SOME RESULTS OF RESEARCHES AT THE SSRT

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Abstract: Results of investigations of powerful flare predictors, fast processes at the time of flares, coronal mass ejections and weak contrast events in the solar corona with the Siberian Solar Radio telescope (SSRT) are presented. Reprints of papers, published and accepted for publication, are attached [1-11].

Powerful Flare Predictors

At most solar observatories, short-term predictions of solar activity are based on using observational data in optical emission. The employment of radio emission data for prediction purposes has not yet occupied a fitting place. Moreover, in cases where they are used, this refers to data obtained at radio telescopes without spatial resolution. At the same time, investigations of microwave emission using high-resolution data from Toyokawa Radioheliograph, BPR and RATAN-600, and SSRT showed that by invoking radio data, it is possible to improve prediction quality [1,2].

The technique for short-term (1-3 days) prediction of powerful solar flares (of importance ≥M1.0) that was developed at the ISTP, is based on using data on total and polarized microwave emission fluxes of active regions, the structure of the magnetic field at the photospheric level, and observational data in the Hα-line.

Signatures of the preflare stage are believed to be:

- the deviation of the observed microwave emission polarization distribution from a normal (not flare-producing) distribution that is determined with due regard for the active region position on the solar disk;
- the solar microwave emission flux F exceeds 20 s.f.u.;
- high values of the microwave emission flux and abrupt changes of the value of the flux-to-sunspot group area ratio F/S are observed simultaneously;
- the ratio of the number of microwave bursts N_b to the number of subflares N_j in the active region under investigation exceeds 0.5;
- microwave emission shows a source above the polarity inversion line of the longitudinal magnetic field of the active region.

One of the factors giving rise to geomagnetic storms includes coronal mass ejections associated with dark filament eruption on the solar disk. For predicting the production and eruption of a dark filament, we developed a method of a quantitative description of the situation along the polarity inversion line of the longitudinal magnetic field, based on measuring the longitudinal magnetic field gradient along the polarity inversion line, constructing the magnetic field gradient distribution, and analyzing the time behavior of distribution parameters.

We have developed a technique for determining the optical thickness, size, velocity and propagation direction (projected onto the solar disk) of coronal mass ejections from microwave emission data .

Fast processes at the time of flares

(Based on an example of the study of the **spectrum, source location and size of the September 17, 2001 microwave subsecond impulse** (SSI) [3]). Spatially resolved observations are crucial for determining the generation mechanism for the fine temporal structure, as they provide a means of localizing the source in the flaring region and, using data from other emissions, estimating the plasma parameters in the region of its generation.

Radio interferometric observations are made in a narrow band and, usually, without simultaneous observations of the dynamic spectrum of the microwave burst. Recently, the initiation of regular observations with the spectropolarimeters of the Beijing observatory (5.2-7.6 GHz, Fu et al., 1995) made it possible to carry out simultaneous observations with spatial resolution (SSRT, 5.7 GHz), and with spectral resolution (BAO).

The SSRT provides frequency scannings of the solar disk thus furnishing a means of observing - at some periods of local time - one-dimensional brightness distributions of sources of subsecond impulses in two frequency ranges simultaneously. The distinguishing feature of the September 17, 2001 event was the combination of the data on the dynamic spectrum with interferometric observations in two coordinates where in the E-W direction the source was observed in two frequency ranges, the receiving frequency of which differed by 80 MHz.

An added interest in this event is caused by the high degree of circular polarization. Before 2000, the SSRT temporal resolution (56 ms) was inadequate for a correct measurement of the degree of polarization of impulses when their duration was shorter than 0.5 s (Altyntsev et al., 1996a). From June 2, 2001 to April 14, 2002, the SSRT recorded 54 events with subsecond impulses, with a resolution of 14 ms; of them, 20 events showed impulses with the degree of polarization over 30%.

The relative emission band width of the September 17, 2001 impulse (spike) made up several percent. In such conditions the time profiles obtained with the SSRT interferometer are controlled by the dynamics of the emission spectrum. The spike source is located near the following sunspot of the active region and is displaced along the flare loop with respect to the corresponding brightness center of the background burst by 6 sec of arc. The apparent size of the spike source along the direction of the flare loop was about 15 sec of arc, and less than 10 sec of arc along the other direction.

The narrow emission band and the high brightness temperature are indicative of a coherent mechanism of emission. The spike generation frequency corresponds to the 6th-7th harmonic of cyclotron radiation by the magnitude of the photospheric magnetic field. On the other hand, the brightness center of the soft X-ray flare corresponds to the region of generation of the SSI, and the estimated plasma densities in the source do not contradict the assumption about the plasma mechanism of its emission. Spike emission is characterized by a high degree of polarization, and the sign of polarization corresponds to the ordinary mode of emission.

Coronal mass ejections and weak contrast events in the solar corona

Dual-filament initiation of a Coronal Mass Ejection: observations and model [4].

A new model for the initiation of solar Coronal Mass Ejections and CME-associated flares is proposed. The model is inferred from observations of a quiescent filament eruption in the north-western quadrant of the solar disk on 4 September 2000. The event was observed with Siberian Solar Radio Telescope (5.7 GHz), Nobeyama Radioheliograph (17 GHz) and SOHO/EIT \& LASCO. Based on the observations, we suggest that the eruption could be caused by the interaction of two dextral filaments. According to model, these two filaments merge together to form a dual-filament system tending to form a single long filament. This results in a slow upward motion of the dual-filament system. Its upward expansion is prevented by the attachment of the filaments to the photosphere by filament barbs as well as by overlying coronal arcades. The initial upward motion is caused by the backbone magnetic field (*first driving factor*) which connects the two merging filaments. Its magnetic flux increases slowly due to magnetic reconnection of the cross-interacting legs of these filaments. If a total length of the dual-filament system is large enough, then the filament barbs detach themselves from the solar surface due to magnetic reconnection between the barbs with oppositely directed magnetic fields. The detachment of the filament barbs completes the formation of the eruptive filaments themselves and determines the helicity sign of their magnetic fields. The appearance of a helical magnetic structure creates an additional upward-directed force (*second driving factor*). A combined action of these two factors causes acceleration of the dual-filament system. If the lifting force of the two factors is sufficient to extend substantially the overlying coronal magnetic arcade, then magnetic reconnection starts below the eruptive filament in accordance with the classical scheme, and the *third driving factor* comes into play.

Coronal holes [5,6]. Coronal holes that were discovered in soft X-ray emission immediately began to be investigated in radio emission. Furthermore, it was found that in the long-wavelength part of radio emission, starting from 8 cm, coronal holes are reliably identifiable at he background of a quiet Sun as regions with decreased brightness temperature. In the short-wavelength part, at 6 cm or lower, coronal holes are distinguished unambiguously: the brightness temperature in the entire coronal hole or in its separate parts can be equal to or larger or smaller than the brightness temperature of a quiet Sun. Model calculations showed that such differences in the manifestation of coronal holes can be accounted for by temperature and electron density variations.

On the assumption about coronal heating by a wave flux from beneath the photosphere and an increased dissipation of these waves in the coronal hole chromosphere, it was concluded that there can be a possible correlation between brightness temperatures in the coronal hole at wavelengths of radio emission: the darker is the coronal hole at wavelengths generated in the corona, the brighter it must be at wavelengths of radio emission generated in the chromosphere.

A coronal hole investigation that was carried out using the data of simultaneous observations made during April 20-24, 1998 at the Siberian solar radio telescope and Nobeyama Radioheliograph did confirm this assumption. According to the SSRT data, the coronal hole boundaries coincided closely with those in ultraviolet emission in the line of Fe XI λ 195 A. Inside these boundaries, inhomogeneities of the brightness temperature T_b were observed. The brightest parts ($T_b \approx 11000$ K) at 1.76 cm wavelength corresponded to the darkest portions of the coronal hole ($T_e \leq 14000$ K) at 5.2 cm wavelength. These portions are characterized by a negative correlation between the brightness temperatures at the two wavelengths.

Filaments [7,8]. Filaments that are observed in microwave emission with the SSRT, usually correspond to their manifestations in H-alpha. The ‘radio filament’ (brightness temperatures of depressions down to 10 thousand degrees) corresponds to the filament observed in H-alpha. We have found that the bright ribbons near the radio filament correspond to flocculus fields. To overlay the SSRT and Big Bear images, we have compensated the angle of solar rotation because the images were produced at different instances of time. By the way, the Hα-image was resized to fit the same frame and grid, and the contrast was enhanced for both images to make brightness features more prominent. At low latitudes the middle part of the ‘radio filament’ structure is the dark filament itself of width about 1 min of arc. It retraces the polarity inversion line of the active region magnetic field. The brightness temperature in such places varies from 5000 to 12000 K. Bright lanes of about the same width are observed here to run parallel to the dark, central filament, and their brightness temperature reaches 50000 K (they seem to be indicative of the specific conditions between the surrounding hot corona and the cooled-down filament in strong magnetic fields of active regions; the manifestation of the emission from flocculi is also possible because bright lanes are not observed at the background of bright flocculi). At high altitudes (in the area of weak magnetic fields) filaments in microwave emission appear only as dark features (here, weak high-latitudes plages are not always manifested by chromospheric flocculi). Low-latitude radio filaments on the limb are observed in the form of continuous brightenings at all heights, starting from the solar limb, and high-latitude radio filaments show up as loop features. In addition to a considerable agreement with the NRH data, some differences were also detected. Filaments with a brightness temperature on the order of 10000 K, seen with the SSRT, are not recorded by the NRH because their temperature at 1.76 cm wavelength approaches the quiet Sun's temperature. Bright lanes as detected along dark low-latitude filaments by the SSRT, are also not observed by NRH. Note that filaments with bright edges are not visible at 17 GHz, as a rule. For details see the Appedices.

For reconstructing the magnetic field in the corona, a new technology was developed [9] to represent the topology of the field with the rate of obtaining full-disk magnetograms. This provided an apportunity to study the dynamics of the corona structure [10]. The site with such data [11] that was created nearly one year ago, was welcomed by many interested investigators.

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