Comment on the paper "Can observations inside the Solar System reveal the gravitational properties of the quantum vacuum?"

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Abstract: In a recent paper of D.S. Hajdukovic (Astrophys. Space Sci. **343**, 505, 2013), it is hypothetically claimed that "the quantum vacuum induces a retrograde precession of the perihelion and the Newton's force of gravity might be accompanied with a tiny radial force that is a signature of the quantum vacuum". However, the present paper argues that the quantum vacuum cannot really be the causal origin of the extra-gravitational effects and the additional radial acceleration and force are in fact a sort of the gravitational induction due to the relative motion of the test-body in the vicinity of the principal gravitational source.

Keywords: Gravitational properties of quantum vacuum, solar system, perihelion precession, gravitational induction, combined gravitational action

1. Introduction

In recent paper "Can observations inside the Solar System reveal the gravitational properties of the quantum vacuum?" (Hajdukovic 2013) the effect of quantum vacuum (QV) is extended to the solar system with the assumption that the QV contains the virtual gravitational dipoles. At first glance, it seems to be a tempting idea to obtain a description of the physics underlying gravitational dipoles *via* QV. However, since QV belongs to the quantum physics, which is quite distinct from general relativity theory and the two paradigms are conceptually proven to be completely incompatible. Therefore, it is epistemologically at least a controversial practice to mix the properties of quantum physics with those of gravitational physics. It seems that the author puts the cart before the horse: because his work is basically founded on the proposal that the QV contains the virtual gravitational dipoles *as if* the graviton is *already* discovered and the gravitational waves are *already* detected, and quantum physics and gravitational physics are *already* unified!

2. Shortcomings of the author's method and result

The first question is focused on author's Eq.(5), which is not lucid! As we know, there is a difference between

$$\mathbf{g} = -\frac{GM}{r^3}\,\mathbf{r}\,, \tag{i}$$

and

$$g \equiv \|\mathbf{g}\| = \frac{GM}{r^2}\,. \tag{ii}$$

Eq.(i) is the gravitational acceleration in vector form (the minus sign (-) means that the gravitational field/force is attractive); Eq.(ii) is the gravitational acceleration in scalar form. However, in gravitational physics and in classical (Newtonian) mechanics, there is also a distinction between acceleration (in scalar form) $a > 0$ and deceleration $a < 0$. Since according to author's Eq.(2), we have $p(r) \equiv \left\| \mathbf{p}_g(r) \right\|$, and as said by the author " $p(r)$ has a constant value (in fact a maximum value) that may be denoted $p_{\max}(r)$." Therefore, what is exactly the origin of the minus sign in Eq.(5)?

In series of papers (Hassani 2009, 2011, 2013), it was shown that the law of universal gravitational attraction

$$\mathbf{F} = -\frac{GMm}{r^3}\mathbf{r}, \tag{iii}$$

is not really a single force in the common classical sense, but a resultant of two forces (*static* gravitational force and *dynamic* gravitational force) that make between them an extremely small angle, especially, when the test-body is in state of motion. The extreme smallness of that angle means that the resultant force and its two components, namely, the static force and the dynamic force are almost in perfect superposition.-the resultant force is called 'Combined Gravitational Action' (CGA). As a direct consequence, the gravitational field, $\mathbf{g}$, itself becomes a combined gravitational field defined by

$$\mathbf{g} = \boldsymbol{\gamma} + \boldsymbol{\Lambda}, \tag{iv}$$

Where $\boldsymbol{\gamma}$ and $\boldsymbol{\Lambda}$ are, respectively, the static and dynamic gravitational field. That is to say, phenomenologically $\mathbf{g}$ is a resultant of two fields. From all that, and without entering in full details, we arrive at the following conclusion: the main consequence of the CGA-formalism is the existence of the Dynamic Gravitational Field (DGF), $\boldsymbol{\Lambda}$, which is in fact an induced field, it is more precisely a sort of gravitational induction due to the relative motion of material (test) body B in the vicinity of the principal gravitational source A. And it is defined by

$$\boldsymbol{\Lambda} = -\frac{v^2}{w^2}\boldsymbol{\nabla}\Phi, \tag{v}$$

where

$$\Phi \equiv \Phi(r) = -\frac{GM}{r}, \tag{vi}$$

is the static gravitational potential; G being the Newton's gravitational constant; M is the mass of the principal gravitational source A; $r = \sqrt{(x-x_0)^2 + (y-y_0)^2 + (z-z_0)^2}$ is the relative distance between A and the test-body B; $v = \sqrt{v_x^2 + v_y^2 + v_z^2}$ is the velocity of B relative to an inertial reference frame momentarily at rest with respect to the source A; and w is a specific kinematical parameter having the dimensions of a constant velocity defined by

$$w = \begin{cases} c_0, \text{ if B is in relative motion inside the vicinity of } A \\ v_{\text{esc}}, \text{ if } B \text{ is in relative motion outside the vicinity of } A \end{cases}, \tag{vii}$$

where c_0 is the light speed in local vacuum and v_{esc} is the escape velocity at the surface of the principal gravitational source *A*. the static gravitational field is given by

$$\boldsymbol{\gamma} = -\,\nabla\Phi\,. \tag{viii}$$

After performing some differential and algebraic calculation we get the expression of the magnitude of DGF

$$\Lambda = \pm\,\frac{GM}{r^2}\frac{v^2}{w^2}\,. \tag{ix}$$

Eq.(ix) means that DGF may play a double role, that is to say, when perceived/interpreted as an extra-gravitational acceleration $(\Lambda > 0)$ or an extra-gravitational deceleration $(\Lambda < 0)$. Furthermore, multiplying the two sides of Eq.(v) by the mass, m, of the moving test-body B, we get the expression of the dynamic gravitational force

$$\mathbf{F}_{\mathrm{D}} = m\boldsymbol{\Lambda}\,. \tag{x}$$

Certainly, the static gravitational field (viii) is in general always stronger than the DGF (v), but $\boldsymbol{\Lambda}$ has its proper role and effects. Indeed, we have studied the DGF-effects inside and outside the solar system. For example, when $\boldsymbol{\Lambda}$ plays the role of an extra-gravitational acceleration inside solar system (ISS) for each planet P_i, we have

$$\Lambda_i = \frac{GM_{\Theta}}{a_i^2}\frac{v_i^2}{c_0^2}, \tag{xi}$$

$$F_{\mathrm{D}_i} = m_i\Lambda_i\,. \tag{xii}$$

The ISS gives us a very good opportunity to test the CGA-formalism because in such a system, the Sun plays the role of the principal gravitational source A of mass $M \equiv M_{\Theta}$, and each planet P_i may be separately played the role of the moving test-body B_i of mass m_i, where subscript (i =1,2,3 ...9) denotes the order of each planet P_i in the ISS. For our purpose, Pluto is always considered as planet since for as long as this celestial body orbits the Sun like exactly the other planets. Thus according to the CGA-formalism, and in terms of field-force, the Sun as principal gravitational source is permanently exerting on each planet, P_i, during its orbital motion at average radial distance , $r_i \equiv a_i$, with average orbital velocity, v_i, a certain couple $\left\langle \boldsymbol{\Lambda}_i, \mathbf{F}_{\mathrm{D}_i} \right\rangle$ acting as an additional field-force. We have for the average orbital velocity the expression

$$v_i = \left[\frac{GM_{\Theta}}{a_i}\right]^{1/2}. \tag{xiii}$$

Hence by substituting (xiii) in (xii), we obtain the important formula of the average magnitude of DGF as an extra-gravitational acceleration in ISS

$$\Lambda_i = \frac{1}{a_i}\left[\frac{GM}{c_0\,a_i}\right]^2, \tag{xiv}$$

or in terms of the dynamic gravitational force of magnitude

$$F_{\mathrm{D}_i} = \frac{m_i}{a_i}\left[\frac{GM}{c_0\, a_i}\right]^2 , \qquad \text{(xv)}$$

Where m_i is the mass of planet P_i. Now, from the formulae (xiv) and (xv), the predicted average magnitude of the couple $\left\langle \mathbf{\Lambda}_i , \mathbf{F}_{\mathrm{D}_i} \right\rangle$ for each planet is computed and listed in columns 4 and 5 of Table1; where for the values of the mass of the Sun and of the physical constants we take $M = M_\Theta = 1.9891 \times 10^{30}$ kg ; $G = 6.67384 \times 10^{-11}\ \mathrm{m}^3\,\mathrm{kg}^{-1}\mathrm{s}^{-2}$ and $c_0 = 299792458\ \mathrm{m\,s}^{-1}$.

Planet	a_i (m)	m_i (kg)	**Predicted CGA-effects** Λ_i ($\mathrm{m\,s}^{-2}$)	F_{D_i} (N)
Mercury	57.92×10^{9}	3.28680×10^{23}	1.008547×10^{-9}	3.314893×10^{14}
Venus	108.25×10^{9}	4.87044×10^{24}	1.544892×10^{-10}	7.524304×10^{14}
Earth	149.60×10^{9}	5.97220×10^{24}	5.853115×10^{-11}	3.497236×10^{14}
Mars	227.95×10^{9}	6394320×10^{23}	1.654486×10^{-11}	1.057931×10^{13}
Jupiter	778.30×10^{9}	1.899770×10^{27}	4.160406×10^{-13}	7.896628×10^{14}
Saturn	1.428×10^{12}	5.689152×10^{26}	6.729722×10^{-14}	3.828641×10^{13}
Uranus	2.870×10^{12}	8.724960×10^{25}	8.289647×10^{-15}	7.232684×10^{11}
Neptune	4.497×10^{12}	1.033848×10^{26}	2.154830×10^{-15}	2.227767×10^{11}
Pluto	5.900×10^{12}	1.254960×10^{22}	9.541699×10^{-16}	1.197445×10^{7}

Table 1. Above, column 1 gives the planet's name; column 2 gives the semi-major axis of each planet; column 3 gives the mass of each planet; columns 4 and 5 give, respectively, the values of Λ_i and F_{D_i} for each planet.

3. Implications

Table 1 shows us the predicted CGA-effects reflected by the existence of Λ_i and F_{D_i} inside the Solar System. Now, we return to the paper under discussion. Concerning the radial acceleration A_r defined by Eq.(5), the author wrote "on the basis of that result and the new work that is in progress, the best estimate is that A_r, lies in the following interval $10^{-11}\,\mathrm{m\,s}^{-2} < A_r < 10^{-10}\,\mathrm{m\,s}^{-2}$." as any one can easily remark it, the above interval is clearly included in Table1, column 4, more precisely the author's interval coincide perfectly with the values of Λ_i for the four inner planets, namely, Mercury, Venus, Earth and Mars. Hence we can affirm without hesitation that the radial acceleration A_r is just the extra-gravitational acceleration inside the Solar System. In the same page (506), the author wrote "Hence, in the region of saturation (the region of a complete alignment of gravitational dipoles) the Newton force of gravity might be accompanied with a tiny radial force that is a signature of quantum vacuum." In one sense, this conclusion is very interesting because it is looked as an additional support for our work (Hassani 2009, 2011, 2013). For instance, the author's idea of so-called a complete alignment of gravitational dipoles corresponds by analogy to our -almost perfect superposition of the resultant force and its two components, *viz*. the static gravitational force and dynamic gravitational force. The values of this (tiny radial force) dynamic gravitational force for each planet are listed in Table1, column 5.

Concerning the suggested contribution of QV to the precession of perihelion, the author wrote "…If relation (5) is correct the quantum vacuum also contributes to the precession of perihelion."

"In the case of two bodies with masses M and m, the perihelion precession induced by a constant gravitational acceleration A_r is described with the equation (Murray and Dermott 1999)

$$\frac{d\omega}{dt} = -\frac{A_r}{e}\sqrt{\frac{a}{M+m}(1-e^2)}\cos f\ , \tag{8}$$

where f denotes the true anomaly."

Since the rest of the author's work is basically founded on Eq.(8), which is physically incorrect. So with the application of the dimensional analysis (DA), we can prove the fallacy of Eq.(8) as follows. First, we split Eq.(8) in two parts, left hand side (l.h.s) and right hand side (r.h.s). In l.h.s: we have *dω/dt* which has a physical dimension of angular velocity or angular frequency, thus by applying the DA, we get

$$\mathrm{T}^{-1}. \tag{8.1}$$

In r.h.s: omitting the dimensionless quantities e and f, and by a direct application of DA, we find

$$\mathrm{L}^{3/2}\,\mathrm{T}^{-2}\,\mathrm{M}^{-1/2}. \tag{8.2}$$

Therefore, from (8.1) and (8.2), we obtain

$$\mathrm{T}^{-1} \neq \mathrm{L}^{3/2}\,\mathrm{T}^{-2}\,\mathrm{M}^{-1/2}. \tag{8.3}$$

Consequently, Eq.(8) is incorrect and in view of the fact that Eq.(9) is directly derived from Eq.(8) *via* integration therefore Eq.(9) is also incorrect.

4. Discussion and Conclusion

As already mentioned, the relative motion of test-body (*e.g.*, planet P_i) in the vicinity of the principal gravitational source (*e.g.*, the Sun) is the causal origin of the dynamic gravitational field/force. Curiously, in his 1912 argument, Einstein himself noted that the inertia of energy and the equality of inertial and gravitational mass lead us to expect that *"gravitation acts more strongly on a moving on a moving body than on the same body in case it is at rest."* Moreover, Lorentz (1900) has already arrived at some conclusion very comparable to that of Einstein, but more than one decade before him. In his very influential work entitled 'Considerations on Gravitation', Lorentz wrote *"Every theory of gravitation has to deal with the problem of the influence, exerted on this force by the motion of the heavenly bodies."* Again, Einstein's and Lorentz's claims clearly reinforcing the fact that $\mathbf{\Lambda}$ and $\mathbf{F}_\mathrm{D}$ are really induced by the motion of massive test-body *B* in the gravitational field of the central body *A*. It is clear from Eq.(iv), that the combined gravitational field, $\mathbf{g}$, may be reduced to the static (Newtonian) gravitational field, $\boldsymbol{\gamma}$, only for the case $\mathbf{\Lambda} = \mathbf{0}$, *i.e.*, when the test-body under the influence of the field is at the relative rest with respect to the principal gravitational source but the author attributed the causal origin of A_r and the 'tiny radial force' to the QV!

Question: Does relative motion equivalent to QV?

Answer: since the test-bodies like asteroids, artificial/natural satellites and planets are not quantum systems like bosons, fermions, atoms and molecules therefore, it is unacceptable to consider the QV to be the causal origin of A_r and the 'tiny radial force' because, first, we are very far from the unification of gravitational physics and quantum physics, secondly, the graviton and gravitational waves remained until now as pure hypothetical things, thirdly, dark mater and dark energy are not quite well-known. Moreover, it was theoretically and experimentally proven, in the context of quantum field theory, that the QV is the main causal origin of the Casimir effect and the Casimir–Polder force.

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