# A new upper limit for the absorption coefficient of gravitation

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**1.** In the theory of gravitation absorption it is suggested that a gravitational ray *l* of intensity *g* be weakened after crossing a layer of material with density *d* according to the law suggested by Bottlinger (1912)

$$g = g_0 \exp(-\lambda \int_l \delta dl) \qquad (1)$$

where λ is the so called absorption coefficient. The experiment made so far allow to assume that $\lambda < 10^{-14}$ $gr^{-1}$ $cm^{-2}$ ; for layer thickness and density sufficiently small we may then write

$$g = g_0 (1 - \lambda \int_l \delta dl) \qquad (2)$$

A straight forward method to verify the reality of the phenomenon or to estimate λ is to measure the weakening of a gravitational ray caused by the crossing of a layer of known density and thickness. The first physicists who investigated this phenomenon and estimate λ followed this path.

In 1897 Austin and Thwing set some screens of different density between the fixed and the mobile masses of a Cavendish balance; however the did not succeed to observe the absorption within a limit of the accuracy of the experiment which was 2% of the acting force.

In the first years of the following century, experiments with the same method were repeated without positive results by Kleiner (1905), by Cremieu (1906) and by Erisman (1908). Erisman (1908) reached the precision of 0.08% of the acting forces. Laager (1904) used a regular balance to weigh a spherical silver ball weighting 1.5 gr, alternatively surrounded or not by a spherical lead layer, however he did not observe any weight variation larger than 0.01% of the acting forces.

Obviously the phenomenon interested also the astronomers; in 1911 some irregularities of the motion of the Moon, for which no causes could be found, were object of a prize emitted by the University of München. The prize was assigned in 1912 to Bottlinger (1912), who showed that the phenomenon of gravity absorption could explain the those irregularities. During Moon eclipses because of the absorption the Moon would be subject to an impulsive force due to the gravity absorption.; Bottlinger (1912) showed the these forces would cause a periodic variation of the mean longitude with a period of about 19 years; assuming that $\lambda = 3x10^{-15}$ the estimated variation would be in agreement with the observed ones. In the same year appeared also a paper by De Sitter who reached the same conclusions of Bottlinger.

Today it is believed that the findings of Bottlinger (1912) and De Sitter be invalidated by the poor knowledge of the time in the epoch of Bottlinger and DeSitter since then the knowledge of the time was related to the Earth rotation which suffers of periodic and a-periodic irregularities which may interfere with the supposed irregularities of the Moon motion.

In 1919 Majorana began a series of studies and laboratory experiments whose results are presented in a set of 18 notes appeared in the Proceedings of Accademia Nazionale dei Lincei from 1919 to 1922. First he made some theoretical studies where he suggested that the substances composing the Sun appear to us as masked in the gravitational effects by the exterior layers, that is due to the supposed effect of the gravitation absorption; in reality the mass of the Sun would appear to us as smaller than shows the classical theory. He showed that if we assume that the Sun is homogeneous With a density of 2 gr $cm^{-3}$ (respectively 20 gr $cm^{-3}$), the value sof the absorption coefficient $\lambda$ assumes the value 1.11 $10^{-11}$ (respectively 2.90 $10^{-11}$).

Subsequently Majorana began a series of laboratory experiments performed with very refined techniques seeking to observe the variation of weight of a 1.3 kg lead sphere when it was screened from the effect of Earth's gravitational field with other masses. As screen he used a 114 kg Mercury cylinder, then a 9.8 kg Lead cube which surrounded completely the sphere.

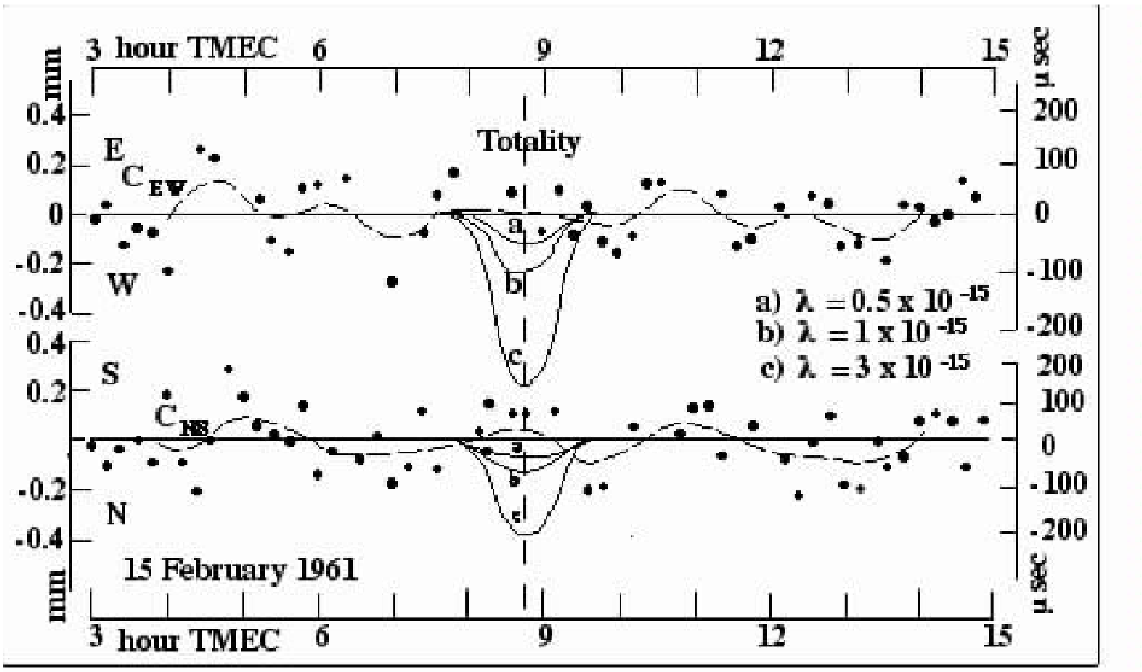
From the results of these experiments Majorana was induced to state that the absorption effect existed . The experiments made with the Mercury cylinder led to conclude that to the value $\lambda = 7\ 10^{-12}$, while the experiments made with the Lead cube gave $\lambda = 2\ 10^{-12}$ .

Following the publication of the first results of Majorana's experiments, Russel (1921) showed that because of the gravity absorption the inertial mass of the planets could not be proportional to their gravitational mass and that consequently their motion should differ notably from what observed in reality. According to Russel this conditions the value of $\lambda$ to be smaller than the values given by Majorana by a factor $10^{-4}$; he further suggested that the phenomenon observed by Majorana was not due to absorption but possibly to a relativistic effect.

Many years went by before the research on this matter would be resumed. In 1954 Brein (1954a), using an idea of Tomashek (1937), tried to observe the gravitation absorption during a Solar eclipse which occurred in Central Europe and the same was done by Tomashek (1955) himself in the Shetland Islands. In that circumstance the Moon would have served as a screen relative to the Sun and relative apparent increase of gravity would have been observed. The experiment was made with a high sensitivity recording gravimeter, but few perturbations of difficult interpretation occurred and made results uncertain. However Brein (1954b) from the results of the experiment inferred for $\lambda$ the limit $\lambda < 3\ 10^{-15}$ which is not in disagreement with the results of Bottlinger (1912).

**2.** The total Sun eclipse of February 15th 1961 was another circumstance to attempt a verification of the phenomenon. Experiments were made in Sofia and Kiev with Askania recording gravimeters by Venedikov (1961) and Dobrokhotov, Parisky and Lysenko (1961) and in Berchtesgaden with horizontal pendulums by Sigl and Eberhard (1961).

The results of these observations were presented at the IV Symposium on Earth Tides in Bruxelles in 1961; no evident effect of absorption was reported moreover no limits for the coefficient were given. The same type of observations in the circumstance of the 1961 Solar eclipse of 1961, with the suggestion of Marussi were made also with the great horizontal pendulums installed since 1958 in the Grotta Gigante near Trieste for the study of the tides of the Earth's crust (Marussi 1960).



The circumstance was exceptional since the totality was in near proximity of the station since the minimum distance of the two bodies at totality was only 58''; moreover the height of the Sun at totality was 13° 30' and the effect on the horizontal pendulums was very near the maximum one could hope. In order to observe the phenomenon the sensitivity of the pendulums was taken from 463 sec to 657 sec for the EW component and form 500 sec to 580 sec for the NS component. The longer period of oscillation implies in the recordings a ratio of 2.185 mm/msec and 1.702 mm/msec respectively. The speed of the recording photographic film was take to 3.8 cm/h. Since the reading resolution is 0.1 mm, follows that the reading have an uncertainty of about 5 $10^{-5}$ arcsec.

The recordings of Earth's tides during February 15th were favoured by excellent environmental and meteorological conditions: the barometric pressure, which could cause very small inclinations around the Dinaric axis, had no appreciable variations nor were recorded disturbances due to the flow of Karst waters.

The analogue recordings of Earth's tides during February 15th for both components EW and NS were digitised with readings every 12 minutes. The values were then fit with the least square method to the following function

$$\begin{aligned} &A_2 + A_1 t + A_0 t^2 + B_1 \sin(2\pi / T_1 + \beta_1) + B_2 \sin(2\pi / T_2 + \beta_2) + \\ &+ B_3 \sin(2\pi / T_3 + \beta_3) + B_4 \sin(2\pi / T_4 + \beta_4) \end{aligned} \qquad (3)$$

where $T_1$ , $T_2$ , $T_3$ , $T_4$ are the periods of the componets of the $M_1$, $M_2$, $S_1$, $S_2$ lunisolar tides and t is time. The differences between the fit curve (3)and the data are residual time series $R'_{NS}$ and $R'_{EW}$.

An first inspection of the two series showed that other periodic phenomena, besides the tidal ones, were effecting the data. In order to eliminate these disturbances a spectral analysis of the two time series was made (Zadro 1961). The resulting periods were $4.0^h$ and $2.33^h$ and with much smaller amplitudes several period near one hour. It is not of interest to discuss here these periods which are almost certainly to be connected with the seiches of the Northern Adriatic sea (e.g. Caloi 1931, Polli 1958, Zadro 1961).

In order to eliminate these secondary periodic effects the $R'_{NS}$ and $R'_{EW}$ time series were examined in a time interval of 12 hours centred a further fitting was made with a function of the type (3) where now $T_1$ , $T_2$ , $T_3$ are the period found with the spectral analysis and $T_4$ the period of the $M_3$ tidal component. The resulting time series were analysed with the $\chi^2$ test which gave confidence levels of 78% and 85% for the two components. Since this result was not considered sufficiently significant the time series were filtered with a symmetric filter which operates on 9 successive values with factors ( 0.0078, 0.0508, 0.1266, 0.1977, 0,2302, 0.1977 ect.). The resulting curves $C_{NS}$ , $C_{EW}$ are shown in the figure 1. The deviations with respect to these curves have a level of randomness of 83% and 99% respectively, which we considered acceptable.

**3.** We compare now the curves $C_{NS}$ , $C_{EW}$ with those which represent the effects which one would have expected according to the theory.

The variations on the horizontal components of the Lunisolar attraction due to gravity absorption in the successive phase of the eclipse have been computed for the particular case which we are considering with a process of graphics integration which ensure a precision of 2 %; to this purpose we considered the Moon homogeneous with for density 3.34 while the density of the Sun we adopted the values, as function of the distance from its centre, given in the tables of Landolt-Börnstein. With g = 980.630 gal at the Grotta Gigante the components of the deflection of the vertical (expressed in milliseconds of arc) which represent $C_{NS}$ , $C_{EW}$ are reproduces in the figure 1 for $\lambda = 3$

$10^{-15}$ (curve c), $\lambda = 10^{-15}$ (curve b), $\lambda = 0.5\ 10^{-15}$ (curve a). The comparison of the theoretical curves with the experimental ones suggests the following considerations: no effect is seen in the NS component, while in the EW component the flattening of the oscillation towards East, which occurs at the time of the maximum of the eclipse,, could be due to the presence of the supposed gravitational absorption with a value of $\lambda < 0.6\ 10^{-15}$ .

Taking into account that this component should have a greater reliability because of the possible effect of absorption, which on this component should be 1.9 times larger than in the other, and also because the confidence level with which have been eliminated the accidental departures is larger than for the other component, we will assume the limit for $\lambda$ which results from it that is $\lambda < 0.6\ 10^{-15}$ . We note that this limit is 1/5 of that so far admitted and is in accord with the forecast of Russel (1921).

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