THE NEUTRAL LINES OF THE LARGE-SCALE MAGNETIC FIELD AND SUNSPOT CYCLE

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ABSTRACT

H-alpha magnetic charts describe real structures of the solar magnetic fields with their topological properties. There are a few morphological characteristics to describe this topology, among them are the length of the magnetic neutral lines, \( L(\phi, \theta) \). The total length of the neutral lines on the H-alpha chart, \( L = \sum_{\theta}^\alpha L(\phi, \theta) \), as a new index of solar activity was calculated for 1915-1999. It was shown that \( L(t) \) reaches maximum in a top of cycle and it has minimum in absence of sunspots. The value \( L(t) \) was increased by 1.3 since 1915 up to 1999. It was found that the index \( K(t) = L^{-1}(t) - \langle L^{-1}(t) \rangle \) in the minimum of the cycle seems to be in good agreement with the sunspot areas of the next sunspot cycle. It was shown that the index \( K(t) \) and Wolf numbers, \( W(t) \), are in antiphase and the maximum of \( K(t) \) precedes to one of \( W(t) \) with shift-time 3.5 yrs. It means that the large-scale magnetic fields are primary regarding the sunspot magnetic fields and they do not result from the dispersal and transport of old active region magnetic fluxes. New index of solar activity, \( K(t) \), may be used in the periods of absence of sunspots, as a deepest minimum of \( K(t) \) was observed before the highest sunspot cycle.

Key words: Sun: global solar cycle; magnetic fields; neutral lines;

1. INTRODUCTION

H-alpha magnetic charts since 1915 up to 1999 present unprecedented tool for detailed analysis of development many manifestations of the solar activity for 9 cycles. H-alpha charts describe real structures of the solar magnetic fields with them topological properties. In the paper Makarov & Tlatov (1999) we indicated arguments for a deep relation between the large scale magnetic fields of the Sun and the sunspots activity using H-alpha charts and Wolf numbers from 1915 to 1999. According to the Babcock-Leighton model of the solar cycle, Babcock (1961); Leighton (1964); Wang et al. (1989) the evolution of the large-scale weak magnetic field explained as being exclusively due to the dispersal and surface transport of active region fluxes through turbulent diffusion, meridional circulation, and shearing motion by differential rotation. In all models of this kind the large-scale field patterns are formed by the redistribution of old magnetic fluxes and consequently the cycles of the weak magnetic field arise from a deep-seated toroidal field which encircles the Sun below the activity belts. The current idea is that the supergranular motions, differential rotation and meridional flows transform the magnetic fields of the active regions to form the large-scale field patterns, DeVore et al. (1997); Wang et al. (1989). It was emphasized that the observed weak polar magnetic fields are a direct manifestation of the poloidal field of the solar dynamo and that the poleward transport of magnetic flux from solar active regions plays a crucial role in reversing this poloidal field. As emphasized by Stenflo (1992), it is far from certain that the only source of the surface's global poloidal magnetic field is the breakup of the large active regions. The ephemeral bipolar magnetic regions, broadly distributed in latitude, have a weak non-random orientation of magnetic axis, Harvey (1992), and this non-random orientation must contribute to the global field. There are arguments that the large-scale field results from a continuous supply of small-scale flux originating deep in the solar convection zone. From another hand, it was shown that the 22-year magnetic cycle, consisting of an even and odd cycle, is a unified dynamic process. The poloidal magnetic field of "+" and "-" polarity for new 22-year magnetic cycle is formed simultaneously, possibly in deep layers of the Sun in the form of a certain magnetic configuration, containing alternating "+" and "-" polarities of the field, Makarov (1994). It was recently shown that the large-scale magnetic fields are primary regarding the sunspot magnetic fields and they do not result from the dispersal and transport of old active region magnetic fluxes, Makarov & Tlatov (1999).

In the present paper we discuss behaviour of the neutral lines of the large scale magnetic field of the Sun and theirs relation to the sunspot cycle during the last 85 years. A possible scenario of the solar cycle 23 are discussed.

2. OBSERVATIONAL DATA

The global structure of the solar magnetic fields and its variations with the phase of the solar cycle are the central interest in development of the modern theory.
Figure 2. (Above). The time variation of the total length of the magnetic neutral lines in part of the solar radius, $L(t)$, according to H-alpha charts for 1915-1999. (Below). North-South asymmetry of the total length of the magnetic neutral lines, $\Delta L(t) = L_{N(t)} - L_{S(t)}$.

Figure 1. H-alpha synoptic magnetic chart for the rotation No.1958, January 1-28, 2000.

to understanding the nature of the activity, also the problems of its forecast.

In this paper we propose and illustrate some new observational way in solving these problems. The special interest are the usage of H-alpha synoptic magnetic charts of the Sun, Fig.1, (e.g. see Makarov & Sivaraman (1986)) obtained at the Kodaikanal (India), Meudon (France), Kislovodsk (Russia) and Solar Geophysical Data, McIntosh (1979). Observational data on the solar magnetic fields were obtained on the basis of H-alpha synoptic charts from 1915 to 1999, Makarov & Fatianov (1980); Makarov & Sivaraman (1986). Charts reflect the distribution of the magnetic field polarity in this period, McIntosh (1979); Makarov & Sivaraman (1989); Callebaut & Makarov (1992); Soln. Dann (1978-1999). Wolf numbers for this period were taken from

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H-alpha charts for 1975-1999 were compared with the Stanford magnetic field observations and they show good correlations, Makarov & Tlatov (1999). An estimation of the topology features of H-alpha synoptic charts for the last 8 solar cycles was obtained to investigate topology complexity of large-scale magnetic field in space and in time, Makarov & Sivaraman (1989); Callebaut & Makarov (1992); Makarov & Tlatov (1999). There are a few morphological characteristics to describe this topology, among them are the length of the magnetic neutral lines, $l(\phi, \theta)$, expressed in part of the solar radius. The sum of the $l(\phi, \theta)$ on every chart, as a parameter $L(t)$, was calculated for 1915-1999. It is the algebraic sum of the length of magnetic neutral lines that outline unipolar magnetic regions. The diagram of the distribution of the value $L(t)$ is represented on the Fig.2 (above) for 1915-1999. The procedure of smoothing by the window per 2 years was applied to elimination of noises. One can see the cycle behaviour of $L(t)$ and it reaches maximum in a top of cycle and minimum in absence of sunspots. It means that topological complexity of H-alpha charts is described by the $L(t)$ characteristic. The value $L(t)$ was increased by 1.3 since 1915.
up to 1999. It is not known the origin that kind of increase. It connects with global topology of solar magnetic fields. The North-South asymmetry of the total length of the magnetic neutral lines, $\Delta L(t) = L_{N}(t) - L_{S}(t)$ is represented on the Fig.2(below). Parameter of $\Delta L(t)$ shows a pronounced long-term variability with a period of about 53 years, Kitchatinov et al. (1999). One can see a priority activity of the large-scale magnetic field in the Northern hemisphere during 1915-1999. In reality, it is convenient to use a parameter $K(t) = L^{-1}(t) - < L^{-1} >$ that reflects the topology of a large-scale magnetic field. The time variations of the indexes $K(t)$ and $W(t)$ for 1915-1999 show on the Fig.3. One can see that there is relation between the maximum Wolf numbers, $W(t)$, and the index of $K(t)$. Both indexes $K(t)$ and of $W(t)$ have cycle behaviour with time about 11 yrs. The phase shift of the parameters $K(t)$ and $W(t)$ is about 5.5 yrs. The amplitudes of the value of $K(t)$ vary in the considered interval and their relative change is close changes of Wolf numbers, but anticipate them. The growth of the parameters $K(t)$ and $W(t)$ was observed for 1920-1956, sharp depression before cycle 20, provisional equality in minima before cycles 21 and 22, rather small value in a minimum before cycle 23. The obtained result is the confirmation of a hypothesis on the crucial role of the large-scale magnetic field in the solar cycle, Makarov et al. (1997); Makarov & Tatlov (1997); Amplitude of the cycle $K(t)$ depends on topology of a field at mean and high latitudes. Thus, topology of the large-scale magnetic field near the minimum sunspot activity determines the intensity of the next sunspot cycle, Makarov & Tatlov (1997); The comparison of the index $K(t)$ with the index of $W(t)$ shows possibility of the forecast of solar activity, Fig.3. For instance, the current cycle 23 is expected less than the cycle 21 and 22 and will make the value $130 \pm 10$ units of Wolf numbers. The solar magnetic cycle can be presented as the periodic waves of the new magnetic field raised on high latitudes, Makarov & Tatlov (1997); Tatlov (1997). The depth of the generation of the new magnetic field is close to the low boundary of the convection zone. The wave of the field is displaced from poles to equator during 15-18 yrs and it is trasersed by a slower-than-average rotation wave of the torsional oscillations, Makarov et al. (1997); Makarov & Tatlov (1997). The sunspot cycle is a completing stage of a global magnetic cycle.

4. CONCLUSION

The present paper confirms that the large-scale magnetic field of the Sun is primary regarding the sunspot magnetic fields and it does not result from the dispersal and transport of old active region magnetic fluxes, Makarov & Tatlov (1999). Numerous statistic properties on the evolution of 22-years magnetic cycle, which consist of a couple of 11-years sunspot cycles, Makarov (1994), make it possible to assume that 22-years cycle is the result of development of some indivisible and dependent topologically magnetic structures of the weak (poloidal) magnetic field in deep layers of the Sun for an even and odd cycles. Poloidal magnetic field for the next 22-years magnetic cycle is formed by the other magnetic structure. The inter-

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