Solar Activity and its Magnetic Origin
Proceedings IAU Symposium No. 233, 2006
V. Bothmer & A. A. Hady, eds.

doi:10.1017/S1743921306001608

Simultaneous measurement of magnetic and velocity fields in the layers of photosphere and chromosphere

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Abstract. In this paper, we have presented high resolution magnetograms around sunspot at CaI 6102.7$\mathring{A}$ photospheric line and in $H\alpha$ chromospheric line.
Futher, more the longitudinal magnetic field difference in two wings(red and blue)around central line in photosphere and chromosphere has been studied.

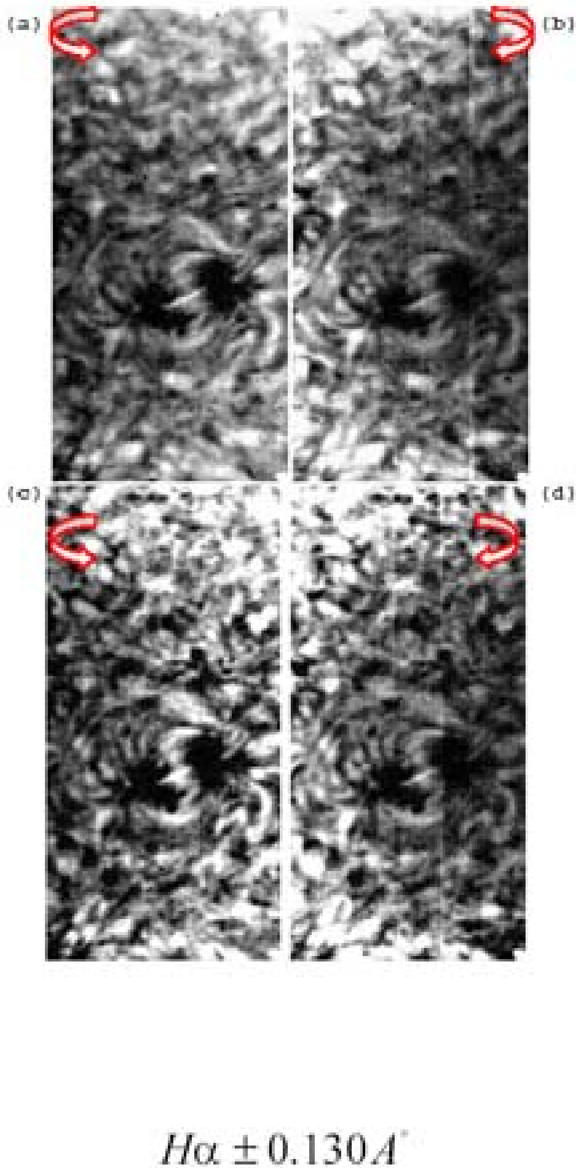
Keywords. Sun: solar photosphere, V stokes parameter, longitudinal magnetic field

1. Introduction

The magnetic flux tube is a key to unified understanding of many solar phenomena.The magnetic field and the motions of the solar plasma are two important factors determining most of the solar phenomena. According to Wiehr *et al.* (1985) and Koutchmy *et al.* (1991) in the photosphere zone the V stokes parameter and longitudinal magnetic field in blue wing are greater than in red wing.

2. Observations

A long series of high resolution filtergrams in a long series of the magnetically sensitive CaI 6102.7 $\mathring{A}$ line center and in wings($\pm 70 m\mathring{A}$), each wing which simultaneously observed in two circular polarizations (right and left circular polarized light),as same as at center and wings of $H\alpha$ were obtained at the sacramente peak vacuum tower telescope and with the Universal Birefringent Filter (UBF). The filter bandpass was 186 $m\mathring{A}$, while the scale of the image on the film was 10 arcsec/mm. The field of view was typically $100'' \times 200''$ and the telescope was pointed near the disk center at heliocentric coordinates N 18° W 12°. For the separation of the two circular polarization a Wollastone prism was used. To eliminate the effect of five minute oscillations in photosphere and three minute oscillation in chromosphere (Hasan 1985) we computed velocity maps averaged over an interval of 5 and 3 minutes. We also computed averaged of the magnetic field maps in order to improve the signal to noise ratio at the expense of slightly degraded spatial resolution. It is important to note that the right and left polarizations in each wing have observed simultaneously, i.e., the atmospheric distortion is the same in both polarization. An example of $H\alpha$ images is illustrated in figure (1).



3. Theoretical interpretation of Dopplegram and Magnetogram signals

Let R Subtraction of two simultaneously opposite polarity images in each wing gives a signal proportional to longitudinal Zeeman effect (line of sight magnetic field component). Substraction of the total intensity in the wings gives a signal proportional to the line of sight velocity. However, the magnetic field maps obtained for the blue and red wings are to some extend different and we don't know which one is correct,so far. So, we use average magnetogram in the two wings.Then instead of using the quantity $\frac{V}{I}$ (where V and I are the stokes parameters), we use average quantity to determine the longitudinal

https://doi.org/10.1017/S1743921306001608 Published online by Cambridge University Press

magnetic field as follows:

$$(R_m)_{ave} = 1/2 \left\{ \frac{V_r}{I_r} - \frac{V_b}{I_b} \right\} = 1/2 \left\{ \frac{|V_r|}{|I_r|} + \frac{|V_b|}{|I_b|} \right\}, \tag{3.1}$$

Also, we defined the quantity R_v,for measure Doppler velocity:

$$R_V = \frac{I_r - I_b}{I_r + I_b} = \frac{I(\lambda_0 + \Delta\lambda_v) - I(\lambda_0 - \Delta\lambda_v)}{I(\lambda_0 + \Delta\lambda_v) + I(\lambda_0 - \Delta\lambda_v)}, \tag{3.2}$$

Where I is the intensity of blue and red wings. $\Delta\lambda_v$ is Doppler shift and λ is center line wavelength. expanding eq. (3.1) in terms of V and I around λ, yields:

$$\Delta\lambda_B \cos\gamma = \frac{\pi^{\frac{1}{2}}}{2} \Delta\lambda_D (R_m)_{ave} \left[\left[1 - erf^2 \left(\frac{\Delta\lambda_v}{\Delta\lambda_D} \right) \right] exp \left(\frac{\Delta\lambda_v}{\Delta\lambda_D} \right)^2 \right] \tag{3.3}$$

Where $\Delta\lambda_D$ is Doppler width and *erf* is the error function. The left hand side of eq. (3.3) is proportional to the magnitude of the longitudinal magnetic field. As $\frac{\Delta\lambda_v}{\Delta\lambda_D}$ is small , we can approximate the curved brackets in eq. (3.3). Then we have:

$$B\cos\gamma \approx \frac{4\pi(mc^2)}{e\lambda^2 g_{eff}} \frac{\pi^{\frac{1}{2}}}{2} \Delta\lambda_D (R_m)_{ave}. \tag{3.4}$$

Solving eq. (3.2) for $\Delta\lambda_v$, we get:

$$\Delta\lambda_v = \Delta\lambda_D inverf(R_v) \approx \frac{\pi^{\frac{1}{2}}}{2} \Delta\lambda_D R_v, \tag{3.5}$$

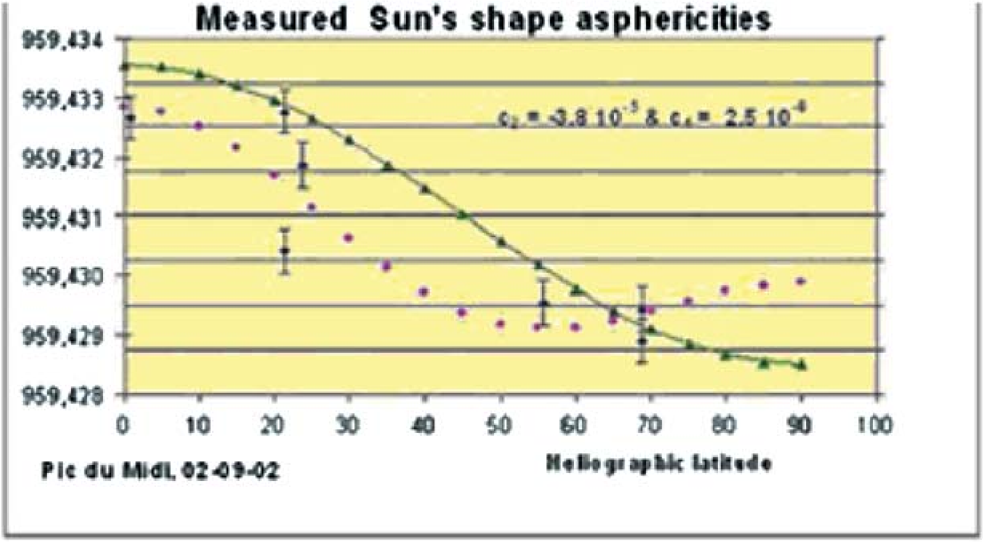
In Eqs. (3.4) and (3.5), to determine Doppler width,the calibration method used by Henze *et al.*(1982) is used:

$$\Delta\lambda_D = \frac{2}{\pi^{\frac{1}{2}}} \frac{\Delta\lambda_c}{(R_{vc} - \bar{R}_v)}. \tag{3.6}$$

Where $\Delta\lambda_c$ is calibration shift,$R_{vc}$the observed shift signal during calibration and $\bar{R}_v$ the average of shift signals observed during three repetitions.

4. Results

In fig. (2) we see that in magnetogram in blue wing is 20 per cent more than field observed in the red wing. Also, averaging the magnetic field of the two wings yields a map that very similar to that of the blue wing.Also,It seems that,the main reason for difference in magnetic fields intensity of the two wings is omitting of the terms in curved brackets of $Eq.$ (3.3). Since these terms demonstration asymmetry of V stokes parameter profile (because this profile is shifted by plasma velocity),since we measuring in equal distances from central wavelength,the discrepancy between the red and blue wings is quite distinct. If the terms inside the curved brackets are expanded 3th order,this difference is decrease to 10 per cent. less noisy, since the noise in the red wing is increased due to influence of the red shift of intergranular lanes. Of course, it should be mentioned that all of values in magnetic field map in figures (2 and 3) have been corrected by 30 due to the error caused by used mirrors in sac-peak telescope optical set-up which reduce circular polarized light.



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