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Astronomy

Solar Radio Emission at 210 MHz Frequency and its Connection with Optical Phenomena on the Sun

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ABSTRACT. Long-term observations ofGeorgian the solar radio noise storms carried out at E. Kharadze Georgian National Astrophysical Observatory on the solar radio telescope at 210 MHz are presented. It is shown that there is a strong correlation between the amplitude of the noise storm, sunspot number and their areas. © *2009 Bull. Georg. Natl. Acad. Sci.*

Key words: *radio emission, radio bursts, sun flares.*

It is known that the discovery and study of the solar radio emission played an important role in the investigation of the processes occurring on the Sun. Radio observations supply the results of optical investigations and in some cases they are the only method of obtaining information on the physical conditions of the generation and propagation of radio waves. It makes a valuable contribution to the understanding of physical processes occurring in the solar atmosphere. They allow studying the processes taking place at various levels of the solar atmosphere. Radio observations have the advantage of attaining a high resolution for the heights in the corona as the velocity of propagation of radio waves distinctly depends on the medium density. This is particularly inherent to the 210 MHz emission band corresponding to λ=1.43m.

Comparison of results obtained in different spectral regions is an important method for the study of different events occurring in the solar atmosphere. In the visible region, comprising most of Sun radiation, the emission variability is very small. Our knowledge of the solar activity has been essentially enlarged due to the development and coordination of optical and radio observations.

The emission at different wavelengths arrives from various depths of the solar atmosphere. Consequently, if we change the wavelengths, investigation of the solar atmosphere through all depths will be feasible.

Our attention is attracted by the fact that the solar radio emission is manifested in two ways, as "quiescent" and "disturbed" (i.e. "sporadic") ones. Their distinguishing features are known as well [1]. They are usually localized in active regions of the solar disc. Bursts are considered to be a basic characteristic of solar activity, and therefore it is a significant object of investigation. The intensity of sporadic radioemission in the meter band can exceed the emission of the quiescent Sun by a few thousand times [2].

The radio emission of a "quiescent" Sun is explained as the atmosphere thermal emission, the power of which is estimated by means of the solar corona temperature. The "disturbed" one is related to the features of the solar surface [3].

It is established that the noise storms are connected with large groups of spots in the photosphere, particularly with those in the central part of the solar disc [4]. The probability of the emergence of radio emission increases with the area of the whole group as well as with that of the largest spot [3]. Both the bursts and the background radiation have a high polarization degree amounting to 100 per cent, with the magnetic field occurring either in the region of the radio emission generation, or at propagation of the radio waves in the corona [4].

The duration of noise storms can vary from a few hours up to a few days in a wide range of frequencies (50-100 MHz) [5]. On the whole, the phenomenon is observable on meter waves and it represents increased emission relative to the background basic level.

The issue whether the noise storm is connected with other solar features, i.e. flares, is solved by various authors in different ways. Some suggest that all the chromosphere flares precede or coincide with the noise storm in time [6]. Others believe that a noise storm is observed only when there are strong chromosphere flares of 2 or 3 points on the Sun [7].

During 50-year intensive radio observations carried out at Abastumani Astrophysical Observatory (Georgia) we have found up to 500 cases showing clear connection of the origin of noise storms with the solar activity cycle.

Solar radio observations in the meter bands (λ=1.43 m, f=210 MHz) have been performed at Abastumani Astrophysical Observatory since 1957 with the solar radiotelescope consisting of three units: an antenna feeder system, a radiometer with a recorder and a power unit.

The antenna comprises 16 active semi-wave dipoles situated on the plane over the reflecting screen. All the dipoles are interconnected by means of the equiphase asymmetric feeder and the antenna outlet - with the radiometer inlet by cable. The antenna construction permits it to be pointed to any sky region. The azimuth directional pattern in horizontal and vertical planes is 12° and 17° respectively. The noise signal received from the Sun through the antenna applies to the modulator where it is modulated at the frequency of 100 Hz. The modulated signal passes through the high frequency filter tuned at 210 MHz with the passband of 2 MHz. Furthermore, a square-low detector is located on the path of the high-frequency modulated signal being detected. Finally, a low-frequency signal of 1000 Hz emerges. The signal enters the heterodyne filter; here it is amplified by means of a low-frequency amplifier with maximum coefficient by 1000 times. It can be changed using the control knobs situated on the facade panel of the receiver. The amplified low-frequency signal passes a synchronous filter transmitting the signal of the frequency by which the high-frequency radio signal is modulated. Further, the signal in the same heterodyne filter is transformed into constant current, which is registered by a recorder.

The radiometer is provided with a rough channel switching in case the signal of a certain value is amplified. On the recorder this signal is determined as 0.9 of the scale. The signal is brought into the rough channel from quadratic detector. Maximum enhancement of the rough channel is 100 times less than that of the accurate one. The rough channel is switched by the automatic unit at closing the relay contacts connecting the recorder to the power supply of 220 V. The rough channel is disconnected by pressing the button on the facade panel of the radiometer.

A noise generator is installed in the radiometer, from which the signal passes to the modulator by means of the toggle switch on the receiver facade panel.

The whole receiver is heat settled. The inside temperature is kept 35° C by means of a thermo-stabilizing unit operating from 220 V alternating current power supply.

Relative calibration of the receiver is performed by the noise generator on the diode at the beginning and end of each observation. The absolute one is done by comparison of the signal at the receiver output from the calibration noise generator and that of Cassiopeia A approximately once a year (duration of observation is 4-6 hours a day).

The observations lasted for 4-6 hours a day. Highly abundant observational data within 1957-2008, comprising the 5 solar cycles (maxima in 1957-1958, 1969-1970, 1980-1981, 1990-1991, 2000-2001), are available. The fifth cycle is at its ascending stage.

The signal was recorded with a plotter. The data are represented in the coordinates of intensity-time. The intensity in the units of 10^{-22} W $M^{-2}Hz^{-1}$ and Greenwich Time (UT) are plotted along the axis of ordinates and that of abscissas, respectively. The value of internal noises is no more than 0.01 of the signal from the “quiescent Sun”. When the solar radio emission is registered the galaxy background is excluded. In case of the registration of a large solar radiation burst, many times exceeding the level of the “quiescent” Sun, sensitivity of the radiometer varied repeatedly. The records were copied at a special laboratory.

The abundant data, collected over the past years, clearly show that the noise storm is closely connected with the solar spot or group of spots. The spot groups often accompanied with solar radio storm are of E or F types (according to the accepted classification). The fact that the spots or spot group of opposite polarity could be the source of the noise storm is established as well.

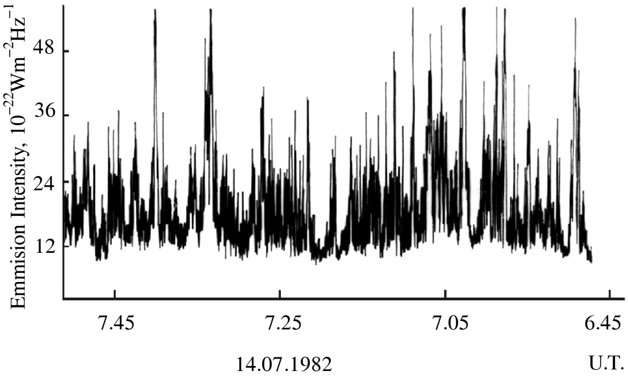
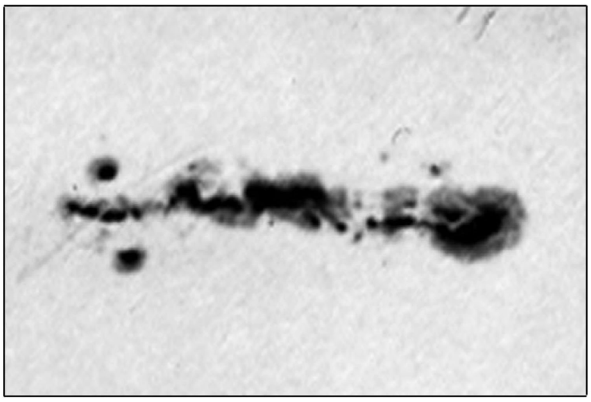


Fig. 1. Diagram of solar radioemission recorded on July 14, 1982.



14.07.1982

Fig. 2. Sunspots in the photosphere on July 14, 1982.

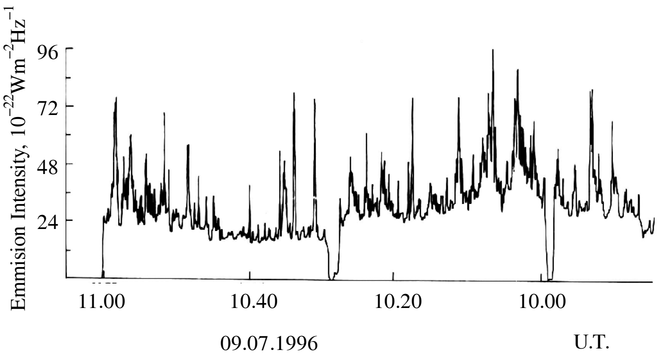
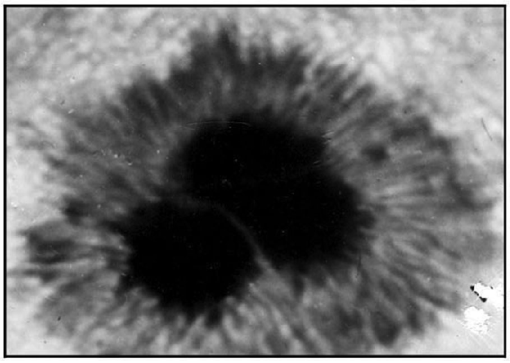


Fig. 3. Diagram of solar radioemission recorded on July 9,1996.



09.07.1996

Fig. 4. Sunspots in the photosphere on July 9, 1996.

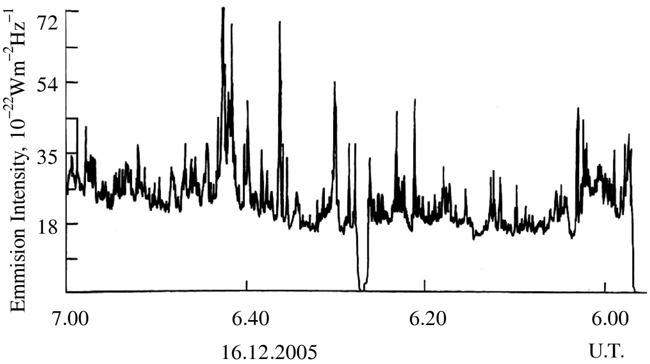


Fig. 5. Diagram of solar radioemission recorded on December 16, 2005.

16.12.2005

Fig. 6. Sunspots in the photosphere on December 16, 2005.

Certain characteristics of the noise storm, such as duration and intensity, have close ties with the 11-year solar activity cycle. All these parameters vary with the variation of solar activity.

Here we pay special attention to three cases from our abundant data which show a clear connection of noise storms origin with the solar activity cycle and compare them with our contemporary optical observations and provide suitable analysis.

Fig. 1 shows the radio emission recorded on July 14, 1982. Fig. 2 shows the sunspot image of the same day obtained with the photosphere-chromosphere telescope of Abastumani Astrophysical Observatory. Here Wolf number is 270 and the total area occupied by sunspots is $1.735 \cdot 10^3$.

Fig. 3 is the diagram of the solar radio emission obtained on July 9, 1996. The observation moments are plotted on X-axis (in U.T.) and the emission intensity -

at Y- axis (in 10^{-22} $WM^{-2}Hz^{-1}$). The diagram corresponds to the type I radio emission [8], i.e. to the noise storm produced in solar active areas observed in the optical band.

Fig. 4 is an image of the sunspots on the same day, when Wolf number attained 270 and the sunspot area was 3.350×10^{3} of the solar hemisphere. The chromosphere flare of class 1 is detected, giving rise to the noise storm observed in the radio band.

According to the observations of December 16, 2005, an especially large sunspot group was observed on the east solar limb near the North Pole (Fig. 5). At the same time a noise storm, displayed in Fig. 6, was recorded in the radio band. The diagram shows that this is a very intensive one and varies within $(40\div100)\times10^{-22}$ WM^{-2} Hz^{-1} units.

Based on the statistical analysis of observational data we conclude that in most cases the radio emission is connected with the sunspot groups. In particular, the noise storm is formed in the sunspot groups of a complex pattern during the growth of large spots. Besides, the maxima of radio emission and magnetic flux of large sunspot groups coincide with the accuracy of a day. On the other hand, the powerful magnetic flux of sunspot group is a precursor of the strong chromosphere flare.

Various researchers [9] obtained similar results at different frequency bands via the interferometric and polarimetric observations. Based on some examples from [10], one with variation of continuous constituent of the noise storm, is closely connected to the area occupied by sunspot groups. As for type I radiobursts, they reveal a close connection with the variation of magnetic field tension related to the sunspots.

Further refinement and improvement of the mechanism of the noise storm require optical observations of the chromosphere flares and sunspots with magnetographs too. Such kind of observations will allow registering both the magnetic field tension of large sunspots and variation of their area with the time interval of an hour. Besides, one should record the noise storm with broad band radiospectrographs of different frequencies, interferometers and polarimeters.

ასტრონომია

მზის რადიოგამოსხივება (f = 210 მჰც) სიხშირეზე და მისი კავშირი მზეზე მიმდინარე ოპტიკურ მოვლენებთან

შ. მაქანდარაშვილი

ე. ხარაძის აბასთუმნის ეროვნული ასტროფიზიკური ობსერვატორია, ი. ჭავჭავაძის სახელმწიფო უნივერსიტეტი, თბილისი

(წარმოდგენილია აკადემიკოს ჯ.ლომინაძის მიერ)

რადიოასტრონომიული მეთოდების გამოყენებამ მზის ფიზიკის შესწავლის საქმეში მოგვცა ახალი შესაძლებლობანი: ჯერ ერთი — მზის ატმოსფეროს ზედა ფენების შესწავლა მისი დაბნელების გარეშე; მეორე — დაკვირვებების დაკავშირება უშუალოდ იმ პროცესებთან, რომლებიც გვაძლევენ კორპუსკულურ გამოსხივებას; მესამე — დაკვირვებების წარმოება ნებისმიერ მეტეოროლოგიურ პირობებში.

მზის რადიოდაკვირვებები გარკვეულწილად ავსებს ოპტიკურ გამოკვლევათა შედეგებს, ზოგ შემთხვევაში კი წარმოადგენს ინფორმაციის მიღების ერთადერთ საშუალებას. ყურადღებას იპყრობს ის, რომ მზის რადიოგამოსხივება ორგვარად წარმოგვიდგება: „მშვიდი“ მზისა და „შეშფოთებული“ ანუ „სპორადული“ მზის სახეობებით, ასევე ცნობილია მათი განმასხვავებელი მახასიათებლებიც.

ე.ხარაძის ეროვნულ ასტროფიზიკურ ობსერვატორიაში სამზეო რადიოდაკვირვებები, ოპტიკურ დაკვირვებებთან ერთად, მიმდინარეობს 1957 წლიდან მეტრიან დიაპაზონში (λ=1,43მ, f=210მგჰ);დაკვირვებათა

ხანგრძლივობა ყოველდღიურად 4-6 საათია. 1957-2008 წლებისათვის მოპოვებულია მეტად მდიდარი დაკვირვებითი მასალა, რომელიც მოიცავს მზის აქტივობის 5 ციკლს (მაქსიმუმები 1957-58, 1969-70, 1980-81, 1990-91, 2000-01).

2007 წლიდან დაწყებულია ახალი ციკლის აღმავლობის პერიოდი.

იმ დიდ მასალაში, რომელიც წლების განმავლობაში დაგვიგროვდა, კარგად გამოხატულია, რომ ხმაურის ქარიშხალი მჭიდრო კავშირშია მზის ლაქებთან ან ლაქათა ჯგუფთან. ხშირ შემთხვევაში ლაქათა ჯგუფი, რომელსაც თან ახლავს მზის რადიოგამოსხივების ქარიშხალი, მიეკუთვნება E და F კლასს (ლაქათა მიღებული კლასიფიკაციის თანახმად).

ნაშრომში განხილულია აქტიური არეების რადიოგამოსხივების ჩანაწერების დამუშავება. 500 სხვადასხვა ჩანაწერიდან მოყვანილია 3 მაგალითი, როგორც ოპტიკური, ასევე რადიოდაკვირვებებისა. გამოთვლილია სხვადასხვა მახასიათებლები. დაკვირვებითი მასალის ანალიზის საფუძველზე დადგენილია, რომ უმრავლეს შემთხვევაში რადიოგამოსხივება დაკავშირებულია ლაქათა ჯგუფთან, კერძოდ, ხმაურის ქარიშხალი წარმოიქმნება რთული კონფიგურაციის მქონე ლაქათა ჯგუფებში, დიდი ლაქების ზრდის პროცესში. ამასთანავე, რადიოდაკვირვებებისა და დიდი ლაქათა ჯგუფების მაგნიტური ნაკადების მაქსიმუმი ემთხვევა ერთმანეთს ერთი დღე-ღამის სიზუსტით. ლაქათა ჯგუფების მძლავრი მაგნიტური ნაკადები კი, თავის მხრივ, მძლავრი ქრომოსფერული ამოფრქვევების წინაპირობაა.

ამავე დროს ხმაურის ქარიშხალი მჭიდრო კავშირს ამჟღავნებს ლაქათა მაგნიტური ველების დაძაბულობათა ცვალებადობასთან.

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