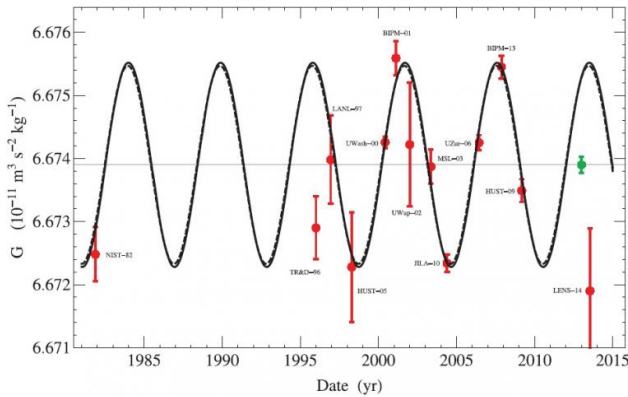


# Why do measurements of the gravitational constant vary so much?

21 April 2015, by Lisa Zyga



A set of 13 measurements of  $G$  exhibit a 5.9-year periodic oscillation (solid curve) that closely matches the 5.9-year oscillation in LOD measurements (dashed curve). The two outliers are a 2014 quantum measurement and a 1996 measurement known to suffer from drift. The green dot is an estimate of the mean value of  $G$  after the 5.9-year periodicity is removed. Credit: J. D. Anderson, et al. ©2015 EPLA

(Phys.org)—Newton's gravitational constant,  $G$ , has been measured about a dozen times over the last 40 years, but the results have varied by much more than would be expected due to random and systematic errors. Now scientists have found that the measured  $G$  values oscillate over time like a sine wave with a period of 5.9 years. It's not  $G$  itself that is varying by this much, they propose, but more likely something else is affecting the measurements.

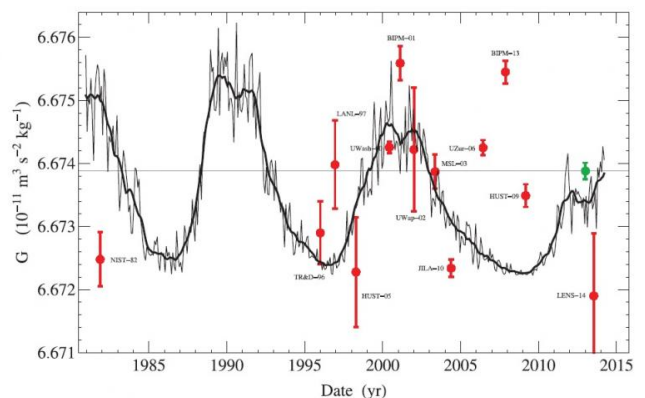
As a clue to what this "something else" is, the scientists note that the 5.9-year oscillatory period of the measured  $G$  values correlates almost perfectly with the 5.9-year oscillatory period of Earth's rotation rate, as determined by recent Length of Day (LOD) measurements. Although the scientists do not claim to know what causes the  $G$ /LOD correlation, they cautiously suggest that the

"least unlikely" explanation may involve circulating currents in the Earth's core. The changing currents may modify Earth's rotational inertia, affecting LOD, and be accompanied by density variations, affecting  $G$ .

The scientists, John D. Anderson, retired from the California Institute of Technology in Pasadena, and coauthors, have published a paper on the correlation between the measurements of Newton's [gravitational constant](#) and the length of day in a recent issue of *EPL*.

As the scientists explained, the main point of the paper is the finding that, while the measured  $G$  values do vary, they do so in a predictable way.

"Once a surprising 5.9-year periodicity is taken into account, most laboratory measurements of  $G$  are consistent, and are within one-sigma experimental error limits," Anderson told *Phys.org*.



The solar cycle (monthly mean of the total sunspot number) (black curve) does not consistently align with the data on  $G$ . Credit: J. D. Anderson, et al. ©2015 EPLA

The constant  $G$  is essential for our understanding of gravity, appearing in both Newton's law of gravity

and Einstein's general relativity.  $G$  is not an intuitive concept, and not the same as the acceleration of an object due to gravity,  $g$ , of  $9.81 \text{ m/s}^2$ .

The official value of  $G$  is  $6.673889 \times 10^{211} \text{ N}\cdot(\text{m/kg})^2$ , but the 13 measurement values analyzed in this study range from approximately  $6.672 \times 10^{211} \text{ N}\cdot(\text{m/kg})^2$  to  $6.675 \times 10^{211} \text{ N}\cdot(\text{m/kg})^2$ , which is a percentage variation of about  $10^{-4}$ . The variations in  $G$  are generally thought to result from measurement inconsistencies because  $G$  is very difficult to measure, partly due to the fact that gravity is much weaker than the other fundamental forces.

Despite the difficulties in measuring  $G$ , the new analysis suggests that the measurements are not flawed, but that something in the measurement process varies. One of the scientists' first considerations was that the 5.9-year period is about half of the 11-year period of a solar cycle. Changes in solar activity are caused by changes in the number of sun spots, which affects Earth's atmosphere, and in turn affects Earth's [rotational inertia](#). However, a closer look at the [solar cycle](#) shows that it does not consistently align with the data on  $G$ .

Next the scientists turned to a 2013 paper published in *Nature* that reported a 5.9-year periodicity in Earth's LOD, using data from the International Earth Rotation and Reference Systems Services (IERS) ([Holme and de Viron](#)). As the data shows, the length of each day varies slightly, with some days slightly longer and some days slightly shorter than others. The LOD variation is a measure of the speed of Earth's rotation, and the scientists in the current study found that its periodic oscillation aligns almost exactly with the  $G$  oscillations. (These 5.9-year LOD periodic variations differ from observations that the Earth's rotation is slowing down and the days getting longer due to tidal friction of the Moon, which occurs on a much longer time scale.)

Despite the close correlation between LOD and  $G$ , the scientists note that the maximum percentage variation of the LOD is on the order of  $10^{-9}$ , which is large enough to change  $G$  by only  $10^{-5}$  of the amplitude—not enough to explain the full  $10^{-4}$

percentage variation in  $G$ . Since this means that the LOD variations cannot cause the  $G$  variations, the researchers surmise that both variations are caused by changing motions in the Earth's core, or perhaps some other geophysical process.

Although the results also raise the possibility that new physics could explain the variations, the scientists believe this is unlikely. One of the 13 measurements of  $G$  used in this analysis is the first-ever [quantum measurement](#), called LENS-14, performed in 2014. The  $G$  value obtained by the quantum measurement is the larger of two outliers in the data, with the other outlier being a 1996 experiment that is known to have problems. Further quantum measurements of  $G$  are needed to understand why the quantum measurement deviates from the classical [measurements](#).

The [scientists](#) are also not fully convinced that the  $G$ /LOD correlation is the full story, and they plan to search for other correlations in the future.

"We plan to look into the possibility of a connection with the Earth flyby anomaly, which also seems periodic, and perhaps other anomalies," Anderson said.

**More information:** J. D. Anderson, G. Schubert, V. Trimble and M. R. Feldman. "Measurements of Newton's gravitational constant and the length of day." *EPL* 110 (2015) 10002, doi:[10.1209/0295-5075/110/10002](https://doi.org/10.1209/0295-5075/110/10002)

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