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The Evolution of Global Twist in Active Region NOAA 10930

KEYWORDS: Sun: magnetic fields, photosphere, sunspots, flares.

Yogita Suthar	S.N.A. Jaaffrey	Mukesh Shrimali
Department of Physics, University College of Science, Mohanlal Sukhadia University,Udaipur 313 001, India.	Pacific Academy of Higher Education and Research (PAHER) University, Udaipur 313001.	Pacific Academy of Higher Education and Research (PAHER) University, Udaipur 313001.

ABSTRACT *Twist parameter αg is measured in the present study with its variability and sign along the magnetic field line of force observed in an active region NOAA AR 10930 by Hinode (Solar Optical Telescope/Spectro-polarimeter). The data has been calibrated from level 0 to level 1 by using the standard "SP_PREP"and taking as1σ for noise level. We estimated accurate value of αg for North polarity from - 4 x 10-8 to 1 x 10-8 m-1 with 60% argumentation with regards to South polarity. Flare occurred on Dec 13, 2006 after which both αg and area of active region started decreasing. At South polarity, αg recovered the initial value very close to zero whereas north polarity did not but persisted with residual of -9 x 10-8 m-1 at the end of flare.*

INTRODUCTION

In 1925, G.E. Hale (Hale 1925,1927) investigated helical feature in the sunspot which was later confirmed by Richardson (1941) over four solar cycle with counterclockwise whirls in the northern hemisphere and clockwise is southern hemisphere. After more than half century other solar features like active regions, filament, coronal loops, interplanetary magnetic clouds, X-ray arcades and fine magnetic structures have been proved to be independent of solar cycle by several studies (Seehafer 1990; Pevtsov et al. 1995; Abramenko et al. 1996; Bao & Zhang 1998; Longcope et al. 1998; Hagino & Sakurai 2004, 2005; Nandy 2006; Bernasconi et al. 2005; Pevtsov & Longcope 2001, 2007).

Twistedness in the field lines is referred to magnetic helicity H_m and is given by expression

$$H_m = \int_v \vec{A}\cdot\vec{B}\, dv$$

H_m is obtained integrating over the volume V with magnetic field B=∇×A. and is measured by the helicity parameter α, a degree of twist per unit axial length along the field lines (Seehafer 1990). Under force free condition Parker (1979) has given helicity parameter α, as ∇×B= αB.

α is enable to give the sign of magnetic helicity under all conditions (for details see Appendix B of Tiwari.et.al. 2009) because of the large uncertainties in the global α values from the frequent observation of the same active region of interest (pevtsov et.al. 1995).

For direct calculation of global α , a Z-component of magnetic field is taken from the force free field as

$$\alpha = \frac{(\nabla X B)_z}{B_z}$$

We employ condition $\Sigma(\alpha-\alpha_g)^2 = minimum\Sigma(\alpha-\alpha_g)^2 = minimum$ for least square minimization with

$$\alpha_g = \left(\frac{1}{N}\right)\Sigma\,\alpha$$

Where α is the local value of each pixel, α_g is the global value of α for complete active region and N is total number of pixels. Hagino & Sakurai (2004)

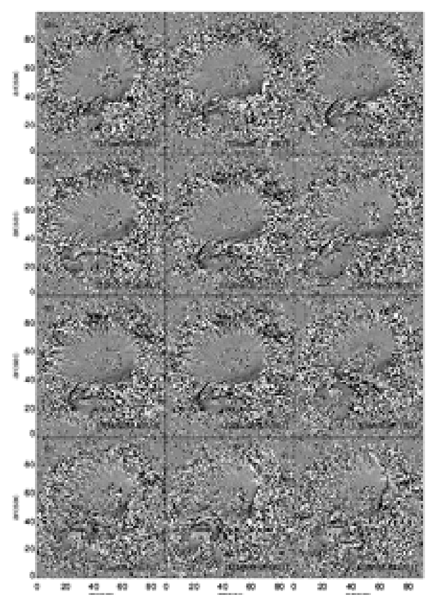

Figure 1: Plots of time series of local alpha maps of NOAA AR 10930.

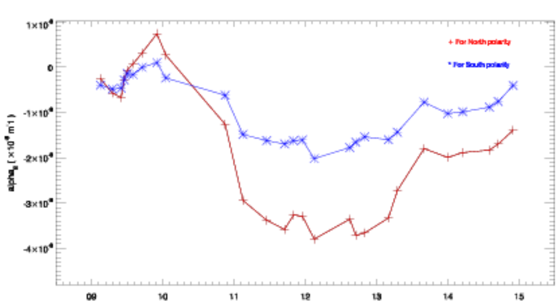

Figure 2: The evolution of alpha in the S-polarity (blue)

and N-polarity (red) regions as a function of time.

Under the condition of moment of minimization

$$\frac{\partial}{\partial \alpha_g}\left(\sum\left(\alpha-\alpha_g\right)^2 B_z^2\right)=0$$

$$\alpha_g=\frac{\sum\left(\frac{\partial B_y}{\partial x}-\frac{\partial B_x}{\partial y}\right)B_z}{\sum B_z^2}$$

This formula gives a singal global value of α in a sunspot (Tiwari et al. 2009).

The accuracy in finding α_g depends upon the Polarimetric noise inverse data of vector magnetograms for all three components of vector magnetic field (B_x, B_y and B_z). It is believed that the reliable measurement of vector magnetograms of vector magnetic fields is needed to study various important physical quantities.

A study of global twist in active region 10930 by Tiwari et al.(2009) showed that the local is distributed as alternate positive and negative filaments in the penumbra. In the present paper, we examine the evolution of α_g in North and South polarities separately in the solar active region 10930 during December 9 – 15, 2006.

DATA ANALYSIS

We have used 27 high-resolution vector magnetograms obtained from the Solar Optical Telescope/Spectro-polarimeter (SOT/SP: Tsuneta et al. 2008; Suematsu et al. 2008; Ichimoto et al. 2008) onboard Hinode (Kosugi et al. 2007) during December 9 – 15, 2006 as shown in figure 1 with plots of time series of local alpha maps of NOAA AR 10930.

The calibration of the Hinode (SOT/SP) data has been done by using the standard "SP_PREP" routine developed by B. Lites, which is available in the Solar Software package. The"SP_PREP" routine first computes the thermal shifts in the spectral and slit dimensions and then applies the drift corrections for calibrating the data from level 0 to level 1. The 180° azimuthal ambiguity in the data is removed by using acute angle method (Harvey, 1969; Sakurai et al., 1985; Cuperman et al., 1992). To minimize noise, pixels having transverse (B_t) and longitudinal magnetic field (B_z) greater than a certain level are only analyzed. A quiet Sun region is selected for each sunspot and 1σ deviation in the three vector field components B_x, B_y and B_z are evaluated separately. The resultant deviations in B_x and B_y are then taken as the1σ noise level for transverse field components while deviations in B_z is taken as1σ for noise level of line of sight component of magnetic field. Only those pixels where longitudinal and transverse fields are simultaneously greater than twice the above mentioned noise levels are analyzed.

RESULTS

Figure 2 shows the result of the global value of twist of an active region which could be measured precisely by calculating α_g. We estimated accurate value of twist for both North and South polarities as under:

(1) The flare was observed in real time scale of about 6 day continuously (Dec 09-15, 2006) in active region 10930 with estimated α_g in the range from - 4 x 10^{-8} to 1 x 10^{-8} m^{-1}.
(2) South polarity showed variation in α_g of about -2 x 10^{-8} m^{-1} as compared to north polarity of -4 x 10^{-8} m^{-1}, which is found with 60% argumentation.
(3) South polarity α_g recovered the initial value very close to zero value whereas north polarity did not but presented with residual twist of -1 x 10^{-8} m^{-1} in the end of flare in the active region.
(4) Both polarities indicated variability in α_g concurrent i.e. from Dec 09 to Dec 11 were almost simultaneous but twist suddenly speeded up and remained almost constant of active region, before flare erupted on Dec 13, 2006.
(5) After Dec 14, 2006, when flare was completed, both polarities α_g decreased. It pointed out net twist of active region decreased.
(6) We also observed that area of active region was small with slow twist before Dec 11 and suddenly increased in twist during Dec 11-13, 2006. As soon as flare occurred on Dec 13, both twist and area of active region started decreasing (Fig.1).

DISCUSSION

We calculate the global twist in solar active region NOAA 10930 using a time series of photospheric vector magnetograms of Hinode/SOT-SP. This active region was highly eruptive and produced a number of large flares. The local α patches are present in the umbra. The filamentary distribution of α is observed in the penumbral region. The distribution of local alpha in the penumbra show higher value than that in the umbral region. The α gives the same sign of the photospheric chirality / magnetic helicity of the sunspot. The α_g gives the axial gradient of twist of sunspot under the force free condition. (Tiwari et al.2009).

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