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Helicity of solar magnetic field from observations

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Abstract. The helicity is an important quantity to present the basic topological configuration of magnetic field transferred form the solar subatmosphere into the interplanetary space. In this paper, we present the observational solar magnetic field and the relationship with the magnetic helicity.

Keywords. Sun: magnetic fields, helicity, interior; turbulence, MHD

1. Importance and definition of magnetic helicity

Helicities are topologically a measure of the structural complexity of the corresponding fields. Woltjer (1958) presented the basic properties of magnetic helicity firstly. As indicated by Taylor (1986) that the topological invariants of ideal plasma so that only total magnetic helicity survives. Helicity is described in terms of the internal structure of a flux tube and the external relations between flux tubes. The helicity of open field configurations not bounded by magnetic surfaces is discussed by Berger and Field (1984), and a measure of the propagation of topological structures across open boundaries is given also.

Pouquet, Frisch, and Leorat (1976) indicated that the turbulence and magnetic fields are a common feature of many celestial bodies. The study confirms the importance of helicity both in its kinetic and in its magnetic form for generation of large-scale magnetic fields by turbulence. Keinigs (1983) and Keinigs and Gerwin (1986) analyzed that in a magnetized plasma the alpha effect represents a turbulently generated emf directed along the mean magnetic field. The alpha effect is reevaluated in terms of ensemble-averaged properties of the magnetic fluctuation spectrum. The results indicate that the turbulent current helicity must be opposite in sign to the mean-field current helicity in order for the alpha effect to play a role in overcoming the resistive diffusion of large-scale magnetic fields. Kleeorin and Rogachevskii (1999) analyzed the evolution of the magnetic helicity tensor for a nonzero mean magnetic field and for large magnetic Reynolds numbers in an anisotropic turbulence.

The magnetic helicity density $h_m = \mathbf{A} \cdot \mathbf{B}$, with **A** the vector potential for magnetic field **B**, measures the chirality of magnetic lines of force. The magnetic helicity is defined as

$$H_m = \int_V h_m d^3x = \int_V \mathbf{A} \cdot \mathbf{B} d^3x, \tag{1.1}$$

where the vector potential **A** can not be observed immediately. It is noticed that the magnetic helicity is a relative quantity and depends on the selection of gauge of magnetic field **B** (i.e. $\mathbf{B} = \bigtriangledown \times (\mathbf{A} + \bigtriangledown\phi)$. It is conserved in a close volume when small resistivity is present.

According to the definition (Berger and Field, 1984), the magnetic helicity can be separated into two kinds. One is the self helicity, which relates to the magnetic flux tubes twisted themselves. This helicity may be used to analyze the twisted magnetic flux loops. Another is the mutual helicity, which relates to the different magnetic flux tubes linked each other. As the helicity contains both, the total helicity can be written in the form

$$H_m = T\Phi^2 + 2L\Phi_1\Phi_2, \tag{1.2}$$

where the T is the twisted number of magnetic flux Φ and the L is the linkage number of different magnetic flux Φ_1 and Φ_2.

The relative change of magnetic helicity in the solar atmosphere can be inferred by the magnetic field across the boundary surface (Berger and Field, 1984)

$$\frac{dH_m}{dt} = -2\oint_S [(\mathbf{V}_t \cdot \mathbf{A}_p)B_n - (\mathbf{A}_p \cdot \mathbf{B}_t)V_n]ds, \tag{1.3}$$

where the magnetic field $\mathbf{B}$ and velocity field $\mathbf{V}$ are observable in the solar atmosphere. The subscripts have their normal meanings. The first term in eq. (1.3) provides the contribution from the twisted motion of footpoints of magnetic field in the solar surface, while the second term does that from the emergence of twisted magnetic flux from the subatmosphere.

An important improvement in this project was demonstrated by Demoulin and Berger (2003) with a relative simple form, who presented that the horizontal motions, deduced by tracking the photospheric cut of magnetic flux tubes, include the effect of both the emergence and the shearing motions whatever the magnetic configuration complexity is. According to the analysis of Demoulin and Berger (2003), one can obtain that

$$\frac{dH_m}{dt} = -2\oint_S (\mathbf{U} \cdot \mathbf{A}_p)B_n ds, \tag{1.4}$$

where

$$\mathbf{U} = \mathbf{V}_t - \frac{V_n}{B_n}\mathbf{B}_t. \tag{1.5}$$

As the linkaged or twisted magnetic flux bundles emerge from the subatmosphere, their footpoints show the sheared or twisted motion and it can be analyzed by the equivalent form in eqs. (1.4) and (1.5). This implies that one can not exclude the contribution of emerging flux in the horizontal motion of magnetic footpoints in the solar surface.

The current helicity density h_c ($h_c = \mathbf{B} \cdot \bigtriangledown \times \mathbf{B}$) is another important physical quantity for the measure of the magnetic field in the solar atmosphere. It is noticed that only as $\bigtriangledown \times \mathbf{A}$ is parallel to $\mathbf{A}$ the relationship of both helicity densities becomes simple, and both helicity density show the same sign constantly (Zhang, 2001). In the statistical analysis of magnetic fields, the mean magnetic and current helicities would probably show the same sign $< h_c > \sim < h_m >$.

The current helicity is defined in the form

$$H_c = \int_V h_c d^3x = \int_V \mathbf{B} \cdot \bigtriangledown \times \mathbf{B} d^3x. \tag{1.6}$$

If neglect the coefficient $\frac{c}{4\pi}$, we can obtain

$$H_c = 2I_1I_2. \tag{1.7}$$

The similar relationship on the linkage and twist of current helicity relative to eq. (1.2) can be inferred also

$$H_c = TI^2 + 2LI_1I_2, \tag{1.8}$$

where T is the twisted number of current system I and L is the linkage number of different current system I_1 and I_2.

Moreover, as comparing with the magnetic helicity density, it is found that only a part (vertical component) of current helicity density in the photosphere (Abramenko *et al.*, 1996; Bao and Zhang, 1998),

$$h_{cz} = \mathbf{B} \cdot (\bigtriangledown \times \mathbf{B})_z \tag{1.9}$$

can be inferred from the photospheric vector magnetograms, due to the observational limitation. A similar limitation can be found also on the analysis by the force free factor (Pevtsov *et al.*, 1994)

$$\alpha = \frac{\mu J_z}{B_z}, \tag{1.10}$$

which also does not contain any information on the horizontal part of current helicity density. The mean photospheric current helicity density $\overline{h}_c$ (or mean force free factor $\overline{\alpha}$) is normally used to infer the handedness of magnetic field quantitatively in active regions.

It is suggested a dynamo mechanism in the solar interior based on the combined action of differential rotation and cyclonic convective vortices (Paker 1955) as a viable way to generate magnetic fields capable of driving the activity cycle. We are able to quantify the differential rotation from the motion of large-scale magnetic fields at the solar surface and from helioseismology in the solar convection zone. However, because of the opacity of the solar atmosphere, knowledge of the action of convective vortices can only be obtained from available observations of helical magnetic fields. We can define the magnetic field as a combination of mean and fluctuate field $\mathbf{B} =< \mathscr{B} > +\mathbf{b}$. According to mean field dynamo theory, the electromotive force $\mathbf{E}$ averaged over convective eddies has a component parallel to the magnetic field, $\mathbf{E} = \alpha < \mathscr{B} > + \cdots$, where the pseudoscalar α is related to kinetic and electric current helicities. The determination of the kinetic helicity in the solar atmosphere is difficult, while the twist of magnetic fields, can be estimated from photospheric vector magnetograms of solar active regions (Abramenko *et al.* 1996; Bao and Zhang 1998). The mean current helicity density can be written in the form

$$h_c =< \mathbf{b} \cdot \bigtriangledown \times \mathbf{b} > . \tag{1.11}$$

According to Kleeorin and Rogachevskii (1999) and Brandenburg and Subramanian (2005), the change of magnetic (current) helicity can been inferred in the form

$$\frac{\partial h_c}{\partial t} \approx -\frac{2}{l^2}[< \mathscr{B} > \cdot \bigtriangledown \times < \mathscr{B} > -(\alpha_k + h_c) < \mathscr{B} >^2], \tag{1.12}$$

where the symbols have their normal meanings. It means that the observational solar vector magnetograms can be statistically used to get the possible message on the generation of magnetic field inside of the Sun due to the solar dynamo. In the normal analysis of vector magnetic field of solar active regions, the symbol difference between **B** and **b** has been neglected.

2. The transfer of magnetic helicity and solar eruptive phenomena

2.1. *Helicity transfer in solar active regions*

Helicity is a notable quantity in the study of solar active regions (Wang, 1996). Chae (2001) shown how to observationally determine the rate of magnetic helicity transport via photospheric footpoint shuffling from a time series of line-of-sight magnetograms. Démoulin and Berger (2003) pointed out horizontal motions include the effect of both the emergence and the shearing motions whatever the magnetic configuration complexity is.

From a series of photospheric-vector magnetograms and corresponding soft X-ray images, Zhang (2001) and Zhang (2006a) found that the newly emerging magnetic flux associates the current helicity from the subatmosphere in the active regions with the redistribution of the current helicity density in the upper atmosphere, i.e. it provides observational evidence that flux and helicity emerge together. Because the injection rate of magnetic helicity and photospheric current helicity density have different means in the solar atmosphere, a combined analysis of the observational magnetic helicity parameters actually provides a relative complete picture of magnetic helicity and its transfer in the solar atmosphere. Liu and Zhang (2002) demonstrated that helicity reversal in magnetic features of a delta -configuration is likely to destabilize the compact structure, as well as to re-organize the magnetic field configuration, and, hence, is important for the rapid disintegration of a delta-spot during major flares. its chirality. Liu and Zhang (2006) found that the rotation of photospheric footpoints forms in the earlier stage of magnetic flux emergence and the relative shear motion of different magnetic flux systems appears later in an active region. The strong shear motion between the new emerging flux system and the old one brings more magnetic helicity into the corona than the twisting motions. Zhang, Liu and Zhang (2008) found the rapidly rotating positive polarity of an extensive δ sunspot in Active Region (AR) NOAA 10486, it produced several powerful flare-CMEs. They found the fastest of them is about 220^o for six days. The helicity injection inferred from such rotational motion is about $-3.0 \times 10^{43} Mx^2$, which is comparable that calculated by the local correlation tracking (LCT) method $-5.2 \times 10^{43} Mx^2$ in the whole AR.

Su *et al.* (2009) studied the distributions of local twist α_z and current helicity hc on the active region of NOAA 10930. They found the patches of positive and negative helicities were intermixed showing a mesh pattern in the umbra and a thread pattern in the penumbra. The fine distributions of α_z and hc on a penumbral filament indicated that it may be possible for the two opposite helicities to coexist in a filament and their magnitudes were nearly equivalent. Moreover, Tian and Alexander (2009) separately calculated the distribution of the helicity flux injected in the leading and following polarities of 15 emerging bipolar ARs, using the Michelson Doppler Image 96 minute line-of-sight magnetograms and a local correlation tracking technique. They found from this statistical study that the leading (compact) polarity injects several times more helicity flux than the following (fragmented) one (typically 3–10 times).

2.2. *Helicity and solar flare-CMEs*

Rust and Kumar (1996) found that images of the X-ray corona near the solar disk's center were examined for large, transient brightenings of the type known to be associated with Hα filament eruptions and coronal mass ejections. Many of the brightenings were sigmoid (S-shaped). López Fuentes *et al.* (2000) described the long-term evolution of a bipolar non-Hale active region that was observed from 1995 October to 1996 January. They compared their results with those of other related studies, and they discussed, in particular, whether the kink instability is relevant to explain the peculiar evolution of some active regions. Nindos and Zhang (2002) and Nindos, Zhang and Zhang (2003) investigated whether the bulk of magnetic helicity carried away from the Sun by CMEs comes from helicity injected to the corona by such motions or by emerging magnetic flux. Green *et al.* (2002) studied the magnetic helicity evolution in an active region (NOAA 8100) in which the main photospheric polarities rotate around each other during five Carrington rotations. It is proposed that the ejected helicity is provided by the twist in the sub-photospheric part of the magnetic flux tube forming the active region. Green *et al.* (2007) found the helicity sign of the erupting field and the direction of filament rotation to be consistent with the conversion of twist into writhe under the ideal MHD constraint of helicity conservation. For positive (negative) helicity the filament apex rotates clockwise (counterclockwise), consistent with the flux rope taking on a reverse (forward) S shape, which is opposite to that observed for the sigmoid. This result is incompatible with two models for sigmoid formation: one identifying sigmoids with upward arching kink-unstable flux ropes and one identifying sigmoids with a current layer between two oppositely sheared arcades.

Zhang, Flyer and Low (2006) have pointed out that the accumulation of magnetic helicity in the corona plays a significant role in storing magnetic energy. They propose a conjecture that there is an upper bound on the total magnetic helicity that a force-free field can contain. LaBonte, Georgoulis and Rust (2007) surveyed magnetic helicity injection into 48 X-flare-producing active regions recorded by the MDI between 1996 July and 2005 July. They found that an empirical fit to the data shows that the injected helicity over the range $10^{39} - 10^{43} Mx^2 s^{-1}$ is proportional to magnetic flux squared. Similarly, over a range of 0.3–3000 days, the time required to generate the helicity in a CME is inversely proportional to the magnetic flux squared. Most of the X-flare regions generated the helicity needed for a CME in a few days to a few hours. Kazachenko *et al.* (2009) used the Michelson Doppler Imager and TRACE observations of photospheric magnetic and velocity fields in NOAA 10759 to build a three-dimensional coronal magnetic field model. Their combined analysis yields the first quantitative picture of the helicity and energy content processed through a flare in an active region with an obviously rotating sunspot and shows that rotation dominates the energy and helicity budget of this event

3. Relationship between magnetic helicity and solar cycles

3.1. *Hemispheric rule of magnetic (current) helicity*

Hale *et al.* (1919) firstly found that Hα penumbral features show the direction of whirl in the Northern hemisphere is left-handed or anti-clockwise, while in the Southern hemisphere it is right-handed or clockwise. Ding, Hong, and Wang (1987) found the distribution of spiral patterns in the southern and northern hemispheres shows that the differential rotation may be a fundamental solar dynamo for the formation of the spiral spots. The statistical directions of the emerging twisted magnetic vectors in the active regions in the southern and northern hemispheres are synchronously inverse with a period of about two years.

Seehafer (1990) demonstrated that the electric current helicity is predominantly negative in the northern hemisphere and positive in the southern hemisphere. He pointed out that this finding contradicts the standard dynamo theory according to which the helicity of the large-scale currents is generated by the alpha effect in the convection zone, since it shows helicity of opposite sign. Pevtsov, Canfield and Metcalf (1995) found in their data set, 76% of the active regions in the northern hemisphere have negative helicity, and 69% in the southern hemisphere, positive. Although the data show considerable variation from one active region to the next, the data set as a whole suggest that the magnitude of the average helicity increases with solar latitude, starting at zero near the equator, reaches a maximum near 15 deg–25 deg in both hemispheres, and drops back toward smaller values avove 35 deg–40 deg.

Rust and Kumar (1996) found that reverse-S brightenings outnumbered forward-S brightenings by six to one in the northern hemisphere. Forward-S brightenings were similarly predominant in the south. This hemispherical segregation suggests that the magnetic fields in the transient features are systematically twisted.

Abramenko, Wang and Yurchishin (1996) and Bao and Zhang (1989) studied the mean current helicty for active regions using a photospheric vector magnetograms from the Solar Magnetic Field Telescope (SMFT) of the Huairou Solar Observing Station. Ii is found that more than 80% of the active regions in the northern (southern) hemisphere show negative (positive) sign of current helicity. Tian *et al.* (2001) found that there is a negative correlation between the sign of the tilt angle and the sign of the current helicity if the tilt angle is set a positive value (0–90°) in the northern hemisphere and a negative value (0–90°) in the southern hemisphere for active regions following Joy's law. Most of the X-ray flares larger than M-class during the 22nd solar cycle have a tendency to locate in some longitudinal bins, where active regions with "abnormal chirality" appear frequently.

Hagino and Sakurai (2004) studied the current helicity of solar active regions inferred from vector magnetograms obtained with the Solar Flare Telescope, located at the Mitaka campus of the National Astronomical Observatory of Japan. The latitude distribution of helicity shows a negative slope; namely, the regions in the northern (southern) hemisphere tend to show a negative (positive) helicity, respectively, in agreement with previous studies. The scatter seen in the helicity is significantly larger than expected from the measurement errors, implying that the process generating the helicity is of random, turbulent nature.

LaBonte, Georgoulis and Rust (2007) also found that the weak hemispherical preference of helicity injection, positive in the south and negative in the north, is caused by the solar differential rotation, but it tends to be obscured by the intrinsic helicity injection, which is more disorganized and tends to be of opposite sign. Yang, Zhang and Büchner, (2009) investigated the accumulation of helicity in newly emerging simple bipolar solar active regions. It is found that the accumulated helicity is proportional to the exponent of magnetic flux ($\mid H \mid \propto \Phi^{1.85}$) in the 58 selected newly emerged simple ARs. 74% of ARs have a negative (positive) helicity when the above defined tilt angle rotates clockwise (counter-clockwise). This means that the accumulated helicity and writhe have the same sign for most of the investigated ARs according to the tilt angle evolution of ARs. They also found that 56% (57.6%) of these ARs in the northern (southern) photosphere provide negative (positive) helicity to the corona in the course of the emergence of magnetic flux.

Pevtsov and Latushko (2000) presented the first results of a study of current helicity of the large-scale magnetic field. Asymmetry is present in high latitudes, where current helicity is negative (positive) in the northern (southern) hemisphere. Zhang (2006b) reported the analysis of a large sample of photospheric vector magnetic field measurements in solar active regions, which sample consists of 17,200 vector magnetograms obtained at Huairou Solar Observing Station. The analysis of strong fields gives an interesting result: both α and current helicity present a sign opposite to that of weak fields.

Gao, Zhang and Zhao (2009) make a comparison between photospheric current helicity and subsurface kinetic helicity in solar active regions. Some parameters are employed: average value of vertical component of current helicity density $< B_z \cdot (\bigtriangledown \times B)_z >$, average force-free field factor and mean subsurface kinetic helicity $< v \cdot (\bigtriangledown \times v) / \mid v \mid^2 >$. Although there is an opposite hemispheric preponderance between the signs of current helicity and that of kinetic helicity at the solar surface, the uncertain correlations between $< hc >$ and $< \alpha >$ do not support that the photospheric current helicity has a cause and effect relation with the kinetic helicity at 0-12 Mm beneath the solar surface.

Pevtsov (2000) found that approximately one-third of all active regions on the Sun exhibit transequatorial loops. He also found that the reconnected regions have approximately the same rotation rate and tend to appear on certain longitudes, similar to the complexes of activity. In most cases transequatorial interconnected regions have the same handedness of their magnetic field. Chen, Bao and Zhang (2007) pointed out that about 50% of the active region pairs carry the same current helicity sign and about 50% of them have the opposite. Out of the 19 cases when the footpoints of the TLs have the same current helicity sign, it is found that the sign of of the TLs is the same as the sign of the current helicity in the footpoints in 12 cases, whereas it is of opposite sign in 4 cases, and in 3 cases the TLs were found to be potential.

3.2. *Evolution of magnetic (current) helicity with solar cycle*

Zhang and Bao (1998) analyzed the latitudinal distribution of the photospheric current helicity for active regions, including most of the large ones observed in the period of 1988-1997. It is found that the negative maximum values of current helicity occurred in 1989 and 1991, while those positive around 1992. Bao, Ai and Zhang (2000) computed the sign of different current helicity parameters (i.e. α_{best} and Hc) for active regions during the rise of solar cycle 23. The results indicate the 59% the active regions in the northern hemisphere have negative α_{best} and 65% in the southern hemisphere have positive. However, the helicity parameter H_c shows a weaker opposite hemisphereic preference in the new solar cycle. Hagino and Sakurai (2005) found that although the hemispheric sign rule of helicity generally holds, it is found significant time variations in the yearly values of helicity during the observation period. The hemispheric sign rule of helicity is satisfied in the solar maximum phase, but may not be so in the solar minimum phase.

Pevtsov, Dun and Zhang (2006) used 270 pairs of vector magnetograms observed by Haleakala Stokes Polarimeter (HSP) and Solar Magnetic Field Telescope (SMFT) of Huairou Solar Observing Station from 1997 to 2000 to compare current helicity derived by these two instruments. They found that in 80% of cases SMFT and HSP data result in the same sign of α, and the Pearson linear correlation coefficient between two data sets is $r_p = 0.64$. The similar comparison with the data by magnetograms by the Solar Flare Telescope (SFT) at Mitaka (MTK) of the National Astronomical Observatory of Japan has been taken by Xu *et al.* (2007). Pevtsov et al, (2008) concluded that because the hemispheric helicity rule is a weak tendency with significant scatter, an annual subset of active regions is likely to produce statistically unreliable results.

3.3. *Helicity and solar dynamo*

Seehafer (1994) indicated that for the build-up of mean-field (dc) magnetic energy the existence of both mean-field and turbulent current helicities and their relation is of particular importance. The role played by current helicity allows a comparison of results obtained by using the two-scale approach of mean-field theory with concepts which assume the conservation of magnetic helicity (as the Taylor relaxation concept) or consider inverse cascades of magnetic helicity as important for inverse energy cascades, respectively. Longcope, Fisher and Pevtsov (1998) discussed the flux-tube twist resulting from helical turbulence. This process, designated the Sigma-effect, operates on isolated magnetic flux tubes subjected to buffeting by turbulence with a nonvanishing kinetic helicity $< \mathbf{u} \cdot \bigtriangledown \times \mathbf{u} >$. The Sigma-effect leads to twist of the same sense inferred from observation and opposite to that predicted by the alpha-effect. The model also predicts that twist is uncorrelated with the tilt angle of the active region. Rüdiger, Pipin and Belvedère (2001) analyzed the kinetic and current helicities for a given field of magnetic fluctuations the dynamo-α, assuming that turbulence is subject to magnetic buoyancy and global rotation. Berger and Ruzmaikin (2000) estimated the α effect contribution; this may well be as high or higher than the differential rotation contribution. Brandenburg, Dobler and Subramanian (2002) shown that artificially induced losses of small scale field of opposite sign of magnetic helicity as the large scale field can, at least in principle, accelerate the production of large scale (poloidal) field. Based on mean field models with an outer potential field boundary condition in spherical geometry, they verify that the sign of the magnetic helicity flux from the large scale field agrees with the sign of alpha.

Kuzanyan *et al.* (2003) summarized studies of helical properties of solar magnetic fields such as current helicity and twist of magnetic fields in solar active regions, that are observational tracers of the alpha-effect in the solar convective zone (SCZ). They found evidence that the alpha-effect changes its value and sign near the bottom of the SCZ, and this is in accord with the theoretical studies and numerical simulations. Kleeorin *et al.* (2003) studied a simple model for the solar dynamo in the framework of the Parker migratory dynamo, with a nonlinear dynamo saturation mechanism based on magnetic helicity conservation arguments. They compared the nonlinear current helicity evolution in this model with data for the current helicity evolution obtained during 10 years of observations at the Huairou Solar Station of China. They concluded that, in spite of the very preliminary state of the observations and the crude nature of the model, the idea of using observational data to constrain their ideas concerning magnetic field generation in the framework of the solar dynamo appears promising. Zhang *et al.* (2006) attempted to connect observational data on current helicity in solar active regions with solar dynamo models. The predictions of this model about the radial distribution of solar current helicity appear to be in remarkable agreement with the available observational data; in particular the relative volume occupied by the current helicity of ‘wrong’ sign grows significantly with the depth.

Choudhuri, Chatterjee and Nandy (2004) calculated helicities of solar active regions based on the idea that poloidal flux lines get wrapped around a toroidal flux tube rising through the convection zone, thereby giving rise to the helicity. They found that during a short interval at the beginning of a cycle, helicities tend to be opposite of the preferred hemispheric trends. Xu *et al.* (2009) studied the the behavior of the electric-current and magnetic helicities in the course of the solar-activity cycle in the framework of Parker’s very simple model for the solar dynamo. They proposed a possibility of the reverse of hemispheric helicity rule in the end of solar cycle.

Yeates, Mackay, and van Ballegooijen (2008) simulated the evolution of magnetic fields in the solar atmosphere in response to flux emergence and shearing by photospheric motions. In their global-scale simulation over many solar rotations, the latitudinal distribution of current helicity develops a clear statistical pattern, matching the observed hemispheric sign at active latitudes. In agreement with observations, there is significant scatter and intermixing of both signs of helicity, where they found local values of current helicity density that are much higher than those predicted by linear force-free extrapolations.

Kuzanyan, Pipin and Zhang (2007) shown that the cross-helicity alternates in sign with the solar cycle (so it is zero in the long time average), and it changes from negative to positive following the toroidal field. They demonstrated how it is possible to tune such models with respect to account of different effects to reproduce particular features of the observable solar magnetic fields and its helical properties.

Jiang, Choudhuri and Wang (2007) presented a possibility on the origin of TLs linking with the Babcock Leighton dynamo process based on the model of Chatterjee, Nandy, and Choudhuri (2004). They proposed that TLs are visible signatures of poloidal field lines across the equator. Moreover, Yokoyama and Masuda (2009) analyzed a TLS observed simultaneously with Yohkoh/SXT and a coronagraph (SOHO/LASCO-C1). SOHO/LASCO-C1 observed loop expansion and eruption at the west solar limb. They proposed a formation mechanism of the TLS that forms between two independent active regions.

4. Discussions

After above discussions, there are still some basic questions on the study of magnetic (current) helicity:

1) The inversion accuracy of Stokes parameters for the measured photospheric vector magnetic field and the resolution of 180°-ambiguity of transverse component of vector magnetic field are still basic questions. From the directorial measurements of magnetic and current helicities taken by the photospheric (vector) magnetograms, one can get the quantities of the transfer rate of magnetic helicity, while one can not get the basic topology of magnetic field in the high solar atmosphere. The measurements of solar vector magnetograms provide a chance to analyze the distribution of partial current helicity density (h_{cz} in eq. (1.9)) of solar active regions only, but it is not the complete helicity density (h_c) in the solar surface.

2) The magnetic helicity in the solar atmosphere is an important quantity in the study of solar active cycles and the relationship with solar dynamo. Even if amount of samples of photospheric vector magnetograms have been observed at different solar observatories in the last more than 20 years and these data have been used to inferred current helicity density of solar active regions, one still finds some slight different helicity results from the different observing sets. Moreover, one also can not get all of vector magnetic fields of solar active regions, due to the absence of the complete observations of vector magnetic fields of the Sun and the evolution with solar cycles.

3) The solar magnetic fields are normally measured in the photosphere, while it is far from the formation layers of the solar dynamo and the eruption of flare-CMEs. The study on the relationship between the magnetic helicity inferred from the observational magnetic field and generation of magnetic field with solar dynamo or flare-CMEs are still basic questions.

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