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RADIO EMISSION FROM THE QUIET SUN AND ACTIVE REGIONS AT DECAMETRIC WAVELENGTHS

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Abstract

The Continuum emission from the Quiet Sun and active regions is the radiation from the solar atmosphere when there is no transient burst activity. At decametric wavelengths this radiation originates in the outer corona. A study of this radiation offers, therefore, a method of obtaining the density and temperature structure of the outer corona. In this review we provide an account of the observations with the Decameter Wave Radio Telescope at Gauribidanur, and possible interpretation of the origin and variations of the radiation.

Introduction

The Continuum radio emission from the quiet sun and active regions was studied in great detail at centimetric and decimetric wavelengths. The background steady emission at these wavelengths originates at chromospheric and inner coronal levels and is purely thermal in nature. The emission from active regions which is also known as the Slowly varying component (SVC) arises in localised regions of high density and temperature. The emission mechanism of SVC is partly thermal and partly non-thermal.

At metric and decametric wavelengths the radio emission arises purely in the corona. Observations of the steady component (Quiet sun) and SVC at these wavelengths have been very sparse. This is mainly due to the lack of large radio telescopes with sufficient angular resolution and sensitivity. The previous observations at decametric wavelengths were made at Arecibo by the French group (Aubier et al. 1971) and at the Clark Lake Radio Observatory by the University of Maryland group. The essential conclusions from these observations are that the observed brightness temperatures cannot be explained on the basis of the generally accepted models of the density and temperature of the corona.

The Decameter Wave Radio Telescope at Gauribidanur

The observations described here, were made with the decameter wave radio telescope at Gauribidanur, India (Lat: 13° 36' N; Long: 05 hrs. 10 Min. E). The beamwidths, at 34.5 MHz, of the radio telescope are 26'x38' in the EW and the NS directions respectively. The collecting area is approximately $250\lambda^2$. The telescope is of the transit type and the beam can be pointed anywhere along the meridian in the zenith angle range ±45° using remotely controlled diode phase shifters. A time multiplexing system is used to cycle the beam through eight different declinations sequentially, the beam being changed from one direction to another in a few milliseconds. The present observations were made by taking drift scans in hour angle for about 15 Min. on either side of the transit of the sun. More details of the observing procedure and calibration are given by Sastry et al. (1983).

Observations

One dimensional scans of the sun were made using the E-W array of the Gauribidanur Radio Telescope during July 1979-March 1980, (Sastry et al, 1981). The measured brightness temperatures ranged from 0.3×10^6 K to 1.5×10^6 K and the E-W half power widths were about 3 to 4 $R_\odot$. In order to estimate the expected brightness distribution of the sun at decametric wavelengths one has to compute the trajectories of the rays which leave the solar atmosphere in the direction towards a distant observer. Intensity changes along the path of a ray are specified by the equation of transfer. The intensity of a ray emerging from the solar atmosphere is obtained as the integrated effect of emission, absorption and refraction along the trajectory. One can then derive the brightness distribution across the emitting disk. The expected peak brightness temperatures and half power widths were computed for various combinations of density and temperature based on Baumbach and Allen density model. It is found that a brightness temperature of 10^6 K can be obtained if the electron density and temperature are in the range of 5-10 times the B & A model and 1.2-1.5 10^6 K respectively.

Since 1981, we have made two dimensional maps of the sun with a resolution of 26'x38' whenever possible (Sastry et al. 1983). During the period 1981-82 we often found that the centroid of the radio brightness distribution is shifted from the center of the optical sun by nearly 1.5 to 2.0 $R_\odot$ (Figure 1). It was also found that the brightness temperature distribution along a line joining the centroid of the radio emission and the center of the optical sun is asymmetric in nature. In general the intensity was found to rise steeply on the side away from the sun and decreases gradually towrads the center of the sun. The brightness temperature at the center of the sun is 0.5 to 0.7 time the peak value. In order to simulate the observed brightness distribution we have used Newkirk's (1961) coronal model for a streamer in an otherwise symmetric corona. The electron density at any point in the corona is given by

$$N_Q = 4.2 \times 10^{(4.32/\rho)} \, (1 + C_N \, e^{-(\beta^2/2\sigma^2)})$$

where ρ is the distance from the center of the sun, β is the distance from the axis of the region of enhanced density and σ is the width of the enhanced region, in units of solar radius. The constant C_N determines the density of the enhanced region. The brightness temperature distribution was computed using the ray tracing technique of Newkirk (1961). The angle between the axis of the enhanced region (streamer) and the sun-earth line was assumed to be 45° and its width is taken to be 1.0 to 1.5 $R_\odot$. For an isothermal corona (0.5 10^6 K) and a density enhancement factor (C_N) of five there is no significant difference between the brightness temperatures of the radio centroid and the center of the sun. Since this model is not adequate to explain the observed decrease of the brightness temperture towards the center of the sun we introduced a temperture enhancement in the region of density enhancement. We assumed that the electron temperature, T, at any point in the corona is given by

$$T = T_0 (1 + C_T \, e^{-\beta^2/2\sigma^2})$$

Where T_0 is the temperature of the ambient corona and C_N is the temperature enhancement factor. We found that the brightness distribution calculated for a temperature enhancement factor of 2.5 and a density enhancement factor of five agrees satisfactorily with the observed distribution.

During the period August 6-30, 1983 the sun was very quiet at meter and decameter wavelengths. No strong radio bursts were detected excepting for an occasional Type III burst reported by Culgoora (Solar-Geophysical Data, 1983). The daily values of the total flux at 200 MHz measured at Hiraiso (Kumagai, 1985) remained constant throughout

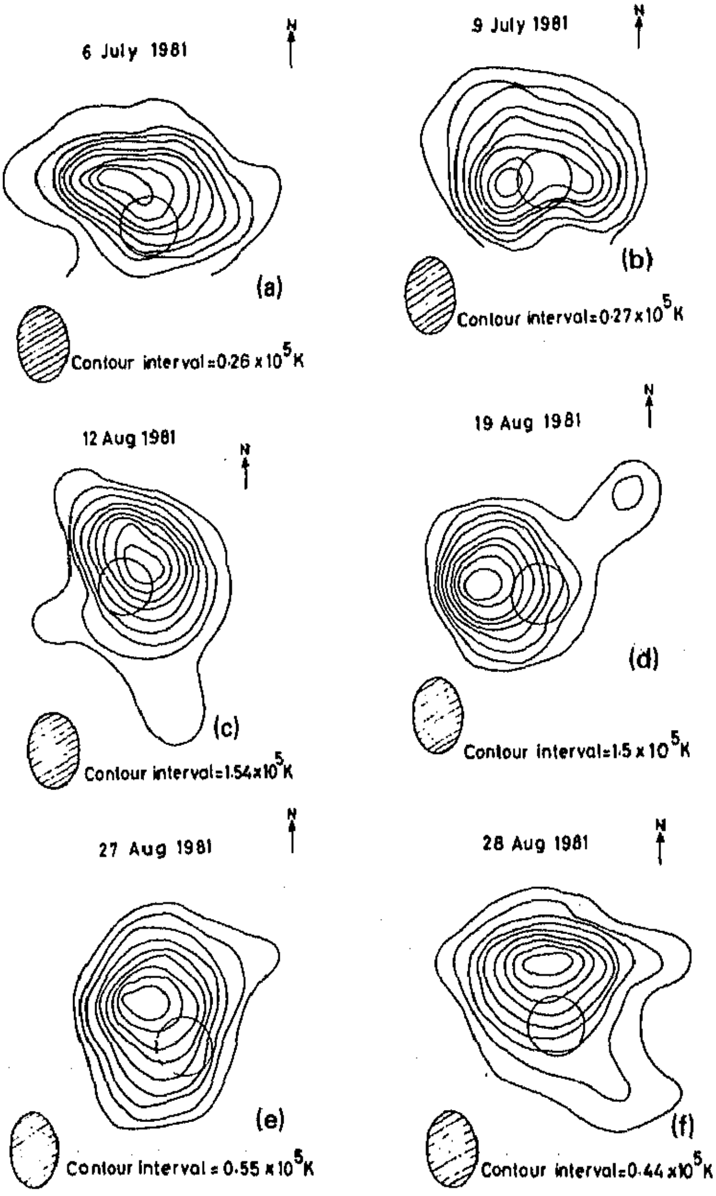

Fig.1. Radio map of the sun at 34.5 MHz made with the Decameter Wave Radio Telescope.

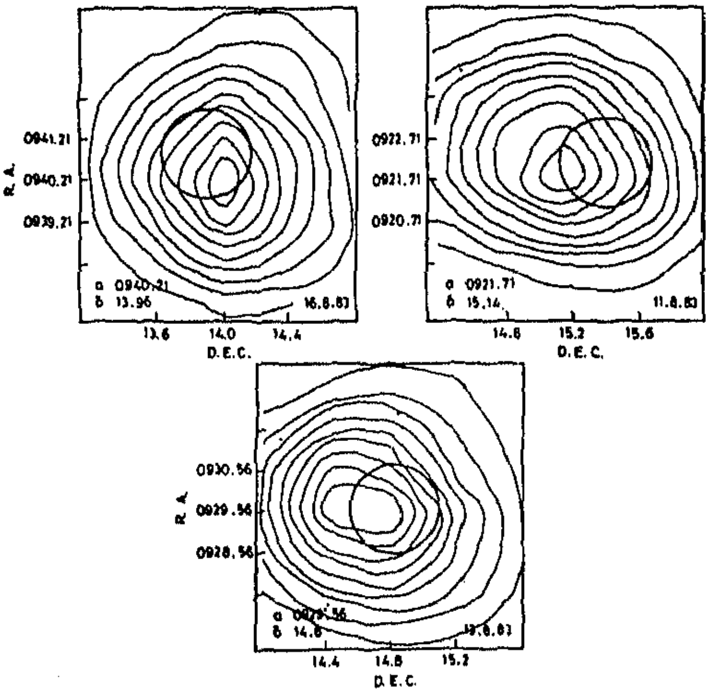

Fig.2. Radio map of the sun at 34.5 MHz made with the Decameter Wave Radio Telescope, on 13 Aug. 1983.

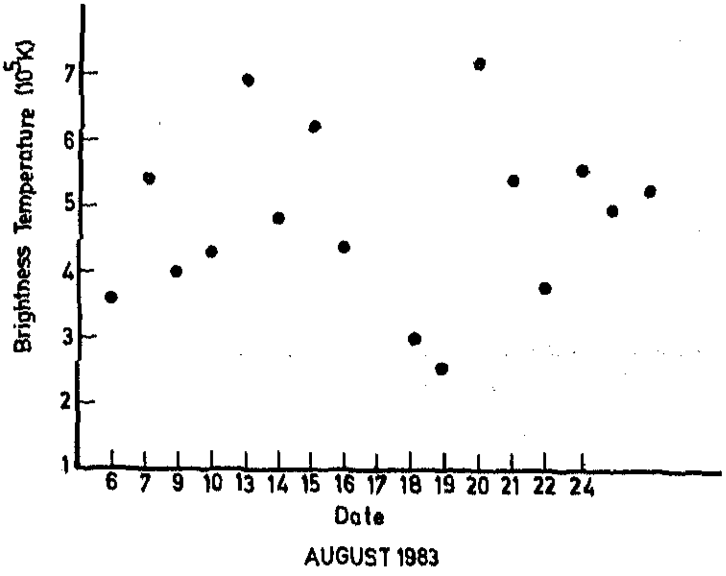

Fig.3. Daily values of the peak brightness temperature during August 1983.

the period at 8 to 9 sfu. The radio maps, at 34.5 MHz, made at Gauribidanur (Figure 2) are reasonably symmetric and the displacement of the radio centroid from the center of the optical sun, is usually <0.5 $R_\odot$. This can be accounted for as due to refraction in the ionosphere and pointing errors of the telescope. Therefore, we conclude that the radio emission is primarily due to the quiet sun. The distribution of the observed peak brightness temperatures on all days when observations were made during 1983 shows that they range from 200,000 K to 800,000 K. Although the sun is very quiet during August 1983 the peak brightness temperature did not remain constant. The daily values of the peak brightness temperture during August 1983 are plotted in Fig.3. It can vary by a factor of two on consecutive days and the ratio of maximum to minimum value is about four for the entire period. The half power width of the radio brightness distribution is generally around 3 to 4 solar radii.

As already noted the optical depth at 34.5 MHz, of the central ray for an isothermal corona of a million degrees and a density distribution of the type (Newkirk 1961) is ~ 1.4 and the observed peak brightness temperature should be of the order of 800,000 K. In order to get a brightness temperature of about 300,000 K the density should decrease by more than a factor of ten. The optical depth is also a sensitive function of the gradient of the electron density in the corona. It is possible to show that the corona becomes optically thin if the density gradient is steeper than that given above. If the density distributions is of the form

$$N_Q = N_0 \, 10^{\frac{5.00}{\rho}}$$

then the optical depth will be about 0.3 and the expected brightness temperature turns out to be 300,000 K. The electron density over the entire corona should increase by a factor of atleast 15 to raise the brightness temperature to 800,000 K. In this case the half power width of the brightness distribution should also increase by a facator of two (i.e. to 6 $R_\odot$) contrary to the observations. Alternatively there could be a temperature gradient in the corona. For temperatures of 200,000 K to 500,000 K the corona becomes optically thick for any accepted model of density distribution, and the observed brightness temperature will be equal to the kinetic temperature. In this case the temperature of the outer corona must be changing by a factor of two to four, with or without accompanying density changes, on time scales of the order of a few days.

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