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CHROMOSPHERIC MAGNETIC FIELDS OF AN ACTIVE REGION FILAMENT

Z. Xu[1], S. Solanki[2] and A. Lagg[2]

Abstract. Vector magnetic fields of an active region filament are co-spatially and co-temporally mapped in photosphere and upper chromosphere, by using spectro-polarimetric observations made by Tenerife Infrared Polarimeter (TIP II) at the German Vacuum Tower Telescope (VTT). A Zeeman-based ME inversion is performed on the full Stokes vectors of both the photospheric Si I 1082.7 nm and the chromospheric He I 1083.0 nm lines. We found that the strong magnetic fields, with the field strength of 600−800 G in the He I line formation height, are not uncommon among AR filaments. But such strong magnetic field is not always found in AR filaments.

1 Introduction

Active region filaments are present in or close to active regions. For AR filaments, many measurements of the magnetic field vector *within* filaments have been made using either the Zeeman or Hanle effect (Rust *et al.* 1967; Landi Degl'innocenti *et al.* 1982; Bommier *et al.* 1994; López Ariste & Casini 2002). Most of the measurements were carried out for quiescent prominences and used the Stokes profiles of the D_3 line of Helium. For AR filaments on the solar disk, the spectro-polarimetric measurements using full Stokes profiles of the He I 1083.0 nm line are rare. Observations by Sasso *et al.* (2007) determined for the first time the magnetic field structure of an AR filament during its eruption phase and revealed the magnetic field strengths are in the range of 100−250 G. Another measurement of magnetic field vectors in a stable AR filament was reported by Kuckein *et al.* (2009). They found field strengths in the range of 600−700 G in the filament at the formation height of the He I. It is the first time that a magnetic field of such a high strengths has been reported in filaments. In this work, we present another

[1] Yunnan Astronomical Observatory, CAS, Kunming, 650011 Yunnan, China
[2] Max-Planck-Institut für Sonnensystemforschung, Max-Planck-Strasse 2, 37191 Katlenburg-Lindau, Germany

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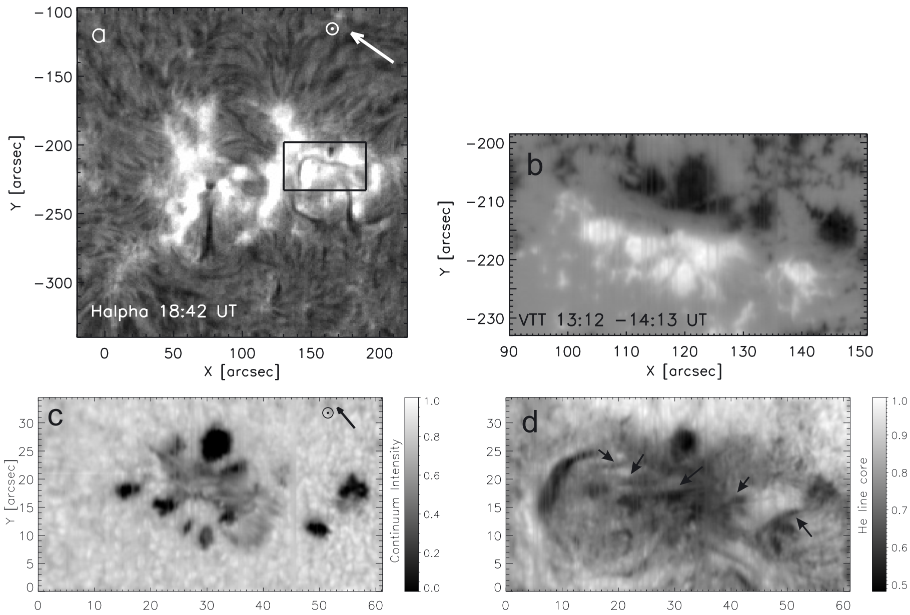

Fig. 1. a) Hα image of the active region NOAA 10763 on 2005 May 17, taken from the full-disk Hα image from Big Bear Solar Observatory. The black box delimits the region scanned by TIP II instrument. b) stokes-V map of the scanned region by the TIP II. The map is obtained by integrating the Stokes V/I_c parameter within a wavelength range of 0.4 Å in the blue wing of the photospheric Si I line. Panels a) and b) are in the same solar coordinate. c) the infrared continuum image at 1083.25 nm. d) the intensity around the He I line core integrated from 1083.0 nm to 1083.06 nm. Segmented He I filaments are pointed out by black arrows. The white arrows in panels a) and c) indicate the direction of the solar disk center.

observation of an AR filament lying over a region with multiple sunspots. We analyze and compare simultaneously recorded full Stokes vector measurements of the photospheric Si I 1082.7 nm and the chromospheric He I 1083.0 nm triplet. It allows us to confirm whether the strong magnetic field strengths found by Kuckein *et al.* (2009) are common to another AR filaments or not.

2 Observations

2.1 Spectro-polarimetric observation on VTT

Spectro-polarimetric observations were carry out for one filament (boxed area in the panel a of Fig. 1) by TIP II installed on German Vaccumm Tower Telescope (VTT) on Tenerife from 2005 May 17 to 18. Presently we only concentrate on the observation on May 17, when the filament stayed in its early stable phase and located at S16 W09 ($\mu = 0.96$). The slit was set ($0.5''$ wide and $35''$ long) almost perpendicular to the Hα filament and carried out spatial scans with a $0.17''$ step size. At each scan position, full Stokes vectors were recorded over a spectral range of 11 Åcontaining the photospheric Si I 1082.7 nm line and chromospheric He I 1083.0 nm triplet. A noise level of typically $5 \times 10^{-4} I_c$ (where I_c is the continuum intensity). From the Hα image (shown in the solar coordinate in panel a of Fig. 1) we find that the filament is composed of two sections, a curved section S1 and a roughly E-W directed section S2. The panel b of Figure 1 shows the Stokes V map (see the figure caption) of the part of the region scanned by the TIP II. Panels c and d of Figure 1 display the scanned area in infrared continuum at 1083.25 nm and He I line core. It is clearly seen in the continuum image that a large penumbra-like structure was formed between these sunspots. At the formation height of the He I line, we also can identify two sections of the filament. However, in section S2, only individual (segmented) absorption patches are visible (as indicated by arrows in panel d of Fig. 1), rather than a complete one seen in Hα.

2.2 Other context observations

We simply describe the context observations of this AR filament taken by SOHO/MDI and TRACE. MDI magnetograms show the opposite polarities on the two sides of the filament converge towards each other from May 15 to 17. Both the negative and positive flux in situ first increased, arriving at a maximum on May 16, which is when this filament became visible in Hα line, then decreased. The decrease amount of both positive and negative fluxes is almost same and equal to 1.5×10^{21} Mx. TRACE data were acquired on May 17 in its 171 Å channel. The filament is clearly seen in this channel and bright coronal arcades were found overlying the filament.

3 Retrieval of stokes profiles

The spectro-polarimetric data were reduced by applying standard TIP data reduction procedures to the observed Stokes profiles. We applied an inversion code based on the Mine-Eddington approximation, HeLIx$^+$ (Lagg *et al.* 2004), to the full Stokes vectors of the Si I and He I lines, respectively, to obtain the magnetic field vectors in the photosphere and the upper chromosphere. Eight parameters were retrieved from the inversion: the magnetic field strength (B), field inclination with respect to the LOS (γ) and azimuth angle (χ), line-of-sight velocity ($v_{\rm los}$), Doppler width ($\Delta\lambda_D$), damping constant (a), slope of the source function (S_1) and the opacity ratio between line-center and continuum (η_0). An additional free parameter, filling factor, f, is used when more than one atmospheric component is considered simultaneously. The Si I line was independently fit on the He I line. To fit the Si I line, we assumed an atmospheric model including a magnetic component and a field-free component. For the He I triplet inversion, only one magnetic component was considered in the atmosphere model. Meanwhile, Hanle effect was neglected in the He I triplet inversion since the Stokes Q and U profiles of He I

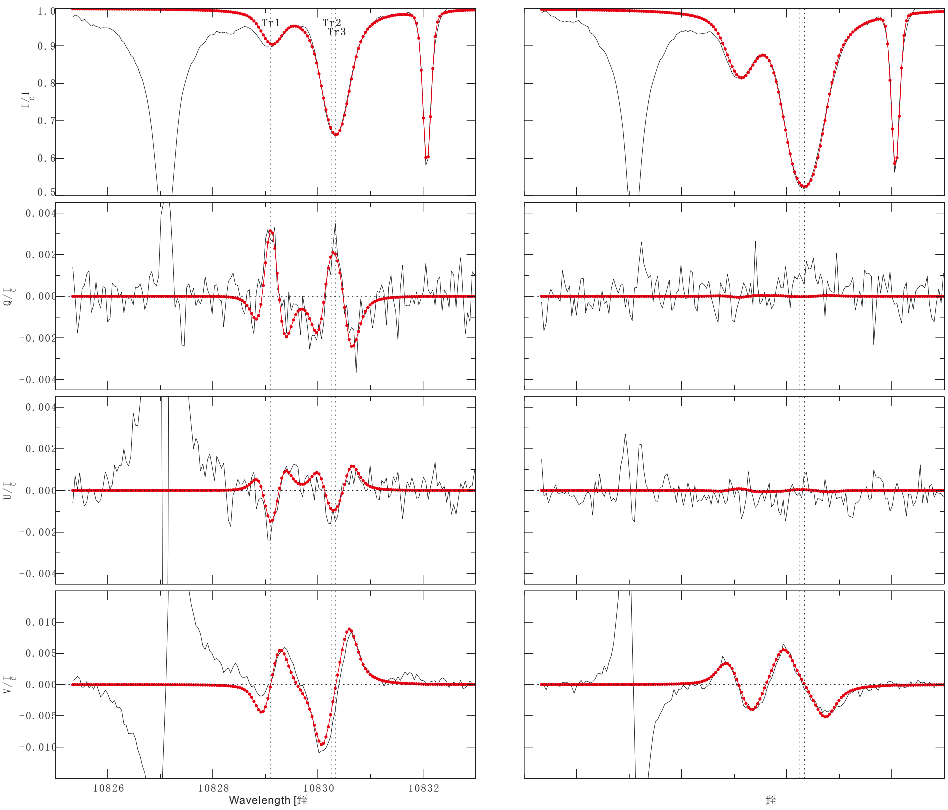

Fig. 2. Typical Stokes profiles of the He I triplet in the filament. *Left*: stokes profiles taken from section S2 with the location at X = 22, Y = 19 in the coordinates of panel d of Figure 1. The observed profile is shown in black (solid line). The best fit by a Mine-Eddington inversion is shown in red (filled circles). Three vertical dotted lines indicate the line-center rest position of the components of He I triplet. The magnetic field retrieved is $B = 751$ G, $\gamma = 105^\circ$ and $\chi = 77^\circ$. *Right*: stokes profiles taken from section S1 with the location at X = 10, Y = 17. The retrieved magnetic field is $B = 164$ G, $\gamma = 48^\circ$ and $\chi = -30^\circ$. The Si I line is fit independently (not shown in this figure).

from the strong helium absorption features dominantly exhibit the signatures of the Zeeman effect. In Figure 2 we display the typical observed profile and the best-fit of the He I line, taken from two different filament sections.

Figure 3 illustrates the inferred magnetic field vectors in the line-of-sight frame on May 17 in the photosphere (left column) and upper chromosphere (right column). The LOS magnetic field ($fB_{//}$) in the photosphere and chromosphere are shown in panels **I** and **II**, In panels **III** and **IV**, we present the absolute value of the horizontal magnetic field ($fB_{\perp}$). Strong horizontal magnetic fields were found in the filament section S2 in both atmosphere layers, with the $fB_{\perp}$ as high as

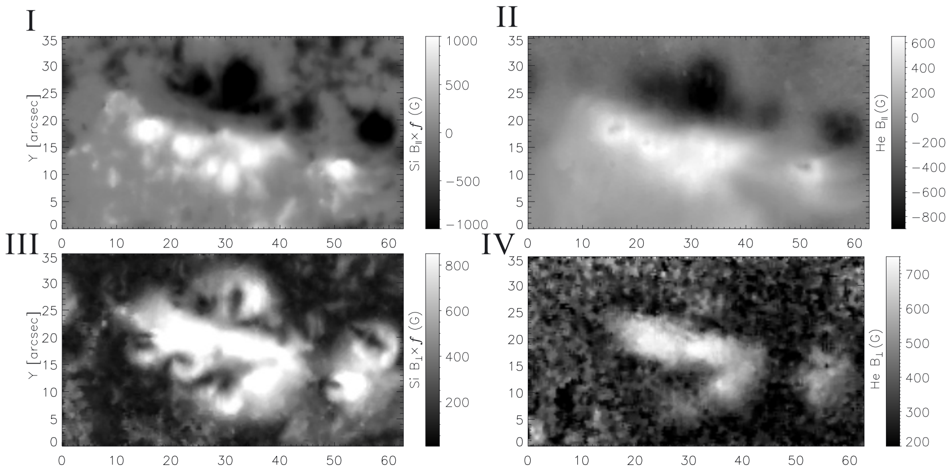

Fig. 3. I and II: LOS magnetic field ($fB_{//}$) in the photosphere and chromosphere, respectively. III and IV: absolute value of the horizontal magnetic field in the photosphere and the chromosphere $fB_{\perp}$, respectively.

500−700 G in the upper chromosphere (with the $f = 1$) and 600 G−800 G in the photosphere (with filling factors larger than 75%). In section S1 of the filament, however, the field strength was everywhere below 200 G, suggesting that fields above 500 G are not always found in AR filament.

4 Conclusion

In this work, we have presented spectro-polarimetric observations of an AR filament, which we analyzed together with other space and ground-based observations. A ME inversion code is used to retrieve the magnetic field vectors in photosphere and upper chromosphere, respectively, from simultaneously observed Stokes profiles in the Si I 1082.7 nm and He I 1083.0 nm lines. We inferred the horizontal magnetic field reaching up to 500–700 G in the upper chromosphere of one section of the filament. This confirms the findings of 2009 for another AR filament and shows that such strong fields are not uncommon among AR filaments. In another section of the filament, however, the field strength was generally smaller 200 G, suggesting that fields above 500 G are not always found in AR filament.

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