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THE USE OF THE RI NAO FEDCHENKO ASTRONOMICAL CLOCK TO RECORD ANOMALOUS FEATURES OF SEISMIC WAVES FROM EARTHQUAKE SOURCES

Shulga Alexandr V.[1)], Bushuev Felix I.[1)], Kalyuzhny Nikolay A.[1)], Kulichenko Nikolay A.[1)], Slivinsky Alexandr P.[2)], Lazarenko Mihail A.[3)]

[1)] Research Institute «Nikolaev Astronomical Observatory» (RI NAO), Nikolaev, Ukraine.

[2)] Ukraine Radio Engineering Institute (URTI), Nikolaev, Ukraine.

[3)] Institute of Geophysics National Academy of Science of Ukraine (IG NASU), Kiev, Ukraine.

1. Registration of seismic disturbances in the RI NAO.

Currently seismic disturbances are recorded in the RI NAO using:

– An automatic digital seismic station (ASS) equipped with a broadband seismic receiver;

– A hardware and software complex (HSC) recorded of Fedchenko astronomical clocks (FAC) readings.

The ASS (alias NE07) developed by the Institute of Geophysics, National Academy of Sciences, was installed in the RI NAO in September 2009. The data access address is http://seismodata.geo.org.ua. A photo of the seismic station is shown in Fig. 1.

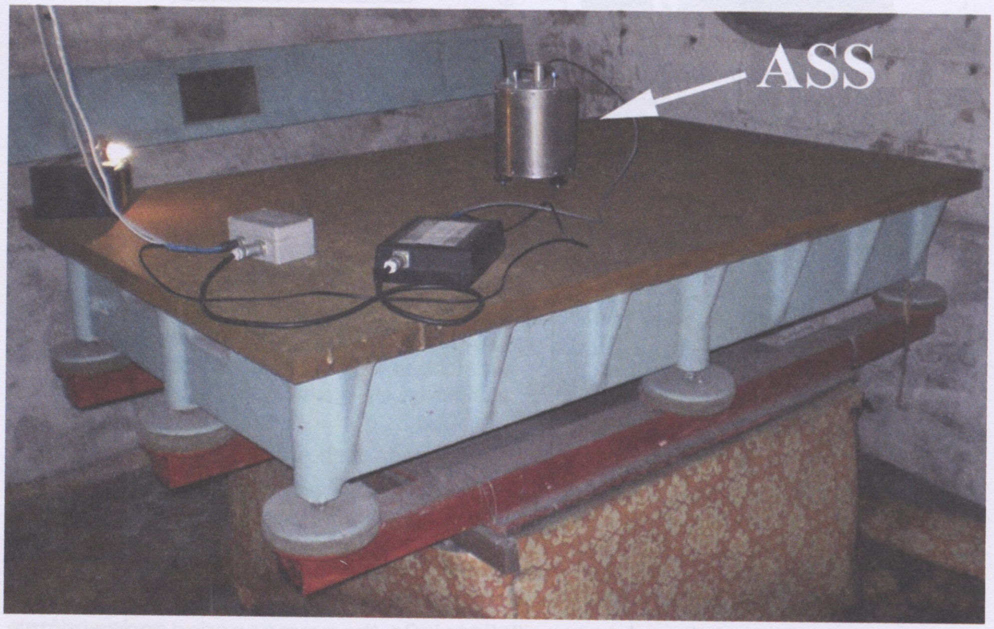

Fig. 1. The automatic digital seismic station of the IG NASU installed in the basement of the main building of the RI NAO on a massive foundation

The hardware and software complex for recording of the Fedchenko astronomical pendulum clocks readings operates in the RI NAO from the end of 2005. A photo and a structure diagram of the FAC are shown in Fig. 2, and a block diagram of the HSC is shown in Fig. 3.

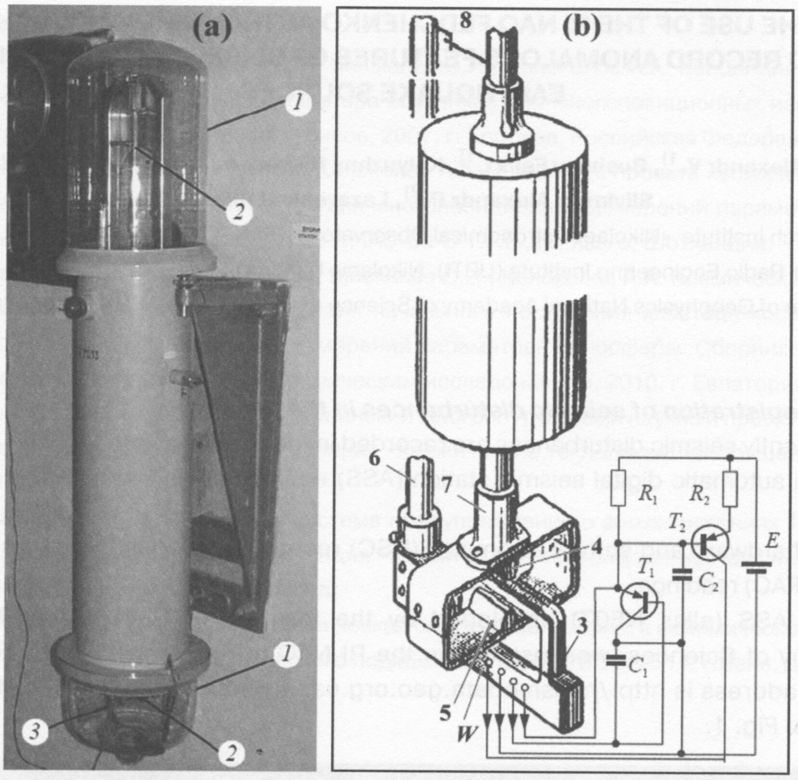

Fig. 2. The photo (a) and the structure diagram (b) of the FAC. Notes: 1) a hermetic flask, the vacuum inside is supported at the ~4 mm of mercury column level; 2) a pendulum consisting of a 8 kg load, a steel rod (7) and permanent magnets (4) and (5); 3) a non-sliding coil of the clock power system; 4) and 5) the permanent magnets; 6) a non-sliding steel rod 7) the sliding steel rod; 8) platinum contacts.

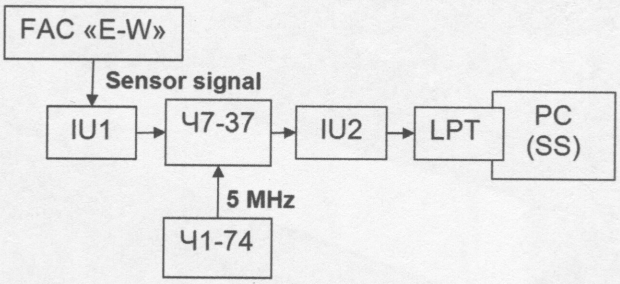

Fig. 3. The HSC block diagram of recording of FAC readings. Legend: "E-W" – "east-west" orientation of the swing plane of the pendulum; IU1 and IU2 – interface units; Ч1-74 – rubidium frequency standard; Ч7-37 – synchronometer, the device for precision measuring of time intervals; PC – personal computer; LPT – parallel port of the PC; SS – special software

The assumed period of pendulum oscillations is 2 s, the average period approximately 18 microseconds more. The orientation of the swing plane is east-west. In addition to the FAC, the HSC consists of a rubidium frequency standard Ч1-74, a synchronometer Ч7-37 (the device for precision measuring of time intervals), an interface unit between the clock and the synchronometer (IU1) and an interface unit (IU2) between the synchronometer and parallel port of personal computer (PC). Each time the platinum contact-breaking occurs synchronometer readings (hours, minutes, seconds and fraction of second up to 10^{-8} s) are sent at the input of the PC. Special software (SS) has been developed to write them to the hard drive. The difference between two adjacent synchronometer readings corresponds to the current value of oscillation period of the FAC pendulum. Deviations (ΔP) of a current period from the average value calculated during a specific time interval characterize perturbations of oscillation period of the pendulum, and named further "FAC readings". Detailed description of the HSC and processing technique of the observed data can be found in [1, 2]. Note that from January 2011 the synchronometer readings are sent at the input of the PC by the signal of photodiode sensor that triggered when the pendulum's rod is crossing the beam of a semiconductor laser.

2. Anomalies of FAC readings caused by the arrival of seismic waves from strong earthquakes.

The 154 cases of abnormal deviations of the oscillation period of the FAC pendulum due to the arrival of seismic waves from strong earthquakes have been recorded since the start of the regular registration in October 2005 and up to December 2010. About half of them simultaneously have been observed on seismic recordings of the ASS NE07 readings. As an example the FAC readings are shown in Fig. 4 for one hour before and one hour after the arrival in Nikolaev the seismic wave from a severe earthquake occurred in Pakistan on 10.08.2005 at 03:50:38 UTC . Magnitude M of the earthquake was equal to 7.6.

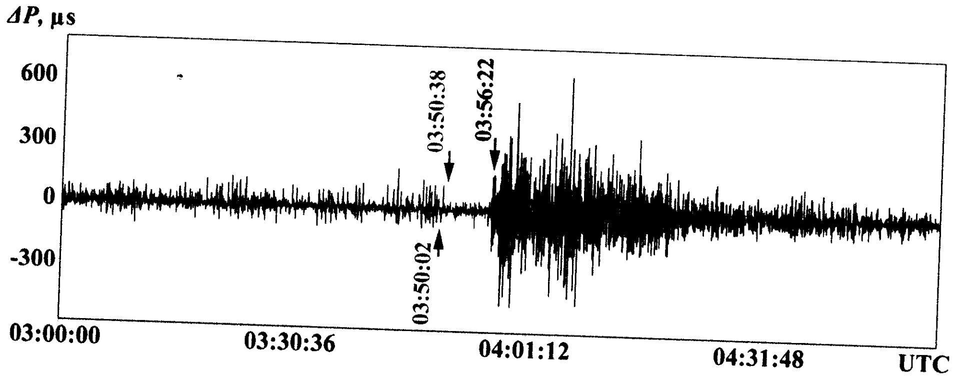

Fig. 4. The FAC readings corresponding the arrival of seismic wave from a severe earthquake (M = 7.6) occurred in Pakistan on 08.10.2005. Legend: 03:50:38 – moment of the earthquake in Pakistan, 03:50:02 – start time of the decrease of FAC readings dispersion and 03:56:22 – time of the arrival of the seismic wave in Nikolaev

In accordance with the data shown in Fig. 4 there is a significant decreasing of the dispersion of background readings of the FAC before the arrival of the seismic wave in Nikolaev. The significant decreasing began at 03:50:03 UTC or about half a minute before the moment of the earthquake in Pakistan.

3. Anomalies of FAC readings prior the arrival of seismic waves from strong earthquakes.

Among the 154 cases there are 57 cases when the decrease of background dispersion of the period of FAC pendulum swing is observed a few minutes before the arrival of seismic waves. The analysis showed that similar decreases of dispersion were not observed according to data of seismic station NE07 in all cases of simultaneous recording of the arrival of seismic waves. This fact is illustrated in Fig. 5, which contains seismograms of the ASS NE07 and FAC readings corresponding to the arrival of seismic wave from an earthquake in the Ionian Sea occurred on 03.11.2009 at 05:25:11 UTC (M = 5.7).

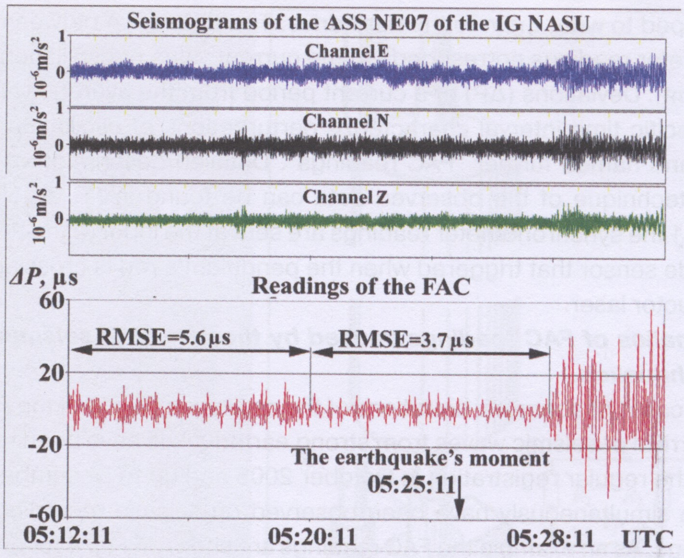

Fig. 5. Seismograms of the ASS NE07 of the IG NASU and FAC readings corresponding the arrival of seismic wave from an earthquake in the Ionian Sea occurred on 11.03.2009 (M = 5.7).

In accordance with the data shown in Fig. 5, the time points when the seismic wave front arrived and which could be detected as by the FAC readings and by the readings of the seismic station almost completely coincide. Anomalous decrease in the root mean square error (RMSE) of noise of the FAC readings, from 5.6 to 3.7 microseconds, occurred about 5 minutes before the earthquake's moment which is marked in the figure by the arrow. Similar decrease of noise dispersion is not observed on the seismograms of the ASS NE07.

4. Distribution in the Earth the earthquakes recorded by FAC readings.

The phenomenon of decreasing the dispersion of FAC readings before the arrival of a seismic wave was not observed in the all events. This may be due to the distance of an earthquake from the point of registration, its magnitude, the depth of its hypocenter, and the characteristics of medium between the hypocenter and the registration point, and the local noise conditions. Thereby it is interesting to consider the distribution over the Earth's surface the projections of hypocenters of earthquakes observed with the phenomenon of decreasing the dispersion of FAC readings. A map of the distribution of epicenters of the all earthquakes recorded in the RI NAO with the FAC is presented in Fig. 6. On the map solid triangles mark earthquakes which were observed with the phenomenon, and the rest of the earthquakes are marked by solid circles.

In accordance with the data shown in Fig. 6, the phenomenon of decreasing the dispersion frequently appeared prior to the earthquakes occurred on the Anatolian and the Eurasian tectonic plates. In Fig. 6 the solid lines show the boundaries of the Anatolian plate and a part of the Eurasian plate between 25°N ... 45°N and 50°E ... 105°E. In Fig. 7 these two areas are shown in an enlarged scale.

Let k be the ratio between the number of earthquakes with prior decreasing the dispersion and the number of earthquakes without it. Then, for the Anatolian plate k = 11:5. In general for the Eurasian plate k = 35:44, and for the part of the plate, shown in Fig. 7 (b) in an enlarged scale, k = 12:7.

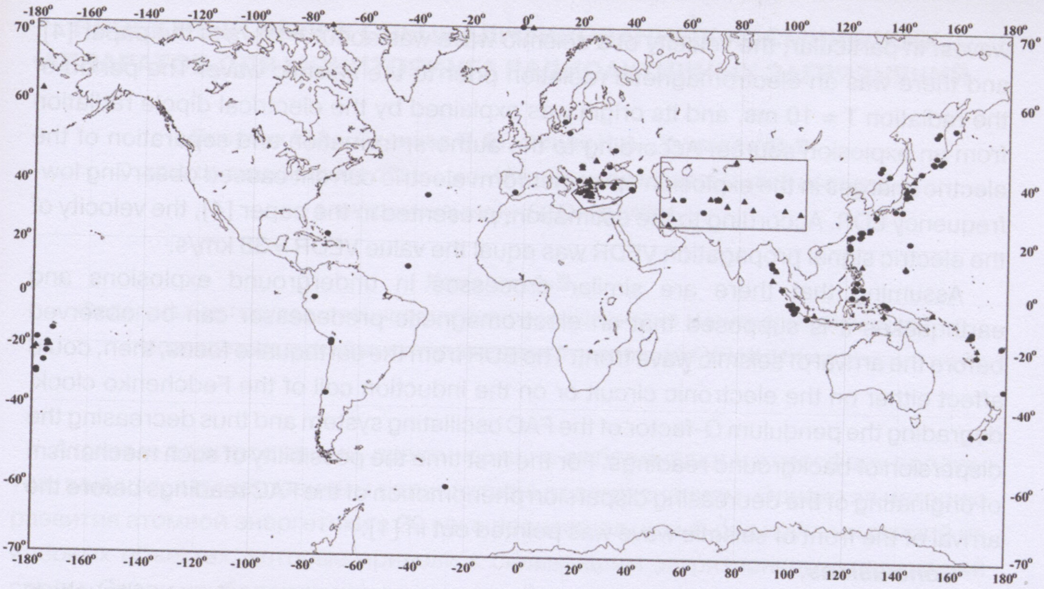

Fig. 6. The distribution in the Earth the epicenters of earthquakes recorded by FAC readings. Legend: ▲ - an earthquake observed with prior decreasing of the dispersion of FAC readings; ● - an earthquake observed without decreasing of the dispersion of the readings.

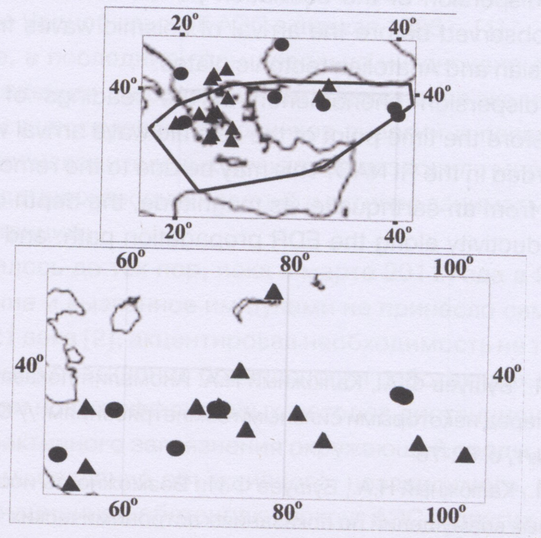

Fig. 7. (a) – the Anatolian tectonic plate (solid line), k = 11:5; (b) - part of the Eurasian tectonic plate, k = 12:7. Legend: ▲ - an earthquake observed with prior decreasing of the dispersion of FAC readings; ● - an earthquake observed without decreasing of the dispersion of the readings.

5. Possible mechanism of anomalous decreasing the dispersion of the FAC readings prior to the arrival of seismic waves.

It is known that the detonation waves occurred during explosions can generate electromagnetic radiation in a wide frequency range including the electrical dipole radiation (EDR) of very low frequency. The EDR propagation speed can be orders of magnitude less than the speed of light in vacuum. So electromagnetic radiation and seismic waves were simultaneously registered in the works [3, 4]. Their authors observed electromagnetic radiation preceded or coincided with the arrival of seismic waves. In particular, the velocity of a seismic wave was about 4 km/s in the paper [4], and there was an electromagnetic radiation prior to the seismic wave. The period of the radiation T ≈ 10 ms, and its origin was explained by the electrical dipole radiation from an explosion source. According to the authors, formation and separation of the electric charges in the explosion epicenter form electric current caused observing low-frequency EDR. According to the estimation, presented in the paper [4], the velocity of the electric signal propagation VEDR was equal the value VEDR ≈ 38 km/s.

Assuming that there are similar processes in underground explosions and earthquakes it is supposed that an electromagnetic predecessor can be observed before the arrival of seismic wave front. The EDR from the earthquake focus, then, could affect either on the electronic circuit or on the induction coil of the Fedchenko clock, degrading the pendulum Q-factor of the FAC oscillating system and thus decreasing the dispersion of background readings. For the first time the possibility of such mechanism of originating of the decreasing dispersion phenomenon of the FAC readings before the arrival of the front of seismic wave was pointed out in [1].

Conclusions.

Unlike blasting the formation of a current in the epicentral area of an earthquake is allowed as after and before the earthquake, including the formation of the current may be missing for the earthquake.

Decrease of the dispersion of the oscillation period of the FAC pendulum was the most commonly observed before the arrival of seismic waves from earthquakes occurring on the Eurasian and Anatolian tectonic plates.

The decreasing dispersion phenomenon of the readings of the Fedchenko astronomical clock before the time point of the seismic wave arrival was not observed for many events recorded in the RI NAO. This may be due to the remoteness degree of the registration point from an earthquake, its magnitude, the depth of its hypocenter, and the medium conductivity along the EDR propagation path, and the level of local noise.

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