Highlights of Astronomy, Vol. 13
International Astronomical Union, 2003
O. Engvold, ed.

Helicity and The Alpha-Effect: Dynamo Theory and Observations

Kirill Kuzanyan

IZMIRAN, Troitsk, Moscow Region 142190, Russia

Abstract. Spatial and temporal distributions of tracers of the alpha-effect in the solar convection zone, such as current helicity and twist factor averaged over solar active regions are available by vector magnetographic observations. We discuss the data obtained at Huairou Solar Observing Station of Chinese Academy of Sciences and confront them with predictions of dynamo theory. At the present time, though the observations are rough, we still have a statistically representative sampling to conclude that the observations do not contradict the theory.

The α-effect plays an important role in mean field dynamo theory as a measure of regeneration of the poloidal fields from toroidal ones and *vice versa*. Furthermore, the magnetic helicity being an integral of motion is crucial for dynamo models. It is challenging to probe these quantities in real astrophysical dynamos, though they have no direct observational counterparts. However, the quantities like current helicity $H_c = \langle b_z(\nabla\times\mathbf{b})_\mathbf{z}\rangle$ and twist $a_{\rm ff} = j_z/b_z$, where $\mathbf{j} = a_{\rm ff}\mathbf{B}$ can be deduced from vector magnetographic observations. Under certain conditions, the latter can be considered as observational tracers of the alpha-effect and magnetic helicity. The problem of calculation of these quantities requires extraction of information on both line-of-sight and transversal magnetic field components, and further, calculation of currents seriously suffers from limited observational accuracy. Nevertheless, consideration of a large number of observations may reveal regularities of spatial and temporal distribution of the averaged quantities useful for confronting the theory. The summarized observational data follow in Table 1.

We develop a one-dimensional Parker dynamo model in an inhomogeneous layer for generation of magnetic fields and evolution of helicity with nonlinear quenching of the α-effect in a form of two additives: one hydrodynamic part is explicitly quenched by magnetic field (e.g., Rogachevkii & Kleeorin 2000), and the other magnetic part depends on current helicity. Our model depends on a number of phenomenological parameters (see Kleeorin et al. 2003 for details). We can estimate their range *a-priori* but some of them (namely, the diffusion and non-advective helicity flux coefficients) must be adjusted by our model calculations in order to reproduce a cyclic dynamo with the profile of helicity similar to its observational counterpart, provided the sign of helicity changes from one hemisphere to another. Thus, we use observational constrains on outputs of our model, and so select the range of our phenomenological parameters.

Then we study evolution of current helicity with solar magnetic cycle. We adjust the phase of the solar cycle using calculated magnetic field energy versus an observational tracer of solar activity (group sunspot number). Thus, we confront our model calculations with observational data on helicity evolution.

https://doi.org/10.1017/S1539299600015173 Published online by Cambridge University Press

Table 1. Upper panel: Latitude Θ, with the averaging interval in brackets, the twist $\langle a_{\rm ff}\rangle$ in units of $10^{-8}\,{\rm m}^{-1}$, the current helicity $\langle H_c\rangle$ in units of $10^{-3}{\rm G}^2{\rm m}^{-1}$, and N is the number of active regions available. The errors correspond to the 95% confidence level. Lower panel: The same data binned by hemisphere and year of observation.

Θ	$\langle a_{\rm ff}\rangle$	$\langle H_c\rangle$	N
28 (24 - 32)	-0.4 ± 1.2	-1.6 ± 1.7	18
20 (16 - 24)	-0.9 ± 0.8	-0.9 ± 0.4	51
14 (12 - 16)	-1.7 ± 1.3	-0.6 ± 0.4	34
10 (8 - 12)	-2.2 ± 0.6	-0.4 ± 0.2	49
4 (0 - 8)	-1.9 ± 0.8	-0.6 ± 0.2	44
-4 (-8 -0)	0.3 ± 0.7	0.7 ± 0.5	31
-10 (-12 - -8)	1.2 ± 0.7	0.7 ± 0.4	59
-14 (-16 - -12)	0.9 ± 0.7	0.9 ± 0.7	46
-20 (-24 - -16)	1.0 ± 0.8	0.4 ± 0.2	68
-28 (-32 - -24)	1.6 ± 1.7	0.5 ± 0.9	14

T	$\langle a_{\rm ff}\rangle$	$\langle H_c\rangle$	N
	North		
1988-89	-1.1 ± 0.8	-1.0 ± 0.5	50
1990-91	-1.0 ± 0.7	-1.0 ± 0.5	61
1992-93	-2.1 ± 0.7	-0.7 ± 0.3	45
1994-95	-2.6 ± 0.9	-0.3 ± 0.1	34
1996-97	-1.2 ± 1.0	-0.2 ± 0.2	9
	South		
1988-89	1.0 ± 1.2	0.2 ± 0.3	38
1990-91	0.9 ± 0.7	0.8 ± 0.6	65
1992-93	1.2 ± 0.5	0.9 ± 0.3	77
1994-95	0.7 ± 0.9	0.1 ± 0.1	35
1996-97	0.3 ± 2.0	0.2 ± 0.3	8

Our observations cover one sunspot cycle. The results show, that the trends in evolution of observable current helicity can be seen in some general sense in our model calculations (Kleeorin et al. 2003, in particular their Fig 3).

Though our dynamo model is simple, we may, nevertheless, conclude, that the observations (noisy though they are) are sufficient to enable us to constrain phenomenological parameters of the model. At the same time, the evolution of current helicity calculated in our model is in accord with observations.

Acknowledgments. The author's thanks go to the IAU for travel grant which enabled him to attend the 25th IAU.

References

Kleeorin, N., Kuzanyan, K., Moss, D., Rogachevskii, I., Sokoloff, D., & Zhang, H. 2003 A&A, 409, 1097

Rogachevskii, I., & Kleeorin, N. 2000, Phys. Rev. E., 61, 5202