Evidence of a dilatant vacuum

Marco Fedi*
Ministero dell'Istruzione, dell'Università e della Ricerca (MIUR), Rome, Italy
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A formula to calculate vacuum's viscous force is presented as a modified, nonlinear Stokes's formula for a dilatant vacuum. From it, the anomalous deceleration of the Pioneer probes is exactly calculated and the formula of general relativity for perihelia precession is derived. When the formula is applied to planetary orbits it indicates stability over billions of years. Eventually, relativistic mass is reinterpreted as the braking action of a dilatant vacuum.

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I. INTRODUCTION

Some authors considered the possibility that the physical vacuum may actually be a superfluid, a special Bose-Einstein condensate [1–8]. Here it is demonstrated that it rather behaves as a dilatant fluid as shear stress increases. As shown below, even for non-relativistic velocities, vacuum's nonlinear apparent viscosity emerges and it is proven that this is the real cause of the anomalous precession of perihelia and of the Pioneer anomaly. The latter is currently considered solved, due to the recoil of thermal photons but without accurately knowing the thermal dynamics of the probes, assumptions and approximations have been adopted, which are now challenged by the direct and exact calculation below (Sect. III). As regards Mercury, the anomalous positive contribution to perihelion precession (one of the most significant tests for general relativity) is actually due to the interaction with a dilatant vacuum (Sect. V), since Einstein's formula is derived from the equation of vacuum's viscous force. In the calculations, Stokes's law for motion through a viscous fluid is used to obtain a modified nonlinear Stokes's law for computing friction in the physical vacuum (Sect. II). Another output of the formula, consistent with observations, concerns the stability over time of planetary orbits (Sect.IV), since the formula indicates that the braking action of dilatant vacuum nonlinearly decreases as a larger mass is taken into account, so a new arena may be defined for aerospace engineering and space exploration. On the contrary, tiny masses, as in the case of particle acceleration, are subject to a huge viscous force exerted by quantum vacuum, which is illusorily interpreted as relativistic mass increase (Sect. VI).

II. MODIFIED STOKES'S LAW FOR A DILATANT VACUUM

Stokes' formula for calculating the viscous force acting on a body traveling through a viscous fluid reads

$$F_v = -6\pi r v \eta \tag{1}$$

where v is the translational velocity, r the radius of the object (the law refers to spherical shape) and η is a coefficient of dynamic viscosity expressed in Pa · s. However, by hypothesizing that quantum vacuum behave as a dilatant fluid (non-Newtonian fluid), its apparent viscosity has to nonlinearly increase according to the applied shear stress, thus the simple coefficient of linear apparent viscosity in (1) is not appropriate. To identify the right mathematical behavior of vacuum's apparent viscosity, we have to consider the presence of an asymptote. That because dilatant fluids transiently become solid-like under shear stress, by forming a quasi-lattice within a relaxation time [9]. This phenomenon generally occurs in all fluids [10, 11], albeit in non-dilatant fluids it is less evident. In a transiently solidified medium, phonons modes emerge [10, 11] and the speed of sound can be exceeded by accelerated bodies only in two cases: a) traveling through the interstices or b) shattering the quasi-lattice. Reasonably assuming that the texture of the physical vacuum is the finest in nature (on Planck scale), case a) is excluded even for a tiny electron. When accelerated to relativistic velocities, it would face an impenetrable wall, as indeed verified in synchrotrons. Consequently, through the locally and transiently solidified vacuum (quasi-lattice condition) and due to its finest texture, only phonon propagation would be possible. Setting the speed of sound in a dilatant vacuum ($v_{s_{vac}}$), as an asymptote, the mathematical behavior of vacuum's apparent viscosity can be expressed as

$$\gamma \equiv \frac{d}{d\beta} \arcsin\beta = \frac{1}{\sqrt{1-\beta^2}} \tag{2}$$

with $\beta \equiv v/v_{s_{vac}}$. If we used the identity $v_{s_{vac}} = c$, where c is the speed of light, we could state that (2) corresponds to Lorentz factor. Now, since $v_{s_{vac}}$ cannot be lower than the speed of light (as we do not detect lower limits for particle acceleration), nor can it be higher, we conclude that (2) is Lorentz factor, which consequently expresses the mathematical behavior of shear-dependent viscosity in a dilatant vacuum. In this case, relativistic mass increase would be illusory and the limit to speed would be actually due to a dilatant vacuum. Similarly, also time dilation would be due to vacuum's apparent viscosity acting on the dynamic processes which time emerges from, also on the scale of Planck length. Finally, as it directly depends on time dilation, also Lorentz-Fitzgerald contraction would be justified in the same way. Therefore, Stokes's law, nonlinearly modified for a dilatant vacuum, assumes the fol-

* E-mail: marco.fedi@istruzione.it

lowing aspect

$$F_{v_{vac}} = -6\pi r\left(\frac{\eta}{\sqrt{1-\left(\frac{v}{c}\right)^2}}-1\right)\kappa = -6\pi r(\eta\gamma-1)\,\kappa \quad (3)$$

where $\eta = 1\ \mathrm{Kg}\cdot\mathrm{m}^{-1}\cdot\mathrm{s}^{-1}$ is a coefficient of dynamic viscosity and κ is a unitary constant expressed in m/s, since speed has been moved to Lorentz factor. Let us now demonstrate the validity of the modified Stokes's equation for a dilatant vacuum (3) in the sections below.

III. FIRST EVIDENCE: EXACT VALUE FOR THE PIONEER ANOMALY

Being the anomalous negative acceleration of the Pioneer spacecrafts 10 and 11 well-known (concrete investigations of the anomaly started in 1994 [12]), it is not necessary to summarize here this issue. In the light of the result presented below, it appears evident that this problem was not correctly solved yet, despite copious previous investigations. At the moment it is indeed generally accepted that the solution to this anomaly is due to anisotropic recoil of thermal photons [12–18]. However, by carefully analyzing these works, we see that due to the absence of an exact thermal model of the probes, especially as far as their internal heat dynamics is concerned, several numerical approximations and assumptions have been made, as for instance in [15], and that weakens the scientific solidity of the thermal explanation. On the contrary, the exact and direct solution is made available from the interaction of the Pioneer spacecrafts with a viscous quantum vacuum. This is evident by resorting to Newton's second law to express acceleration, where the force is Eq. 3 and entering the data of the Pioneer

$$\begin{aligned} a_P = -\frac{F_{vvac}}{m} &= -\frac{6\pi r\left(\frac{\eta}{\sqrt{1-\left(\frac{v}{c}\right)^2}}-1\right)\kappa}{m} \\ &= -\frac{6\pi\cdot 1.371\,\mathrm{m}\cdot\left(\frac{1\,\mathrm{kg}\cdot\mathrm{m}^{-1}\cdot\mathrm{s}^{-1}}{\sqrt{1-\left(\frac{36737\,\mathrm{m}\cdot\mathrm{s}^{-1}}{299792458\,\mathrm{m}\cdot\mathrm{s}^{-1}}\right)^2}}-1\right)\cdot 1\,\mathrm{m}\cdot\mathrm{s}^{-1}}{222\,\mathrm{kg}} \\ &= -8.74\times 10^{-10}\mathrm{m}\cdot\mathrm{s}^{-2}. \end{aligned} \quad (4)$$

As we see, the result exactly corresponds to the detected anomalous negative acceleration of the Pioneer

$$a_P = -(8.74\pm 1.33)\times 10^{-10}\ \mathrm{m}\cdot\mathrm{s}^{-2} \quad (5)$$

The data used for the calculation are: the mass of the spacecrafts (258 kg) minus the mass of the burned fuel (36 kg), the radius of the antenna, 1.371 m (antenna diameter is 9 ft) and the maximum speed of the probe (36737 m/s = 132252 Km/h [19]) after the swing-by caused by Jupiter. This exact and direct result cannot be ignored and the Pioneer issue should be therefore reopened.

IV. STABILITY OF PLANETARY ORBITS

As far as orbital stability over time despite the existence of a dilatant vacuum is concerned, by using the modified Stokes's formula (3) in Newton's second law, exactly as for the case of the Pioneer probes analyzed above, and putting in it the data of Mercury (mean radius, mean orbital velocity and mass), we see that Mercury decelerates because of vacuum's viscosity by the following negligible value

$$\begin{aligned} a = -\frac{6\pi\left(2.44\times 10^6\,\mathrm{m}\right)\left(\frac{1\,\mathrm{kg}\cdot\mathrm{m}^{-1}\cdot\mathrm{s}^{-1}}{\sqrt{1-\left(\frac{47362\,\mathrm{m}\cdot\mathrm{s}^{-1}}{c}\right)^2}}-1\right)\cdot 1\,\mathrm{m}\cdot\mathrm{s}^{-1}}{3.3\times 10^{23}\ \mathrm{Kg}} \\ = -1.74\times 10^{-24}\ \mathrm{m}\cdot\mathrm{s}^{-2} \end{aligned} \quad (6)$$

which corresponds to a decrease in mean orbital speed of $5.48\times 10^{-8}\mathrm{m}\cdot\mathrm{s}^{-1}$ over 10^9 years. That means planetary orbits are stable over billions of years despite the existence of a dilatant vacuum. On the contrary, the much smaller momentum of the Pioneer probes let them more evidently decelerate under the action of vacuum's viscosity. Indeed, orbital deceleration of more massive planets is even lower than for Mercury: for Jupiter it is only $6.59\times 10^{-28}\mathrm{m/s}^2$.

V. SECOND EVIDENCE: DERIVING EINSTEIN'S FORMULA FOR THE PRECESSION OF PERIHELIA

Net of classical gravitational contributions, perihelia precessions show an anomalous positive contribution, which is particularly evident for the planet Mercury. The correct calculation of this anomaly is one of the most solid proofs for general relativity (GR). However, here it is demonstrated that the role of curved spacetime is actually played by a flat dilatant quantum vacuum, yielding a different qualitative explanation from quantum physics, as awaited. In GR [20], the anomalous perihelia precession is represented by a formula which can be observed in three equivalent forms

$$\Delta\phi = \frac{24\pi^3 a^2}{T^2(1-e^2)c^2} = 6\pi\left(\frac{v}{c}\right)^2\frac{1}{1-e^2} = 6\pi\frac{GM}{a(1-e^2)c^2} \quad (7)$$

where $\Delta\phi$ expresses the relativistic contribution to perihelia precessions in radians per revolution corresponding, using the data of Mercury, to the known value of ∼43" per century (or 5.022×10^{-7}rad/rev.), a is the semi-major axis, T the orbital period and $e = 0.205$ orbital eccentricity. The expression in the center of (7) is obtained via the equivalence $T^2 = 4\pi^2 a^2/v^2$, as mean orbital velocity is used, and in the expression on the right we see the stable second cosmic velocity squared, $v^2 = GM/a$, where GM/a is the classical gravitational potential, putting the radius $r = a$. As for the case of the Pioneer, we resort to the modified Stokes's law for a dilatant quantum vacuum (3). In this case, the treatment of the planet as a point mass is respected, so the direct proportionality to planetary radius is not taken into account. Resorting to the

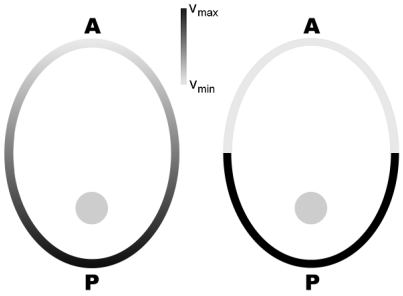

FIG. 1. Left: variable orbital velocity in the elliptic orbit (P and A are respectively perihelion and aphelion). Right: a reduced model used in the present study which considers half an orbit at max orbital velocity and the other one at minimum velocity.

nondimensionalized norm of (3) after dividing by r yields

$$6\pi\left(\frac{1}{\sqrt{1-\left(\frac{v}{c}\right)^2}}-1\right)=6\pi(\gamma-1) \tag{8}$$

which can be expressed in radians. Resorting to Taylor we proceed using the approximation

$$2(\gamma-1)\approx\left(\frac{v}{c}\right)^2 \tag{9}$$

and (8) now reads

$$3\pi\left(\frac{v}{c}\right)^2=3\pi\frac{GM}{ac^2} \tag{10}$$

where, on the right, the planet's velocity is written as stable second cosmic velocity squared, as in the rightmost expression in (7). As we refer to motion in elliptic orbit, we have to use the elliptic parameter, correcting a into $a(1-e^2)$ and we obtain a formula which exactly gives 1/2 the result of GR (7)

$$\Delta\phi=3\pi\frac{GM}{a(1-e^2)c^2}=3\pi\left(\frac{v}{c}\right)^2\frac{1}{1-e^2} \tag{11}$$

This result would be wrong (-50%) if we considered v as the mean orbital velocity. Actually, the real situation is represented in Fig.1 on the left, with variable orbital velocity. Since mean orbital velocity is $v=(v_{max}/2)+(v_{min}/2)$, we are allowed to use the reduced model on the right side of Fig.1. For describing the precession occurring in a semi-orbit, Eq.(11) is now correct. Then we use it twice (respectively with v_{max} and v_{min}) to express the precession during a full orbit and that yields the full result of GR (7)

$$\begin{aligned}\Delta\phi&=3\pi\left(\tfrac{v_{min}}{c}\right)^2\tfrac{1}{1-e^2}+3\pi\left(\tfrac{v_{max}}{c}\right)^2\tfrac{1}{1-e^2}\\&=6\pi\left(\tfrac{v}{c}\right)^2\tfrac{1}{1-e^2}=\tfrac{24\pi a}{T^2(1-e^2)c^2}\end{aligned}$$

where v_{max} and v_{min} combine into mean orbital velocity. In this way it is demonstrated that perihelia precession actually occurs via the interaction with a dilatant vacuum, of which Einstein's curved spacetime is just a mathematical representation. After all, this is in agreement with the stress-energy tensor of the field equation, in which T^{00} is vacuum's density (ρ_{vac}), also present in the cosmological constant $\Lambda=\kappa\rho_{vac}$, and the remaining components can be as well hydrodynamically interpreted, being pressure, shear stress, momentum flux and momentum density.

VI. PARTICLE ACCELERATION IN A DILATANT VACUUM

Taking into account a dilatant vacuum whose apparent viscosity obeys Lorentz factor (Sect. II), it is obvious that particles which are accelerated toward the speed of light are subject to a nonlinearly increasing viscous force (3), currently interpreted as relativistic mass increase, which would therefore be an illusory effect. No increase of inertia then, actually an increasing opposite force caused by a dilatant quantum vacuum, as shown in Fig. 2, in which we see that as a particle approaches the speed of light,

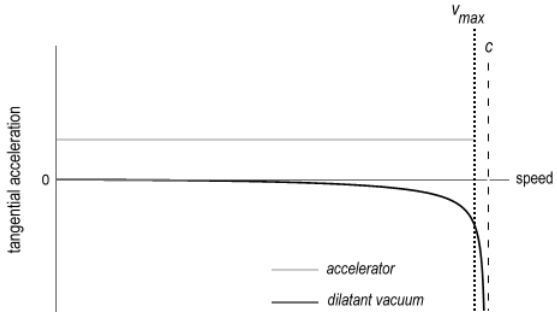

FIG. 2. Total tangential acceleration is zero when particles reach their maximum speed (v_{max}) in an accelerator, due a dilatant vacuum.

vacuum nonlinearly reacts by decelerating it, $a_{T_{vacuum}}=-F_v/m$, thus when total tangential acceleration is zero (dotted line in Fig. 2), the particle reaches its maximum speed (v_{max}) for a given accelerator

$$v_{max}\Rightarrow a_{T_{tot}}=a_T-a_{T_{vacuum}}=0 \tag{12}$$

The more powerful the accelerator the closer to the speed of light the dotted line (v_{max}). As we see by putting (3) in the second law of motion, the tiny mass of a proton exposes the particle to a huge deceleration, in contrast to the case of planetary orbits (IV). This leads to the considerations below.

VII. NEW PROSPECTS IN AEROSPACE ENGINEERING

Since in $a=-F_{v_{vac}}/m$ the braking action due to dilatant vacuum nonlinearly decreases as the value of mass increases in the equation, the case of heavier accelerated objects is different from what we observe in synchrotrons, a fact which aerospace engineering and space research are currently unaware of. For instance, a hypothetical spherical spacecraft with the same mass of the International Space Station (ISS) and radius 6 m (i.e. of a sphere whose volume is equal

to pressurised volume in the ISS) traveling at 0.9999991 c, that is at the maximum speed a proton achieves in the LHC, would undergo a negative acceleration due to dilatant vacuum of just -0.2 m/s^2, which even reduces to only -0.002 m/s^2 by increasing 100 times the mass of the spacecraft. In short what we currently and erroneously call relativistic mass increase would not be a problem for large masses accelerated up to almost the speed of light. Space exploration at quasi-luminal speed using large spacecrafts would therefore not be a problem, if not for different reasons such as those concerning propulsion etc. Another aspect of what we might call vacuum-applied aerodynamics emerging from (3) is that the smaller the section of the accelerated body perpendicular to the direction of motion, the weaker vacuum's viscous force. Cylindrical shape would be advantageous and transportation of large amounts of fuel would not be a problem. On the contrary, that would actually help to increase mass, reducing the braking action of quantum vacuum. Progressive in-orbit assembly of large-mass spacecrafts with very capacious tanks may therefore be the future correct strategy for space exploration.

VIII. CONCLUSION

Hypothesizing a dilatant vacuum implies an asymptote for speed (Sect. II). We know the one at the speed of light. Since no lower limit has been detected in nature and since no higher limit may exist, (2) was equated to Lorentz factor to obtain a modified Stoke's law (3) which successfully solves the Pioneer anomaly, Mercury perihelion precession, stability of planetary orbits despite a dilatant vacuum and reveals that relativistic mass increase is an illusion in lieu of a nonlinear viscous force exerted by a dilatant vacuum. The case of Mercury perihelion (Sect. V) indicates that Einstein's curved spacetime rather corresponds to a dilatant quantum vacuum, whose existence is in this way proven, and that therefore appears as the right direction for merging relativity with quantum physics, overcoming pure differential geometry, which after a century remains unsuccessful in reaching this goal. Finally, as far as the acceleration in free space of large-mass bodies (compared to particles) is concerned, the modified Stokes's formula yields negligible values of vacuum friction up to about the speed of light, opening interesting scenarios for aerospace engineering and space exploration. In conclusion, a new approach based on a dilatant vacuum seems to be useful in various fields of modern physics and therefore deserves further efforts and investigations.

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