

Study of active region temporal evolution at 17GHz

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Abstract. We present a statistical study of the evolution of active regions observed at microwave wavelengths during the 23rd solar cycle (1992-2004). Active regions are sites of increased magnetic fields, thus the radio emission at microwave wavelengths is mostly due to gyro-resonance of thermal electrons around relatively strong magnetic fields. We analyze active regions observed in full Sun images obtained daily by the Nobeyama Radioheliograph (NoRH) at 17 GHz. Additional information is obtained from photospheric magnetograms of the same day. Also a multiwavelength study provides a global view of the solar atmosphere above active regions, the radio images will be further compared to ultraviolet (SOHO) and H-alpha images. The active regions are characterized by: position, area, maximum and mean brightness temperatures, and magnetic field. The inferred magnetic fields are used to estimate the contribution to the emission at 17 GHz. We discuss the results of the correlation among these physical parameters.

Keywords: Solar physics: Electric and magnetic fields — Astronomical observations: radio emission

PACS: 96.60.hv, 95.85.Bh

OBSERVATIONS

The Nobeyama Radioheliograph has been observing the Sun routinely since 1992 [1]. With 10-18 arcsec resolution at 17 GHz, it represents an excellent data base for long time variations of solar features.

In this work we studied the slow variation (S-component) of active region emission at 17 GHz, that are associated with the gyro-resonance radiation mechanism.

We have compared these regions with magnetograms observed by MDI and with EIT ultraviolet images obtained at 195Å. Both instruments are on board the SOHO (Solar and Heliospheric Observatory) satellite.

DATA ANALYSIS

We have selected active regions in the radio maps with lifetimes of about one week, and without flares in the studied period. Then we compared this region with EUV and magnetogram images at approximately the same time (Figure 1).

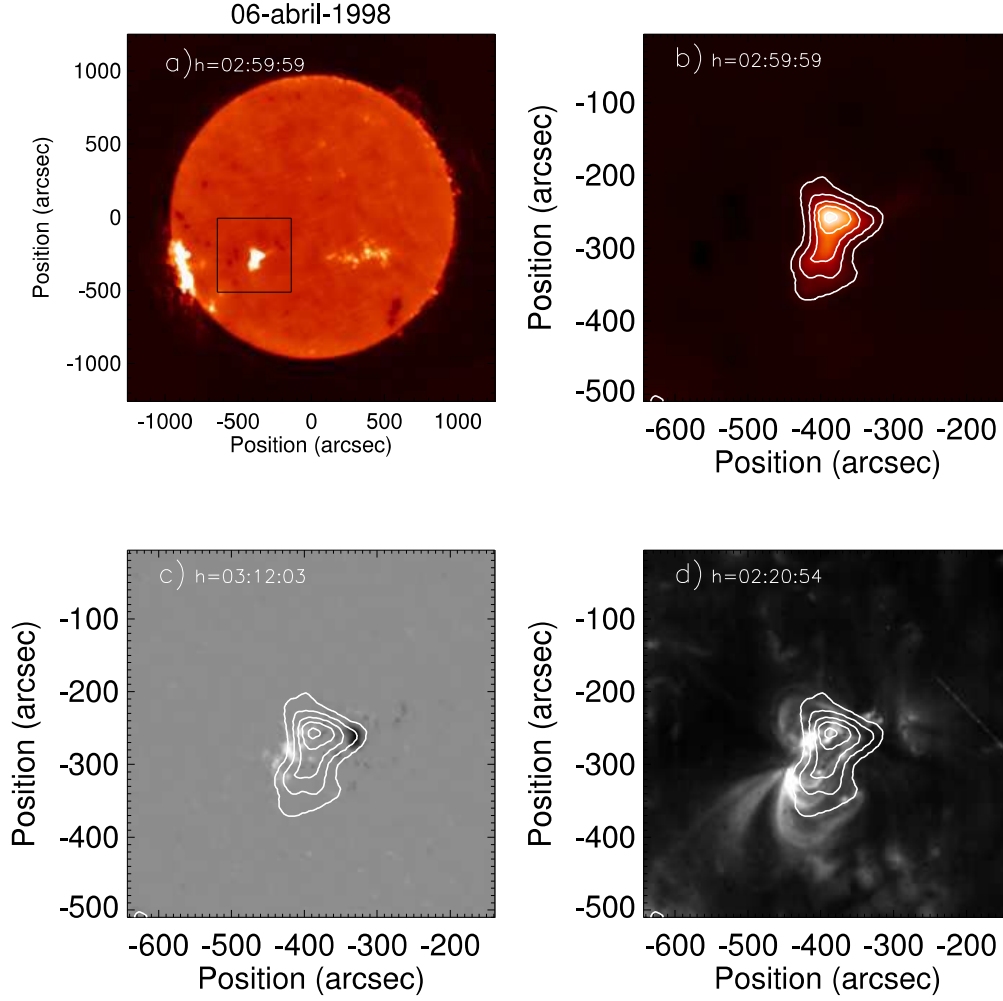


FIGURE 1. a) Solar map at 17 GHz showing the active region selected. b) Active region selected, with brightness temperature curves of 13, 20, 30, 40 and 50×10^3 K. c) Magnetogram of the region. d) EUV (195Å) region, showing a maximum emission close to the 17GHz maximum.

Presently, we have analyzed 31 different active regions. Due to the active regions life time, we have a total of 152 observations. In Figure 2 we plot the area against the maximum brightness temperature of active regions. The figure shows that the active region area increase yields greater maximum brightness temperature.

The correlation between the temperature maximum and the mean magnetic field is shown in Figure 3. The data present a good correlation, except for some points of high brightness temperatures. There is no clear correlation between the other parameters (position in solar disc and mean brightness temperature).

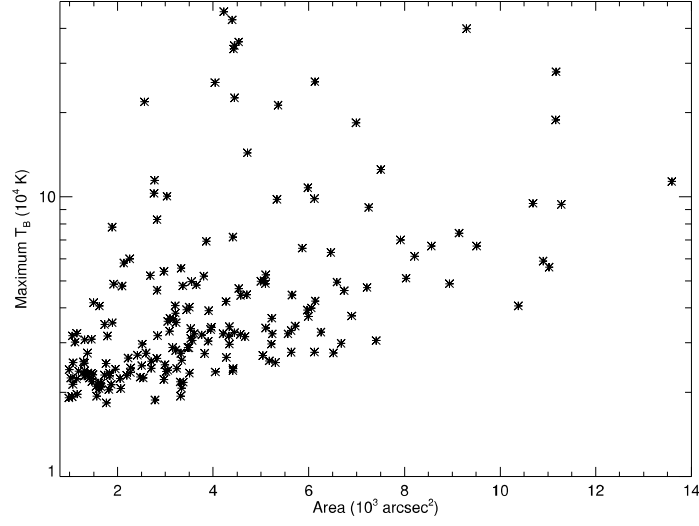


FIGURE 2. Correlation between the area and the maximum brightness temperature of active regions.

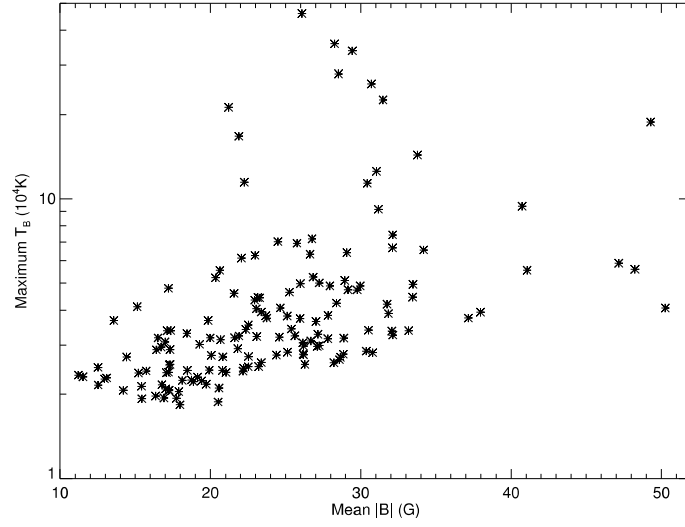


FIGURE 3. Correlation between the mean absolute value of magnetic field and the maximum brightness temperature of active regions near to the solar disc center.

The evolution of active region AR0008 during 6 days is showed in Figure 4. This region presents strong negative polarization, while the positive counterparts are dispersed around.

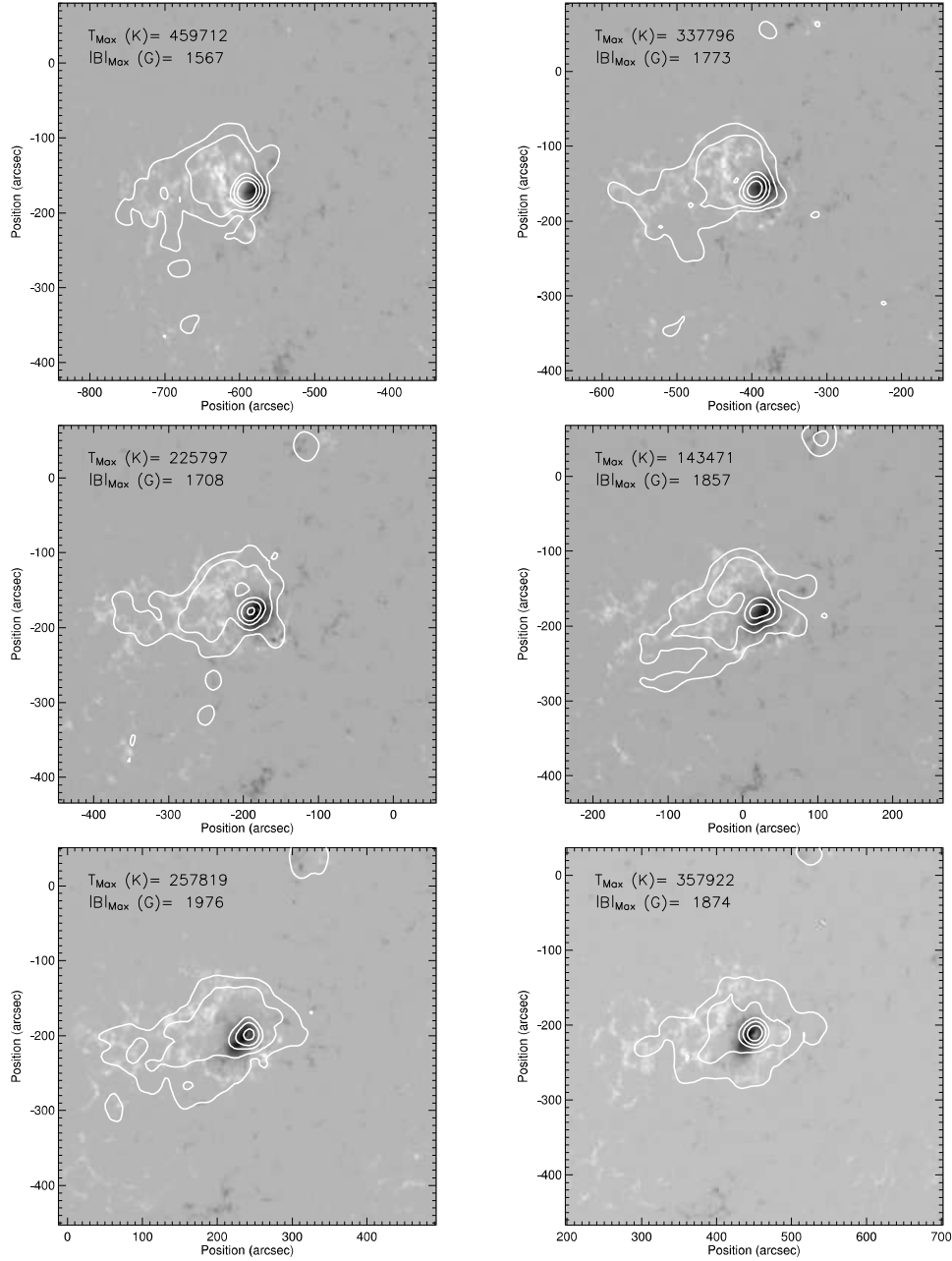


FIGURE 4. Magnetograms of active region AR0008 for 6 days. The contour levels correspond to brightness temperatures of 13, 20, 50, 100 and 200×10^3 K.

MAGNETIC FIELD EXTRAPOLATION

Following Nakagawa and Raadu [2], we have developed a computational program for potential and linear force-free field extrapolation from magnetograms.

Figure 5 show the potential field extrapolation for active region AR0008.

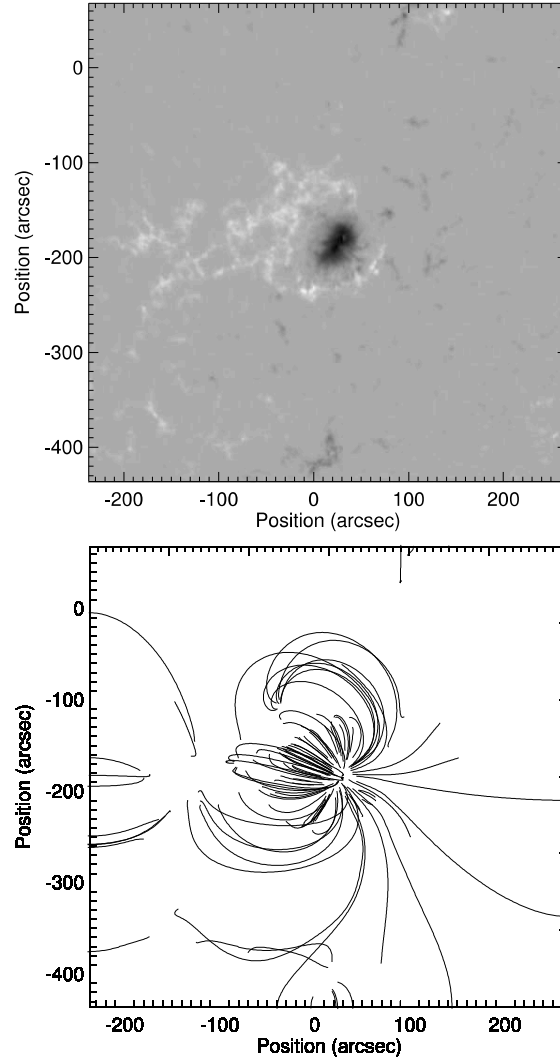


FIGURE 5. Magnetogram of active region and potential field extrapolation.

DISCUSSION AND CONCLUSIONS

As can be seen in Figures 3 and 4, the 17 GHz brightness temperature of active regions depends on the local magnetic field. The main emission mechanism suggested to work in the slow component (S) of active regions is gyro-resonance ([3], [4] and [5]).

The data analysis showed that faint 17 GHz active regions ($T_B < 10^5\text{K}$) usually have weakly polarized bipolar magnetograms and present a good correlation between

the location of 195 Å emission and radio maximum. Aschwanden et al. [6] observed that EUV loops have a foot-point density of $n \simeq 10^9 \text{cm}^{-3}$, which is optically thin for free-free emission at 17 GHz ([7]). This suggests that both mechanisms (gyro-resonance and free-free) contribute to the 17 GHz brightness temperature of these active regions.

Nevertheless, in strongly magnetically polarized regions (Figure 4), the 17GHz emission is polarized too. In this case, the region of maximum intensity in radio does not coincide with the bright regions in EUV images, however, its position correlates very well with the strong polarity sunspot. We employed the Dulk [8] equations to estimate the local temperature and density that yield the observed brightness temperature. The magnetic field extrapolation was used to estimate the effective path length ($L \propto B/\nabla B$) of the order of 10^8cm .

All brightness temperatures in Figure 4 are consistent with densities of $1 - 10 \times 10^{10} \text{cm}^{-3}$ and temperatures of $1.0 - 2.5 \times 10^6 \text{K}$. These results are in agreement with the hydrodynamic simulations of Aschwanden and collaborators [6].

ACKNOWLEDGMENTS

C.L.S. would like to thank the Organizing Committee for providing partial support to attend the conference. The Nobeyama Radioheliograph is operated by NAOJ/Nobeyama Solar Radio Observatory. SOHO is a project of international collaboration between ESA and NASA.

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