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Helicity of solar active regions

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Abstract. Helicity is an important quantity to present the basic topological configuration of magnetic field in the solar atmosphere, which is transferred from the solar subatmosphere into the interplanetary space. In this paper, we present the observational magnetic helicity in solar active regions and corresponding questions.

Keywords : Sun: activity – Sun: magnetic topology

1. Importance and definition of magnetic helicity

Helicities are topologically a measure of the structural complexity of the corresponding fields (Woltjer 1958a). 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 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

$$H_m = \int_V h_m d^3x = \int_V \mathbf{A} \cdot \mathbf{B} d^3x, \quad (1)$$

where the vector potential **A** can not be observed immediately. It is conserved in a close volume when small resistivity is present. 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 to each other. As the helicity contains both, the total helicity can be written in the form

$$H_m = T\Phi^2 + 2L\Phi_1\Phi_2, \quad (2)$$

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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 & Field 1984)

$$\frac{dH_m}{dt} = -2 \oint_S [(\mathbf{V}_t \cdot \mathbf{A}_p)B_n - (\mathbf{A}_p \cdot \mathbf{B}_t)V_n]ds, \tag{3}$$

where the magnetic field **B** and velocity field **V** are observable in the solar atmosphere. The subscripts have their normal meanings. The first term in eq. (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.

As demonstrated by Démoulin & Berger (2003), 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. Moreover, Pariat, Démoulin & Berger (2005) provided the analysis on the possibility of the flux density coming from shearing and advection motions if plasma motions are known.

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

The current helicity is defined in the form

$$H_c = \int_V h_c d^3x = \int_V \mathbf{B} \cdot \nabla \times \mathbf{B} d^3x. \tag{4}$$

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

$$H_c = 2I_1 I_2. \tag{5}$$

The similar relationship on the linkage and twist of current helicity relative to eq. (2) can be inferred also

$$H_c = TI^2 + 2LI_1 I_2, \tag{6}$$

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, it is found (Abramenko, Wang & Yurchishin 1996; Bao & Zhang 1998) that only a part (vertical component) of current helicity density in the photosphere

$h_{cz} = \mathbf{B} \cdot (\nabla \times \mathbf{B})_z$ can be inferred from the photospheric vector magnetograms, due to the observational limitation. A similar limitation can be found also in the analysis of the force free factor $\alpha = \frac{\mu J_z}{B_z}$ (Pevtsov Canfield & Metcalf 1994), 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. According to mean field dynamo theory, the electromotive force $\mathbf{E}$ averaged over convective eddies has a component parallel to the magnetic field, $\mathbf{E} = \alpha < \mathbf{B} > +...$, where the pseudoscalar α is related to kinetic and electric current helicities (cf. Brandenburg & Subramanian 2005; Radler & Rheinhardt 2007).

The alpha effect is reevaluated in terms of ensemble-averaged properties of the magnetic fluctuation spectrum. It is proposed 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. Pouquet, Frisch & Leorat (1976) indicated that study of helicity is important in its kinetic and magnetic form for generation of large-scale magnetic fields by turbulence. Keinigs (1983) and Keinigs & Gerwin (1986) presented that in a magnetized plasma the alpha effect represents a turbulently generated electromotive force directed along the mean magnetic field. Kleeorin & 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. According to Kleeorin & Rogachevskii (1999) and Brandenburg & Subramanian (2005), the change of magnetic (current) helicity can been inferred in the form

$$\frac{\partial h_c}{\partial t} \approx -\frac{2}{l^2}[< \mathbf{B} > \cdot \nabla \times < \mathbf{B} > -(\alpha_k + h_c) < \mathbf{B} >^2], \tag{7}$$

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. 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, Wang & Yurchisin 1996; Bao & Zhang 1998).

Cross helicity is another quantity to measure the complicity between the magnetic and velocity field, which is estimated by Woltjer (1958b) and Moffatt (1969),

$$H_{cross} = \int_V \mathbf{B} \cdot \mathbf{V} d^3x. \tag{8}$$

The integral expresses the fact that the parallel components of $\mathbf{B}$ and $\mathbf{V}$ do not interact, while the effect of cross helicity in the Sun is a basic question and needs to be investigated also.

2. The transfer of magnetic helicity and solar eruptive phenomena

2.1 Helicity transfer in solar active regions

Helicity in solar active regions has been noticed recently (cf. Seehafer, 1990; Pevtsov, Canfield & Metcalf 1994; Wang 1996; López Fuentes et al., 2000). Chae (2001) showed how to observationally determine the rate of magnetic helicity transport via photospheric footpoint shuffling from a time series of line-of-sight magnetograms. From a series of photospheric-vector magnetograms and corresponding soft X-ray images, it is found (Zhang 2001; Zhang 2006a) 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. Kusano et al. (2002) indicated that the photospheric shear motion and the flux emergence process have equally contributed to the helicity injection and have supplied magnetic helicity of opposite signs into the active regions. Liu & 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 in Fig. 1. 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. Jeorg & Chae (2007) indicated that the evolution of injective quantity of magnetic helicity depends on the developing phase of active regions.

In the analysis of fine helical features in the active regions, it is found that the patches of positive and negative helicities were intermixed showing a mesh pattern in the sunspot umbra and a thread pattern in the penumbra (Su et al. 2009). The fine distributions of α_z and h_c 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. It is found (Zhang 2010) that the individual magnetic fibrils are dominated by the current density component caused by the magnetic inhomogeneity, while the large-scale magnetic region is generally dominated by the electric current component associated with the magnetic twist. The current mainly flows around the magnetic flux fibrils in the active regions. Venkatakrishnan & Tiwari (2009) pointed out that the existence of a global twist for a sunspot even in the absence of a net current is consistent with a fibril-bundle structure of the sunspot magnetic fields. Moreover, Tian & Alexander (2009) indicated from this statistical study that the leading (compact) polarity injects several times more helicity flux than the following (fragmented) one (typically 3-10 times).

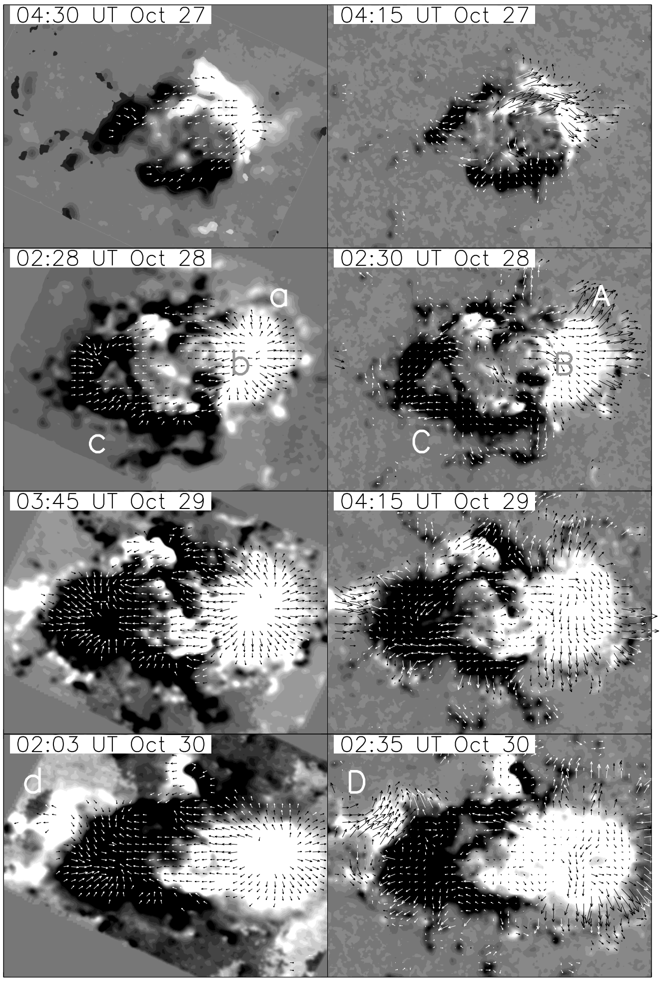

Figure 1. Vector magnetograms of HSOS (left) and computed horizontal velocity vectors being superposed on MDI longitudinal magnetograms (right). The maximum arrow length measure transverse magnetic field of 1200 G and velocity of 0.8 km s^{-1}, separately. The field of view is $225'' \times 168''$. (Liu & Zhang 2006)

2.2 Helicity and solar flare-CMEs

It is normally believed that the complex helical configuration of magnetic field relates to flare-CMEs (cf. Bao et al. 1999; Deng et al. 2001; Liu & Zhang 2002; Zhang 2002; Wand, Zhou & Zhang, 2004). Rust & Kumar (1996) found that many of soft X-ray brightenings were sigmoid (S-shaped). Nindos & Zhang (2002) and Nindos, Zhang & Zhang (2003) investigated whether the bulk of magnetic helicity carried away from

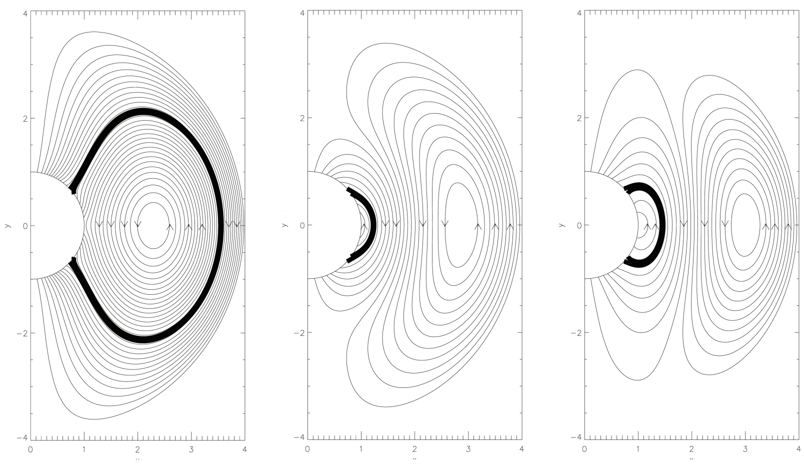

Figure 2. Three current-sheet fields that have the same ratio and same total helicity but different magnetic energies. (Zhang & Low 2003)

the Sun by CMEs comes from helicity injected to the corona by such motions or by emerging magnetic flux. Zhang, Liu & 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 with the helicity injection in order of $-5.2\times10^{43}Mx^{2}$ in the whole AR. A similar analysis was taken by Kazachenko et al. (2009). LaBonte, Georgoulis & 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. Most of the X-flare regions generated the helicity needed for a CME in a few days to a few hours.

Zhang & Low (2003) and Zhang, Flyer & Low (2006) have pointed out that the accumulation of magnetic helicity in the corona plays a significant role in storing magnetic energy in Fig. 2. The ejected helicity is provided by the twist in the sub-photospheric part of the magnetic flux tube forming the active regions (cf. Green et al. 2002). It is 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 (Green et al. 2007).

From the above discussions, it is found that the magnetic helicity is important to reflect the handedness of active regions and relevant eruptive processes, while it does not bring more information on the morphological configuration of magnetic field in detail. The synthetic analysis with other parameters for the solar active processes is also necessary.

3. Relationship between magnetic helicity and solar cycles

3.1 Hemispheric rule of magnetic (current) helicity

Hale et al. (1919) firstly discovered 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 & Wang (1987) statistically analyzed the distribution of spiral patterns in the southern and northern hemispheres and believed 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. Pevtsov, Canfield & 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. It is roughly consistent with the statistical results on the handedness of spiral sunspots by Ding, Hong & Wang (1987). The soft X-ray loops in the solar atmosphere also provide the signatures of the handedness of magnetic fields (Rust & Kumar 1996). Moreover, Abramenko, Wang & Yurchishin (1996) and Bao & Zhang (1989) for active regions using a photospheric vector magnetograms from the Solar Magnetic Field Telescope (SMFT) of the Huairou Solar Observing Station (HSOS). It is found that more than 80% of the active regions in the northern (southern) hemisphere show negative (positive) sign of current helicity. Hagino & Sakurai (2004) studied the current helicity of solar active regions inferred from the weak field in the vector magnetograms of active regions obtained with the Solar Flare Telescope, located at the Mitaka campus of the National Astronomical Observatory and found the similar hemispheric trends of helicity also. The confirmation on the hemispheric sign rule of large-scale helicity has been done by Pevtsov & Latushko (2000) and Wang & Zhang (2010) from full disk magnetograms observed by MDI/SOHO. Moreover, Zhang (2006b) reported that the statistical analysis of strong fields gives a result: both α and current helicity present a sign opposite to that of weak fields in the active regions. The distinguishability between the weak and strong field relates to the basic question on the analysis of vector magnetograms in the active regions.

As following the injection of magnetic helicity from active regions, LaBonte, Georgoulis & Rust (2007) proposed that the weak hemispherical preference of helicity injection, positive in the south and negative in the north, is caused by the solar differential rotation. 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 Yang, Zhang & 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 ($| H | \propto \Phi^{1.85}$) in the 58 selected newly emerged simple

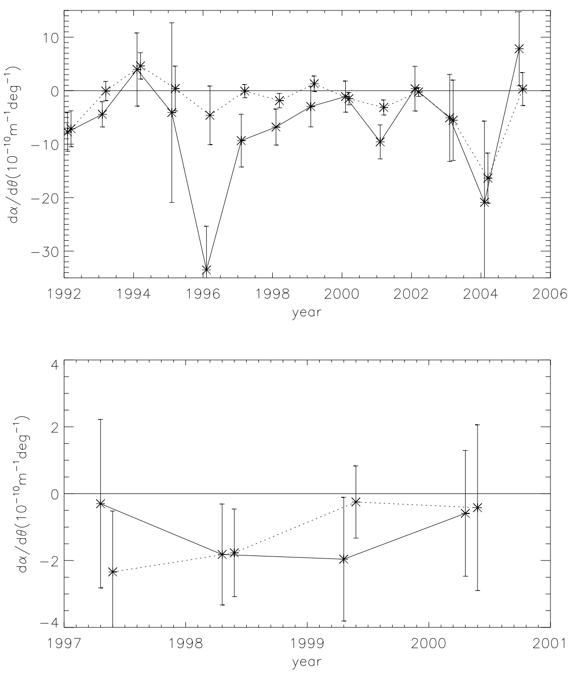

Figure 3. Comparison on the statistical variation of mean α (helicity parameter) of same solar active regions with latitude from different data sets between Huairou Solar Observing Station of National Astronomical Observatories of China (solid line) and National Astronomical observatory of Japan (dash line) (top), and also that between Mees Solar Observatory (solid line) and National Astronomical observatory of Japan (dash line) (bottom). (It is the same as the results by Xu et al. 2007)

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.

A statistical relationship between photospheric current helicity and subsurface kinetic helicity in solar active regions has been analyzed by Gao, Zhang & Zhao (2009). The parameters are employed: average value of vertical component of current helicity density, average force-free field factor and mean subsurface kinetic helicity. It is found that 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 them 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. It is inconsistent with the theoretical prediction by Keinigs (1983) for the relationship between both helicities.

For estimating the accuracy on the measurements of current helicity in the solar active regions, Pevtsov, Dun & 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 1997–2000 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 $r_p = 0.64$. A comparison also with a series of magnetograms observed by the Solar Flare Telescope (SFT) at Mitaka (MTK) of the National Astronomical Observatory of Japan has been taken by Xu et al. (2007) in Fig. 3. It is consistent with the results of Hagino & Sakurai (2005) on the analysis of hemispheric magnetic helicity rule with solar cycles. Moreover, 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.

3.2 Evolution of magnetic (current) helicity with solar cycle

By comparing the relationship between the helicity and solar dynamo models by Seehafer (1994), Rüdiger, Pipin & Belvedère (2001) and Brandenburg, Dobler & Subramanian (2002), Longcope, Fisher & 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 non-vanishing kinetic helicity. The Sigma-effect leads to twist of the same sense inferred from observation and opposite to that predicted by the alpha-effect.

Based on the observational current helicity of solar active regions with the possible formation depth in the solar convective zone (SCZ) (Kuzanyan, Pipin & Zhang, 2003), Kleeorin et al. (2003) and 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. Yeates, Mackay & van Ballegooijen (2008) simulated the evolution of magnetic fields in the solar atmosphere in response to flux emergence and shearing by photospheric motions. In agreement with observations, there is significant scatter and intermixing of both signs of helicity, where they indicated local values of current helicity density that are much higher than those predicted by linear force-free extrapolations.

The distribution and evolution of magnetic helicity of solar active regions in the solar atmosphere are more interesting for understanding the generation of magnetic field inside of the Sun. Berger & Ruzmaikin (2000) indicated that rotation of open

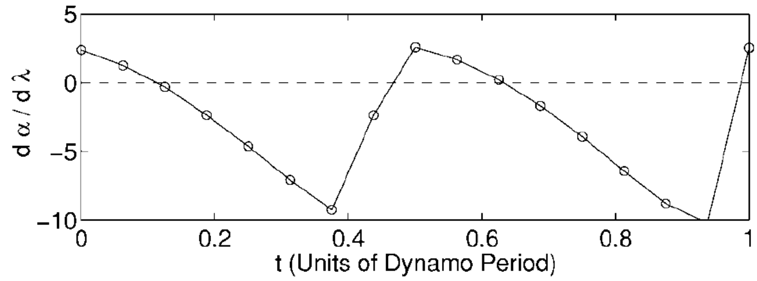

Figure 4. $-d\alpha/d\lambda$ as a function of time covering the equivalent of two sunspot cycles. To find out the values of time that correspond to maxima or minima. (Choudhuri, Chatterjee & Nandy 2004)

fields creates the Parker spiral which carries outward $10^{47} Mx^2$ of magnetic helicity (in each hemisphere) during a solar cycle. Zhang & 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 & Zhang (2000) computed the sign of different current helicity parameters (i.e. α_{best} and h_c) for active regions during the rise of solar cycle 23. The results indicate that 59% of 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 & 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.

Choudhuri, Chatterjee & 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 in Fig. 4. Xu et al. (2009) studied 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 the solar cycle. These are basically consistent with observational tendency by Bao, Ai & Zhang (2000), Hagino & Sakurai (2005) and Xu et al. (2007).

The statistical imbalance of magnetic helicity of solar active regions in both hemispheres with solar cycles was discovered by Zhang et al. (2010a) recently, who analyzed a series of vector magnetograms of solar active regions observed at Huairou Solar Observing Station in China for more than 20 years is shown in Fig. 5. They found the following observational evidence: magnetic (electric current) helicity and twist patterns are, in general, anti-symmetric with respect to the solar equator. The helicity pattern is more complicated than Hales polarity law for sunspots. Areas of the "wrong" sign have been found at the ends of the butterfly wings as well as at their very beginning. The maximum value of helicity, at the surface at least, seems to occur near the edges of the butterfly diagram of sunspots. It is consistent basically with the results by Tiwari, Venkatakrishnan & Sankarasubramanian (2009) based on the analysis of 43 sunspots in a period of solar cycle. The handedness of large scale soft X-ray loops near solar active regions with solar cycle was analyzed by Zhang et al. (2010b). By comparing with the reversal models of hemispheric helicity distribution proposed by Choudhuri, Chatterjee & Nandy (2004) and Xu et al. (2009), the new possibilities on the large-scale non-antisymmetric components of magnetic helicity of solar active regions in both hemispheres with solar cycles need to be investigated.

The diagnosis on the transequatorial connection of magnetic field from active regions in both hemispheric atmospheres is useful for understanding the evolution of large-scale magnetic helicity of the Sun. Pevtsov (2000) found that approximately one-third of all active regions on the Sun exhibit transequatorial loops (TLs), and 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 & 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.

Jiang, Choudhuri & Wang (2007) presented a possibility on the origin of TLs linking with the Babcock Leighton dynamo process based on the model of Chatterjee, Nandy & Choudhuri (2004). They proposed that TLs are visible signatures of poloidal field lines across the equator. Moreover, Yokoyama & Masuda (2009) analyzed 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. Yokoyama & Masuda (2010) also found that some TLs were originating with large-scale magnetic fields of the coronal-hole boundary through magnetic reconnection between the active region and a coronal hole.

Moreover, Kuzanyan, Pipin & Zhang (2007) showed 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. By means of a quasilinear theory and by numerical simulations, Rüdiger, Kitchatinov & Brandenburg (2011) found the cross helicity and the mean vertical magnetic field to be anti-correlated and predicted that the cross helicity at the solar surface will exceed the value of 1 gauss km/s. Zhao, Wang & Zhang (2011) used line-of-sight magnetograms and Dopplergrams from SOHO/MDI to determine the distribution of cross helicity in

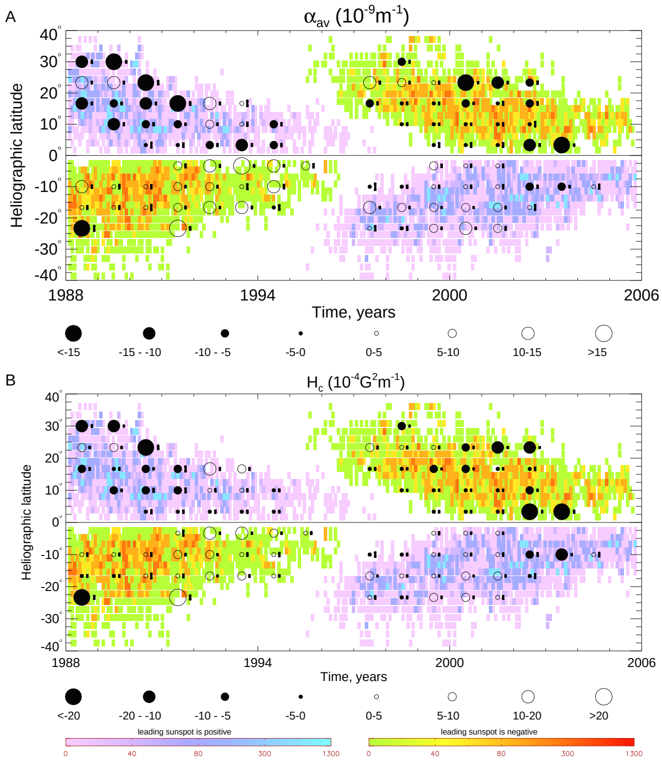

Figure 5. Top: the distribution of the averaged twist $\alpha_{\rm ff}$; and bottom: electric current helicity H_{Cz} of solar active regions in the 22^{nd} and 23^{rd} solar cycles. Superimposed, the underlying coloured "butterfly diagram" shows how sunspot density varies with latitude over the solar cycle. Vertical axis gives the latitude and the horizontal gives the time in years. The circle sizes give the magnitude of the displayed quantity. The bars to the right of the circles show the level of error bars computed as 95% confidence intervals, scaled to the same units as the circles. 72 out of 88 groups for current helicity (82%) as well as 67 out of 88 groups for twist (74%) have the error bars lower than the signal level. (Zhang et al. 2010a)

the solar surface and found that the large-scale and weak magnetic field (less than 50 G) is correlated with the velocity statistically, even if it is a preliminary analysis on the cross helicity in the solar surface.

4. Discussions

The study of helicity in the solar active regions is an interesting topic, which relates to the measurements and analysis of solar activities basically.

It should be noticed that 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 from the photospheric (vector) magnetograms, one can get the quantities of the transfer rate of magnetic helicity, while one cannot 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}) of solar active regions in the solar surface, but it is not the complete helicity density (h_c).

A systematic analysis of magnetic helicity in the solar atmosphere is an important chance to know the formation of solar active cycles, and the relationship with possible 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 infer the current helicity 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.

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. One still cannot know more information on the generation of the magnetic field inside of the Sun, while the twisted magnetic fields in the solar surface have been analyzed in the form of helicity to infer their possible generation. Even if one knows that the formation of flare-CMEs relates to the complex configuration of magnetic fields in the solar surface, while the study on topology of magnetic fields in the high solar atmosphere some basic questions still remain.

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