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ИЗВЕСТИЯ КРЫМСКОЙ АСТРОФИЗИЧЕСКОЙ ОБСЕРВАТОРИИ

Regularities in the solar background magnetic field

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Abstract. We are searching for the physical cause of regular long periods of solar activity recurrences and regularities in the background magnetic field distribution. We use the Stanford synoptic maps of the magnetic field and of the source surface magnetic field divided into different longitudinal zones. We demonstrate that the longitudinal background field concentrations and their longitudinal shift with time in the individual zones run parallel with lines connecting points of projections of meetings of some planetary pairs into the same maps.

Further we show that very specific mutual positions of Jupiter and Saturn with respect to Venus and Earth during their oppositions and conjunctions principally differ during the phase of highest activity in the recent three odd cycles and two even cycles. Parallel with the sudden changes of the longitudinal field distribution, we again ascribe to Venus and Earth meetings, we characterize large-scale uni-polar magnetic structures, the development of which we also connect with these meetings. During the meetings, it is the positive polarity which predominates in the structures occupying the solar side facing the Earth, while the negative polarity is concentrated on the opposite side of the Sun. We suggest that another agent, possibly the magnetic and electric field acts parallel with the gravitational forces of the planetary system.

Key words: activity, magnetic field, planetary meetings

1 Introduction: Solar activity recurrences

In studying the long-lasting development of solar activity, we work with Greenwich daily sums of sunspot areas. Their curves are characterized, parallel with the rotational emphasizing of the discrete distribution of activity in heliographic longitudes, by series of isolated, suddenly appearing increases, often regularly repeated in one, or simultaneously in both hemispheres with their peaks regularly spaced in time. They can be observed throughout the whole activity cycle, but best during the periods of lower activity, when they mostly represent single active regions. During the intervals of higher activity, they cluster into packages of five, or even more peaks, resembling regularly coupled oscillations with determinable periods. They represent formation of one or several successive complexes of activity. But the most outstanding seem to be the recurrences of very long (often more than one year) segments of the daily sunspot area curve. They are repeated in very similar form, with the same frequencies and amplitudes of their maxima and minima distribution. They recur after time intervals of several years, or even in successive cycles.

During the recent several years, series of papers have appeared investigating regular time variations of different solar activity characteristics, bringing evidence of the existence of short and long-term activity oscillations, estimating their periods, amplitudes etc., and demonstrating explicit quantization of the time intervals between the extremes in the course of solar activity of various kinds, as well as changes of their rotation rates. The periods they emphasize most are the quasi-biennial oscillations, periods of about 1.3, 1.6 and 1.8 years, oscillations of about 155 days, and several other periods (Nnaack et al., 2005; Kuznecova and Cirulnik, 2006; Gulyaev, 2006; Vasilyeva et al., 2002).

Moreover, recently Berdyugina with her colleagues (Berdyugina et al., 2003) returned to the problems of solar active longitudes. They show two opposite longitudinal concentrations on the solar surface mostly, above all, of magnetic activity, separated by 180°, migrating continuously in longitude in the Carrington reference frame with a variable rate, alternating similarly to the "flip-flop" phenomenon, known in star-spot activity with periods of oscillations 3.8 and 3.65 years.

In summing up, the whole eleven-year cycle of sunspot activity is composed of a certain number of individual activity links, represented on the daily sunspot area curve, or on graphs of the magnetic field distribution by specific recurrent regularities. More than that, the force responsible for them seems to affect the activity with different intensity during different cycle phases, strengthening or dampening them. The frequency with which such regularities occurrence, and especially the existence of recurrences of long activity periods in the same form, indicate that solar activity could be modulated, or even generated by cyclic processes, reoccurring at several well-defined periods, substantially shorter than eleven years. At the same time, it seems that these periods are mutually bounded in a certain hierarchical manner.

The problem is that there exists one system of cyclic processes, mutually bounded in a certain hierarchical manner only, i. e. the solar planetary system. Moreover, the frequency of planetary pair meetings are very similar to those frequencies, published in so many recent papers. But the tidal deformations of the Sun, caused by planets, are of the order of millimeters only. What physical power serves as the source of these observed regularities?

Published papers indicate that many authors are aware of the possibility of planetary influences, as well as of the fact that "planetary influences" represent a certain "taboo" for journal publishers. Also we want nothing else, but to demonstrate that there exists a real, not yet solved physical problem, which it is necessary to investigate seriously.

2 Longitudinal distribution of the solar background magnetic field

Recently in Coimbra (Bumba et al., 2007), we published the preliminary results of the investigation of the longitudinal distribution of the background magnetic fields on the solar surface, measured at the Stanford Wilcox's Solar Observatory during the recent three cycles.

We studied the temporarily aligned synoptic charts, displaying a succession of the magnetic patterns development. We cut the individual synoptic charts into five latitudinal strips, and then put them in chronological order. The used latitudinal zones were as follows: +/−20°, 20°− 40°, −20° − −40°, +/−40°, and +/−60°. Each of them differ in the longitudinal organization of their magnetic fields, in the direction and value of their longitudinal shift with time.

The main feature of the equatorial (+/−20°) background magnetic field are the characteristic patterns formed of negative and positive polarity strips lasting tens of rotations, inclined in the Carrington rotational system in, and slightly around the main direction, represented by the rotational period of 26.8 days. Due to their slightly slower or faster rotational periods, these strips used to be the source of deviations in the statistical estimations of rotational periods for the individual structural features. The effect of the higher intensity local fields on these topological patterns is suppressed. But the developed activity centers or complexes, with life-times often longer than one year, remain at approximately the same longitude, or their shift is substantially smaller, and its rotational period is close to 27.14 days. The general character of this longitudinal distribution of the equatorial background magnetic field polarities and concentrations does not change with the cycle phase.

The same construction of the sequence of strips from Stanford magnetic maps representing the latitudinal zones between 20° and 40° on both solar hemispheres, yields similar results: The magnetic field distribution in the form of strips of both polarity forms a similar system of long chains or streams as in the equatorial zone, but their inclination is reversed; they rotate slower than the Carrington system. Their rotational period is close to 28.2 days. The magnetic streams start on both hemispheres at the same longitude, although their polarity can be different.

Although the sequence of broader equatorial zones (+/−40°) represents a combination of both preceding sequences, the character of their background magnetic field patterns is different. The separated polarity chains are more compact, demonstrating more often the apparent bipolarity of the global magnetic field. All three inclinations of the individual polarity strips, visible in the two previous sequences, are visible too, but they are encoded in other way in the magnetic features. Also the local stronger fields are more outstanding in these broader zones. The inclination with the faster 26.8 days rotational period can be observed during the whole sequence, but there are periods during the ascension of new cycles, when they almost vanish, and the opposite direction with the slower rotational period of 28.2 days is more pronounced. And again, during the periods of the highest activity the chain rotating almost with Carrington's rotational velocity (27.14 days) can be recognized.

The sequence of all the synoptic charts will be discussed later.

How should the regularities observed in the background magnetic field distribution be explained? There may really exist some kind of a feedback between the whole solar system and the activity of the solar atmosphere. Our graphs support such an idea: if we plot the sequence of dots into which the conjunctions and oppositions of some planetary pairs are projected in the same Carrington system, into our series of sequences of the longitudinal magnetic field distribution in the individual latitudinal zones, we can see the clear parallelism of both systems of sequences: of the longitudinal concentrations of the magnetic field and of the planetary meetings. The periodicity of 26.8 days is connected with the meetings of the Earth and Mercury, the periodicity of 28.2 days with the meetings of Venus and Jupiter, and the period of 27.14 days with the meetings of Mercury and Jupiter.

3 Periodicity of 1.6 years, Venus and Earth

Recently Charvátová (2007) published a paper explaining her point of view on the role of the inner (terrestrial) planets, above all, of Venus and Earth in the solar motion around their center of gravity with the period of 1.6 years, well known from solar activity variations and solar-terrestrial relations.

During this type of motion, the center of the Sun circumscribes a cardioid. The fastest motion occurs in the circumference of this curve, and the velocity substantially decreases when the Sun moves towards the center of gravity. The time interval between two consecutive closest points is very close to 584 days, and the dates of the closest point meetings approximately coincide with the moments of the oppositions of Venus and Earth. There the Sun and center of gravity are closest and Sun has the smallest velocity.

We have five such points in space and time: April, November, June, January, August, when the Sun can slow down its motion as much as twenty five times (Charvátová, 2007). At these five points, the vector connecting the center of the Sun with the mass center of the terrestrial planets changes its position in space very slowly (around 12° during the recent 50 years), as well as the date of the five meeting days in the year (around 12 days during the recent 50 years).

The point is in the fact that already in 1978 (Petrova et al., 1978) demonstrated that solar activity expressed by the Wolf relative numbers for the time interval 1800−1974 is influenced by the ecliptical position of the center of gravity of the whole solar system against the center of the Sun. The authors demonstrated that the absolute minimum of solar activity is connected with the direction identical with the projection of direction into the ecliptic, representing the motion of the solar system in space.

4 Positions of Jupiter and Saturn against Venus and Earth during their meetings

In order to find out if the longitudinal distribution of the background magnetic fields does not depend somewhat on the position of Venus and Earth in space during their meetings, and to estimate to what degree the positions (on the same dates) of Jupiter and Saturn, the heaviest planets, could play some role, we constructed graphs of Jupiter's and Saturn's angular distances from Venus and Earth, separately for their oppositions and conjunctions. For the last five cycles, our graphs demonstrate that during the phases of the cycles highest activity, Venus, Earth, Jupiter and Saturn meet mutually, or that their mutual angular distances were minimal for the oppositions in the odd cycles (Nos. 19, 21, 23), and for the conjunctions in the even cycles (Nos. 20, 22). During the activity minima, the angular positions of these four planets seem to be maximally dispersed.

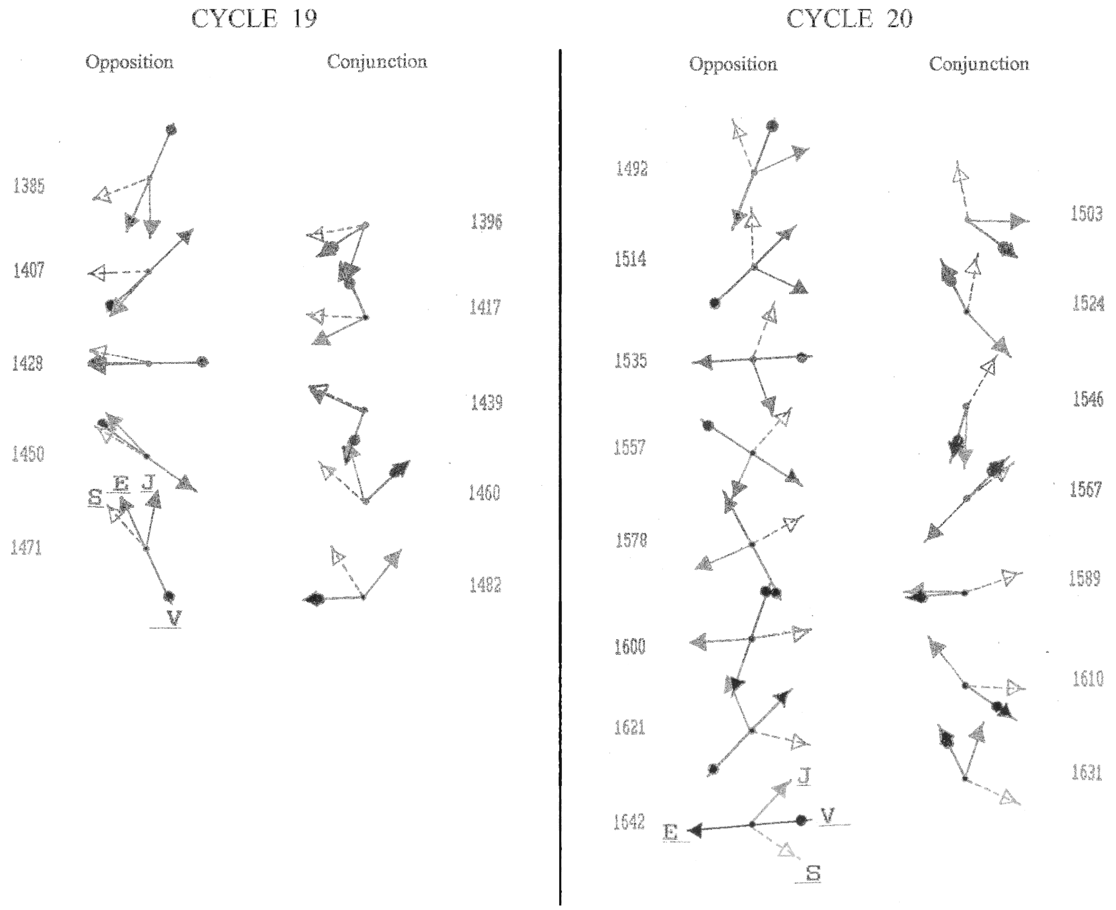

Fig. 1. Heliocentric positions of Jupiter (J) and Saturn (S) against Venus (V) and Earth (E) during their meetings

Consequently, in the odd cycle No. 19, during the oppositions of Venus and Earth, and in phase of the highest activity, the direction given by the connections of Venus and Earth (and vice versa), and the direction from the Sun to Jupiter and Saturn are practically identical (Rot. Nos. 1428 and 1450), and in the conjunctions in the same cycle phase, the joint direction to Jupiter and Saturn differs from the joint direction Venus − Earth by 90° (Rot. Nos. 1417 and 1439) (Fig. 1). In the odd cycle 21 in oppositions of Venus and Earth, the same applies (Rot. Nos. 1707 and 1728), as well as to their conjunctions (Rot. Nos. 1696 and 1717). We observed the same for the odd cycle 23: in oppositions Rot. Nos. 1963, 1985, in conjunctions Rot. Nos. 1953 and 1974, eventually No. 2038.

During interval of the highest activity of even cycle No. 20, the directions from the Sun to Jupiter and Saturn on the dates of the oppositions of Venus and Earth differ by 90° from the direction of these two planets. But in this case, Jupiter and Saturn are on opposite sides of the Sun (their mutual directions differ by 180°) (Rot Nos. 1535, 1578 and 1600). In the conjunctions of Venus with the Earth, the directions of all four planets are almost identical, again only Jupiter and Saturn are directed oppositely (Rot. Nos. 1546, 1567 and 1589) (Fig. 1). We see the same in even cycle No. 22 (in the Venus − Earth oppositions: Rot. Nos. 1814, 1835, 1856, and in their conjunctions: Rot. Nos. 1824, 1846).

As regards Mercury and Mars, on the graphs of the planetary angular distances the commensurability of Mercury's and Jupiter's orbits are evident, on the one hand, and of Mars's, Venus's and Earth's orbits, on the other.

Incidentally, the meetings of Venus and Earth in the above enumerated rotations occur twice as often in the April and June terms than in the remaining terms, which in ecliptical longitudes is close to 195°and 265°. Let us remind the reader that the directions for the activity maxima given by Petrova (Petrova et al., 1978) are 180° − 195°and 60° − 75° (+180° = 240° − 255°).

5 Sudden changes in the longitudinal distribution of the integrated magnetic fields

More than twenty years ago, we found that in cycle No. 20 and at the beginning of cycle No. 21 (Carrington rots. 1490−1690; 1965−1979) the longitudinal distribution of the integrated background magnetic fields measured at the Mount Wilson Observatory suddenly changed its structure during the time intervals close to the dates of the Venus and Earth meetings (Bumba, Hejna, 1986, 1988). To learn more about the behavior of the solar magnetic fields in such cases during cycles Nos. 21−23, we used the Stanford synoptic charts of the source surface magnetic fields during their whole existence (Carrington Rots. Nos. 1642−2060; 1976−2008). We put together into time sequence their strips of the heliographic zone +/−40°.

The obtained graphs demonstrate again that during the time intervals of a few rotations around the rotations with the oppositions and conjunctions of Venus and Earth, we mostly observe a sudden reorganization of the longitudinal distribution of these integrated magnetic fields. And again this restructuralization occurs most significantly during the increase and maximum of solar activity.

Comparing the longitudinal structural changes -of integrated magnetic fields with the total solar irradiance measurements in cycle No. 23 (Mekaoui et al., 2008), we see interesting agreements in the longitudinal field distribution and the irradiance changes, as well as their coincidence with the Venus and Earth meetings.

Of course, in interpreting these graphs we cannot forget a large number of important circumstances, such as, for example, the fact that the field restructuralization is a process which requires several rotations to be realized. Further, if we compare the primary Stanford synoptic charts with the integrated maps, the direct measured charts display much stronger extended unipolar structures formed from the weak fields, while on the integrated maps the field intensities, concentrated into much smaller areas, play a more important role, etc. Let us underline that these facts will be even more important in the next chapters.

6 The large-scale structures and polarity distribution of the background magnetic fields

In investigating the background magnetic field topology on all types of synoptic charts in their whole span (+/−60°), we can very often observe the formation of characteristic large-scale features (their perspicuity fluctuates strongly). Ambrož et al. (1974) were the first to report and described them (Bumba, Sykora, 1974; Bumba 1976). They are formed from the concentrated fields of both polarities.

They present a huge drop-shaped structure, more than half of the equator in length in the whole latitudinal extent. Their main body has the leading polarity of one hemisphere and its tail of the same polarity is stretched out far into the higher latitudes of the opposite hemisphere, where it plays the role of the following polarity. In an ideal case, the centers of gravity of both opposite polarity structures are concentrated on opposite longitudes and their forms are antisymmetric.

They can be seen better on the synoptic charts constructed from the H-alpha spectroheliograms (McIntosh, 1979; Makarov and Sivaraman, 1986), or sometimes on the Mt. Wilson Observatory maps (Howard et al., 2005). Physically they represent the results of a process of redistribution, lasting several rotations, of the regularly produced larger portion of the magnetic flux into the photosphere, mainly due to differential rotation, meridional motion, magnetic field dissipation, etc. Their whole life-time is of the order of 11−12 rotations, with much faster ascension and longer-lasting descent. They often culminate by producing a complex of activity, generating large proton flares. Practically all activity complexes we studied in the seventies and eighties (Bumba and Sykora, 1974; Bumba, 1976) were connected with the formation of such structures and dates of the Venus and Earth meetings.

These structures also play another important role: they estimate not only the longitudinal distribution of the solar magnetic fields, but also of their polarities on the solar surface. Moreover, they demonstrate that this distribution is not accidental, but that it is closely related to the Venus and Earth meetings. Since the polarity dividing line of the large-scale features follows the points into which the Venus and Earth meetings are projected into the same Carrington maps. Once again, during oppositions and conjunctions of Venus and Earth the positive polarity predominates on the side of the Sun, facing the Earth (in 63.4 % of the cases), and the negative polarity is concentrated on the opposite solar side (in 69.2 % of the cases).

7 Conclusions: What is the physical basis of the observed regularities?

How should one explain that the observed regularities of the background magnetic field distribution on the solar surface and in time seem to be connected with certain planetary constellations? To come closer to a conclusion, we have to take into account many other results, published a long time ago, as well as recently.

For example, Kopecky (1952) demonstrated on fifty one and a half synodical periods of Venus that the Wolf number regularly oscillates and that the general mean curve has its maximum during the oppositions of Venus with Earth, and minimum during their conjunctions. Recently, Akimov (2005) showed that the maximal occurrence of X-ray flares is connected with a very high degree of certainty with Mercury's aphelion, and the minimum of X-ray flares occurs during Mercury's passage through its perihelion and the 25 following days. They found that Venus had a similar influence on the occurrence of X-ray flares.

In 1972 Ambrož demonstrated that in then highest cycle No. 19 (1955−1965) the solar calcium plages, sunspots and prominences were concentrated into two active longitudes, running parallel on both sides of the temporal sequence of positions of maximal amplitudes of the tidal pulses of six planets (Mercury − through Saturn) on the solar surface.

But not only the Sun responds to planetary meetings. We see many similar reactions displayed in the interplanetary magnetic field. In 1975, Svalgaard and Wilcox published graphs of the interplanetary magnetic field polarity distribution for the 16th to 20th cycles (1926−1973). They showed that the main sectors of the negative polarity form long strips, lasting through the whole period of time, and repeating their passages with the period of 26.84 days. The secondary sectors rotated with periods of 27.14 and 29 days. Reshetov in 1981, in analyzing long series of observations of geomagnetic disturbances, observed the direct influence of some planets (Mars, Jupiter, Saturn) on the structure of the solar wind. Recently, Skryabin (2005) showed, on a large series of daily solar-wind densities, temperatures and velocity, 399-day variations, which represent the synodic period of Jupiter. In their most recent paper, Timofeev (2007) demonstrate that the maximum response in electron density and the minimum response in interplanetary magnetic field magnitude coincide and lie near the magnetic field line that runs along the Sun − Earth − Jupier axis. The minimum response in cosmic ray intensity is shifted against the solar rotation by 75 days from the magnetic field line connecting Jupiter and Earth.

We could quote many papers which bring more evidence of the further reaction of the circumsolar environment to certain directions in space, often connected with the position of Jupiter or other planets.

Let us remind the reader of the statement published by Israelevich (2000): “The magnetic field produced by the heliospheric current system is not negligibly small near the Sun and, hence, it may be necessary to take it into consideration in the problem of solar magnetic field generation”.

Thus the Sun and the heliosphere and their activities seem to be influenced by the arrangement of planets not only as regards their positions, but also in dependence on their distance from the Sun, and their specific constellations by which the field polarity distribution is influenced. We suggest that, highly probably, parallel with the gravity yet another agent, possibly magnetic (or even electric) force is in play. But the question expressed recently by Akimov and Belkina (2006): “Does the influence concern the violation of stability conditions in the solar atmosphere only, or is it more seriously engaged in production and emerging of the magnetic flux, the source of all the solar activity” still remains unanswered. To learn the physical basis of the demonstrated processes, we need even more systematic observational data and investigations.

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