Large-scale Structures and their Role in Solar Activity
ASP Conference Series, Vol. 346, 2005
K. Sankarasubramanian, Matt Penn, and Alexei Pevtsov

Low Frequency (< 100 MHz) Thermal Radio Emission from the Solar Corona and the Effect of Radial Magnetic Field

R. Ramesh[1] and Ch. V. Sastry[2,3]

[1] *Centre for Research and Education in Science and Technology, Indian Institute of Astrophysics, Hosakote 562 114, Bangalore, India*

[2] *MEENAKSHI, No.3, 2nd Cross, 1st Block, Koramangala, Bangalore 560 034, India*

Abstract. We measured the degree of circular polarization of the thermal radiation from discrete structures in the solar corona at a frequency of 77 MHz and attempted to derive the magnetic field strength of these regions.

1. Introduction

Radio maps of the solar corona show several kinds of thermally emitting discrete structures corresponding to streamers, holes, arches, etc. The magnetic field strength in such regions is estimated at high frequencies ($\sim$ 1 GHz) by measuring their polarization characteristics. Such measurements have not yet been made at low frequencies. It is also necessary to determine the ray paths in a magnetised corona to compute the expected degree of polarization and to study its dependence on the magnetic field strength, at radio frequencies.

2. Observations

The polarisation characteristics of the thermal radio emission are measured with the recently constructed polarisation array at the Gauribidanur radio observatory. The frequency range of observation is 30-110 MHz. The array consists of four groups, each of 8 log periodic dipoles. All the dipoles in a group are at the same position angle (PA, measured counter-clockwise from the North through the East). The PA of the four groups are 0°, 45°, 90° & 135°. We extract all possible correlations between the four groups and get six complex visibilities. These visibilities are used to determine the Stokes parameters I, Q, U & V following the method of Weiler (1973). Since the length of each group (70 m) and the spacing between the phase centers of adjacent groups (80 m) is not sufficient to resolve the Sun and other sidereal sources, we get information only on the average polarisation of the source (see Ramesh et al. 2005, for a detailed description of the array and calibration of the observed data). The solar data are calibrated using observations on the sidereal source Virgo A which

---

[3] Retired Professor, Indian Institute of Astrophysics, Koramangala, Bangalore 560 034, India

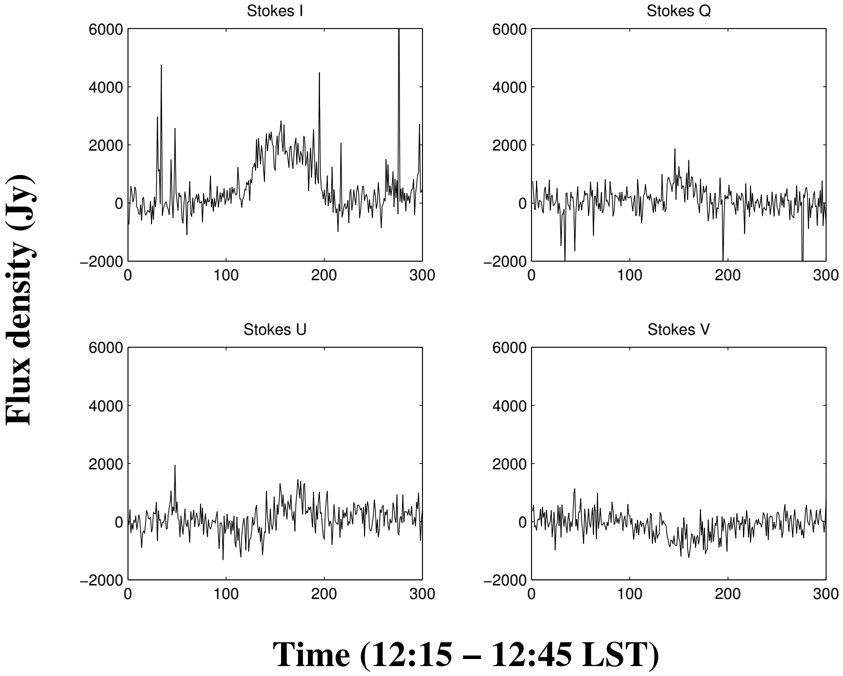

Figure 1. Time profile of the Stokes parameters for Virgo A (3c274) observed on September 26, 2004. Since it is an unpolarised source, the deflections in Q, U &V channels are treated as instrumental errors, and are used to calibrate the solar observations.

is taken to be unpolarised in our frequency range. Figure 1 shows its Stokes profiles obtained on September 26, 2004 at 77 MHz. Figure 2 shows the solar observations carried out on September 26, 2004 around 06:30 UT at 77 MHz. The Sun was ‘undisturbed’ and no non-thermal burst activity was noticed during our observing period with either the Gauribidanur radioheliograph (GRH; Ramesh et al. 1998) or the radio spectrograph in our observatory (Ebenezer et al. 2001). Also, no Hα/X-ray flare and non-thermal radio emission were reported (http://sgd.ngdc.noaa.gov/sgd/jsp/solarindex.jsp). The solar data was calibrated using observations of the sidereal source Virgo A carried out on the same day (Figure 1). The observed total flux density (Stokes I) from the Sun was about 9500 Jy. There are no significant deflections in Stokes Q & U channels. The deflection in the Stokes V channel corresponds to $\approx$ 2500 Jy. The estimated average degree of circular polarisation (i.e. V/I) of the whole Sun is $\leq 15\%$ (Figure 3). The radioheliogram obtained with GRH at 109 MHz and the GOES soft X-ray map of the solar corona, both on the same day as above, are shown in Figure 4 & 5. There are bright active regions close to the East & West limb in both of them. The observed deflection in the Stokes V channel (Figure 2) and the degree of circular polarisation (Figure 3) show that their maximum are shifted to the West compared to the time profile in the Stokes I channel

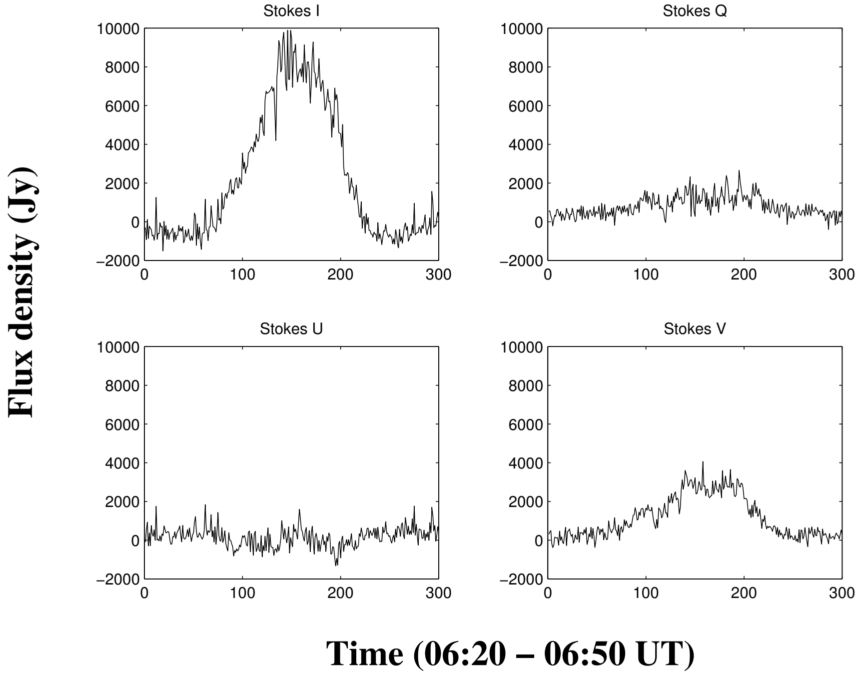

Figure 2. Time profile of the Stokes parameters for the ‘undisturbed’ Sun observed on September 26, 2004 at 77 MHz. Solar east is to the left.

(Figure 2). This indicates that the observed circular polarisation corresponds more likely to the active region on the West limb in the radio and X-ray maps.

3. Discussion

The propagation of radio waves through the coronal plasma is profoundly influenced by the presence of magnetic field. The medium becomes anistropic and the refractive index becomes a function of the direction of propagation. The radiation will be circularly polarised and propagates in two modes of opposite senses, usually referred to as ordinary and extraordinary modes. The energy in each mode will travel in a direction perpendicular to the phase refractive index surface of that mode, called the ray direction. There will be two refractive index surfaces for each mode, i.e. the phase index and the ray index. In such a medium one cannot determine the path of the radiation by simple application of Snell’s law. Haselgrove (1955) derived a set of differential equations for determining the paths of the two modes in the Earth’s ionosphere, a magneto-ionic medium. These equations are based on the Hamilton equations of geometrical optics. We applied these equations to the case of solar corona and determined the paths of the ordinary and extraordinary modes of propagation using Newkirk’s density model (Newkirk 1961). The magnetic field (B) at a

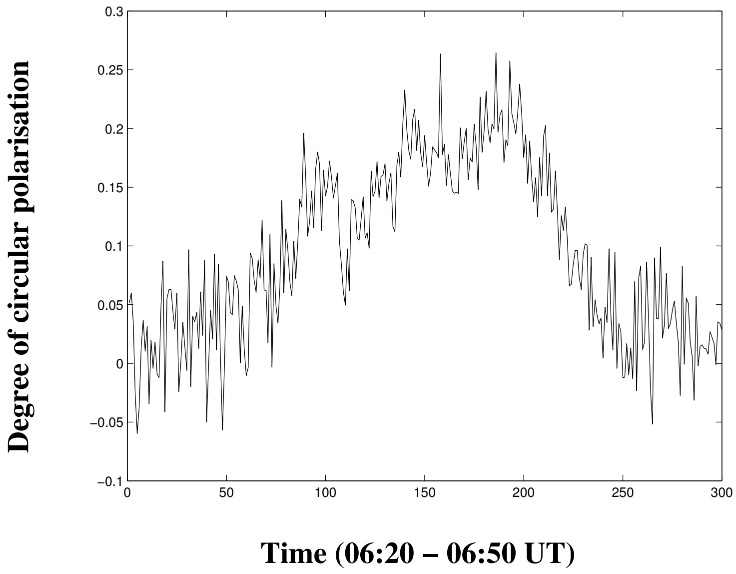

Figure 3. Time profile of the degree of circular polarisation calculated from the observations in Figure 2. Solar east is to the left.

radial distance R from the center of the Sun is assumed to vary according to the empirical formula $B(R) = B_0/(R/R_\odot - 1)^{3/2}$, similar to the one derived by Dulk & McLean (1978). The optical depth for the two modes of propagation were computed assuming that the magneto-ionic parameter $y = \frac{f_H}{f}$ (where f_H is the electron gyro-frequency and f is the observing frequency) is < 1 (Smerd 1950). For the present calculations we took the observing frequency to be 77 MHz and $R = 1.5\ R_\odot$ (the altitude of the plasma level corresponding to the former in the Newkirk's density model for active region corona). The constant B_0 in the above equation was varied from 2 to 5.5 insteps of 0.5, and the resultant brightness temperature for both the ordinary and extraordinary mode of propagation was calculated for each case. The temperature of the 'background' corona was assumed to be 10^6 K. The results of the computation show that the magnetic field strength should be ≈ 10 G to account for the observed degree of polarization (Figure 3). A detailed account of the ray tracing calculations discussed above will be reported separately.

4. Conclusions

We made a direct estimate of the magnetic field in the solar corona on September 26, 2004 through circular polarisation observations of the thermal radio emission from the Sun obtained with the polarisation array at the Gauribidanur radio observatory at 77 MHz, and ray tracing analysis in the presence of a radial magnetic field. The field strength of the discrete structure in the corona responsible for the observed circular polarisation was estimated to be ≈ 10 G.

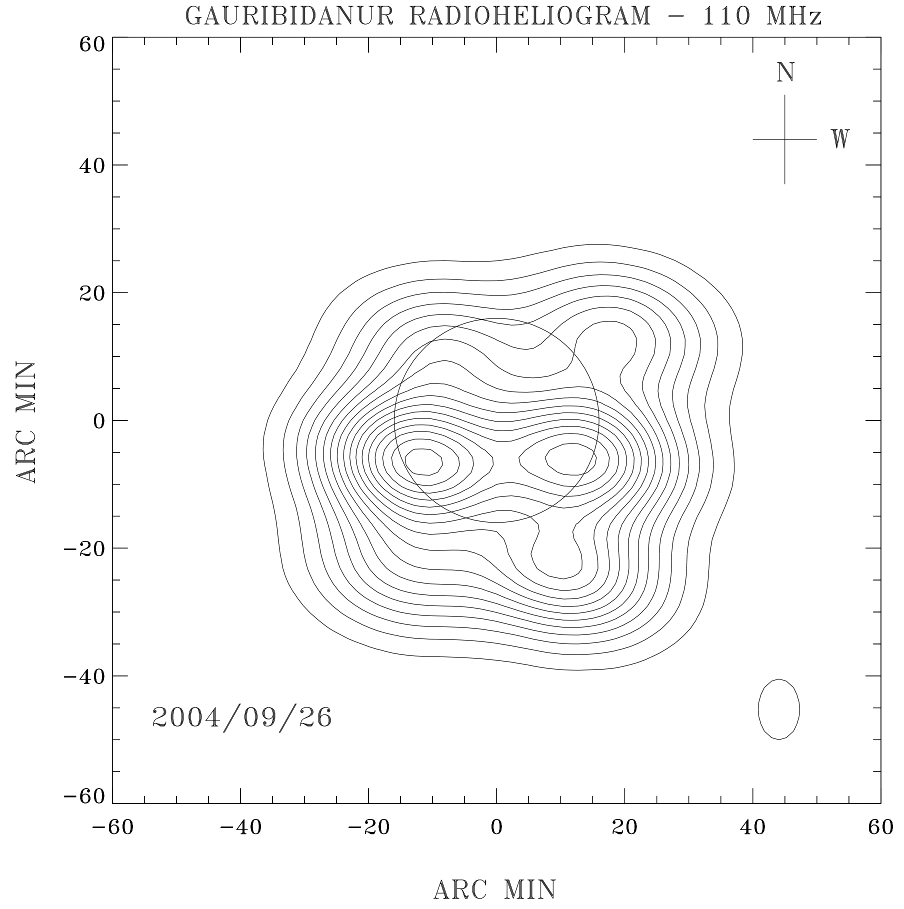

Figure 4. Radioheliogram obtained with the GRH at 109 MHz on September 26, 2004 around 06:30 UT. The open circle at the center is the solar limb. The instrument beam is shown near the bottom right corner.

References

Dulk, G. A., & McLean, D. J. 1978, Solar Phys., 57, 278

Ebenezer, E., Ramesh, R., Subramanian, K. R., SundaraRajan, M. S. & Sastry, Ch. V. 2001, A&A, 367, 1112

Haselgrove, J. 1955, in Physics of the Ionosphere, The Physical Society, London, 355

Newkirk, G. 1961, ApJ, 133, 983

Ramesh, R., Subramanian, K. R., SundaraRajan, M. S. & Sastry, Ch. V. 1998, Solar Phys.181, 439

Ramesh, R., Kathiravan, C. SundaraRajan, M. S., Subramanian, K. R., & Sastry, Ch. V. 2005, in preparation

Smerd, S. F. 1950, Aust. J. Sci. Res., A3, 34

Weiler, K. W. 1973, A&A, 26, 403

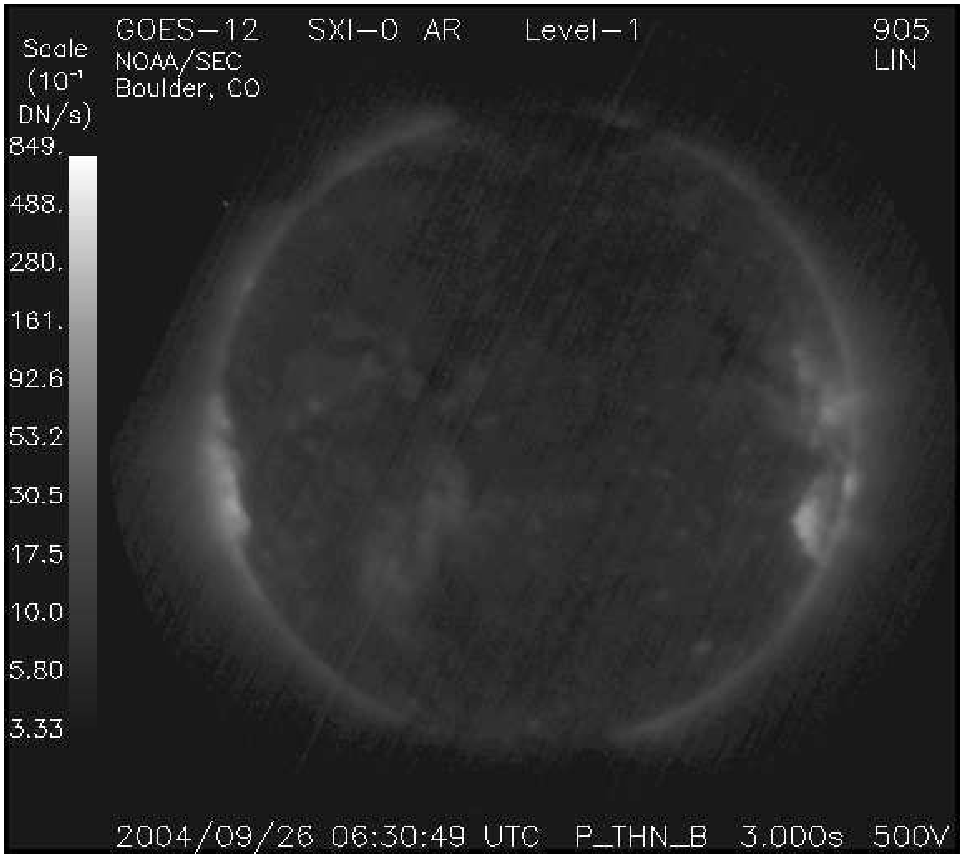

Figure 5. Soft X-ray map of the solar corona obtained with the GOES X-ray satellite on September 26, 2004 around the same time as in Figure 4. There is a striking similarity between the two images.