Time dilation and gravitational acceleration

Stefano Quattrini

Via Jesi 54 ANCONA, ITALY
stequat@libero.it
01/10/2014

Gravitation affects clock-rates, it is an evidence since the Hafele and Keating [2] experiment verified it. It is widely recognized the influence on atomic clocks is not due to the local gravitational acceleration but depends on the local Einstein energy momentum stress tensor [3]. A simple demonstration will be provided to show that in a Pound and Rebka [9] alike experiment, admitting that the acceleration is the responsible of the gravitational time dilation between two vertical positions, an infringement of the conservation law is encountered, simply denying such possibility.

I. INTRODUCTION

The gravitational time dilation was indirectly tested in the Pound and Rebka experiment for the first time in 1960 through the phenomenon of gravitational redshift.
In that period it was believed that the gravitational redshift of photons could be interpreted in two ways, as a consequence of the clock hypothesis and as an energy exchange of the photons with the gravitational field.
The second hypothesis was discarded in the following years, since there is no gravitational potential energy of photons to sustain it [5]. This is due to two main reasons, massless photon y[3] and GP-A experiment interpretation [4],[11] denying any energy difference in the travelling photons between two positions in a gravitational field. Though the frequency perceived is different at different heights. That everything depends only on the clock hypothesis is for some still an open issue [5].
In order to simply clarify that the origin of the gravitational time dilation does not depend on the local gravitational field at all, a similar experiment as the Harvard Tower ones is presented. Admitting the dependence of the time dilation on gravitational acceleration, it will be shown an infringement of the energy conservation law.

II. THE GRAVITATIONAL FIELD PROFILE

The most are familiar with the configuration of the gravitational field below.

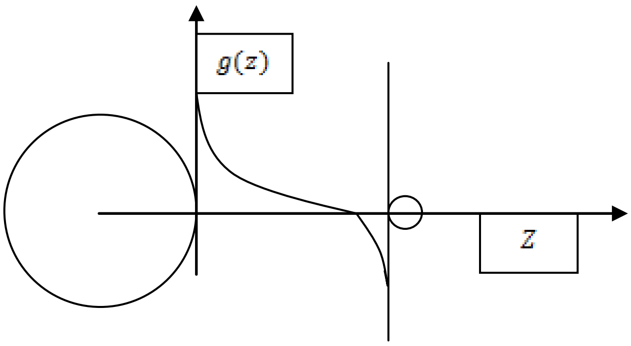

Fig. 1. **The gravitational field outside the masses**: the field is a monotonic derivable function.

The field is the largest on the surface or along the geoid of each mass and goes to zero at a point, closer to the smallest mass, along the line joining the center of the masses.

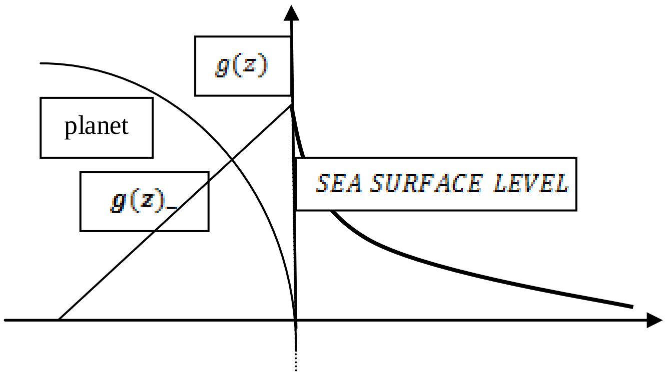

Fig. 2. **The gravitational field from inside out, it is not a monotonic function**, not derivable at a point, a piecewise continuous function

The configuration above is not so familiar as the preceeding one. For a full homogeneous spherical mass: (r = z) gravitational g field is 0 approaching to infinity, maximum on the surface or geoid, 0 in the center.

III. THE PROPOSED EXPERIMENT

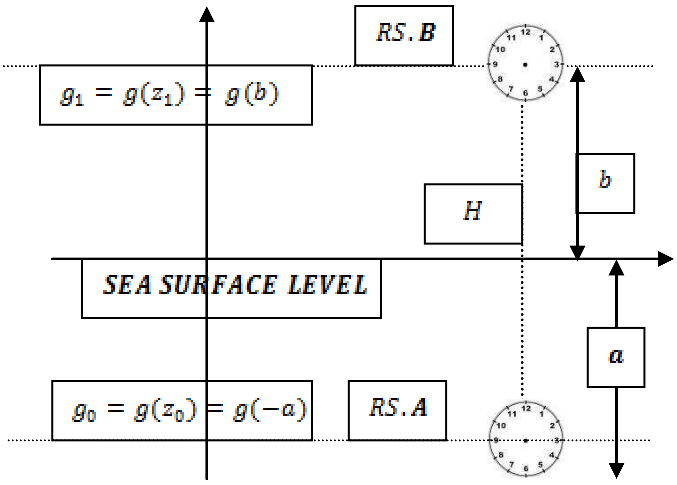

Fig. 3. **Configuration of the experiment**: one clock is situated under sea level, the other is above, such that gravitational acceleration is the same.

Let's set a + b = H the distance between A and B (a, b): $g^{-}(-a) = go$ and $g^{+}(b) = g1$.

Let's consider an atom T of rest mass m_o ,in its ground state (not excited) in A. The atom T is lifted up from A to B letting the necessary energy in, from an external source, in order to work against the gravity field to reach B. Potential energy gets:

$$\Delta U(A,B) = U(B) - U(A) = m_o\, g_x H \quad , \quad U(A) = 0.$$

For the "first mean value theorem for integration", it is in fact possible to find a suitable average value $g_x = g(\alpha)$ of a continuous real function g(z) in an interval of real numbers (a, b) where $\alpha \in$ (a, b), such that the definite integral in (a, b), is equal to the g_x value, times the distance H of (a, b) . This implies that $\Delta U(A,B) = m g_x H$ with a generic m (provided that gravity field doesn't affect the variation of mass itself) ***no** other hypotheses are required, not even the m << M (mass of Earth) approximation or H<<R.*

Hypothesis: time dilation is affected by gravitational acceleration

A round trip of the atom and radiation bottom-> top → bottom: A→B→A, is considered.

Bottom to top: A→B (T arrives in B from A and then is excited by the photon emitted from A) A photon of energy $h\nu_o$ is generated in A and directed to B. Being the gravity field the same, in the two positions it means that there should not be any time dilation. The photon is unaltered by the transition from A to B, since no gravitational potential of photons is possible. The external energies to produce the state in B would be: E (B) = $\Delta U(A,B) + Eph = m_o g_x H + h\nu_o$; The atom T already in B absorbs the photon $h\nu_o$. The atom T, excited by the photon, becomes T' having mass m_e = $(m_o + h\nu_o/c^2)$.

Top to bottom: B → A (the excited atom falls and then re-emits the photon) kinetic energy released in the fall of the T' atom from B to A is equal to its potential energy A to B. E(A) = $(m_o + h\nu_o/c^2) * g_x * H$; In A, the atom emits the photon, T'→T, $h\nu_o$ is given back;

The energy balance in the round trip for the system is:

$$\Delta E(tot) = Eoutput - Einput = kinetic(T') + E(emitted\ photon) - [E(absorbed\ photon) + potential\ (T)]$$

$$\Delta E(tot) = \left(m_o + \frac{h\nu_o}{c^2}\right) g_x H + h\nu_o - [m_o g_x H + h\nu_o] = m_o g_x H + \frac{h\nu_o}{c^2} g_x H - m_o g_x H = \left(\frac{h\nu_o}{c^2}\right) g_x H > 0 .$$

In order to account for such violation of the principle it has to be admitted that the time dilation has to be present. Such variation brings properly to $\left(\frac{h\nu_o}{c^2}\right) g_x H$, being this the gravitational potential of the mass relevant to the energy absorbed by the atom [10 - page 69] . It corresponds to a local frequency increase of the absorber atom set at an higher gravitational potential.

Since photons do not lose or gain energy in a gravitational field, having admitted that different gravitational accelerations determine time dilation would open the possibility to perpetual motion.

IV. Conclusions

In the configuration proposed, two clocks exposed to the same gravitational accelerations in different vertical positions in a gravitational field have been compared, in a very similar fashion of the Harvard Towers experiments. The fact that the geoid is the point of maximum gravitational acceleration has been exploited. The time dilation between points allocated in opposite semi-planes respect to the geoid has to be present unless infringing the energy conservation law. This states that time dilation does not depend on the local accelerations of the clocks which were the same.

References

[1] A. Einstein, H. A. Lorentz, H. Minkowski, H. Weyl, *The Principle of Relativity* (Dover, New York, 1952).

[2] Hafele J C, Keating R E. Science (1972);177 166-168.

[3] Quattrini S. "GP-A experiment review," Doi.

[4] THE MEANING OF RELATIVITY (Princeton university press, Princeton, N.J.) (1921-1955) Albert Einstein.

[5] L. B. Okun', K. G. Selivanov, V. L. Telegdi, "Gravitation, photons, clocks", *UFN*, 169:10 (1999), 1141–114.

[6] Einstein A. Ann. Phys. (Leipzig) 35 898 (1911).

[7] J. L. Synge, *Relativity; The General Theory* (North-Holland, Amsterdam, 1971), pp. IX-X.

[8] L.I. Shiff. "On experimental tests of the General Theory of Relativity" Am. J. Phys., 28, 340–343(1960)

[9] C. M. Will, "The confrontation between general relativity and experiment," Living Rev. Relativity 9, 1–100 (2006).

[10] R. P. Feynman. "Lectures on gravitation"

[11] Vessot R, Levine M. Gen. Rel. Grav. 10 181 (1979).

[12] A. Einstein, (1907); "On the relativity principle and conclusions drawn from it,"Am. J. Phys. 45(10) 899–902 (1977).