Changes of Vector Magnetic Field During a Powerful Flares in Active Region (NOAA 6659) on June 6, 1991

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Abstract

The active region of 1991 June, NOAA 6659, was the most prolific white light flare-producing region in recent history. About five white light flares were observed in the active region. We present here the observational results of photospheric vector magnetic fields of this region at the Huairou Solar Observing Station of the Beijing Astronomical Observatory and discuss the magnetic fields and the relation with the powerful (white light) flares.

After analysis of a series of monochromatic images of Stokes parameters Q, U and V with high spatial resolution, the following new phenomena observed are found that before and after powerful (white light) flares, the obvious change of vector magnetic fields occurred at the magnetic neutral line near the sites of these flares. The white light flares probably are caused by the violent motion of the photospheric lines of force.

1. Introduction

NOAA 6659 was a largest solar active region of the abnormal magnetic configuration after solar cycle 22 began. This region produced some powerful flares which include five white light flares. When the first great (white light) flare occurred in this active region at the east limb of the Sun on June 4, we arranged magnetograph observation. A series of photospheric vector magnetograms, chromospheric longitudinal magnetograms and Dopplergrams in Active Region 6659 were obtained at Huairou Solar Observing Station of the Beijing Astronomical Observatory during the international campaign of June 3 – 16, 1991.

2. Observational Data

The observations of this study were using the vector video magnetograph at the Huairou Solar Observing Station (Ai, 1987). The magnetic structures of the active region 6659 are complicated. Some magnetic gulfs and islands formed in this region. The magnetic structures of this region was a δ-configuration. The total measured field in this region was concentrated in a great central row of p-polarity spots, completely surround by f-polarity. On June 9, 1991, this active region was located near the center of the solar disk. The transverse components of the field showed the evident rotation around the main pole of negative polarity clockwise. The transverse components near the magnetic neutral line were strongly sheared and almost parallel to it in the east side of the active region.

A large number of flares were registered in X-ray. Five white light flares (WLFs) were obtained (Zhu *et al.*, 1991; Yan and Zhang, 1991; Sakurai *et al.*, 1992). Some of these flares and corresponding magnetic fields in this active region were observed at Huairou Solar Observing Station.

3 A 4B/X12 (White Light) Flare on June 6, 1991

A series of chromospheric Hβ images of 4B/X12 flare on June 6, 1991 given was obtained at Huairou Solar Observing Station. The initial sites of this flare as the thread-like pattern appeared in the middle of the active region along the magnetic neutral line at 0100 UT, then the flare ribbons separated away from the magnetic neutral line, and the Hβ post-flare loops formed and bridged over the neutral line at 0123 UT. A white light flare was observed at 0105–0108 UT at Shahe Station of Beijing Observatory (Zhu *et al.*, 1991). The emissions of the WLF were located in the ribbons of the Hβ flare. But the appearance of post-flare loops formed on Hβ images was later than the white light flare about 20 min. The end time of this flare was 0215 UT.

A series of longitudinal and transverse magnetograms of this active region is shown in Figure 1. We can see that two large-scale magnetic structures A and B of positive polarity in Figure 1 almost connected together to form a ribbon-like structure and separated the field of negative polarity near the middle area in the active region. The average width of this magnetic ribbon of opposite polarity is about $9''$. The obvious change of magnetic field appeared near the sites of white light flare. The black pieces in Figure 1 mark the sites of the white light flare. The largest changing area was located at the east side of the preceding main spot. Two large-scale magnetic structures A and B of positive polarity, discussed above, connected together to stretch over the active region then broke again twice from 0050 to 0650 UT. The evident shift of the magnetic neutral line toward the preceding main pole P occurred at 0127 UT. Perhaps, this change of magnetic neutral line was caused by following possibilities: (a) The direction of the field changed near the inversion line due to the fast winding or emerging of twisted force lines, if we consider the project effect of the magnetic field and the spatial configuration of the field in the active region; (b) The inversion or distortion of the photospheric line profile at the working wavelength of the magnetograph after the white light emission about a half hour also kept at the surrounding of patches of white light flare and it influenced the measured results of the photospheric magnetic field near sites of the white light flare. Even the second possibility exits, we also point up a fact that after the Hβ flare the longitudinal magnetic structures (0234 UT) near the sites of WLF also show more different than before one (0050 UT). At 0234 UT, a new magnetic structure $f2$ of positive polarity occurred at the connecting place of large-scale magnetic structures A and B.

Because the region on June 6 was located near the east limb of the Sun (N30, E43), the transverse components of the field contained some information of the vertical components of the field relative to the solar surface. If we compare the difference between the transverse magnetograms in Figure 1 carefully, we can find that the orientations of transverse components of the magnetic field changed in between the two sites of the white light flare near the magnetic neutral line. Transverse fields with a tendency rotated toward the direction of the connected line of WLF's sites. The largest change of the orientations of the transverse field here was about $30° - 40°$. Because the transverse magnetograms are inverted from Stokes parameters Q and U, we return to study the monochromatic images of Stokes parameters Q and U and confirm their evolution. In Figure 2, we show four couples of corresponding monochromatic images of Q and U in AR 6659 at about 0052, 0145, 0518 and 0643 UT on June 6. Near the sites of the white light flare in the vicinity of the magnetic neutral line of the active region, the structures on Q and U components changed obviously from 0050 to 0146 UT. These changes contain the intensities and polarities of Q and U components of the linear polarization light. But other structures in Q and U images were relative stable.

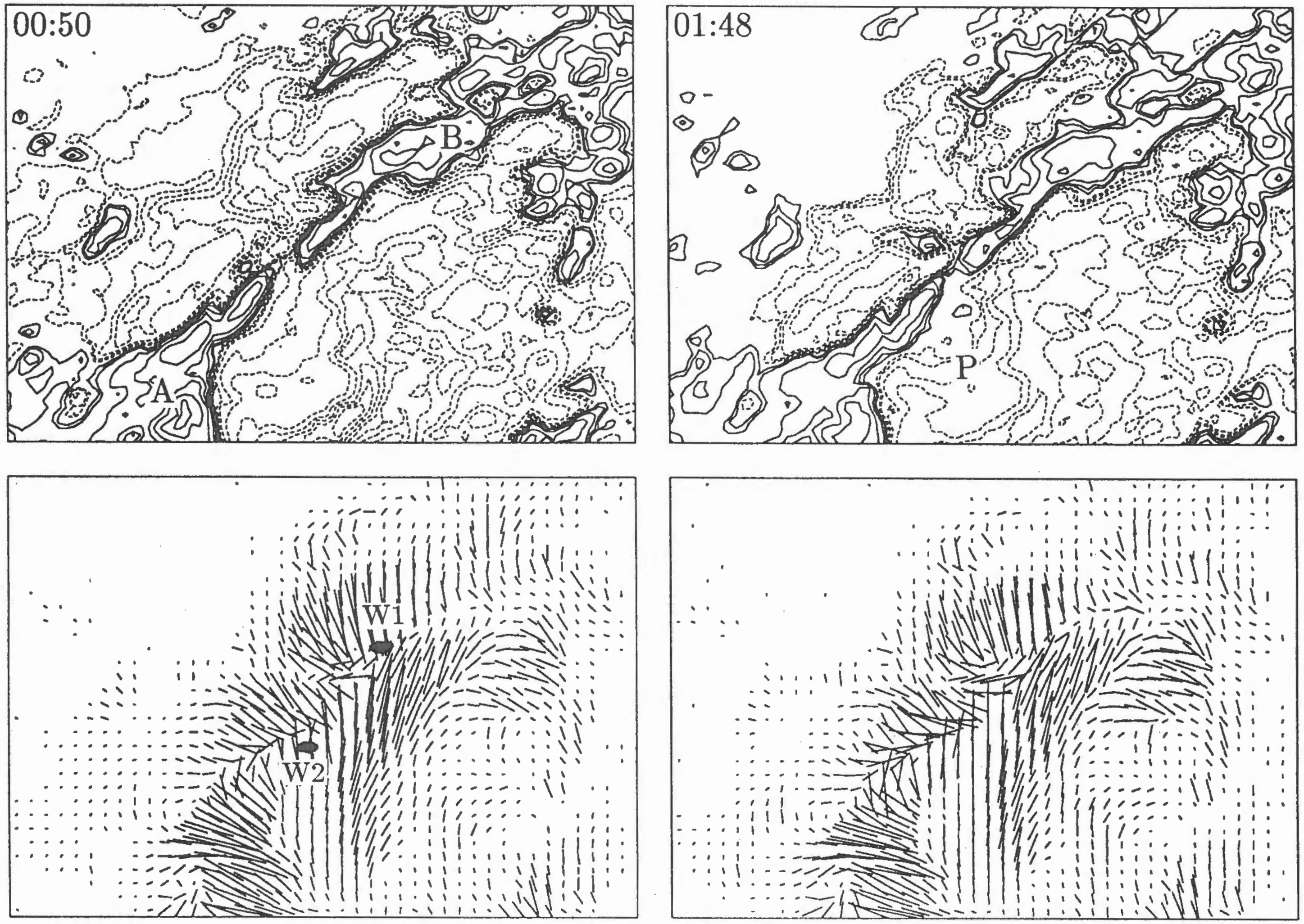

Fig. 1a. A series of photospheric longitudinal and transverse magnetograms in AR 6659 on June 6, 1991. The black structures mark the sites of the white light flare. The change of the transverse field occurred on the area between the both sites (w1 and w2) of WLF.

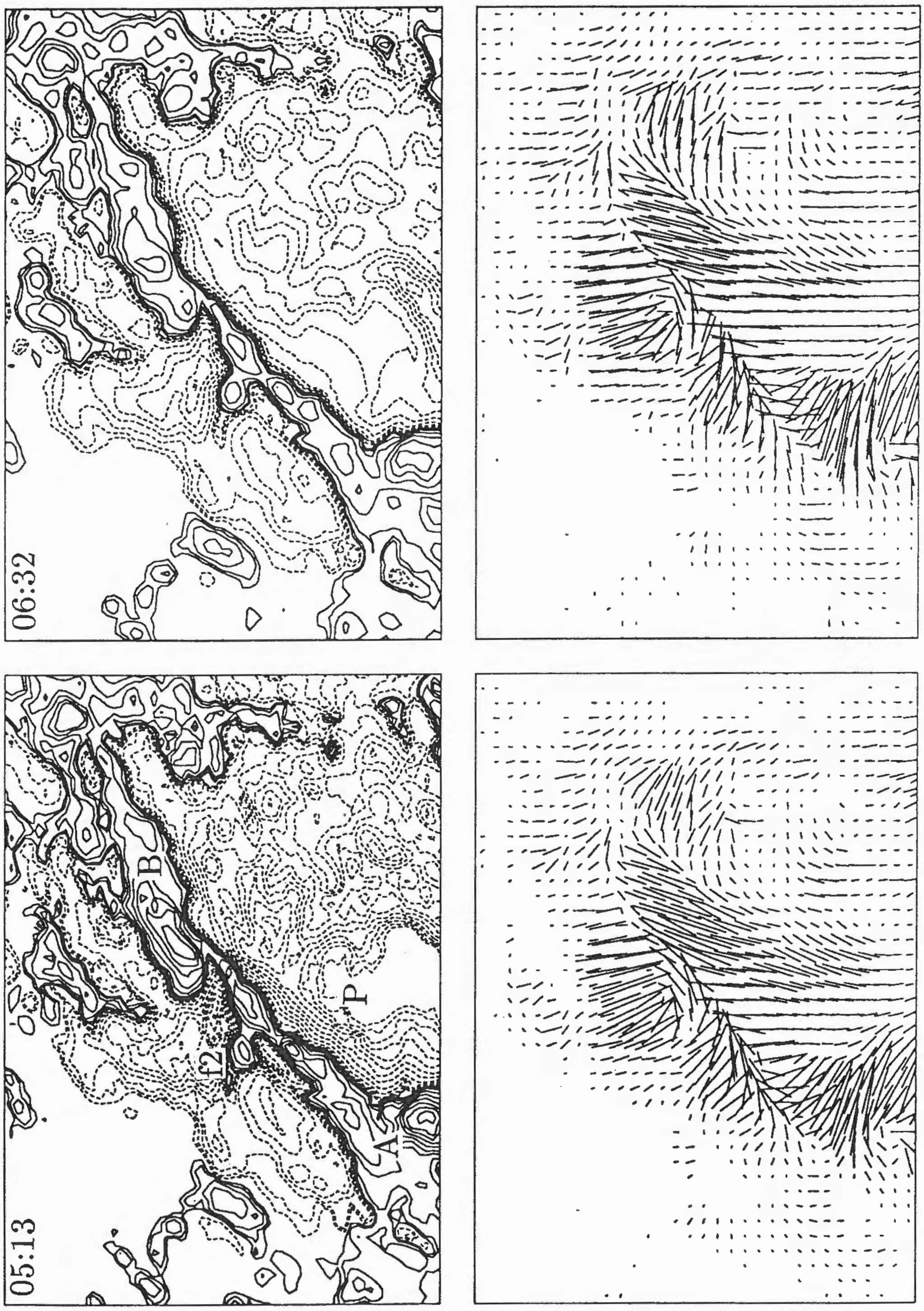

Fig. 1b.

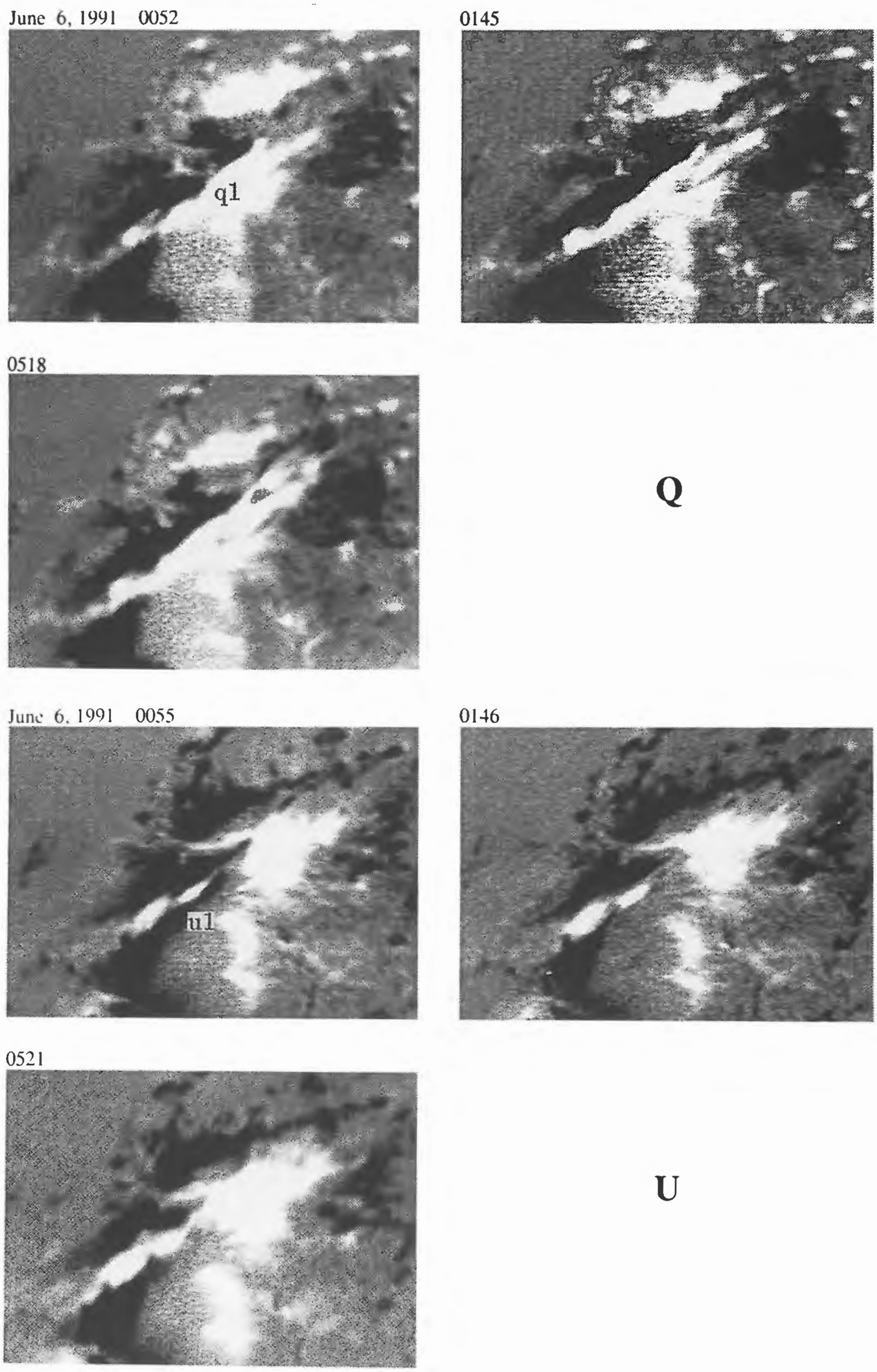

Fig. 2. A series of monochromatic images of Stokes parameters Q (a) and U (b) in AR 6659 on June 6.

We see that in the middle of the monochromatic image of Stokes parameter Q the peak $q1$ of positive polarity during this time shifted toward the east-south direction to form a ribbon-like structure, and where a structure $u1$ of negative polarity in the monochromatic image of Stokes parameter U shifted at same direction obviously while the neighbouring structures of positive polarity moved toward here gradually. According to the formulae $B_{\perp}=C_{\perp}\sqrt[4]{q^2+u^2}$ and $\varphi=0.5\mathrm{tg}^{-1}(\frac{u}{q})$, where φ is the orientational angle of the transverse component of the field, the evolution of Stokes parameters Q and U, in the middle of the active region, actually reflects the changes of the transverse magnetic field. These variations of the Q and U discussed above were consistent with the analysis of the transverse field and roughly synchronized with that of the longitudinal magnetic field before and after the WLF of June 6. This means that the changes of the field during this powerful flare did not only take place in the line-of-sight component. The powerful flare was accompanied with change of the photospheric vector magnetic field in the active region.

4. Discussion and Results

The main pole of this active region was negative and some enhanced networks of positive polarity were located around this region. Some of magnetic lines of force probably connected both structures of opposite polarities at the higher atmosphere. A series of homologous flares in AR 6659 probably was triggered by interaction between the twisted magnetic ropes and the large-scale magnetic field of the main pole near the magnetic neutral line. The former probably was new emerging flux and formed at lower atmosphere. If we compare the magnetograms of June 4, 6 and 9 and consider the perspective effect of the field in the active region on the solar disk, we can easily imagine that some of magnetic lines of force immediately connected the both sites of white light flares and bridged over the magnetic inversion line at the lower solar atmosphere. The magnetic field of high shear and gradient near curved neutral line stored the enough free energy for the trigging of a series of white light flares in this active region.

After analyses of the vector magnetograms and the relationship with powerful flares in the active region (NOAA 6659), the main results are following:

(a) Active Region 6659 was a complex region. The preceding polarity spots had more than 80 % of flux and umbra area. Large-scale magnetic field shows the polarity order inverted from the Hale-Nicholson low.

(b) The vector magnetic field of AR 6659 appeared obvious variation during the white light flares on June 6, 1991. The changes of the magnetic neutral line and the orientation of the transverse components of the field taken place near the sites of the white light flares. The observed results of flares also demonstrated that the magnetic shear increases after powerful flares.

Acknowledgements

This research was supported by the Chinese Academy of Sciences and National Science Foundation of China.

References

Ai, G. 1987, *Publ. Beijing Astron. Obs.*, 9, 27.

Sakurai, T., Ichimoto, K., Hiei, E., Irie, M., Kumagai, K., Miyashita, M., Nishino, Y., Yamaguchi, K., Geng, F., Kambry, M. A., Zhao, Z. 1992, *Publ. Astr. Soc. Japan*, 44, L7.

Yan, X. and Zhang, H. 1991, *CSGD*, 218, 40.

Zhu, C., Gao, F. and Qiao, Q. 1991, *CSGD*, 215, 78.