THE STUDY OF PROMINENCE FINE STRUCTURE DURING RATAN-600 – SOHO SUPPORT PROGRAMME IN SEPTEMBER – OCTOBER 1996

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Abstract. We observed the structure of an off-limb prominence (4 October 1996) with a fan-beam resolution of RATAN-600 up to heights of 0.4 $R_{\odot}$ above the optical limb in the wavelength range 1.8 – 15 cm, in intensity and circular polarization. Multi-component structures were discovered, and physical parameters of each component are discussed in conjunction with current theoretical models.

1. Introduction

According to optical observations, prominences are complicated structures, including chromospheric channels, coronal cavity and arcades, which surround a cool filament with a definite orientation of the axial magnetic fields (Martin, Bilimoria, and Tracadas, 1994). Model simulations predict that the filament's twisted magnetic field lines, and the coronal arcade fields may have opposite directions at the site of their contact (see Schmieder, 1992) and be the source of a continuous energy release due to reconnection. For both the 'dextral' and 'sinistral' helical patterns, an expected magnetic reconnection area should lie near the top of the cold filament and inside the coronal arcade (Kuijpers, 1997). In this work we tried to detect this reconnection area by studying its radioemission and compare it with space-borne data. Also, we attempted to shed some light on the problem of the structure of the prominence – corona transition region (PCTR) (Chiuderi Drago, 1990). We show here the possibility of prominence magnetic field measurements at coronal heights by a sensitive circular polarization detector. During the fall of 1996, many programs of RATAN-600 were made in support of SOHO observations. Here we report the results of observations of two large prominences, one situated near the centre of the disk (25 September 1996, S20 – S40, W18) and the other above the W-limb (4 October 1996, S30 W90). We used the multi-frequency observations by RATAN-600 (35 frequencies in a range of wavelengths 1.8 – 15 cm) in intensity and circular polarization and INTERNET-published images from SOHO (LASCO-C1), *Yohkoh* (SXT), and the Nobeyama radioheliograph (at 17 GHz).

The observed prominences have rather typical structures. According to Hα observations on the solar disk from 25 September, there was a long filament in the NW–SE direction with a break in the middle of it, and it was surrounded by a bipo-

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lar plage area with a large coronal arcade structure (*Yohkoh*/SXT observations). We shall mainly pay attention here to the study of the W limb prominence on 4 October 1996.

2. RATAN-600 Observations

RATAN-600 was used to observe the Sun each day at local noon (9 UT) with the Panoramic Analyzer of Spectrum (PAS) at 35 wavelengths between 1.7 and 15 cm (see Lang *et al.*, 1993). Half-power beamwidths in the east–west (north–south) direction range from $14.45''$ ($10.6'$) at 1.7 cm to $112''$ ($102'$) at 15 cm. Daily full-Sun fluxes were used for absolute flux calibrations.

On 25 September 1997 a cold filament was observed near the centre of the disk in Hα and in Nobeyama images. According to RATAN-600 observations, there is a definite brightness depression at the location of the filament inside the large plage area.

On 4 October the multi-frequency RATAN-600 observations reveal a complicated picture with four distinct sources situated at different heights up to $400''$ above the optical limb. We exploited the great dynamical range (more than 1000 :1) and high instrumental stability of our observations to subtract scans with low activity (6 October) from the scans on 4 October at each frequency. The residual brightness profiles were decomposed into three Gaussian components (see Figures 1 and 2). Figure 1 presents the prominence images at the different energy ranges: SOHO (LASCO-C1 image), *Yohkoh* (SXT) and RATAN-600 (microwave scans in intensity and circular polarisation at several short wavelengths). Figure 2 presents an example of prominence brightness scans at several wavelengths inside the full frequency range. Component A at high frequencies is identified with the cold filament (brightness temperature $T_{\rm fil} = 7000$ K at 17 GHz according to the Nobeyama map). The sources B and C are identified with an X-ray coronal arcade and a streamer from comparison with observations of *Yohkoh*, SXT and SOHO, LASCO-C1 respectively.

The brightness peak, labeled source A in Figure 2, is a superposition of two sources overlapping along the line of sight. Source A peaks at a height of $40''$ above the limb at high frequencies, but at a height about $100''$ at longer waves. We treat this as an indication of the existence of two physically different sources (A$'$ and A$''$) at the two mentioned locations above the limb.

We can identify the nature of these sources by their spectral characteristics, which are quite different for the sources A$'$ and A$''$. The sources A$''$, B and C correspond to optically thin radio emission of a hot plasma ($T > 10^6$ K), and the source A$'$ is optically thick with temperatures about 10 000 K. This interpretation is in good agreement with the results of observations. For an optically thick component (cold source A$'$) we have $T_b = \text{constant}$, $S = \text{constant}/\lambda^2$, and for an optically thin components we have $T_b = \text{constant} \times \lambda^2$, $S = \text{constant}$ (with different constants).

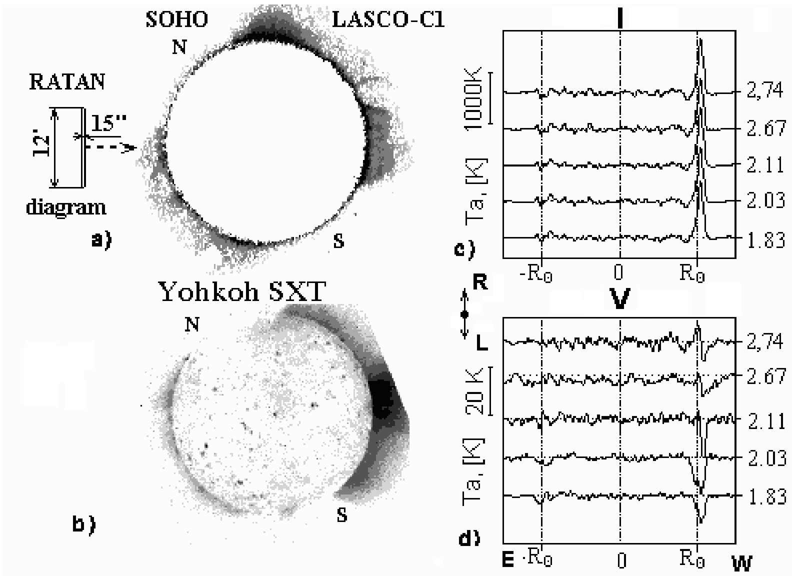

Figure 1. Prominence images on the W-limb 4 October 1996: (a) SOHO LASCO-C1, (b) *Yohkoh* SXT, (c) RATAN-600 one-dimensional scans at microwaves in intensity from 1.83 cm to 2.74 cm, (d) the same in circular polarization.

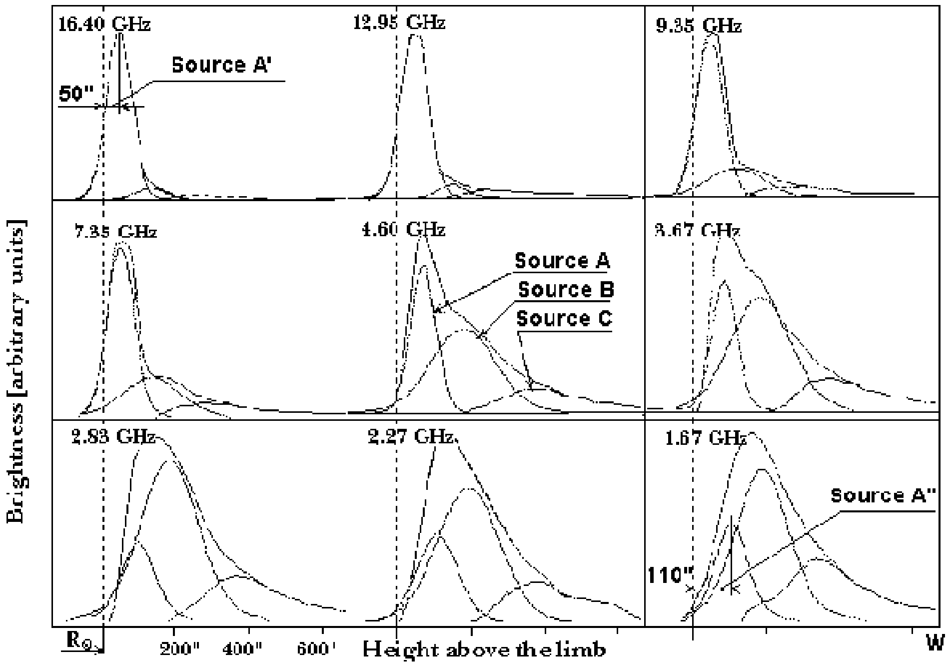

Figure 2. Examples of prominence observations on the W-limb 4 October 1996. The subtraction of the quiet Sun and separation of the three sources are made. Source A−prominence emission. Source B−X-ray arcade emission. Source C−emission of a streamer.

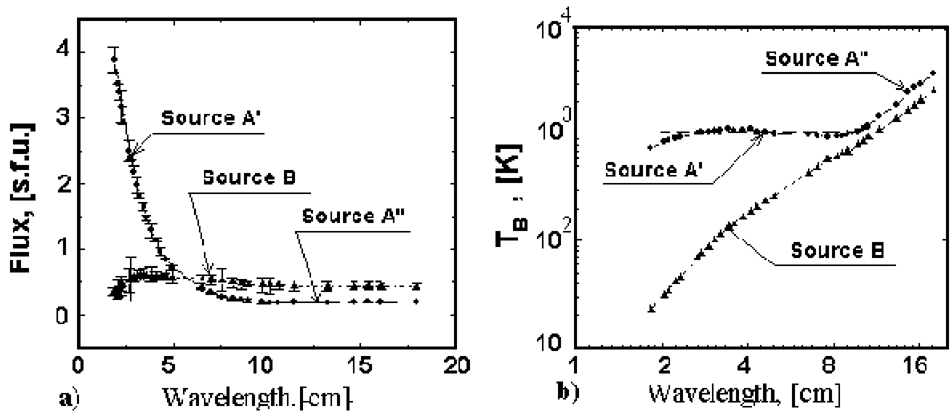

Figure 3. Flux density and brightness-temperature spectra for the A and B sources (thin emission). The A-source brightness-temperature spectrum consists of two different sources A′ (thick emission) and A″ (thin emission).

Thus, the cold source A′ (T_b = constant) dominates at high frequencies, and the hot sources A″, B, and C (T_b = constant $\times\ \lambda^2$) dominate at long wavelengths (see Figure 2). The calibrated spectra of flux and brightness temperatures of the A and B components, shown in Figures 3(a), and 3(b), confirm our suggestions on the nature of all sources.

We estimated the ‘column emission measure’ $EM = N_e^2 L$ for the brightness peak locations of the optically thin sources A″, B, and C: $EM = 7 \times 10^{26}$ cm^{-5}, $EM = 6 \times 10^{26}$ and 3×10^{26} cm^{-5} according to the known relation between brightness temperature and EM for free-free radioemission.

The brightness spectrum of source A′ shows a slight decline at high frequencies (Figure 3). It corresponds to a mixture of threads with temperatures about 7×10^3 K (a surface filling factor about 0.4), surrounded by matter with a temperature about 10^4 K (spectral turnover near a frequency of 15 GHz). We propose that source A″ relates to the site where the reconnection energy is released at the internal contact between the filament and the magnetic structures of the coronal arcade.

Our observations demonstrate the lack of PCTR matter inside or around the cold filament (source A′ location): the hot matter is concentrated at the location of source A″.

3. Polarization Measurements

According to RATAN-600 observations, circular polarization is definitely present at several microwave frequencies (see Figure 1) between the locations of the sources A′ and A″, with a maximum polarization degree of about 1.5%. The physical nature of the polarized emission source needs further studies to extract information about the coronal magnetic fields at the prominence location.

4. Discussion

Our results on the discovery of complex prominence structures at microwaves are in reasonable agreement with recent theoretical models (Kuijpers, 1997). Our estimates of the physical parameters at the A″ source location may be treated as evidence of the existence of a region of continuous energy release in a place of reconnection of two magnetic systems inside coronal arcades. The lack of hot material (PCTR) around the cold source A′ location is seen as support for multi-thread filament models (Chiuderi-Drago, Engvold, and Jensen, 1992; Fontenla *et al.*, 1996) with a possible screening of PCTR matter by the cold threads at microwaves.

Acknowledgements

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