Multi-Wavelength Investigations of Solar Activity
Proceedings IAU Symposium No. 223, 2004
A.V. Stepanov, E.E. Benevolenskaya & A.G. Kosovichev, eds.

DOI: 10.1017/S1743921304005939

On the relationship between chromospheric oscillations of radio brightness at 1.76 cm with periods from minutes to hours and magnetic field changes

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Abstract. We present the results of Fourier and wavelet time series analysis for the high-cadence observations of an active region NOAA 8011, obtained with the Nobeyama Radioheliograph (NoRH) at the wavelength of 1.76 cm on 17.01.1997. Oscillations in brightness are found to be present with periods in the range from minutes to hours. The relationship between the active region oscillations in the microwave total intensity (I) and circular polarization (V) emission and changes of the magnetic field, deduced from the high-resolution magnetograms from MDI/SoHO, is investigated. We concentrate on the identification of different oscillation modes, the temporal behavior of the oscillations and the spatial distribution of different oscillating frequencies.

1. Observations and data analysis

Radio images of active region NOAA 8011 in total intensity (Stokes I) and circular polarization (Stokes V) were synthesized from NoRH interferometer data with 10 s cadence for 6 hours with spatial resolution of about 10 arcseconds. Together with radio data we have analyzed high resolution (pixel size of 0.605 arcseconds) simultaneous observations of the continuum intensity, a proxy of the magnetic flux (magnetogram) and the Doppler velocity, obtained with the Michelson Doppler Interferometer (MDI) onboard the Solar and Heliospheric Observatory (SOHO) with a cadence of 1 minute for 1 hour run. Not high magnetogram values (1150 G and -740 G for leading and following spots, respectively), low polarization of the radio source (peak polarization of ± 0.4 %) and not high brightness excess over the quiet sun values (peak excess of 65 %) lead to the conclusion that the mechanism responsible for the region emission at 1.76 cm is thermal bremsstrahlung. The first detection of the spatially resolved oscillations by radio observations was reported by Gelfreikh et al. (1999). The authors studied the cyclotron sunspot-associated source emission. In this work we search for oscillatory signatures in thermal bremsstrahlung radio emission of an active region. For the region under consideration the location and sign of the polarization source coincide with the location of the leading and following spots while radio source in brightness is located at the magnetic field neutral line.

Data reduction included the alignment of the images, correction for the solar differential rotation and removing of the long term evolution. Power spectra were obtained applying the Fast Fourier Transform algorithm with the statistical significance of the power peaks, estimated according to Groth (1975). For the study of the duration of the significant oscillations as well as the evolution of their frequency/period we applied a wavelet analysis using software provided by C. Torrence and G. Compo and available at URL: http://paos.colorado.edu/research/wavelets/. Two dimensional power maps in selected frequency bands, namely in the ranges of [120-240] s, [240-400] s and [400-3600] s, were constructed for the investigation of spatial distribution of the oscillation frequencies and identification of the oscillations with active region structures. We analyzed the temporal and spatial variations of the radio emission and magnetogram signal throughout the whole active region but further will focus on selected locations such as sunspots and neutral line.

2. Discussion and Conclusions

Intensity oscillations are detected above the sunspots and in the source above the neutral line, which apparently corresponds to the coronal loop at the temperatures of $10^4 - 10^6$ K. In polarization channel the oscillations are found only above the sunspots.

Radio brightness oscillations in 3-minute range which are present in the locations of the extreme polarization are the manifestation of the well known oscillation above sunspots. In the magnetogram and velocity data for the active region under consideration the oscillations in this range were not detected. In 5-minute band the radio brightness oscillations were found to be non-stationary and registered above the spots and in coronal structures above the neutral line while magnetograms and dopplerograms showed confident 5-minute oscillations over sunspots. The non-stationary behavior of radio variations can be interpreted as the effect of the global oscillations on the local processes in the active region.

The oscillations with the periods of about 10 minutes (7-12 min) are found mainly in the intensity channel thus are intrinsic to coronal arches above neutral line. Longer periods (from 10 minutes up to 1 hour) are revealed in total intensity above the neutral line and in the polarization channel above the sunspots. Though the existence of the oscillations with the period longer than ten minutes were reported by several authors their nature is far from understanding and may regard to the fundamental processes in the solar atmosphere.

While analyzing circular polarization changes we have detected the existence of polarization oscillations from the locations where intensity oscillations are absent. This observational result can be interpreted in terms of magnetic field changes under the conditions of thermal bremsstrahlung emission of the optically thick chromosphere. In this case polarization depends on the density gradient and oscillatory changes of the magnetic field directly influence the polarization but not the total intensity.

In general, our study shows that the analysis of the radio observations with high spatial and temporal resolution assists in obtaining of new information on the manifestation of the solar plasma structures. Thus, the investigations of active regions at radio wavelengths expand the results of the optical observations and make them more precise.

Acknowledgements

This work was supported by INTAS (grant 00-543), RFBR (grant 02-02-16548), RFBR (grant 03-02-17357), RAS “Non-stationary phenomena in astronomy”, OFN-16 and Russian Federal Program (project 40.022.1.1.1105).

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https://doi.org/10.1017/S1743921304005939 Published online by Cambridge University Press