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SYNCHRONIZATION OF HEART RATES AND GEOMAGNETIC FIELD VARIATIONS: A PILOT STUDY

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Abstract

The project "Heliobiology" (2011 – 2015) reflects the intense interest towards the influence of solar activity on the human health. One of its tasks is to study the putative relationship between geomagnetic activity and the changes of heart rate variability in healthy volunteers.

The paper presents the first results from 5 simultaneous experiments performed in 2013 at 3 different latitudes - Sofia, Moscow and Arkhangelsk. The aim of the experiment is to study the degree of conjugation of the heart rate variability with the variations of the geomagnetic field.

To minimize the experimental bias one and the same hard- and software is applied during the testing. ECG signals are recorder via "KARDI-2"; the software package is "Ecosan-2007", both developed by "Medical Computer Systems", Zelenograd, Russia. The duration of the observations ranged from 60 to 100 minutes. A comparison of the dynamics of the minute variations of the heart rate with the horizontal components of the geomagnetic field vector has revealed a synchronization of the research parameters. Further experiments are planned in the years to come to confirm the results in a larger experimental group.

Introduction

Geomagnetic field is a natural phenomenon. When the Earth was formed 4.5 billion years ago magnetic fields were already present.

Long before the appearance of human species, almost 2 billion years ago, marine magnetotactic bacteria evolved. Magnetotactic bacteria developed membrane-encapsulated nano-particles known as magnetosomes. Magnetosomes allowed and still permit bacteria to orient themselves along the Earth's magnetic field lines in order to migrate to more favorable environments. Magnetosomes are result of Earth's evolution. They contain the iron-oxygen composite, magnetite, and presumed to play a key role in navigation. Magnetosomes are widely speared over various species. Example is the avian magnetic compass, developed 90 million years ago, enabling pigeons to detect magnetic field changes from 20 nT to 0.02 μT or even lower. To put it short: Geomagnetic sensitivity is phylogenetically widespread. It exists in fishes, major groups of vertebrate animals (chickens, mole rats, etc.), as well as in some mollusks, crustaceans and insects [1] Humans are not an exception.

When humans are concerned the impact of the geomagnetic field (GMF) variations on health is an underexplored area. Studies revealed that geomagnetic variations may causes changes in the normal functioning of the central and vegetative nervous systems, cardiovascular system and cognitive performance [2-7]. It is already accepted that:

- A subset of the human population (10-15%) is not only sensitive but a bona fide hypersensitive and predisposed to adverse health problems due to geomagnetic variations;
- Extremely high as well as extremely low values of geomagnetic activity seem to have opposing health effects;
- Geomagnetic effects are more pronounced at higher magnetic latitudes.

The biological mechanism of geomagnetic variations on human health is not clear. Researchers are trying hard to understand magnetic sensitivity which still remains one of nature's extraordinary secrets. During last decades two theories are widely discussed. According to the first melatonin hypotheses temporal geomagnetic variations are acting as an additional zeitgeber (a temporal synchronizer) for circadian rhythms. The second, Cryptochrome gene hypothesis, considers that changes in the geomagnetic field are mediating stress responses more broadly across the hypothalamic–pituitary–adrenal axis. To use different wording – in both cases the reactions of biological systems to geomagnetic field variations is supposed to be evident when the main frequencies present in the spectrum of geomagnetic fluctuations is similar to the main frequencies of the physiological processes [8-11]. Despite of the fact that some experimental results supporting the above statement were published recently [12] sufficient amount of experimental data with humans is still lacking. The authors of this paper have already found similar periods in the spectra of the heart rate variations and in the vector components of GMP in the milli hertz frequency range. The periods were not only similar but they appeared and disappeared at one and the same time. The synchronization effect was observed in small group of health volunteers [13-14].

It is well-known that the decreasing of the geographical latitude results in a reduction of the amplitude variations of the magnetic field vector. The aim of this experiment is to study the degree of conjugation of the heart rate variability and the variations of the geomagnetic field at one hand and its dependence on the latitude of the place of observation on the other. To do this, simultaneous monitoring of heart rate variability of healthy volunteers was conducted at three geographic locations.

Methodology

At the very beginning it is necessary to underline that the experiment is difficult and time consuming. It is also connected with lots of ethical principles that have to be respected and were followed strictly, i.e. (a) an informed consent from research participants was obtain before the experiment; (b) the risk of harm to participants was minimized; (c) participants had the right to withdraw from the research; (d) deceptive practices were avoided; and (e) participants anonymity and confidentiality is protected and their real names will not be revealed. In this paper the participants or subjects are marked as No. 1, No. 2 etc.

Subjects are 5 healthy volunteers, women, mean age 39,4 years – 1 in Sofia, 2 in Moscow and 2 in Arkhangelsk.

Locations of the experiment and their latitudes are: Sofia, Bulgaria 42° 40' N 23° 20' E; Moscow, Russia 55° 45' N 37 ° 36‘ E and Arkhangelsk, Russia 64° 34' N / 40° 32' E.

The procedure is as follows: Monitoring of heart rate activity is performed simultaneously in the 3 locations. The four leads electrocardiogram (ECG) is recorded at rest, in a supine position, after a 10-

minute adaptation. There are specific dietary requirements to be followed 24 hours before the experiments, i.e. exclusion of some types of drugs, natural stimulants, etc.

To minimize any potential bias of the results one and the same device, specified for measuring electrical micro alternation of ECG, Kardi-2, is used. The software package is "Ecosan-2007". Both are developed by "Medical Computer Systems", Zelenograd, Russia. The duration of the observation periods ranged from 60 to 100 minutes.

Parameters used in the analysis are:

- Physiological - the minute values of heart rate (HR);
- Geophysical – the minute values the horizontal components of the geomagnetic field.

Geomagnetic data were derived from 2 geomagnetic stations for each location, i.e.

- For Archangel (64° 34' N / 40° 32' E) data from the geomagnetic stations Sodankyla (SOD, 67.400 26.600) and Nurmijarvi (NUR, 60.500 N, 24.600 E) were used;
- For Moscow (55° 45' N / 37° 36' E) data from the geomagnetic stations Borok (BOX, 58.070 N, 38.230 E) and Kiev (KIV, 50.70 N, 30.30 E) were used;
- For Sofia (42° 40 N/ 23° 20 E) data from the geomagnetic stations Panagjurishte (PAG, 42.50 N, 24.20 E) and Surlari (SUA, 44.68 N, 26.25 E) were used.

The INTERMAGNET network (International Real-time Magnetic Observatory Network, http://ottawa.intermagnet.org/Welcom_e.php) listed for free all these data.

The aim of the experiment is to look for synchronized minute variations of the heart rate indices that match the minute variations GMF.

Analysis and Results

MATLAB R2010a software was applied for the analysis. Priory the calculations the linear trend was excluded from all analyzed time series. To delete a range of high-frequency noise, the constant component of the signal and the linear trend, the records were passed through a band pass filter with a Blackman-Harris window with the values of the lower and upper cut-off frequencies, respectively, 0.025 and 0.95 of the Nyquist frequency.

When physiological parameters are concerned important is not only the presence or absence of a certain period in the signal spectrum, but also the time of its appearance and disappearance. The records analyzed in these experiments were relatively short – from 60 up to 100 minutes. This does not allow applying the method of spectral-temporal transformation. A more convenient for this case, the method of wavelet transformation (applied in digital signal processing and exploration geophysics) with the basic function of Morlet [15] is used.

To make the comparison of the results easier, large-scale parameters obtained in the wavelet analysis, have been converted into temporary characteristics similar to the period of oscillation in the spectral analysis.

Geomagnetic conditions at the time of observation: The geomagnetic activity was low in the days of the experiments. The values of the three-hour Kp index at the time of the experiments ranged from 0 to 1.7 according ftp://ftp.ngdc.noaa.gov/STP/GEOMAGNETIC_DATA/INDICES/KP_AP

The horizontal components of the GMF at the time of the experiments are presented at Fig. 1. Time series are shown after applying thereto a band pass filter, i.e. bring them to a form suitable for comparison with the physiological data.

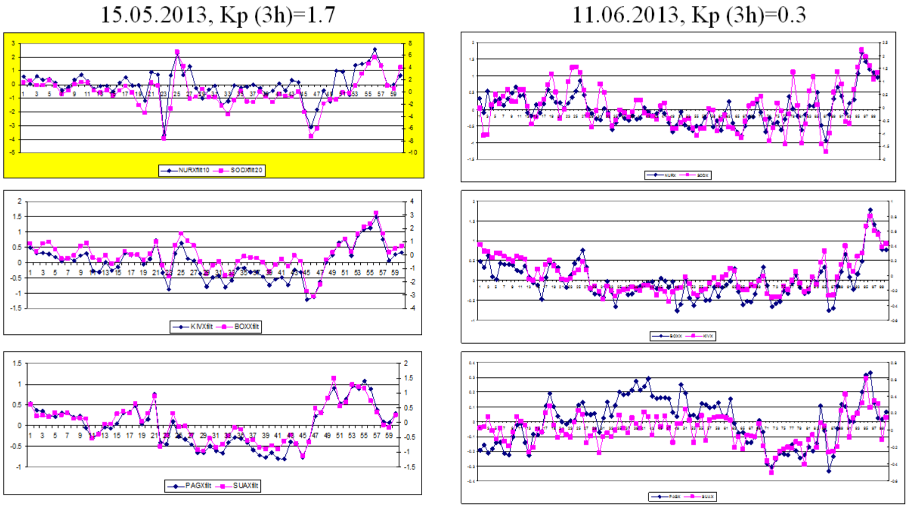

Fig. 1. Comparative dynamics of the horizontal components of the geomagnetic field at the time of one of the synchronous experiments (15.05.2013, 07-08 UT)

The figure reveals that the variations of the horizontal component of the GMF are very close despite of the significant distance between the recording stations. At the same time, the comparison of the GMF variations at different latitudes and the comparison of the magnitude scales show that the amplitude of the rapid variations decreases with the decreasing latitude, a fact that is in correspondence within the nowadays understanding of the behavior of GMF variations. Such a comparative analysis was performed for all five experiments.

In contrast to the horizontal X-component, the minute variation of the vertical component Z of GMF is highly dependent on the underlying surface at the point of measurement. As the experiments are performed far away from the recording geomagnetic stations, the dynamics of the Z-components cannot be used in the statistical analysis.

Figures 2 and 3 present the results of wavelet analyses of two out of the five experiments.

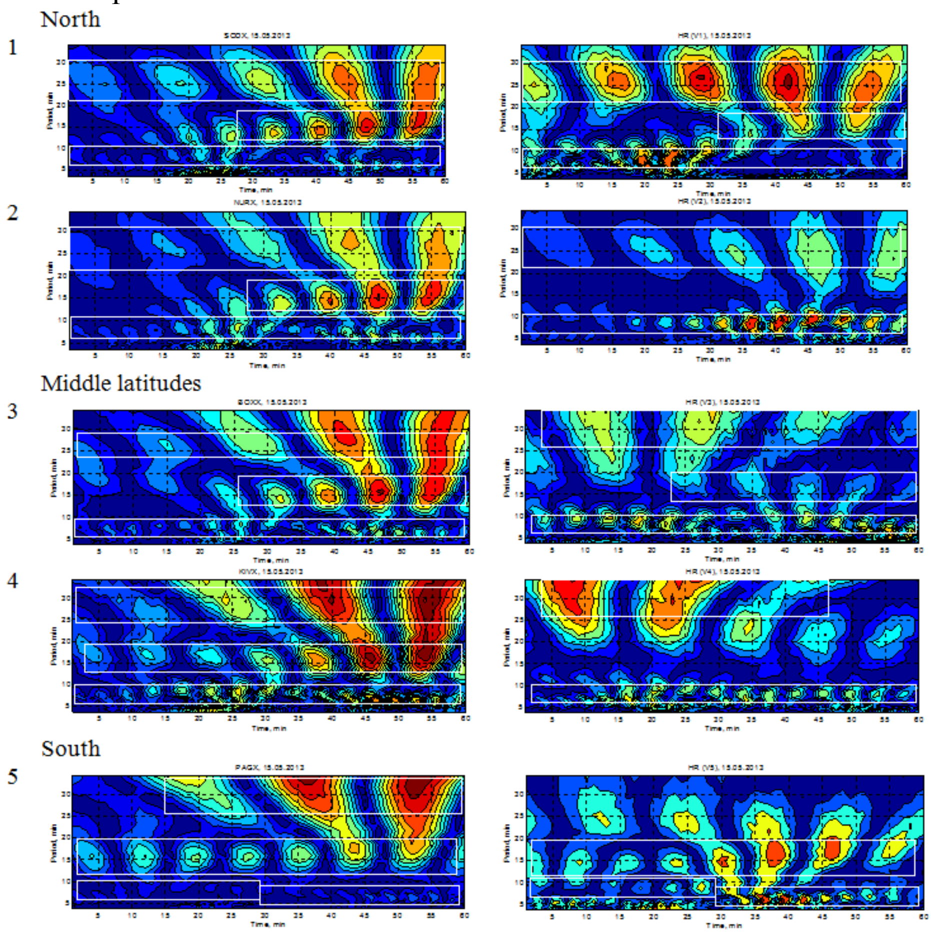

Fig. 2. The wavelet transform of time series of geophysical and physiological data, 15.05.2013

Fig. 2 reveals the results from experiments performed on 15.05.2013, starting at 7 UT. The left column contains the wavelet images of minute variations of GMF. The order of the data is as follows (1) Sodankyla (67.4167° N, 26.5833° E), (2) Nurmijarvi (60.4667° N, 24.8083° E), (3) Borok (49° 51' 0" N, 31° 34' 0" E), (4) Kiev (50.4500° N, 30.5233° E), (5) Panagjurishte (42.5000° N, 24.1833° E), i.e. the latitude is descending. The right column contains images of wavelet time-series of the heart rate data, measured in corresponding latitudes - (1) and (2) are subjects No.1 and No.2 in Arkhangelsk , (3) and (4) – subjects No. 3 and No. 4 in Moscow while No. 5 - in Sofia.

Applying wavelet analyses similarities were searched for in the patterns of variation of GMF and heart rates. No matter whether the geomagnetic data or the heart rates were analyzed, the following requirements were fixed - periods must not be smaller than 3 and not larger than 33. The boundaries of 3 and 33 gave the chance to delete noise and yet to "catch" available periods in the data. The upper level of 33 was chosen as the experimental lines of the physiological measurements in part of the experiments do not exceed 60 minutes. Thus even if there are only 2 periods during an experiment, they will be marked. The upper level 33 also explains why on the Y axes the maximum mark is 35.

The analysis of the five figures in the left column reveals 3 periods in horizontal variations of the components of the GMF – 7-10 minutes, 15 minutes and 25-28 minutes. They are indicated with white rectangles on the figure. The first period (7-10 minutes), although present in all measure, has a lower intensity and is less pronounced in the southern latitude (5). The second one (15 minutes) is observed during all the experiments in the southern latitudes. It is also evident in middle latitudes (parts 1-3) too but with a slight delay - approximately after 30 minutes from the beginning of the experiment. On the contrary, the third period (25-28 minutes), is visible throughout the experiment in northern latitudes (with increasing amplitude to the end of the experiment), while at the southern (5) is exposed as separate perturbations somewhat to the second half of the experiment.

The comparisons of the dynamics of the heart rate variability and the GMF variations have a significant number of matches. Thus, for subjects No. 1-4 wavelet spectra reveals a period 25-27 minutes. Its amplitude is increasing in the second half of the experiment especially in the data of subjects No. 1 and 2, tested in the most northern location, i.e. the dynamic is similar to the variations in the geophysical rows.

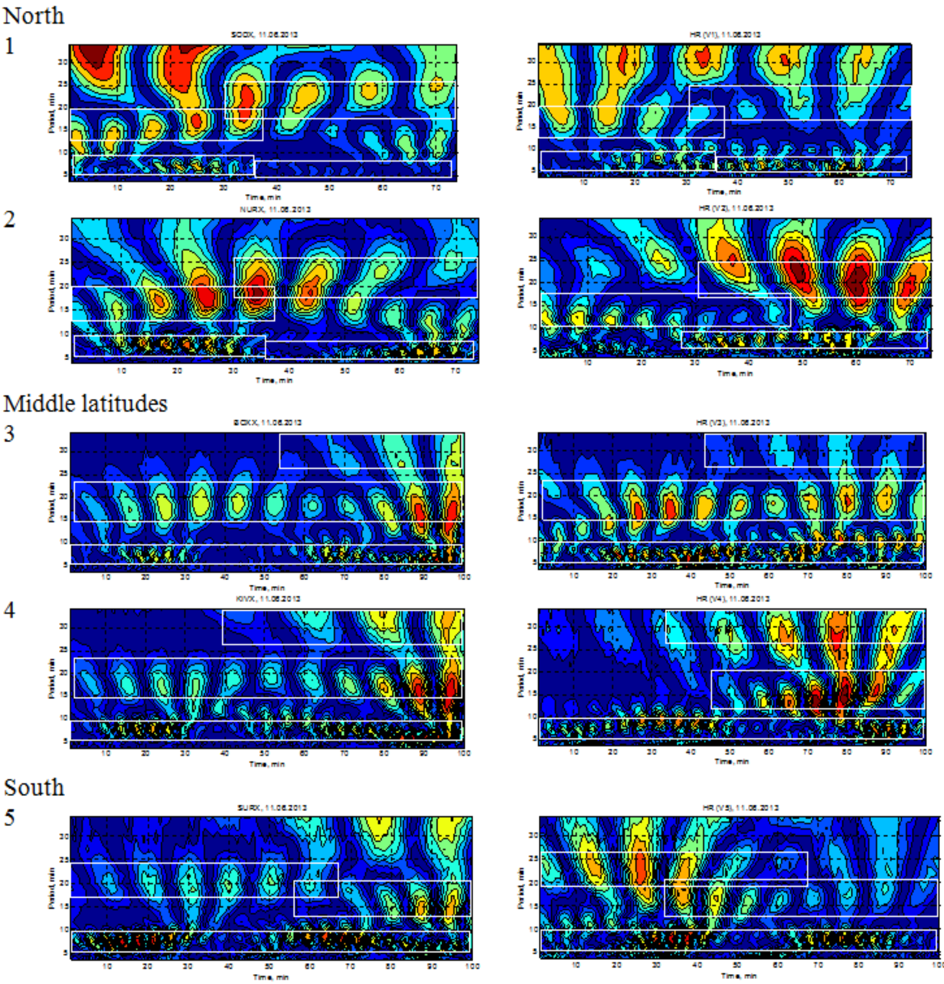

Fig. 3. The wavelet transform of time series of geophysical and physiological data, 11.06.2013

A 15 minutes period is evident in the southern latitudes. It is clearly visible throughout the entire experiment in both physiological and geophysical data. To a larger extent it is also present in the results of subjects No. 1 and 3 in the second half of the experiment and is observed as a decrease in the value of the longer, 27 -minute, period.

A period of 9-10 minutes, rather similar to the 7-10 minutes period revealed in the geophysical series, is detected in the physiological records of all 5 subjects. The fact that the time of the maximum amplitude of this period is different for different subjects is not a surprise. Even though strong emotional stimuli were excluded from the experimental environment, short-term (1-2 min) changes in the level of heart rate may be result of differences in personalities of the subject participating in the experiment or be provoked from their thoughts.

Figure 3 shows the results of an experiment conducted by 11.06.2013, starting time of the experiment – 7 UT. The dynamics of the horizontal component of the GMF variation is on the right side, while the left side presents the heart rate variability.

The comparative analysis of the different spectral components of the geomagnetic variations at different latitudes discloses that a period of 7-10 minutes, despite of changes in its intensity, is represented in all five wavelet spectra over the entire period of the observation. The same period is shown in all wavelet spectra of the heart rate variations.

Another period that is detected is a 15-20 minutes one. The dynamics of this period is different at different latitudes. It started as a 15 minutes period in the Northern latitude during the first half of the experiment. 30 minutes after the beginning of the experiment it increases to 20-23 minutes. In the middle latitudes (BOXX and KIVX) its value is approximately constant at 17 minutes, while in the South is 20 minutes in the first half and 15 in the second half of the observation. A similar trend is revealed in the variability of the physiological data. The match between the geophysical variability and heart rate variability is rather good in 3 out of 5 subjects tested (No. 1, 3 and 5).

Individual differences between subjects taking part in the experiment could also be detected. For example, heart rate variability of subject No. 4 demonstrates a period of 15 minutes only the second half of the experiment, whereas GMF values in middle latitudes contained a period of 20 minutes during the entire observation period.

The result of the analyses all five experiments are summarized in Table 1.

Table 1

	19.04.2013	15.05.2013	17.05.2013	11.06.2013	13.06.2013
No. 1					
No. 2			No measures		
No. 3					
No. 4					
No. 5	No measures				

The grey color indicates the “full” matches between geophysical data and heart rate data, i.e. the trends, moments of appearance and the end of the periods, changes in the average. Such matches are especially evident in the records of subject No. 3 on Fig. 2 and 3.

The white (no color) color indicates the experiments in which there are small fragments that are not presented simultaneously in both geophysical and physiological data lines, despite of the fact that all other parameters match. Example is the record of subject No. 5 from 15.05.2013. During that experiment only 2 out of 3 periods are matching. The dark grey color indicates very weak match, i.e. the there is only one period of coincidence as for examples data received from subject No. 4 on 15.05.0213.

Conclusion

The pilot experiments revealed that the matches of the variations of heart rates and the variations of the horizontal component of the geomagnetic vector are observed not only in the North but also in the southern latitudes. The sample presented in this paper is not sufficient to make firm conclusion about the correlation between the trends in the variability of GMF vector and physiological parameters recorded. More extensive study is required. However, the results received demonstrate that it is worth dedicating efforts and time to study the above mentioned trend in more details as well as to expect strong correlation. Based on the results summarize in Table 1 the conclusion is that event in the available small sample size (5 subjects per 5 measures) 47,8% (grey color) of the data revealed fully matching of geophysical and physiological data. In additional 30,4% the variation trends of the physiological and geophysical parameters is high although not entirely identical (white color). Or, in 78,2% of the experimental data a similar patterns of variation of geophysical and heart rate variability is recorded.

Experiments, as those described in this paper, are important. The experiments discussed in the paper involved healthy volunteers, i.e. people that have good adaptation reserves, and the response to variation of GMF will not push them beyond the physiological norms. However, for people suffering from cardiovascular diseases such as instability of sinus node function, external factors affecting the generation of the cardiac impulse and controlling the heart rate may cause serious problems. The observed effect of synchronization of heart rate fluctuations of healthy subjects with fluctuations in GMF may give us an effective tool to address further one of the most important tasks geliobiophysics – the revealing the mechanism of geomagnetic sensitivity.

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СИНХРОНИЗАЦИЯ НА ВАРИАБИЛНОСТИТЕ НА СЪРДЕЧНИЯ РИТЪМ И ГЕОМАГНИТНОТО ПОЛЕ: ПИЛОТНО ПРОУЧВАНЕ

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Резюме

Проектът "Heliobiology" (2011 - 2015) отразява големия интерес към влиянието на слънчевата активност върху здравето на човека. Една от задачите му е да проучи предполагаемата връзка между геомагнитната активност и промените на вариабилността на сърдечната честота при здрави доброволци.

Статията представя първите резултати от 5 едновременни експерименти, извършени през 2013 г. в три различни географски ширини - София , Москва и Архангелск . Целта на експеримента е да се изследва степента на съответствие във вариабилността на сърдечната честота и вариации на геомагнитното поле.

За да се намали влиянието на редица странични фактори една и съща апаратура се използва за регистрация на сърдечните параметри и в трите града. Тава е ЕКГ холтер "Kardi -2" със софтуерен пакет е

"Екосан - 2007", разработени от " Медицински компютърни системи", Зеленгород, Русия. Продължителността на експериментите варира от 60 до 100 минути. Сравнението на динамиката на минутните промени в сърдечната честота с хоризонталната компонента на вектора на геомагнитното поле разкри синхронизация на изследваните параметри независимо от географската ширина. Допълнителни експерименти са планирани в следващите години, за да се потвърдят резултатите на по-голяма експериментална група.