# Newtonian Constant of Gravitation
## International Consortium

### I. BACKGROUND

Recent measurements of the Newtonian constant of gravitation $G$ are in disagreement, with discrepancies that are roughly ten times the quoted uncertainties in some cases. This is clearly an unsatisfactory situation for one of the most basic fundamental constants in classical physics.

The disagreement calls into question our ability to measure small forces on a laboratory scale. It also raises the question of whether the Newtonian force law is a complete description of gravity at these distances.

This issue was recently discussed at a Royal Society scientific meeting entitled *The Newtonian constant of gravitation, a constant too difficult to measure?* [1] The conclusions of that meeting are included as the appendix to this proposal.

Given the history of discrepancies, it is unlikely that one or two more experiments will resolve the situation even if they are done with the oversight of an advisory committee. Instead possible sources of bias, not previously tested for, should be checked. In addition there needs to be redundancy and tests for reproducibility order to determine a reliable value for $G$. This proposal describes an approach to arrive at such a value.

### II. METHOD

As an effort to resolve this situation, a consortium will be formed consisting of capable individuals and institutions willing to collaborate on a large-scale project to determine a reliable value for $G$. Participants would either produce the necessary apparatus and make measurements of $G$, or they would use an apparatus made at another institution and repeat the measurements. In some cases, participants that produce an apparatus might also make measurements with a different apparatus produced at another institution. It is expected that different institutions will produce different types of apparatus to implement independent experimental approaches.

In contrast to previous projects, it is proposed that two identical copies of each type of apparatus be produced and used to make the measurements. Work will continue until consistency is achieved between the two devices by the institution that produced them. Then, each of the two devices will be taken apart and loaned to two other members of the consortium who will repeat the measurements using their own procedures and data analysis. Basic instructions for putting the device back together will be provided, but to avoid bias, operating procedures and data analysis will be done independently. Details of how the apparatus will be distributed will depend on the number of members in the consortium and their availability to make the measurements.

When the experiments are completed, the results will be compared. If they agree, then a valid value for $G$ will have been obtained. If not, then there will be multiple results that could uncover a pattern for the disagreements to guide the search for possibly overlooked systematic effects.

This approach will test for possible systematic bias associated with the location of the measurement, the design of the apparatus, and the personnel carrying out the measurement, which have not previously been fully tested.

## III. PARTICIPANTS

NIST will consider being one of the institutions where two copies of an apparatus will be produced and new measurements of $G$ will be carried out. Simultaneously with NIST, other institutions might each make two copies of an apparatus based on a different design and carry out the proposed measurement and redistribution procedure. Participants could also collaborate by repeating measurements with either of the two copies already made at one of the primary institutions. Another role for participants who are experienced in doing such experiments would be as members of an international advisory board to act as consultants for the groups making the measurements.

## IV. JOINING THE CONSORTIUM

People considering participating in this project are invited to apply for a collaborative partnership. A statement of possible interest and intended level of participation may be sent to bigg@nist.gov.

## V. WORKSHOP

To refine the plan for the project and exchange ideas for experiments, a workshop will be held at NIST on 9-10 October 2014. Potential participants are invited to attend. To register and for detailed information see the website at pml.nist.gov/bigg.

The workshop is intended to cover the following topics:

- Methods of measuring $G$.
- Timescale of the overall project.
- Procedures for carrying out the cross comparisons.
- Whether there should be blind offsets until all measurements are done.
- Drafting of a joint article on the project for Metrologia.

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[1] Website: royalsociety.org/events/2014/gravitation/.

## Appendix: Outcome of the Royal Society meeting on *G* held at Chicheley Hall on 27th and 28th February 2014

Terry Quinn, 7 March 2014

A broad consensus was reached on the following main points;

1. The problem of arriving at a reliable value for $G$ in the face of the wide dispersion of recent results (some 450 ppm, more than ten times the sigma of the individual results) is unlikely to be resolved by one or two additional results obtained, as in the past, by teams working independently.

2. There is nevertheless an urgent need to resolve this situation, unprecedented in the determination of one of the fundamental constants of physics. Although at present there is no pressing problem in theoretical physics that requires an accurate value of $G$, accurate values of the fundamental constants are an essential part of the foundations of physics. In almost all areas of the physical sciences, determinations of fundamental constants are at the frontiers of science. This is so in experimental gravitational physics where one of the characteristics of the work is the need to measure extremely small forces. The science and techniques used in the determination of $G$ are those also used in tests of the equivalence principle, in tests of the inverse square law and in the search for other non-Newtonian forces. Quite apart from the results of such measurements, whether they are null experiments or ones leading to a value of a constant, the training of young scientists who participate has always been an important product of high metrology. The wide disagreement among recent measured values of $G$ must cast some doubt on our abilities in this crucial area of small-force measurement and in other areas where similar techniques are used. This is an unsatisfactory situation.

3. There are a number of key parameters some or all of which have to be measured with the highest accuracy in determinations of $G$. These include mass, density, length, time, electric current, voltage, capacitance and angle. In some experiments there may be others. Measurements of these must be traceable to verified national and international standards with evaluated uncertainties with respect to the SI. The experiments themselves must be carried out in laboratories having the highest quality of temperature and environmental control. All of this strongly points to a national metrology institute, or a laboratory closely associated with a national metrology institute, as being the most appropriate place for future experiments to take place.

4. Thus, instead of simply calling for new determinations of $G$, it is suggested that an international advisory board be created, made up largely of those who have already carried out a $G$ experiment, to advise on the choice of method or methods, on the design of the experiment, on its construction and finally on the interpretation of the data and calculation of the results. This would be in contrast to the present situation in which outside criticism and comments can be brought to bear only when the experiment is finished and published when it is too late to affect the outcome. It is only by proceeding in this way that one might hope to obtain results that are demonstrably reliable.