Solved anomalies prove a shear-thickening vacuum

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Abstract

By reinterpreting the Lorentz factor as the rheogram of the physical vacuum and using it in Stokes's law to measure the viscous force exerted by the vacuum, Mercury's perihelion precession and the Pioneer anomaly are directly and exactly solved, demonstrating that the physical vacuum is a shear-thickening fluid. The modified Stokes's equation also correctly indicates that planetary orbits are stable over trillions of years. Furthermore, relativistic kinetic energy is revealed as the necessary energy to oppose a shear-thickening vacuum. This unexpected feature of physical vacuum implies interesting consequences for various fields of modern physics.

Introduction

Some authors considered the possibility that the physical vacuum may be a superfluid, a special Bose-Einstein condensate (*1–8*). Here, by exactly solving two known anomalies, along with other correct results, it is demonstrated that the physical vacuum rather behaves as a dilatant fluid, as shear stress increases. Sect. 1 introduces a modified Stokes's formula for motion in a shear-thickening vacuum. In Sect. 2, by applying this formula, the Pioneer anomaly, the orbital stability of the planets and Mercury's perihelion precession are correctly calculated. The Pioneer anomaly is currently considered solved after thermal simulations, whose results, approximate and based on various assumptions and scenarios (*9, 10, 16*), are now challenged by the simpler, direct and precise result presented in Sect. 2.1, which *exactly corresponds to the acceleration of* $-8.74 \times 10^{-10}\mathrm{m} \cdot \mathrm{s}^{-2}$ *measured by the NASA*. The modified Stokes's formula, put into Newton's second law of motion, says that due to the large masses of planets (unlike the case of the Pioneer probes), planetary orbits are stable over billions of years, averting what would be otherwise a major objection to the existence of a shear-thickening vacuum, i.e. its effect on orbital stability. Sect. 2.3 shows that vacuum's apparent (shear-dependent) viscosity emerges as the real cause of the anomalous precession of perihelia, suggesting that the quantum foundations of relativity are situated in a fluid, shear-thickening quantum vacuum. In fact, it is shown that Einstein's formula for the precession of perihelia is directly derived from the modified Stokes's formula. In Sect. 3, we see that the relativistic formula for kinetic energy corresponds to particle rest energy multiplied by the term of vacuum dilatancy. Relativistic mass is therefore reinterpreted as the work necessary to oppose the shear-thickening vacuum, which becomes solid-like as a body approaches the speed of light. Also time dilation and the Lorentz-Fitzgerald contraction are shown to depend on vacuum dilatancy, as they depend on the Lorentz factor, which the solved anomalies in Sect. 2 demonstrate to be the rheogram of a shear-thickening vacuum.

1 Methods: modified Stokes's law for a dilatant vacuum

Stokes' law, derived in 1851, to calculate the viscous force acting on a body traveling through a viscous, Newtonian fluid (*11*) 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 $\mathrm{Pa} \cdot \mathrm{s}$. However, for a shear-thickening vacuum, the viscosity coefficient η, in Eq. (1), is not appropriate, since it is valid only for Newtonian fluids. To express a dilatant vacuum, we need a nonlinear law. In the present investigation it is demonstrated (Sect. 2) that the correct mathematical behavior of shear stress for the physical vacuum is expressed by the Lorentz factor, therefore reinterpreted as vacuum's rheogram, in which the asymptote at the speed of light consequently refers to a transient solid-like condition of the vacuum, which occurs by approaching a certain level of shear stress. Let us then replace η with the Lorentz factor in the form $\gamma - 1$. We arrive to a modified Stokes's equation (MSE)

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

where κ is a unitary constant expressed in $\mathrm{Kg} \cdot \mathrm{s}^{-2}$. Let us also define

$$D = \gamma - 1 \tag{3}$$

as the dimensionless term of vacuum dilatancy. The formula is therefore simply written as $F_{vac} = -6\pi r D\kappa$. If we use this formula for bodies traveling in a vacuum, such as probes or planets, the viscous force it refers to is of course that of the physical vacuum, so Eq. (2) is the formula for the viscous force exerted by a dilatant vacuum and its applications and validity are presented in the following sections, by precisely solving two known anomalies and by obtaining other correct results, such as the stability of planetary orbits.

2 Results: shear-thickening vacuum proven

2.1 Exact value for the Pioneer acceleration

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 exact result presented below, it appears evident that this problem has not been correctly solved yet, despite copious investigations, based on thermal simulations (*9, 10, 12–16*), which gave approximate results based on several assumptions and different scenarios. In 2012 (*9*) a value of $-7.4(\pm 2.5) \times 10^{-10} \mathrm{m} \cdot \mathrm{s}^{-2}$ was proposed. On the contrary, the exact solution (without models and assumptions) is directly produced by Eq. (2), that is, via the interaction of the Pioneer probes with a shear-thickening vacuum. Let us put Eq. (2) in Newton's second law, using the known data of the Pioneer probes and *we directly obtain the exact negative acceleration of the Pioneer (a_P) detected by the NASA*

$$a_P = \frac{F_{vac}}{m_P} = -\frac{6\pi r_P\left(\frac{1}{\sqrt{1-\left(\frac{v_{max}}{c}\right)^2}}-1\right)\kappa}{m_P} =$$
$$-\frac{6\pi\cdot 1.371\,\mathrm{m}\cdot\left(\frac{1}{\sqrt{1-\left(\frac{36737\,\mathrm{m\cdot s^{-1}}}{299792458\,\mathrm{m\cdot s^{-1}}}\right)^2}}-1\right)\cdot 1\,\mathrm{kg\cdot s^{-2}}}{222\,\mathrm{kg}} = \tag{4}$$
$$-8.74\times 10^{-10}\mathrm{m\cdot s^{-2}}.$$

where $m_P = 222\,\mathrm{kg}$ is the mass of the spacecrafts (258 kg) minus that of the burned fuel (36 kg hydrazine) after the Jupiter flyby; $r_P = 1.371\,\mathrm{m}$ is the radius of the antenna (diameter is 9 ft) and $v_{max} = 36737\,\mathrm{m/s}$ is the maximum speed of the probe, as indicated by the NASA's Scientific and Technical Information Office (*17*) after the swing-by caused by Jupiter. This exact and direct result cannot be ignored and the Pioneer issue has to be reopened. Moreover, the NASA should now consider to Doppler track other probes. Unfortunately this was not the case of the New Horizons spacecraft, for which data are missing. Testing other probes (maybe a dedicated probe) with Eq.(2) is definitely recommended.

2.2 Second test: Stability of planetary orbits

The existence of a shear-thickening vacuum lets immediately arise an objection as regards orbital stability. However, considering the second law of motion in the form $a = F/m$ and putting the large mass of a planet in the denominator and the MSE in the numerator, we see that, despite the existence of a dilatant vacuum, planetary orbits are stable over trillions of years. For instance, the deceleration of the Earth ($a_{\oplus}$) corresponds to the following negligible value

$$a_{\oplus} = \frac{F_{vac}}{m_{\oplus}} = -\frac{6\pi(6371000\,\mathrm{m})\left(\frac{1}{\sqrt{1-\left(\frac{29780\,\mathrm{m/s}}{299792458\,\mathrm{m/s}}\right)^2}}-1\right)\cdot 1\,\mathrm{kg/s^2}}{5.97\times 10^{24}\,\mathrm{kg}} = -9.92\times 10^{-26}\mathrm{m}\cdot\mathrm{s}^{-2} \tag{5}$$

using the mean radius and the mean orbital velocity of the Earth in the MSE and the mass of the Earth in the denominator. Subscript $\oplus$ refers to the Earth. Such a negative acceleration corresponds to a decrease in orbital speed $< -3.13\times 10^{-9}\,\mathrm{m/s}$ per billion years, making orbits stable for thousands billions years. For Jupiter, orbital deceleration is $-6.59\times 10^{-28}\mathrm{m/s^2}$. One therefore concludes that planetary orbits are stable despite the presence of a shear-thickening vacuum.

2.3 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 classical tests for general relativity (GR). Here Einstein's formula for the precession of perihelia is differently derived via the MSE presented above. In this way, it is demonstrated that the long-awaited quantum foundations of general relativity are situated in a shear-thickening quantum vacuum. In GR (*18*), the anomalous perihelia precession is represented by a formula which can be observed in three equivalent forms

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

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 42.98” per century (or 5.0186×10^{-7}rad/rev.), $a = r$ is the semi-major axis, T the orbital period and $e = 0.205$ the orbital eccentricity. The expression in the center of Eq. (6) is obtained via the equivalence $T^2 = 4\pi^2 a^2/v^2$, resorting to mean orbital velocity, and in the expression on the right the stable second cosmic velocity, $v = \sqrt{GM/r}$, is used. As for the case of the Pioneer, the MSE for a dilatant vacuum is used below. In this case, the treatment of the planet as a point mass is respected, as in general relativity, so the direct proportionality to planetary radius is not taken into account. By resorting to the nondimensionalized norm of the MSE one obtains

$$6\pi \left(\frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} - 1 \right) = 6\pi \left(\gamma - 1\right) \tag{7}$$

which can be expressed in radians. Resorting to Taylor, let us proceed via the approximation

$$2\left(\gamma - 1\right) \approx \left(\frac{v}{c}\right)^2 \tag{8}$$

and Eq. (7) now reads

$$3\pi \left(\frac{v}{c}\right)^2 = 3\pi \frac{GM}{ac^2} \tag{9}$$

where, on the right, we see again the stable second cosmic velocity (here squared), as in the rightmost expression in Eq. (6). Since we are considering an 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 (6)

$$\Delta\phi = 3\pi \frac{GM}{a(1 - e^2)c^2} = 3\pi \left(\frac{v}{c}\right)^2 \frac{1}{1 - e^2} \tag{10}$$

This $1/2$ result can be considered as the precession *occurring in a semi-orbit* and is due to the use of mean orbital velocity. Indeed, in the elliptic orbit, orbital speed actually varies as in Fig. 1 on the left side. Since the mean orbital velocity is given as $(v_{max}/2) + (v_{min}/2)$, let us adopt the reduced model on the right side of Fig. 1, i.e. one semi-orbit at maximum orbital speed and one at minimum speed. The full precession (6) is therefore given by

$$\Delta\phi = 3\pi \left(\frac{v_{max}}{c}\right)^2 \frac{1}{1 - e^2} + 3\pi \left(\frac{v_{min}}{c}\right)^2 \frac{1}{1 - e^2} = 6\pi \left(\frac{v}{c}\right)^2 \frac{1}{1 - e^2} = \frac{24\pi^3 a^2}{T^2(1 - e^2)c^2} \tag{11}$$

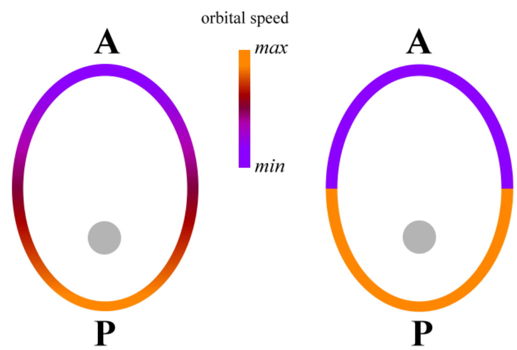

Figure 1: Left: variable orbital velocity in the elliptic orbit (P and A refer to perihelion and aphelion, respectively). Right: the reduced model used in the present study which considers half an orbit at maximum orbital velocity and the other one at minimum velocity.

where v_{max} and v_{min}, each referring to a semiorbit, recombine in the mean orbital velocity v and the rightmost equivalence comes from Eq. (6). Now, by merging the steps above in a single formula, we can look at the relationship between the MSE, which expresses the viscous force in a dilatant vacuum, and the contribution to the precession of perihelia. The formula reads

$$\Delta\phi \equiv \left\| \frac{2F_{vac}}{\kappa r(1-e^2)} \right\| = 12\pi \frac{D}{(1-e^2)} \tag{12}$$

where D is the term of vacuum dilatancy of the MSE. By testing Eq.(12) with the parameters of the planet Mercury, we see that *it exactly gives the well-known value of general relativity*

$$\Delta\phi = 12\pi \frac{D}{(1-e^2)} = 12\pi \frac{\left(\frac{1}{\sqrt{1-\left(\frac{GM}{ac^2}\right)}} - 1 \right)}{(1-e^2)} = \tag{13}$$

$$12\pi \frac{\left(\frac{1}{\sqrt{1-\frac{(6.67408\times10^{-11}\,\mathrm{m}^3\cdot\mathrm{kg}^{-1}\cdot\mathrm{s}^{-2})(1.98847\times10^{30}\mathrm{kg})}{(5.7909\times10^{10}\,\mathrm{m})(299792458\,\mathrm{m}\cdot\mathrm{s}^{-1})^2}}} - 1 \right)}{1-0.20563^2} =$$

$$5.018649 \times 10^{-7}\mathrm{rad/rev.} \Rightarrow 42.98''/\mathrm{century}$$

where, in D, $v = \sqrt{GM/a}$ is used, as in Eq. (6). Einstein's equation for the precession of perihelia has been in this way directly derived from the MSE and the positive contribution to the precession of perihelia treated in general relativity turns out to be a phenomenon actually driven by a shear-thickening vacuum, not by a purely mathematical, deformable space-time. After the present investigation, perihelion precession due to the interaction with a quantum fluid has been simulated and confirmed also by Marcucci and Conti (*19*). We see that nothing in the present study contradicts general relativity: this investigation, by rederiving Einstein's formula for perihelia precession, only highlights that the quantum foundations of relativity are in a dilatant quantum vacuum and that Einstein's formula can be rewritten by revealing the role of the shear-thickening vacuum (12). After all, this is compatible with the stress-energy tensor of the field equation, in which T^{00} is vacuum's energy/mass density (ρ_{vac}), also present in the cosmological constant $\Lambda = \kappa\rho_{vac}$, and the remaining components of the tensor can be as well hydrodynamically interpreted, being pressure, shear stress, momentum flux and momentum density.

3 Particle acceleration in a shear-thickening vacuum: revisiting relativistic mass

Since the three exact solutions discussed above indicate the existence of a shear-thickening vacuum, it becomes clear that, if bodies traveling in a vacuum undergo a nonlinear negative acceleration due to the viscous force exerted by the dilatant vacuum, relativistic mass increase should be reinterpreted as actually the braking action of the vacuum, i.e. something that occurs in the vacuum, leaving particle mass actually unaffected. This agrees with Taylor and Wheeler (*20*), who state that the increase of energy originates not in the accelerated object but in the geometric properties of space-time itself. More precisely, let us say now in the hydrodynamic properties of the physical vacuum, which is fluid and dilatant. In general relativity, the kinetic energy of an accelerated particle is given by

$$E_k = -mg_{tt}u^t u^t_{obs} - mc^2 = mc^2\sqrt{\frac{g_{tt}}{g_{tt} + g_{ss}v^2}} - mc^2 \tag{14}$$

factoring out the rest energy

$$E_k = mc^2 \sqrt{\frac{g_{tt}}{g_{tt} + g_{ss} v^2}} - 1. \tag{15}$$

According to the present investigation, and especially as regards the case of Mercury's perihelion, curved space-time is actually the mathematical expression of the hydrodynamics of a fluid, dilatant vacuum and space is flat. Under this condition, we can substitute $g_{tt} = -c^2$ and $g_{ss} = 1$ and after some simple algebra Eq. (15) familiarly reads

$$E_k = mc^2 \left(\frac{1}{\sqrt{1 - \left(\frac{v}{c}\right)^2}} - 1 \right), \tag{16}$$

that is, particle rest energy, mc^2, multiplied by the term of vacuum dilatancy D (3). We are therefore actually observing the energy corresponding to the work done by the synchrotron on the accelerated particle to oppose vacuum dilatancy,

$$W = E_0 D, \tag{17}$$

where $E_0 = mc^2$ is rest energy (with m rest mass). As accelerated bodies approach the speed of light, the work to be done becomes infinite, since the vacuum becomes solid-like. Further solidification is not possible, so we observe an asymptote. In this way, relativistic kinetic energy is revealed as the necessary energy to oppose vacuum dilatancy. This issue is however treated in detail in (*22*).

In addition to relativistic mass and to quickly complete the list of relativistic phenomena in the light of a shear-thickening vacuum, it is interesting to reflect that also time dilation is due to vacuum dilation. Indeed, it depends on the Lorentz factor, which is proven to be the rheogram of the physical vacuum, via the exact results of the MSE. Basically, in the framework of Newton's third law, traveling clocks are slowed down by the increased shear stress (measured as pressure) applied to physical vacuum, with respect to another observer who is not subject to the apparent flow, or is subject to a weaker apparent flow. Now, as regards gravitational time dilation, we know it is linked to time dilation in a flat space-time (following Einstein's relativity) via the second cosmic velocity. In fact,

$$\Delta t' = \frac{\Delta t}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{\Delta t}{\sqrt{1 - \frac{R_S}{r}}} \tag{18}$$

hence $\frac{v^2}{c^2} = \frac{R_S}{r} \Rightarrow v^2 = \frac{2GM}{r}$, that is $v = \sqrt{2V}$, where V is the classical gravitational potential. The action of gravity is equated to that of speed. Due to the presence of radius in the velocity $\sqrt{2V}$, a velocity field is implied. In short, a body is subject to an apparent flow by traveling through the dilatant vacuum and to a real flow due to the gravitational field, whose physical nature becomes in this way clear, beyond pure differential geometry, as an incoming flow of fluid vacuum, according to the flux described in Gauss's law for gravity, $F_g = \oint_S \mathbf{g} \cdot \mathbf{n}(\mathbf{r}) dS$ (equivalent to Newton's law of universal gravitation). In this case the flow is however *real*, as hypothesized also by Cahill (*21*), who considers a quantum foam inflow into any mass. *Time dilation is therefore due to vacuum dilation*, according to vacuum's rheogram (Lorentz factor). To complete the picture of relativistic effects in special relativity, one can now declare that the Lorentz-Fitzgerald contraction depends on vacuum dilatancy too, as it directly depends on time dilation, without the need for further demonstrations. Every relativistic effect, in which Lorentz factor is at stake, is directly reinterpretable as due to vacuum dilatancy.

Conclusion

Einstein's relativity is classical physics plus the action of a shear-thickening vacuum, whose hydrodynamic behavior has been sofar interpreted via the differential geometry of a deformable space-time. The modification of Stokes's law, obtained by inserting into it the Lorentz factor (in the form $\gamma - 1$), reinterpreted as the rheogram of a fluid, shear-thickening vacuum, has produced a new formula expressing the viscous force exerted by physical vacuum. This formula has been confirmed valid by solving two well-known anomalies, the relativistic contribution to perihelia precession and the Pioneer anomaly, for which a direct and exact result has been obtained, to be therefore preferred to the more approximate and more complicate solutions sofar presented. Deriving Einstein's formula for the precession of perihelia from the viscous force of the vacuum, along with the presence of the vacuum dilatancy factor in the relativistic formula for kinetic energy and the dependence of time dilation and length contraction on vacuum's rheogram, clearly indicate that the quantum foundations of relativity are rooted in the existence of a shear-thickening quantum vacuum. We can conclude by reflecting that this fluid, dilatant vacuum likely corresponds to the dark sector, i.e. to 95% of the universe's mass-energy, in which diffused dark matter particles (a granular component) could play the role of a dopant in a sea of superfluid dark energy, determining vacuum dilatancy. For sure, the shear-thickening aspect of the physical vacuum now helps us to better understand its nature, along perhaps with that of dark energy and dark matter.

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