Tidal Effects on Gravity Experiments with a Balance

Schlemminger *et al.* [1] recently reported on a high precision, beam balance determination of G, Newton's gravitational constant. It is a very significant paper, because G is one of the most important and least precisely known constants in nature. In gravitational research, balances have a long history; Mitchel was the first to employ a torsion balance [2] and Cavendish inherited and improved on it to perform his celebrated experiment [3]. However, all balances have to contend with the local background, $\mathbf{g}(r, t)$ and with astrophysical influences (tides), that vary uncontrollably with time, in both magnitude and direction.

Reference [1] discusses δW, the difference in the weights of two test masses measured at times $t1$ and $t2$. In our Fig. 1, the eight points in Fig. 2 of Ref. [1] show a remarkable correlation (29 June–12 September 2001) with lunar phase with a period of about a month. This is strong evidence for tidal effects. The amplitude of the curve is about 20 ng. This 10–20 ppm residue is a testament to how closely the double difference procedure "nulls" out the two test mass signals. Indeed, it is only a mere $\sim 10^{-5}$ part of the canonical tidal signal expected of a single 1 kg test mass. However, it is also comparable to the error bars of Ref. [1].

Another consequence of tide is its short time influence. Can this short time behavior also be a factor in the experimental error? Fine mesh data are needed for a diurnal analysis. We have such data from our research [4] on gravitational effects [5], for the variation in the apparent weight of a test mass $\Delta W(t)$. Data were obtained with a commercial digital balance, inside a vibration isolated, temperature (0.1 K/day) and humidity stabilized, subterranean enclosure.

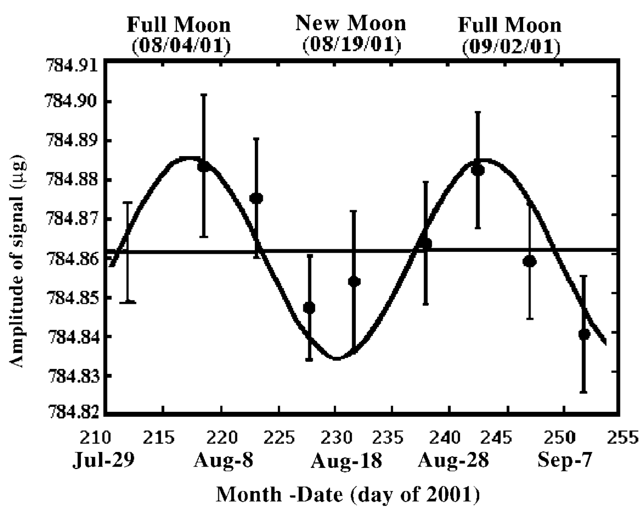

FIG. 1. Correlation between the spring tides in August 2001 and the data of Fig. 2 from Ref. [1]. The moon was in perigee on 19 August 2001. The amplitude of the solid curve is about the size of the error bars.

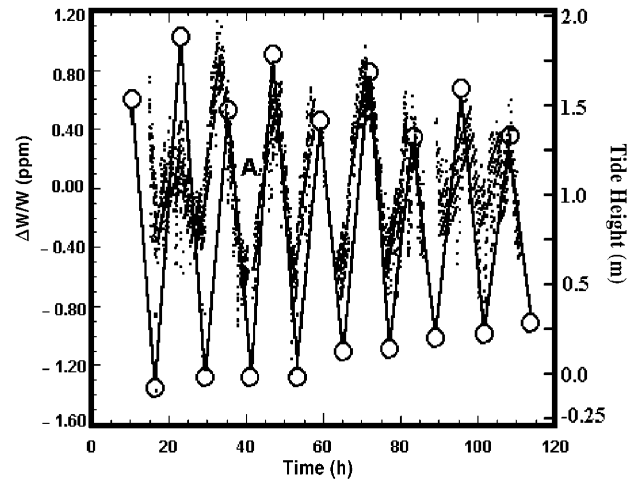

FIG. 2. Quantitative agreement and diurnal synchrony between ΔW (dots) and the tide levels (circles).

Figure 2 shows the short time dependence of our $\Delta W(t)$ data (dots) along with the high and low tide levels (circles) at Charleston, SC (the nearest 160 km station for which US-NOAA tide tables were available). Time zero is at 00 hr, 29 April 2002. There is a quantitative agreement with the daily variations in the tidal acceleration and the weight of a test mass. Such fluctuations in weight should cause noise in the signal of interest [1] and contribute to the error. Clearly, $\Delta W(t)$ tracks the tide, and in rather short time intervals steep changes take place (see around "A" in Fig. 2).

Although tidal effects may be small they are not negligible. Consequently, as experiments move to higher precision, it will be imperative to fully account for these effects.

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