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Different magnetic features between solar polar and equatorial magnetic fields

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Abstract. Solar polar and equatorial photospheric (FeIλ5324.19 Å line) magnetic fields have been observed using the vector video magnetograph at Huairou Solar Observing Station of Beijing Astronomical Observatory.

It is found from our observations that the magnetic fields of small-scale magnetic features near the solar poles are stronger than in quiet equatorial regions near the limb, and that strong polar magnetic elements appear to have the same magnetic polarity as the general large-scale polar magnetic field, which is in agreement with previous results by Homann et al. (1997) and Zhang et al. (1997). It is also found from our observations that there are more opposite polarity magnetic pairs near the solar poles than in quiet equatorial regions near the limb.

Key words: Sun: magnetic fields – Sun: photosphere

1. Introduction

Recent studies show that polar magnetic fields differ from quiet equatorial magnetic fields near the limb in several ways. Zhang et al. (1997) found that polar fields are stronger than quiet equatorial fields, but no greater than equatorial limb data containing unipolar regions. Homann et al. (1997) found that polar faculae appear to have the same magnetic polarity as the general polar magnetic field, while the equatorial faculae show both magnetic polarities. They also found that the sizes of polar faculae are larger than the sizes of equatorial faculae.

In this paper, we present our study on this comparison. Observations are described in Sect. 2. Results and discussion are presented in Sect. 3. Conclusion is presented in Sect. 4.

2. Observation

The tunable birefringent filter of the solar telescope magnetograph at Beijing Astronomical Observatory can be aimed at different passbands for different observations (Ai & Hu 1986). For photospheric observations, the passband of the filter is set at -0.075 Åfrom the FeIλ5324.19 Å line center for the measurement of longitudinal magnetic field. The equivalent width of FeIλ5324.19 Å line is 0.344 Å, the FWHM of the filter passband is 0.15 Å. Solar polar (southern and northern poles) and equatorial (eastern and western limbs) photospheric magnetic fields have been observed on 11 July 1993. The field of view is about $6' \times 4'$ for each field. The pixel resolution of the CCD is about $0.7'' \times 0.5''$. The spatial resolution of each magnetogram is actually $2'' \times 2''$ after a smoothing average of 3×4 pixels. The temporal resolution of each magnetogram is 3 minutes.

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3. Results and discussion

Photospheric longitudinal magnetograms near solar poles and equatorial limbs observed on 11 July 1993 are presented in Fig. 1. The calibration of FeIλ5324.19 Å line in the magnetic field was made by Ai et al. (1982). By estimating standard deviations (rms) of Stokes parameter V in blank fields, the noise level is estimated as 3 Guass for each field. To study these magnetograms quantitatively, we chose to study those magnetic elements whose peak positions are within a distance of $80''$ to each limb in each magnetogram. Magnetic elements are detected for those ones whose absolute peak flux densities are greater than 10 Gauss ($> 3 \times$ noise level). 215 magnetic elements are detected in the described region near solar northern pole. 232, 110 and 76 magnetic elements are detected respectively in the described regions near solar southern pole, eastern and western limbs. Peak positions of these magnetic elements are shown in Fig. 2 by plus symbols over-plotted on contour maps of each region. Some elements with their absolute peak flux densities greater than 10 Gauss ($> 3 \times$ noise level) are too small to have contours in the contour maps (Fig. 2), but these elements can be seen in the black-white magnetograms (Fig. 1).

3.1. Field strength

It is found that the magnetic elements near solar poles are stronger than in quiet equatorial regions near the limb and that strong polar magnetic elements appear to have the same magnetic polarity as the general large-scale polar magnetic field. Numbers and ratios of magnetic elements with peak flux densities (B) in different ranges are archived in the four regions (northern pole, southern pole, eastern limb and western limb) and are listed in Table 1. Table 1a lists the number and ratio of

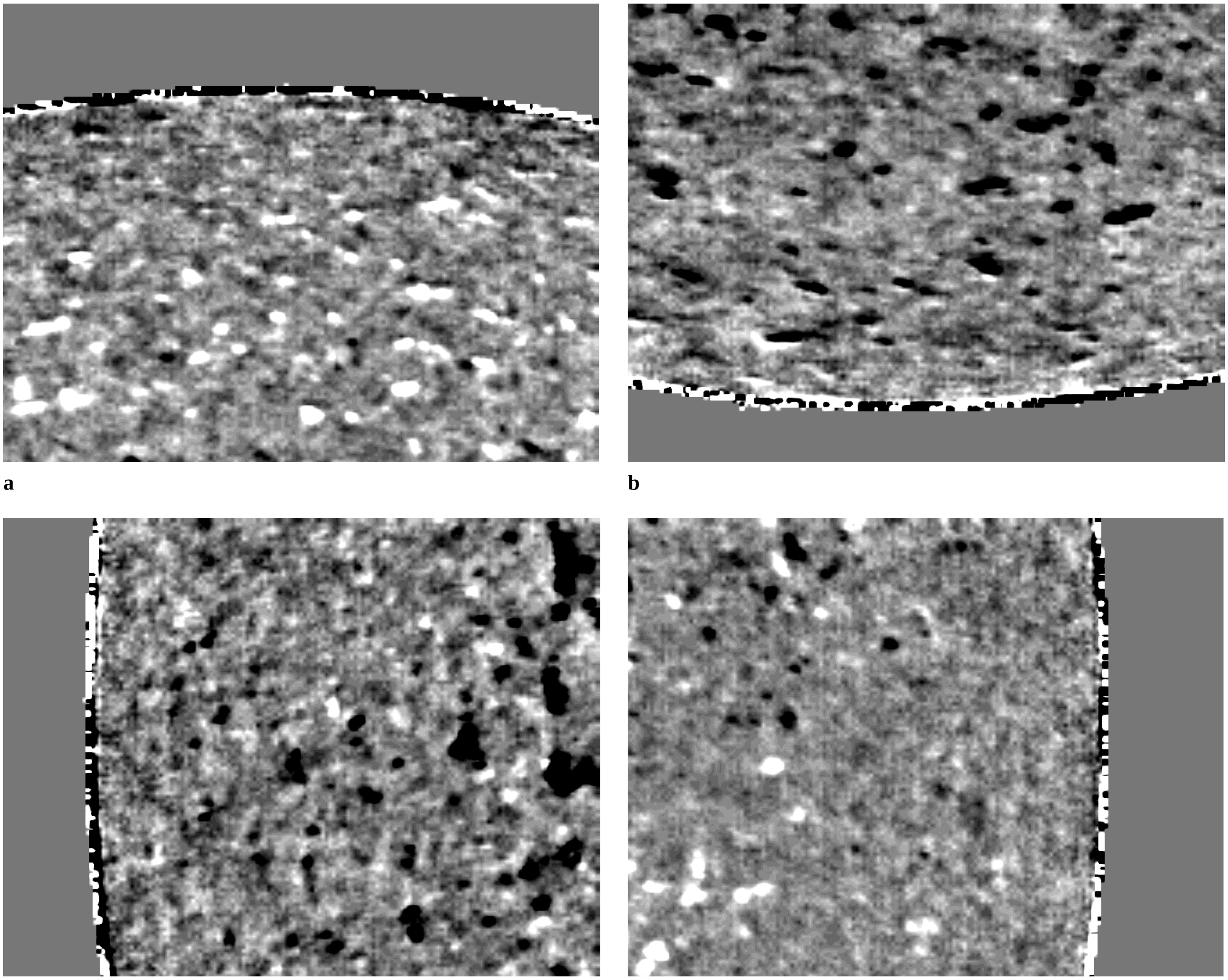

Fig. 1a–d. Photospheric longitudinal magnetograms near solar poles (**a** northern pole; **b** southern pole) and equatorial limbs (**c** eastern limb; **d** western limb) observed on 11 July 1993. The field of view is $330'' \times 220''$ for each field. Bright (dark) structures correspond to positive (negative) polarities.

magnetic elements whose peak flux densities are greater than 40 Gauss or smaller than -40 Gauss respectively in each region. Table 1b lists the number and ratio of magnetic elements whose peak flux densities are greater than 20 Gauss or smaller than -20 Gauss respectively in each region. Table 1c lists the number and ratio of magnetic elements whose peak flux densities are greater than 10 Gauss or smaller than -10 Gauss respectively in each region.

The ratio here is defined as the number in each number column divided by the total number of magnetic elements detected in that region. For example, there are totally 215 magnetic elements detected in the northern polar region. 3 magnetic elements in this region have their peak flux densities greater than 40 Gauss. This number corresponds to $3/215 = 1.4\%$ of magnetic elements in this region.

Table 1a. Numbers and ratios of magnetic elements in different flux density ranges

	$B > 40$ Gauss		$B < -40$ Gauss	
	Number	Ratio	Number	Ratio
Northern pole	3	1.4%	0	0
Southern pole	0	0	6	2.6%
Eastern limb	0	0	2	1.2%
Western limb	0	0	0	0

From Table 1a we find that for those strong magnetic elements whose absolute peak flux densities are greater than 40 Gauss, the northern polar region is dominant for positive magnetic elements and the southern polar region is dominant for negative ones. This trend is also obvious in Table 1b. This is in agreement with Homann et al.'s (1997) conclusion that polar

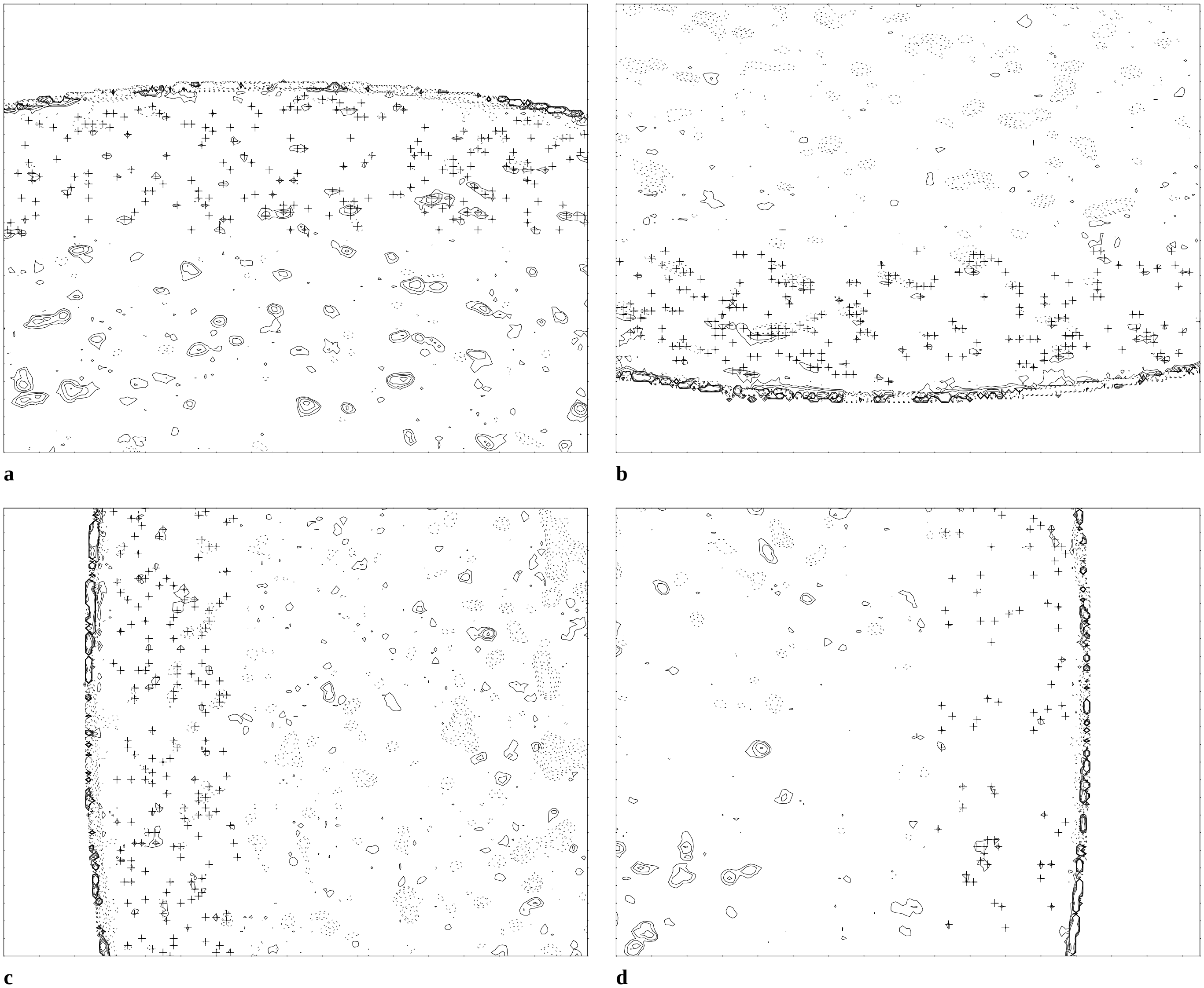

Fig. 2a–d. Contours of photospheric magnetograms near solar poles (**a** northern pole; **b** southern pole) and equatorial limbs (**c** eastern limb; **d** western limb) observed on 11 July 1993. The field of view is $330'' \times 220''$ for each field. Solid (dashed) contours correspond to positive (negative) fields of 10,20,40,80,160 Gauss. Plus symbols indicate peak positions of magnetic elements in areas within $80''$ to each limb.

Table 1b. Numbers and ratios of magnetic elements in different flux density ranges

	$B > 20$ Gauss		$B < -20$ Gauss	
	Number	Ratio	Number	Ratio
Northern pole	22	10%	3	1%
Southern pole	11	5%	25	11%
Eastern limb	5	3%	13	8%
Western limb	1	1%	1	1%

Table 1c. Numbers and ratios of magnetic elements in different flux density ranges

	$B > 10$ Gauss		$B < -10$ Gauss	
	Number	Ratio	Number	Ratio
Northern pole	128	60%	87	40%
Southern pole	117	50%	115	50%
Eastern limb	74	44%	96	56%
Western limb	50	66%	26	34%

faculae appear to have the same magnetic polarity as the general polar magnetic field.

Tables 1a and 1b also show that the magnetic elements near solar poles are stronger than in quiet equatorial regions near the limb. The numbers and ratios of strong magnetic elements in polar regions are greater than in the quiet equatorial region (western limb) and are in agreement with Zhang et al.'s (1997) conclusion.

The eastern limb region, which has a unipolar region nearby in the right side of the magnetogram of Fig. 1c, shows a stronger field than the quiet western limb region. It has a field almost as strong as the northern polar field although it is still weaker

Table 2. Numbers and ratios of magnetic elements with a paired opposite polarity magnetic element

	$\mid B \mid \geq 20$ Gauss		$\mid B \mid \geq 10$ Gauss	
	Number	Ratio	Number	Ratio
Northern pole	9	4%	50	23%
Southern pole	23	10%	78	34%
Eastern limb	4	2%	21	12%
Western limb	0	0	4	5%

than the field near southern pole. This partially supports Zhang et al.'s (1997) conclusion that polar fields are not greater than equatorial fields containing unipolar regions. Our data show that one of the polar fields (northern pole) is evidently not greater than the equatorial field containing unipolar regions, although another polar field (southern pole) is.

Homann et al. (1997) found that the equatorial faculae show both magnetic polarities. This is also shown from our data. Our data show more balanced numbers of positive and negative magnetic elements among weak elements. Since quiet equatorial fields lack strong magnetic elements, they show more balanced numbers of positive and negative magnetic elements as a whole.

3.2. Opposite polarity magnetic pairs

It is also found that there are more opposite polarity magnetic pairs near solar poles than in equatorial regions near the limb.

Opposite polarity magnetic pairs are defined as those magnetic elements which have an opposite magnetic element nearby with the distance between these two elements less than $6''$. Numbers and ratios of magnetic elements with a paired opposite polarity magnetic element are presented in Table 2. The ratio definition is the same as in Table 1.

From Table 2, we find that the numbers and ratios of magnetic elements with a paired opposite polarity magnetic element are greater in solar polar regions than in equatorial regions near the limb. This is different from the finding of Homann et al. (1997). Presumably, it is because the sensitivity of the observations of these authors was lower than in our measurements, especially for detecting those close-by pairs as we detected here. There are also more opposite polarity magnetic pairs near the northern pole than near the eastern limb, even though the field strength near the northern pole is not so evidently greater than that near the eastern limb as discussed before. If we explain these opposite polarity magnetic pairs as evidence of horizontal components of the magnetic field, then this implies that magnetic elements in polar fields have greater horizontal components than those in equatorial fields.

4. Conclusion

From our observation and analysis, we find that:

1. The magnetic elements near solar poles are stronger than in quiet equatorial regions near the limb and strong polar magnetic elements appear to have the same magnetic polarity as the general large-scale polar magnetic field, which is in agreement with previous results by Homann et al. (1997) and Zhang et al. (1997).
2. There are more opposite polarity magnetic pairs in solar southern and northern polar regions than in equatorial regions near eastern and western limbs, which disagree with the findings by Homann et al. (1997), possibly due to the higher sensitivity of our observations than those of these authors.

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