SRYAHWA PUBLICATIONS

Open Access Journal of Physics
ISSN: 2637-5826 | Volume 8, Issue 3, 2026
https://doi.org/10.22259/2637-5826.0803009

RESEARCH ARTICLE

On a Branch-State Interpretation of the Spread in Measurements of the Newtonian Gravitational Constant

Jiří STÁVEK

Independent researcher, Prague, Czech Republic.

Received: 14 July 2026 Accepted: 29 July 2026 Published: 04 August 2026

Corresponding Author: Jiří STÁVEK, Independent researcher, Prague, Czech Republic, stavek.jiri@seznam.cz

Abstract

The Newtonian gravitational constant G remains the least precisely known of the major fundamental constants. Modern measurements report small internal uncertainties, yet their values remain spread beyond a simple common-error interpretation. This paper refines a branch-state proposal for organizing reliable G measurements. The data are not treated as a single random cloud, nor primarily as a function of publication year, source-mass atomic number, mass number, or calendar month. Instead, the measurements are organized as LOW, MIDDLE, and HIGH branches, interpreted as signatures of apparatus family and campaign state. The 2026 NIST redetermination using the BIPM torsion balance is included as a central clue, because it connects the historical BIPM lineage to a lower central value. The proposed hidden variable X is the Gerber-Mach gravitational potential where the radial velocity (dr/dt) represents the relative velocity of the source mass + test mass towards the Sagittarius A*. The Mach angle ω describes the interaction of the mass of the Milky Way Galaxy with the measured system – the source mass + the test mass. The Mach angle can be adjusted by the observer and to obtain "the delayed choice" value of G – the observed spread of reliable values of G. The paper does not claim that the branch model is proven. It proposes a testable diagnostic map and a research program in order to scan suspected hidden variable – the Gerber-Mach gravitational potential.

Keywords: Earth ↔ Sagittarius A* Radial Velocity, Newtonian Gravitational Constant G, Gerber-Mach Gravitational Potential, Hidden Variable X, Delayed-Choice Experiment.

1. Introduction[1]

The Newtonian gravitational constant G appears in Newton´s law of universal gravitation. In the equation it is simple, in the laboratory it is extremely difficult. The gravitational force between laboratory masses is weak, and the desired signal is easily accompanied by small mechanical, gas-pressure, thermal, electrostatic, magnetic, and geometrical effects. The Newtonian gravitational law is written in a simple form:

$$F = \frac{GMm}{r^2} \qquad G = 6.67430(15) * 10^{-11}\ m^3 kg^{-1} s^{-2} \quad (1)$$

where F is the attractive force between two masses M and m separated by a distance r, and G is the universal gravitational constant with the CODATA-2022 recommended value. This corresponds to a relative standard uncertainty of about 22 ppm, much larger than for most other fundamental constants [1]-[20]. The difficulty is not that the law is conceptually complicated.

The key difficulty is not merely that G is hard to measure. The deeper problem is that high-quality experiments do not agree as well as their quoted uncertainties might suggest. Schlamminger, Gundlach, and Newman [21] emphasized this disturbing situation in their 2015 analysis of recent G measurements as a function of time.

This refined paper proposes that the spread of G values is best viewed as a map of apparatus-family and campaign-state biases. In this view, the values form experimental branches rather than a single featureless cloud. This paper proposes a hidden parameter X that may represent a correction of Newtonian gravity – the Gerber-Mach gravitational potential, e.g. [22]-

Citation: Jiří STÁVEK, On a Branch-State Interpretation of the Spread in Measurements of the Newtonian Gravitational Constant. Open Access Journal of Physics. 2026;8(3): 118-127.

[35]. The question is not whether it can replace general relativity, e.g. [36]-[49]. The question is what information should be inserted into the Gerber-Mach formula in order to describe the observed spread of G values.

2. Working Hypothesis and Data Organization Strategy

The working hypothesis is that each experiment measures the true gravitational constant plus small apparatus-dependent and campaign-dependent offsets. These offsets may be positive or negative and may differ across apparatus families:

$$G_{measured} = G_{true}\left(1 \pm X_{hidden}\right) \quad (2)$$

The proposed hidden parameter X is introduced as a compact diagnostic parameter measuring the size of some unknown effects modifying the value of G_{true}. The scientific task is therefore to replace the abstract rank-order parameter X by a physically measured state variable constructed from real experimental metadata, [50]-[51].

The analysis follows six organizational steps: composition parameters, calendar month, short acquisition campaigns, BIPM/NIST lineage, branch-state grouping, and the G Atlas Project. Table I surveys the program for ordering the reliable measurements of G.

Table 1. *Ordering of reliable measurements of G*

Step	Test	Purpose
1	Composition test	Plot G versus Z, A, and Z/A of source masses.
2	Calendar-month test	Reorganize Schlamminger et al. Table II by month of mean acquisition date.
3	Short-campaign filter	Use measurements with acquisition duration shorter than 75 days; add NIST-26
4	BIPM/NIST lineage	Compare BIPM-01 and BIPM-13/14 family values with NIST-26.
5	Branch model	Organize reliable values into LOW, MIDDLE, and HIGH branches.
6	A hidden variable X	The G Atlas Project

A natural first question is whether the spread of G correlates with the source-mass composition. The figures published in [52] do not show a simple monotonic law where G does not depend on the source mass atomic number Z, the atomic mass A, and the fraction of proton number Z/A.

3. Calendar-Month Organization

Schlamminger, Gundlach, and Newman [21] tabulated start dates, end dates, average acquisition dates, and acquisition durations. This enables a reorganization of their values by calendar month instead of publication year. Calendar month may be only a proxy, but it can contain an unknown parameter X. Table II organizes G values of those campaigns for the middle month of those long-time experiments.

Table 2. *Calendar-month projection of the G data*

Month group	Representative entries	Method family	Observed region
Mar	LANL-97; UWUP-02; UW-00	mixed methods	around 6.6740-6.6743
Apr	HUST-09a; UCI-14b; UCI-14c	time-of-swing family	around 6.6735-6.6746
May-Jul	JILA-10; LENS-14; MSL-03	pendulum, atom interferometer, servo	low to central
Aug	UZH-06	beam balance	middle-high
Sep-Oct	HUST, NIST-82, UCI, BIPM entries	mixed; BIPM high values appear	wide spread
Nov-Dec	BIPM family entries	BIPM torsion balance	high branch

Fig. 1 documents the spread of reliable measurements of the Newtonian gravitational constant G as a function of calendar month.

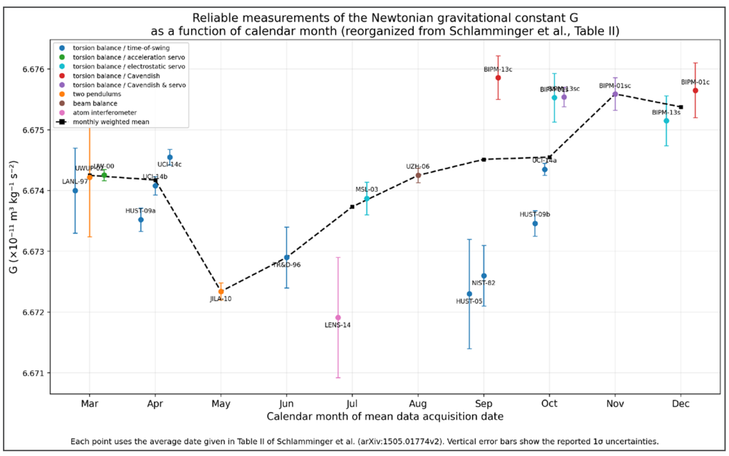

Figure 1. *Reliable measurements of G as a function of calendar month, reorganized from Schlamminger et al. Table II [21].*

A more refined filter is to select measurements acquired over relatively short campaigns. This reduces mixing of different apparatus states over long-time intervals. The working criterion is: Δt (acquisition) < 75 days. Table 3 and Fig. 2 show these selected short-campaign measurements of G.

Table 3. *Selected short-campaign measurements of G. (Reorganized from Schlamminger et al. Table II [21]). Values are in units of 10-11 m3 kg-1 s-2.*

Month	ID	G	u(G)	Duration	Method
Mar	UW-00	6.674255	0.000092	39 d	acceleration servo
Apr	HUST-09a	6.67352	0.00019	60 d	time-of-swing
Apr	UCI-14b	6.67408	0.00015	48 d	time-of-swing
Apr	UCI-14c	6.67455	0.00013	36 d	time-of-swing
Apr*	NIST-26	6.67387	0.00038	150 d	BIPM torsion balance at NIST
May	JILA-10	6.67234	0.00014	25 d	two pendulums
Jul	LENS-14	6.67191	0.00099	7 d	atom interferometer
Aug	UZH-06	6.67425	0.00012	21 d	beam balance
Sep	NIST-82	6.6726	0.0005	42 d	time-of-swing
Sep	HUST-05	6.6723	0.0009	72 d	time-of-swing
Sep	BIPM-13c	6.67586	0.00036	10 d	Cavendish
Oct	BIPM-01s	6.67553	0.00040	34 d	electrostatic servo
Oct	HUST-09b	6.67346	0.00021	39 d	time-of-swing
Oct	UCI-14a	6.67435	0.00010	38 d	time-of-swing
Dec	BIPM-01c	6.67565	0.00045	18 d	Cavendish
Dec	BIPM-13s	6.67515	0.00041	69 d	electrostatic servo

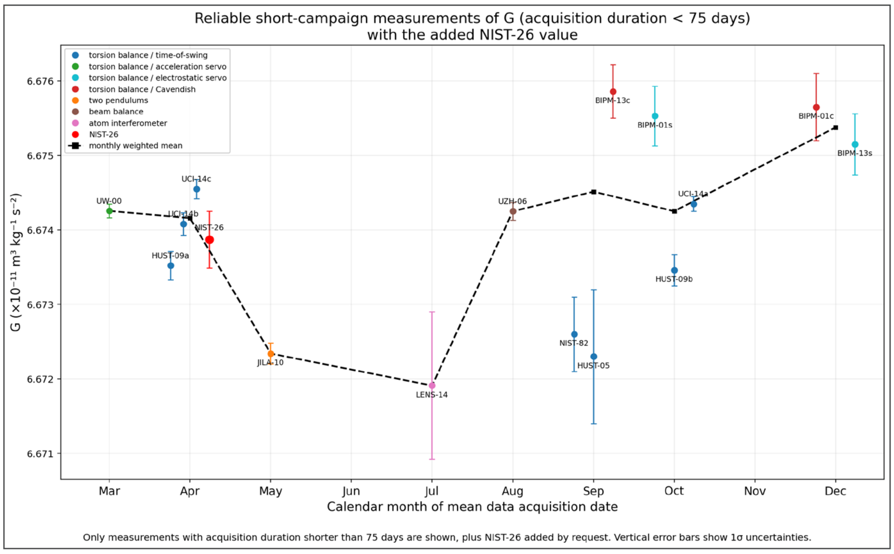

Figure 2. *Short campaign measurements of G with NIST-26 added as a modern comparison point, reorganized from Schlamminger et al. Table II [21].*

4. The BIPM/NIST Clue

The 2026 NIST redetermination [12] is a central clue because it used the historical BIPM torsion-balance lineage but obtained a lower value than the earlier BIPM branch. This suggests that the same apparatuses lineage can move from the HIGH branch toward the MIDDLE branch, depending on campaign state and correction model. Fig. 3 documents BIPM-01, BIPM-13/14 and NIST-26 values of G.

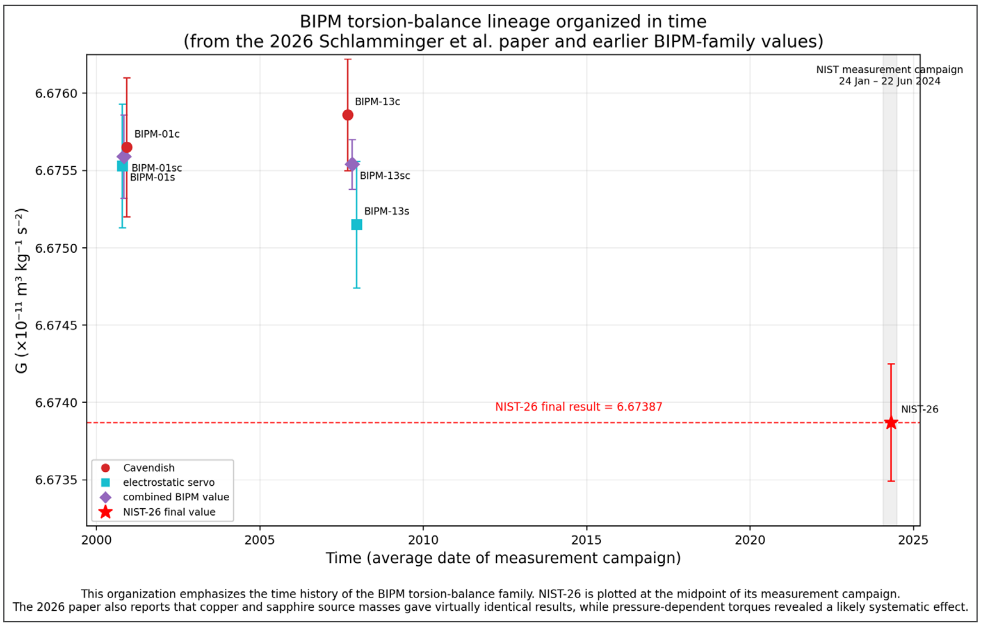

Figure 3. *BIPM torsion-balance lineage organized in time, from BIPM-01 and BIPM-13/14 to NIST-26.*

5. LOW, MIDDLE, and HIGH Branches

The most useful organization found in this study is the branch-state organization. The reliable values are divided into LOW, MIDDLE, and HIGH branches:

LOW: $G < 6.6730$

MIDDLE: $6.6730 \leq G < 6.6750$ (3)
HIGH: $G \geq 6.6750$

The branch structure is interpreted as a diagnostic map of hidden apparatus and campaign-dependent biases. Each branch may represent a family of hidden parameters that should be discovered in the future. In this interpretation, the branch model does not replace precision metrology. It provides a map for deciding which hidden variables should be measured and deliberately scanned. Tables 4 and 5.

Table 4. *Reliable G values organized into LOW, MIDDLE, and HIGH branches. Values are in units of 10^{-11} m^3 kg^{-1} s^{-2}.*

Branch	ID	G	u(G)
LOW	LENS-14	6.67191	0.00099
LOW	HUST-05	6.67222	0.00087
LOW	NIST-82	6.67248	0.00043
LOW	JILA-18	6.67260	0.00025
LOW	TR&D-96	6.67290	0.00050
MIDDLE	HUST-09	6.67349	0.00018
MIDDLE	MSL-03	6.67387	0.00027
MIDDLE	NIST-26	6.67387	0.00038
MIDDLE	LANL-97	6.67398	0.00070
MIDDLE	HUSTT-18	6.674184	0.000078
MIDDLE	UWup-02	6.67422	0.00098
MIDDLE	UZur-06	6.67425	0.00012
MIDDLE	UWash-00	6.674255	0.000092
MIDDLE	UCI-14	6.67435	0.00013
MIDDLE	HUSTA-18	6.674484	0.000077
HIGH	BIPM-14	6.67554	0.00016
HIGH	BIPM-01	6.67559	0.00027

Table 5. *Approximate weighted branch means of G values organized into LOW, MIDDLE, and HIGH branches. Values are in units of 10-11 m3 kg-1 s-2.*

Branch	Number of values	Weighted mean G	Interpretation
LOW	5	6.67258	low branch; mostly below CODATA
MIDDLE	10	6.67426	central branch; includes NIST-26 and CODATA neighborhood
HIGH	2	6.67555	BIPM high branch

The next step is a structured G Atlas Project: a metadata-rich database of reliable G experiments. The purpose is to turn the hidden parameter X from a conceptual coordinate into a measured experimental-state variable. Table 6 proposes G Atlas metadata fields.

Table 6. *Proposed G Atlas metadata fields.*

Category	Parameters to collect
Time	start date, end date, midpoint date, month, duration
Method	time-of-swing, acceleration servo, electrostatic servo, Cavendish, beam balance, atom interferometer
Apparatus family	BIPM, HUST, UWash, UCI, JILA, LENS, MSL, NIST, others
Source masses	material, density map, geometry, surface state, mounting circle
Vacuum/gas	pressure, pressure drift, gas composition, pump state
Thermal state	mean temperature, gradients, source-mass heating, chamber asymmetry
Mechanical state	torsion fiber or strip, Q factor, anelasticity correction, drift
Electrical state	patch potentials, shielding, servo voltage, capacitance gradients
Magnetic state	susceptibility, magnetic shielding, ambient magnetic field
Data treatment	blind analysis, correction model, covariance handling, residuals
Gerber-Mach gravitational potential	**The mass distribution in the Milky Way Galaxy**

Figure 4 shows these three branches in the organization model of reliable values of G.

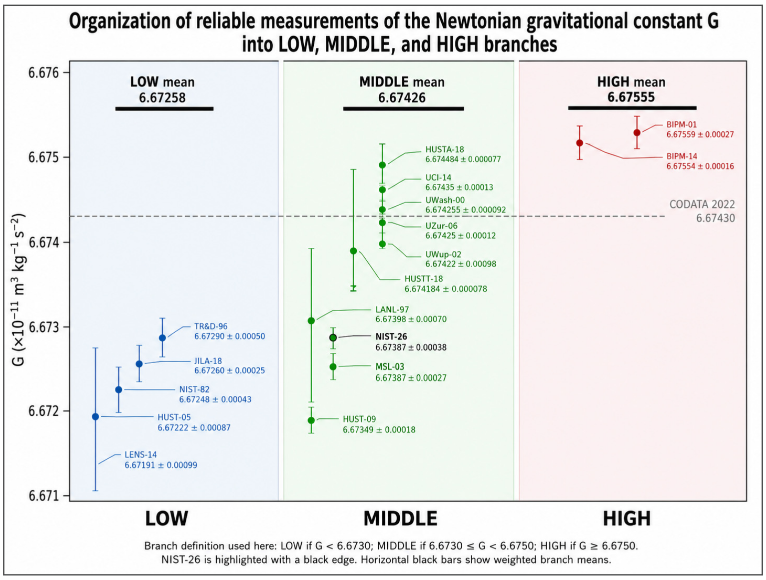

Figure 4. *Organization of reliable G values into LOW, MIDDLE, and HIGH branches. NIST-26 is highlighted in the MIDDLE branch.*

6. Unknown Parameter X: from Composition to a Hidden Parameter X

If the observed spread is not organized by source-mass composition and calendar month campaign alone, one may ask whether it is organized by a hidden experimental state variable. Let X denote an unknown parameter or combination of parameters that orders the apparent value of G. This is not yet a measured physical quantity: B(X) = hidden experimental bias. It is phenomenological coordinate shown in Eq. 3:

$$G_{measured(X)} = G_{true} + B(X) \tag{4}$$

The measurements can be ranked from the smallest to the biggest measured G values or vice versa. The midpoint of the full range is then given in Eq. 4:

$$G_{mid} = \frac{G_{\max} + G_{\min}}{2} = 6.67375 * 10^{-11} \; m^3 kg^{-1} s^{-2} \tag{5}$$

This midpoint is not proposed as a new recommended value. It is a visual and conceptual line for studying the bias landscape.

7. The Gerber-Mach Gravitational Potential

Newtonian potential energy of two masses M and m separated by a distance r is:

$$V\_N(r) = -\frac{GMm}{r} \tag{6}$$

Gerber´s velocity dependent gravitational potential may be written in modern notation as:

$$V\_G(r,\dot{r}) = -\frac{GMm}{r}\frac{1}{\left(1-\frac{\dot{r}}{c_g}\right)^2} \quad (7)$$

Here dr/dt means the radial rate of change of the separation, and c_g is the propagation speed that Gerber associated with gravity. In many historical presentations c_g is simply written as c, because Gerber inferred a value close to the speed of light from Mercury´s perihelion data.

Ernst Mach proposed his famous Mach´s principle: the gravitational constant is a function of the mass distribution in the Universe, e.g. [53]-[55]. In our model we propose to insert into the Gerber´s gravitational potential the radial velocity of the Earth towards the Sagittarius A* and the Mach angle ω describing the orientation of the system source mass + test mass towards the Sagittarius A*:

$$V\_G(r,\dot{r},\omega) = -\frac{GMm}{r}\frac{1}{\left(1-\frac{\dot{r}\cos\omega}{c_g}\right)^2} \quad (8)$$

Here dr/dt means the radial rate of change of the separation, and c_g is the propagation speed that Gerber associated with gravity. In many historical presentations c_g is simply written as c, because Gerber inferred a value close to the speed of light from Mercury´s perihelion data.

Fig. 5 documents that the geometrical arrangement of the system the source mass + the test mass + the mass of the Milky Way Galaxy represented by the Sagittarius A* could play a role in the observed spread of reliable values G.

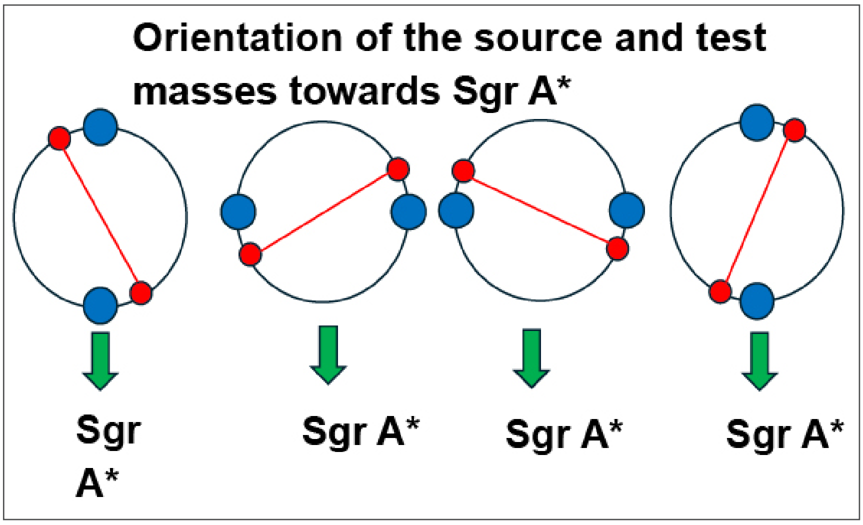

Figure 5. *Orientation of the source mass (blue points) and the test mass (red points) towards the Sagittarius A*.*

8. The Radial Speed of the Earth Towards Sagittarius A*

The radial speed of the Earth toward the center of the Milky Way Galaxy (the radial velocity relative to the galactic core, Sagittarius A*) fluctuates throughout the calendar year between roughly – 21 km/s (moving away in September) and +41 km/s (closing speed toward the galactic center in March). Our Solar System does not circle the galactic center in a flawless circle. Over its 230-million-year orbital period, the Sun travels along a slightly eccentric path. In our current cosmic epoch, the Sun is actively drifting closer to the galactic center as it heads toward the perigalacticon. This foundational inward drift gives the Sun - and by extension, the Earth system – a baseline average radial velocity of roughly + 10 km/s toward the galactic center.

The maximum inward speed (~+41 km/s) occurs in March. During this season, Earth´s orbital velocity vector points almost directly toward the galactic core, compounding the Sun´s baseline motion. The minimum radial speed (~-21 km/s) occurs around September. As Earth swings to the opposite side of its orbit, it moves away from the galactic center at 31 km/s. Because this outward speed exceeds the Sun´s 10 km/s inward drift, the Earth experiences a net retreat from the galactic core, denoted by the negative value.

Gerber gravitational potential contains the derivative dr/dt (+ for the outward motion, and – for the inward motion). This situation is shown in Figure 6.

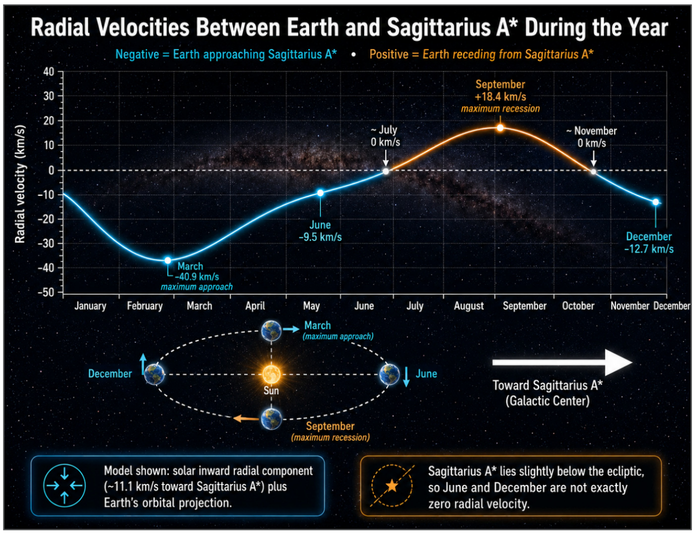

Figure 6. *The radial velocity of the Earth towards the Sagittarius A* in the Gerber's notation.*

9. The Allowed Spread of Reliable Values of the Newtonian Gravitational Constant

The Gerber-Mach gravitational potential might explain the reality of the spread of G reliable values collected by Schlamminger et al. in [21]. If we insert the radial velocity between the Earth and the Sagittarius A* and the Mach angle ω into the Gerber-Mach gravitational potential (Eq.8) we will get Figure 7.

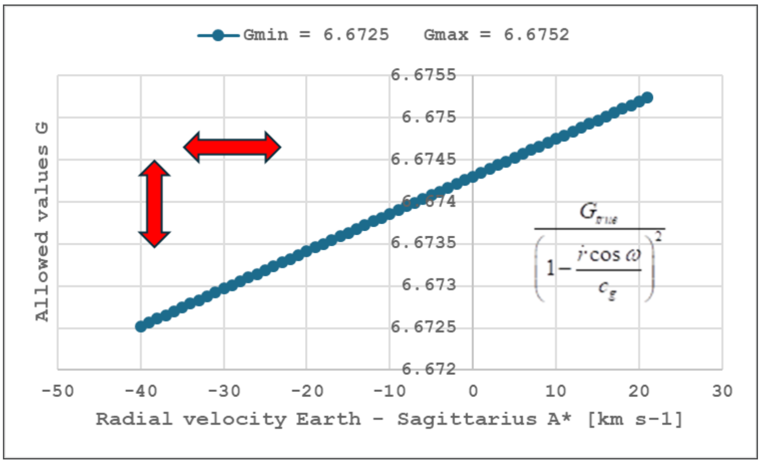

Figure 7. *The allowed spread of reliable values of the Newtonian gravitational constant from March to September calculated using the Gerber-Mach gravitational potential.*

Fig. 7 represents a "DELAYED CHOICE" experiment when the observed value of G can be determined by the geometrical orientation of the system: the source mass + the test mass towards the Sagittarius A*. This situation is interpreted in Table 7.

Table 7. *The "delayed choice" determination of G.*

Apparent value G	Position of masses	Angle of position ω
MINIMUM	$Source\ mass \leftrightarrow Test\ mass \rightarrow Sagittarius\ A^*$	$\omega = \pi$
MIDDLE	$\frac{Test\ mass}{Source\ mass} \rightarrow Sagittarius\ A^*$	$\omega = \frac{\pi}{2}$
MAXIMUM	$Test\ mass \leftrightarrow Source\ mass \rightarrow Sagittarius\ A^*$	$\omega = 0$
Gerber-Mach gravitational correction	$\frac{1}{\left(1 - \frac{\dot{r}\cos\omega}{c_g}\right)^2}$	

10. Conclusion

The comparison of reliable values of G shows no simple dependence on source-mass Z, A, and Z/A and on the calendar-month. This excludes the hypothesis that proton or nuclear composition directly explains the present spread of reliable values of the Newtonian gravitational constant. The calendar-month can contribute to the final observed value of G but there is still an unknown hidden parameter X.

There might exist an unknown parameter X that could organize the present spread. The preferred physical meaning of X is the Gerber-Mach gravitational potential where the radial velocity between the Earth and the galactic center of the Milky Way Galaxy and the geometrical arrangement of the source mass + the test mass towards to the Sagittarius A* could cause the observed spread of reliable values of the Newtonian gravitational constant.

The observer can manipulate with the geometrical arrangements in these experiments and thus obtain *"the delayed choice" value of G.*

The spread of measured values of G should not be read as a failure of precision, but as a message from the experimental world: Newton's constant is simple in the equation, yet difficult in the laboratory, because every apparatus carries its own hidden memory — the unknown parameter X.

Acknowledgment

We were supported by the contract number 0110/2020. ChatGPT formulated the Tables with reliable values of the Newtonian gravitational constant and the background material for the search of an unknown physical parameter X. The author applied the Gerber-Mach gravitational potential as a possible interpretation of that unknown parameter X.

Conflict of Interest

The author declares that there is no conflict of interest.

11. References

1. NIST CODATA value: *Newtonian constant of gravitation*. Gaithersburg: National Institute of Standards and Technology. 2022. Available: https://physics.nist.gov/cgi-bin/cuu/Value?bg
2. Mohr PJ, Newell DB, Taylor BN, Tiesinga E. CODATA recommended values of the fundamental physical constants. *J. Phys. Chem. Ref. Data*. 2022; 2025; 54: 033105.
3. Gillies GT. The Newtonian gravitational constant: recent measurements and related studies. *Rep. Prog. Phys*. 1997; 60: 151-225.
4. Karagioz OV, Izmailov VP. Measurement of gravitational constant with a torsion balance. *Meas. Tech*. 1996; 39:979-987.
5. Speake CC, Quinn TS. Special Edition: The gravitational constant: theory and experiment 200 years after Cavendish. *Meas. Sci. Technol*. 1999; 10, 422-530.
6. Luther GG, Towler WR. Redetermination of the Newtonian gravitational constant G. *Phys. Rev. Lett*. 1982; 48: 1231-123.
7. Milyukov VK, Luo J, Tao C, Mironov AP. Status of the experiments on measurements of the Newtonian gravitational constant. *Gravitation and Cosmology*. 2008; 14(4): 368-375.
8. Quinn T, Speake C. (Eds): „Theo Murphy Meeting Issue on The Newtonian constant of gravitation, a constant too difficult to measure? "Philosophical *Transactions A*. 2014; Vol. 372.
9. Xue C, Liu JP, Li Q, Wu JF, Yang SQ, Liu Q, et al. Precision measurements of the Newtonian gravitational constant. *Natl. Sci. Rev*. 2020; 7(12): 1803-1817.
10. Schlamminger S, Holzschuh E, Kündig W, Nolting F, Pixley RE, Schurr J, Straumann U. Measurement of Newton´s gravitational constant. *Phys. Rev. D*. 2006; 74:082001.
11. Rothleitner C, Schlamminger S. Measurements of the Newtonian constant of gravitation G. *Rev. Sci. Instrum*. 2017; 88(11): 111101.
12. Schlamminger S, Chao L, Lee V, Shakarji C, Newell DB, Stirling J. et al. Redetermination of the gravitational constant with BIPM torsion balance at NIST. *Metrologia*. 2026; 63: 025012.
13. Luo J, Liu Q, Tu LC, Shao CG, Liu LX, Yang SQ, Li Q, Zhang YT. Determination of the Newtonian gravitational constant G with time-swing method. *Phys. Rev. Lett*. 2009; 102:240801.
14. Parks HV, Faller JE. Simple pendulum determination of the gravitational constant. *Phys. Rev. Lett*. 2010; 105: 110801.
15. Li Q, Xue C, Liu JP, Wu JF, Yang SQ, Shao CG, et al. Measurements of the gravitational constant using two independent methods. *Nature*. 2018; 560: 582-588.
16. Rosi G, Sorrentino F, Cacciapuoti L, Prevedelii M, Tino GM. Precision measurement of the Newtonian gravitational constant using cold atoms. *Nature*. 2014; 510:518-521.

17. Gundlach JH, Merkowitz SM. Measurement of Newton´s constant using a torsion balance with angular acceleration feedback. *Phys. Rev. Lett*. 2000; 85:2869-2872.

18. Quinn TJ, Speake CC, Richman SJ, Davis RS, Picard A. A new determination of G using two methods. *Phys. Rev. Lett*. 2001; 87: 111101.

19. Quinn TJ, Parks H, Speake CC, Davis R. Improved determination of G using two methods. *Phys. Rev. Lett.* 2013; 111:101102.

20. Cavendish H. Experiments to determine the density of the Earth. Phil. *Trans. R. Soc. Lond.* 1798; 88:469-526.

21. Schlamminger S, Gundlach JH, Newman RD. Recent measurements of the gravitational constant as a function of time. *Phys. Rev. D*. 2015; 91: 121101. arXiv: 1505.01774.

22. Gerber P. Die räumliche und zeitliche Ausbreitung der Gravitation. (The spatial and temporal propagation of gravity). *Zeitschrift für Mathematik und Physik*. 1898; 43, 93-104. In German.

23. Gerber P. Die Fortpflanzungsgeschwindigkeit der Gravitation. (The rate of propagation of gravity). *Annalen der Physik*. 1917; 357(4): 415-444. In German.

24. Mach E. *Die Mechanik in ihrer Entwicklung Historisch-Kritisch Dargestellt*. (A historical-critical account of the development of mechanics) (5th Ed.), Brockhaus, Leipzig 1904, p. 201. In German.

25. Einstein A. Erklärung der Perihelbewegung des Merkur aus der allgemeinen Relativitätstheorie. (Explanation of Mercury´s perihelion motion based on the general theory of relativity). *Sitzungsberichte der Königlich Preussischen Akademie der Wissenschaften.* 1915; 831-839. In German.

26. Seelinger H. Bemerkung zu P. Gerbers Ansatz „Die Fortpflanzungsgeschwindigkeit der Gravitation. (Note to P. Gerber´s approach „The rate of propagation of gravity“). Annalen der Physik (Leipzig). 1917; 53, 31-32. In German.

27. Seelinger H. Weiters Bemerkungen zur „Fortpflanzungsgeschwindigkeit der Gravitation“. (Additional notes to „The rate of propagation of gravity“). Annalen der Physik (Leipzig). 1917; 54, 38-40. In German.

28. Laue M. Die Fortpflanzungsgeschwindigkeit der Gravitation. Bemerkungen zur gleichnamigen Abhandlung von P. Gerber. (The rate of propagation of gravity. Notes to the paper of P. Gerber). *Annalen der Physik*. 1917; 358(11): 214-216. In German.

29. Treder HJ. The post-Newtonian effect of gravitation and the retardation of the gravitational potential in classical and relativistic theories of gravitation. *Annalen der Physik*. 1975; 487(5): 338-350.

30. Roseveare NT. *Mercury´s perihelion, from Le Verrier to Einstein*. Oxford: Clarendon Press. 1982.

31. Giné J. On the origin of the anomalous precession of Mercury´s perihelion. *Chaos Solitons Fractals*. 2008; 38(4): 1004-1010.

32. Carlip S. Aberration and the speed of gravity. *Physics Letters A*. 2000; 267(2-3): 81-87.

33. Will CM. The confrontation between general relativity and experiment. *Living Reviews in Relativity*. 2014; 17,4.

34. Janssen M, Renn J. Einstein and the perihelion motion of Mercury. *Arxiv*: 2111.11238, 2021. Accessed 2026 June 22.

35. Brown K. *Gerber´s Gravity*. MathPages. Available from: https://www.mathpages.com/home/kmath527/kmath527.htm Accessed 2026 June 22.

36. Einstein A. Die Feldgleichungen der Gravitation. (The field equations of gravitation). *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin.* 1915; 844-847. In German.

37. Einstein A. *Relativity: The Special and the General Theory*. Princeton University Press. Reprint of the original 1916 title. ISBN 978-0-691-16633-9.

38. Einstein A. Die Grundlagen der allgemeinen Relativitätstheorie. (The fundamentals of the general theory of relativity). *Annalen der Physik.* 1916; 49(7): 769-822. In German.

39. Einstein A. The general theory of relativity. In *The meaning of relativity*. Dordrecht: Springer Netherlands. 1922.

40. Schwarzschild K. Űber das Gravitationsfeld einer Kugel nach der Einsteinschen Theorie. (On the gravitational field of a sphere according to Einstein´s theory). *Sitzungsberichte der Preussischen Akademie der Wissenschaften*. 1916; 424-434. In German.

41. Weinberg S, Wagoner RV. Gravitation and Cosmology: principles and applications of the general theory of relativity. 1973.

42. Israel W, Hawking S. Eds. *Three Hundred Years of Gravitation*. Cambridge University Press. 1987. ISBN 9780521343121.

43. Dirac PAM. *General Theory of Relativity*. Vol. 14. Princeton University Press. 1996.

44. Will CM. The confrontation between general relativity and experiment. *Living Reviews in Relativity*. 2006; 9(1): 3.

45. Will CM. *Theory and Experiment in Gravitational Physics*. 2nd edition, Cambridge Univeristy Press, 2018. ISBN 978-1-107-11744-0.

46. Abraham M. Sulla teoria della gravitazione. (On the theory of gravitation). *Rend. Reale Accad. Lincei, cl. Sci. Fis., Mat. et Nat.* 1911; 20, 678-682. In Italian. English translation: https://neo-classical-physics.info/uploads/3/4/3/6/34363841/abraham_-_th_of_grav.pdf

47. Renn J. *The summit almost scaled: Max Abraham as a pioneer of a relativistic theory of gravitation.* In Janssen M. et al. (Eds). The genesis of general relativity. Boston Studies in the Philosphy of Science. Vol. 250. Springer. Dordrecht.

48. Weinstein G. Einstein´s struggles with gravitation theory: importance of static gravitational fields theory. *Arxiv:* 1202.2791. 2012. Accessed 2026 June 22.

49. Valentini MM. Max Abraham´s and Tulio Levi-Civita´s approach to Einstein theory of relativity. PhD Thesis. 2014. https://amsdottorato.unibo.it/id/eprint/6421/1/Valentini_Michele_Mattia_Tesi.pdf

50. Stávek J. On the conical Pappus spiral in a gravitational field. *Open Access Journal of Physics*. 2026; 8(3): 91-97.

51. Stávek J. What is hidden in the Gerber´s gravitational constant? *Open Access Journal of Physics*. 2026; 8(3): 98-105.

52. Stávek J. On an unknown-parameter organization of reliable measurements of the Newtonian gravitational constant G. *Open Access Journal of Physics*. 2026, 8(3): 106-113.

53. Barbour JB, Pfister H. (Eds). *Mach´s principle: from Newton´s bucket to quantum gravity* (Einstein Studies, 6). Birkhäuser. Boston. 1995. ISBN-10: 0817638237.

54. Sachs M, Roy AR (Eds). *Mach´s principle and the origin of inertia*. Aperion. Montreal. 2008. ISBN-10: 0973291100.

55. Assis AKT. *Relational mechanics and implementation of Mach´s principle with Weber´s gravitational force*. Apeiron. Montreal. 2014. ISBN-10: 0992045630.