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Observation of Solar Gravitational Waves

Chernobay IA

Associate Professor, Institute of Applied Physical Problems named after A. N. Sevchenko of the Belarusian State University, Republic of Belarus

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Abstract

To date, astronomical observations and studies have failed to detect solar gravitational waves. By developing a new, promising detection method, the author of this paper has succeeded in detecting gravitational waves emitted by the Sun. This detection method relies on ultrasonic technology, which is new and original, and enables reliable gravitational wave detection. The technology underlying the method relies on the creation of two independent measuring channels with acoustically transparent media, in which ultrasonic waves propagate in opposite directions. To ensure the method's operation in acoustically transparent media, specific nonlinear conditions for ultrasonic wave propagation are created. This transforms the ultrasonic waves into test bodies suspended continuously in the acoustically transparent media. These test bodies, in the form of ultrasonic waves, are directly exposed to gravitational waves as they propagate through nonlinear media. By differentially separating mutual alternating phase shifts and fluctuations of ultrasonic waves traveling in opposite directions through two channels of acoustically transparent nonlinear media, gravitational waves are reliably detected directly. This results in a direct effect of gravitational waves on test bodies, which represent ultrasonic waves. The physical essence of this direct effect lies in the fact that gravitational waves represent alternating accelerations propagating through space at high speed. These accelerations cause alternating accelerations of counter-propagating ultrasonic waves, which are mutually detected. This is the simplicity and fundamental nature of the detection method. The ultrasonic detector created in this way allows for continuous observation of numerous gravitational waves from our Sun. Gravitational waves and signals from numerous stars in our Galaxy, including the Universe as a whole, are also observed. Observations of solar gravitational waves have yielded evidence of their enormous propagation speed compared to the speed of light. In particular, it has been found that the propagation speed of gravitational waves is at least three orders of magnitude greater than the speed of optical waves. The detector allows selective listening to solar gravitational waves in the audio frequency range. Evidence has been obtained that, in most observations, the signal level of solar gravitational waves caused by coronal mass ejections or local solar flares is comparable to the signal level of gravitational waves caused by both supernova explosions and possible black hole mergers. Therefore, observing solar gravitational waves can and should be a test of the sensitivity and efficiency of gravitational observatories being developed and operating. This circumstance is important for confirming the objectivity and validity of the obtained results. Objectivity will prevail if the expensive gravitational observatories currently in operation obtain tangible evidence of the detection of gravitational waves caused by coronal mass ejections and flares from our nearest star, the Sun.*

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***Corresponding author:** Chernobay IA, Associate Professor, Institute of Applied Physical Problems named after A. N. Sevchenko of the Belarusian State University, Republic of Belarus.

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Introduction

Currently, gravitational astronomy is a highly sought-after technology in observational astronomy. In the course of research in this area, the author of this paper has theoretically substantiated and experimentally established a new physical phenomenon: the influence of gravitational fields on acoustic and ultrasonic waves of finite amplitude propagating in acoustically transparent media [1-5]. This phenomenon consists of the acceleration or deceleration of the velocity of acoustic and ultrasonic waves depending on their propagation in the direction or against the direction of the gravitational field strength vector. The concept of acceleration and deceleration of their propagation velocity becomes applicable to acoustic and ultraacoustic waves in the literal physical sense of this definition. Previously, such definitions and concepts did not exist, were not applied, and were not encountered in physical acoustics [6]. The positive properties of this phenomenon lie in the fact that, under certain propagation conditions, ultrasonic waves actually represent a continuous stream of test bodies constantly hanging in gravitational fields. For this reason, ultrasonic waves are recognized as a perfect mechanism for the free fall of bodies, the fluctuations of which can be continuously measured and recorded, making them an ideal method for observing gravitational waves. Based on this, ultrasonic technology was developed in the form of a precision detector capable of detecting solar gravitational waves. Gravitational waves emanating from the surrounding space are continuously and continuously detected and recorded [3,5].

Thus, the developed ultrasonic method has enabled the repeated detection and study of gravitational oscillations and coronal gravitational ejections from our nearest star, the Sun, as well as gravitational waves from other stars, in a frequency range from fractions of a hertz to tens of kilohertz. Gravitational vibrations and oscillations of the Sun are recorded in real time. A study of the results of the detection and detection of solar gravitational waves has provided evidence of the enormous propagation speed of gravitational waves compared to the speed of light. This article is devoted to these studies and new experimental results on the detection and detection of solar gravitational waves, as well as evidence of the reliability of the obtained results.

Physical Principles of the Ultrasonic Method for Observing and Detecting Solar Gravitational Waves

The fundamentals of the ultrasonic method and the detector developed based on it are based on a new physical phenomenon: the effect of gravity on the propagation of ultrasonic waves. The physical essence of gravity's effect on the propagation of acoustic or ultrasonic waves is that, due to nonlinearity, an excess density associated with the wave arises in a propagating wave of finite amplitude. The appearance of excess density, in turn, is equivalent to excess mass, which, in a gravitational field, generates a force associated with the propagation of the acoustic or ultrasonic wave. The resulting force is fast-acting and causes a change in the speed of ultrasound propagation depending on the direction and magnitude of the external acceleration. The external acceleration, in turn, is a gravitational wave, so the described mechanism of action forms the fundamental basis of the method for detecting gravitational waves.

A more detailed implementation of the method is as follows. For an elementary volume of the medium, in accordance with the derivation of the wave equation in [4,6], an equation of motion was compiled. To avoid additional difficulties associated with considering static influences, we exclude from this equation the product of static density ρ and gravitational acceleration g:

$$\rho_0 \frac{\partial^2 \xi}{\partial t^2} = -\frac{\partial P}{\partial x} + g\Delta\rho, \quad (1)$$

where: ρ_0 is the initial density of the acoustic medium in an undisturbed state;

ξ - displacement of the elementary volume of the medium; P - excess pressure of the environment;

$g\Delta\rho$ - characterizes an additional force equal to the product of the excess mass generated by the excess density and the acceleration of gravity.

In accordance with the reasonable analysis and transformations given in [4], based on the original equation (1), the following equation was obtained:

$$\frac{\partial^2 \xi}{\partial t^2}\left[1 + (\gamma + 1)\frac{\partial \xi}{\partial x}\right] + \gamma g \frac{\partial \xi}{\partial x} = c^2 \frac{\partial^2 \xi}{\partial x^2} \quad (2)$$

where: γ - nonlinearity parameter; c - is the speed of propagation of ultrasound.

The resulting wave differential equation (2) is nonlinear and describes the processes of propagation of acoustic waves of finite amplitude in a nonlinear medium, including gas, under the influence of a gravitational field. It should be noted that the resulting nonlinear wave equation (2), in the first approximation, coincides with the equation given in [7], obtained there as a special case of wave equations for media with an arbitrary equation of state. It should also be noted that the wave equation (2) transforms into the known relations in equation [8] when nonlinearity is "turned off" and into the known equation [9] when gravity is "turned off." In addition, when nonlinearity and gravity are simultaneously turned off, equation (2) with sufficiently high accuracy transforms into the ordinary wave equation [6], known in acoustics. Thus, equation (2) should be considered reliably justified.

The solution to the nonlinear differential equation (2) was previously obtained in [4] and has the form:

$$x_1 = ct\left(1 - \frac{A}{2}\right) - \frac{\gamma A}{4} g t^2, \quad (3)$$

$$x_2 = -ct\left(1 - \frac{A}{2}\right) - \frac{\gamma A}{4} g t^2, \quad (4)$$

where: x_1 - equation of wave propagation in one direction;

x_2 - equation of wave propagation in another direction;

W - nonlinearity parameter associated with the absolute value of the amplitude W of the ultrasonic wave.

Based on the fact that the obtained solutions (3) and (4) of the original wave equation (2) are valid for both constant and alternating values of the acceleration of free fall, in [6] the practical application of the formula for calculating the alternating value g~ :

$$g_{\sim} = \frac{16\,L\,(T_2 - T_1)}{\gamma A\,(T_1 + T_2)^3} \tag{5}$$

where g~ is the alternating value of the acceleration of free fall, proportional to the alternating effect of gravitational waves;

$(T_2 - T_1)$ - the difference in the propagation times of ultrasonic waves caused by the direct effect of gravitational waves on the acoustic medium.

If the initial frequency ω of propagation of ultrasonic vibrations is known, then the received ultrasonic signals that have passed through acoustically transparent media can be represented in the form of total phase shifts $\varphi_{\Sigma 1}$ and $\varphi_{\Sigma 2}$:

$$\varphi_{\Sigma 1} = \omega T_1 \qquad \varphi_{\Sigma 2} = \omega T_2 \tag{6}$$

However, the values of the propagation times T1 and T2 are important to us, therefore

$$T_1 = \frac{\varphi_{\Sigma 1}}{\omega} \quad \text{and} \quad T_2 = \frac{\varphi_{\Sigma 2}}{\omega} \tag{7}$$

Based on the basis of the functioning of the detector, which consists in differential measurements, based on (7) we can write:

$$T_2 - T_1 = \frac{\varphi_{\Sigma 2} - \varphi_{\Sigma 1}}{\omega} = \frac{\Delta\varphi(t)}{\omega} \tag{8}$$

Returning to equation (5) based on (8) for acceleration g~ we finally obtain:

$$g_{\sim} = \frac{16 \cdot L \cdot \Delta\varphi(t)}{\gamma A\,\omega\,(T_1 + T_2)^3} \cong K \cdot \Delta\varphi(t), \tag{9}$$

where: K – detector conversion coefficient;

$\Delta\varphi(t)$ - current difference in phase shifts measured by the detector.

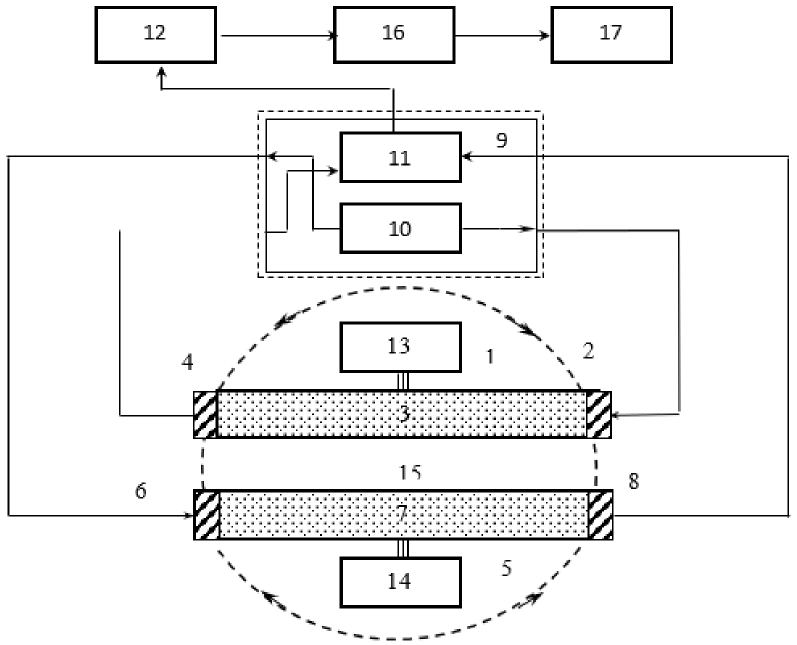
Thus, based on theoretical and experimental justifications of gravitational influences on propagating ultra-acoustic waves, the calculation formula (9) of ultrasonic technology, which forms the basis for the functioning of the gravitational wave detector, was obtained.

Structural Diagram of the Solar Gravitational Wave Detector

The gravitational wave detector is a further development of the technical solutions presented in [10,11]. The detector contains two identical, oppositely directed measurement circuits, of which the upper and lower ones can be conventionally distinguished (see Figure 1). The upper circuit consists of the structure of the first ultrasonic chamber 1, which includes the first emitting ultrasonic transducer 2, the first acoustic medium 3 and the first receiving ultrasonic transducer 4, which are acoustically connected in series. The lower circuit consists of the structure of the second ultrasonic chamber 5, which includes the second emitting ultrasonic transducer 6, the second acoustic medium 7 and the second receiving ultrasonic transducer 8, which are which are acoustically connected in series. The unit 9 of the electronics of the installation contains a highly stable signal generator 10, the outputs of which are connected to the emitting ultrasonic transducers 2 and 6. The unit 9 also contains a differential meter 11 of time intervals, which is a phase detector, the inputs of which are connected to the receiving ultrasonic transducers 4 and 8, and the output is connected to the pre-amplifier 12. In the detector, pressure measuring regulators 13 and 14 are used, which make it possible to independently set the internal pressure of the first and second acoustic media 3 and 7 in the ultrasonic chambers 1 and 5. The detector is equipped with a spectrum analyzer 16 with a recording device 17 connected to its output, which can be a computer.

The detector is also equipped with a rotating device 15 for spatial alignment and alignment with the direction of the gravitational wave source—the Sun.

Operation of the Solar Gravitational Wave Detector



1 – the first ultrasonic chamber; 2 - the first emitting ultrasonic transducer; 3 – first acoustic environment; 4 - the first receiving ultrasonic transducer; 5 – second ultrasonic chamber; 6 – second emitting ultrasonic transducer; 7 – second acoustic environment; 8 – second receiving ultrasonic transducer; 9 - electronics block; 10 – highly stable signal generator; 11 - differential meter of time intervals, which is used as a phase detector; 12 - preliminary amplifier; 13, 14 - measuring pressure regulators; 15 - rotary device; 16 – spectrum analyzer; 17 - recording device (computer)

Figure 1: Structural diagram of the Solar Gravitational Wave Detector.

The detector's precise operation is based on the high frequency stability of the master oscillator 10. Oscillations of master oscillator 10 are transmitted through transmitter transducers 2 and 6 as ultrasonic waves into acoustically transparent media 3 and 7 and then transmitted to receiving transducers 4 and 8. As they propagate through acoustically transparent nonlinear media 3 and 7, the ultrasonic waves are modulated by the interaction of gravitational waves.

Electrical oscillations from receiving transducers 4 and 8 are fed to differential time-interval meter 11. Meter 11 can operate in both time-interval measurement mode and synchronous detection mode by extracting the mutual difference in phase fluctuations of received signals. The first mode of detector operation is based on the high-speed extraction by meter 11 of the difference in propagation times T1 and T2 of ultrasonic signals in opposite directions in ultrasonic chambers 1 and 5. In this case, the algorithm for calculating the instantaneous value of gravitational acceleration is implemented using formula (5). The second mode of detector operation is based on the extraction by meter 11 of the mutual difference in phase fluctuations of received signals. In this case, the algorithm for calculating the instantaneous value of gravitational acceleration is implemented using formula (9). The choice of one or the other mode is determined by the objectives of the current research.

Features of the Solar Gravitational Wave Detector

- An important technical solution is the design of ultrasonic chambers 1 and 5, which create and maintain a traveling wave mode in acoustically transparent media, minimizing the influence of reverberant interference and internal multiple reflections of signals.
- Ultrasonic transducers 2, 4, 6, and 8 are designed and manufactured to achieve the necessary physical parameters for matching signal levels with the acoustic environment, which is necessary to achieve a high signal-to-noise ratio.
- A third feature of the Solar Gravitational Wave Detector is that ultrasonic measuring chambers 1 and 5, each with a base of at least 2 m, are filled with a nonlinear acoustic medium, which maintains the required internal pressure and temperature.
- Protection measures against external vibrational, acoustic, and ultrasonic interference have been adopted and implemented. Specifically, the vibration and acoustic protection systems comprise three sequential structures, each with a protection efficiency of at least 25-30 dB.
- All fundamental circuit designs are designed to ensure minimal noise parameters to maximize the signal-to-noise ratio when processing received signals. To achieve this, electronic components with the lowest achievable noise level are used, providing an equivalent input-referred noise of 1,5 nV/ $\sqrt{Hz}$ (1,5 nV/ divided by the square root of one hertz).
- A distinctive feature of the Solar Gravitational Wave Detector is complete electrical shielding from external electrical, electromagnetic, and, if possible, magnetic interference, including network and electromagnetic interference. This is achieved by closed-loop shielding of the detector structure.
- One of the key components of the Solar Gravitational Wave Detector is the combined analog and software components of the spectrum analyzer 16 and computer 17, which enable the identification of useful signals within a given frequency range of received gravitational signals.
- The entire primary ultrasonic transducer assembly is mounted on a horizontal platform, which can be freely rotated 360˚ horizontally and up to 60˚ vertically. This enables exploratory research by quickly setting the direction of reception of solar gravitational signals.
- One important result of the operation of the solar gravitational wave detector is the frequency resolution of the received signals, which in the limit is no worse than 10 microhertz (10×10^{-6} Hz).
- Estimates have shown that the overall sensitivity of the solar gravitational wave detector for detecting alternating accelerations is no worse than one ten-millionth of a meter per second per second (10-7 m/s^2) in the observed frequency band from F1 = 0.5 Hz to F2 = 500 Hz. In a wide frequency band up to F3 = 20,000 Hz, the sensitivity of the solar gravitational wave detector is no worse than one millionth of a meter per second per second (10-6 m/s^2).

Main Experimental Results

Detection of gravitational waves caused by solar coronal mass ejections. This is the first important result of the experimental data obtained. One of the numerous spectrograms obtained, characterizing the gravitational explosive non-stationary oscillatory processes of our Sun, is shown in Figure 2. The majority of the Sun's gravitational oscillations are in the frequency range from zero to 500 Hz. The most intense spectral characteristics of gravitational waves associated with a typical solar coronal mass ejection appear in the frequency band up to 60 Hz (sometimes in the range of up to 100-200 Hz). In this frequency band, the amplitude ranges the solar gravitational oscillations and vibrations are typically quite high. Other observed coronal gravitational ejections or solar prominences have a similar appearance. Their average duration ranges from several minutes to several tens of minutes. Thus, the observation interval for solar gravitational coronal ejections and processes has a fairly wide range of amplitudes and durations in the low-frequency region. It follows that solar gravitational coronal ejections typically manifest themselves in the low-frequency region, in the range of up to 100-200 Hz.

On the other hand, the following conclusion is significant: other solar gravitational wave oscillations and vibrations are observed in the frequency range of up to ten kilohertz and higher, with comparatively low intensity in the high-frequency region. To obtain clear evidence of this, it is necessary to methodically determine the differences between the detection of solar gravitational waves and other accompanying waves of cosmic origin. These differences are ensured, first of all, by the vectorial orientation of ultrasonic chambers 1 and 5 (Figure 1) toward the object under study – the Sun. At the same time, a remarkable quality of gravitational waves was revealed: gravitational waves are longitudinal, which differs from generally accepted literary statements [12, 13].

To clarify other differences from gravitational coronal mass ejections and gravitational vibrations of the Sun, we present the type of gravitational waves caused by supernova explosions. A typical spectral signature of a gravitational signal generated by a supernova explosion, selected based on its maximum amplitude from many hundreds of similar gravitational explosions, is shown in Figure 3. Compared to gravitational coronal mass ejections (CMEs) occurring on the Sun, this case exhibits three significant differences.

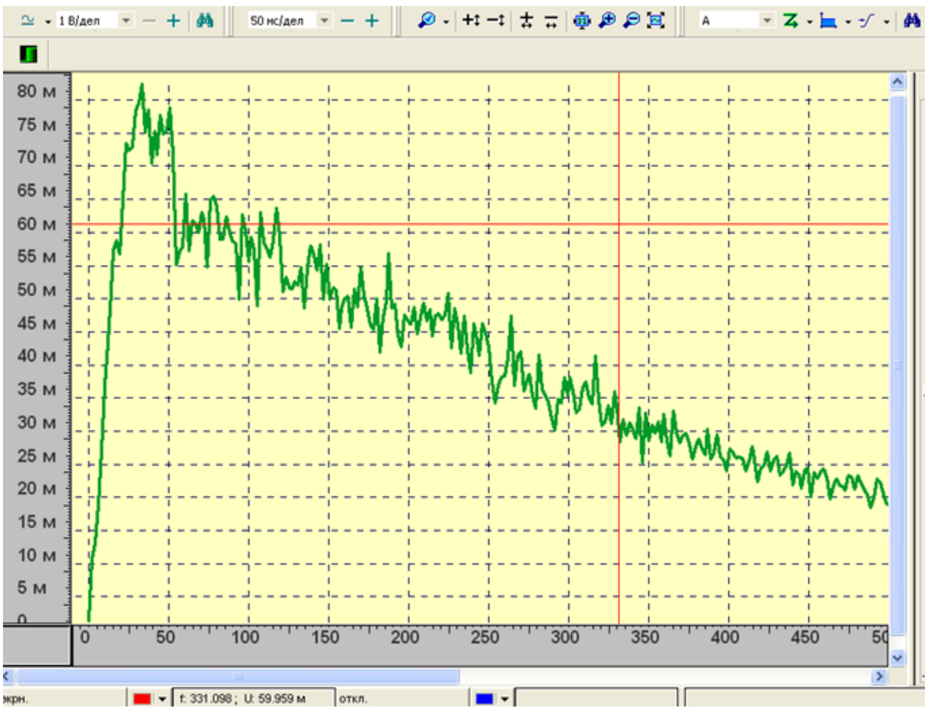


Figure 2: Characteristic spectrum of gravitational signals associated with a solar coronal mass ejection in the frequency band up to 500 Hz.

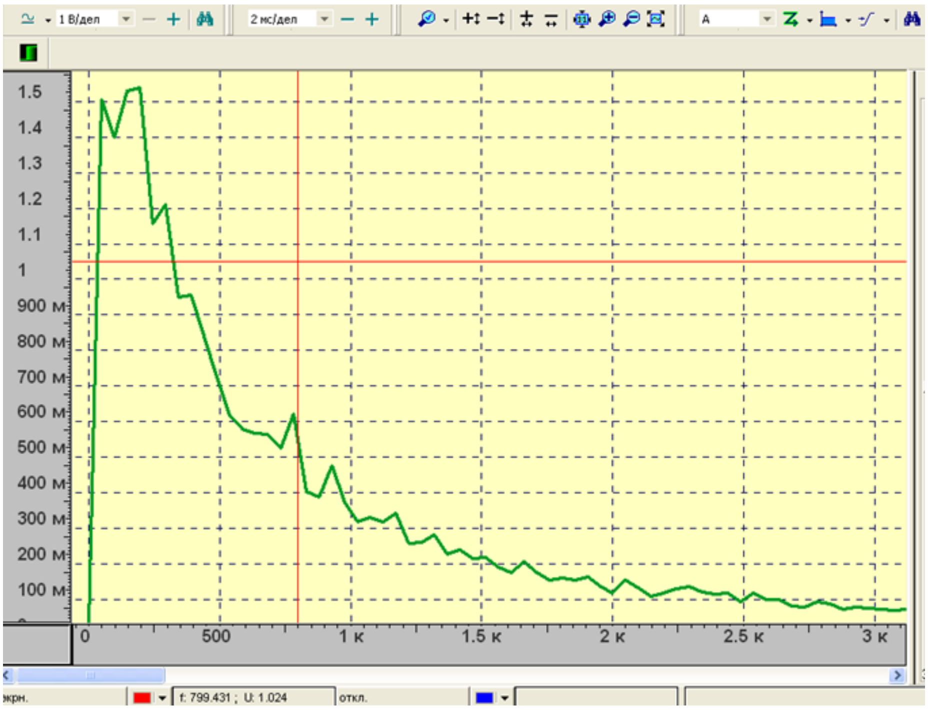


Figure 3: Characteristic spectrum of gravitational signals from a supernova explosion.

First, the spectral composition of gravitational signals generated by supernova explosions is broadband. Specifically, the signals presented in Figure 3 show that the gravitational spectrum of a supernova explosion reaches frequencies of up to two kilohertz or more. In contrast, CMEs and flares associated with the Sun have a low-frequency spectrum of up to several hundred Hertz. Second, the gravitational spectra of supernova explosions contain a frequency spectrum that begins with a sharp spike from zero frequency. Such emissions are characteristic of the spectral characteristics of abrupt explosive processes, as is clearly evident from a comparison of Figures 2 and 3. Thus, the development of the spectrogram from zero to maximum in Figure 2 exhibits a break, while no such break is observed in Figure 3. Third, the duration of the development of gravitational signals caused by supernova explosions ranges from several tens of minutes to several hours or more. Moreover, observations of gravitational supernova explosions have been reported for up to several days [11]. Gravitational coronal mass ejections and flares associated with the Sun typically have a maximum duration of up to several tens of minutes.

Detection of gravitational signals from the Sun at various times before its optical rise. Of particular interest are the characteristic low-frequency spectra of gravitational waves caused by coronal mass ejections and solar flares, nine and eight minutes before its optical rise, which are presented in Figures 4 and 5. The presented experimental evidence was timed and designed so that no additional explosive-type gravitational signals were observed at the indicated times. Consequently, the spectral characteristics of the signals presented in Figures 4 and 5 are not associated with explosive gravitational processes, including supernova explosions and black hole mergers. * Evidence for this follows from the fact that the gravitational signals in Figures 4 and 5 do not contain a frequency spectrum beginning with a sharp spike from zero frequency. Signatures of sharp spikes from zero frequency, as noted above, are characteristic of the spectral characteristics of gravitational explosions of supernovae, as clearly evident in the signals in Figure 3. Thus, the spectrograms of signals presented in Figures 4 and 5 characterize normal and quiet coronal gravitational ejections, flares, and vibrations generated by the Sun. This approach to organizing the experiment ensures reliable reliability.

The moment in time nine minutes before optical sunrise corresponds to Figure 4. At this point in time, our Earth partially absorbs and partially shields gravitational waves and signals from the Sun. After gravitational sunrise, which corresponds to Figure 5 and, accordingly, eight minutes before optical sunrise, our Earth neither absorbs nor shields gravitational signals from the Sun. This is why, at these moments in Figure 5, a real fivefold increase in the level of gravitational signals from the Sun is observed. This fact clearly implies that gravitational sunrise precedes

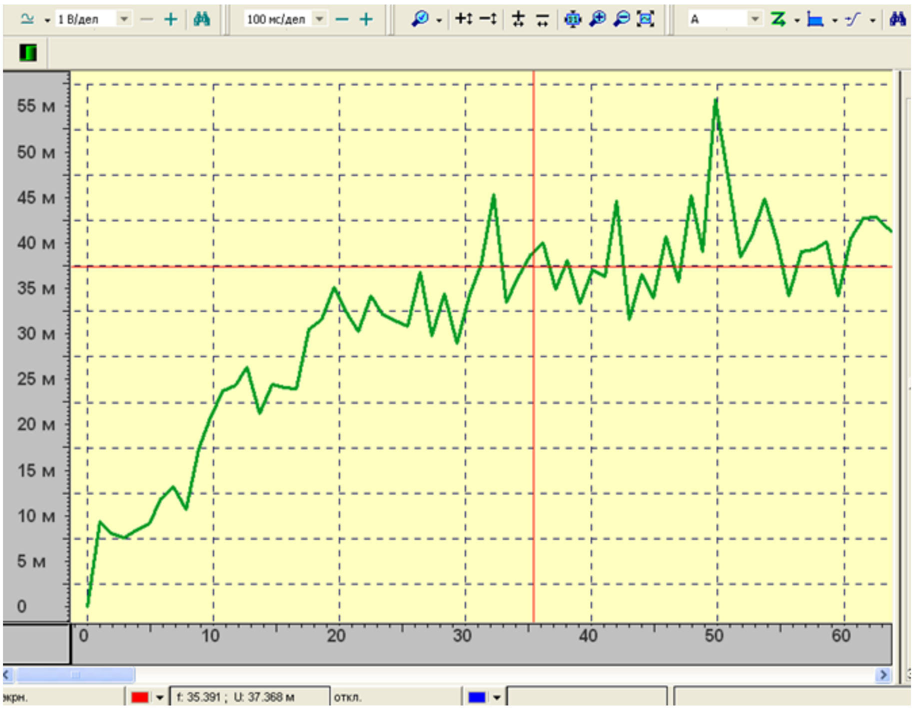


Figure 4: Low-frequency spectrum of the Sun's gravitational signals at a time nine minutes before its optical sunrise.

Optical sunrise by a time interval ranging from eight to nine minutes. Therefore, the speed of propagation of gravitational waves is many times greater than the speed of propagation of light. The obtained result is confirmed by comparing and measuring the conventionally named mid-frequency spectra of solar gravitational waves in the frequency range from 160 Hz to 230 Hz at times nine minutes and eight minutes before their optical rise (Figures 6 and 7). The moment nine minutes before optical rise in the frequency range from 160 Hz to 230 Hz of solar gravitational waves corresponds to Figure 6. At this point in time, our Earth also partially absorbs and partially shields gravitational waves and solar flares. However, the appearance and shape of the signals in Figure 6 indicate that the received signals partially contain gravitational waves from cosmic sources. This follows from the fact that the received gravitational waves have a uniform, smoothed spectrum within the given frequency band. Furthermore, the signals exhibit the expected attenuation of approximately three times, which is only partially consistent with the results shown in Figures 4 and 5. However, this does not fundamentally change anything and, for the signals in Figure 6, is explained by additional interference with the cosmic gravitational wave detector's measurement

Figure 5: Low-frequency spectrum of the Sun's gravitational signals at a time eight minutes before its optical sunrise.

The time eight minutes before optical sunrise for mid-frequency spectra in the frequency range from 160 Hz to 230 Hz of solar gravitational waves corresponds to Figure 7. After gravitational sunrise, which corresponds to eight minutes before optical sunrise, our Earth does not absorb or screen solar gravitational signals. Based on the appearance and shape of the signals in Figure 7, it can be determined that the received signals primarily consist of solar gravitational waves and a small amount of gravitational waves from cosmic sources. This follows from the fact that the received solar gravitational waves have a random, variable, and non-stationary spectrum in the specified frequency band from 160 Hz to 230 Hz. Furthermore, the average level of received and recorded gravitational signals rises from 35 mV (Figure 6) to 90 mV (Figure 7). Undoubtedly, in this case, too, at the moments between Figure 6 and Figure 7, a real, almost threefold increase in the level of gravitational signals from the Sun is observed, as mentioned above. Furthermore, the appearance and shape of gravitational waves changes. This fact also implies that gravitational rise precedes optical rise by a time interval of eight to nine minutes. Consequently, these results also confirm that the propagation speed of gravitational waves is many times greater than that of optical waves.

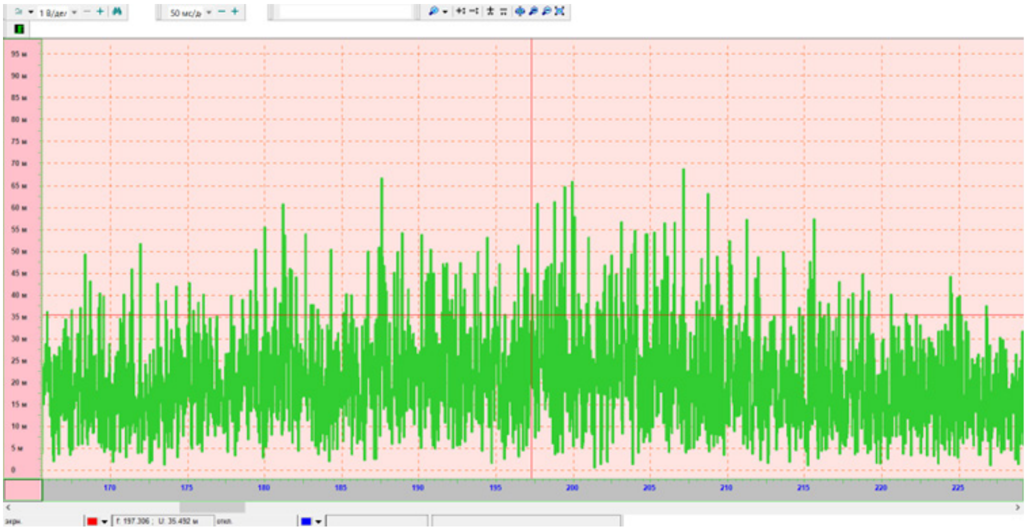


Figure 6: The mid-frequency (conventionally named) spectrum in the frequency range from 160 Hz to 230 Hz of the Sun's gravitational waves at a time nine minutes before its optical sunrise

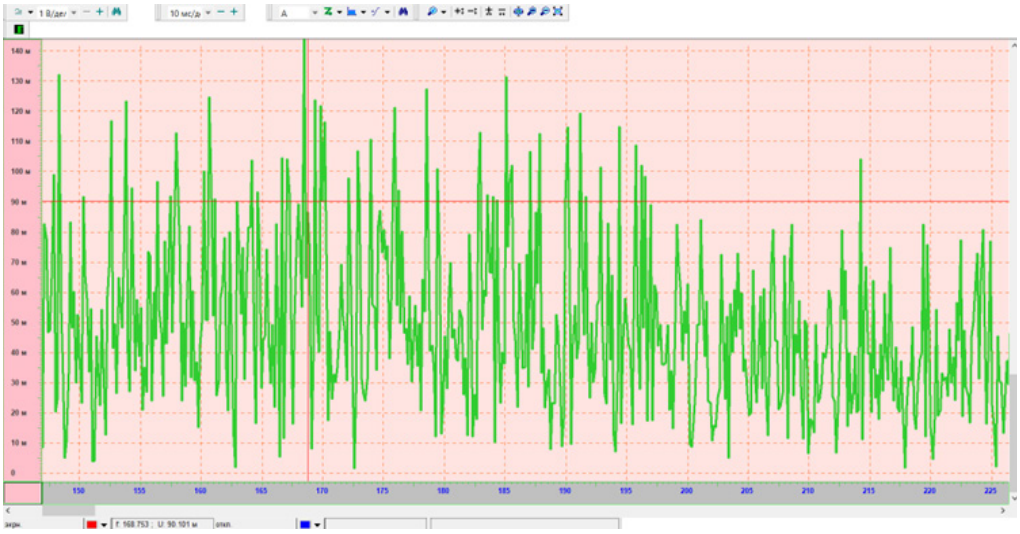


Figure 7: The mid-frequency (conventionally named) spectrum in the frequency range from 160 Hz to 230 Hz of the Sun's gravitational waves at a time eight minutes before its optical sunrise

Gravitational wave processes have been detected in the Sun's general gravitational flux in the frequency range up to and above 10 kHz (ten kilohertz). Therefore, let's consider the frequency range from 4100 Hz to 4700 Hz of solar gravitational waves corresponds to Figures 8 and 9. After gravitational rise, which corresponds to eight minutes before optical rise, our Earth does not absorb or screen the solar gravitational signals. Based on the appearance and shape of the signals in Figure 8, it can be determined that the received signals, in addition to attenuated solar waves, partially contain gravitational waves from cosmic sources. This follows from the fact that the received gravitational waves have a uniform, smoothed spectrum in a given frequency band.

The time eight minutes before optical rise of high-frequency spectra in the frequency range from 4100 Hz to 4700 Hz of solar gravitational waves corresponds to Figure 9. By this time, gravitational rise, which corresponds to eight minutes before optical rise, has occurred, and our Earth does not absorb or screen the solar gravitational signals. Based on the appearance and shape of the signals in Figure 8, it can be established that the received signals partially contain solar gravitational waves and a certain number of gravitational waves from cosmic sources. This follows from the fact that the received solar gravitational waves have a random, variable, and non-stationary spectrum in a given frequency band from 4100 Hz to 4700 Hz. In addition, the average level of the received and recorded gravitational signals rises from 0.65 mV (Figure 8) to 1.6 mV

(Figure 9). Undoubtedly, in this case, at the moments in time between Figure 8 and Figure 9, a real, almost threefold increase in the level of gravitational signals from the Sun is observed. Moreover, the appearance and shape of the gravitational wave's changes. From this fact it also follows that gravitational rise precedes optical rise by a time interval of eight to nine minutes. Consequently, the propagation speed of gravitational waves is many times greater than the propagation speed of optical waves. This number ***k*** times can be estimated by the ratio of the time T_{opt} of propagation of optical waves from the Sun to the Earth to the measured time error. This error is defined as the time difference between the propagation time of optical waves T_{opt} from the Sun to the Earth and the measured advance of the gravitational rise T_{g} relative to the optical rise:

$$k=\frac{T_{opt}}{\grave{O}_{opt}-\grave{O}_{g}} \quad (10)$$

where: T_{opt} - the light propagation time; T_{g} - is the measured gravitational rise time.

Multi-day studies, refinements, and averaging of the T_{opt} and T_{g} times, along with refinements to the calendar correction for the distance from the Earth to the Sun, as well as refinements to the start time of gravitational signal arrival, failed to yield a difference between these values more

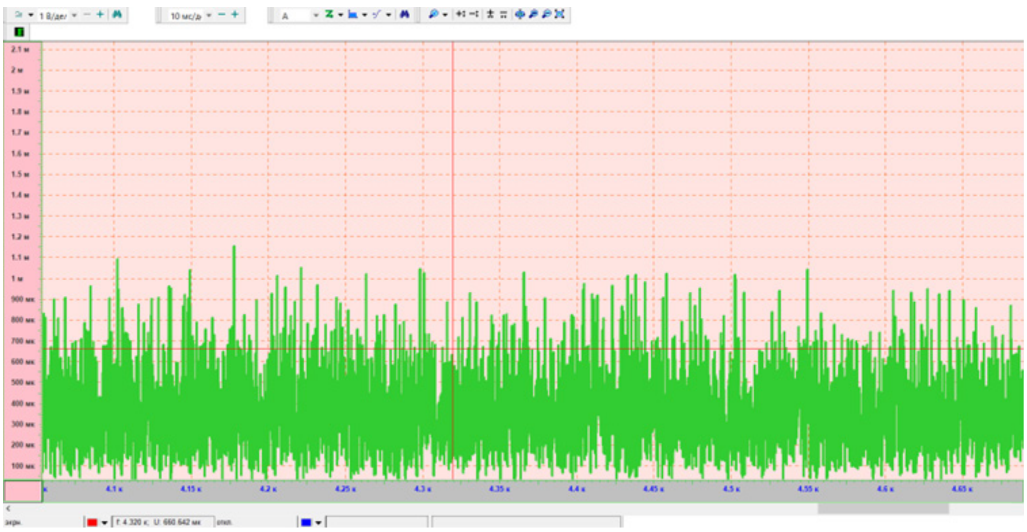


Figure 8: High-frequency (conventionally named) spectrum of gravitational waves in the frequency range from 4100 Hz to 4700 Hz of the Sun at a time nine minutes before its optical sunrise.

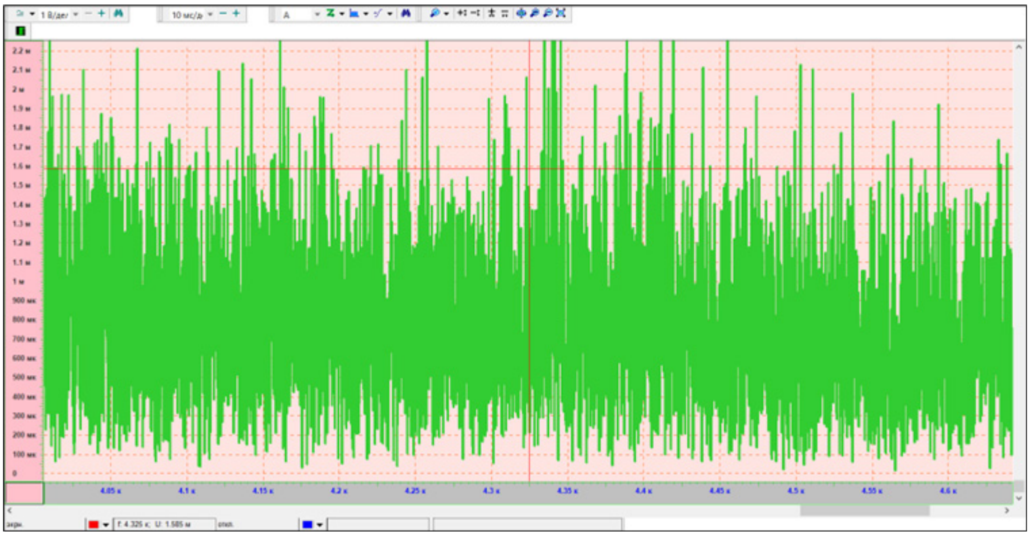


Figure 9: High-frequency (conventionally named) spectrum of gravitational waves in the frequency range from 4100 Hz to 4700 Hz of the Sun at a time eight minutes before its optical sunrise.

accurate than 0.5 seconds. Based on formula (10), the coefficient k, which indicates the excess of the propagation velocity of gravitational waves over the propagation velocity of optical waves, can be tentatively determined as ***k = 1000***. This means that the propagation velocity of gravity is at least one thousand times greater than the speed of light. Overall, given their importance for refining the propagation velocity of gravitational waves, it is appropriate to devote a separate, more detailed article to these studies.

To obtain more accurate values for the excess of the propagation velocity of gravitational waves over the propagation velocity of optical waves, it is advisable to organize direct comparative measurements of the arrival times of gravitational and optical signals from the Sun. The developed ultrasonic detector of solar gravitational waves makes this possible, while organizing optical observations of solar coronal mass ejections presents no problems.

The advantages of the ultrasonic method for observing solar gravitational waves compared to gravitational observatories. On the one hand, gravitational waves are localized alternating accelerations propagating through space at high speed. On the other hand, the developed ultrasonic detector allows for the detection and recording of external alternating accelerations, which are gravitational waves. Therefore, the developed ultrasonic technology, in the form of a solar gravitational wave detector, is a method of direct physical measurements, demonstrating its fundamental nature.

In contrast, it should be noted that the observatories created by the LIGO, VIRGO, KAGRA, and GEO600 collaborations [12–14] employ gravitational wave detectors based on indirect physical measurements. The operating principle of these observatories is based on laser measurements of tidal accelerations and deformations of a reference measurement system under the action of gravitational waves. In this case, the measurement system is coupled to bodies in a state of inertial rest and in a state of coupling with a neighboring framework of bodies. Under the action of a received gravitational wave, local tidal accelerations in the measurement system should produce a difference in the applied forces along the length of the measurement base. However, all objects and items in the measurement base, including the interferometric system with reflecting mirrors of the interferometer, exhibit inertia. Any object or body exhibits static inertial resistance to any external spatial force, including variable and extremely small ones. Therefore, this property can be called the inertial resistance of an object. It is precisely because of the high inertial resistance of the measuring system under the influence of gravitational waves that existing gravitational observatories have extremely low sensitivity [15,16].

The second challenge facing existing and future gravitational observatories in achieving sufficiently high sensitivity to detect gravitational waves is related to the speed of gravitational wave propagation. Based on the enormous speeds of gravitational waves, which are more than a thousand times greater than the speed of light, the following fact emerges. At extremely high gravitational wave speeds, the entire measuring system, including the measuring sensors, measuring channels, base, platform, installation, etc.—that is, the entire "physical support"—"falls" equally everywhere in the wave's gravitational field. In this case, no changes in the inertial resistance along the baseline of the measuring system, including the laser interferometric measuring system, occur. Thus, due to the enormous propagation speed of gravitational waves, the entire structure of the measuring system experiences identical phase effects, so the expected results are compensated. This, along with the inertial stability of the measuring system to the received gravitational waves, is the main challenge facing gravitational observatories in achieving sufficiently high sensitivity [16,17].

In contrast to the above facts, it should be emphasized that the operation of the ultrasonic solar gravitational wave detector is based on measuring the oscillations of freely incident ultrasonic waves. In fact, these waves are physically equivalent to freely suspended bodies in acoustically transparent media, directly affected by gravitational waves. Therefore, the developed solar gravitational wave detector implements a direct method for detecting gravitational waves, for which no better alternative exists. Therefore, in terms of the physical nature of operation, there is a significant difference between the ultrasonic method underlying the ultrasonic detector and the well-known tidal acceleration method underlying gravitational observatories. The differences identified lie in the completely different degrees of sensitivity to gravitational wave detection.

Discussion and Analysis of the Obtained Results

The applied method for detecting solar gravitational waves indicates the longitudinal nature of their propagation. This fact is confirmed by the maximum gravitational signals of ultrasonic channels 1 and 5 (Figure 1) when their vector direction is toward the Sun. Overall, this result does not coincide with the generally accepted concept that gravitational waves are quadrupole-polarized [15,16].

Solar gravitational waves are generated not only by explosive processes, coronal mass ejections, and prominences, but also by numerous oscillatory processes of the Sun's condensed masses and structures.

Based on the relatively high-frequency gravitational waves detected from the Sun, with frequencies of several kilohertz, the following conclusion can be drawn. The majority of solar gravitational waves are generated by internal moving and boiling layers, as well as by individual alternating accelerations of condensed masses and structures.

Gravitational oscillatory processes in the frequency range above 10 kHz (ten kilohertz) have been detected in the general gravitational flux of the Sun.

It cannot be ruled out, and is most likely the case, that the extensive gravitational flux emitted by the Sun contains spectral components of gravitational waves up to 100 kHz (one hundred kilohertz) and higher. In this direction, it is advisable to conduct work to improve the detector.

Based on the obtained results, a relatively simple question arises: how do known gravitational observatories detect ultra-distant gravitational mergers of "black holes," including neutron stars? This is despite the fact that they don't detect gravitational waves from our nearest star, the Sun? Moreover, numerous long-term gravitational measurements show a roughly equal balance between ultra-distant gravitational explosions, which are observed very rarely, and gravitational coronal mass ejections and solar flares, which are observed almost continuously.

Based on the above result, 7.6., it seems that observing gravitational waves from our nearest star, the Sun, should be a control test method for verifying, assessing, and calibrating the sensitivity of gravitational observatories being built and operating.

Preliminary Conclusion

A promising ultrasonic technology for observing solar gravitational waves has been developed. Direct interaction of gravitational waves with test bodies, representing ultrasonic waves, has been realized. The physical essence of the developed direct interaction technology is that gravitational waves are alternating accelerations propagating through space at high speed. These accelerations induce alternating accelerations of counter-propagating ultrasonic waves in acoustically transparent nonlinear media, which are mutually detected. This underlies the simplicity and fundamental nature of the detection method. Experimental results have been obtained that clearly demonstrate that the developed ultrasonic detector enables continuous observation of numerous gravitational waves from our Sun. The detector also enables observation of gravitational waves not only from our nearest star, the Sun, but also from our Galaxy and the Universe as a whole. This is confirmed by the detection of gravitational explosions of supernovae. The results of observing solar gravitational waves also demonstrate the enormous propagation speed of gravitational waves compared to the speed of light. The importance of these results lies in their fundamental nature. The advantages of a new technology in the form of a gravitational wave detector compared to gravitational wave observatories are analyzed and substantiated. This is currently unattainable for existing gravitational wave observatories. Based on the obtained results, it is advisable to abandon expensive projects to create gravitational observatories based on laser interferometric observation methods.

Conclusions

Ultrasonic technology and the solar gravitational wave detector created based on it are a method and, accordingly, a device for direct measurements. For this purpose, ultrasonic waves are converted into test bodies suspended continuously in acoustically transparent media. These test bodies, in the form of ultrasonic waves, are directly exposed to gravitational waves as they propagate through nonlinear media.

By differentially identifying mutual alternating phase shifts and fluctuations of ultrasonic waves traveling in opposite directions through two channels of acoustically transparent nonlinear media, spatially propagating accelerations representing gravitational waves are directly detected, detected, and recorded without additional transformations.

Assessments have shown that the sensitivity of the created detector to gravitational waves in the frequency range from 0.5 Hz to 500 Hz is no worse than one ten-millionth of a meter per second per second. Over a wide frequency range of up to 20.0 kHz, the detector's sensitivity is equal to one millionth of a meter per second per second.

One important result of the operation of the Solar Gravitational Wave Detector is the frequency resolution of the received signals, which in the limit is no worse than 10 microhertz (10×10^{-6} Hz).

The experimental results obtained convincingly confirm that the developed ultrasonic detector enables continuous observation of numerous gravitational waves caused by coronal mass ejections, flares, as well as vibrations and oscillations of the internal structures of our Sun.

The detector's results also demonstrate the enormous propagation speed of gravitational waves compared to the speed of light. A fundamental result has been obtained showing that the propagation speed of gravitational waves is at least a thousand times greater than the speed of optical waves.

The detector enables the reliable recording of other gravitational waves from the Universe, in particular, gravitational explosions of supernovae, which are observed almost continuously.

The detector enables selective isolation and high-quality real-time monitoring of gravitational waves from the Sun in the audio frequency range.

The advantages and fundamental nature of the obtained results lie in new possibilities and prospects for studying the Universe, as well as the possibility of abandoning expensive projects to create gravitational observatories based on laser interferometric observation methods.

Annotation

This work relates to new methods and instruments in observational astrophysics, particularly gravitational astrophysics. A new type of astronomical instrument has been developed: an ultrasonic detector of solar gravitational waves. The detector's operation is based on the nonlinear physical phenomenon of the influence of gravity on ultrasonic waves propagating in nonlinear acoustically transparent media. To achieve this, ultrasonic waves are transformed into test bodies suspended continuously in acoustically transparent media. These test bodies, in the form of ultrasonic waves, are subject to the influence of gravitational waves as they propagate in nonlinear acoustic media. Due to the nonlinearity of the medium, gravitational waves directly influence the test bodies, which are ultrasonic waves. The physical essence of this direct influence lies in the fact that gravitational waves represent alternating accelerations propagating through space at high speed. These accelerations cause alternating accelerations of counter-propagating ultrasonic waves, which are mutually detected. This is the simplicity and fundamental nature of the detection method. The detector enables fundamentally new experimental results in the field of gravitational wave detection. Using the developed ultrasonic detector, it has become possible for the first time to continuously observe numerous gravitational waves from our Sun, including gravitational coronal mass ejections and gravitational oscillations caused by internal oscillatory processes and vibrations of various internal structures of the Sun. The detector also enables reliable recording of gravitational signals coming from the Universe, in particular those caused by supernova explosions, which are observed almost continuously. The detector's results also demonstrate the enormous propagation speed of gravitational waves compared to the speed of light. A fundamental result has been obtained showing that the speed of gravitational wave propagation is at least a thousand times greater than the speed of optical waves. The detector allows for the selective isolation of any gravitational signals from the Sun and their detection in the audio frequency range. Based on the obtained results, it can be assumed that gravitational signals from neutron star pulsations are detected at distances within our Galaxy, while supernova explosions are detected from stellar systems located tens and hundreds of millions of light-years from Earth. It appears that the developed technology, in the form of the newly created solar gravitational wave detector, will become a worthy replacement for expensive laser interferometer gravitational observatories. It is also believed that the work will open up new possibilities for studying and understanding the Universe.

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