GLOBAL SOLAR MAGNETOLOGY AND SOLAR CYCLE REFERENCE POINTS

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ГЛОБАЛЬНАЯ МАГНИТОЛОГИЯ СОЛНЦА И ОПОРНЫЕ ТОЧКИ СОЛНЕЧНОГО ЦИКЛА

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Абстракт

Показано, что солнечный цикл можно описать как сложное взаимодействие двух систем полей: глобально (крупномасштабного) и локального. Подтверждена ранее высказанная концепция глобальной магнитометрии и естественной шкалы циклов. С использованием полученных данных можно оценить сценарий дальнейшего течения 23 цикла и указать ожидаемую дату конца 23 (середина 2007 г.) и 24 (декабрь 2018 г.) циклов. Отмечены некоторые особенности 23 цикла и несовпадение систем Китт Пик и WSO

1. Scenario of the Cycle and Forecast of Reference Point

In our previous work, we have shown that a solar cycle can be represented as a complex interaction of two field systems: global (large-scale) and local fields. The first step on that way was to introduce the reference points of the solar cycle and to demonstrate that the main phases of the cycle were easily described with their aid [1, 2]. Then, we introduced the full integral indices of solar activity, such as the squared radial component of the magnetic field averaged over a sphere of fixed radius, and the so-called partial integral indices, such as the zonal-even (ZE), zonal-odd (ZO), sectorial-even (SE), and sectorial-odd (SO) indices. The physical meaning of the partial indices is as follows.

The index ZO accounts for part of the magnetic field with the odd zonal symmetry (analog of the vertical dipole). The index ZE is small as a result of the Hale law. The sectorial-odd index SO characterizes, in particular, the tilted dipole and manifests itself in the 2- and 4-sector structure. The sectorial-even index (SE) is usually manifested in the 4-sector structure.

The totality of the integral indices comprises the "passport" of the reference points, which allows their precise identification and description of the **entire** scenario of a cycle [3-6].

Later, the conception; of the global magnetology of the Sun was suggested [7,8]. It describes the solar cycle on the basis of the integral energy indices of the normal and abnormal magnetic fluxes. A natural duration of the cycle could be established.

It turned out that the maximum of the Wolf numbers did not to coincide with the cycle maximum in the integral energy indices of the global magnetic field. On the contrary, the curve of the integral index in the vicinity of the cycle maximum has a typical two-humped shape with the local trough ("gap") just near the calendar date of the Wolf number maximum. The comparison of the photospheric and source-surface indices showed that the first peak (preceding the Wolf number maximum) was mainly determined by the fields of small and medium space scales, while the second one, e.g., observed in late 1982, was entirely due to the global fields.

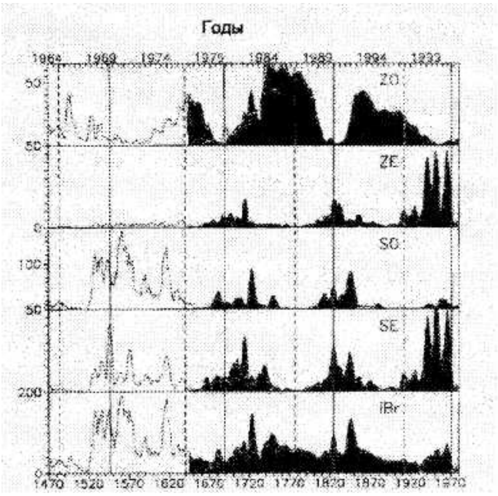

Fig.l illustrates cyclic variations of the index i(B_r) and partial indices at the source surface in units $(\mu T)^2$. The dashed curves are based on the Kitt Peak and Mt. Wilson data, and the solid curves, on the WSO data. The vertical solid and dashed lines are drawn through the maxima and minima of the local fields, respectively.

In [7], the authors introduced the notions of the normal *(Φ_N)* and abnormal *(Φ_A)* flux. The former is determined by the dipole component, and the latter comprises all other harmonics.

As shown in [7,8], these fluxes are complementary. And yet there is an equilibrium point α in each cycle, where these fluxes get equal. A limited statistical database was used in [7] to demonstrate that the total magnetic flux was equal at the points α corresponding to the even cycles 20 and 22, and the time integral of the flux taken over the interval from α_{20} to α_{22} was zero. In 1995, we suggested that the even equilibrium points were just where one "22-year" magnetic cycle ended and another one began to form the natural scale of the successive cycles.

The new diagrams plotted for cycles 20-23 show that the points a_{20} (CR1528, Nov. 1967) and α_{22} (CR1805, July 1988) on the phase diagram coincide, and the respective fluxes are equal to -3.45x10^{21} Mx, The points α_{21} (CR1669, June 1978) and a_{23} (CR 1939, July 1998) are also close to each other. The flux value at $a_2$3 is 1.41xlO^{21} µs and, within the limits of error, is close to the flux at α_{21} (1.84*10^{21} Mx)

The mean total flux over a "22-year" cycle is 0.5x10^{20} Mx for α_{20}-α_{22} and -4.4*10^{20} Mx for α_{21}-α_{23}. Both values are close to zero within the limits of error. The duration of the cycle is 271 CR for α_{21}-α_{23} and somewhat longer (278 CR) for α_{20}-α_{22}. This corroborates the suggestions of [6].

Proceeding from these values and assuming the mean "22-year" cycle to be equal to 274 CR, we can estimate the expected dates of the points α_{24} (CR 2079, Jan. 2009) and α_{25} (CR 2212, Dec. 2018).

Note that the reference point t_{mA} in cycles 21 (CR1665), 22 (CR1804), and 23 (CR1940) virtually coincided with the natural cycle boundaries α_{21}, α_{22}, and α_{23}, while in cycle 20 it was observed half a year earlier. In fact, the forecast of points α_{24} and α_{25} means the forecast of the starting points of cycles 24 and 25.

The data described above and the obtained position of point α_{24} can be used to estimate the duration of cycle 23 (CR 140-145) and to locate the points t_{MD} (CR 1988-1990, March-June 2002), t_{Dm} (CR2014-2020, April-June 2004), and ***min*** (CR2056-2060, mid 2007), thus determining the further scenario of cycle 23.

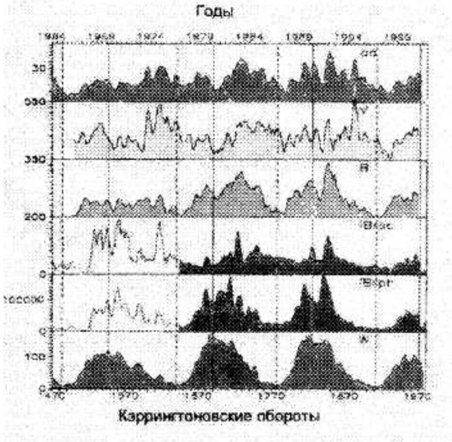

Fig.2 illustrates the cyclic variation of a some helio-geophysical indices, such as the Wolf numbers (W), full indices of the global field in the photosphere (i(B_r)$_{ph}$) and at the source surface (i(B_r)$_{ss}$), chromospheric magnetic field (B), solar wind velocity (V), and geomagnetic aa-index.

The similarity of variations in the heliospheric and geomagnetic parameters to the behaviour of the $i(B_r)_{ss}$ index revealed in cycle 21 [5] is corroborated on a more extensive database for cycles 20-23. It is also found that both $i(B_r)_{ph}$ and $i(B_r)_{ss}$ contribute to variations of the heliospheric magnetic field, but their role is different. The former determines the general increase of the heliospheric field, while the latter is responsible for its narrow extrema.

It is interesting to note that the amplitudes of the cycles, the Wolf numbers, and the integral global indices at the reference points differ much more than the positions of the points within a cycle. It seems as if the rhythmics and energetics of heliogeophysical cycles were formed to some extent independently.

2. Some specific features of cycle 23

It should be noted that cycle 23 is, in general, very unusual. To begin with, it had to be higher than cycle 22 in accordance with the rule of Gnevyshev-Ohl. It is not the case in the Wolf numbers (see Fig. 3a,b,c). However as far as the 10.7-cm flux is concerned, cycle 23 is only a little lower than cycle 22; and in MgII it is even somewhat higher.

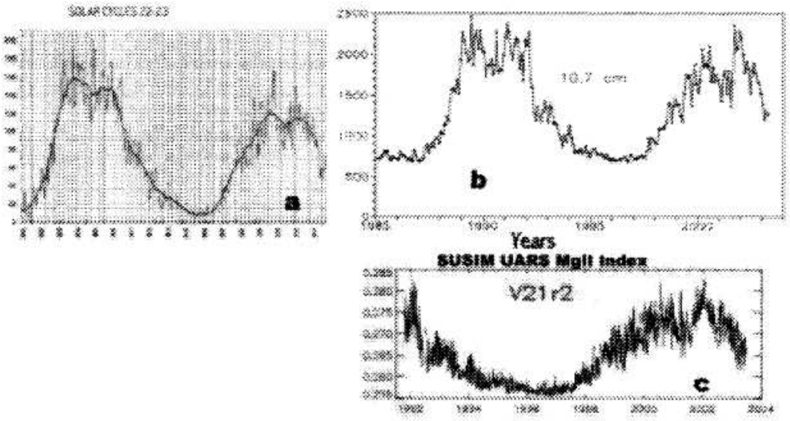

Fig. 3.

The behaviour of the parameters ZE and SE in cycle 23 is also queer. They are too large suggesting either a strongly developed sector structure or an error in drawing zero at the WSO Observatory.

Figure 4 illustrates the mean over a Carrington rotation value of the observed magnetic field as derived from the Stanford (solid) and Kitt Peak (dashed) synoptic maps. This value should, obviously, be zero within the limits of error. The Kitt Peak data (dotted) behave in just this way. As for the WSO data (solid line), they display such behaviour until 1995, after which an uncompensated increasing shift towards the positive values begins.

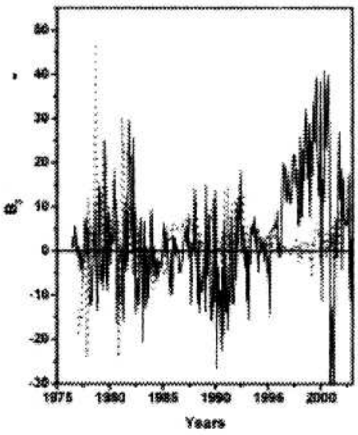

Fig.4.

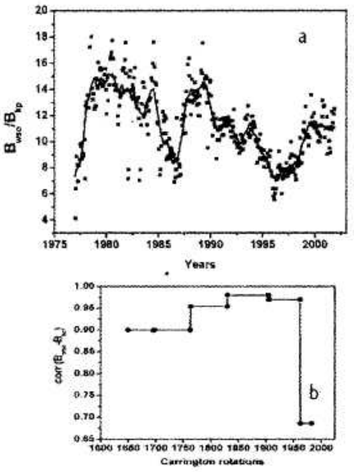

Fig.5.

Figure 5 shows the ratio of the mean absolute values of the magnetic field measured at WSO and Kitt Peak (Fig. 5a) and their annual mean correlation coefficient (Fig. 5b). One can see that the two systems are not uniform. The ratio of the WSO and Kitt Peak mean values decreases gradually by more than 50% undergoing quasi-cyclic oscillations: the ratio somewhat increases at the maximum of the cycle. The correlation coefficient changes insignificantly, except cycle 23, when it drops sharply.

We have compared the Fourier spectra of the rotation-mean absolute values of the measured magnetic field in the Kitt Peak and WSO systems. Over long time intervals, these spectra turned out to be identical, correlating with the coefficient 0.975. Over the intervals less than 1.5 years, however, the spectra differ significantly, and the correlation coefficient is as small as 0.574. The WSO spectrum displays isolated peaks with the periods of 0.6 and 0.9 year that are absent in the Kitt Peak spectrum.

On the whole, despite the discrepancy between the two systems of data, we arrive at the conclusion that the singularity of cycle 23 is largely due to the changing ratio of the local, background, and global fields.

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References

1. Yu.l. Vitinsky, G.V. Kuklin, and V.N. Obridko, Sonlechnye Dannye, N3, 53 (1986).
2. G.V. Kuklin, V.N. Obridko, and Yu.l. Vitinsky, Modern Scenario of 11-Year Cycle, Proc. of the Solar-Terrestrial Predictions Workshop, Leura, Australia, 1989.474(1990).
3. V.N. Obridko and F.A. Ermakov, Astr. Tsirk., N 1539 (1989).
4. V.N. Obridko, B. Shelling, and F. Yermakov, Astr.Tsirk., No 1540, 23-24 (1989).
5. V.N. Obridko and B.D. Shelting, Solar Phys, **137,** 167 (1992).
6. V.N. Obridko and B.D. Shelting, Astron. Zh., 80, N 11 (2003).
7. F.A. Ermakov, V.N, Obridko, and B.D. Shelting, Astron. Zh., **72**, N 1, 99 (ARep,39,86)(1995).
8. F.A. Ermakov, V.N. Obridko, and B.D. Shelting, Astron. Zh., **72**, N 5, 753 (ARep,39,672)(1995).