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# TO THE STUDY OF THE INFLUENCE OF PLANETS ON THE VARIATION OF PRESSURE OF THE SOLAR ACTIVITY

***Abstract.*** *It is accepted to name solar activity the set of non-stationary phenomena on the Sun that are revealed in visually observable blackened areas of the star (sun spots) - areas with the reduced transfer of thermal energy flow caused by the magnetic field suppression of the convective movements of substance. Therefore, the solar activity is connected with the evolution of local magnetic fields leading to the formation of sunspots - formations sizing some angular minutes. These non-stationary phenomena of cyclic character still remain a subject of discussion among the scientists. One of latest discussions in the form of the articles in the journal of Astronomy & Astrophysics is connected with the work of the group of scientists (J. A. Abreu, J. Beer, A. Ferriz-Mas and others,* [1]*) that has come to the conclusion about the influence of planets on the variations of solar activity basing on the statistical analysis of the isotope records of solar activity (radioactive isotopes* $^{10}$*Be and* $^{14}$*C in ice cores). However, the same journal soon published the article (R. H. Cameron and M. Schüssler, 2013) denying this conclusion.*

*With a view of revealing conditionality of variations of pressure of solar activity by gravitational interaction of the Sun with planets to the time series of the composite force of gravitational interaction (RFGI) of the Sun with the objects of the solar system received on specially developed program complex and Wolf's numbers (1849-2010), the correlation, spectral, wavelet and causal analyses have been applied.*

*The results are presented in favor of the hypothesis of the causality of variations in the stresses of solar activity by variations in the gravitational interaction of the Sun with the objects of the Solar system, confirming the conclusions obtained by J. A. Abreu, J. Beer, A. Ferris-Mas and others in* [1].

***Key words:*** *solar activity, gravitational interaction, Fourier transformation, wavelet transformation, correlation, causality function.*

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# К ИЗУЧЕНИЮ ВЛИЯНИЯ ПЛАНЕТ НА ВАРИАЦИИ СОЛНЕЧНОЙ АКТИВНОСТИ

***Аннотация.*** *Совокупность нестационарных явлений на Солнце, проявляющихся в визуально наблюдаемых зачернённых областях звезды (солнечные пятна) – области с уменьшенным переносом потока тепловой энергии, обусловленные подавлением магнитным полем конвективных движений вещества, принято называть солнечной активностью. Таким образом, солнечная активность связана с эволюцией локальных магнитных полей, приводящей к формированию солнечных пятен – образований размером несколько угловых минут. Эти нестационарные явления, имеющие циклический характер, до настоящего времени остаются предметом дискуссии учёных. Одна из последних дискуссий развернулась на страницах журнала «Astronomy&Astrophysics», связанная с работой группы учёных J. A. Abreu, J. Beer, A. Ferris-Mas и др.* [1]*, в которой на основе статистического анализа изотопных записей солнечной активности (радиоактивных изотопов* $^{10}$*Be и* $^{14}$*C в кернах льда) делается вывод о гравитационном влиянии планет на вариации солнечной активности. Позже в этом же журнале вышла статья [Cameron и др.* [5]*, опровергающая этот вывод.*

*В данной работе в целях выявления наличия (отсутствия) обусловленности вариаций напряжений солнечной активности гравитационным взаимодействием Солнца с планетами к* *временным рядам результирующей силы гравитационного взаимодействия Солнца с объектами солнечной системы, полученной по специально разработанному программному комплексу, и чисел Вольфа (1849-2019 годы) был применён корреляционный, спектральный, вейвлет и причинный анализы.*

*Представлены результаты в пользу гипотезы обусловленности вариаций напряжений солнечной активности вариациями гравитационного взаимодействия Солнца с объектами Солнечной системы, подтверждающие выводы, полученные J. A. Abreu, J. Beer, A. Ferris-Mas и др. в работе* [1].
***Ключевые слова:*** *солнечная активность, числа Вольфа, гравитационное взаимодействие, Фурье преобразование, вейвлет преобразование, корреляционная функция, функция причинности.*

**Introduction and problem statement.** The question whether the solar activity is of exclusively intrasolar origin or the variations of its pressure reflect the dynamic processes of the entire solar system raised by the pioneers of study of solar activity, R. Kerrinkton R., R. Shpyorer, R. Wolf and others, has not yet found the proved answer. Following the methodology of patriarchs of solar activity studies, many their followers tried to compare separate periodic components of the Sun activity and orbital periods of various planets, repeatability of their configurations and etc. Basic influence was attributed to the variations of tidal force of the planets which cause vortex indignations in the atmosphere of the Sun. Nevertheless, in the opinion of some scientists, this hypothesis is untenable because it is impossible to increase the radius of the Sun by tidal forces by over 1 mm. As it will be shown below, this conclusion is erroneous. The dynamic influence of the planets leads to a significant displacement of the center of the Sun regarding the center of the weights of the solar system and other characteristics of the dynamic movement of the Sun. Hence, the current condition of the solar system parameters system results from its long evolution that has been reflected in the magneto dynamic characteristics of the system, the features of which reveal as variations of the pressure of solar activity. It fully agrees with the conclusion of J.A. Abreu and others [1] about the possible influence of the planets on the variations of solar activity made on the basis of the statistical analysis of isotope records of solar activity that was denied [5] because of small statistical significance of the results received by J.A. Abreu and others [1].

**Study of the problem.** Without going in deep details of the critical analysis of the results processing of the isotope records of solar activity carried out by R.H. Cameron and M. Schüssler, I shall highlight the formal consistency of their estimate. Nevertheless, the formal part of a negative estimate is not a 100% criterion of absence of positive result. Generally speaking, any indirect estimation method of conditionality of one process by another one always bears an element of chance in itself. As a rule, uniqueness of the results does not raise doubts if it is obtained when the analysis of the investigated processes is carried out by the direct methods based on the objective criteria, for example, on the basis of the analysis of causes (M.L. Arushanov, S.M. Korotaev, 1994; S.M. Korotaev, 2011). Besides that, the conclusions made by J.A. Abreu and others are not new as the question of influence of planets on the variations of solar activity mentioned above is not new in itself; it is periodically touched upon in the scientific publications. For example, variations of solar activity linked with the movement of the Sun in relation to barycenter meaning variations of gravitational interaction of the Sun and objects of the solar system, have been investigated by many authors [8,10,11,12]; they are unanimous in their conclusions on the really existing influence of the planets upon the variations of pressure of solar activity, on its cycles, in particular.

**The aim and objectives of the work.** In this work, possible conditionality of the variations of solar activity by the variations of gravitational interaction of the Sun and planets has been investigated by the direct methods with the application of correlation and cross-spectrum analyses, wavelet transformations and causal analysis.

**Materials and methods.** The resultant force of the gravitational interaction of the Sun with the objects of the solar system has been calculated upon a specially developed program complex as a consecutive solution of the problem of interaction of two bodies including the combination theory of planets arrangement in relation to the Sun and each other (a linear combination of vectors) for the fixed date corresponding to the given epoch in the heliocentric system of coordinates, except for the Uranus and the Neptune; from all satellites of the planets only the Moon was taken into consideration:

$$\vec{F}_{\Sigma} = \vec{F}_{\oplus☽} + \vec{F}_{\odot\oplus☽} + \vec{F}_{\odot☿} + \vec{F}_{\odot♀} + \vec{F}_{\odot♂} + \vec{F}_{\odot♃} + \vec{F}_{\odot♄},$$

where $\vec{F}_{\Sigma}$ is the vector of the resultant force of the gravitational interaction of the Sun with the objects of the solar system; $\vec{F}_{\oplus☽}$ – vector of the force of the «Earth-Moon» and respectively: $\vec{F}_{\odot\oplus☽}$ – the «Sun-Earth-Moon» systems, $\vec{F}_{\odot☿}$ – «Sun-Mercury», $\vec{F}_{\odot♀}$– «Sun-Venus', $\vec{F}_{\odot♂}$ – «Sun-Mars», $\vec{F}_{\odot♀}$ – «Sun-Jupiter', $\vec{F}_{\odot♄}$ – «Sun – Saturn»; $|F| = G\frac{M_i M_j}{R_{i,j}^2}$, where $G$ is the gravitational constant, $M_i$, $M_j$ - weights of the *i-th* and *j-th* objects, *Rij* – distance between the *i-th* and *j-th* objects.

With a view of assessing sustainability of the results, calculations have been made for two time periods: 30 years (198-2010) and 162 years (1849 -2010).

Wolf's numbers for the same time periods have been taken from the database on http://sidc.oma.be/sunspot-data and applied as an index of solar activity.

Output files of calculation results of the force of gravitational interaction have been generated for the systems 'Sun-Earth', 'Sun-planets', 'Sun-Earth-Moon-planets'. Such allocation has allowed estimating the contribution of each of the above mentioned systems into resultant force of gravitational interaction of the Sun with the objects of the solar system. Further on, there has been carried out the averaging of the received numbers for each day of the year. As a result, there have been received rows of average force of gravitational interaction between the allocated systems for each day of the year. The same procedure has been applied to Wolf's numbers.

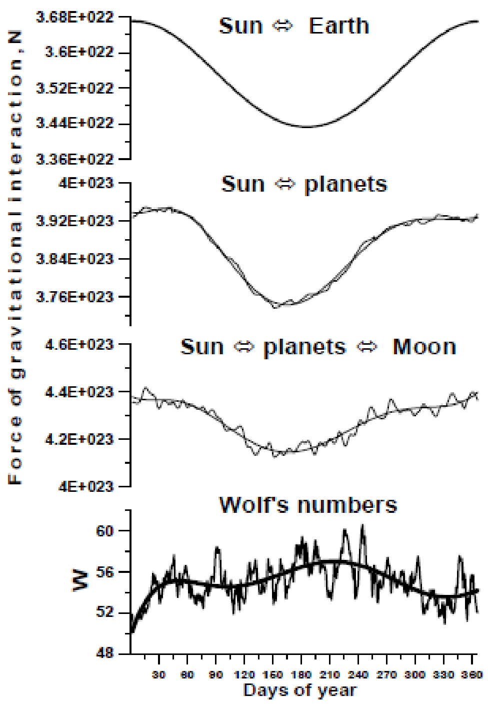


**Fig. 1. Annual course of the average (1849-2010) for each day of the year of the force of gravitational interaction of the systems shown in the figure; Wolf's numbers.**

The specified averaging has been made for the following reasons. If the force of gravitational interaction of the Sun with the objects of the solar system is really the factor preconditioning one of the reasons, regarding the external intrasolar factors, of variations of pressure of solar activity, then this influence must be also reflected in the average field of gravitational interaction (fig. 1) irrespective of the individual periods of parameters of the orbits of the solar system objects. In such averaged gravitational field, only annual peculiarities of the response to the variations of solar activity on external the factor should be revealed if, only they are really linked.

Methods of spectral analysis [7], wavelet transformations [13] and the analysis of causes [2-4] have been applied to the above-stated averaged numbers to reveal conditionality of solar activity by the variations of gravitational interaction of the Sun with the objects of the solar system Special attention should be attached to the analysis of causes. Principle of causality is the fundamental principle used in physics; it is based on the consequence lagging behind the cause. However, lagging is a necessary but not a sufficient condition of causality. Until recently the concept of ‘causal relationship’ remained uncertain. The paradoxical provision in physics due to the absence of the formalized concept of ‘causality’ at times led to the erroneous conclusions in theoretical and experimental researches. For example [9] «… *that the electric field can be presented as convolution of a magnetic field by all previous moments of time, there can be a perception that the electric field is the consequence of the magnetic one* [15], *that is incorrect* [6], *even because it is admissible to symmetrically represent the magnetic field through the electric one»* In the estimation of causal conditionality of one process by another one based on the experimental data with use of the correlation approach, the probability of an erroneous conclusion increases.

As at rule, the conclusion is made on the basis of the presence of significant correlation added with the lag between the investigated processes, and the question of orientation of causal relationship is solved on the basis of comparability of power capacities of the processes at the intuitive level. However, there can be high correlation between processes *A* and *B* induced by process *C* which for whatever reasons can drop out of the field of vision of the researcher, and processes *A* and *B* are not anyhow connected at all.

The situation has changed when S. M. Korotaev, with the participation of the author of this article, developed the classical analysis of causes [2-4]]. Later on, S. M. Korotaev developed the analysis of causes at the quantum level; it appeared to be a powerful tool for researching non-local processes [9].

With a view of clear understanding of the results described below, we would in brief present the fundamental provisions of the classical analysis of causality.

Let *A* and *B* be the investigated processes set up by their realizations during the consecutive moments of time $t_i$ ($i$ =1, 2, 3, T). Their Shannon conditional and unconditional entropies are determined by the formula [14]:

$$H(A) = -\sum_{j=1}^{J} P(A_j)\, log_2\, P(A_j),$$

$$H(B) = -\sum_{k=1}^{K} P(B_k)\, log_2\, P(B_k), \tag{1}$$

$$H(A|B) = -\sum_{k=1}^{K} P(B_k) \sum_{j=1}^{J} P(A_j|B_k)\, log_2\, P(A_j|B_k),$$

$$H(B|A) = -\sum_{j=1}^{J} P(A_j) \sum_{k=1}^{K} P(B_k|A_j)\, log_2\, P(B_k|A_j), \tag{2}$$

where $P(A_j)$, $P(B_k)$ is the probability of the $j$-th ($k$-th) level of $A$ and $B$ accordingly;

$P(A_j|B_k)$, $P(B_k|A_j)$ – are corresponding conditional probabilities. Further on, unconditional $\alpha$ and conditional $\beta$ asymmetries are entered:

$$\beta = \frac{H(B|A)}{H(A|B)}, 0 \leq \beta \leq \infty.$$
$$a = \frac{H(B)}{H(A)}, 0 \leq a \leq \infty; \quad (3)$$

And the independence function is:

$$i_{B|A} = \frac{H(B|A)}{H(A|B)}, 0 \leq i_{B|A} \leq 1$$

$$i_{A|B} = \frac{H(B|A)}{H(B)}, 0 \leq i_{A|B} \leq 1. \quad (4)$$

The sense of independence functions is transparent: at $i_{B|A}$ =1, $B$ does not depend on $A$, at $i_{B|A} = 0$, $B$ is a one-valued function $A$, i.e. values 1-i determine the one-valued dependences of the variables. Direct and inverse independences coincide only in the limiting case:

$$i_{B|A} \Leftrightarrow i_{A|B} = 1.$$

And at last, the causality function ϒ is entered:

$$\Upsilon = \frac{i_{B|A}}{i_{A|B}}$$

$$0 \leq \Upsilon \leq \infty. \quad (5)$$

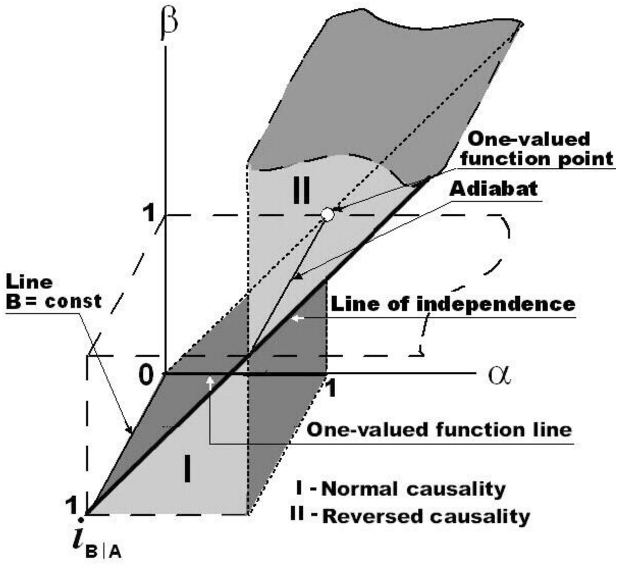


**Fig. 2. Classical entropic diagram (S. M. Korotaev, 2011).**

At ϒ=0 $B$ is one-valued function $A$, *but not on the contrary* – an extremely irreversible process A⇒B. At ϒ=1, $A$ and $B$, to the same extent, depend on each other - absence of causal relationship. At ϒ=∞, $A$ is one-valued function $B$, *but not on the contrary* – an extremely irreversible process *B⇒A*. These limiting cases evidently show properties of the function of causality. Fig. 2 shows even the more evident sense of the entered parameters of causality, where the space of parameters (the entropy diagram) α, β , $i_{B|A}$ classifying all types of links has been constructed.

Considering irreversibility of the information *I = H (B) −H (B|A) =H (A) −H (A|B)*, it is simple to see that the forbidden areas are: **1.** α<1,ϒ≥1; **2.** α>1, ϒ≤1; **3.** Plane β=1, excluding the crossing line with plane α=1; **4.** Plane α=1, excluding the crossing line with plane β=1 and the crossing line with plane $i_{B|A}$= 0; **5**. Plane β =1, excluding section on axes a [0,1] and axes $i_{B|A}$; **6.** Plane α=0, excluding axis $i_{B|A}$; **7.** Plane, $i_{B|A} = 0$, excluding line α =1 and axis section α [0, 1]; **8.** Plane $i_{B|A}$=1, excluding line ϒ=1; **9.** Plane ϒ=1, excluding axis $i_{B|A}$, line $i_{B|A} = 1$ and line α=β =1.

All other areas of the diagram are resolved, namely:

- Area of normal causality: ϒ <1, α<1, β <1;
- Area of reversed causality:ϒ >1, α>1, β >1;
- Line *B – const* irrespective of *A*;
- The line of one-valued functions $i_{B|A}$=0, β= 0, 0 < α< 1. Her $H(B|A)$=0, i.e. $B$ is completely determined by *A*, but not on the contrary;
- Line of independence $i_{B|A} = 0$,ϒ=1;
- One-valued point $i_{B|A}$= 0. Here $H(B|A) = H(A|B) = 0$;
- Adiabata α=β=1 – isentropic process.

In view of the above described properties of the entropic parameters (parameters of causality), the definition has been formulated as follows:

**Definition:** *processes referred to as cause A and consequence B are those realization of which meets condition ϒ <1.*

**Results of Research. 1. Spectral Analysis.** The discrete smoothed estimation of spectral density $\overline{C}(t)$ (discrete step Δ=1) was carried out as Fourier transformation of correlation function *R*(t) with the correlation window *w*(k) for time rows of Wolf's numbers and the resultant force of the gravitational interaction (RFGI) of the Sun with the objects of solar system, averaged in the way described above:

$$\overline{C}(t) = 2\left[1 + 2\sum_{k=1}^{L-1} R(k)w(k)\cos\frac{\pi tk}{T}\right],\ \ t = \overline{0,T} \tag{6}$$

Random estimations of smoothed cross-spectra of RFGI and Wolf's numbers (a coherence spectrum, a phase spectrum) have been calculated similarly to autospectra as Fourier transformation of cross- correlation function $R_{\mathrm{WF}_\Sigma}(\tau)$:

*Smoothed estimate of square of coherence spectrum*

$$\overline{K}^2_{WF_\Sigma} = \frac{\overline{A}^2_{WF}(t)}{\overline{C_W}(t)\overline{C_{F_\Sigma}}(t)} \tag{7}$$

*The smoothed estimation of the phase spectrum*

$$\overline{\Psi}_{WF_\Sigma} = arctg\left[\frac{\overline{Q}_{WF_\Sigma}(t)}{\overline{L}_{WF_\Sigma}(t)}\right] . \tag{8}$$

In (7), (8) $\overline{A}_{WF_\Sigma}(t)$ – amplitude smoothed cross spectrum, $\overline{C_W}(t)$, $\overline{C_{F_\Sigma}}(t)$ – the smoothed auto-spectra, $\overline{Q}_{WF_\Sigma}(t)$, $\overline{L}_{WF_\Sigma}(t)$ – the smoothed estimations cospectrum and quadrature spectrum.

Fig. 3 shows results of calculations of autospectra RFGI and Wolf's numbers, and fig. 4 presents their cross-spectra according to the data of random rows for 30-year and 162-year periods. In the distributions of fluctuations by frequencies in RFGI spectra calculated on two random samples, the time range of one exceeds another by over five times; we see the practical identity both in the maxima lying above the confidence line with the periods of 38, 18 and 10 days and in the character of fluctuations of the spectrum. Spectrum's «trend» is described with high accuracy by the logarithmic curve *lnY=B·LnX +A* with the indices very close in value for both samples: $B_{1849-2010} = -3{,}411$, $A_{1849-2010} = -17{,}069$; $B_{1981-2010} = -3{,}261$, $A_{1981-2010} = -16{,}207$. Generally speaking, it is the obvious result despite the fact that the greater time range sample has century-old indignations in the parameters of planet orbits which have been considered in the program complex of calculations of the gravitational interaction of the Sun with the objects of solar system. Therefore, spectra of average RFGI for each day of the year calculated on two samples displays high stability following the laws of celestial mechanics.

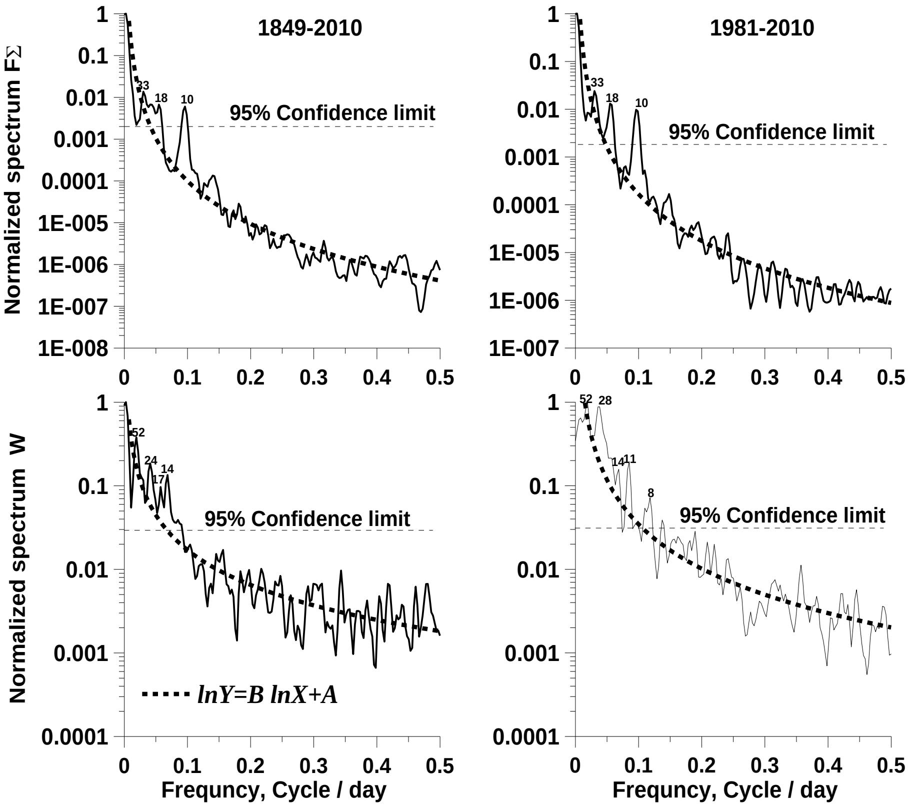


**Fig. 3. Spectrum density RFGI (FS) and Wolf's numbers (W).**

**Note**: the numbers above the peaks – periods in days.

The same refers to the spectra of Wolf's numbers. First of all, it is necessary to note, that «trends» of fluctuations of RFGI spectrum and Wolf's numbers are with high accuracy approximated by one and the same logarithmic curve with indices close in values; namely, these indices for Wolf's numbers are equal to: $B_{1849-2010} = -1{,}391$, $A_{1849-2010} = -7{,}273$; $B_{1981-2010} = -1{,}767$, $A_{1981-2010} = -7{,}433$. Besides that, the peaks of periods of spectral density of RFGI and Wolf's numbers (fig. 3), correspond to the significance level and are also close enough. Their correlation in frequency area is described by a cross- spectrum of coherence (7) and a phase spectrum (8). As fig. 4 shows, the former displays high values of square index of correlation on the corresponding frequencies, and the latter displays insignificant phase shifts.

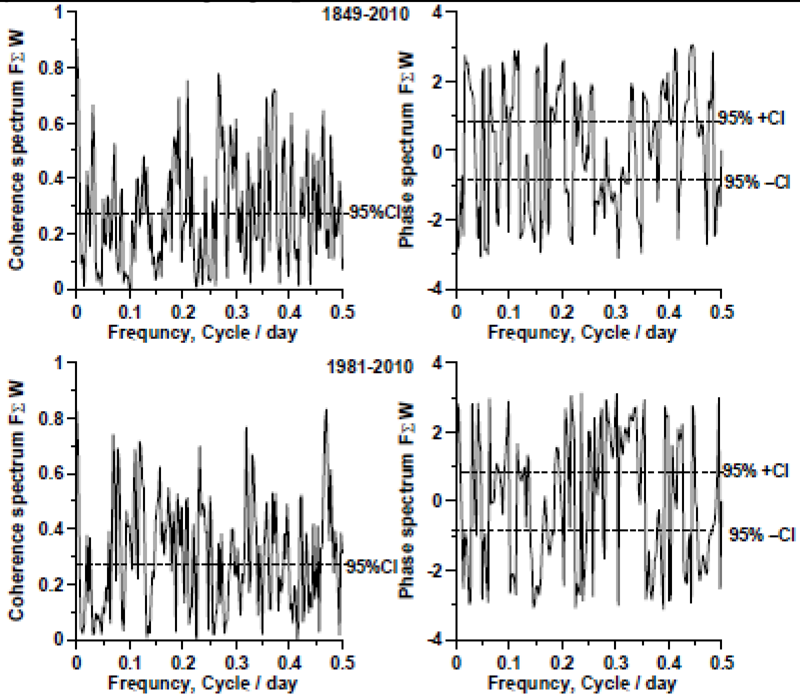


**Fig. 4. Spectrum of coherence and phase spectrum RFGI and Wolf 's number.**
**Note**: *Cl* – confidence limit.

Thus, the implemented analysis of auto- and cross-spectra of RFGI and Wolf's numbers provides the basis for believing that, probably, variations of the gravitational interaction of the Sun with the objects of the solar system make up one of the external factors determining the variations of intensity of solar activity. However, because of the limitation of opportunities of Fourier's transformation in the time-and-frequency area, the drawn conclusion cannot be accepted as 100% probability. Indeed, by virtue of Heisenberg's principle of uncertainty relating to canonically conjugated pair of "frequency-time", the best concentration of the investigated row in time area leads to a bigger "smearing" in the frequency area. As a result, it is impossible to track the *stability of this or that time period at the fixed frequency* because of limiting localization in the frequency area of kernel $e^{-i2pt}$ of Fourier's transformation. But, there is one circumstance in the results of the executed spectral analysis specifying the reality of existence of the links in the investigated processes. Above, we saw the stability of spectra of averages for each day of RFGI and Wolf's numbers received on two samples with different time ranges. The ability of Fourier's transformation to focus in the point "smeared" by time the information on the periodicity of the investigated row during transition from time area to frequency, becomes determining when *stationary* processes are investigated. It is the circumstance considering stability in the time of processes investigated in this work serves an argument in favor of the reality of their links.

Further on, with a view of the profound analysis of presence (absence) of links of the investigated processes with time periods of RFGI and Wolf's numbers, the wavelet analysis has been applied.

**2. Duration Frequency Transformation – Wavelet Analysis.** Wavelet decomposition *W (a, b),* an amplitude wavelet function, is represented by the equation [13]:

$$W(a,b) = \frac{1}{n(a.b))} \sum_{i=1}^{N-1} f_k(t) \times \vartheta^* \left(\frac{t_k - b}{a}\right), \quad (9)$$

where $\vartheta^* \left(\frac{t_k - b}{a}\right)$ – parent complex conjugate of the wavelet function (a kernel wavelet),

$$n(a,b) = \sum_{k=0}^{N-1} e^{-0,5\left(\frac{t_k-b}{a}\right)},$$

$t_k$ – time readout of some length $N$ realizations of are set up with step Δt; $a_i$ - *scale* ($i=0,1,$ …, $N_a$-1), $b_j$ - *shift* ($j$ = 0,1, …, $N_b$-1) – discrete multiplicity of values of arguments of the function (9), determined by formulas:

$$a_{min} = \frac{2\Delta t}{\sqrt{2}}, a_{max} = \frac{(N-1)\Delta t}{\sqrt{2}};$$

$$b_{min} \geq 0, b_{max} \leq (N-1)\,\Delta\, t.$$

Integrated spectrum of energy or skeylogramm

$$G(a_i) = \frac{1}{N}\sum_{j=b_{min}}^{b_{max}} S(a_i, b_j) - \tag{10}$$

– direct analogue of spectral density, but its spectrum of fluctuations is always more smooth.

In (10) $S(a_i, b_j) = |W(a_i, b_j)|^2$ is a power spectrum or scalogram.

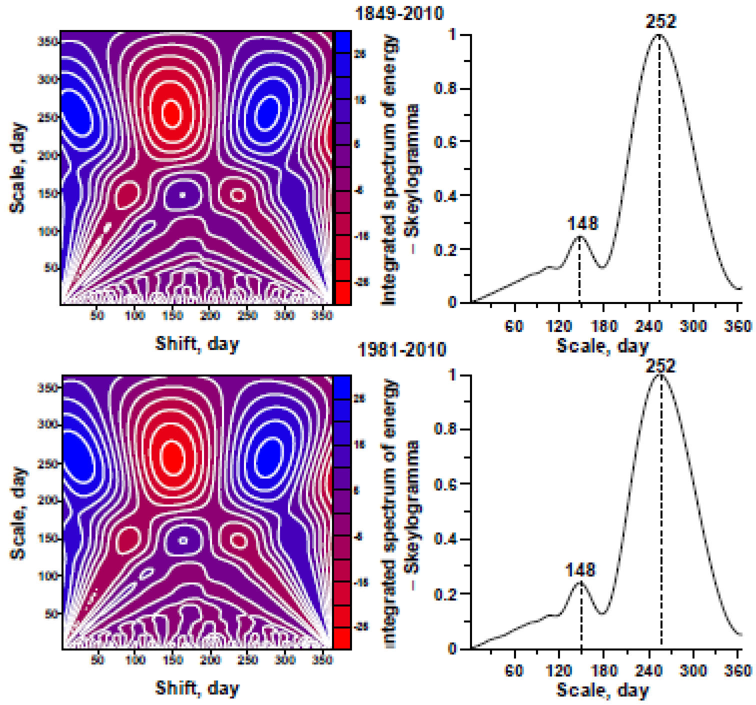


**Fig. 5. The amplitude wavelet function (on the left) and an integrated wavelet-spectrum of energy (skeylogramm, on the right) average for each day of the RFGI year on 30-year and 162-year rows.**

In fig. 5, results of the wavelet transformation of the averages for each day of the year of the resultant forces of gravitational interaction (RFGI) of the Sun with the objects of the solar system, and in fig. 6, the same transformation for Wolf's numbers are shown. The result has surpassed all expectations. Indeed, comparing these two figures one can possibly draw a conclusion that they reflect the same process. Only the careful analysis allows seeing their insignificant differences, mainly in high-frequency area. Integrated wavelet spectra (skeylogramm) practically coincide with that only one difference: in Wolf's numbers on a 30-year sample skeylogramm two peaks with 27- and 62-day periods that are missing on the skeylogramm calculated on the 162-year sample both for RFGI and Wolf's numbers. This result already allows, practically with 100% probability, ascertain conditionality of the variations of pressure of solar activity variations of gravitational interaction of the Sun with planets. Nevertheless, to dot all «i» and cross all «t», we shall address to causal analysis.

**3. The Causal Analysis.** In accordance with the above stated tools of causal analysis (section 2), conditional and unconditional entropies of the resultant force of gravitational interaction of the Sun with the objects of solar system and Wolf's numbers (7) calculated by the rows of averages for each day of the year calculated from the 162-year random samples of data, their corresponding functions of According to distribution of entropy characteristics and, accordingly, functions of independence in a greater part of the range of positive shifts («consequence» is lagging behind in relation to «cause» - area of normal causality in the entropy diagram (рис.2)); function of causality ϒ <1. Hence, maximal reaction of solar activity on RFGI is shown with about a three-day delay. With negative shifts («consequence» advances «cause» – the reverse causality area), ϒ≥1.

Thus, the causal analysis, as well as above executed spectral and wavelet analyses, allow to approve, that variations of gravitational interaction of the Sun with planets act as the external factor causing variations of pressure of solar activity.

**Conclusion.** Conclusion of R. H. Cameron and M. Schűssler [5]: «*The statistical test proposed by Abreu et al.* [1], *a comparison of the coincidences of spectral peaks from time series of planetary torques and cosmogenic isotopes (taken as a proxy for solar activity in the past) with red and white noise, is logically unable to substantiate a causal relation between solar activity and planetary orbits»* is formally consistent, but actually erroneous. This happens, and this is not a unique case when the formalized statistical tools applied to physical processes fail.

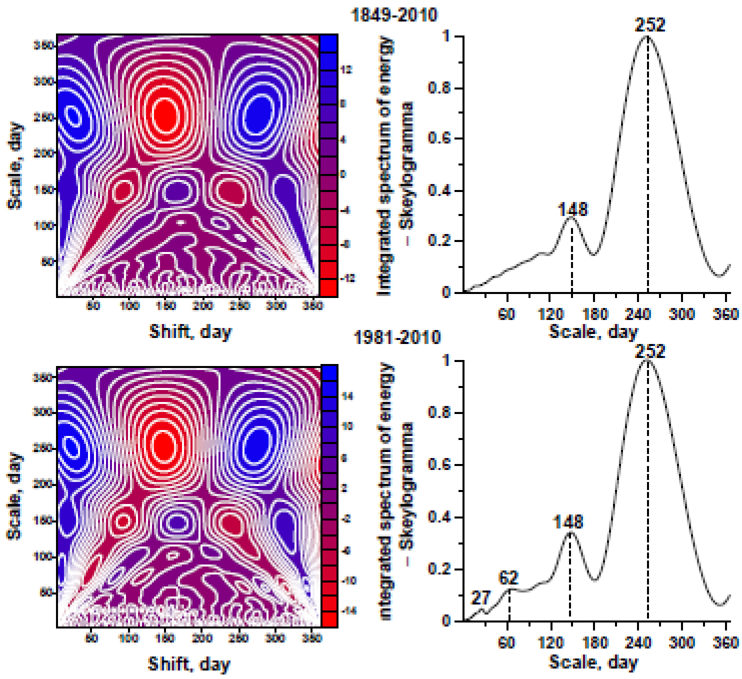


**Fig. 6. The same, that is in fig. 5 for Wolf 's numbers**

Let's note, that distribution of correlation as the time shift function, for shifts Δt ≥ –50 and Δt≤+100 days displays negative correlation between the RFGI and Wolf's numbers (fig. 8).

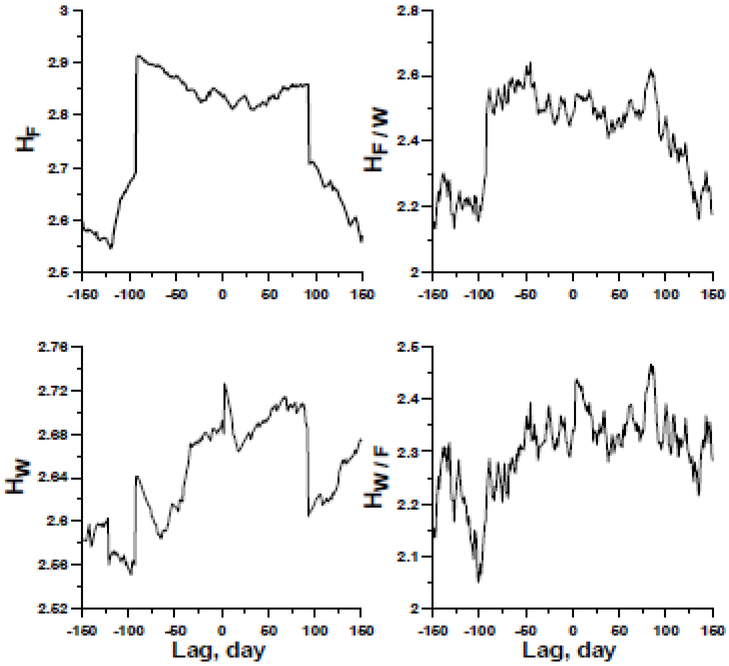

**Fig. 7. Unconditional ($H_F$, $H_w$) and contingencies ($H_{f|W}$, $H_{W|F}$) entropy processes studied**

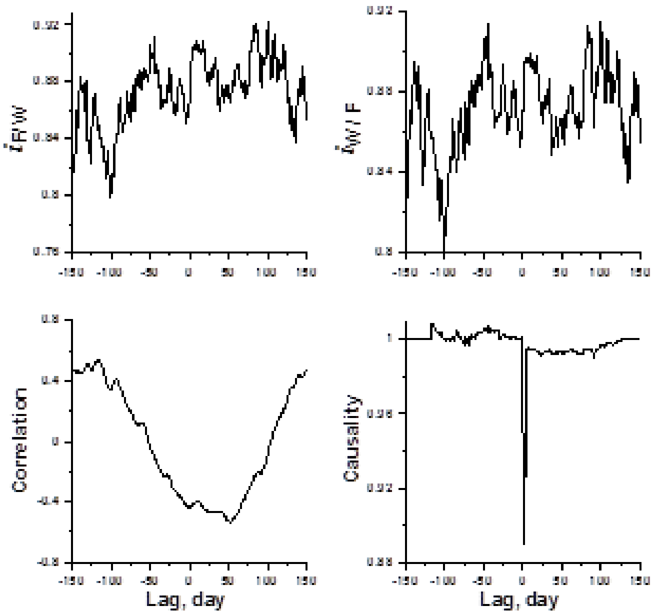

**Fig. 8. Functions of independence, correlation and causality of researched processes**

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