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## A NEW DETERMINATION OF THE NEWTONIAN GRAVITATIONAL CONSTANT AT MSL

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### Abstract

This paper describes a new determination of the Newtonian gravitational constant, G. Since our last compensated measurement of G, modifications have been made to the apparatus and operating procedures to further identify possible measurement errors and improve the uncertainty. Our latest value and its uncertainty will be presented at the conference.

### Introduction

The MSL torsion balance has been used for three series of *G* measurements, two using the torsion balance in its compensated mode [1,2] and more recently in an oscillating mode [3]. Between each measurement we have made changes to the apparatus including varying the dimensions and materials of key parts of the torsion balance. These dimensional changes were important in identifying errors in the early measurement. We have now produced three consistent measurements of *G* although the oscillating result has a much larger uncertainty.

| Year | $G$ / $10^{-11}$ $m^3kg^{-1}s^{-2}$ | Ref. |
|---|---|---|
| 1995 | 6.6746(10) | [1,2] |
| 1998 | 6.6742(7) | [2] |
| 2000 | 6.675(10) | [3] |

At the time of writing we are carrying out a new determination of *G* using the apparatus in its compensated mode. The aim of this measurement is to take advantage of the modifications made during the oscillation measurement and obtain another value for *G* with a lower uncertainty. As well, we have been reviewing the measurement procedure and analysis to ensure we have identified all significant measurement errors.

### Apparatus

The MSL apparatus, shown in Figure 1, has been well described [1-4]. The current version of our torsion balance consists of a cylindrical copper mass (500 g) suspended from a tungsten wire, which has a rectangular cross-section (300 μm by 17 μm). Two large cylindrical masses (27 kg each) are used to produce a torque on the suspended mass. These large masses are rotated, every 80 minutes, about the fibre axis to angular positions that produce a maximum in the torque. An electrometer

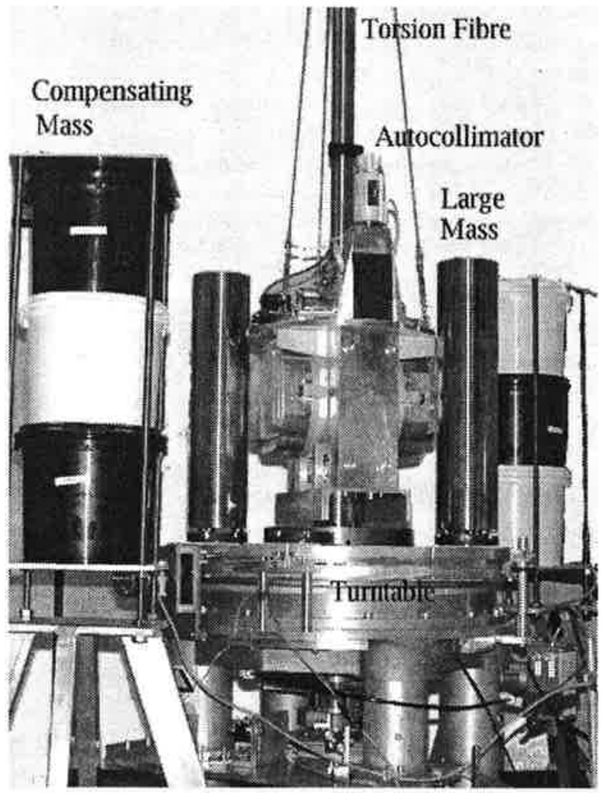


Figure 1 The MSL torsion balance

surrounding the suspended mass is used to electrostatically balance the gravitational torque so the torsion balance fibre is not required to twist during the measurement. Typically 30 V is required to balance the gravitational signal.

The torque produced by the voltage applied to the electrometer is determined in a separate measurement. A large voltage (80 to 300 V) is applied to one side of the electrometer to accelerate the suspended mass. This acceleration is measured by accelerating the entire torsion balance apparatus at the same rate as the suspended mass and recording the apparatus angular position with time.

The main changes made to the torsion balance since the last compensated measurements are:

- The stainless steel attracting masses have been replaced with copper masses
- A magnetic damper has been added to the torsion balance to damp out the pendulum modes of

oscillation [5] and

- The vacuum system has been remotely mounted to allow continuous pumping when measuring the gravitational signal.

## Progress

We have spent the early part of 2001 setting up the measurement and are now collecting data. As part of setting up the measurement we made several changes to the torsion balance control and measurement method.

We have improved the electrometer calibration by increasing the range of voltages used to accelerate the torsion balance. Now we are routinely using voltages in the range 80 to 300 V. This allows us to measure the residual torque due to the twist in the fibre as part of the calibration. In earlier measurements this residual torque was measured separately and contributed a large uncertainty to the measured acceleration. As well, the wider voltage range provides good confirmation of the voltage independence of the electrometer system.

The results of recent accelerations are shown in figure 2. The electrometer constant $\partial C/\partial\theta$ is the change in capacitance $C$ of the electrometer system with angular position $\theta$ of the suspended mass. The combined relative uncertainty is reduced from $7 \times 10^{-5}$ in the 1998 measurements to $2 \times 10^{-5}$ in the current series of measurements.

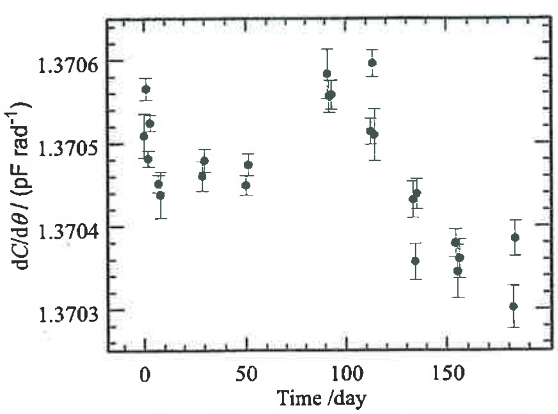


Figure 2 The results of the acceleration measurements

We have improved the control loop performance to ensure that the torsion balance has completely settled after shifting the large attracting masses. In making this change, we observed that the settling time of the control loop was different when the field masses were rotated clockwise around the suspended mass to when they were rotated in an anti-clockwise direction. This occurs because the large mass positions are not at equal angular spacing with respect to the suspended mass. To eliminate any possible bias in the result due to this effect, we have made measurements with the large masses rotating in both directions and plan to average these measurements to obtain the final value of G.

We have been measuring $G$ since March 2001 but we have been experiencing some difficulties with sporadic disturbances in the signal. These are often correlated with local seismic disturbances. In the absence of any disturbance we can measure the gravitational torque with a Type A relative standard uncertainty of about $5 \times 10^{-5}$ for an 80 minute measurement. However this can rise to over $5 \times 10^{-4}$ in the presence of noise. These disturbances can be identified by corresponding disturbances in the angular position of the torsion balance.

The measurement is well advanced and we will be presenting a new value for G along with its uncertainty budget at the conference.

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$6.6732(0.0007) \times 10^{-11}\ m^3/kg\,s^2$