THE ”BIG G” CRISIS: metrological deadlock or triumph of precision metrology?

Mykola Kosinov
e-mail: nkosinov@ukr.net

Abstract. *"Big G" is a constant of the Universe; this is its fundamental meaning. Despite more than 200 years of sophisticated experiments, it remains the least precise fundamental constant in physics. "Big G" is not measured directly; it is calculated from Newton's law of gravitation. However, this law has a limitation: it does not take into account the gravity of the Universe. All laboratories obtain G values that are outside the permissible error limits. It is shown that the reason for the discrepancies lies in the fact that the gravitational background of the Universe is not taken into account in the calculation: (mc^2)√Λ. This leads to a shift in the G values by varying amounts, depending on the contribution of (mc^2)√Λ. In essence, metrologists were the first to experimentally detect an external factor of a gravitational nature, which is not included in Newton's law. Physics has traditionally posed challenges to metrology and developed thanks to the results of precise measurements. As R. Davis [2] notes, an increase in accuracy by even one decimal place reveals new physical realities and confirms or refutes existing theories. In the situation with measuring "big G," metrology has outpaced physical theory. Discrepancies in G values showed that Newton's local law of gravity does not allow for its precise value. For the first time in the history of science, metrology had grounds to pose a challenge to theoretical physics: "We have no doubt about the accuracy of our instruments; we have discovered an unaccounted cosmological factor that is not included in your law; a new law of gravity is needed that will allow us to correctly calculate the value of Big G." The Big G crisis is not caused by "bad instruments," but by the imperfection of the physical law from which it is calculated.*

Keywords: *gravity; gravitational constant; cosmological constant; Big G problem; Universe; Great Attractor; astronomy; Newton's law of gravity.*

1. Introduction

In measuring "big G," metrology has encountered an anomaly that cannot be explained within the framework of random or systematic errors. While the stated uncertainty (error) of individual experiments has been reduced to a record 11.6 ppm and 21 ppm (parts per million), the actual discrepancy between results between independent laboratories reaches and exceeds 500 ppm. A ten-year series of experiments by the National Institute of Standards and Technology (NIST) to independently replicate the standard measurements of the International Bureau of Weights and Measures (BIPM), completed in 2026, recorded a statistical gap of 0.0235% (235 ppm) [1]. Perfect instruments produce inconsistent values. Such a discrepancy is a catastrophically large amount for fundamental physics. It cannot be attributed solely to the imperfections of measuring instruments.

The history of physics has repeatedly proven that the "hunt for the next decimal place" is not simply a bureaucratic exercise for metrologists, but the main driver of scientific revolutions [2, 3]. As R. Davis [2, 3] notes, an increase in accuracy by even one decimal place reveals new physical realities and confirms or refutes existing theories. Richard Davis concludes that the pursuit of ultra-precise measurements ("the next decimal place") is the driving force behind discoveries in physics. If metrologists ultimately prove their experiments flawless, but discrepancies in the measurements remain, this will mean the collapse of the classical understanding of gravity. The problem with measuring the gravitational constant is precisely the case where metrology can challenge physical theory.

If we assume that metrologists measured everything correctly over the course of dozens of experiments [4–21], but used the classical formula $F = GmM/r^2$, which doesn't include the gravitational force of the entire Universe, then they could have ultimately obtained not a constant of the Universe itself, but a number close to G. This fundamentally changes the essence of the problem. The hypothesis that the spread of G values is not a metrological dead end, but a signal of the incompleteness of the Newtonian model of gravity, allows us to uncover the deep roots of this problem. This allows us to view the "big G" crisis not as a consequence of "bad instruments," but as an imperfection in the physical law from which it is calculated.

2. The Newtonian model of gravity does not take into account the gravity of the Universe.

The theoretical basis for deriving the value of the gravitational constant G is Newton's law $F = GmM/r^2$. We see that calculating "big G," which is the universal constant, uses a physical law that is inapplicable to describing the gravity of the Universe. This is the main methodological contradiction of an approach that attempts to measure and derive a parameter for the entire Universe solely from the properties of its isolated small parts.

When using Newton's law, the following must be considered:

1. Newton's formula was originally derived by solving the problem of two-body gravity. This is an overly simplified model of gravity. In the real Universe, there is no isolated gravitational interaction between two bodies.

2. Newton's law describes a hypothetical gravitational situation of attraction between two bodies and completely ignores the actual gravitational force of all N bodies in the Universe. Newton's formula describes the gravity of a single local source of attraction and does not take into account that bodies are simultaneously attracted to all other bodies in the universe.

3. Newton's law does not include the parameters of the real universe.

4. Newton's law describes the idealized gravitational interaction of only two bodies in absolutely empty space, assuming that no other bodies exist in the universe. Newton's "miniature universe" completely ignores the gravitational influence of the rest of the cosmos. In the real universe, there is no isolated gravitational interaction between two bodies.

5. Attempting to obtain an exact value for the universal constant from an approximate formula that "ignores" the gravity of the entire universe is mathematically incorrect.

From such an idealized, simplified, and approximate mathematical model of gravity, it is impossible to obtain an exact value for G. Therefore, the root cause of the discrepancy between the measured values of the fundamental constant G should be sought in Newton's formula, which "ignores" the gravitational forces of all other bodies in the universe. From the approximate law of gravity one can only obtain an approximate value of the fundamental constant G.

3. "Big G" is a constant of the Universe.

"Big G" is a constant of the Universe; this is its fundamental meaning. "Big G" is not measured directly; it is calculated from Newton's law of gravitation, $F = GmM/r^2$, assuming that the local interaction of two masses is completely isolated from the rest of the cosmos. By ignoring the contribution of the Universe in the theoretical model for calculating G, we commit a fundamental error. Calculating a parameter of the Universe from the local law of gravitation without taking into account the influence of the Universe's gravity is incorrect. Mach's principle states that the inertia and gravitational properties of any body are related to the entire mass of the Universe. This means that G must follow from the strength of the gravitational interaction of all bodies in the Universe, and not from the idealized law of two-body gravitation, $F = GmM/r^2$, which is not applicable to the Universe. We are not discussing the influence of gravitational anomalies such as the Great Attractor, discovered in 1986 by a group of astronomers known in the scientific community as the "Seven Samurai" [22], on the measurement results. We focus on the influence of the mass of the entire universe on the measurement results.

Accounting for gravitational anomalies of the universe, its scale structure, or the mass of the entire universe does not affect the fundamental constant G itself, but rather its accuracy when calculated in a specific ground-based laboratory. The constant G itself remains unchanged. However, the Earth is a dynamically moving, deforming platform immersed in the highly complex gravitational landscape of the universe. The desire to perfectly isolate both the measuring system and the mathematical formula from the component of the external gravitational background leads to the loss of the component of the gravitational force of the Universe, which is so necessary for the calculation of G.

The influence of the Great Attractor on the measurement results of "big G" is insignificant: the direct gravitational acceleration from the Great Attractor is on the order of 10^(-13) m/s^2. The same cannot be said for the gravitational background of the entire Universe. Calculations show that the maximum gravitational acceleration due to the mass of the Universe is on the order of 10^{-9} m/s^2. The acceleration imparted by external attractive masses to internal test masses in a torsion balance is extremely small, amounting to about 10^{-7} m/s^2. Compared to an acceleration of about 10^{-7} m/s^2, an acceleration due to the mass of the Universe of 10^{-9} m/s^2 is an enormous value.

According to Einstein's equivalence principle, it is impossible to directly measure the gravitational background of the Universe with any local instruments. But it exists, and it must be taken into account when calculating the gravitational constant. Therefore, the problem of "big G" should be considered more broadly: both as a measurement problem and as a calculation problem. It is a complex problem. Therefore, the requirement for the accuracy and completeness of the physical law from which "big G" is calculated comes to the fore.

4. The "double blindness" situation.

The measurement problem is related to the limitations of the ultra-precise instrument. These limitations manifest themselves in the fact that torsion balances or atomic interferometers are "blind" to the vector of the Universe's gravitational force, since the instrument is in free fall with the Earth and the Solar System.

The calculation problem is related to the limitations of the mathematical model of gravity. The limitation of the formula $F = GmM/r^2$ is that Newton's equation completely ignores the real, but instrumentally unobservable, gravitational force. This is a "double blindness" situation, where both the instrument and the calculation formula are limited.

The "double blindness" situation combines instrumental limitations and the incompleteness of the law of gravity into a single methodological trap, making it impossible to accurately calculate the value of the fundamental constant in terrestrial laboratories. The "blindness" of the instrument and the "blindness" of the equation $F = GmM/r^2$ complement each other, locking themselves into a local coordinate system and ignoring the external gravitational force of the Universe, which actually exists and is necessary for calculating the gravitational constant.

On the one hand, Newton's formula does not take into account the gravity of the Universe, while on the other hand, the instrument is designed to reject any external influences and record only the gravitational force of two masses. In other words, the instrument is forcibly adapted to Newton's local formula. As a result, we calculate the constant within the framework of physical and mathematical isolation from the gravity of the Universe, but attempt to pass it off as a constant of the Universe itself. When perfectly functioning instruments fail to measure complete data, and the results of precise but incomplete measurements are calculated using an incomplete mathematical formula, this is not a metrological impasse, but something more. It is a crisis of methodology, which attempts to describe the whole through an isolated part, and a crisis of the theory of gravity.

The discrepancy between the values of the constant G is a natural phenomenon for the local physical model of gravity and the local law of gravity. It can be concluded that precision metrology has made a discovery—it has experimentally discovered limits beyond which the old mathematical model of gravity, which does not take into account the gravity of the entire Universe, fundamentally fails to function.

5. A new formula for calculating "big G" that takes into account the gravity of the Universe.

A new law of gravity, which will allow metrologists to correctly calculate "big G," must include the parameters of the observable Universe. When calculating the gravitational constant G, it is proposed to use a law of gravity that takes into account the gravity of the Universe instead of Newton's law [23]:

$$F_U = \frac{GmM}{r^2} + mc^2\sqrt{\Lambda} \qquad (1)$$

Fig. 1. The law of universal gravitation, taking into account the gravity of the universe.
Where: m and M are the masses of objects, r is the distance, c is the speed of light in a vacuum, G is the gravitational constant, and Λ is the cosmological constant.

Formula (1) paves the way for calculating a more precise value for the gravitational constant G, which is a constant of the Universe. Formula (1) has two components: the Newtonian force and the gravitational force of the Universe:

$$F_U = F_{\{Newton\}} + F_{\{Universe\}} \quad (2)$$

To simplify formula (1), we introduced the maximum value of the cosmological force F{Universe} = $(mc^2)\sqrt{\Lambda}$. Instruments do not directly detect the gravitational force of the Universe F{Universe}, since both laboratories and instruments are in free fall with respect to this force vector. However, this force exists and is necessary for the correct calculation of the constant G. It must be taken into account during the mathematical calculation of the results. Taking F{Universe} into account eliminates not instrumental errors, but rather the error in calculating "big G," which led to the "chaotic" scatter of G values obtained by different laboratories.

6. The reason for the chaotic spread of G values.

According to the extended formula $F_U = GmM/r^2 + (mc^2)\sqrt{\Lambda}$, the cosmological force of the Universe $F_{Cos} = (mc\text{^}2)\sqrt{\Lambda}$ acts as a constant external vector. When physicists at different points on Earth and at different times measure the force of attraction between test masses, their laboratory setup is oriented at different angles (α) to the common "universal vector." Because of this, the projection of the external cosmological force $((mc^2 \bullet \sqrt{\Lambda}) \bullet \cos\alpha)$ onto the instrument's measurement axis differs each time [23]. However, Newton's formula does not take this into account. The result is an artificially created, chaotic spread in the calculated value of the constant G from laboratory to laboratory.

For this reason, the "Big G crisis" may not be an instrumental error, but a signal that the basic formula did not take into account the contribution of the Universe. There are precedents for this:

1. Additional noise from a cosmic source, modulated not by the sun (24 hours), but by the stars (23 hours 56 minutes 4 seconds), was observed in the TR&D-96 experiment during repeat measurements in 2002 [24, 25].

2. In 2015, a group of physicists led by John Anderson discovered that the "chaos" in the calculated values of Big G has a clear periodicity: the calculated values of G fluctuate with a period of 5.899 years [26].

Perhaps this reflects the indirect influence of an external gravitational field on the results of Big G measurements. The results obtained by the groups of Mikhail Gershtein and John Anderson have been harshly criticized. It is advisable to return to these results and reanalyze them, taking into account the mathematical incompleteness of Newton's law.

If there is an external gravitational field, then the vector of this hidden influence is projected differently onto the measuring axes of instruments at different points on the planet. The contribution of the second component of formula (1) depends on the angle between the cosmological force vector and the sensitive axis of the instrument. Accordingly, this contribution depends on the laboratory's geographic coordinates and the Earth's orientation as it moves through space. Failure to account for this contribution, given such complex instrument motion, leads to a "chaotic" scatter of values obtained by different laboratories.

When a physical law is used as a "mathematical tool" to extract a constant, any incompleteness of the law itself automatically becomes an anomaly in the calculation of that constant. What metrologists call a "systematic error of instruments" may in fact be an incompleteness of the formula used in the calculation. Instead of shifting the blame to the instruments, it is time to acknowledge that the mathematical tool for calculating ($F = GmM/r^2$) has exhausted its accuracy for this problem.

Since Newton's law is fundamentally incomplete and does not take into account the cosmological scale, its use yields not a fundamental constant of the Universe, but a "coefficient" close to its value for isolated bodies in absolutely empty space. This is the profound conceptual conflict between Newton's local physics and the real gravitational interaction of all bodies in the Universe. There is a fundamental limitation of the Newtonian approach: it is impossible to obtain the constant G of the entire Universe in a local experiment, completely abstracting from the fact that the experiment itself is carried out within the unified gravitational field of the Universe.

7. An unaccounted for external factor of gravitational origin.

The "big G" crisis is pushing for a paradigm shift: instead of "measurement error," it has become possible to view metrologists' results as the discovery of a new physical phenomenon. Viewed from this perspective, metrologists, unwittingly, were the first to stumble upon experimental proof that the gravity of a local system is fundamentally open to the outside. A local system always contains an unaccounted for "external factor," which is ignored by Newton's law.

To resolve this discrepancy, an extended formula is proposed: $F_U = GmM/r^2 + (mc^2)\sqrt{\Lambda}$, which includes a component that includes the cosmological constant Λ to account for cosmic-scale mass.

Newton's equation (F = GmM/r^2) takes into account only two local masses and ignores the fact that these masses are located within the colossal external field of the Universe. The spread of G values is the first direct laboratory evidence of the influence of the global structure of the Universe on local processes (in the spirit of Mach's principle).

Metrology has experimentally revealed the limits of applicability of the local law of gravity. This is the most important conceptual conclusion from this long-standing metrological drama. It is a direct indication that the problem should be moved from the category of "bad measurements" to the category of "incomplete theory of gravity."

8. Shifting the focus from "bad instruments" to the imperfections of the physical law of gravity.

Science typically develops according to the following formula: Theory → Metrological verification → Confirmation (or correction). In the case of measuring the constant G, this cycle broke down. Metrologists created incredibly sensitive instruments capable of eliminating known types of instrumental and systematic errors, but instead of the long-awaited agreement in their results, they encountered chaos.

When ultra-precise instruments in different laboratories around the world systematically produce inconsistent, yet perfectly reproducible, results, this proves that metrology has fulfilled its mission to the fullest. The problem was not the imperfections of the instruments, but the imperfections of the physical law of gravity. The stable discrepancy in Big G values, confirmed in multiple measurements, is a valuable experimental result for rethinking gravity.

Metrologists accurately and honestly documented reality. And the fact that the measurement results diverge means the following: *the spread of values indicates the existence of a reality that Newton's formula "does not see."*

9. Metrology has outpaced physics.

For centuries, metrology followed in the footsteps of theoretical physics, confirming its hypotheses. Physicists postulated laws, and metrologists confirmed them numerically. In the case of measuring "big G," metrology outpaced physical theory. Discrepancies in G values demonstrated that Newton's local law of gravity does not allow for its precise value. This precedent transformed metrology from a "service staff" into the primary taskmaster for theoretical physics. For the first time in the history of science, metrology had grounds to pose a challenge to theoretical physics: "We have no doubt about the accuracy of our instruments; we have discovered an unaccounted cosmological factor that is not included in your law; a new law of gravity is needed that will allow us to correctly calculate the value of the gravitational constant." The "big G" crisis is not caused by "bad instruments," but by the imperfection of the physical law from which it is calculated.

The discrepancy in G measurements reveals a crisis in the long-standing formula for the gravitational force, not instrumental error. If G is considered a parameter inextricably linked to the entire Universe, then the laboratory results become logical. What were previously called "unaccounted systematic errors" are actually explained by the contribution of the cosmological term $(mc^2)\sqrt{\Lambda}$. Laboratories do not measure "pure" G, but only its effective local value, which does not include the gravitational factor of the Universe. Since the contribution of the cosmological background depends on the specific experimental conditions and the orientation of the instrument in space, this unaccounted factor is always different.

The discrepancy in G values has exposed the incompleteness of a fundamental law of physics. The fact that ideal instruments produce different values means one thing: the classical gravity equation does not describe reality in laboratories. It does not take into account the gravitational force of the mass of the Universe, which is necessary to calculate G.

10. The Triumph of Precision Metrology.

This creates the false impression that metrology is incapable of measuring "big G." In fact, by detecting discrepancies in "big G" values, it has reached a hard limit of the existing gravity paradigm. When ideal instruments under ideal conditions yield different results, this means that the formula from which these results follow is imperfect. A dead end turns into a triumph, since this dead end experimentally proves the incompleteness of Newton's local law. Metrology has made a major discovery by contradiction: it has documented discrepancies in "big G" values and, thus, established the limits of the applicability of classical physics. This is not a dead end, but a triumph.

The triumph of metrology lies not only in achieving the highest precision, but also in the fact that this high precision allowed for the detection of discrepancies that revealed the presence of an additional external factor of gravitational origin, absent from Newton's law. This is experimental proof that in the real world, an additional external factor of gravitational origin exists that Newton's law simply cannot describe.

If physicists simply added another decimal place to the value of "Big G," it would be a triumph of engineering, but it would not change our understanding of the influence of the Universe's gravity. Everything points to a modeling error. Scientists tried to solve the problem in a closed system, forgetting that the system is actually open. The formula suitable for calculating "Big G" is: $F_U = F_{\{Newton\}} + F_{\{Universe\}}$. However, metrologists use only the first part of $F_{\{Newton\}}$.

The opportunity to obtain the true value of "Big G" still remains! There is no need to conduct repeated measurements. Every laboratory's source data archives contain everything necessary! It is sufficient to perform calculations using the open-system formula $F_U = F_{\{Newton\}} + F_{\{Universe\}}$, which takes into account the gravity of the Universe. The differences in results between China, the United States and Europe may be directly related to the fact that the influence of the gravitational field of the Universe, which has a different value at a particular point and depends on the coordinates of the laboratory and the movement of the Earth, was not taken into account.

All scientific groups have expended colossal effort and time on this "capricious" constant. Everyone has arrived at different values for the constant. Everyone is disappointed. I believe that every scientific group is interested in a recalculation to salvage decades of their titanic work and turn this "failure" into a scientific discovery.

11. Final Remarks.

1. "Big G" is a constant of the Universe, but it is calculated from Newton's law of gravity, which ignores the gravity of the Universe. Attempting to derive an exact value for the constant of the Universe from an approximate formula that "ignores" the gravity of the entire Universe is mathematically incorrect. This is the profound conceptual conflict between the local nature of Newton's law and the global nature of gravity itself.

2. Persistent discrepancies in "big G" measurements are due to an incomplete Newtonian model. There is a fundamental limitation of the Newtonian approach: it is impossible to obtain an exact value of G in a local experiment, which completely ignores the fact that the experiment itself is conducted within the unified gravitational field of the Universe.

3. The chaotic distribution of "big G" values arises because the mathematical model of gravity does not take into account the gravitational background of the Universe. When ultra-precise instruments show chaos, this is not an experimenter's error, but direct evidence of an incomplete mathematical model of gravity.

4. Discrepancies in measurements of large G values are not a scatter of G itself and do not indicate a variation in the constant. The constant G remains constant. The scatter of G values is a computational artifact.

5. Metrology has experimentally discovered the limits of the applicability of local physics. For this reason, the problem of "big G" should be reclassified from the category of "poor measurements" to the category of "incomplete theory of gravity."

6. The metrological impasse with "big G" turns into a triumph for metrology and becomes direct evidence of the imperfections of gravity theory. This is an even more significant result for science than an extra decimal digit in the value of the constant G. The spread of G values does much more than that—it demands a new cosmological paradigm.

7. The triumph of metrology lies not only in achieving the highest precision, but also in the fact that, thanks to high precision, discrepancies were discovered that revealed the presence of an additional external factor of a gravitational nature, absent from Newton's law.

8. For the first time in the history of science, metrology had grounds to pose a problem to theoretical physics: “*a new law of gravity is needed that will allow the value of the gravitational constant to be correctly calculated*.”

9. The opportunity to obtain the true value of "Big G" is still not lost! There is no need to conduct repeated measurements. While theoretical physicists are busy searching for a new law of gravity (as the history of science shows, this could take several hundred (!) years), we can already use the formula $F_U = F_{\{Newton\}} + F_{\{Universe\}}$. It is quite possible that the scatter will disappear, and the calculated values of "Big G" will miraculously converge within a narrow range of their values.

10. The world's leading laboratories have accumulated a colossal array of ultra-precise measurements. There's no need to rebuild a torsion balance. We can take these existing numbers and run them through a new mathematical filter: $F_U = F_{\{Newton\}} + F_{\{Universe\}}$. The price at stake: the true value of the "Big G" constant of the Universe.

References.

1. Schlamminger, S. , Chao, L. , Lee, V. , Shakarji, C. , Newell, D. , Stirling, J. , Cochrane, R. and Speake, C. (2026), Redetermination of the Gravitational Constant with the BIPM torsion balance at NIST, Metrologia, [online], https://doi.org/10.1088/1681-7575/ae570f, https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=961075
2. R. Davis, "Science and Precision Measurement," in IEEE Instrumentation & Measurement Magazine, vol. 20, no. 1, pp. 8-10, February 2017, doi: 10.1109/MIM.2017.7864542.
3. Davis, R. Big G revisited. Nature 468, 181–182 (2010). https://doi.org/10.1038/468181b
4. Quinn T J, Speake C C, Richman S J, Davis R and Picard A 2001 A new determination of G using two methods Phys. Rev. Lett. 87 111101
5. Quinn T J, Speake C, Parks H and Davis R 2014 The BIPM measurements of the Newtonian constant of gravitation, G Phil. Trans. R. Soc. A 372 20140032
6. Bagley C H and Luther G G 1997 Preliminary results of a determination of the Newtonian constant of gravitation: a test of the kuroda hypothesis Phys. Rev. Lett. 78 3047
7. Kleinevoß U 2002 Bestimmung der newtonschen gravitationskonstanten G PhD Thesis (University of Wuppertal)
8. Armstrong T R and Fitzgerald M P 2003 New measurements of g using the measurement standards laboratory torsion balance Phys. Rev. Lett. 91 201101
9. Luo J, Hu Z-K, Fu X-H, Fan S-H and Tang M-X 1998 Determination of the Newtonian gravitational constant G with a nonlinear fitting method Phys. Rev. D 59 042001
10. Hu Z-K, Guo J-Q and Luo J 2005 Correction of source mass effects in the HUST-99 measurement of G Phys. Rev. D 71 127505
11. Schlamminger S, Holzschuh E, Kündig W, Nolting F, Pixley R E, Schurr J and Straumann U 2006 Measurement of Newton's gravitational constant Phys. Rev. D 74 082001
12. Luo J, Liu Q, Tu L-C, Shao C-G, Liu L-X, Yang S-Q, Li Q and Zhang Y-T 2009 Determination of the Newtonian gravitational constant G with time-of-swing method Phys. Rev. Lett. 102 240801
13. Tu L-C, Li Q, Wang Q-L, Shao C-G, Yang S-Q, Liu L-X, Liu Q and Luo J 2010 New determination of the gravitational constant G with time-of-swing method Phys. Rev. D 82 022001
14. Parks H V and Faller J E 2010 Simple pendulum determination of the gravitational constant Phys. Rev. Lett. 105 110801
15. Parks H V and Faller J E 2014 A simple pendulum laser interferometer for determining the gravitational constant Phil. Trans. R. Soc. A 372 20140024

16. Rosi G, Sorrentino F, Cacciapuoti L, Prevedelli M and Tino G M 2014 Precision measurement of the Newtonian gravitational constant using cold atoms Nature 510 518
17. Newman R, Bantel M, Berg E and Cross W 2014 A measurement of G with a cryogenic torsion pendulum Phil. Trans. R. Soc. A 372 20140025
18. Li Q et al 2018 Measurements of the gravitational constant using two independent methods Nature 560 582–8
19. Luther G G and Towler W R 1982 Redetermination of the Newtonian gravitational constant g Phys. Rev. Lett. 48 121
20. Karagioz O V and Izmailov V P 1996 Measurement of the gravitational constant with a torsion balance Meas. Tech. 39 979
21. Gundlach J H and Merkowitz S M 2000 Measurement of Newton's constant using a torsion balance with angular acceleration feedback Phys. Rev. Lett. 85 2869–72
22. Dressler, Alan; Faber, S. M.; Burstein, David; Davies, Roger L.; Lynden-Bell, Donald; Terlevich, R. J.; Wegner, Gary. Spectroscopy and photometry of elliptical galaxies — A large-scale streaming motion in the local universe // Astrophysical Journal, Part 2 — Letters to the Editor. — 1987. — T. 313 (15 February). — C. L37—L42. — doi:10.1086/184827
23. Kosinov, M. (2026). THE PROBLEM OF MEASURING THE GRAVITATIONAL CONSTANT G: The greatest metrological dead end in history or proof that gravity is more complex than Newton thought? *Cambridge Open Engage*. doi:10.33774/coe-2026-xrl0t-v3
24. Gershteyn, Mikhail L. et al. "Experimental evidence that the gravitational constant varies with orientation." arXiv: Classical Physics (2002): n. pag.
25. Experimental evidence that the gravitational constant varies with orientation. by Mikhail L. Gershteyn, Lev I. Gershteyn, Arkady Gershteyn, Oleg V. Karagioz. arXiv:physics/0202058.
26. Anderson J. D., Schubert G., Trimble V., Feldman M. R. Measurements of Newton's gravitational constant and the length of day // EPL. — 2015. — Vol. 110, No. 1. — P. 10002.