HELICITY THINKSHOP ON SOLAR PHYSICS

ABSTRACT BOOK

October 27–31, 2013
Beijing, China

National Astronomical Observatories
Chinese Academy of Sciences

HELICITY THINKSHOP ON SOLAR PHYSICS

OCTOBER 27–31, 2013, BEIJING, CHINA

Topics

- Observational evidences of helicity in the Sun and other astrophysical bodies
- Role of helicity in the dynamo theory and simulations
- The origin of helicity in the Sun, and the relationship with eruptions of solar flares and CMEs; helicity in the solar wind
- Future directions of helicity studies

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Abstracts

NEW FORMULAE FOR RELATIVE MAGNETIC HELICITY

Jean-Jacques Aly
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Abstract
We consider an arbitrary magnetic field $\boldsymbol{B}$ occupying some domain D and having a simple topology, and give new expressions of its relative helicity in terms of the normal component B_n on the boundary of D and the magnetic mapping associating together the two footpoints of any field line.

SELF-ASSEMBLY OF SHALLOW MAGNETIC SPOTS THROUGH STRONGLY STRATIFIED TURBULENCE

Axel Brandenburg†, Nathan Kleeorin, Igor Rogachevskii
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Abstract
Recent studies have demonstrated that in fully developed turbulence, the effective magnetic pressure of a large-scale field (non-turbulent plus turbulent contributions) can become negative. In the presence of strongly stratified turbulence, this was shown to lead to a large-scale instability that produces spontaneous magnetic flux concentrations. Furthermore, using a horizontal magnetic field, elongated flux concentrations with a strength of a few per cent of the equipartition value were found. Here we show that a uniform vertical magnetic field leads to circular magnetic spots of equipartition field strengths. This could represent a minimalistic model of sunspot formation and highlights the importance of two critical ingredients: turbulence and strong stratification. Radiation, ionization, and supergranulation may be important for realistic simulations, but are not critical at the level of a minimalistic model of magnetic spot formation.

SCALE-DEPENDENCE OF MAGNETIC HELICITY IN THE SOLAR WIND

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Abstract
We determine the magnetic helicity, along with the magnetic energy, at high latitudes using data from the Ulysses mission. The data set spans the time period from 1993 to 1996. The basic assumption of the analysis is that the solar wind is homogeneous. Because the solar wind speed is high, we follow the approach first pioneered by Matthaeus et al. (1982, Phys. Rev. Lett. 48, 1256) by which, under the assumption of spatial homogeneity, one can use Fourier transforms of the magnetic field time series to construct one-dimensional spectra of the magnetic energy and magnetic helicity under the assumption that the Taylor frozen-in-flow hypothesis is valid. That is a well-satisfied assumption for the data used in this study. The magnetic helicity derives from the skew-symmetric terms of the three-dimensional magnetic correlation tensor, while the symmetric terms of the tensor are used to determine the magnetic energy spectrum. Our results show a sign change of magnetic helicity at wavenumber k $\sim$ 2 AU^{-1} (or frequency nu $\sim$ 2 μHz) at distances below 2.8 AU and at k $\sim$ 30 AU^{-1} (or nu $\sim$ 25 μHz) at larger distances. At small scales the magnetic helicity is positive at northern heliographic latitudes and negative at southern latitudes. The positive magnetic helicity at small scales is argued to be the result of turbulent diffusion reversing the sign relative to what is seen at small scales at the solar surface. Furthermore, the magnetic helicity declines toward solar minimum in 1996. The magnetic helicity flux integrated separately over one hemisphere amounts to about 10^{45} Mx^2/cycle at large scales and to a 3 times lower value at smaller scales.

MEASUREMENTS OF SOLAR MAGNETIC FIELD IN HSOS

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Abstract
In this presentation, we will summarize the progress in the measurements and study of solar magnetic field in Huairou Solar Observing Station (HSOS), National Astronomical Observatories, Chinese Academy of Sciences (NAOC). Some limitation of current-used methods and techniques in the magnetic measurement are discussed too.

OBSERVATION ON CURRENT HELICITY AND SUBSUFACE KINETIC HELICITY IN SOLAR ACTIVE REGIONS

Yu Gao
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Abstract
I will introduce some recent observations that show the further details of hemispheric helicity sign rule and the connection between photospheric current helicity and subsurface kinetic helicity. The former part is based on the vector magnetic field measurements over long term at Huairou Solar Observing Station and the latter part is based at both the vector magnetic field measurements and subsurface vector velocity field with the time–distance helioseismology method to the Doppler-shift Helioseismic and Magnetic Imager onboard the Solar Dynamics Observatory.

SELF-CONSISTENT CALCULATION OF MAGNETIC HELICITY IN THE SOLAR MAGNETIZED ATMOSPHERE: OUTCOME AND PERSPECTIVE

Manolis K. Georgoulis†, K. Tziotziou
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Abstract
Undertaking a major analytical and numerical effort we have recently developed a computationally inexpensive method to calculate the relative magnetic helicity and the non-potential (free) magnetic energy in parts of the solar corona bounded only by a known photospheric vector magnetogram. Calculation of both helicity and free energy is self-consistent, relies on the principle of minimum free magnetic energy, and requires neither photospheric flow velocities on, nor three-dimensional extrapolated magnetic fields above, the photospheric boundary. We applied the calculation to thousands of high-cadence SDO/HMI vector magnetograms and provided physical interpretations of both general evolution and the triggering of eruptive flares in active regions. From these results we have also proposed the "energy-helicity" diagram of solar active regions featuring a monotonic dependence between free magnetic energy and relative magnetic helicity and further establishing that most eruptive regions tend to have a dominant sense of magnetic helicity. Surprisingly, the energy-helicity diagram seems to hold in the quiet solar atmosphere, as well. We provide evidence that active regions with enhanced photospheric polarity inversion lines (PILs) enter eruptive territory when mutual helicity is locally transferred to self helicity, most likely by magnetic reconnection along the PIL. This, however, gives rise to a causal chain of events that invariably makes strongly-PILed active regions what they are: intensely eruptive. Concluding, we demonstrate that the future of our method is promising and we highlight the decisive role of magnetic helicity in credibly interpreting eruptive solar activity.

The above work is supported by an EU Seventh-Framework Marie Curie Programme under grant agreement No. PIRG07-GA-2010-268245.

SOLAR CYCLE VARIATION OF HELICITY CHARACTERISTICS

Juan Hao†, Mei Zhang
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Abstract
In this talk we present our study on solar cycle variation of helicity characteristics using a sample of all active regions observed by SP/Hinode up to June 2012. We first confirmed our previous finding that the usual hemispheric helicity sign rule is not followed in the descending phase of solar cycle 23 and is followed in the ascending phase of solar cycle 24, with a further finding that the later phase of solar cycle 24 shows an even stronger evidence to follow the usual hemispheric helicity sign rule. We also checked our previous finding that the strong and weak magnetic fields possess opposite helicity signs and found that this rule is not followed in the later phase of solar cycle 24. This means that this helicity character also possesses a solar cycle variation, in addition to the solar cycle variation of the usual hemispheric helicity sign rule, and there is a roughly 2-years time delay between these two.

BUTTERFLY DIAGRAM OF MAGNETIC HELICITY IN ACTIVE REGIONS

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Abstract
We have analyzed magnetic helicity of solar active regions using a huge magnetogram database obtained with the vector magnetograph (the Solar Flare Telescope) of the National Astronomical Observatory of Japan (NAOJ).

Previous studies suggested that the latitudinal distribution of magnetic helicity, the so-called hemispheric sign rule, holds over solar cycles. However, we found that the hemispheric sign rule of magnetic helicity is violated at some phase of solar cycle. Similar tendencies were found in theoretical dynamo simulations.

To confirm this variability in the hemispheric sign rule of helicity, we have derived the time-latitude distribution (butterfly diagram) of helicity by using long-term database. The diagram shows not only the usual hemispheric sign rule but also evidence of sporadic appearance of patches with wrong sign of helicity. The implication of this result is discussed in terms of the dynamo processes in the interior of the Sun.

SOLAR TILT ANGLE DATA IN LIGHT OF SOLAR HELICITY DATA

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Abstract
We present the latitude-time distribution of the averaged tilt angle of solar bipoles. For large bipoles, which are mainly bipolar sunspot groups, the spatially averaged tilt angle is positive in the Northern solar hemisphere and negative in the Southern, with modest variations during course of the solar cycle. These results develop findings of Kosovichev and Stenflo (2012) concerning Joy's law, and agree with the usual expectations of solar dynamo theory. Quite surprisingly, we find a pronounced deviation from these properties for smaller bipoles, which are mainly solar ephemeral regions. They possess tilt angles of approximately the same absolute value, but of opposite sign compared to that of the large bipoles. Of course, the tilt data for small bipoles are less well determined than those for large bipoles; however they remain robust under various modifications of the data processing.

ON THE HELICAL NEGATIVE TURBULENT VISCOSITY OF THE SOLAR PLASMA

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Abstract
The negative turbulent viscosity at certain conditions may play important role in the reconsruction of magnetic fields on the Sun. It turns out that helical motions in the rotating convection zone promotes to the origin of inversion energy cascade in three-dimensional turbulence which results in the effect of negative viscosity. On the turbulent parameters from two solar convection zone models our calculations have shown that favourable conditions for exciting the helical negative turbulent viscosity are created near bottom of the convection zone. The possible role of the helical negative turbulent viscosity in the formation of the magnetic force flux tubes is discussed.

OBSERVATIONAL EVIDENCE OF ANISOTROPY OF CURRENT HELICITY COMPONENTS

H. Xu, R. Stepanov, K. Kuzanyan†, D. Sokoloff, H. Zhang, Y. Gao
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Abstract
Current helicity is a pseudo-scalar quantity which comprises of a few parts involving second-order moments of magnetic field vector components and its derivatives. In ideal homogeneous turbulence averages of all these parts are equal. Using vector magnetographic data of solar active regions obtained at Huairou Solar Observing Station we compute all observationally available parts of current helicity individually.

We present the results of distribution of components of current helicity, its averages over magnetograms of solar active regions and long-term averages of these quantities with the solar cycle. We show that the parts which are available observationally demonstrate consistency with basic properties of current helicity, and, at the same time, possess strong anisotropy with respect to solar rotation and other sources of inhomogeneity.

Furthermore, detailed analysis of solar-cycle properties of distribution of these components of current helicity indicate presence of non-vanishing biases on the observations due to projection effects of the image plane with respect to the solar disk. We discuss further implementation of the findings on our observational knowledge of helicity in the Sun.

THE QUANTITATIVE ANALYSIS OF THE SPIRAL CHARALITY OF PENUMBRAL FILAMENT

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Abstract
Using the G-band data set taken by SOT/ HINODE, the screw pitch instability of the penumbral filament of active region 10930 were analyzed. The ratio of the screw pitch to the radius of the magnetic flux, i.g., h/R, were estimated, which decrease with the shrink of the penumbra filament. The value of h/R in the unwinding stage and that in the chirality changing stage are all agree with the screw pitch instability theory and the Lundquist solution of magnetic fields and currents in twisted magnetic flux tubes.

MAGNETIC HELICITY CONSERVATION AND ITS IMPACT ON THE SOLAR CYCLE

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Abstract
It is believed that magnetic helicity conservation is an important constraint on large-scale astrophysical dynamos. We discuss applications of the magnetic helicity conservation law for the mean-field dynamos. It is shown that properties of the magnetic helicity balance in the solar convection zone influence properties of the solar cycle, e.g., the strength of the polar magnetic field. We apply the mean-field solar dynamo model to study the reversals of the magnetic helicity sign for the dynamo operating in the bulk of the solar convection zone. We found that the reversal of the sign of the small-scale magnetic helicity follows the dynamo wave propagating inside the convection zone. Therefore, the spatial patterns of the magnetic helicity reversals reflect the processes which contribute to generation and evolution of the large-scale magnetic fields. We demonstrate the impact of fluctuations in the dynamo parameters and variability in dynamo cycle amplitude on the reversals of the magnetic helicity sign rule. The obtained results suggest that the magnetic helicity of the large-scale axisymmetric field can be treated as an additional observational tracer for the solar dynamo.

A SOLAR ERUPTION DRIVEN BY RAPID SUNSPOT ROTATION

GuiPing Ruan†, Yao Chen, Shuo Wang, HongQi Zhang, Gang Li, Ju Jing, Xing Li, HaiQing Xu, HaiMin Wang
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Abstract
We present the observation of a major solar eruption that is associated with fast sunspot rotation. The event includes a sigmoidal filament eruption, a coronal mass ejection, accompanied by a GOES X2.1 flare from active region AR11283. The filament and some overlying arcades were partially rooted in a sunspot. The sunspot rotated at $\sim 10^\circ$ per hour during a period of 6 hours prior to the eruption. Due to the rotation, significant amount of magnetic energy ($\sim 10^{31}$ erg) and Helicity ($\sim 10^{41}$ Mx^2) were transported into the corona. Based on HMI observation during this period, for an area along the polarity inversion line underneath the filament, we found an overall decrease of the mean photospheric horizontal field strength (B_h), although the flare triggered a rapid increase of such a field. Furthermore, using Non-Linear Force-Free extrapolation, we found evidence of gradual upward propagation of the current density before its sudden collapse due to the flare. Our study provides direct evidences that sunspot rotation plays a major role to twist, energize, and destabilize the coronal filament-flux rope system, leading to the eruption. In addition, we also calculate the helicity transported from the photosphere to the corona via the sunspot rotation (Berger et al., 1984; Pevtsov et al., 2003) and the local correlation tracking (LCT) method respectively (Chae, 2001). They are consistent in order.

HELICITY SHEDDING IN SIMULATED CMES

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Abstract

It has been suggested that coronal mass ejections remove the magnetic helicity of active regions from the Sun. Such removal is often regarded to be necessary due to the hemispheric sign preference of the helicity, which inhibits a simple annihilation by reconnection between volumes of opposite chirality. To check this hypothesis, we have monitored the relative magnetic helicity contained in the coronal volume of simulated flux rope CMEs. New expressions for the computation of the vector potential from the magnetic field in the simulation box allow us to determine the relative helicity efficiently and exactly. The simulations use modified, force-free Titov-Démoulinequilibria as the initial condition to model an active region. A parametric study comprising torus-unstable and kink-unstable equilibria reveals that the helicity shed by the erupting flux rope can vary in a wide range of roughly 1/3 to 2/3 of the initial helicity. Torus-unstable equilibria shed their helicity more efficiently than kink-unstable equilibria. We also address the question of helicity accumulation up to the stability limit by driving stable equilibria to an eruption through prescribed photospheric motions. The substantial amount of helicity remaining in the CME source region is related to the evolution of the currents in the course of the eruption. Since many active regions erupt only once in their lifetime, our finding suggests that a significant part of the helicity which is transported into the corona by emerging active regions is redistributed into the coronal field upon the dispersal of the active regions and is eventually transported back into the solar interior as the field submerges.

HIGHER HELICITY INVARIANTS

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Abstract
Current and magnetic helicities are the simplest topological invariants for magnetic lines. Topology suggests a sequence of higher topological invariants for magnetic lines. We discuss possibility to calculate these invariants from solar vector magnetograms.

THE EFFECT OF NON-RADIAL MAGNETIC FIELD ON MEASURING HELICITY TRANSFER RATE

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Abstract
Calculating magnetic helicity transfer rate through photospheric observations is an important tool to monitor the magnetic helicity accumulation in the corona. In most previous studies,when calculating magnetic helicity transfer rate, only line-of-sight magnetograms such as MDI/SOHO data are used, assuming that the magnetic field in active regions is radial. However, this hypothesis of being radial is not true. Here, we check the effect of this hypothesis by comparing the results using vector magnetograms taken by HMI/SDO with those using only line-of-sight magnetograms. We find that: 1) The effect of the non-radial magnetic field on the calculation of magnetic helicity transfer rate is strong when the active region is observed near the limb and is relatively small when the active region is close to the disk center; 2)If only considering the accumulation of magnetic helicity from the shearing term, the effect of non-radial magnetic field then becomes very small.

THE REASONS FOR THE DIFFERENCES OF CALCULATED HELICITY PARAMETERS WITH SMFT AND SFT DATA

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Abstract
In this study, we analyzed the effect of transverse magnetic field, longitudinal field and azimuthal angle on the correlation of h_c (α_{av}) between SMFT and SFT data sets. We found that: (1) there is a good correlation between the longitudinal field observed by these two instruments and so it has small influence on the correlation of h_c (α_{av}); (2) the influence of azimuthal angle and transverse field is significant. When the azimuthal angle is same, the correlation coefficient of h_c (α_{av}) increases from 0.74 (0.56) to 0.83 (0.72). If the transverse field is same, the correlation coefficient of h_c (α_{av}) is 0.86 (0.78). (3) The correlation of h_c is better than the correlation of α_{av} between these two instruments. The observing precision of transverse field and azimuthal angle is very important for helicity calculation.

MODELING THE RELATIVE MAGNETIC HELICITY AND ITS APPLICATIONS TO SOLAR ACTIVITY

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Abstract
Magnetic helicity is a key geometrical parameter to describe the structure and evolution of solar coronal magnetic fields. For a better understanding of solar magnetic field evolution it is appropriate to evaluate the magnetic helicity based on observations and to compare it with numerical simulation results. We have developed a method for calculating the relative magnetic helicity in a finite volume and also applied our method to the magnetic field above active region NOAA 8210 obtained by a photospheric-data-driven MHD model. We found that the amount of accumulated relative magnetic helicity coincides well with the relative helicity inflow through the boundaries in the ideal and non-ideal cases. The temporal evolution of relative magnetic helicity is consistent with that of magnetic energy. The maximum value of normalized helicity when a drastic energy release by magnetic reconnection is close to the corresponding value inferred from the formula that connects the magnetic flux and the accumulated magnetic helicity based on the observations of solar active regions.

ROLES OF HELICITY PROXIES IN PREDICTING SOLAR FLARES

Xiao Yang†, HongQi Zhang, GangHua Lin
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Abstract
Helicity is an important way to reflect the nonpotentiality of magnetic field. Magnetic non-potentiality in active regions relates closely to the violent solar activities such as flares and CMEs. We investigate the statistical relations between some of the helicity proxies and flare eruptions, and try to build up an effective flare prediction system based on routine observations of vector magnetic field in the solar photosphere.

FLOW INDUCTION DUE TO HELICITY EFFECT

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Abstract
Pseudoscalars (kinetic, magnetic, cross helicities) play important role in dynamics of turbulent transport phenomena. In addition to the magnetic induction treated in dynamos, some helicities are relevant to the momentum transports in hydrodynamic (HD) and magnetohydrodynamic (MHD) turbulence. The helicity effects in the Reynolds stress and the mean Lorentz force are examined with a special reference to the solar internal motions.

HELICITY FROM OBSERVATIONS

HongQi Zhang
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Abstract
The helicity is important to present the basic topological configuration of magnetic field in solar atmosphere. The study of observational helicities provides an important chance for the confirmation on the generation of magnetic fields in the subatmosphere and solar eruptive process in solar atmosphere also. I would like to discuss some properties of helicity inferred from observational vector magnetograms, such as the distribution of photospheric magnetic helcity in solar active regions and the relationship with solar cycles.

CYCLONES (TORNADOES) IN THE QUIET SUN

Jun Zhang
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Abstract
The question of what heats the solar corona remains one of the most important puzzles in solar physics and astrophysics. Here we report the first Solar Dynamics Observatory Atmospheric Imaging Assembly observations of Extreme UltraViolet (EUV) cyclones in the quiet Sun. These cyclones are rooted in the Rotating Network magnetic Fields (RNFs). Such cyclones can last several to more than ten hours, and, at the later phase, they are found to be associated with brightenings (microflares) and even EUV waves. Helioseismic and Magnetic Imager observations show an ubiquitous presence of the RNFs, and their rotation senses present a weak hemisphere preference. These observational findings demonstrate a process of buildup and release of magnetic energy which may make a substantial contribution to heating the corona.

SOLAR-CYCLE VARIATION OF KINEMATIC HELICITY

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Abstract
This study investigates the solar-cycle variation of kinematic helicity. Previous observations on current helicity have shown that hemispheric helicity sign rule is observed and shows solar-cycle variation. This is in contradiction with the sigma-effect model that predicts no solar-cycle variation of the hemispheric helicity sign rule. To save this model, here we check one fundamental assumption of this model, that is, there is no solar-cycle variation of kinetic helicity. We use flow maps either obtained through 3D MHD dynamo models or inverted using local helioseismology time-distance method. We show that both in the dynamo model and by helioseismology observation indeed no solar-cycle variation of kinematic helicity is present.

Participants Roster

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