I., Adelkhaniov, S.S., et al., On the Power of Large Solar Flares, *Romanian Astronomical Journal,* 1999, vol. 9, Suppl., pp. 49–55.

SPELL: 1. Asai, 2. Filtrograms, 3. Inhester