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Correction due to the finite speed of gravity in absolute gravimeters

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***Abstract**: The correct correction of gravimeters for the finite speed of interaction is still experimentally undecided. The measurement results are important for better understanding of interactions.*

***Keywords**: interaction, retarded potential, field, acceleration, speed of light, speed of gravity, relativity, gravitation, gravimeter, correction, radiation*

The retardation effect for the first order term in β (such as the flyby anomaly [1]) is often forgotten in the relativistic approach. However the finite speed of interaction can itself explain all relativistic effects [2]. Another example of unsuitability of the relativity concepts (such as the Lorentz factor) is the absolute gravimetry. The effect of the finite speed of light has many different correction factors k in literature [3], however it should be k=2 [4]. It is important, if measurements often systematically disagree in order of 10 ppb [5]. This correction of measured acceleration (by relative change -2β, that corresponds approximately to 12 ppb decrease of acceleration g) is also incorporated in the software for (the most widely used) FG5 gravimeters. Nevertheless the finite speed of gravity correction (a relative difference between the effective and the natural length/time) is omitted and it is resulting to the unaccounted remaining offset +2β (for FG5 gravimeters) from the static (or slow motion) value of g. We can introduce the analogy (like for the beam light divergence [6] and the gravitational field divergence/gradient) between the electromagnetic interaction (with retarded Liénard-Wiechert potentials) and the gravitational interaction and then we will obtain the velocity-dependent force (like in [7]). The equations for a radial movement in the field and for the first order in β will be

$$\varphi_{EM} \cong \frac{qQ}{4\pi\varepsilon R}(1+\beta) \quad \text{and} \quad \varphi_{G} \cong \frac{GM}{R}(1+\beta)$$

where β is the speed relative to the speed of interaction. The sign for this ("Doppler") correction can be obtained on the following considerations. If the retroreflector moves upward with a speed close to the speed of light, then interferometer fringes tends to do not move (time is like stopped and the optical intensity is decreased). However the gravity also acts weaker (tends to zero), as the speed of gravity cannot catch the retroreflector. Then if the source of gravity (the Earth) and the electromagnetic source of light (the laser beam) are in the same direction from the test mass, then the acceleration measurement correction effects are added. If they are in the opposite direction, effects of the finite speed of gravity and light cancel out (and both of them are not present in a gravimeter with the symmetric measurement).
The correct correction is important in future experiments such as the Watt balance and measurements with precision clocks. Then it should be checked and decided experimentally and distinguished from other various corrections, which may randomly cancel out.
Also for more precise measurements, the gravitational radiative term (as an irreversibility in the electromagnetic radiation [8] or a retarded equilibrium [2] – i.e. the radiation is a form of

asymmetry) should be taken into account (if the “advanced field” [9] does not cancel out this effect). The radiation reaction force (from jerk as a quadrupole effect)

$$F \cong \frac{2}{3}\frac{GmM}{c^3}\dddot{x} = \frac{2}{3}\frac{GmM}{R^2}\frac{R^2\dot{a}}{c^3} \cong 6\cdot 10^{-18} F_0$$

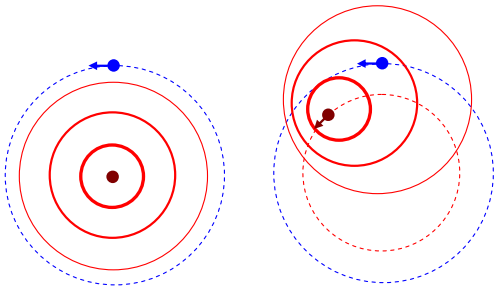
is very small for FG5 (for acceleration changes $\dot{a} = \gamma\dot{x}$ induced by the gradient γ of the Earth gravitational field). However the power for the gravitational “bremsstrahlung” (which is emitted almost symmetrically) for the free fall is

$$P \cong \frac{2}{3}\frac{GmM}{c}\dot{\beta}^2 = \frac{2}{3}\frac{GmM}{R^2}\frac{R^2a^2}{c^3} \cong 10^{-10} F$$

on the surface of the Earth (source of the advanced acceleration/radiation) and in SI units – and exists thanks to retardation effects (the gravitational acceleration (i.e. dipole) radiation waves are also possible for gravitationally “unbound” systems [10]). Thus the free fall experiments (with speeds in the order of 1 m/s and times 0.1 s, the energy is roughly 0.1 nJ and corresponds to 10 pm in the height difference in gravitational field, i.e. up to 0.1 ppb of the fall height) can test it.

The synchrotron radiation (and precession) is caused by a field from used magnets (with charge currents forced to be curved). The magnetic vector potential (or the gravitomagnetic analogy of a dragging [11], that is based on the mass current and the mechanical momentum or the angular momentum when trajectory is curved) deflects “free” charges (currents), which tend to compensate it by an opposite (back-reaction) process (“radiation”) in magnets (keeping the current/momentum conserved). Also another example is the oscillating dipole. The power/energy for applied forcing (absorbed in advance) and radiation (retarded fields) are in balance (conserved). Also the thermal radiation of a body (caused by accelerations and decelerations in particle “collisions” like in plasmas [12], where the black-body spectrum is obtained without the field quantization) is balanced in the equilibrium.

The dipole radiation is not observed at an orbit (e.g. for the electron electromagnetic radiation in atom or the binary pulsar gravitational radiation). We cannot use an equation derived for a uniformly accelerating particle (such as the Larmor formula), because there is no retardation ([de]kinetization by radiation) effect (for the scalar field) in a circular motion (the time of “arrival” is the same along a circle for the interaction effect of the central charge, i.e. it is without a mutual movement relative to the field propagation wavefront, or we can introduce the advanced field to compensate the retarded field as well as centrifugal acceleration for centripetal acceleration) and the (theoretical) “absence” of radiation imbalance can not be used for the disconfirmation of “whole” classical electrodynamics (however it can be used for better accelerators). The difference between electric monopole and magnetic dipole bending of the charge trajectory is sketched in the following figure. The electric current in a magnet can easily disappear (is relative as well as velocity), however the (monopole) charge cannot (the left figure) without its annihilation.



Also other terms and near field contributions, such as jerk, can decrease radiated power [13] ("spin-orbital" effects), and should be taken into account. Thus "physics problems" must be solved/simulated in a more generally approach (e.g. by introducing the higher order vector potential $\vec{A}_2 = \ddot{x}\varphi$ or directly evaluated only from the scalar potential with finite speed of light effects) without scholar myths. The counterintuitive (or "incredible") metric or quantum interpretations [14] are counterintuitive themselves (counterintuitiveness is not present in the reality) and so are confusing. Simulations of objects, such as atomic and galactic nuclei, can help our understanding rather than believe to (for example) strange particles, interactions and singularities such as black holes or the Big Bang. Also it should be mentioned, that the field is not a particle (pseudoparticle such as photon or graviton), it is an image of sources, which can take various forms and values of misconceptual quantities such as spin (monopole s=0, dipole s=1, quadrupole s=2), i.e. "pseudoquantity", that works in the same way for both fields (the graviton is not "boson" with only s=2) – the "electromagnetic" and the "gravitomagnetic" field (simply named gravity, because magnetic properties comes from the relativity in a rotating reference frame described by a pseudovector [15]).
Another example is also the electromagnetic radiation pressure and the gravitational radiation pressure (both obtained from the velocity-dependent force correction). The equilibrium with this pressure/temperature (or potential, i.e. $const = \Delta\varphi \propto \beta/R$ and $c/R_{obs} = \omega_{cutoff} = 1/T_{obs}$) creates the ("fictitious") Doppler shift proportional to the distance.

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