The Physics of Sun and Star Spots
Proceedings IAU Symposium No. 273, 2010
D.P. Choudhary & K.G. Strassmeier, eds.

doi:10.1017/S1743921311015262

Evolution of twist-shear and dip-shear in flaring active region NOAA 10930

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Abstract. We study the evolution of magnetic shear angle in a flare productive active region NOAA 10930. The magnetic shear angle is defined as the deviation in the orientation of the observed magnetic field vector with respect to the potential field vector. The shear angle is measured in horizontal as well as vertical plane. The former is computed by taking the difference between the azimuth angles of the observed and potential field and is called the twist-shear, while the latter is computed by taking the difference between the inclination angles of the observed and potential field and is called the dip-shear. The evolution of the two shear angles is then tracked over a small region located over the sheared penumbra of the delta sunspot in NOAA 10930. We find that, while the twist-shear shows an increasing trend after the flare the dip-shear shows a significant drop after the flare.

Keywords. Sunspots, flares

1. Introduction

The non-potential magnetic field in solar active regions stores the free-energy which is needed to fuel the energetic events like solar flares. The conventional measure of non-potentiality has been the so-called magnetic shear angle (Hagyard *et al.* 1984). This angle measures the difference between the observed and potential field azimuths and has been studied in relation to the flares (Venkatakrishnan *et al.* 1988). However, this angle measures only the deviations of the observed field from potential field vector in the horizontal plane alone. Such deviations are also possible in the vertical plane i.e., in the magnetic field inclination angles of the observed and potential field. In order to distinguish between these two types of shear we call the shear in the horizontal plane as the twist-shear while the shear in the vertical plane as the dip-shear.

In this paper we show how the observed magnetic field deviates from the potential field in the vertical plane in flare productive active region NOAA 10930. Further, we show the evolution of these two shear parameters in the penumbral region located close to the polarity inversion line (PIL) of the delta sunspot before and after the flare. The high-resolution vector magnetograms were derived by using the spectropolarimetric observations from *Hinode* Solar Optical Telescope (SOT) (Tsuneta *et al.* 2008). We describe these results in the following sections.

2. Observations and Analysis Methods

The delta sunspot in NOAA 10930 was observed during 12–13 December 2006 by *Hinode* space mission (Kosugi *et al.* 2007). The spectropolarimetric data was obtained

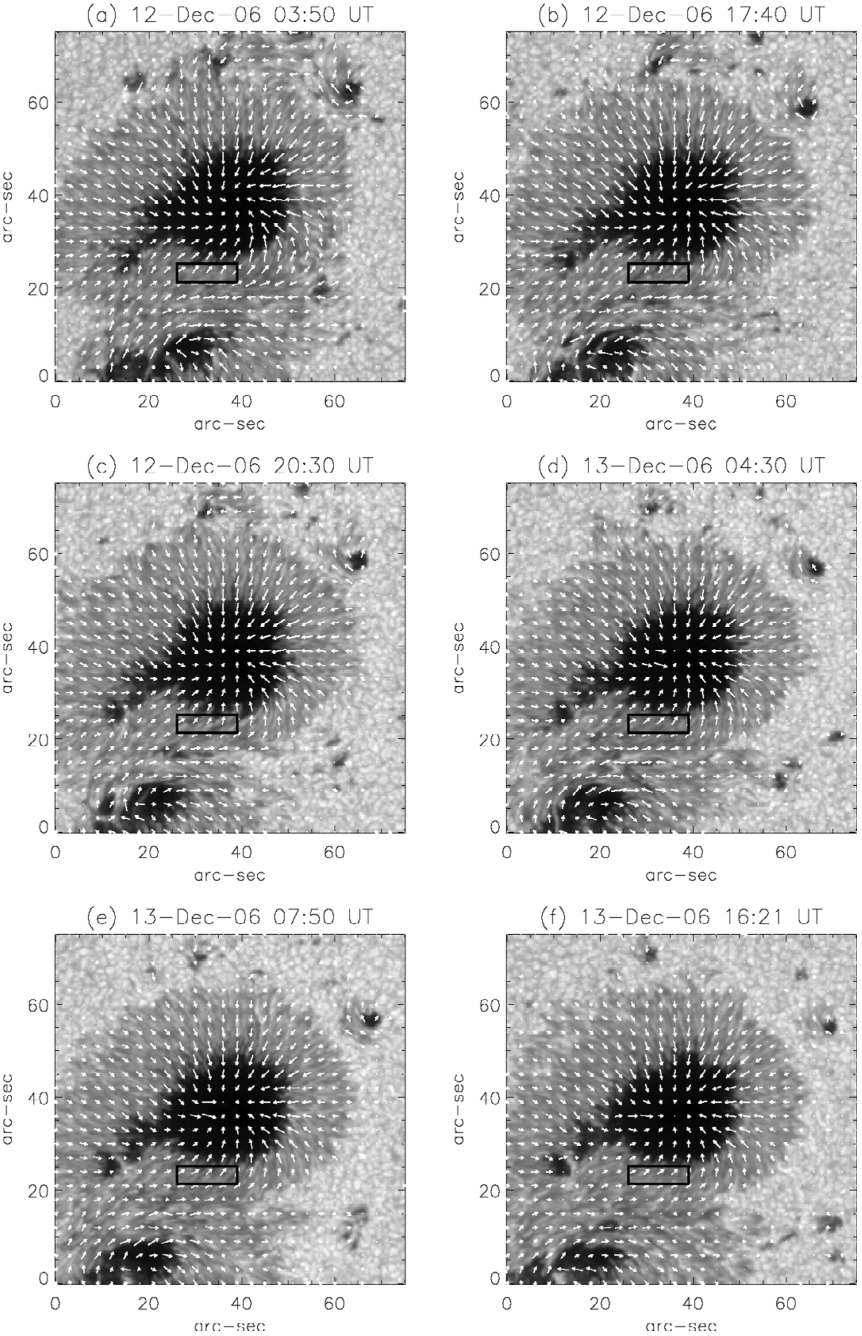

Figure 1. Panels (from top to bottom) show a continuum intensity map of the delta-sunspot in NOAA 10930 during the times mentioned at the top. The transverse magnetic field vectors are shown by arrows overlaid upon these maps. The black rectangle, as shown in all panels, is the region where we monitor the evolution of the twist-shear and dip-shear.

from *Hinode* SOT/SP instrument (Ichimoto *et al.* 2008) and was reduced and calibrated using SolarSoft package. The calibrated spectropolarimetric data was then inverted using MERLIN inversion code (Lites *et al.* 2007) at HAO, Boulder, USA. This inversion code

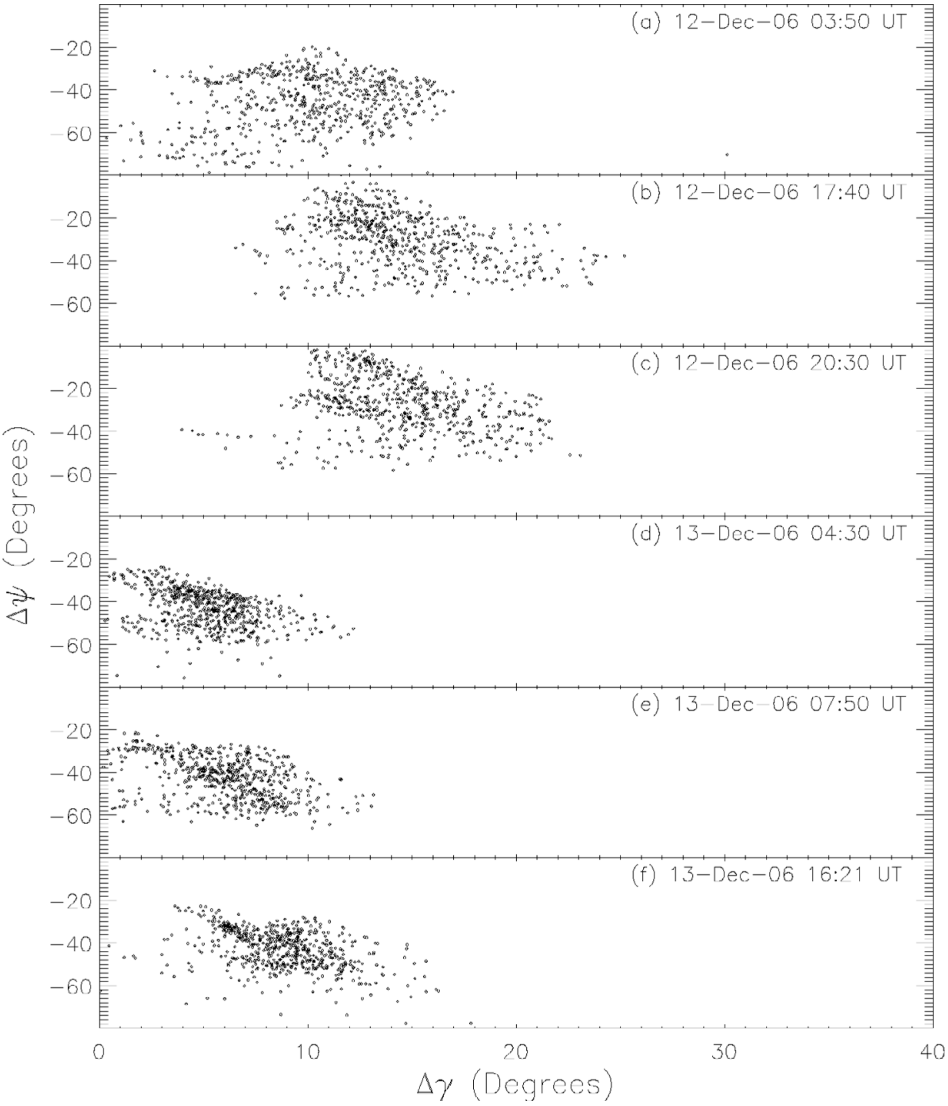

Figure 2. Panels (from top to bottom) show the evolution of the twist-shear and the dip-shear inside the region marked by the rectangle in figure 1.

performs the non-linear least squares fitting of the observed Stokes profiles with the theoretical Stokes profiles computed under Milne-Eddington model atmosphere assumptions. The resulting best-fit magnetic parameters were then resolved for 180 degree azimuth ambiguity by using the acute angle method. These were then transformed into heliographic coordinates using the method of Venkatakrishnan *et al.* (1988). The potential field was computed using the method of Alissandrakis (1981). The magnetograms were registered by applying the image cross-correlation method on the continuum intensity images. The figure 1 shows the continuum intensity maps of the six magnetograms obtained during 12-13 December 2006. The black rectangular box is the location where we monitor the dip-shear and the twist-shear. The figure 2 shows the evolution of the shear parameters inside this box during the observations.

3. Results and Discussions

It can be clearly noticed that: (i) the twist-shear and dip-shear are correlated i.e., the pixels with large twist shear also tend to have large value of dip-shear and vice-versa, with some spread in either parameter, (ii) the dip-shear shows an increasing trend before the flare, (iii) the dip-shear decreases significantly after the flare, (iv) the twist-shear increases after the flare which was also observed by Jing *et al.* (2008).

Any flare related change in the observed parameters of the active regions is useful in order to understand the nature of the energy build-up and its subsequent release in flares and CMEs. The changes in the line-of-sight magnetic field was been studied by Sudol & Harvey (2005) in large number of powerful flares and firmly established that there is abrupt and permanent flare related change in active regions. The present study tries to establish those results on more firm footing by detecting the changes in the magnetic field vector directly. However, the slow cadence of the *Hinode* SOT/SP observations present the biggest limitation in moving forward with such studies. We plan to conduct similar study in near future by using high-cadence vector magnetograms from the recently launched Helioseismic and Magnetic Imager (HMI) onboard Solar Dynamics Observatory (SDO).

Acknowledgements

The presentation of this paper in the IAU Symposium 273 was possible due to financial support from the National Science Foundation grant numbers ATM 0548260, AST 0968672 and NASA - Living With a Star grant number 09-LWSTRT09-0039. Hinode is a Japanese mission developed and launched by ISAS/JAXA, with NAOJ as domestic partner and NASA and STFC (UK) as international partners. It is operated by these agencies in co-operation with ESA and NSC (Norway).

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