Towards a Better Determination of Big G

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Newtonian gravitational constant G is the first proposed and measured universal constant [1]. However, after over two hundred years of its first measurement by Cavendish, G is poorly determined in both precision and accuracy when compared to other universal constants. Many of the measurements were done using a torsion pendulum [2–5], and large discrepancies were found among them [6]. One possible reason could be the hypothesis raised by Kuroda in 1995, that the anelasticity of the hanging fibers leads to such observation. Therefore, a modification to the technique was developed by Gundlach to minimize this effect [7]. In his design, the angular motion of the pendulum was detected by an autocollimator, allowing the entire container (where the pendulum was mounted) to move in the same pattern, keeping the fiber almost untwisted. Until today, the most precise measurements ever performed [8, 9] were based on this modified torsion pendulum technique, and uncertainties close to 10 ppm were achieved. To improve the measurement even more, a new apparatus applying the same methodology is currently under construction in our lab at IUPUI (Indiana, U.S.). Our design's modification is focused mainly on the attractors, which gravitational field is actually being measured. In our approach, four cylinders made of single crystalline silicon (Si) ingots will be used as attractors. Compared to the traditional spherical ones made of stainless steel, Si is less dense. But, on the other hand, Si ingots can be easily manufactured in larger size, and it is simpler to check their density and uniformity using IR optics. Meanwhile, we are investigating a digital imaging technique which holds the promise of providing a precision of 50 nm in detecting the positions of the attractor masses. Using cylinders complicates the multipole moments expansion of the gravitational field, but also provides the possibility to diminish the contribution of higher order terms by adjusting their locations. Therefore, numerical calculations of our system were carried out and an error of 3 ppm was obtained. With this apparatus, measurements in three different modes will be performed. The first one is repeating Gundlach's measurement on a larger system, expecting a smaller systematic error. The second mode is also a small amplitude mode and consists on extracting the resonance frequency of the pendulum through noise measurements. The measurements will be performed with the attractor masses in different angular positions with respect to the pendulum. The third mode consists on inducing a large amplitude on the pendulum oscillator by rotating the attaractor masses. The idea is to address a potential Kuroda effect by comparing G determined by different methods in the same apparatus. Because the gravitational interaction is weak, environmental control is very critical, and the entire measurement needs to be well isolated. Hence, a $2.4\,\mathrm{m} \times 2.4\,\mathrm{m} \times 3\,\mathrm{m}$ (width×length×height) aluminum enclosure integrated with a temperature regulation system was built in our lab, providing thermal and electromagnetic isolation. Mechanical stability of the apparatus will be ensured by building it on a granite table weighting about 1000 kg, sitting on four air floating pillars. To further isolate the system, the pillars are partially filled with sand and standing on top of a sandbox. Characterization of the enclosure and the floated granite table is currently in progress. Details of our experimental setup and the characterization results of our system up to date will be discussed in the presentation.

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