Dynamic gravity experiment with physical pendulum

D. Sarkadi*
Research Centre of Fundamental Physics, Vaci M. 8., H-7030 Paks, Hungary
(Dated: September 8, 2018)

In recent decades, several methods significantly different from the classic method of the Cavendish torsion balance have been developed and used for measuring the gravitational constant G. Unfortunately, the new determinations of G have not reduced significantly its uncertainty. It seems that in recent times, the accuracy problem for the gravitational constant has not been the focus. This paper presents a new type gravity experiment used a big and heavy physical pendulum, not for a newest gravitational constant measure, but for the study of special gravitational effects encountered accidentally. Surprisingly strong gravitational effects have been observed between moving masses. We have named the whole new group of gravitational phenomena by "dynamic gravity". Despite the simplicity of our gravity experiment, the observed extraordinary results could lead to an unexpected revolution in gravity science.

PACS numbers: 04.80.y
Keywords: experimental gravity, dynamic gravity, physical pendulum, quasi-resonance measuring method, extension of the Newtonian Law of Gravity

I. INTRODUCTION

For a long time the main motivation for experimental gravity studies has been only the more and more precise determination of the gravitational constant G with different kinds of experiment. Despite the long time and strong efforts, the gravitational constant is at present the least-well measured fundamental constant [1, 2]. However, it seems that in recent times, the accuracy of the gravitational constant has not been the main focus of experimental gravity research.

Nowadays the main stream of experimental research has branched into state-funded and private spheres. The "official" researches concentrate primarily for the experimental proofs of the GRT consequences; i.e. for the reliable detection of gravitational waves [4], observation of black holes and newly re-examine the equivalence of inertial and gravitational mass of free falling bodies, including Bose-Einstein condensates of gases [3]. The *"Gravity Proba B"* space experiment is also connected to the validity control of GRT [5].

In the private sphere, physicists now prefer to study the unknown features of gravitational interaction. Mainly, the different kinds of exotic antigravity experiments and theories have become very popular. The aim is not just to proceed to Newtonian gravity, but to overcome the GRT of Albert Einstein. A number of private experiments are planned and executed to demonstrate the possibility of gravitational shielding, or even of the gravitational repulsion (in other words, "antigravity").

In our case, a blind chance helped us when we investigated a physical pendulum's sensitivity for gravity measurement. In our experiment, the applied relatively big and heavy physical pendulum was built, not for a newest measure of the gravitational constant, but for the study of special gravitational effects encountered accidentally. We have named a whole new group of gravitation phenomena *dynamic gravity.* Despite the simplicity of our gravity experiment, the observed extraordinary results could lead to an unexpected revolution in gravity science.

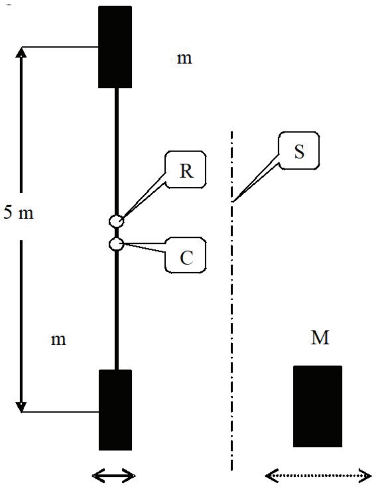

FIG. 1: Setup for gravity measurement. (R: pivot point; C: mass-center; S: shielding; m: pendulum masses; M: source mass)

II. EXPERIMENTAL SETUP

Our new unconventional gravity measuring method is illustrated in FIG. 1. The "M" source mass is periodically moved by outer force which causes modulation in the movement of the physical pendulum through a currently unknown (suspected gravitational) interaction with the lower mass "m" of the pendulum.

Some of the technical features of the realised physical

---

*Electronic address: dsarkadi@gmail.com

pendulum are

Pendulum arms: 2.5 + 2.5 meter (in vertical position)
Upper and lower masses: 24 - 24 kg (cubic lead)
Pendulum frame: made of aluminum
Total mass with frame: 54.7 kg
Support of pendulum: two "in-line" wedges (steel)
High frequency filter: hydraulic damper
Applied pendulum period: 60 - 80 s
Position detector: light-coupling without mechanical contact

Due to the relatively large dimensions, the adjustment of the pendulum period is very easy. The small pendulum amplitude results an acceptable low level of friction. The test masses used were made of lead cubes. During the control tests, we put an iron isolation plate (shielding) into the gap between roundtable and pendulum to prevent magnetic and air-draft disturbances. The targeted investigation demonstrated that the applied shielding has had no significance for the pendulum movement, because the supposed side effects were extremely weak. Reliable grounding of the whole apparatus is necessary for protecting against the electrostatic disturbances.

The pendulum movement was recorded on-line by a personal computer, and was displayed in zoomed graphic form on the computer screen. For the recording of the pendulum movement, an optical measuring system was developed. The sampling period of pendulum position is adjustable between 0.2 and 2.0 sec; the resolution of the position detector is about 5 - 10 microns. Limitation of the pendulum amplitude was realized by using two soft mechanical breaks with adjustable distance in the range of 15-50 mm.

Our laboratory is situated at about 500 meters from the nearest traffic road, and in an environment of low gravitational and mechanical noise. The building of the laboratory is hermetically closed against the outer air draft. Nevertheless, on the floor of the laboratory continuous small mechanical vibrations could be observed, and the coupled vibration energy was transferred to the pendulum. An important part is not shown on FIG. 1, a plastic container filled with water, in which rides a light plastic damping sheet of about 500 cm2 surface area connected to the lower arm of the pendulum. This works as a hydraulic damper that minimizes the high frequency disturbances. The remaining low frequency components of the background noise cause permanent swinging of the pendulum with amplitude about 2-3 mm. To avoid any gravitational noises, no persons should be present in or near the laboratory during measurements. The application of the physical pendulum for the gravity measurement has two important advantages over the torsion balance method: firstly, the "spring constant" of the physical pendulum is very stabile due to constant local gravity acceleration g, secondly, the dissipation factor of the physical pendulum is relatively smaller in comparison with the torsion balance method.

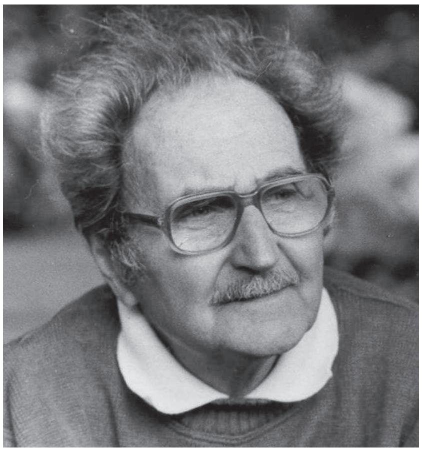

FIG. 2: Laszlo Bodonyi (1919-2001).

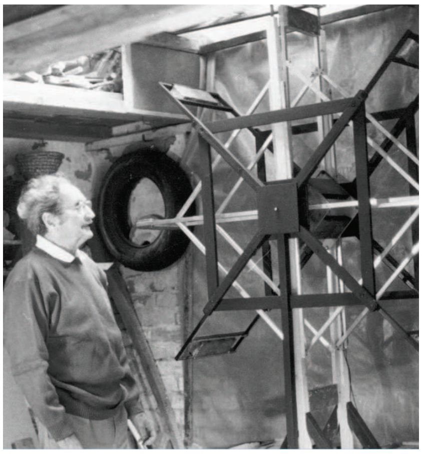

FIG. 3: Bodonyi's instrument for gravity measure.

The disadvantage of the physical pendulum is its small sensitivity; that is why gravity measure of such type has not occurred until this time (or we have no information about it). Now here is a short calculation of the physical pendulum sensitivity. In the case of a small swing, the motion of the physical pendulum is a harmonic oscillation. The spring constant of the pendulum oscillator is

$$k = m^*\omega^2 = 4\pi^2 m^*/T^2 \tag{1}$$

where m^* is the *effective mass* of the pendulum, and T is the period of the pendulum. The typical value of T is about 60 s, the effective pendulum mass is about 50 kg. From these data the spring constant of our physical pendulum is

$$k = 0.087 \text{ N/m}. \tag{2}$$

In the case of a typical torsion balance measure the mass dipole is about 100 grams, the swing period is at least 1200 s which leads to the spring constant

$$k = 4.36 \times 10^{-7} \text{N/m}. \tag{3}$$

From this simple calculation one can conclude that the physical pendulum is not appropriate device for the gravity measure. The photos in FIG. 2. and FIG. 3. are of the Hungarian experimenter Laszlo Bodonyi, and the gravity-measuring instrument devised by him. Bodonyi built a large physical pendulum, intuitively supposing its capability for the gravity measurement, but he did not have enough knowledge to analyze the sensitivity of it. Nevertheless, from the beginning it seemed that the physical pendulum "really" measured the "gravity". Checking later into his experiment, we have concluded that the measured effect is neither an electromagnetic influence, nor a vibration side effect, but really a new physical interaction between the neutral masses having orders of magnitude kilograms. Firstly we have used the name "strong gravity", and later we called the new phenomenon by "dynamic gravity".

Features of the explored dynamic gravity

- The dynamic gravity effect occurs only between moving masses.
- In contrast to the Newtonian (static) gravity approach, there is no static pendulum deflection. The pendulum deflection suddenly rises up only for a short duration, when the source mass starts to move or stops.
- The dynamic gravity effect appears either in attractive or in repulsive forms. The repulsive force occurs in the case when the source mass is moving in the direction of the pendulum mass. Otherwise, an attractive force occurs.
- The dynamic gravity is significantly stronger comparing to the Newtonian (static) gravity.

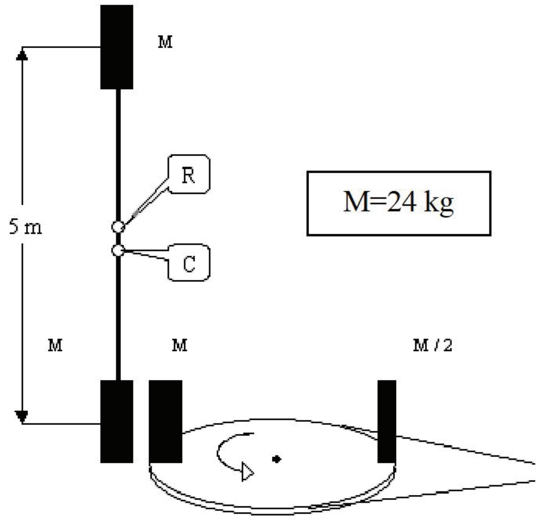

FIG. 4: Setup for quasi-resonance measurement of the dynamic gravity (R pivot of pendulum, C mass center of pendulum, M-s are cubes of lead).

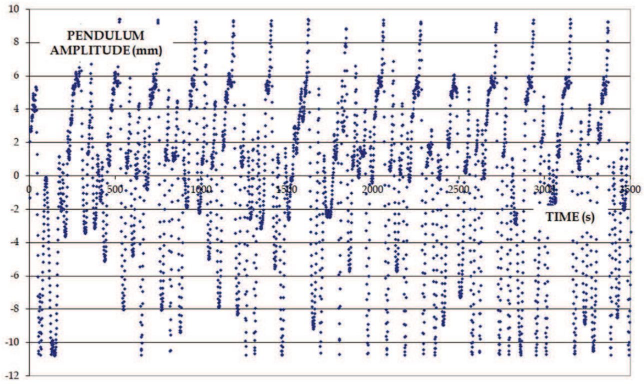

FIG. 5: Gravity measurement by quasi-resonance method: physical pendulum amplitude vs. time. Total duration of the measurement was 3500 s.

III. THE QUASI-RESONANCE MEASUREMENT

When the physical pendulum is tuned to its maximum reachable period (about 60-70 s), it shows a "perpetual-motion machine" in consequence of the environment's mechanical noises. The successful measure of the dynamic gravity requires permanent motion of the physical pendulum, avoiding its adhesive friction in its rest state. The source masses must be continuously periodically moving. For the purpose of detailed investigation of the dynamic gravity we have realized a *quasi-resonance* measurement using big physical pendulum introduced above. The experimental setup is shown in FIG. 4. This gravity measurement uses two moving source masses ($M = 24$ kg, $M/2 = 12$ kg,) placed diametrically on the rotating table (turntable) driven by a small electromotor through a narrow rubber belt. The rubber belt reduces the vibration noise of the motorized driver. The turntable is made of hard wood in our particular case, but generally any non-magnetic material could be used for this purpose. The turntable and its driver system are placed on the floor, while the hanging of the pendulum is fixed to the ceiling of the laboratory. This solution gives a good isolation against the coupled vibrations of the whole instrument. The fixation of the parts of the measuring system is realized with flexible materials (rubber and plastic spacers). The preliminary control tests proved that there was no measurable mechanical coupling between the turntable and the pendulum. It has also been shown that the automatic system for moving the source masses did not significantly affect the pendulum movement. The radius of the turntable is 0.5 meter; the minimum distance between the source masses and the pendulum lower mass is about 0.2 meter.

In the resonance method for gravity measurement, the rotation frequency of the source masses are adjusted to the natural frequency of the physical pendulum[6]. In the beginning of the test period, we tried this usual measuring procedure, but we were not able to reach the desired resonance. Fortunately, in time we succeeded in discovering the reason for this fault. The relatively quick-rotating source masses cause strong amplitude modulation to the pendulum movement, and simultaneously a strong frequency modulation.

From our experience, we have learned that in the case of a relatively long-period pendulum, the period strongly depends on the amplitude of the pendulum. In our experiment the amplitude and period are approximately proportional to one another, showing the fact that the kinetic energy of the pendulum is almost constant. This situation occurs when the pendulum period is unusually big. Because of the pendulum frequency instability, resonance conditions were not fulfilled.

The solution was to reduce the turntable rotation frequency until gravitational resonance appeared. Away from resonance, pendulum amplitude is less than 2-3 mm, which we qualified as the background noise of the pendulum. In our most successful measurements, the period of the pendulum was about 72 s, and the rotation period of the turntable was slowly reduced, with resonance at period of about 4 x 72 = 288 s. Then the pendulum amplitude increased up to 10 mm. For this reason, our experimental measurement method could more precisely be called "quasi-resonance measuring method". The rotating source masses produce modulation of the pendulum amplitude caused by the new gravitational effect. The FIG. 5 presents the result of the dynamic gravity measure with quasi-resonance method.

IV. THEORETICAL BACKGROUND OF DYNAMIC GRAVITY

A reliable theoretical analysis of the above-described gravitational experiment was not an easy task. It was only clear that in the experiment a continuous energy transport realized from the source masses into the physical pendulum. The quasi-resonance experiment was conducted at the end of 1999. Many years have been spent without an acceptable theoretical model describing our new "dynamic gravity". We have executed many calculations to check different erroneous ideas before reaching a physically comforting result. At last we have found the most simple successful math expression for dynamic gravity force

$$\mathbf{F}_D = G_D \, \frac{m_1 m_2 \mathbf{v}_1 \mathbf{v}_2}{r^2} \frac{\mathbf{r}}{r} = G_D \, \frac{\mathbf{p}_1 \mathbf{p}_2}{r^2} \frac{\mathbf{r}}{r}, \tag{4}$$

where G_D is the dynamic gravity constant determined by experimentally. The dynamic gravity force is proportional to the product of the impulses of the interactive masses and inverse proportional to the square of the distance between them. The goal our computer simulation was to prove the validity of force law (4) for the experienced dynamic gravity. We have supposed that the free pendulum movement is nearly harmonic, considering the relatively very small amplitude of its motion. The gravity effect acts on the pendulum as excitation force. From classical theory of mechanics, the movement of the pendulum is determined mathematically with an inhomogeneous second order differential equation

$$\begin{gathered} \ddot{x} = -\omega^2 x - 2\lambda\dot{x} + f_D, \ (f_D = F_D/m_{eff}); \\ m_{eff} = effective\ mass\ of\ the\ pendulum. \end{gathered} \tag{5}$$

Here ω is the natural frequency of the physical pendulum, which is approximately $2\pi/72$ s. In optimal circumstances, the pendulum has a sharp resonance curve and the outer excitation force rigorously affects to the pendulum with the same pendulum frequency. In a real situation, these conditions are far from fulfilled. The pendulum behaves as a broadband radio receiver. The two lead masses of the turntable radiate with different frequencies which both excite the pendulum. From the optimal (approximately periodic) part of measured pendulum movement (FIG. 6) we can determine the dominant pendulum frequencies and their intensities with Fast Fourier Transformation (FFT). In FFT calculation, besides to the natural pendulum period 72 s, the 36 and 18 s periods (harmonics) also occurred. In addition, the 144 and 288 s periods mainly dominated in the motion movement, which are from the 288 s period of the roundtable. Thus all five harmonics had to solve the motion equation of the pendulum, and then the solutions had to be "superposed" with appropriate weight factors. To summarize, the following periods were included in the computer simulation of the pendulum motion

$$T_n \Rightarrow 288\ s,\ 144\ s,\ 72\ s,\ 36\ s,\ 18\ s, \tag{6}$$

which means that in the movement of the pendulum only the even harmonics are the major ones. For calculation, the speed harmonics of the pendulum motion is required

$$\begin{gathered} v_n = a_n \omega_n \sin \omega_n t; \\ \omega_n = 2^n \omega_0,\ \omega_0 = 2\pi/288s,\ n = 0, 1, 2, 3, 4. \end{gathered} \tag{7}$$

At the first stage of the simulation program, the pendulum amplitude can be selected as a small value, and after the periodic excitation the pendulum amplitude was continuously calculated, feedbacking to the input of the calculation algorithm. The excitation of the harmonics

$$\ddot{x}_n = -\omega_n^2 x_n - 2\lambda\dot{x}_n + f_D(t),\ (n = 0, 1, ...4). \tag{8}$$

The solution of these second-order equations

$$x_n(t) = \int_0^t e^{-\lambda\tau} \sin(\omega_n \tau) f_D(t - \tau) d\tau,\ (n = 0, 1, ...4). \tag{9}$$

Instead of this convolution integration, the Verlet approximation method [7] was chosen to solve these equations. The simulation computer program contains two fitting parameters: the dynamic gravity constant G_D, and the pendulum damping constant λ. The pendulum movement is described by the superposition of the dominant harmonics

$$x(t) \cong \sum_{n=0}^{4} c_n x_n(t),\ \sum c_n = 1. \tag{10}$$

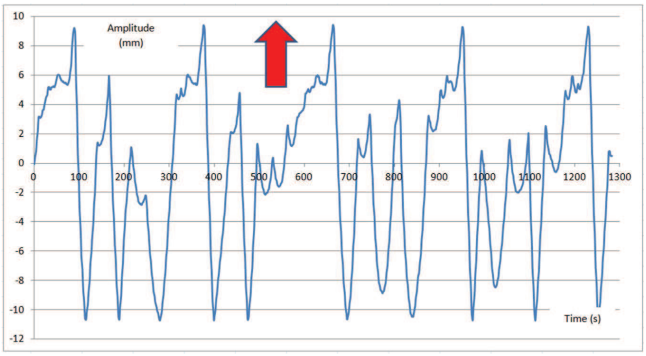

FIG. 6: A part of gravity measure with quasi-resonance method. The physical pendulum amplitude vs. time. Red arrow shows the direction of the source masses.

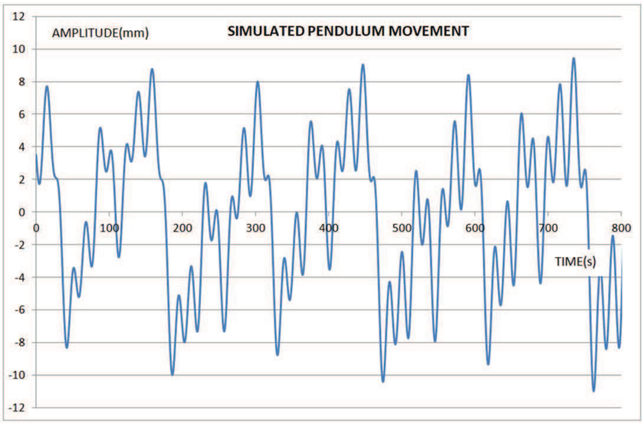

FIG. 7: The simulated part of the gravity measure. The calculated physical pendulum movement vs. time.

The dynamic gravity force is proportional to the speed of harmonics. The acting gravity forces to the harmonics increase in proportion to the frequency, that is, the power of two, so the superposition weight factors are the following

$$c_n = 2^n / \sum_{k=0}^{4} 2^k, \; (n = 0, 1, ..4). \tag{11}$$

The simulation procedure of the measured pendulum movement led to the following results

$$G_D \approx \{c\}\,\{G\}\,\frac{m}{kg} \approx 0.02\frac{m}{kg}; \; \lambda \approx 1/1850\; s, \tag{12}$$

where c *is the speed of light*. The simulated pendulum movement is shown in FIG.7.

V. REMARKS AND CONCLUSIONS

From the beginning we have tried to interpret our experiment as a consequence of Newtonian gravity, as a special gravitomagnetic effect. Finally, the experimentally obtained very strong gravity constant G_D foiled this idea. On the other hand, it seems not a good idea for the physical science community the hypothesis that the gravity has two independent forms (weak and strong). We hope that our final correct statement is that the dynamic gravity is a special appearance of the Newtonian gravity. Newtonian gravity law in its original form is valid for the closed gravitational systems, when the energy of system is constant and the systems are in equilibrium state. This final state of the gravitational system is achieved after a certain time, and we can experience it every day. If the gravitational system is not in equilibrium state then the dynamic gravity effects are immediately present. A remarkable analog exists in the well-known fact that the nucleons within the nuclei are weakly bound (closed system, equilibrium state) in contrast to the strong nuclear reactions, where the energy of interactive nuclei are drastically changing in time.

In our gravitational experiment a continuous energy exchange is realized between the interactive masses. Regarding to the relatively long-term experiment, our measuring system could not reach the gravitational equilibrium because of the permanent energy dissipation of the physical pendulum. The total energy of this gravitational system periodically changes. We can finally agreed that this is the objective reason of our newly experienced gravitational phenomenon. The exact condition of this dynamic gravity effect is an outer, strong time-dependent force (from a motor-driven turntable) holding far the pendulum from the gravitational equilibrium.

The planets of our Solar System constantly interact with each other, but the origin of these forces is only those gravity that caused by themselves inside the Solar System. The Solar System is very like in gravitational equilibrium state. If an outside force (for example a collision with a big asteroid) would act on any of them, probably a significantly stronger effect (dynamic gravity effect) would appear in our Solar System. Fortunately, we have no such experience of cosmic-scale dynamic gravity catastrophe, but our experiment could give important information about this extraordinary event in a small laboratory.

Based on the experiments carried out so far and their theoretical interpretation, it can now safely assert that the strong gravitational effect, i.e. the dynamic gravity really exists between the moving bodies in non-conservative systems, which can be described by a formula other than Newtonian gravity. We have shown that the dynamic gravity is proportional to the scalar product of the impulses of the interacting masses and the dynamic gravitational constant G_D (in numerical value) is the product of the Newtonian constant of gravity multiplied by the speed of light.

The new apperance of the gravitational interaction is unknown until now to physics. Naturally, this discovery requires further independent experimentation and theoretical investigations. Given that dynamic gravity is of many magnitudes greater than Newtonian gravity, it is not excluded that this newly recognized interaction may be a macroscopic version of the *strong interaction*. If further independent laboratory experiments confirm the results so far, then dynamic gravity can be considered one of the greatest discoveries of contemporary physics.

Finally it is important to mention the currently strongly investigated problem regarding with the dark energy and dark matter of the Universe [8]. It is possible that the dark energy and dark matter existence hypotheses are wrong because of the actual insufficient knowledge of gravity. It seems the dynamic gravitational interaction, explored in our experiment, will help to understand these gravitational mysteries in the future.

[1] G. T. Gillies, Metrologia, **24** (suppl. 1) 56, (1987).

[2] D. Kestenbaum, Science **282**, 2180-2181, (1998).

[3] `https://www.mpg.de/621637/pressRelease201006224`

[4] B. P. Abbott *et al.*, (LIGO Scientific Collaboration and Virgo Collaboration) Phys. Rev. Lett. **116**, 061102, (2016)

[5] `http://en.wikipedia.org/wiki/Gravity_Probe_B`

[6] L. Facy and C. Pontikis, C. R. Acad. Sci. **272**, 1397, (1971)

[7] `https://en.wikipedia.org/wiki/Verlet_integration`

[8] `http://science.nasa.gov/astrophysics/focus-areas/what-is-dark-energy/`