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# Some Properties of Microwave Emission From Flaring Regions*

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**Abstract** A study is made of the differences in the polarization distribution and other characteristics of microwave emission for several active regionswith high flare productivity. Conclusions are drawn about the magnetic field structure of these regions at coronal heights.

**Key words** Microwave emission, Solar activity, Solar flare prediction

## 1 Introduction

Microwave emission from the active region has a complicated origin and consists of several components. We shall examine only those components, on the basis of which we have developed the forecasting algorithm for powerful solar flares.

**Sources above sunspots**. These sources lie above sunspots at 2—3 thousand kilometers above the photosphere. The emission represents thermal cyclotron radiation at the second and third gyrofrequency harmonics in strong magnetic fields. The emission is circularly polarized, and the polarized component is anisotropic along the magnetic field direction.

**Halo**. Historically, it was customary to include in this component all radio emission of a non-sunspot origin. Subsequent investigations showed that it is separated into the emission from solar faculae and a so-called coronal condensation. The origin of microwave emission from the coronal condensation is significantly more complicated. Thermal gyroresonance radiation and the emission of nonthermal electrons in magnetic fields on the order of 10 Gauss are invoked to explain it.

As microwave emission propagates from sunspot sources through a quasi-transverse magnetic field, in the active region corona there occurs the inversion of the sign of the circular polarization.

Thus the observed microwave emission has a different origin and is generated in different parts of the active region. Characteristics of this emission depend on the angle between the line of sight and the magnetic field direction both in the region of generation and along the propagation path in the active region corona. Consequently, for a correct interpretation of microwave emission, it is necessary to take into account the position of the active region on the solar disk.

The evolution of the active region is accompanied by a magnetic field restructuring, which involves changes of plasma parameters in the regions generating microwave emission along its propagation path as well. There is also a change of the proportion of the contributions from different areas of the active region to the observed total emission of the active region. Structural changes and changes of parameters of the active region can lead to process of accumulation of energy and its subsequent release in the form of a solar flare and may not be accompanied by the storage of energy. For that reason, the chief objective of solar flare prediction is to identify energy build-up signatures and to develop-on the basis of these signatures forecasting algorithms.

## 2 Changes in the Sign of Circular Polarization of Microwave Emission From Active Regions

Our short-term prediction algorithm for powerful so-

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lar flares was developed on the basis of the data obtained with the Siberian solar radio telescope[1],[2].

The forecasting algorithm for powerful flares implies that the most dramatic changes during the preflare stage of development of the active region are taking place in the corona and show up as changes of coronal condensation characteristics. During the quiet stage of development of the active region the coronal condensation is optically thin, and its contribution to total emission is small. In this case when the active region appears from behind the solar limb, its emission is unpolarized, and during its solar disk passage the polarization distribution of microwave emission changes consistently from unipolar to bipolar in the eastern hemisphere and from bipolar to unipolar and unpolarized in the western hemisphere. Fig.1 shows such changes in the sign of circular polarization of 5.2 cm microwave emission from AR 9068 during its passage across the solar disk.

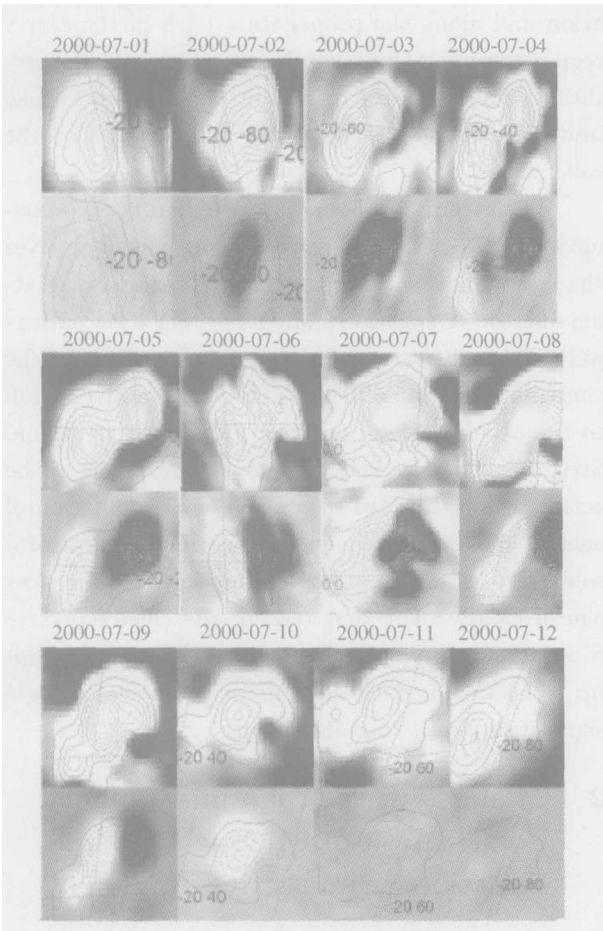



Fig.1 AR 9068 in total (top) and polarized (bottom) microwave emission from July 1, 2000 to July 12, 2000 (grayscale Stokes I and V, black contours Stokes I)

At the preflare stage of development of the active region the coronal condensation becomes optically thick and makes already a considerable contribution to total emission. An example of such a behavior is given in Fig.2. Radio emission from AR 9087 was recorded one day before the appearance of a sunspot group on the visible disk. The polarized emission component was absent. No flares were observed that day. Radio emission from AR 9090, under the same conditions, contained a polarized component, and a flare of importance M1.1 was observed on that day. In the former case the main contribution to the active region emission was made by the sunspot source, and as magnetic fields lie mainly in the plane of the sky, it was not observed because of the anisotropy of polarized emission. The latter case showed emission from the coronal condensation, the magnetic field of which had a component directed along the line of sight. The source was therefore observed in total and polarized emissions.

When the active region with an optically thick coronal condensation lies near the center of the solar disk, the emission from sunspot sources is blanketed by the condensation, and a unipolar polarization distribution of the coronal condensation, rather than a bipolar, or the more complicated, polarization distribution produced by the sunspot sources, is observed. Fig.3 shows the polarization distribution for the active region 9077 on those days when it gave powerful solar flares, including the "The Bastille Day" flare of importance X5.7 of July 14. It is evident that, with a complicated multipolar structure of magnetic fields at the photosphere, the polarization distribution of microwave emission is unipolar.

A total of 52 active regions travelled across the solar disk in July 2000. They produced three flares of importance $\geqslant$ X1.0, 42 flares of importance $\geqslant$ M 1.0 and about 250 subflares. Large flares occurred in nine active regions, and the active region NOAA 9077 produced 15 flares, of which three flares were of importance X, the active region NOAA 9087 produced nine flares, and eight flares occurred in the active region 9090.

One-day short-term predictions were made for each particular active region and for each day of the period under investigation. The number of quiet days and of days with flares of importance $\geqslant$ M 1.0

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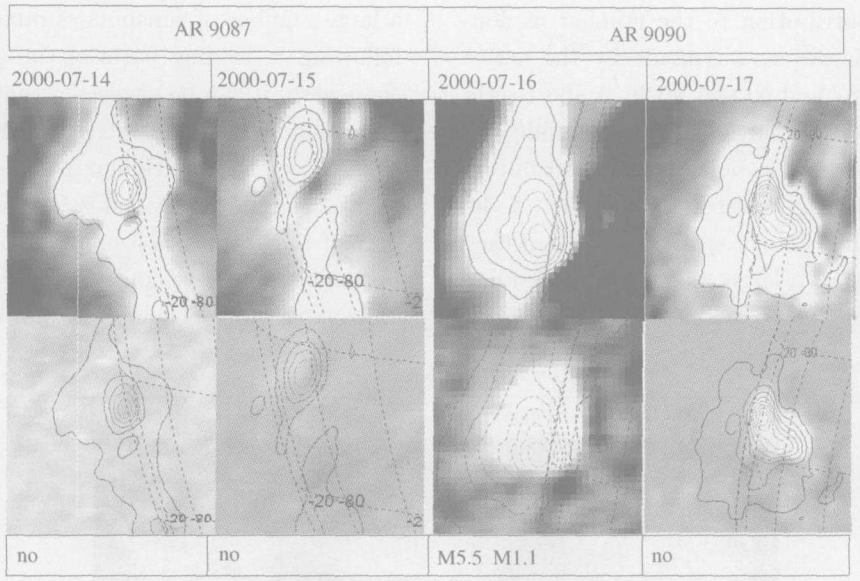



Fig.2 Images AR's 9087 and 9090 in total (top) and polarized (bottom) microwave emission




Fig.3 Images AR 9077 in total (top) and polarized (bottom) microwave emission

was predicted.

Note that good results were obtained for the active region NOAA 9077: of 15 events, an accurate prediction was made for 13 events, including the well-known "Bastille Day"——flare of importance X 5.7 that occurred in this region on July 14 (Fig.3). Some cases where flares were not predicted or false alerts were issued occurred near the boundaries of the zones. These errors are due to the accuracy, with which the boundaries were determined, and we know how to remove them: by increasing the number of radio images to be processed (a single image is used in this study), and by taking into account the latitude of the sunspot group, its extent, and the slope of the axis of the group with respect to the equator.

43 active regions transited across the solar disk in November 2000, which produced 11 flares of importance M, and five flares of importance X. The predictability of powerful flares made up 72%, and all the five flares of importance X were predicted. All errors in the prediction were made near the boundaries of the areas.

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The main contribution to the number of non-predicted flares, however, was made by the active regions NOAA 9087 and NOAA 9090. A short-term prediction of powerful solar flares by a simplified algorithm that includes the polarization distribution only, did not yield any satisfactory results. A detailed investigation of these regions showed that they have good properties: a large sunspot in the leading (9087) or following (9090) parts of the group, and a large number of sunspots of mixed polarity in the following or leading parts of the group (Fig.4). In these cases it can be suggested that the coronal condensation is not symmetric and lies, for the most part, above the multipolar part of the group. For that reason, microwave emission from the multipolar part of the group has a unipolar polarization distribution of microwave emission, and the emission from an isolated sunspot has a sunspot origin.

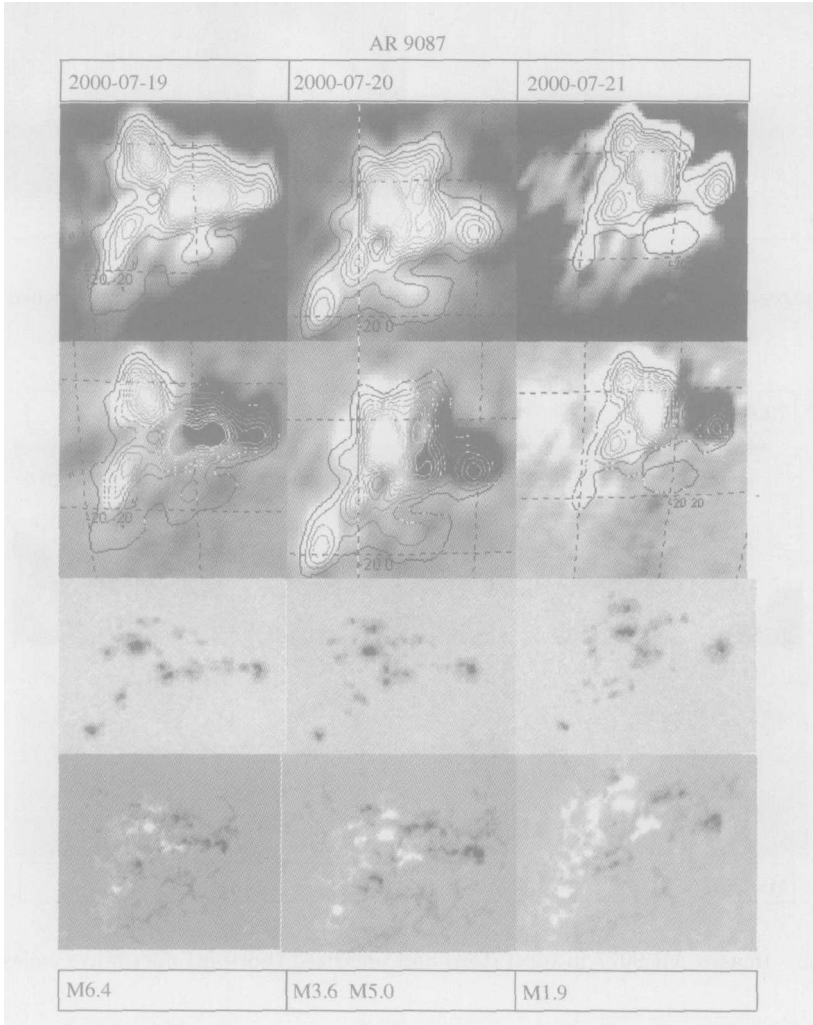



Fig.4 Active region 9087. First and second row, microwave images in total and polarized emission; third row, Big Bear Solar Observatory photoheliograms; fourth row, SOHO/MDI magnetograms

To verify this assumption we used other characteristics of microwave emission: flux in total emission, and the ratio of the flux to the area of the group[3] (Fig.5). As is apparent from these plots, the microwave emission flux for both groups exceeds the threshold value for quiet regions. The behavior of the ratio of the flux to the area of the sunspot group has a nonmonotonic character. Since the flux from the sunspot component is proportional to the area of the group, the abrupt changes of this quantity may be attributed to the action of the contribution from the coronal condensation to total emission.

Besides, we reconstructed the three-dimensional configuration of the magnetic field for these regions

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using the program[4] (Fig.6). These figures suggest the conclusion that the assumption about the asymmetric nature of the coronal condensation is not without foundation.

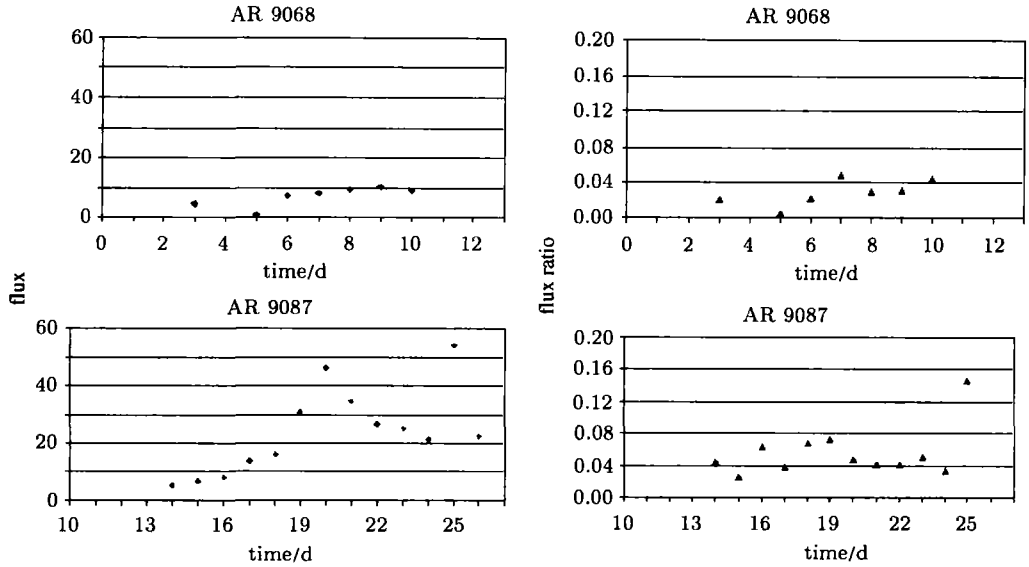



Fig.5 Flux (left) and the ratio of the flux to the area of the sunspot group (right) for AR's 9068 and 9087

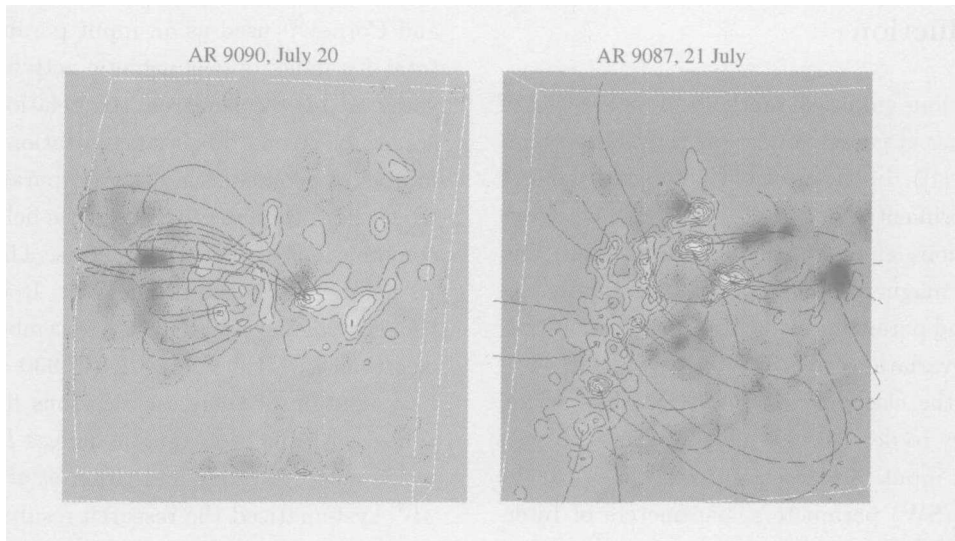



Fig.6 Three-dimensional configuration of the magnetic field for AR's 9087 and 9090

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