The Measurements of the Newtonian Constant of Gravitation - A Short Overview

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Newton's gravitational constant, G, is the measure of the coupling strength of gravity, the weakest of the four fundamental interactions known to men. Henry Cavendish carried out the first laboratory measurement of that interaction strength in 1798 using a torsion balance. In the next 227 years, many more measurements of the gravitational constant were carried out. In some periods, there was lots of activity. In other time periods, it was relatively quiet with only one or a few measurements.

The last forty years have been a time where many measurements of G were carried out. The figure shows the result of sixteen results that were published between 1982 and 2018. The large scatter compared to the reported uncertainty of the measurements is readily visible in the therein. The relative difference of the largest to the smallest numerical value is 5.5×10^{-4}. In contrast, the smallest self-reported 1-σ error is 11.7×10^{-6} and the largest 148×10^{-6}. Hence, the span of the data is between 3.7 and 47.2 times the relative uncertainty of the individual experiments. Clearly, the data-set lacks internal consistency.

Having all these groups working on the measurement of a single value infused a lot of energy into the field. Many articles were published, several conferences were held, and fun ideas were developed. As is shown in the figure many results were published. However, the data is still not sufficiently consistent. So, why is that?

The reason the results are not consistent is, because these measurements are hard. As of 2025, the current accepted value of the gravitational constant is

$$G = (6.674\,30 \pm 0.000\,15) \times 10^{-11}\ \mathrm{m^3 kg^{-1} s^{-2}}. \tag{1}$$

In this talk, a narrative arc from the historical beginnings of the different methods to their modern implementation is given. Finally, a brief overview of the current state-of-the-art and an outlook will be given.

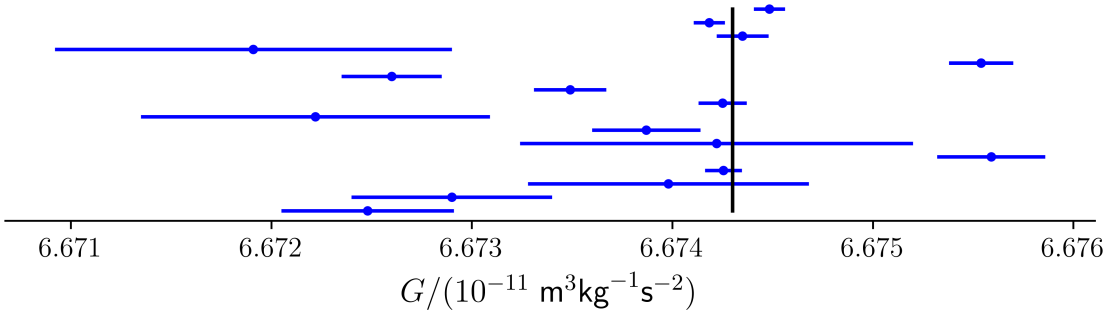

Figure 1: Measurements of the gravitational constant from 1982 (bottom) to 2018 (top). The numerical value recommended by the Committee on Data for Science and Technology (CODATA) is given by the black vertical line. The horizontal lines denote $1-\sigma$ uncertainties that were self reported by the researchers. Clearly the scatter between the data is larger than one would expect based on the reported uncertainties.

References

[1] Michaelis, W. and Haars, H. and Augustin, R., *Metrologia* **32**, 4 (1995).

[2] Fischbach, E. and Sudarsky, D. and Szafer, A. and Talmadge, C. and Aronson, S. H., *Phys. Rev. Lett.* **56**, 3 (1986).