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Precise measurement of gravity variations during a total solar eclipse

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The variations of gravity were measured with a high precision LaCoste-Romberg D gravimeter during a total solar eclipse to investigate the effect of a solar eclipse on the gravitational field. The observed anomaly $(7.0 \pm 2.7)\times 10^{-8}$ m/s^{2}during the eclipse implies that there may be a shielding property of gravitation.

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I. INTRODUCTION

Although gravitation may have the property of shielding in theory, it is very difficult to test the possible effect experimentally. If gravitation were carried by particles, a mass between two bodies could partially shield each of them from the gravity of the other. Anomalies can be expected in the motions of certain artificial Earth satellites during eclipse seasons that behave like shielding of the Sun's gravity as suggested by VanFlandern [1]. The possible existence of gravitional shielding and gravitational-wave absorption [2] and some theoretical analysis of a weak shielding of the gravitational interaction by a disk of high temperature superconducting materials has been investigated [3–5]. An experiment of an electrically charged pendulum [6] was carried out during an eclipse to test Saxl's effect [7] although there was no noticeable effect observed. Some related works were reviewed by Gillies [8].

If there was gravitational shielding, we would expect that the effect should be only significant during an eclipse when the gravity of the Sun may be shielded slightly by the Moon so that the gravity of the Earth may fluctuate accordingly; however such an effect may be extremely small even if it exists. The present work was thus motivated to test the possible effect of gravitational shielding during a total solar eclipse with a high precision modern gravimeter.

II. EXPERIMENT

To investigate the effect of possible gravitional shielding, we conducted a precise measurement of the vertical gravity variations during a total eclipse of the Sun on 9 March 1997 in China. The observation and measurement during the total eclipse were carried out in Moho, Helongjiang province, China with the global position $\phi = 53°29'20''$N and $\lambda = 122°20'30''$E, which lies in the center of the shadow of the totality during the eclipse. The parameters of the total eclipse are: sunrise at 06:20:00 (local time), first contact at 08:03:29, second contact at 09:08:18, third contact at 09:11:04, and fourth contact at 10:19:50. The duration of totality of the solar eclipse is 2 min and 46 s. The angular height of the Sun during the totality is 21°.

A very high-accuracy LaCoste-Romberg D gravimeter (L & R D-122) was used to measure the variations of vertical gravitional acceleration with a high precision of $2-3\times 10^{-8}$ m/s^{2}or $2-3$ μgal. The equipment was kept in a constant temperature with ± 1 °C inside an undisturbed room. The output signal of the gravity variation from the gravimeter was automatically collected by a PC. The surrounding environment (within 200 meters) was kept undisturbed during the whole process of recording data so that there was no man-made gravitational disturbance (e.g., gravity disturbance due to the movement of people conducting the experiment).

The gravimeter (LaCoste-Romberg D) was very stable and had been used for various field surveys as well as daily records of tidal forces for several years. However, in order to ensure the accuracy of the measurement, the gravimeter was installed well earlier before the eclipse. The gravimeter reading was tested for several times to simulate real-time recording. The real-time recording began at 15:00 in the afternoon on 5 March 1997, and went on continuously until 15:00 on 12 March 1997. The sampling reading interval is 1 min. The sampling was increased near the eclipse. The data reading was recorded at a rate of 2 readings every minute from 06:00 am to 12:30 pm and at a higher sampling rate of 1 reading per second during the eclipse from 08:00 am to 10:30 am.

III. RESULTS AND DISCUSSIONS

The vertical gravitational acceleration measured consists of several components: (1) gravitational forces due to the Earth, the Sun, and the Moon, and (2) the Earth's rotation. The former includes the static gravity by the Earth and the tidal force by the Sun and the Moon due to changes of moving positions. The tidal component can be calculated theoretically with a precision of 1 μgal or 1×10^{-8} m/s^2, which is a routine practice in geophysics.

After making all these corrections, the difference left shown Fig. 1 is the variation of vertical gravity during the eclipse due to some unknown effect, which may be a possible shielding effect of gravitation. The solid curve is the averaged values with a 10-minute window and the variation can be more clearly identified.

The variation around zero has an amplitude of $\pm 3-4$ μgal. The important and interesting anomaly is that there exist two regions with significant gravity decrease. One such region occurred within about 30 min around 07:30 am with a maximum significant decrease of 6.0 ± 2.5 μgal, and another took place within 30 min around 10:20 am with a maximum

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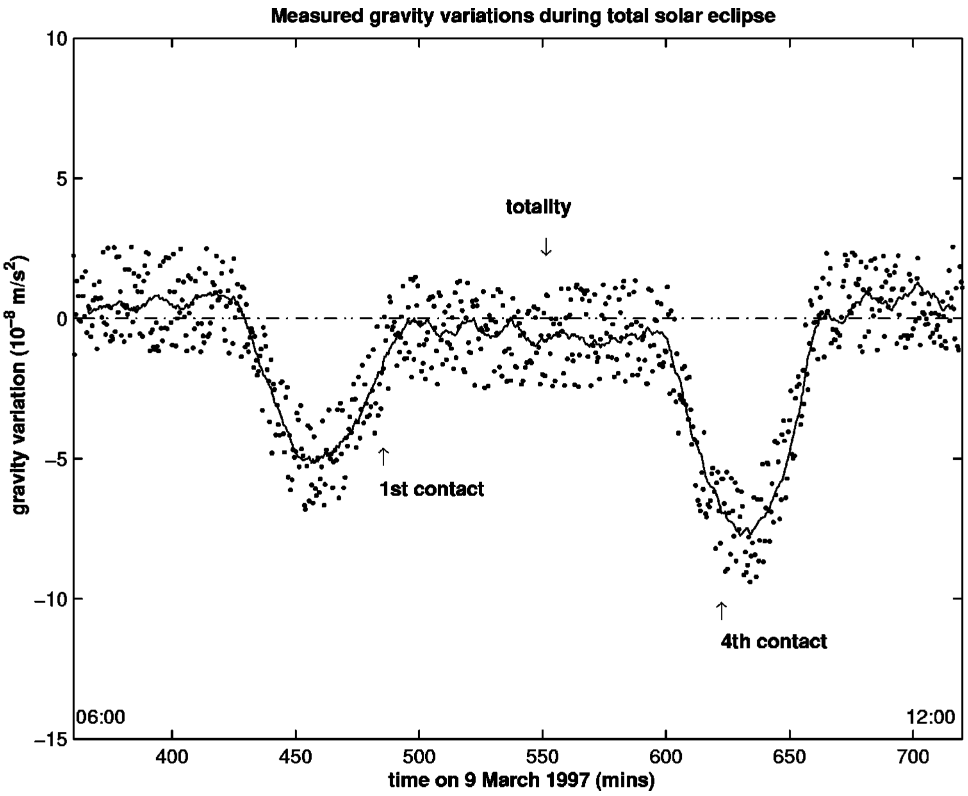

FIG. 1. Variations of vertical gravity measured during the total solar eclipse on 9 March 1997. The solid curve is the averaged variation over a moving 10-minute window. Two regions of gravity anomaly during the eclipse were observed, which may be the effect of gravitational shielding.

change of 7.0 ± 2.7 μgal. The deviation is calculated by using the standard formulas in measurement data processing. If the solid curve is used for the calculation, the maximum changes shall be 5.3 ± 1.4 μgal at first contact and 6.8 ± 1.4 μgal at fourth contact, respectively. These two changes took place between first contact and fourth contact, and were quite closely related to the timing of eclipse phases of first contact and fourth (last) contact.

Figure 2 shows the measured gravity variation in the week of the eclipse from 5 March 1997 to 12 March 1997. The significant variation during the eclipse on 9 March 1997 is also shown (for details see Fig. 1). In plotting this figure,

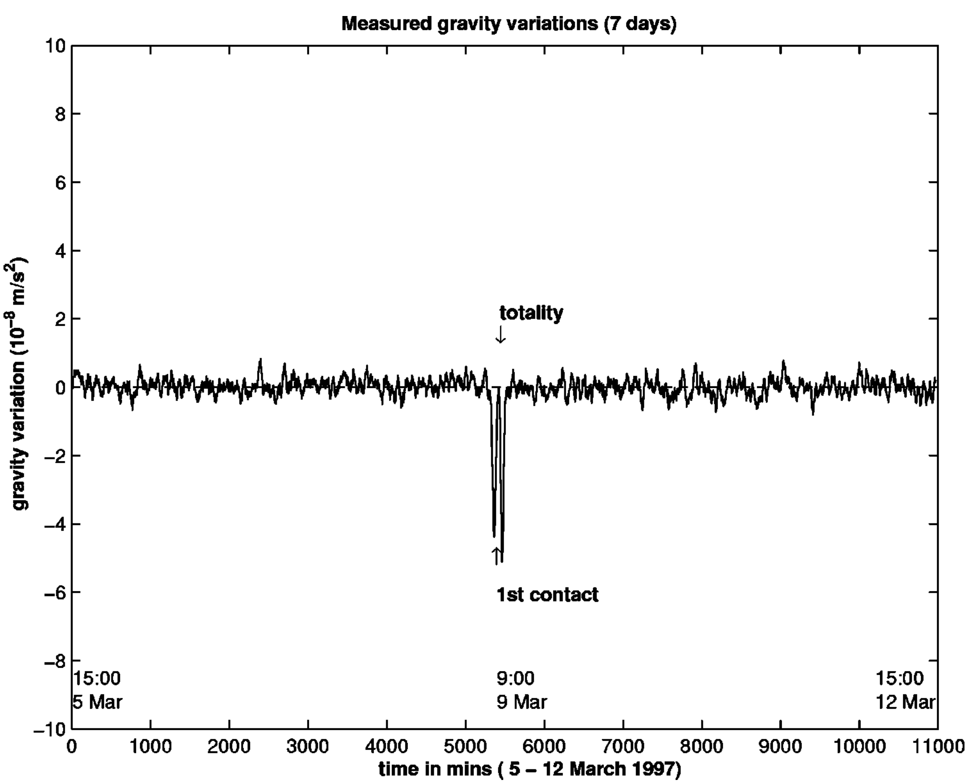

FIG. 2. Measured variations of vertical gravity measured during the whole week from 5 March to 12 March 1997. Significant change was observed during the eclipse on 9 March 1997, which is shown in more detail in Fig. 1.

TABLE I. Measured data distribution.

Data deviation range (μgal)	Number of data
<2	9948
$\geqslant 2$	87
$\geqslant 4$	45

the data were averaged with a 10-minute moving window so that the curve is more smooth than the actual measured data and the signal looks more significant. We can see that the reading was quite stable before the eclipse and after the eclipse. The change during the eclipse is remarkable. Table I shows the number of data deviated from the average value with a total of 10 080 data. Please note that the actual number of data during the eclipse is much more than those listed this table (with a resampling rate of 1 reading per minute) because the sampling rate during the eclipse is much higher (1 reading per second).

The changes are quite significant and they are not the effect of temperature and pressure changes. According to the calibration precision of the LaCoste-Romberg gravimeter provided by the manufacturer, the variation of 8°C in temperature would lead to 5 μgal change in gravity reading. The actual temperature change in controlled room temperature during the eclipse is within ±1°C, so the actual effect of temperature change is less than 1 μgal. The actual change in pressure during eclipse from 07:00 am to 11:00 am is about 1 mmH and the change is less than 3 mmH in that whole day. According to the manufacturer, the effect of actual pressure change on gravity reading is much less than 1 μgal. Therefore, the actual noticeable changes of gravity during the eclipse may imply some extraordinary phenomenon associated with gravity such as the possible shielding effect of the Moon on the gravitational force of the Sun. In addition, another puzzle is that the anomalies of the gravity variations occurred at the first and last contact but not during the totality. This certainly requires more precise measurements in the future during totality of a solar eclipse.

In summary, we have used the best available gravimeter, with a high precision of 2–3 μgal, to measure the variation of vertical gravity during the total eclipse on 9 March 1997. Although there were no noticable changes around the totality during the solar eclipse, we have observed quite significant decreases in vertical gravity during the first contact and the last contact. This may imply the new property of gravitation, which certainly needs more high precision experiments to be conducted in the future especially during solar eclipse. Although the purpose of this Rapid Communication and the present work is not intended to prove the shielding effect of gravitation, however, we would be delighted if the present work can initiate more work on the possible new property of gravitation.

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