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Skew Angle and Magnetic Helicity in Solar Active region

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Introduction

The skew angle and magnetic helicity are important to understand magnetic structures in solar active regions. In this study, we have made the first attempt to examine the relationship between the skew angle and magnetic helicity. We found that an active region which has a small skew angle tends to have a large helicity value. This result implies that while a strong twist coronal loop is nearly parallel to a PIL axis, a weak twist coronal loop is perpendicular to a PIL, like a potential field structure. The objective of this study is to examine the relationship between magnetic helicity and skew between orientation of sigmoid and polarity inversion line (PIL). In order to achieve this purpose, we measure skews of PILs and coronal loops. We will focus our attention on Solar Active Region Skews.

Observation

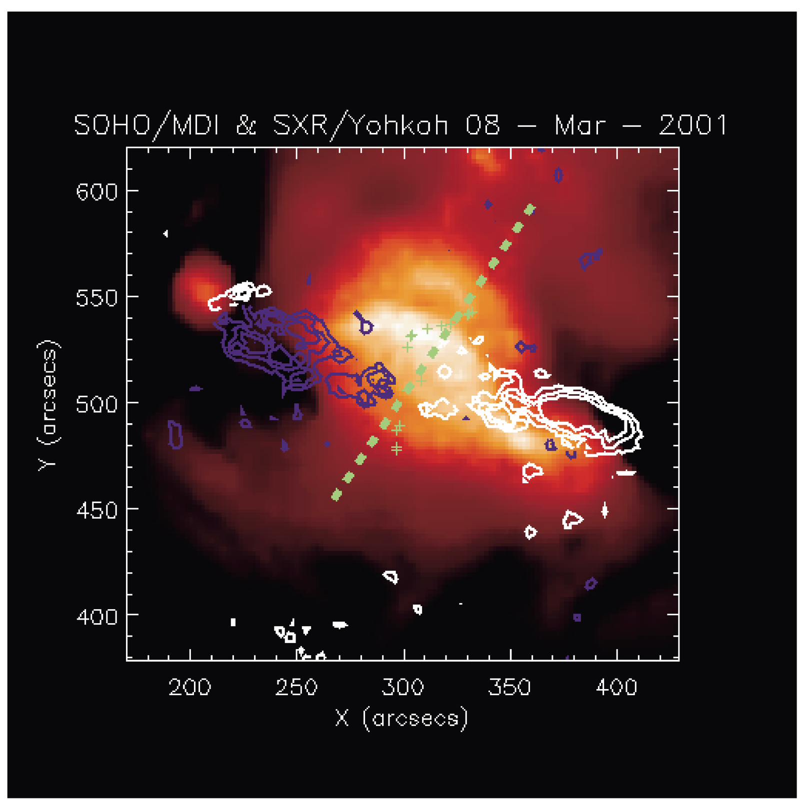

Fig.1

On the measurement the coronal helicity, we used 106 different loops observed by Yohkoh SXT during 1992-2001. To avoid the projection effect, we select active regions appeared within ±30 degree of the solar longitude. These data include both sheared loops and non-sheard loops.

The vector magnetic field we used for this study were obtained with the Solar Flare Telescope (SFT) at Mitaka headquarters of the National Astronomical Observatory of Japan. The noise levels for longitudinal and transverse fields are 10G and 100G respectively. In order to minimize the effect of Faraday rotation, we used only the data points with |Bz|<500G.

Figure 1 is a sample of the non-sheared loop. White(Blue) contours indicate positive(negative) polarity, respectively. A dotted-line shows the polarity inversion line determined by linear fit. In the back ground, we can see a non-sigmoidal bright loop. The the coronal loop axis is perpendicular to polarity inversion line. Figure 2 is a sample of the sheared loop. In this image we can see a sigmoidal loop. The the coronal loop axis is parallel to polarity inversion line.

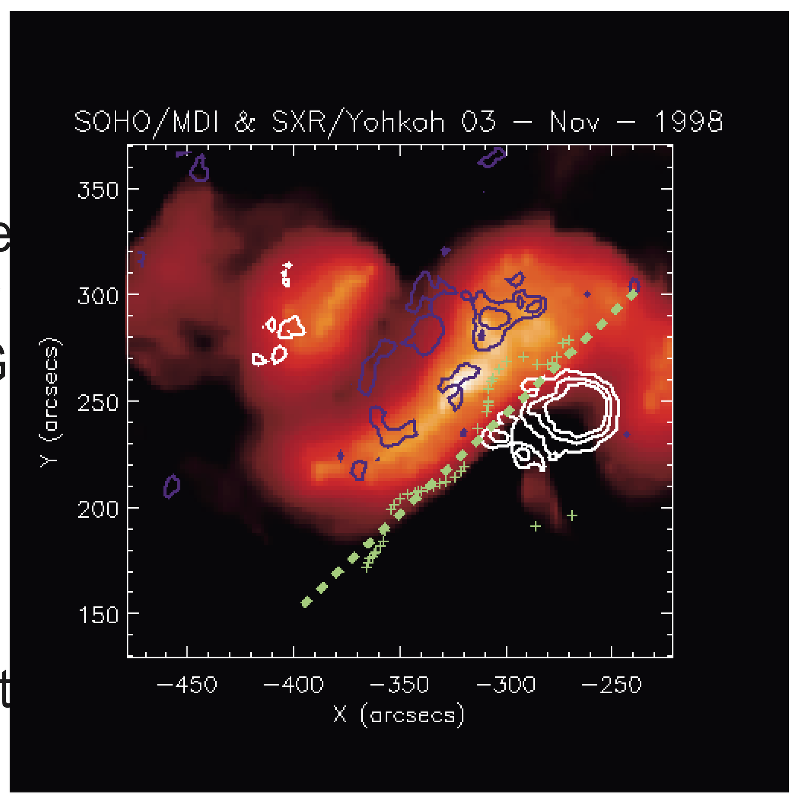

Fig.2

Analysis

(1) Detection of a PIL

Using gradient longitudinal magnetic fields and a limitation within 150G, we look for polarity inversion line (PIL). In the case of island spots between main spots, we used smoothing and mask of these small spots near the PIL line. Moreover, in order to focus on PIL between main sunspots, we selected an area by hand. Finally, we decided a line, adopted by the linear fitting method about above PILs. We defined the PIL angle against the sunspot axis (Figure 3).

(2) Detection of Coronal Loop angle

Using soft X-ray image (removed saturations) observed by Yohkoh SXT, we identified only a brightest coronal loop. If we assume that these bright pixels distribute on a 2D plane, we can measure a coronal loop tilt angle against sunspot axis, used by the linear fitting method (Figure 4).

(3)Definition of Skew angle

The acute angle between the PIL and the coronal loop axis. The sign of chirality in this study used Martin's cartoon (Martin, 1998,Solar phys, 182, 107), i.e. if the loops cross over the PIL in the sense of threads of a left(right)-hand screw, they defined the loops as left(right)-skew (Figure 5).

(4)Photospheric Helicity

The photospheric helicity was determined by

$\alpha = \Sigma Jz \cdot \mathrm{sign}(Bz) / \Sigma |Bz|$,

where $\boldsymbol{J}$ is the electric current, $\boldsymbol{J}=\mathrm{curl}(\boldsymbol{B})$. Since an inconvenient feature of which characterizes the best-fit linear force-free field is that the minimization sometimes fails within the allowed range of force-free value, we only use the α as above mention.

(5)Cronal Helicity

To determined the coronal helicity we used Pevtsov's method (Pevtsov et al. 1997, ApJ, 481,973). They used a linear force-free field solution for which

$\alpha = (\pi / L) \sin \gamma$.

Here L is the distance between footpoints of a loop and γ is the shear angle at the center of its loop.

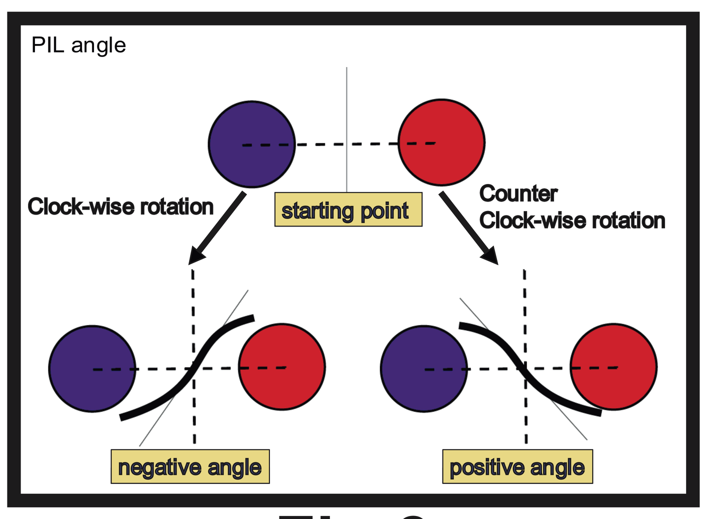

Fig.3

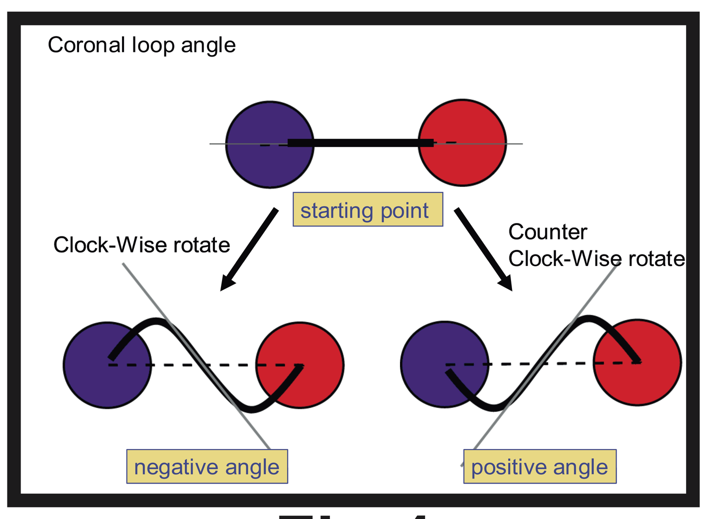

Fig.4

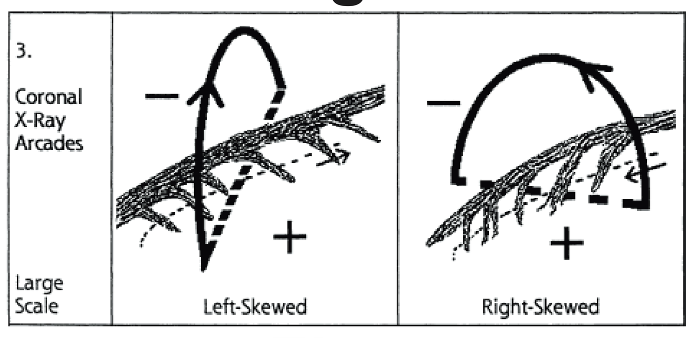

Fig.5

Results

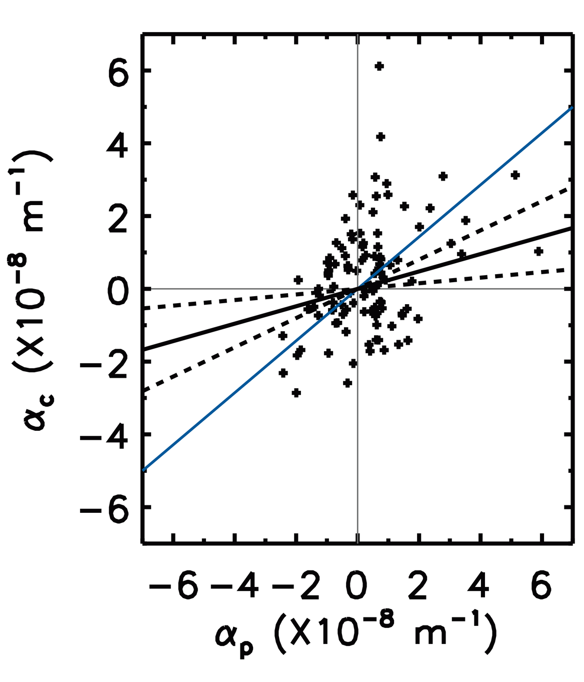

Fig.6: Photospheric and coronal helicity for 106 active regions. A solid line and dashed line indicate the linear fit and 1 σ, respectively. Slope: 0.23±0.16, Correlate coefficient :0.14. A blue line shows the Pevtsov's result.

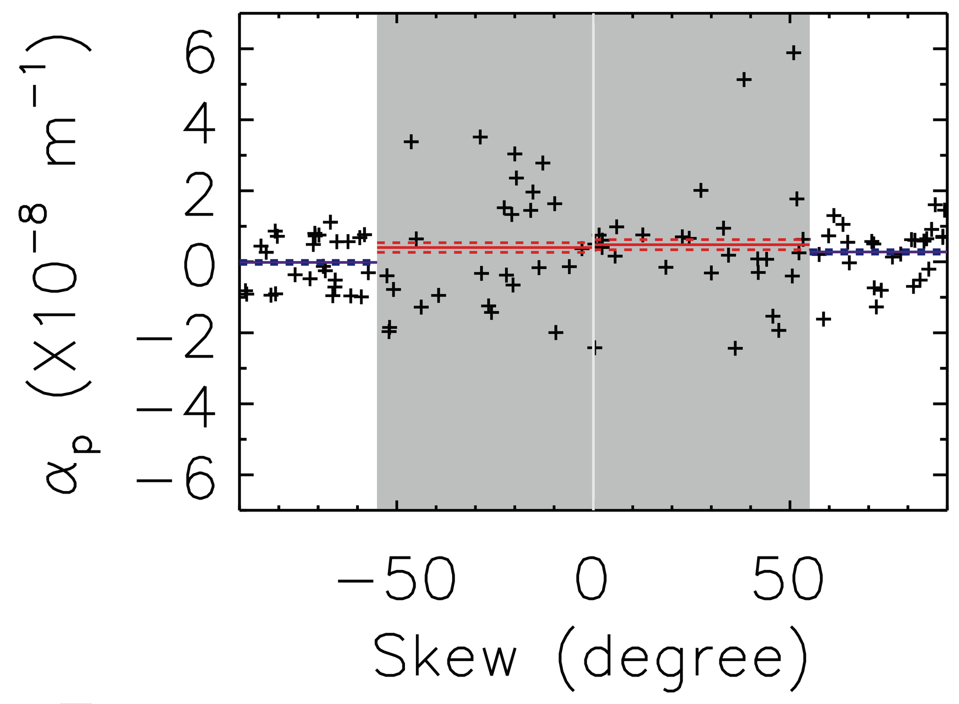

Fig.7: Photospheric helicity as a function of skew angle between PIL angles and coronal loop angles of each active regions. Solid lines show mean value of helicity and dotted lines are 2 σ. Within ±55° scatter are large value. Small skew angle denotes that coronal loop angle is parallel to PIL angle.

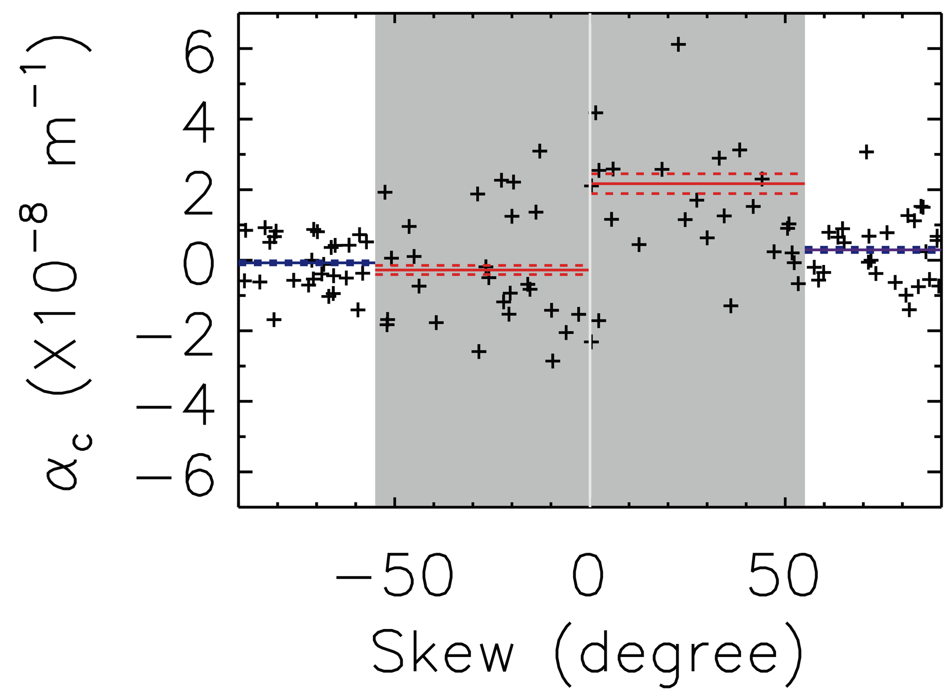

Fig.8: Coronal helicity as a function of skew angle. This plot shows a similar trend with Fig7. Since coronal helicities are measured by shear angles γ, coronal helicities correlate with skew angles in the shade zone.

Discussion

We confirmed that the coronal and photospheric helicity shows a positive correlation, supporting Pevtsov et al. (1997). We found that an active region which has a small skew angle tends to have a large helicity value. This result implies that while a strong twist coronal loop is nearly parallel to a PIL axis, a weak twist coronal loop is perpendicular to a PIL, like a potential field structure.

Table1: Summary of photospheric and coronal helicity mean values of the each skew angle ranges from Figure 7 and 8, respectively.

	−95<skew<−55	−55<skew<0	0<skew<55	55<skew<95
α_p	−0.018±0.027	0.40±0.068	0.48±0.071	0.28±0.031
α_c	−0.074±0.029	−0.28±0.065	2.17±0.14	0.29±0.037