DUAL FREQUENCY VARIABILITY STUDY OF AN ACTIVE REGION

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ABSTRACT. A short-time variability study of a solar active region simultaneously at 6 and 2 cm wavelengths was carried out using the VLA. The observations show interesting uncorrelated brightness temperature variation at the two wavelengths. The observed low brightness temperatures indicate that the emission is mainly originating from the chromosphere - corona transition region.

A transition region model with constant pressure and power-law temperature variation as a function of height has been assumed to analyse the data. The uncorrelated variation of the observed brightness temperature at the two wavelengths suggest different dominant emission mechanisms (bremsstahlung at 2cm and gyro-resonance at 6cm) operative at the two wavelengths. It is shown that an independent variation of a few percent in the magnetic field (900 ±45 G) and a factor of two variation in the density (2 to 4 x 10^{10} cm^{-3}) over a time scale of few hours is required to explain the uncorrelated brightness temperature variations at the two wavelengths.

1. INTRODUCTION

Optical observations indicate that solar active regions undergo continual structural changes. These changes should manifest in the emission at radio wavelengths. A time variability study of meter wavelength emission from active regions has recently been carried out (Shevgaonkar et al, 1988). However, this study was confined only to variability at the coronal level. In this paper we present dual frequency centimetric observations of an active region and study its variability. The centimetric emission mainly originates from the transition region and the lower corona where temperature and density gradients are sharp. The brightness temperature is therefore very sensitive to the changes in these parameters.

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A study of the brightness temperature variability at centimeter wavelengths will help us in better understanding the dynamics of active regions at lower heights in the solar atmosphere.

2. OBSERVATIONS AND RESULTS

An active region at S26E54 heliographic coordinates was observed with the VLA on June 8, 1987. The full-day 6 and 2 cm maps of the active region with angular resolution of 18" x 18" and 6" x 6" respectively are shown in Fig.1(a,b). The degree of circular polarization at both wavelengths was less than ~10% and it is therefore assumed that for all practical purposes the emission is unpolarized.

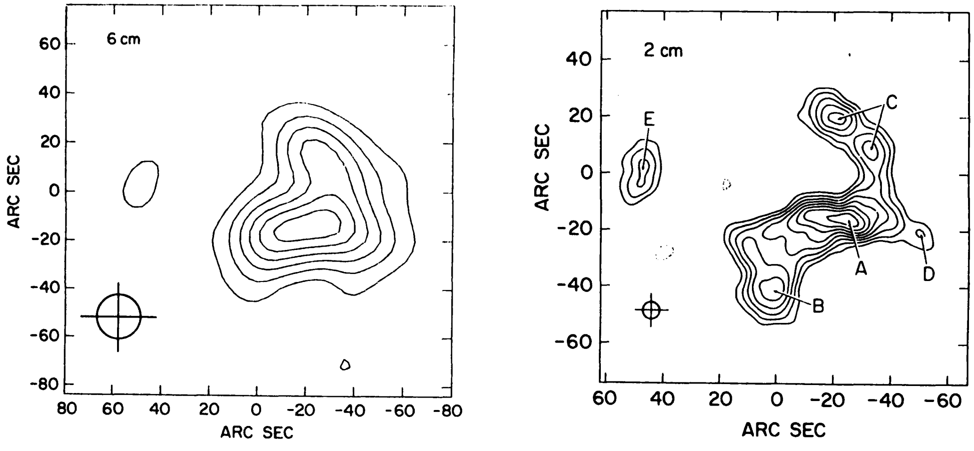

FIG. 1*a*

FIG. 1*b*

Figure 1a-b Full-day synthesis maps of the active region at 6 and 2 cm wavelengths. Contour intervals are 3.4×10^3 K and 333 K respectively for 6 and 2 cm maps.

After applying the appropriate corrections (For details see Shevgaonkar and Kundu, 1989) the peak brightness temperatures at 2 and 6 cm wavelengths are found to be 12 - 18 x 10^3 K and 4 - 11 x 10^4K respectively. To study the variability of the active region, 1-hr duration snap-shot maps were produced. All the sources marked in the full-day 2 cm map show short time variability. However, the brightness temperature variation only for the strongest source A (Fig.1.b) is shown here in Fig.2. It is evident that the brightness temperature shows uncorrelated variations at the two wavelengths. At 2 cm the brightness temperature varies between 15 and 18 x 10^3 K and at 6 cm it varies between 4 and 7 x 10^4 K.

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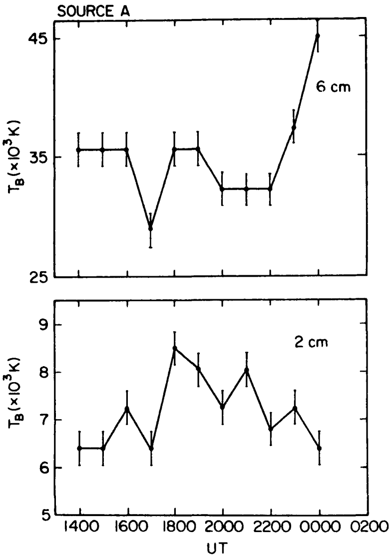

Figure 2 Variability of brightness temperature of source A as a function of time at 2 and 6 cm wavelengths.

3. DISCUSSION

From the computations carried out by Rao and Kundu (1977) and Kundu, Melozzi and Shevgaonkar (1986) it can be seen that the electron temperature T_e in the transition region has almost a power-law variation with height h above the chromosphere (we assume the height of chromosphere to be about 2000 Km). Therefore let us assume that the temperature in the transition region can be written as

$$T_e(h) = 10^4 \ (h \ / \ h_{min} \ )^{\alpha} \qquad (1)$$

where α is a constant, and at $h = h_{min}$, that is at the bottom of the transition region, the electron temperature is 10^4 K. For low heights it is also reasonable to assume the pressure to be constant as a function of height. If h_{max} is the height at which the temperature reaches coronal temperature, the optical depth upto a layer at height h_1 due to free-free emission is given as

$$\tau = \frac{14\times10^{-6} \ N_0^2 \ h_{min}^{3.5\alpha}}{2 - 7\alpha} \ \{ h_1^{-3.5\alpha+1} - h_{max}^{-3.5\alpha+1} \} \qquad (2)$$

where N_0 is the density at a height where temperature is 10^4 K. Now since $\alpha > 0$ and $h_{max} >> h_{min}$ and/or h_1, we can see that most of the opacity comes from layers close to h_1 or h_{min}. Taking a typical value of $N_0 = 3 \times 10^{10}$ cm^{-3} (for details see Shevgaonkar and Kundu, 1989), the heights of τ = 1 layers for 2 and 6 cm emissions come out to be 2250 km and 4250 km above the photosphere respectively. Therefore the height difference between the emitting layers at the two

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wavelengths is only about 2000 km. To explain the uncorrelated variation of the brightness temperature at the two wavelengths, it is essential that the physical conditions in the two emitting layers change independently. Since the height difference between the two layers is small, these type of independent changes are unlikely. Even if we assume some kind of localized heating at different heights, thermal conduction will transport the energy over a distance of 2000 km within a few seconds, and therefore slow uncorrelated variability can not be explained.

To obtain uncorrelated variation in the brightness temperature the layers emitting at the two wavelengths must move up or down independently. This is certainly not possible within the frame work of free-free emission without magnetic field. However, if we take into consideration the presence of the magnetic field the independent movement of the emitting layers can be obtained. If the magnetic field density is adequate (e.g. ~1000 G) the 6 cm emission could be due to gyro-resonance mechanism. In this situation we see that the 6 cm emission will originate from a height where the observing frequency equals the 2nd or 3rd harmonic of the gyro-frequency, whereas the 2 cm emission will originate from a layer which is optically thick due to free-free emission. Any fluctuation in the electron density will change the height of the 2 cm layer (free-free emission) without affecting the height of the 6 cm layer. On the other hand, any change in magnetic field will change the height of the 6 cm (gyro-emission) layer without significantly changing the height of the 2 cm emission layer. Taking exponential variation of the magnetic field as a function of height, the observed variation in the 6 cm brightness temperature corresponds to a few percent change (900 ± 45 G) in the magnetic field. On the contrary the variation in 2 cm brightness temperature requires a change in density by a factor of 2, that is, from 2×10^{10} cm^{-3} to 4×10^{10} cm^{-3} at the bottom of the transition region.

4. REFERENCES

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DISCUSSION

GELFREIKH: (i) Why do you refer in your models to the chromospheric instead of the photospheric level?
(ii) Do you not suppose that the chromospheric level in an active region may be quite different?

SHEVGAONKAR: (i) The model essentially is for the transition region where there is a high temperature gradient. The heights therefore are measured from the level above which the temperature increases steeply. Since in the chromosphere the temperature is more or less constant, the power-law model does not apply to the chormosphere. The heights therefore are estimated from the chromosphere rather than from the photosphere.
(ii) The height of the chromosphere could very well be different over an active region. Depending upon the chromospheric level the height of the emitting layer above the photosphere will change accordingly.

FORBES: I would like to make sure I understand your conclusion. Am I correct in stating that you have ruled out the possibility that the lack of correlation between the 2 cm and 6 cm level is due to a hot magnetic loop which extends to the 2 cm height but not to the 6 cm height?

SHEVGAONKAR: Yes, we have ruled out the possibility of low-level magnetic loops to some extent. The magnetogram shows essentially unipolar magnetic field (as we have considered). I would say that in this particular case, the presence of low-level hot magnetic loops is probably not plausible. However, I agree with you that a small magnetic loop which extends to the 2 cm level but not to the 6 cm height can produce uncorrelated variations in the brightness temperatures at the two wavelengths.

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