Distribution of Photospheric Current Helicity

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Abstract

In this paper, we analyze the current helicity parameter $\mathbf{B}_{\|} \cdot (\bigtriangledown \times \mathbf{B})_{\|}$ of active regions, which is inferred from vector magnetograms. It is found that most of the active regions in the northern hemisphere have negative helicity and those in the southern hemisphere have positive helicity. Only less than 20% of active regions have the sign of helicity opposite to that of the majority sign in the same hemisphere. These active regions with reversed signs of helicity normally occur at some specific heliographic longitudes over long time periods.

Key words: Sun: activity — Sun: magnetic fields — Sun: photosphere

1. Introduction

In the study of twisted magnetic fields in the solar atmosphere, vortex, magnetic and current helicity have played an important role. The helicity can normally be separated into two parts, one related to the parallel component in the direction of the line of sight to the observer and the other to the vertical one. For example, the current helicity can be written in the form

$$H_c = \mathbf{B}_{\|} \cdot (\bigtriangledown \times \mathbf{B})_{\|} + \mathbf{B}_{\perp} \cdot (\bigtriangledown \times \mathbf{B})_{\perp}. \tag{1}$$

The first term can be inferred from photospheric vector magnetograms (Abramenko, et al., 1996), while the second term is hard to compute because we have magnetic measurements only at a single height in the solar atmosphere.

2. Distribution of Current Helicity of Solar Active Regions

We compute the photospheric current helicity for 422 active regions, including most of the large ones observed in the time period of 1988-1997 at Huairou Solar Observing Station of Beijing Astronomical Observatory (Bao and Zhang, 1998; Zhang and Bao, 1998). This provides the basic information on the twist of the magnetic field emerging from the subatmosphere and also the relationship between the mean current helicity parameter $\mathbf{B}_{\|} \cdot (\bigtriangledown \times \mathbf{B})_{\|}$ of active regions and the solar activity cycle.

In Figure 1, we can see that most current helicities in sunspot groups in the northern hemisphere show negative sign, while those in the southern hemisphere show positive helicity, consistent with Seehafer's result (Seehafer, 1990). The distribution of current helicity in active regions also shows the Butterfly pattern through the solar cycle. This means that the positions of high electric current helicities are firstly in the middle latitudes at the beginning of a new solar cycle, then shift to high latitudes towards the equator with time, giving rise to the characteristic Butterfly pattern. We see that less than 20% of the active regions do not follow the general trend.

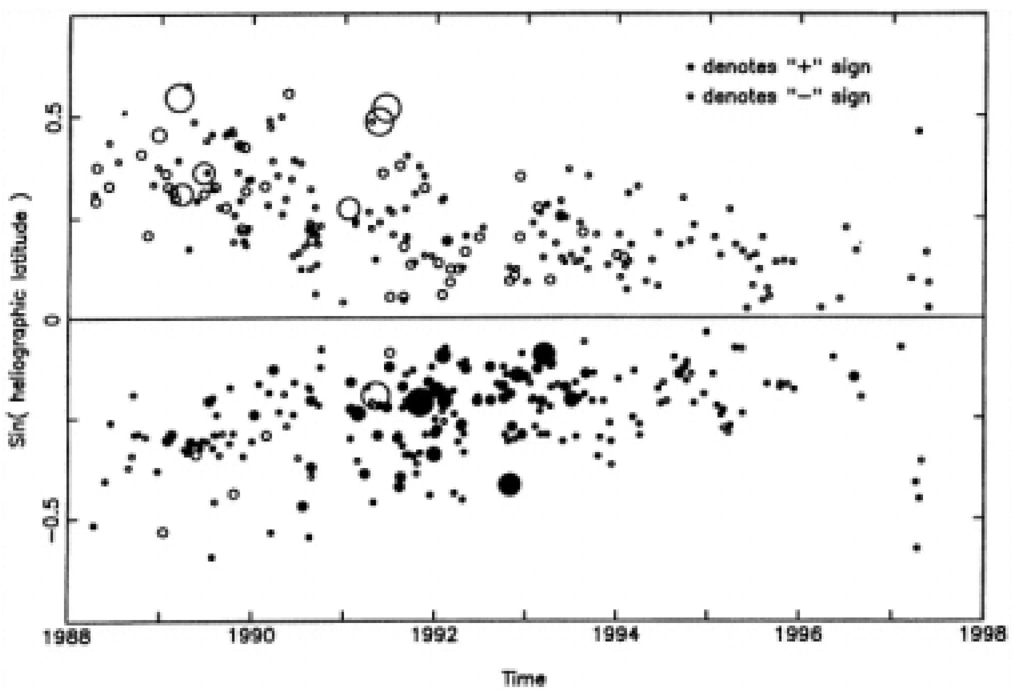

Fig. 1.. Butterfly diagram of the electric current helicity $\mathbf{B}_{\|} \cdot (\bigtriangledown \times \mathbf{B})_{\|}$ with time (year). The mean density of the current helicity of active regions is marked by the size of the circles for grades: 0, 1, 3, 5, 7 ($\times 10^{-3} G^2 m^{-1}$).

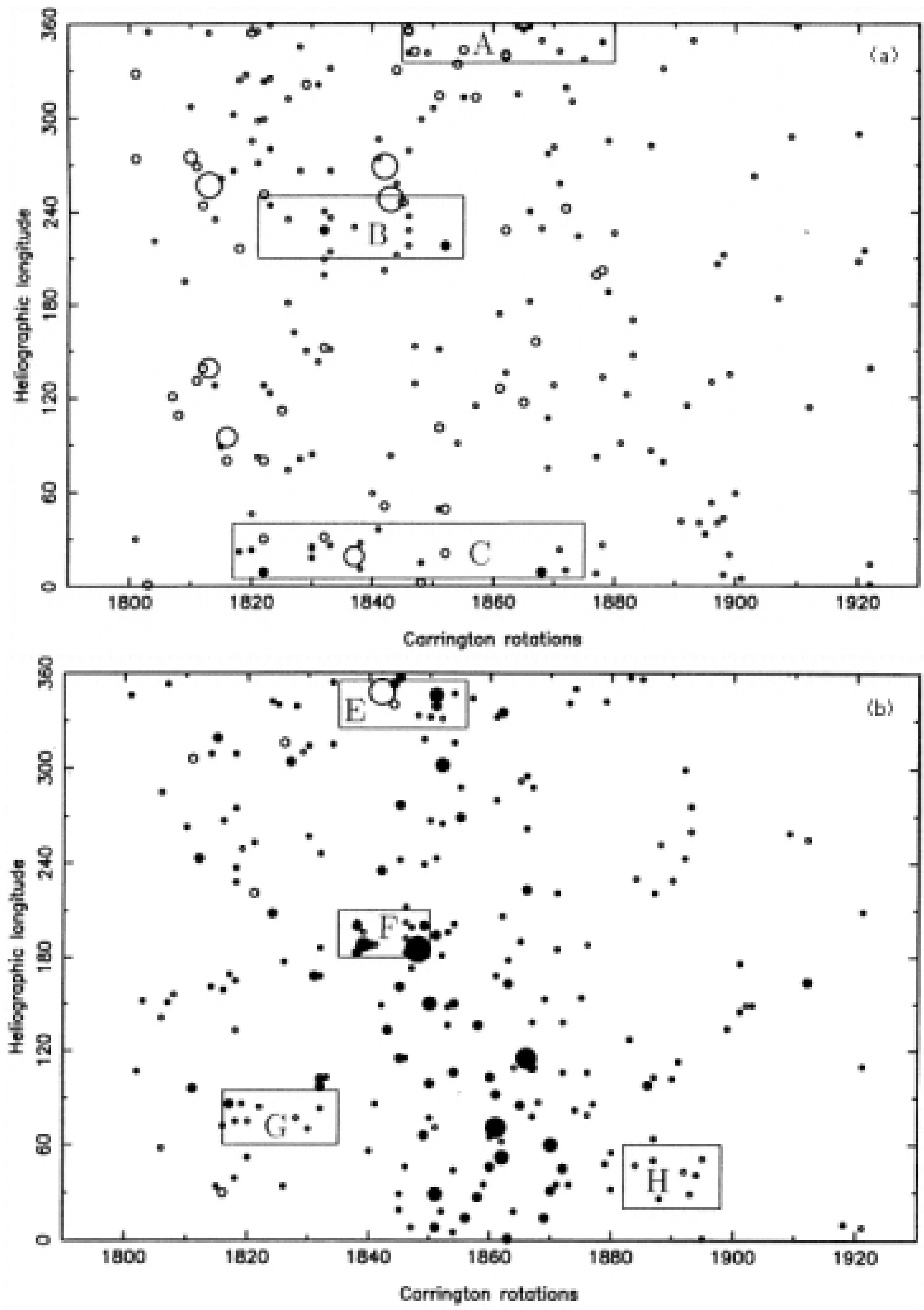

Fig. 2.. Distribution of the mean density of the current helicity parameter $\mathbf{B}_{\parallel} \cdot (\nabla \times \mathbf{B})_{\parallel}$ of active regions with Carrington rotations. The mean density of the current helicity of active regions is marked by the size of the circles for grades: 0, 1, 3, 5, 7 ($\times 10^{-3} G^2 m^{-1}$). The signs of current helicities are the same as in Figure 1. (a) The mean density of the current helicity in the northern hemisphere. (b) The mean density of the current helicity in the southern hemisphere.

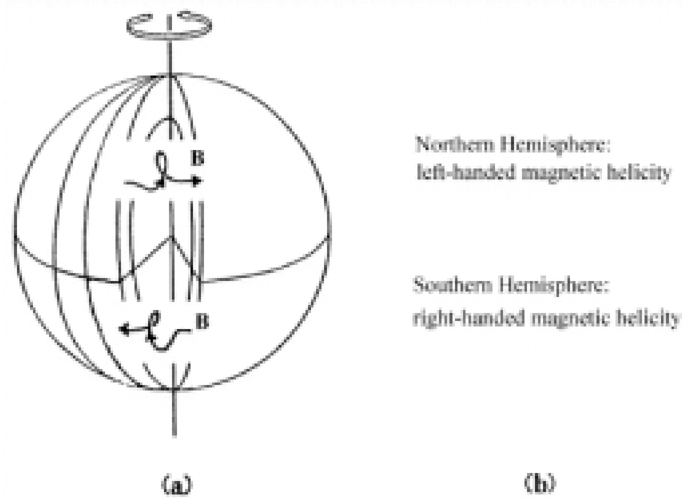

Fig. 3.. A possible schematic representation of helically twisted magnetic field lines in the convection zone.

Figure 2 shows the longitudinal distribution of the electric current helicity parameter $\mathbf{B}_{\parallel} \cdot (\bigtriangledown \times \mathbf{B})_{\parallel}$ of active regions in the both hemispheres with solar rotation cycles in about last decade. By carefully analyzing the distribution of the electric current helicity, we find that the current helicities of solar active regions tend to be uniformly distributed in solar longitude (even if their intensity is not uniform). However, the helicities with minority sign show a tendency to occur in some special longitudinal bands, such as A, B, C in the northern hemisphere and E, F, G, H in the southern hemisphere; these active regions are long-lived, e.g. about $20 - 40$ solar rotations (about $1.5 - 3$ years). It provides information on the generation of the reversal current helicity in the subatmosphere brought up by emerging magnetic flux.

From the above discussion on the normal distribution of the current helicity of active regions in the solar surface, we can infer the possible configuration of the twisted magnetic lines formed in the subatmosphere. A possible model of twisted normal magnetic field lines in active regions in both hemispheres is shown in Figure 3.

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