Measurements of Coronal and Chromospheric Magnetic Fields using Polarization Observations by the Nobeyama Radioheliograph

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Abstract

In magnetized plasma, the ordinary and extraordinary modes of the radio free–free emission have different optical depths. This creates a circularly polarized component in an atmosphere with a temperature gradient. We derived coronal and chromospheric magnetic fields from polarization and spectral observations of the thermal free–free emission using the Nobeyama Radioheliograph (NoRH). The derived magnetic field is about 20% to 50% of the corresponding photospheric magnetic field at the center of the active region. The derived magnetic field is seems to be an emission-measure-weighted average of the coronal and chromospheric magnetic fields.

① Introduction

Radio Polarization at the Chromosphere

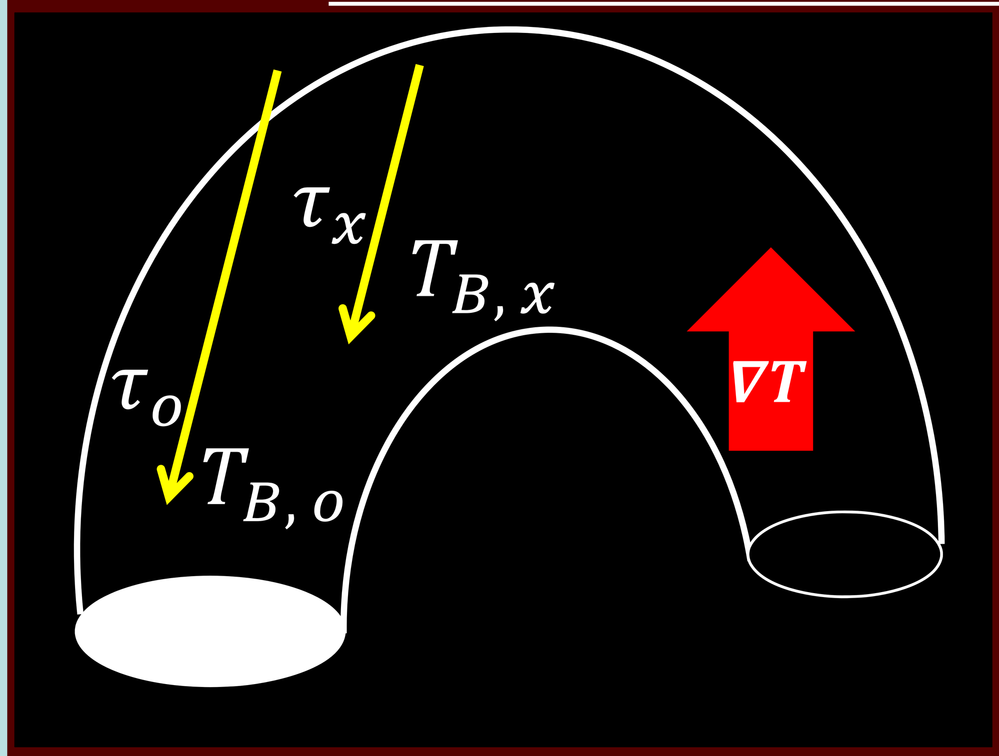


Fig.1 Radio polarization by the chromospheric and coronal magnetic fields.

Thermal bremsstrahlung (Free-free emission) at the microwave range become τ≈1 at the chromosphere.

$\tau_o \neq \tau_x$ in Magnetized plasma

(x- and o-modes Penetrate into different layers)

$T_{B,o} \neq T_{B,x}$ with temperature gradient

$$P = \frac{(T_{B,x} - T_{B,o})}{(T_{B,X} + T_{B,o})} \neq 0$$

$$B_l[G] = 10700 \frac{1}{n\lambda_{[cm]}} P \qquad n = \frac{\partial \log T_B}{\partial \log \lambda}$$

② Instrument

Nobeyama radioheliograph

Fig.2 An overview of NoRH

Frequency	17 GHz (I and V) 34 GHz (I)
Field of view	Full disk
Spatial resolution	10″ (17GHz) 5″ (34GHz)

Radio interferometer dedicated to solar observation

1 frequency band with polarization
2 frequency bands with intensity

2-D Radio magnetic filed

③ Purpose

Derive the chromospheric and coronal magnetic fields by combining two-dimensional radio polarization and radio spectral imaging observations.

④ Data Analysis

2012/04/13 NOAA 11455

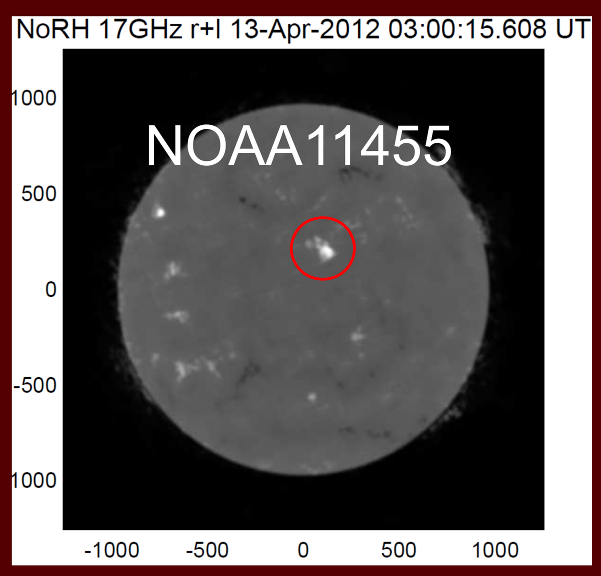


Fig.3 NoRH 17 GHz Intensity

No flare activity
→No gyro-synchrotron emission
No strong sunspots
→No gyro-resonance emission

Pure free-free emission

Fig.4 (a) Radio polarization is corresponds to the photospheric magnetic field, (but it is not an exact match).

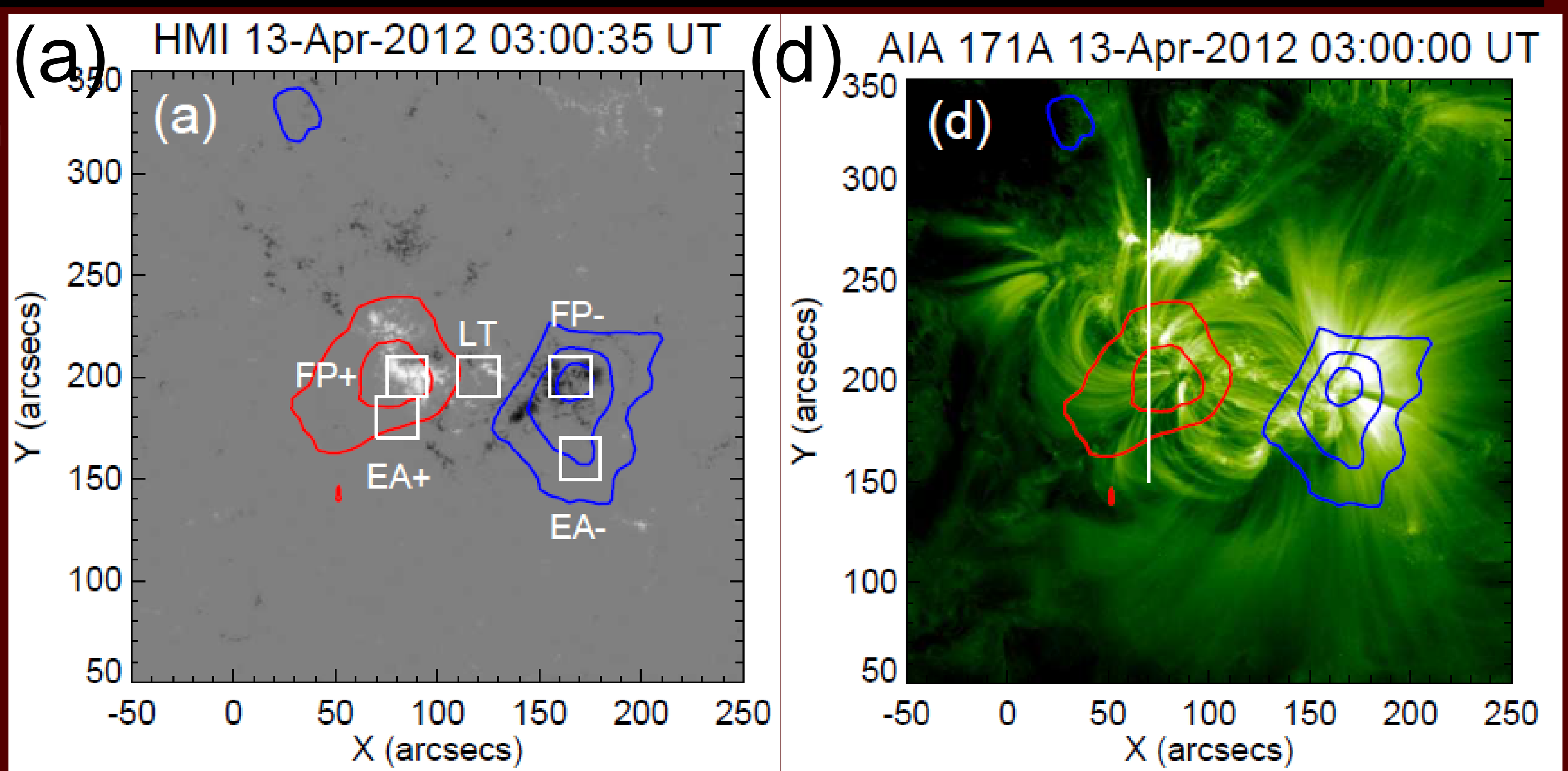


Fig.4 (a) Magnetic fields observed by HMI. Radio circular polarization at 17 GHz is superimposed as contours: positive components in red, 0.5%, 1.0%; negative components in blue, 0.5%, 1.0%, 1.5%. (d) EUV image at 171A observed by AIA. Red and blue contours indicate radio circular polarization degree at 17 GHz.

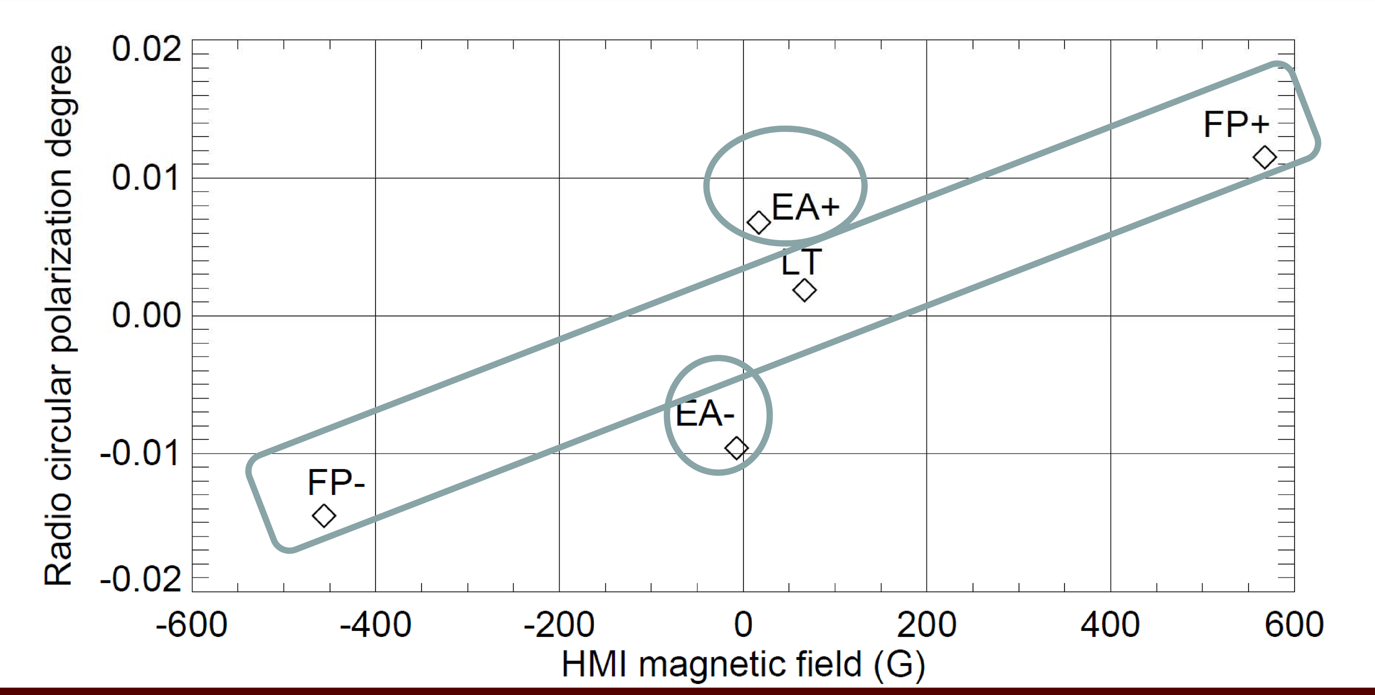


Fig.5 Relationship between the radio circular polarization degree at 17 GHz and photospheric magnetic field observed by HMI

・Active region:
Polarization is correlated with the magnetic field
・Outside the active region:
No correlation (coronal loop structures)

⑤ Discussion

Coronal and Chromospheric Components

Two components atmosphere

$$T_b(\lambda) = T_{chr}(\lambda)\exp(-\tau_c(\lambda)) + T_{cor}(\lambda)(1 - \exp(-\tau_c(\lambda)))$$

$$\tau_c(\lambda) \ll 1$$

$$T_{chr}(\lambda) \ll T_{cor}(\lambda)$$

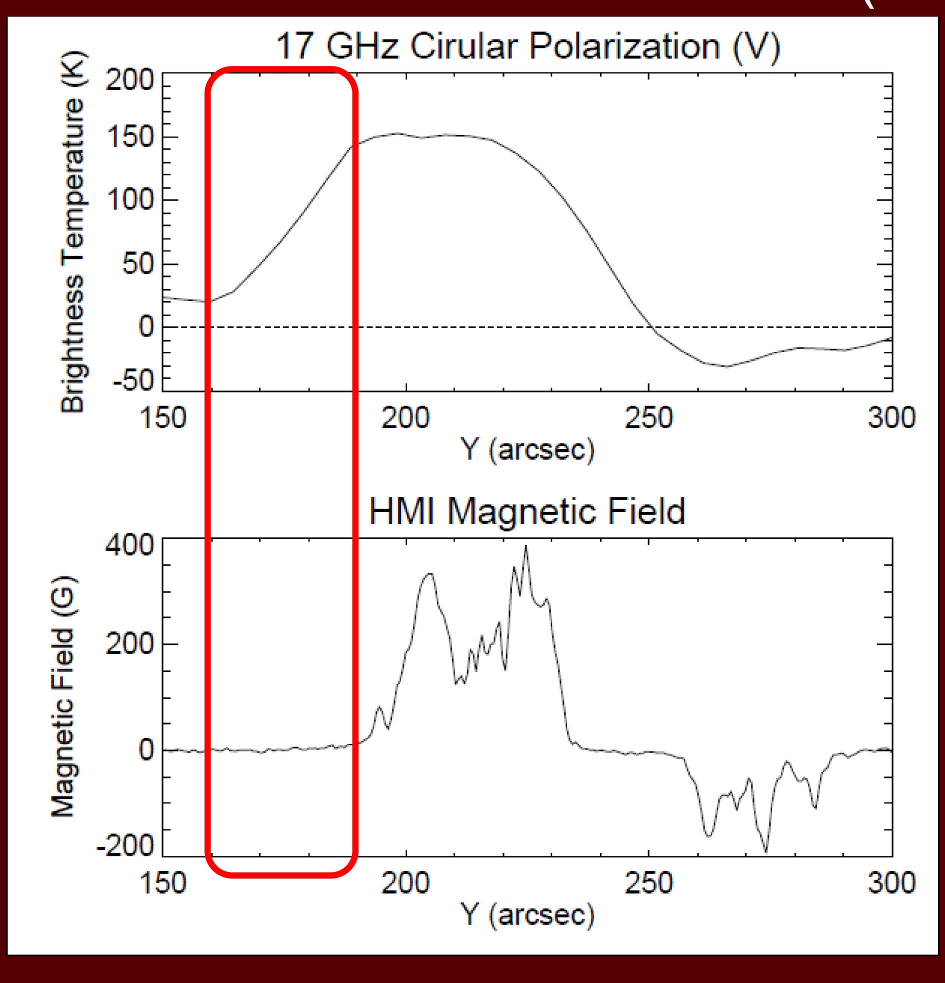
$\sim 10^4$ $\quad\sim 10^6$ Zirin et al 1991

$$I(\lambda) = I_{chr}(\lambda) + I_{cor}(\lambda) \qquad V(\lambda) = V_{chr}(\lambda) + V_{cor}(\lambda)$$

chromosphere: disk temperature

$$I_{chr}(17GHz) \sim 10{,}000\ K \qquad V_{chr}(17GHz) = ??\ K$$

$$I_{cor}(\lambda) = I(\lambda) - I_{chr}(\lambda) \qquad V_{cho}(17GHz) = ??\ K$$



The polarized component expands more than the beam size of NoRH (10″)

The coronal component is dominant at the edge of the active region.

Fig.6 (top) circular polarization at 17 GHz, and (bottom) magnetic field observed by HMI, along the white line in Fig.4(d).

⑥ Summary

① Around the AR

$$V_{chr}(\lambda) = 0$$
$$I_{chr}(\lambda) = 10000$$

$$B_{l_{co}}[G] = 10700 \frac{1}{n_{co}\lambda_{[cm]}} \frac{V_{co}}{I_{co}}$$

Pure coronal magnetic field
Ex. EA+: 73G

② Center of the AR

$$V_{chr}(\lambda) = ?$$
$$V_{co}(\lambda) = ?$$

Average magnetic field of corona and chromosphere. (emission-measure weighted)
Ex. FP-: 217G