

Activities of Working Group 13 “Newtonian Constant of Gravitation, G”

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Introduction

The goal of the working group is to understand the discrepancy between different measurements of the gravitational constant G . Figure 1 shows the results of measurements of G published in the last more than 40 years. As can be seen from the figure, the relative spread of the results is on the order of 100 parts in 10^6 , while the best experiments show relative uncertainties of 12 parts in 10^6 . The figure also gives an overview over the different measurement approaches used. No method-dependent systematic error can be identified.

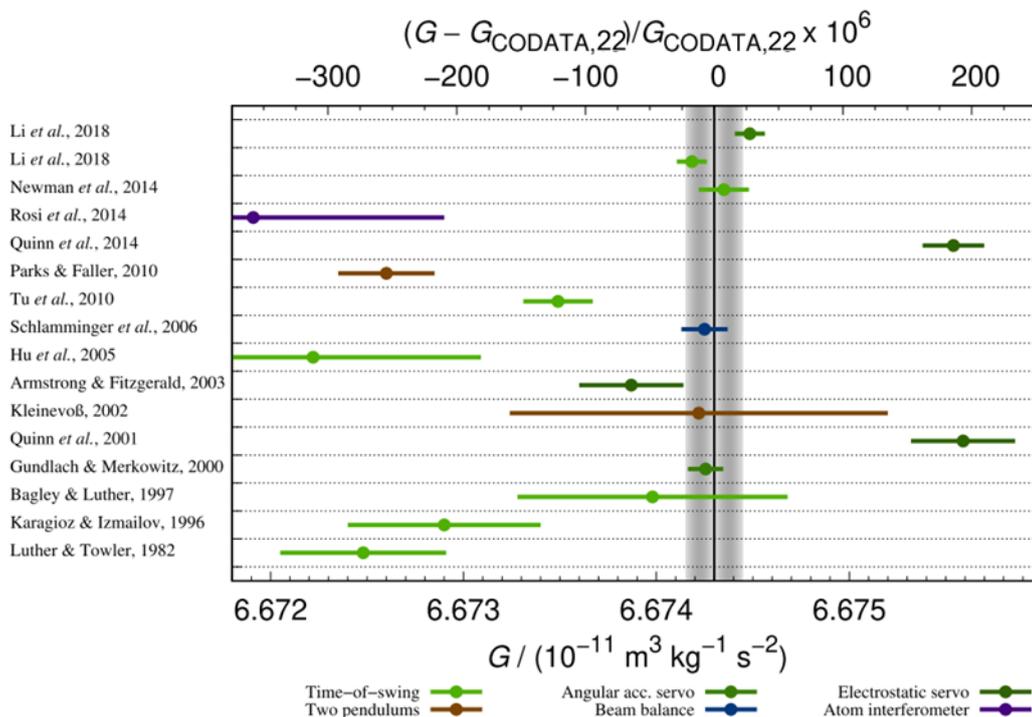


Figure 1 Measurements of G published during the past more than 40 years. No dependence on the measurement method can be derived.

Activities of the Working Group

Stephan Schlamminger presented preliminary results of their G experiment at NIST at the Conference on Precision Electromagnetic Measurements (CPEM) 2024 in Denver, USA. The measured value turned out to be lower than the current CODATA value (see Figure 2), with a preliminary combined uncertainty of 24.1 ppm. A scientific paper is to be published by end of 2025. The experiment consists of a setup already used by a group at BIPM (see Quinn *et al.* in the upper graph) over 10 years ago. The BIPM group conducted the experiment twice with a slightly modified setup. Both experiments yielded consistent values for G , but these values deviated from the CODATA value by multiples of the determined standard deviation. At the time, the values were higher than the CODATA value.

Christian Rothleitner presented a talk at the 10th International Conference on Precision Physics and Fundamental Physical Constants (FFK2025), Warsaw, 26-30, May 2025, Poland. This talk explores the long and challenging history of measuring Newton's gravitational constant G , from Cavendish's 1798 experiment to modern precision methods. Despite decades of effort, recent measurements still show significant inconsistencies. The talk outlines the evolution of measurement techniques, highlights the persistent difficulties, and concludes with a brief overview of the current state of the field.

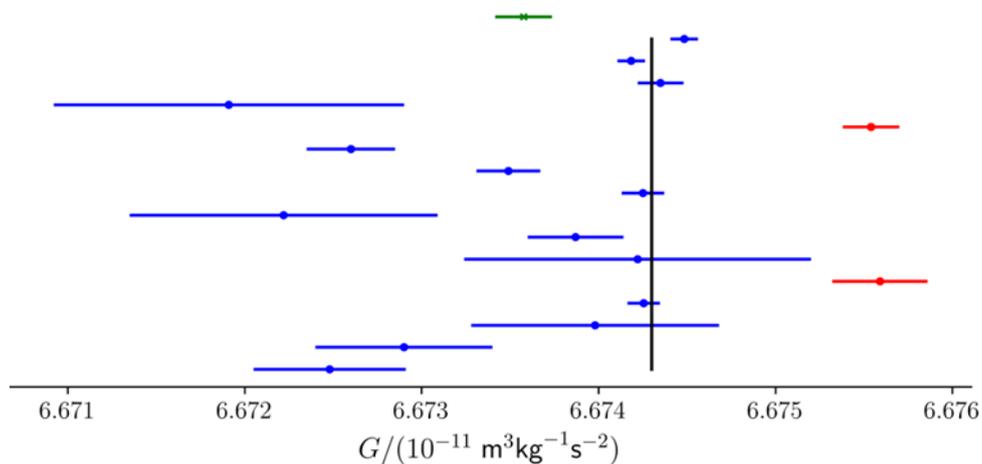


Figure 2 Preliminary result of the G experiment at NIST (green dot at top of graph), published at the CPEM Conference in Denver in 2024. The determined G value by the group is lower than the CODATA value (vertical black line). In red are presented the values published by the BIPM group with the essentially same setup.

Further plans of WG13

Christian Rothleitner of PTB will take over as chair of the working group, with the former chair Stephan Schlamminger helping as appropriate.

The planned living review article by Stephan Schlamminger and Christian Rothleitner on the measurements of G should be finished by the first half of 2026.

An IUPAP WG13 meeting is planned for 2026. The site has to be defined yet.

The group is also considering updating the WG13 website and using it as a resource for the groups conducting research on measuring the gravitational constant. This includes a comprehensive list of citations of G publications. A guide on how to select materials for source masses and their material properties.

Scientific News

A cosmology-derived value of G

In a recent article the authors derive a value of G from cosmology [2]. They treat Newton's gravitational constant G as a free parameter in cosmological models and constrain it using a combination of CMB (Planck PR4), BAO (DESI DR1), and BBN data. By fitting these observations with MCMC techniques, they estimate how much G can deviate from its CODATA value without conflicting with cosmological data. They find that G is consistent with the standard value within $\sim 2\%$ uncertainty. Cosmological constraints on Newton's constant G offer several advantages: they are independent of laboratory setups, test

gravitation on vastly different (cosmic) scales, and allow sensitivity to possible variations in G over time or distance - features predicted by some modified gravity theories. Such constraints complement local measurements and could reveal new physics. However, they are strongly model-dependent, suffer from parameter degeneracies (e.g., with H_0), and are far less precise than lab experiments. Systematic uncertainties and the ambiguity of whether the inferred G reflects the *local* or *cosmic* coupling further limit their interpretation. The conclusion: cosmological observations can constrain G , though less precisely and more model-dependently than lab measurements.

An alternative approach to CODATA calculation of G by means of a preferential median

In a recent manuscript [3] the authors propose a novel statistical method called the *preferential median* to improve the combined estimation of the Newtonian gravitational constant G . Unlike traditional approaches relying on arithmetic or weighted means, the preferential median incorporates measurement uncertainties as weights while retaining the robustness of the median against outliers. This approach mitigates biases caused by inconsistent or scattered G measurements and potential underestimation of uncertainties. Applying this method to existing experimental data, Muravyov et al. derive a value of

$$G = 6.674486(48) \times 10^{-11} \text{ m}^3\text{kg}^{-1} \text{ s}^{-2}$$

which shows a much smaller uncertainty than previous CODATA adjustments. The CODATA 2018 value is

$$G_{\text{CODATA}} = 6.67430(15) \times 10^{-11} \text{ m}^3\text{kg}^{-1} \text{ s}^{-2}$$

Their preferential median value lies within the CODATA error bars but offers a more stable central estimate by reducing the influence of outliers and inconsistent measurements. The authors argue this method provides a complementary and potentially superior statistical framework for combining G measurements, especially given the persistent spread and tension in experimental results.

Review article on G

Recently a new review article has been published by Zhang, Y. J., et al. [5]. The article reviews ongoing challenges and recent progress in measuring Newton's gravitational constant G , which remains the least precisely known fundamental constant. Despite many precise experiments over the past decades, significant discrepancies between results persist. The authors highlight the importance of G in various scientific fields and summarize the latest measurements. They emphasize the need for improved experimental techniques and future developments to achieve more accurate and consistent values of G .

On-going experiments

University of Florence, Italy

The group of Gabriele Rosi is continuing its work on the setup proposed in [1]. In this cited paper the author proposes a new experimental setup for measuring Newton's gravitational constant G using cold atom interferometry (a standard cold atomic fountain) to reach a relative accuracy at the 10^{-5} level. It discusses key systematic error sources in

detail and evaluates the expected statistical uncertainty. The authors also consider the feasibility of pushing the precision to the 10^{-6} level. In doing so, the work represents a shift away from classical macroscopic methods (torsion balances, pendulums) toward quantum-based measurement techniques.

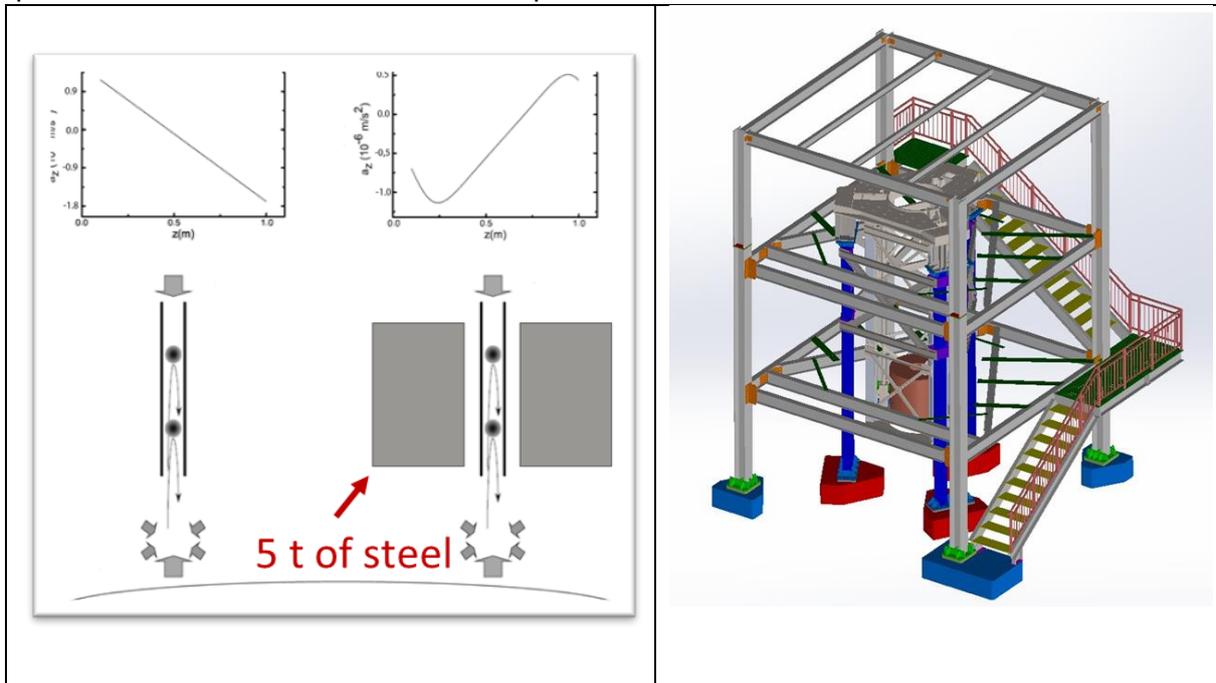


Figure 3 Experiment to measure G by means of an atom-interferometer-based gravity gradiometer. Left: As a source mass, the group uses 5 t of steel. The masses describe a constant gravity gradient along the trajectory of the freely falling atom clouds. Right: Set-up – The source masses need to be translated by approx. 4 m, between the two experimental measurements (with and without source masses).

IUPUI–Cal Poly Humboldt G Experiment

This is a collaborative project between Cal Poly Humboldt and Indiana University–Purdue University Indianapolis (IUPUI), led by Ricardo Decca and C. D. Hoyle. This experiment is funded by the National Science Foundation (NSF) and is based at the Department of Physics, IUPUI where it began in 2018, with first results expected in 2025.

The setup uses a torsion balance operated in two modes:

- Angular Acceleration Feedback (AAF)
- Time of Swing (ToS)

This dual-mode capability on a precision turntable allows detailed investigation of systematic effects.

Key technical features include:

- Single-crystal silicon source masses, placed at large diameters (~ 1 m) to minimize metrology errors.
- Titanium pendulum bob, suspended on an $18 \mu\text{m}$ tungsten fiber.
- Design inspired by the well-known Gundlach & Merkowitz [4] setup, with specific configurations chosen to suppress certain multipole moments (e.g., $Q_{62}=0$, $Q_{42}=0$).

The experiment aims to measure G with a target uncertainty at the 10 ppm level.

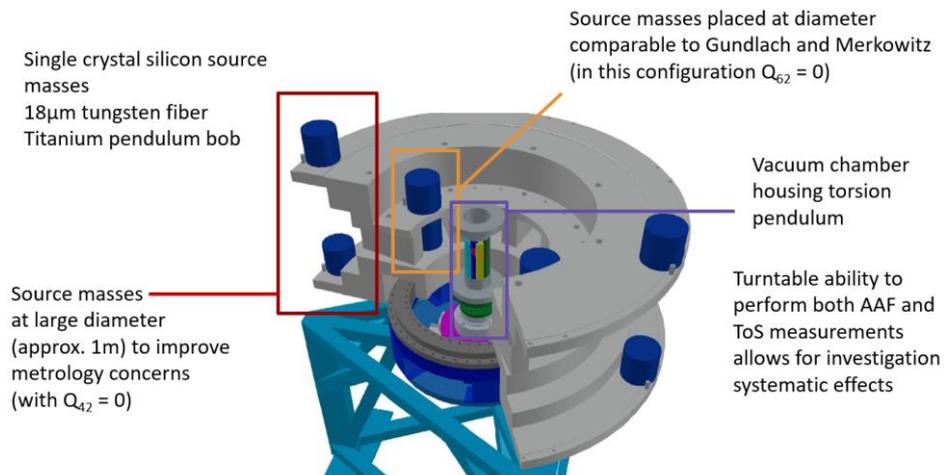


Figure 4 Drawing of the experimental set-up of the IUPUI–Cal Poly Humboldt G Experiment. The experiment is similar to the one performed by Gundlach & Merkwitz.

HUST, China

At HUST, multiple generations of Time-of-Swing experiments have been conducted, progressively refining the experimental design. Early configurations used long-period torsion pendulums with cylindrical or spherical source masses. Over time, improvements such as the use of fused silica torsion fibres with high quality factors (reducing mechanical dissipation) and careful electrostatic shielding have been implemented. To address remaining uncertainties - particularly fibre anelasticity - HUST now plans to coat fibres with materials like germanium or bismuth to suppress electric noise without degrading mechanical performance. They also explore designs that allow better gravitational compensation and more precise mass modelling. The goal is to push the uncertainty of G to below 20 ppm, continuing their contribution as one of the leading groups in precision gravitational measurements.

ETH, Zurich, Switzerland

Furthermore, the group of Jürg Dual, at ETH Zurich, Switzerland, after their publication on a single vibrating rod [7], designed and conducted another experiment [8]. In this experiment, the gravitational constant G is determined by exciting structural resonances using dynamic gravitational fields produced by two rotating bars. The system's response is evaluated through Frequency Response Function (FRF) measurements, and fitted using complex curve fitting of a single-degree-of-freedom model with high accuracy ($r^2 > 99.5\%$). This yields key parameters such as resonance frequency, amplitude, phase at resonance, quality factor Q , and allows assessment of complex, frequency-independent crosstalk. The theoretical analysis is supported by finite element modelling based on Newton's law of gravitation, which links the measured mechanical response to the gravitational interaction. The current uncertainty in G is approximately 0.5 %, primarily limited by calibration errors in laser interferometers and lock-in amplifiers. Future improvements include ceteris paribus experiments to explore gravitational shielding effects by inserting dense materials (e.g. brass, lead) between source and detector, and enhancing precision by implementing a double lock-in detection scheme.

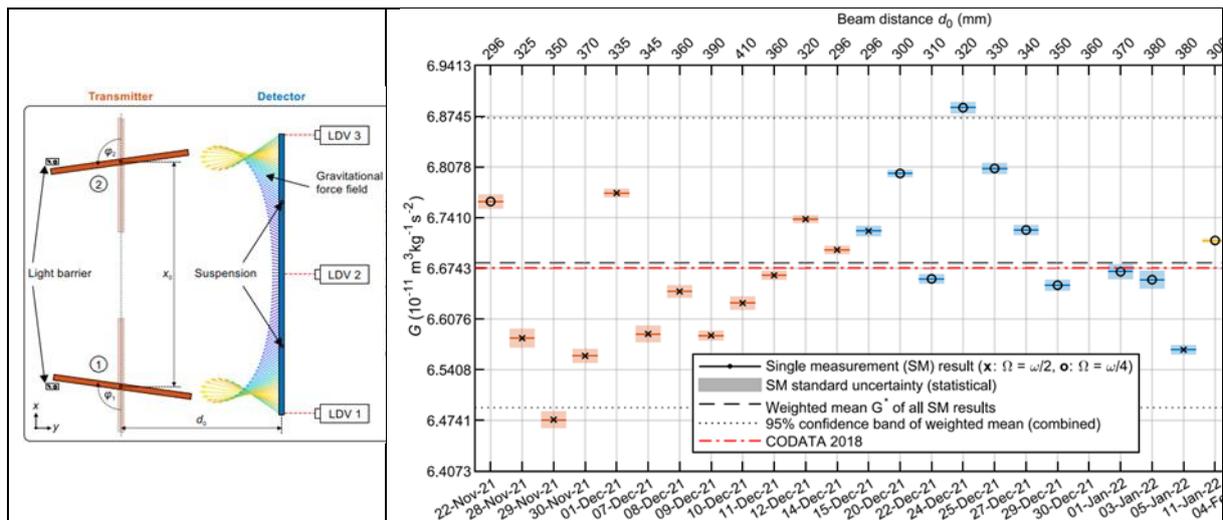


Figure 5 Left: Sketch of the experimental setup of the ETH experiment. Two exciting bars that simultaneously rotate, excite a detector rod by gravitational coupling. Right: Results of the experiment for different distances between exciting and detecting bar.

University of Vienna, Austria

Finally, the group of Markus Aspelmeyer at the University of Vienna, Austria, is continuing their investigations of G and the inverse square law with very small masses, as published in [6].

The experiments by Aspelmeyer and Dual are important because they show new approaches. On the one hand, the Aspelmeyer experiment goes into regions of small masses for which G has not been investigated before. Dual, on the other hand, uses a completely different geometry (long rod). Both experiments are dynamic: the test mass is set into oscillation solely by gravitational coupling through the dynamic change in position of the source mass.

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List of group members

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Riley Newman (University of California Irvine, USA)
Harold Parks (NRC, Canada)
Bill Phillips (NIST, USA)
Terry Quinn (Director emeritus of the BIPM, France)
Christian Rothleitner (PTB, Germany)
Clive Speake (University of Birmingham, United Kingdom)
Guglielmo Tino (University di Firenze, Italy)

James Faller (JILA, USA); Passed away in 2023