LOCATION OF COMPACT MICROWAVE SOURCES WITH RESPECT TO CONCENTRATIONS OF MAGNETIC FIELD IN ACTIVE SOLAR REGIONS

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1. INTRODUCTION

The slowly varying (S-) component of solar microwave emission originates in the vicinity of sunspots and chromospheric plages. A significant portion of this component is produced by bright, compact sources which are much smaller than the active regions in which they occur (Lang, 1974; Kundu *et al.*, 1977; Donati Falchi *et al.*, 1978; Lang and Willson, 1979). The combined radio-optical investigation reported here was initiated to explore, in regions at various stages of evolution, both the variability of compact microwave sources and their association with specific optical features.

2. OBSERVING PROCEDURE

The 46m radio telescope at the Algonquin Radio Observatory[1] is used at a wavelength of 2.8 cm in real-time collaboration with the multiple Hα photoheliograph of the Ottawa River Solar Observatory[2]. Both telescopes scan the sun in rasters in order to locate and record the regions of interest. Microwave sources are designated compact when they produce no detectable broadening of the 2.7' antenna beam, an indication that their angular size must be less than 20". Subsequen to the scanning procedure, the radio observer measures the position of maximum intensity of each microwave source to within 20 arc-sec or less depending upon the brightness distribution within the source. The optical raster scans provide a series of photographs on a scale of 15 arc-sec/mm such that 102 overlapping images cover the entire solar disk at one wavelength. At each solar position, the tunable Hα filter in the photoheliograph is cycled through 5 wavelength steps in the range Hα±1.0A. An optical scan of the entire disk on this scale at 5 wavelengths requires 25 min while the corresponding radio scan requires 45 min. Filtergrams of the whole disk in Hα are also secured on a small scale in order to assist in establishing the spatial correspondence between radio and optical features.

From September 1977 to July 1979, joint optical and radio observations were made successfully on a total of 20 days; in all, 28 active

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regions with compact microwave sources have been examined. This sample includes active regions at various stages of their development. Although the analysis of these data is incomplete, examples of microwave emission from two regions at extreme positions on the evolutionary scale merit special attention.

3. EMERGING FLUX REGION: McMATH 15467

This small plage region developed from pre-existing elements of the chromospheric network which were well isolated from larger active features. On 11 and 12 August 1978, the bipolar elements of this region were interconnected by a complex system of fine arches; by 13 August, the region had produced a miniature but conspicuous arch-filament system in which flare-like activity was evident on a micro-scale. Pores were first visible on 14 August when four of them, each 1" or less, formed a cluster about 5×10^3 km across at the leading edge of the widening plage. Microwaves were undetectable from this region at $\lambda 2.8$ cm during radio searches made on 12 and 13 August; a compact, steadily-emitting source of microwaves was located in the region on 14 August.

4. REGION NEAR MAXIMUM DEVELOPMENT: McMATH 14943

This magnetically complex region was oriented with its "neutral line" principally E-W rather than N-S. Between 11 and 15 September 1977 the sunspots in this region exhibited strong proper motions: a spreading apart of all spots and a pronounced rotation by the large leader of this complex, a spot of f polarity. The microwave emission from this region consisted of two components: a diffuse plateau at an antenna temperature of 10^4 K distributed over the whole region and a single compact source with a peak antenna temperature of 1.1×10^5 K. The absence of beam-broadening for this source implies a brightness temperature of at least 10^7 K. The compact source was located in the leading plage which partially obscured a rapidly decaying spot to the large leader spot of f polarity. On 13 September, the source pulsated at a period of 2.5s throughout the entire observing period of 5½h. The measured peak-to-peak fluctuations in brightness temperature were at least 2.5×10^5 K. There was no evidence from optical data to suggest that the pulsations were excited by flare processes.

5. DISCUSSION

In 11 of the 28 observed regions, the compact microwave sources varied in intensity with time-scales from minutes to several hours by as much as 50%, neglecting obviously impulsive events. The brightness temperatures of the sources at $\lambda 2.8$ cm were in the range 3×10^4 K to more than 10^7 K; for six sources, the brightness temperatures exceeded 2×10^6 K. Because these values were maintained for hours, they do not describe impulsive events. Such high values cannot be explained in terms of thermal emissive processes.

The presence of just a single compact microwave source in a large, magnetically complex region suggests a uniqueness to the immediate environment of the source which is also difficult to explain in terms of thermal models. Alternative mechanisms, including plasma oscillations and gyrosynchrotron emission, require a continuous supply of high energy electrons. The source would otherwise decay in minutes. Electron acceleration is most likely at particular points rather than generally over an active region. Microwave emission driven by a supply of high energy electrons would consequently arise only at those points.

[1]The Algonquin Radio Observatory is operated as a national facility by the National Research Council Canada.

[2]The Ottawa River Solar Observatory is operated by the National Research Council Canada.

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DISCUSSION

Pallavicini: I would like to point out that high-resolution observations at 2.8 cm from Stanford (Pallavicini et al. 1979, Ap. J., 229, 375) have shown that all bright compact radio sources with a life-time of the order of several days occur directly above the umbra of large sunspots, where the photospheric magnetic field has an intensity in excess of about 2000 gauss. Comparison of the radio data with simultaneous X-ray and EUV observations, together with extrapolations of the photospheric magnetic field to coronal levels in the current-free approximation, indicate that the bright radio sources can be interpreted as produced by thermal cyclotron emission in the strong sunspot magnetic field (Pallavicini, 1979, IAU Symposium No. 86). Are you referring to the same type of compact radio sources, or are your sources of much shorter life-time?

Gaizauskas: All the sources we examined were long-lived. Our results, as well as some of those in the cited references, indicate however that not all long-lived compact microwave sources occur directly over sunspot umbrae. Some of our sources had brightness temperatures well in excess of thermal values. In order for thermal cyclotron processes to be significant in these cases (especially the emerging region McMath 15467), we would have to postulate unacceptably high magnetic field strengths in the corona. Furthermore, although the very large region McMath 14943 contained many spots and many areas with large magnetic field gradients, it had just a single, very bright, compact microwave source. A thermal model would predict multiple sources.