Observational possibilities of RATAN-600 and some problems of solar activity

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Introduction

RATAN-600 (Special Astrophysics Observatory, Zelenchuk, Russia) is one of a few regular working instrument in the world which give the daily spectral information on solar radio emission in the centimeter and decimeter wavelengths. Solar observations are performed now with antenna system including South sector and Periscope (Korol'kov & Parijskij, 1979). Now this regime has an additional possibility for multi-scanning and tracking of the Sun. Because this new regime is used we would like to consider the several tendencies in study of solar activity.

New technical possibilities of RATAN-600

The antenna system "South sector and Periscope" together with the multi-channel panoramic spectral analyzer in wide frequency range from 0.9 GHz to 17 GHz are using now for the monitoring of solar activity. The additional tracking of the Sun during during $\pm$ 2 hours near meridian time (using all circular railway track) opens new possibilities in the study of the Sun with RATAN-600 and allows us to research some actual problems of solar physics. In principle, two new aspects appear in the analysis of solar emission:
– temporal oscillation of the spectrum, polarization and structure of the sources;
– spatial separation of the sources.

New possibilities are as follows:
– monitoring of the Sun (1 - 3 observations in the range 1.7 cm - 32 cm with intensity and circular polarization measurements with frequency resolution 5%);
– study of temporal parameters of AR structure, spectra on the scales minutes and tens of minutes during four hours;
– study of weak spike sources with high temporal resolution in decimeter wavelengths in tracking regime;
– study a polarization emission of different solar sources with high accuracy up to 0.3%;
– spatial separation AR in North and South hemispheres;
– mapping of the Sun on the base of azimuth observations.

Now, there is a nice chance to use 2D-maps of Nobeyama radioheliograph in order to determinate the radio sources location on the disk together with wide range spectral data of RATAN-600.

Solar astrophysical problems

1. Radiomagnetography. Spectral observations allow to separate the contribution of chromosphere and corona in the polarized emission. Methods of radio tomography based on spectral data are under development (Bogod & Grebinskij, 1997; Grebinskij et al., 1999).

Combination of 2D-maps of Nobeyama and RATAN spectral data will allow to create 3D-magnetic structure of AR. Hereby, the Metsähovi data are very essential.

2. Oscillation and helioseismology of AR. Nobeyama data allow begin to study the oscillation of cyclotron thermal sources above sunspots with the period of 3-5 minutes at radio wavelengths. Combination of spectral RATAN-600 data and long time azimuth observations may be very promising for this task.

3. Bursts and CME. The long-term observations allow us to carry out the regular study of flares and compare the flare data with weak pre-flare spectral phenomena. The last are studied with RATAN-600 traditionally [Akhmedov et al., 1986; Borovik et al., 1989).

4. Emergence of new magnetic flux. The emergence of magnetic flux have being studied in solar physics in connection with problems of corona heating, CME and flares. Here we demonstrate of these phenomena on the example of spectral-polarization observations. The comparison of multi-channel polarization solar scans for May 12 and 13, 1997 is presented in Fig.1. In the West part of the disk there is the active region AR NOAA 8038. One can see from Fig.1 for May 12 that the polarization emission has simple bipolar structure in wide wavelength range with R-hand polarization for leading spot and L-hand polarization for the following part of the group. But for May 13, the spectral polarization structure is quiet complicate at all wavelengths with several inversions of polarization. Detailed consideration indicates the appearance of new opposite polarity magnetic flux on the level of chromosphere-corona transition region (short centimeter range) and perturbation of coronal plasma (decimeter range) driven by bursts and/ or CME.

The short wavelength part of the spectrum (from 1.83 cm to 3.21 cm) is used preferably for the analysis of sunspot magnetic field structure. The polarized emission spectrum of sunspot associated source informs us about the magnitude, sign and structure of magnetic field. According to cyclotron emission mechanism, in the case, when the third gyrofrequency harmonic reach the coronal temperature levels (Akhmedov et al., 1986), the maximal value of longitudinal magnetic field can be estimated as: $B[G] = 3570/\lambda[cm]$. RATAN-600 observations in May 12 (see Fig.1) give the evidence of very weak polarization signal in the AR NOAA 8038 only at the shortest wavelength 2.67 cm. It permits us to estimate the magnetic field value (about 1330 G). Here the R-hand polarization associates with North polarity of magnetic field and it corresponds to the x-mode emission at third harmonic of gyrofrequency.

The northern polarity dominates in the middle part of the spectrum from 2.67 cm to 10.17 cm for both day of observations (see Fig.1). On the next day the new polarized signal with L-hand polarization is appeared at the short wavelengths 2.11 cm and 2.24 cm. The estimation of the southern polarity magnetic field gives 1700 G. The difference in both magnitudes and fluxes for magnetic fields with opposite polarities in AR NOAA 8038 led to appearance of the new type of polarization inversion at short wavelengths, which was detected in spectral polarization observations during May 13. Such phenomenon differs from well-known inversion in the quasi-transverse (QT) field regions and current sheets (Bogod et al., 1995). In our case this effect is the sum of old southern polarity field and new north polarity. This sum is equal to zero at wavelength 2.32 cm for May 13. The ascent of new flux occurred between May 12 and 13 observations.

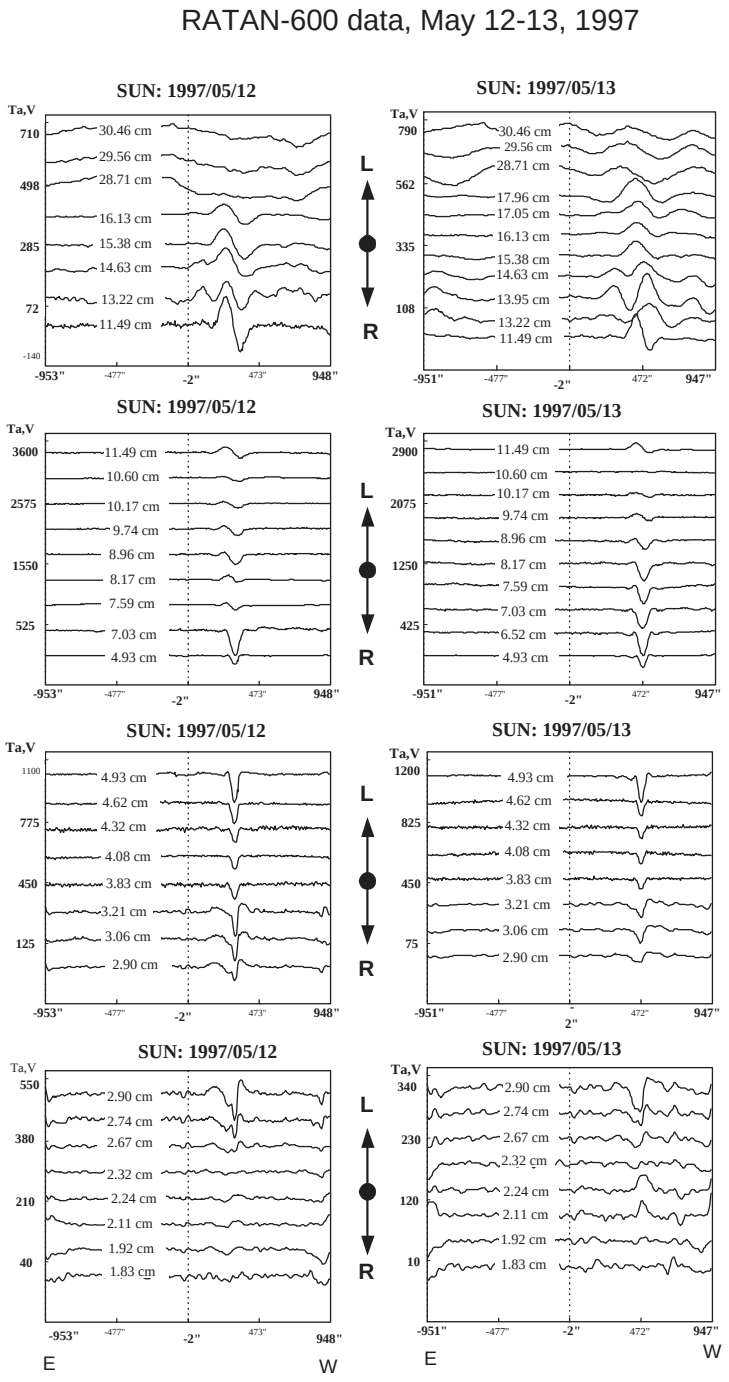

Figure 1: One-dimensional polarization scans with Panoramic Analyzer of Spectrum at RATAN-600 for May 12 (left) and May 13 (right). Entire wavelength range is presented in 4 sub-ranges with different scales. One can see stable bipolar behavior of AR NOAA 8038 on May 12 and perturbated character on May 13. In the short part on May 13 (the lowest picture) at wavelengths 2.24 cm and 2.11 cm new magnetic flux opposite polarity is recorded

Analysis of the long wavelength part of the spectrum demonstrates the complicated inversion polarization structure for May 13 events. Except the short inversion mention above

there is the inversion in the range from 10 cm to 15 cm. Such inversion also differs from inversion in QT-region, which has the very strong exponential dependence of the inversion on frequency. One can propose that in this case the inversion may be the result of plasma emergence from the AR.

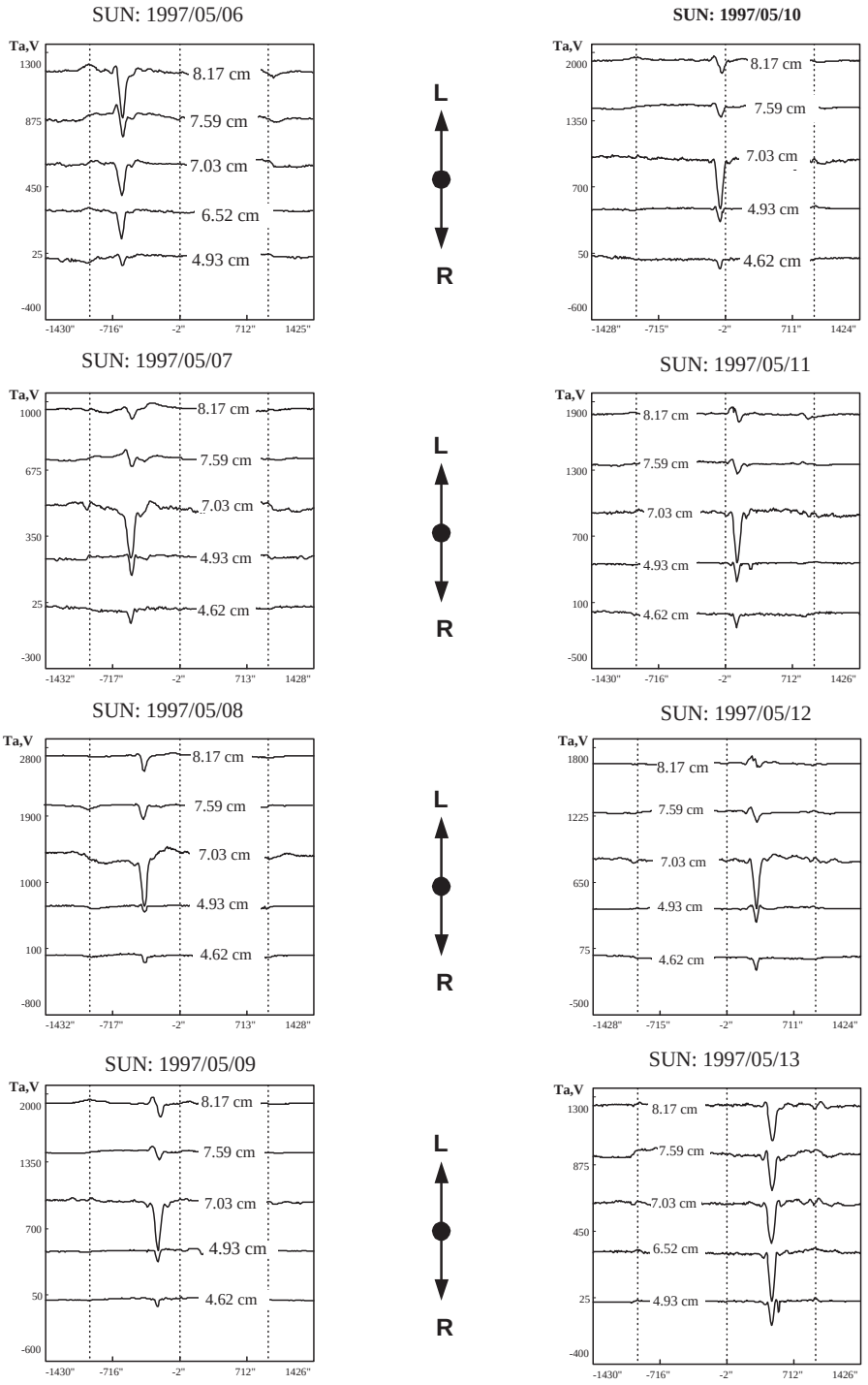

Figure 2: The example of registration of line-like spectral sources in polarized emission during 8 days from May 6 to May 14 1997. The line-like source at the wavelength 7.03 cm manifestates stability in time and reflects the process of accumulation energy in AR before large flare in May 12-13, 1997

5. Cyclotron lines and fine spectral structure. RATAN-600 observations allow to detect fine spectral features in wide frequency range. Existence of line-like structures in the spectra of microwave sources, attributed to the cyclotron emission was predicted a long time ago (Zheleznyakov & Zlotnik, 1980; Zheleznyakov, 1970). The distribution of plasma parameters may determined the frequency spectrum and polarization in different AR. RATAN-600 observations revealed such line-like structure at the wavelength 8.5 cm (Bogod et al., 1998).We also demonstrate here in the Fig.2 another example of such line-like structure at the wavelength 7.03 cm. This line- like source has quiet stable parameters during passage along the disk. It is interesting to note that this AR NOAA 8038 was very active and produced a lot of bursts and CME. Likely, the such type of the sources is connected with processes of accumulation energy before flares. The study of such fine spectral structures is very important in the contest of corona heating problem. Another types of polarization inversion at decimeter part was studied by Alissandrakis et al. (1998).

6. Polar zone activity. The modern study of solar cyclicity consider this phenomenon likes global process. The observational methodic used in Metsähovy, RATAN-600, Nobeyama and Crimea look very effective. Spectral method can help a lot in analysis the magnetic field structure.

7. Magnetic traps, current sheets, particle accelerations outside flares. Here we continue the study of the origin of: (i) decimeter halo (spectrum, polarization, temporal oscillations); (ii) relation of the polarization inversion with Noise Storms (Bogod et al., 1995); (iii) millisecond spikes in AR.

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