Finding the Newtonian Torque

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Finding the Newtonian torque is a multi step process. It begins with an AutoCAD model of the experimental apparatus.

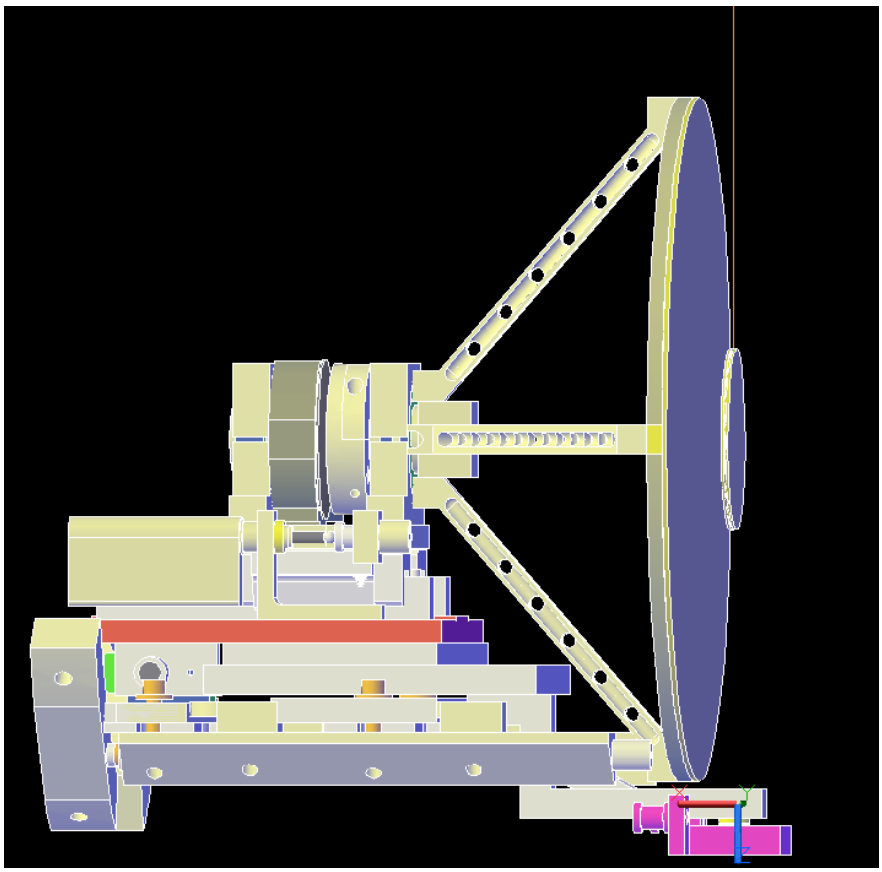

Figure 1: AutoCAD model of both Source Mass Assembly and Torsion Balance

First the model is segregated into groups based on the types of motion they are able to perform: yaw motion and linear & yaw motions. These models are broken into small pieces, a process called voxalization. Each voxel is a cube of space which is labeled with the material of which it is composed.

Next a volume is defined. It surrounds the torsion balance's test mass. This volume is filled with a grid of points.

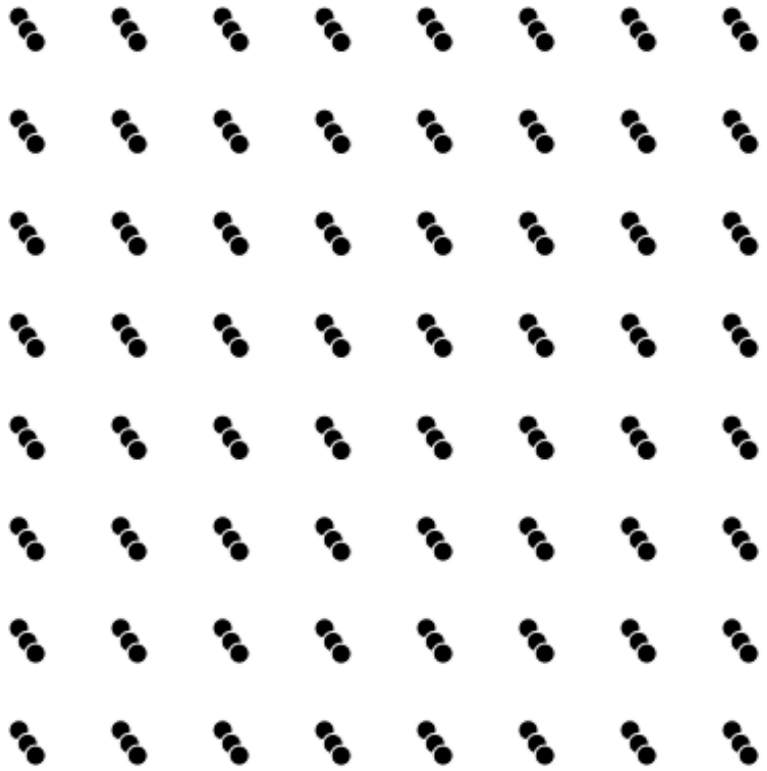

Figure 2: A representation of the 3D grid defined around the test mass.

At each of these points the Newtonian force is calculated due to interaction of every filled voxel from the source mass assembly.

$$\mathbf{F} = \sum_i G\rho_i\rho_{Al}V^2\frac{\hat{\boldsymbol{r}}}{r^2}$$

Actually, the force vector is stored as three separate cartesian components for added ease. As the test mass is made of aluminum and quartz float glass, which have nearly the same density, every point in the volume is calculated as if filled with aluminum. This is done twice, once with of the models, as separated due to their motion.

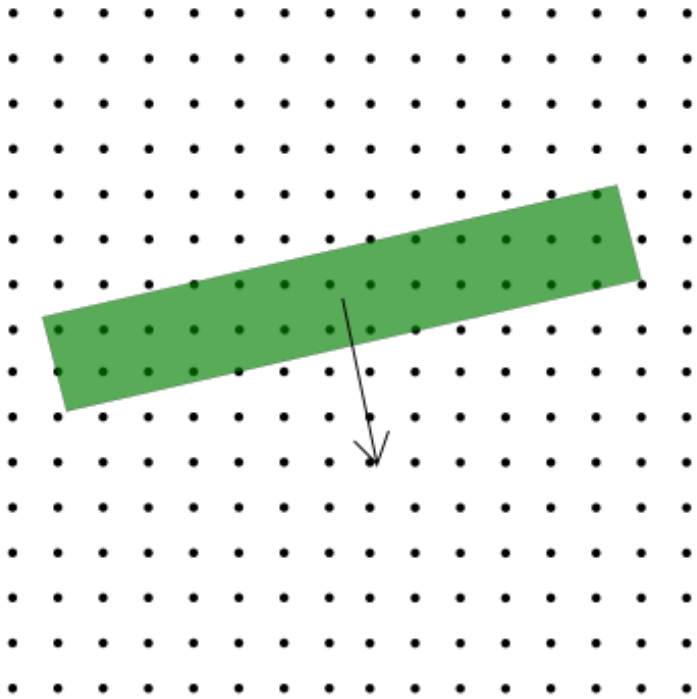

Figure 3: A top down view of the test mass's volume inside the larger grid of calculated points. The grid as shown is not as dense as the real grid in comparison with the test mass's volume.

There are now two separate volumes, one from each model. The volumes are then adjusted, based on the initial position of the source mass assembly. The adjusted volumes are then added together. Knowing the initial position of the torsion balance, we can look at the

volume of points enclosed by the torsion balance's test mass.

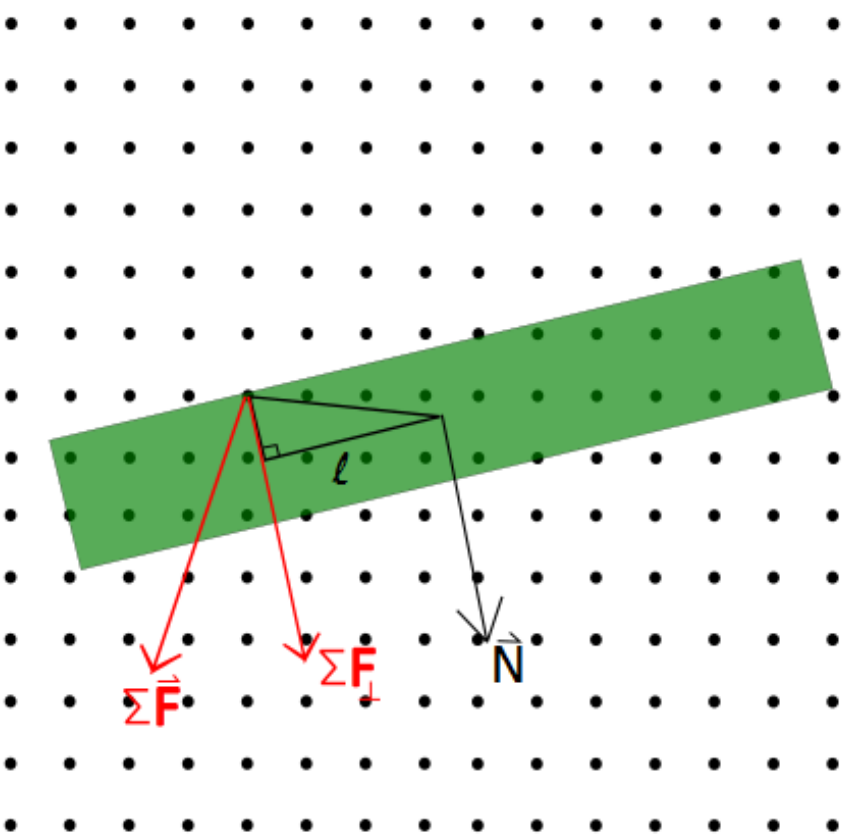

Figure 4: The sum of forces at a single point in the volume and the component that induces a torque

The gravitational force vector is then projected onto the axis of the normal force, which is what contributes to the torque, and the length of the lever arm calculated. The torque is added to a running sum. Once all points inside the volume are included and as this is the measured equilibrium position of the balance, the sum of the torques must be balanced by the torsion fiber's restoring torque.

Next the positions of the source mass assembly are moved as they are in the experimental run and the grid of gravitational force vectors is updated. The torque due to the new gravitational field recalculated and the restoring torque is kept the same. The angle of the

balance is moved a small step in the direction of the sum of the torque indicate. Then the sum of the gravitational torques is recalculated and the restoring torque of the fiber also updated. The balance's angle is again moved a small step in the direction of the sum of all torques. This process of summation and advancement continues until the sign of the total torque drops below 0, meaning the restoring force of the fiber has just overcome that of the gravitational torque due to the new position of the source mass assembly. This is the position we expect from a purely Newtonian gravitational signal.

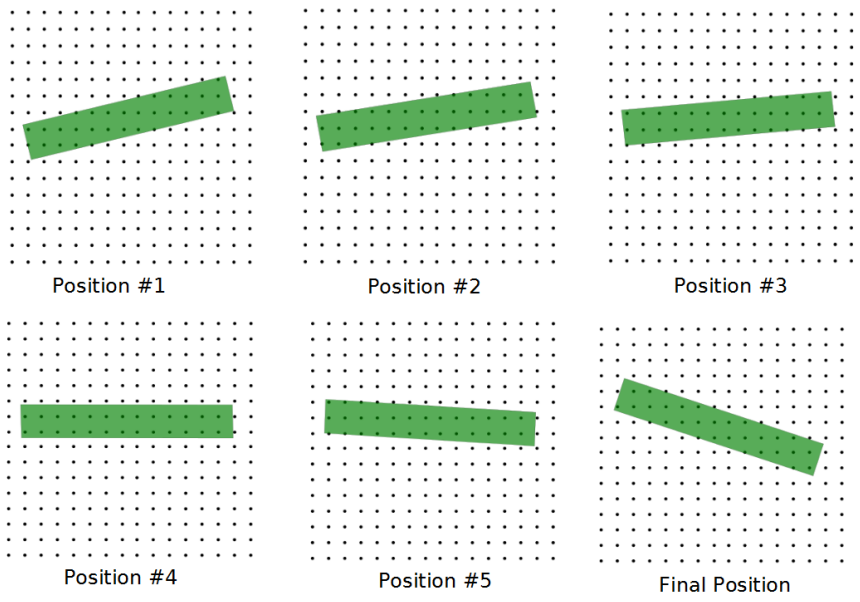

Figure 5: This is a depiction of the the different steps of progression of the torsion balance when looking for the Newtonian signal.

Once we have found the position which balances torques due to purely Newtonian gravity, we may subtract that motion from that recorded. Whatever remains is the non-Newtonian signal