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Inconsistency of General Relativity Predictions for the Universe Expansion vs. the Black Hole Model

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Abstract

A consistency argument proves that the General Relativity predictions of a time power law decelerated Universe expansion in the matter dominated era to be untenable by more than an order of magnitude. This questions the usual matter conservation law and supports the black hole approach which predicts continuous matter creation for the expanding black hole we are living in. The role of homogeneity in the equations for gravity and its consequences in this respect are discussed. Further arguments in favour of the black hole model are presented.

Keywords

Cosmology, General Relativity, Black Hole

1. Introduction

The Universe time evolution seems to be common both to the classical Newtonian picture and its relativistic General Relativity (GR) [1] extension. Indeed a decelerated Universe expansion is predicted in both schemes. However a consistency argument seems to disprove this picture. We show that an alternative theoretical model, the black hole (b.h.) one [2] [3] [4], claims to account successfully for data.

2. Cosmic Microwave Background and Time Reconstruction

Let us consider the predictions of the two approaches describing a different Universe time evolution: the GR and b.h. one. The cosmological redshift is described by the redshift parameter z

$$\frac{\lambda_r}{\lambda_e} = \frac{\chi_r(t)}{\chi_e(t)} = 1 + z \quad (1)$$

(where χ stands for the scale factor, usually denoted by *R*, the subscript *e* for emission and *r* for reception). As well known bigger *z*'s from different objects tell us that light was emitted at earlier times and that the Universe size was smaller by the corresponding factor. Now if $z = \left(\frac{t_0}{t'}\right)^{3/2}$ (decelerated GR) (where the suffix 0 stands for the present time and where the prime stands for a generic instant in the matter dominated era, which will be specialised to the cosmic microwave (CMB) time) or $z = t_0/t'$ (steady black hole), the time corresponding to a given *z* will be different. The difference of the two approaches can be easily understood. In the decelerating case the time at which a phenomenon occurs is of course bigger than in steady state case. We want to show that we can discriminate between them due to the *z* dependence of the Hubble parameter and of the Hubble radius. Of particular relevance is the consideration of the CMB which we receive as the black body spectrum of the 3 K radiation. It originated at last scattering time (where last scattering (l.s) and decoupling (dec) are such that $z_{l.s} \simeq z_{dec} \simeq 1100 = z_{CMB}$ so that the last scattering surface is more of a last scattering layer (see e.g. the related pictures in [5] [6]). Thus in the following use of the (very good) approximation

$$1 + z \simeq z \simeq 1100$$

will be made.

Therefore the scale factor essentially determines the ratio of the Universe dimensions at the present time to those at that time. One can therefore assume that this yields the corresponding Hubble radius in terms of the present one.

Let us now proceed to the backward reconstruction of matter age according to GR. Our argument is very simple: we first determine the Hubble time dependence in terms of the matter content, we relate it to the Hubble radius and we evaluate it in two alternative ways. The relevant piece of information is the connection between Hubble parameter and density, according to GR

$$\frac{H'^2}{H_0^2} = \frac{\rho'}{\rho_0} \simeq z^3 \quad (2)$$

whence

$$\frac{H'}{H_0} \simeq z^{3/2} \quad (3)$$

(see e.g. Ryden [6] and Maoz [7]) where ρ stands for the matter density and the apex ʼ for a generic z and time which will then be specialised to those of CMB.

The cosmological term has not been considered for the reasons which will be given in next paragraph.

However evaluation of the Hubble radius, the size of the causally connected part of the Universe simply denoted by R, yields a contradictory result.

Of course the connection between the Hubble radius and the scale factor χ

is not so straightforward although it is absolutely reasonable, and naturally obtains in the present approach (see later paragraphs).

From its very definition, at the CMB time

$$R_{CMB} = \frac{c}{H_{CMB}} \simeq \frac{c}{H_0 z^{3/2}} = \frac{R_0}{z^{3/2}} \tag{4}$$

where in the last step use has been made of the expression for the Hubble radius at the present time ($\frac{c}{H_0} = R_0$). This confirms the naive and direct considerations based on the explicit form of t at the Hubble time. However from the scale conditions one has

$$R_{CMB} \simeq \frac{R_0}{z} \tag{5}$$

Trivially the two equivalent ways should yield the same result which is not the case for the given form of the matter density.

Just this argument contradicts GR predictions and the assumption of matter conservation [8]. Apart from that it confirms more directly (than the consideration of inertial forces and the self energy argument) the b.h. approach where

$$\frac{H'}{H_0} \simeq z \tag{6}$$

valid for any z (and of course for z_{CMB}).

We reach therefore the remarkable conclusion that the very use of the Hubble radius at two different times together with the definition of z essentially disproves the decelerated Universe expansion predicted by GR and supports the matter creation scheme (*next paragraph*). One might rightly wonder why the standard model has nevertheless survived. In that respect let us quote Perlmutter [9] (one is tempted to speculate that these ingredients are add-ons like the Ptolemaic epicycles, to preserve an incomplete theory). As a matter of fact one may counter the preceding argument by introducing the percentage of the baryonic component which should anyhow depend again on time to cure this time dependent contradiction, or invoke the notorious cosmological term. And the comments by Fermi [10] in another context also apply. The previous result not only supports the proposed scheme of the Universe evolution but also seems to make less puzzling the results of the traditional approach: the presumed accelerated supernovae distancing (evaluated in terms of the comoving distance [11] in the same scheme) in a decelerated expansion.

Similar considerations apply of course also to the radiation dominated regime.

3. Homogeneity

We now consider the energy Friedman equation [12] where the scale factor is again denoted by χ .

Let us recall that the common starting point is the consideration of a spherical ball of given matter density and a mass m at its surface. Its motion is determined only by the matter inside. It is worth stressing that *the dimensions of the ball disappear*. Indeed $v^2 \simeq H^2 r^2 \simeq G\rho r^2$. Or in other words, since H^2 has dimensions t^{-2}, ρ' can only be time dependent. Hence no constant is allowed in such a homogeneous equation. Therefore both in GR and in the alternative black hole scheme the velocity v obeys the usual energy conservation equation which can be written in terms of the Hubble-Lemaitre parameter

$$H = \frac{\dot{\chi}}{\chi} \tag{7}$$

as

$$H^2 - G\tilde{\rho} = 0 \tag{8}$$

where $\tilde{\rho}$ stands for the usual $(4\pi/3)\rho$. Between the GR and the b.h. approach there is a factor of 2 difference which is fundamental in the interpretation but irrelevant to our purposes.

Notice that homogeneity comes not as a request but just from a judicious consideration of the equation. In that respect, it seems contradictory to postulate it afterwards on a non-homogeneous equation (with a cosmological term). **Therefore the potential, unlike in the Newtonian case, is not a state function and the time derivative of the mass (density) appears in the acceleration equation**.

Indeed in the Newtonian case, *the density is of course time independent whereas in cosmology it is not* (*as a state of evidence*). **Thus in principle the treatment of the discrete solar system case cannot be taken over directly to cosmology in spite of a formal similarity**.

Nevertheless a time dependent matter density does not necessarily imply a time dependent mass. Without loss of generality, we specialise again to the matter dominated regime. The standard expression of the matter density corresponds to mass conservation. Indeed

$$\mathrm{d}M/\mathrm{d}t = 0 \simeq \mathrm{d}/\mathrm{d}t\left(\chi^3 \rho(t)\right) = 3\chi^2\,\mathrm{d}\chi/\mathrm{d}t\,\rho + \chi^3\,\mathrm{d}\rho/\mathrm{d}t \tag{9}$$

implies in turn the well known result for the time dependent density

$$\mathrm{d}\rho/\rho = -3\,\mathrm{d}\chi/\chi \tag{10}$$

In that case, the time derivative yields the familiar

$$\mathrm{d}/\mathrm{d}t\,(GM/\chi) = -GM/\chi^2 \tag{11}$$

and the dimensionally correct $\rho \simeq 1/t^2$.

In fact, if one imposes in Equation (8)

$$(\dot{\chi}\chi)^2 \simeq 1/\chi^3 \tag{12}$$

one obtains the desired result

$$\chi \simeq t^{2/3} \tag{13}$$

and obviously

$$\rho \simeq 1/t^2$$

However with a different $\rho(t)$ the time derivative of the mass necessarily follows thus modifying the Newtonian (and GR) formulation with the unavoidable appearance of an additional term in the acceleration equation.

This is the case if

$$\mathrm{d}\rho/\rho = -2\,\mathrm{d}\chi/\chi \tag{14}$$

embodying the linear relation between radius and mass

$$\mathrm{d}M/M = \mathrm{d}\chi/\chi \tag{15}$$

of the zero total energy of the black hole we are living in (motivated also by the consideration of inertial forces and solving at the same time the causality problem without the necessity of invoking artificial inflation), then

$$\chi \simeq t$$

The same behaviour of the density $\rho \simeq 1/t^2$ is again obtained, but this time the derivative of the mass necessarily follows and

$$a = 0 \tag{16}$$

because of the negative contribution of the $\mathrm{d}M$ term

$$a = -\frac{GM}{\chi^2} + \frac{G\mathrm{d}M}{\chi \mathrm{d}\chi} = 0 \tag{17}$$

This can also be immediately realised by considering that in this case

$$\left(\dot{\chi}/\chi\right)^2 \simeq 1/\chi^2 \tag{18}$$

and hence no acceleration follows since the velocity $v_\chi = \dot{\chi}$ is constant unlike in the GR case where $v_\chi \simeq 1/\chi^{1/2}$.

As already stressed in [3] [4] the same density in the two approaches does not imply they are equivalent and finer details can indeed discriminate between them, as it is here the case.

Of course one might wonder why two totally different schemes yield the same time dependence of the density. This is due first of all to the fact that the dimensions of ρ are essentially $1/t^2$, different approaches differing only on coefficients and this can be understood qualitatively because during an expansion the density must necessarily decrease irrespective of whether the expansion is decelerated or steady.

In conclusion the homogeneity condition can be alternatively obeyed both for $\rho \simeq 1/\chi(t)^2$ and the traditional GR $\rho \simeq 1/\chi(t)^3$ but of course with different $\chi(t)$, the b.h. one forecasting the correct time expansion considered in the previous paragraph. This theoretical framework also predicts a different comoving distance which disposes of the presumed supernovae acceleration.

The proposed form automatically guarantees at the same time constant velocity (which cannot be but *c*) and that the counterterm in the acceleration equation, accounting for the unfamiliar matter creation, exactly compensates the usual Newtonian term.

4. Cosmic Microwave Background and Before: Endorsement for the Black Hole Model

Our present understanding of the Universe evolution rests on two solid experimental pieces of evidence: Lemaitre-Hubble's law and the CMB. On the contrary the theoretical situation is debatable.

We are going here to summarise and expose in a simplified way the results of refs. [2] [3] [4]. In particular, it will be shown how a critical consideration of CMB data can be used as a guidance and a justification for the present theoretical treatment at variance with the commonly accepted one. The fundamental point is that we should be guided by the experimental evidence apart from our theoretical prejudices.

The most relevant (and probably unexpected) piece of information coming from the CMB is its homogeneity. Its reproduction of the Planck spectrum is astonishing.

1) How can we reproduce the CMB homogeneity?

Simply by assuming and accepting that the density be given by

$$\tilde{\rho} = \frac{(KT)^4}{c^2} \tag{19}$$

which is manifestly homogeneous.

2) matter non-conservation

The argument of the previous paragraph can be reproduced in a simpler way. Comparison of the Hubble radius in terms of its matter content and of its expression with reference to the cosmological redshifts implies matter non-conservation.

The very definition of the cosmological redshift in terms of the Universe dimensions (radius) at the CMB

$$z = \frac{\chi_0}{\chi_{CMB}}$$

implying a linear relation between the dimensions of the Universe and z (the suffix 0 standing for present quantities) also entail that $c/\chi = H$ at given instant must be in the same proportion *i.e.*

$$\frac{\chi_{CMB}}{\chi_0} \simeq \frac{H_0}{H_{CMB}}$$

Thus a linear dependence of *H*, contradicting the usual time power law predictions. This justifies the assumption of b.h. condition

$$1 = \frac{GM}{c^2 R}$$

which backs up matter creation from M_P at R_P to the present M_U at R_U and which reads for pre-CMB times

$$1 = G\frac{(KT)^4 R^2}{c^4} \tag{20}$$

The two previous equivalent expressions imply a decreasing matter for decreasing radii and in turn an increasing temperature, but "photon" number $N_\gamma = (KT)^3 R^3$ decreases for decreasing radii and the total "photonic" energy

$(KT)^4 R^3$ also decreases as is the case for matter. This can be easily understood since the b.h. condition implies

$$T^2 \simeq 1/R$$

This formulation is clearly relativistic and implicitly contains the repulsive role of pressure which is widely used in the treatment of star formation in contradiction to GR.

3) Same homogeneity in the past?

If we accept the black body spectrum

$$\tilde{\rho} = \frac{(KT')^4}{c^2} \tag{21}$$

where T' represents a generic pre-CMB temperature the fact that different (as a function of T) black body spectra were present in the past renders the CMB homogeneity not a surprise but a logical consequence of the past history. This position is a reasonable one since with increasing energy baryon masses were irrelevant and the original plasma was like a photonic one. Gravitation did not play any role, first because of the energy involved and second because at the Planck era

$$E_P R_P = kT_P R_P = \hbar c$$

where G has disappeared[1].

Indeed also numerically (by using 200 MeV fm = 1)

$$10^{19}\ \text{GeV} \cdot 10^{-35}\ \text{m} = 10^{22}\ \text{MeV} \cdot 10^{-20}\ \text{fm} \simeq 1/2$$

which indicates heuristically a "strong interaction" relation between gravitational Planck quantities arising just from first principles. This persists up to the CMB where gravitation starts playing a role.

4) The flatness problem (?) and quantum gravity

The previous result further clarifies the connection [2] between gravity and QM. Indeed clearly black body is undoubtedly "the" quantum mechanics effect and its introduction in gravity produces the following remarkable results.

First of all, it cures the infinities of gravitation providing a natural cut-off in a similar way to what happens for atomic radii where classical infinities are fixed by the uncertainty principle (of course because of the weakness of the gravitational interaction with respect to e.m. this happens here at much smaller scales). As a matter of fact the smallest conceivable energy comes from equating the Compton wavelength to the Schwarzschild radius

$$\lambda_C = \frac{\hbar}{M} = R_S = \frac{2GM}{c^2} \tag{22}$$

Thus the Planck energy represents the smallest quantum black hole with corresponding dimensions

$$R_P \simeq 10^{-35}\ \text{m}$$

[1]This is the same relation connecting the muon mass to the strong interaction range in natural units.

and the maximal attainable temperature

$$T_P \simeq 10^{32}\ \mathrm{K}$$

Because of the energy mass equivalence this entails a gravitational energy proportional to the previous density $\tilde{\rho}$. But the total energy is however zero because of the black hole condition.

This also justifies why in a gravitational interaction of two point particles [13] the scattering probability

$$P \simeq \frac{E^4}{E_P^4}$$

is less than one because of the limits on the attainable energy *E*.

Thus the problem of granularity of space time at tiny scales is disposed of by this mechanism. **The black hole condition (supplemented by the quantum requirement at the origin) justifies satisfactorily the null curvature of the Universe although locally (solar system) space time is curved**.

The possibility of other bubbles and of other universes is manifestly a metaphysical problem.

5) Causality. Outer Universe?

Where the b.h. model differs most from the existing ones is that *it denies reality to the unmeasurable part of the Universe* unlike what is commonly assumed, resulting in an extra parameter. Its existence is partly due to the idea that homogeneity (which naturally results even for a finite Universe in the present approach) has to imply an infinite universe and to the aversion for a point like origin of our Universe.

It is worth stressing that the postulated outside matter is in our model created during the expansion because of the black hole mechanism and that since the expansion proceeds with velocity *c* the Hubble radius $R_H = \frac{c}{H}$ coincides with the dimensions of the Universe.

Let us consider the Hubble-Painleve-Gullstrand (LHPG) coordinate system. This is obtained by taking as the invariant interval (we keep here the same notation of the original paper [3])

$$\mathrm{d}s^2 = c^2\mathrm{d}t^2 - \chi^2(t)\mathrm{d}x^2 \tag{23}$$

$y = \chi x$ and the Hubble parameter $H = H(t) = \frac{\dot{\chi}}{\chi}$.

Thus

$$\mathrm{d}s^2 = c^2\mathrm{d}t^2 - \chi^2(t)\left[\left(\frac{\mathrm{d}y}{\chi} - \frac{\dot{\chi}}{\chi}y\mathrm{d}t\right)^2\right]$$

or

$$\mathrm{d}s^2 = \mathrm{d}t^2\left(c^2 - (\dot{y} - Hy)^2\right) \tag{24}$$

So the original space part of the invariant interval has been transformed in a *velocity dependent one*.

Here

$$Hy = v(t, y)$$

represents the velocity of expansion of the point y at the time t.

Its most relevant result comes from the consideration of radial light propagation which is got by setting to zero the previous invariant interval

$$c = \pm(\dot{y} - Hy)$$

or in terms of $\boldsymbol{y}$, $|\boldsymbol{y}| = y$ in the (y,t) plane

$$\frac{\mathrm{d}\boldsymbol{y}}{\mathrm{d}t} = H(t)\,\boldsymbol{y} - \boldsymbol{c}$$

where the case of backward propagation is considered in order to see objects in the past.

This implies first that the velocity of light, always c in the local frame changes in space-time as the vector composition with the Hubble expansion velocity. Thus light was more and more deviated in the past because of the increasing role of $H(t)$ in light propagation. Therefore **Figure 1**), which is generally reproduced qualitatively, derives here from our equation.

It is worth stressing that the point where light deviates toward us is obtained by imposing $\mathrm{d}y/\mathrm{d}t = 0$ *i.e.* no radial "escape" in the previous equation obtaining

$$Hy = c$$

or

$$y_t = ct$$

in our model. *This quantity can be identified with the Hubble radius*

$$R_H = \frac{c}{H}$$

delimiting our visible Universe which increases in size as a function of time, expanding at the velocity c.

When squared and introducing the expression for H one has

$$G\tilde{\rho}y^2 = c^2$$

i.e. the b.h. model equation.

Thus a LHPG invariant interval which reproduces the Hubble expansion, backs up the global properties of b.h. matter creation and the finer details of **Figure 1**.

Another way to underline the importance of the invariant interval is to consider it in another form

$$\mathrm{d}s^2 = \chi^2(t)\left[c^2\mathrm{d}\tau^2 - \mathrm{d}x^2\right]$$

where

$$\mathrm{d}\tau = \mathrm{d}t/\chi(t)$$

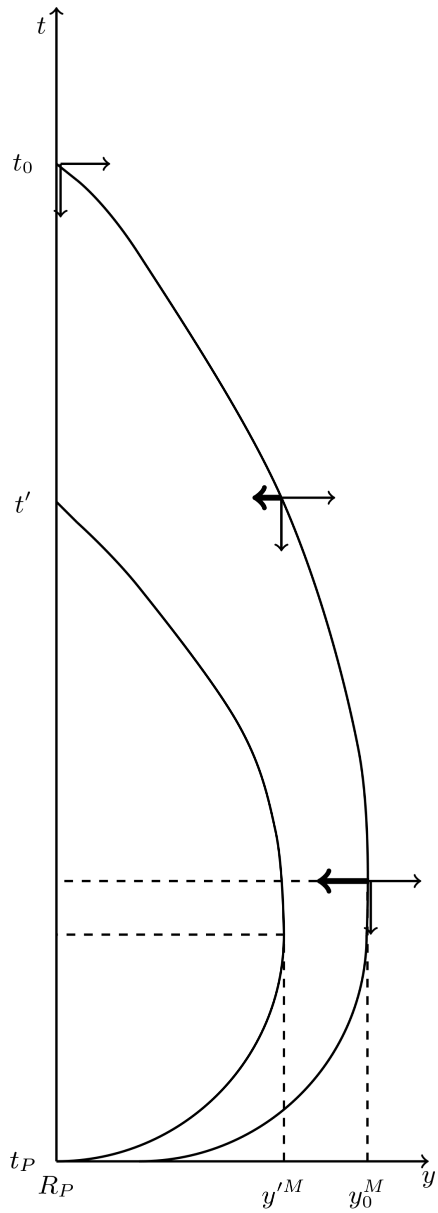

Figure 1. Light propagation in the (t, y) plane. Because of the vector composition of the local relativistic invariant light cone with the frame velocity determined by the varying Hubble parameter $H = \frac{1}{t}$ (thick arrow), light deviates more and more when emitted at former times (with an analogous effect to light deviation in a static gravitational field). At $y = y^M$ the Hubble velocity becomes smaller than the transverse light component thus allowing all the "light" emitted at the Big Bang to reach the earth at different times. Since $y = y_0^M$ is bigger than $y = y'^M$ the maximal world "dimensions" identified with the Hubble radius increase with time. Not In scale.

This coordinate system is particularly suited for the discussion of causality since it is of the Minkovski form and it puts strong bounds on the behavior of the scaling factor χ.

Notice that

$$\int \mathrm{d}t/t$$

(non accelerated expansion) is divergent for early times unlike $\chi \simeq t^{\alpha}$ (decelerated expansion) for the α of the GR treatment. If χ is integrable, time has had a beginning and there are regions not causally connected in the past, if not this time is infinite in the past and any two finite regions have a common one in the past which they were causally connected to.

The interpretation of $\tau(t)$, the conformal time, is important. It represents the comoving distance traveled by light at time *t*. Since two points can communicate at most with light velocity it therefore represents the dimensions of the region causally connected at time t, thus defining the causal horizon.

This $1/t$ *behavior which "stretches" early times with respect to the present ones, is enough to solve the problem of causality and the connected horizon problem. It predicts naturally the inflationary explosion.*

6) Constancy of physical laws?

This problem has represented a matter of considerable concern. To the best of our knowledge, it has only dealt with possible time variation of *G*. There is however another quantity which enters in our description of physical laws *i.e.*

$$\varepsilon = \frac{GM}{c^2 R}$$

which represents the coefficient of the expression for gravitomagnetism *h*, dimensionally

$$[h] = [T^{-1}]$$

i.e. a gravitomagnetic field produced by rotating masses is dimensionally equivalent to an angular velocity

$$\boldsymbol{h} \simeq \boldsymbol{\omega}$$

Thus the previous quantity enters Coriolis and centrifugal forces as well as gravitational radiation and the equality of inertial and gravitational masses. Its constancy in the matter dominated era yields an additional support for the b.h. model. An additional argument for the constancy of ε has been given in Ref. [3]. Thus the fact that $\varepsilon_P = \varepsilon_U$ is not just a fortuitous coincidence but is predicted by the present model. Note that such a (much weaker) parameter enters also the relativistic corrections for the solar system.

7) Matter-antimatter asymmetry.

Another interesting feature of the b.h. model is the predicted equality of the number of photons N_γ and nucleons N_n at $T = 10^{13}\ \mathrm{K}$, the temperature of nucleons threshold. This is not an ad hoc fit but comes from the reconstruction of the history of the Universe. That goes along with the equally remarkable puzzling [14] equality of the photon and matter energy at recombination. Coming back to the first equality, it realises the equilibrium annihilation of photons and baryons. But the number of antinucleons cannot be the same as that of nucleons since below threshold photons cannot any longer produce $n-\bar{n}$ pairs and the equality of particle-antiparticle would result in a null number of nucleons.

However a tiny constant ratio x of the number of anti baryons to baryons $\frac{N_{\bar{n}}}{N_n} = x$ is enough to explain the observed baryon dominance at the present time as a result of the same ratio due to an *unknown baryon violation mechanism* at the transition temperature. The present picture, where N_n goes from 10^{57} to the present 10^{80}, differs substantially from the current one where baryon number is conserved. The b.h. model somehow seems to account only for baryons as observed as well as the traditional approach. Finally a word about the role of gravitation. A common misconception is the call into question thermodynamics at the CMB time and before. Penrose [15] for instance argues it to be contrary to the second law of thermodynamics, which implies thermal equilibrium to correspond to the maximum random state. However Penrose's argument is essentially disproved by Fang's [16] objections. The inclusion of gravitation comes necessarily after the CMB, thus contradicting, because of the negative thermal capacity, thermodynamics which is based on thermal equilibrium [17] (the 18th century thermal death).

As a final comment it is remarkable that the matter destruction mechanism, via absorption by hypothetical black holes, is widely accepted whereas one cannot say the same for matter creation for the black hole we are living in.

5. Conclusion

In this note, intuitive considerations have been presented to support the b.h. description of gravitation. Particularly interesting is the prediction of a different time evolution with respect to GR which follows from a consistency requirement thus questioning matter conservation. The relation to the standard Newtonian case is discussed and the repulsive role of pressure is regained. The main drawback of this model might be ascribed to its excessive simplicity which compares to the unnecessary even if appealing (but inconsistent) reigning formalism.

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Data Availability Statement

All data generated or analysed during this study are included in this published article (and its supplementary information files).

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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