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Dark Energy, a Repulsive Gravitational Force Due to a Gravitational Field from General Relativity Equivalent to a Fictitious Negative Apparent Mass

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Abstract

We have published several articles explaining dark energy (DE) through repulsive gravitation. This explanation led to many very interesting results. In addition to solving the mystery of DE, this solution notably explained cosmic inflation and the absence of antimatter in our universe. Unfortunately, this repulsive gravitation relied on the hypothesis of a negative gravitational mass for antimatter, a hypothesis that has proven false following experiments at CERN. This new article proposes another way to explain the existence of repulsive gravitation, this time based on the second component of general relativity (which is responsible for the Lense-Thirring effect and frame-dragging). This component of general relativity, that we call "gravitic" field, is the equivalent of the magnetic field in electromagnetics. Just as magnets can attract or repel each other, we propose that this gravitic field can also generate attractive or repulsive gravitational forces. When this field is repulsive, it can result in a negative fictitious apparent gravitational mass. Replacing the gravitational mass hypothesis with these potentially repulsive gravitic fields allows us to recover most of the results from our previous studies on DE, which erroneously relied on the assumption of a negative gravitational mass.

Subject Areas

Cosmology, Astrophysics, Theoretical Physics

Keywords

Dark Energy, Gravitation, Cosmic Inflation, Quantum Gravity, Cosmology: Early Universe

1. Introduction

This article follows several articles [1]-[5] proposing to explain dark energy (DE) by a repulsive form of gravitation. These works hypothesized that repulsive gravitation was due to a negative gravitational mass of antimatter. This hypothesis has been experimentally proven false [6]. However, the results of such repulsive gravitation are so compelling (explanation of the absence of antimatter, primordial inflation, etc.) that it seemed necessary to reconsider this solution and see if it might be possible to maintain this idea of repulsive gravitation by imagining another source for this repulsive interaction. In article [7], we demonstrated that the explanation of dark matter (DM) by gravitic fields was very difficult to distinguish from the solution by exotic mass (cf. Relation (3) of [7]), more precisely that the mass (called exotic for DM) could most often be interpreted as a gravitic field. This leads us to propose another way of interpreting the repulsive gravitational force, no longer as a negative gravitational mass but as a gravitic field which, if translated into an equivalent mass, would give a fictitious negative apparent gravitational mass. Equation (3) of [7], even if only approximate (valid in weak fields), allows us to verify the possibility of such an erroneous interpretation in the form of a negative gravitational mass depending on the orientation of the gravitic field relative to the object's motion. It is remarkable that, in addition to allowing us to recover much of our previous work [1]-[5], explaining the absence of antimatter, primordial inflation, and DE, this alternative to our previous solution could also explain the chirality of our world, another great mystery of science.

2. Theoretical Foundations

2.1. Foundations of Linearized General Relativity Similar to Electromagnetism

As indicated in [8], General Relativity (GR) in its linearized version (GRL) leads to equations equivalent to Maxwell's equations, hence their name Einstein-Maxwell equations.

$$\Delta\varphi = 4\pi G\rho;\ \ \Delta H^i = \frac{4\pi G}{c^2}\rho u^i = 4\pi K^{-1}\rho u^i \tag{1}$$

In which φ is the traditional Newtonian scalar potential, ρ is the mass density, u^i are the three spatial components of the velocity and H^i a vector potential of gravitation, similar to the vector potential of electromagnetics (EM). The constant K (introduced in [8]) is defined by:

$$GK = c^2 \tag{2}$$

This definition gives $K^{-1} \sim 7.4\times10^{-28}\ \text{kg}\cdot\text{m}^{-1}$ very small compared to G. G and K are then similar to the two constants of EM, the vacuum permittivity ϵ_0 and the vacuum permeability μ_0.

With the following definitions of $\boldsymbol{g}$ (gravity field) and $\boldsymbol{k}$ (gravitic field), those Poisson relations can be obtained from the following equations (also called gravitomagnetism) with the differential operators "$\boldsymbol{rot} = \nabla\wedge$", "$\boldsymbol{grad} = \nabla$" and

"$div = \nabla \cdot$":

$$\begin{aligned} &\boldsymbol{g} = -\boldsymbol{grad}\,\varphi; \;\; \boldsymbol{k} = \boldsymbol{rot}\,\boldsymbol{H} \\ &\boldsymbol{rot}\,\boldsymbol{g} = 0; \;\; div\,\boldsymbol{k} = 0; \\ &div\,\boldsymbol{g} = -4\pi G\rho; \;\; \boldsymbol{rot}\,\boldsymbol{k} = -4\pi K^{-1}\boldsymbol{j}_p \end{aligned} \tag{3}$$

Finally, from the geodesic equations, we can write the equations of motion [9] of a particle in a gravitational field ($\boldsymbol{g}$, $\boldsymbol{k}$) where $\boldsymbol{p}$ is the particle's momentum and m_p is its mass:

$$\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} = m_p\left[\boldsymbol{g} + 4\boldsymbol{v} \wedge \boldsymbol{k}\right] \tag{4}$$

The gravitic field $\boldsymbol{k}$, the 2nd component of GRL, is at the origin of the Lense-Thirring effect observed in the Gravity Probe B mission [10] [11]. According to the Einstein-Maxwell equations, $\boldsymbol{k}$ is equivalent to the magnetic field in electromagnetism as it can be seen in the Equation (4). The only difference between EM and GRL is this factor of 4 on the gravitic force component.

In other words, GR implies the existence of two gravitational components: the Newtonian field $\boldsymbol{g}$ and the gravitic field $\boldsymbol{k}$, equivalent to the electric and magnetic fields $\boldsymbol{E}$ and $\boldsymbol{B}$ of EM. Given the equivalence of the GRL equations and Maxwell's equations, we can reasonably expect similar phenomena. Thus, just as the magnetic field induces a precession phenomenon (Larmor precession), the gravitic field (the second component of GR) similarly leads to a precession phenomenon called the Lense-Thirring effect, the existence of which has already been demonstrated. In parallel, in EM, the magnetic field $\boldsymbol{B}$ generates a particular magnetization effect, arising from the elementary magnetic moments of the particles (magnetic dipoles) $\boldsymbol{\mu}$. The magnetic moment $\boldsymbol{\mu}$ is proportional to the angular momentum $\boldsymbol{L}$. Since the mathematics of EM and GRL are similar, in gravitation, the gravitic field $\boldsymbol{k}$ can generate a form of "gravitic" magnetization, arising from the elementary gravitic moments of the particles, which we will denote $\boldsymbol{k}_\mu$. The gravitic moment $\boldsymbol{k}_\mu$ will be proportional to the angular momentum $\boldsymbol{L}$. At this stage, the existence of $\boldsymbol{k}_\mu$ is, of course, a hypothesis. We will develop this idea further at the end of the article.

2.2. Principles of the Scenario for Our Story of the Origin of the Universe

To understand the concept behind our scenario, it's simply a matter of remembering that in GRL, as in EM, gravitic moments can exist that either repel or attract each other. We'll look at the specific gravitic moments that might come into play later.

Fundamentally, our explanation is based on the early appearance of pairs of particles in which gravitation is repulsive, hence the earlier hypothesis that one of the particles in the pair has negative gravitational mass. Since this hypothesis (the simplest and most immediate way to obtain repulsive gravitation) has proven false, we now propose to explain this repulsive gravitation not by negative gravitational mass but by an elementary gravitic field, more precisely by an elementary gravitic moment. At this stage, in our scenario, the EM interaction has not yet appeared.

From now on, in our new hypothesis, when pairs appear, it is no longer the gravitational masses that cancel each other out (as we proposed based on the conservation of energy under which the symmetry was broken), but the angular momentum that is conserved. The particle and antiparticle of the pair then appear with opposite rotations. These rotations according to the GRL then generate, for each particle, a gravitic moment (a dipolar gravitic "magnet"), one of which is in the opposite direction to the other because it is linked to the angular momentum of each particle.

As with the EM magnetic field (whose gravitic field is the equivalent in GR), depending on the orientations of these fields, the force between magnets can be either repulsive or attractive. At this stage, we assume that these elementary gravitic magnets carried by each particle repel each other, hence repulsive gravitation. This will allow us to explain our idea in principle. We will see later that our scenario certainly implies a somewhat more complex, richer initial configuration. Since this second gravitational component is repulsive in this context, if this component dominates within the particle-antiparticle pairs (before the appearance of the EM interaction), primordial gravitation will initially be repulsive and even potentially explosive, thus generating primordial inflation (known as cosmic inflation). Let's try to justify this scenario more concretely.

In EM, the intensity of magnetic moments and the magnetic field can only be explained within the framework of quantum mechanics (particularly through the introduction of the concept of spin). However, we can still express the interaction between magnets (between magnetic dipoles) in EM. Consequently, lacking quantum mechanics of gravitation and in order to explain our proposition, we can attempt an order-of-magnitude calculation based on the approach used in EM. In the framework of EM, the force $F_{\mu_1\mu_2}$ between two magnetic dipoles μ_1 and μ_2 is of the following form [12]:

$$F_{\mu_1\mu_2} = \pm\frac{3\mu_0}{2\pi}\frac{\mu_1\mu_2}{r^4} \tag{5}$$

As can be seen in the GRL equations, we can go from the EM expressions to the GRL expression (up to a factor of 4 for the force expression) essentially by making the following 2 substitutions:

$$\epsilon_0 \Leftrightarrow -\frac{1}{4\pi G};\ \mu_0 \Leftrightarrow -\frac{4\pi G}{c^2} \tag{6}$$

We can then deduce that the GRL implies an interaction force $F_{k_{\mu1}k_{\mu2}}$ between 2 "gravitic" dipoles $k_{\mu1}$ and $k_{\mu2}$ of the following form:

$$F_{k_{\mu1}k_{\mu2}} \propto \frac{3}{2\pi}\frac{4\pi G}{c^2}\frac{k_{\mu1}k_{\mu2}}{r^4} \sim \frac{G}{c^2}\frac{k_{\mu1}k_{\mu2}}{r^4} \tag{7}$$

In our scenario, at the appearance of a particle-antiparticle pair, $\boldsymbol{k}_{\mu1}$ and $\boldsymbol{k}_{\mu2}$

will be the gravitic dipoles of the particle and its antiparticle. Their magnitudes will be identical. Again, we assume that these dipoles repel each other, but we will see later what this assumption implies for primordial pairs. To obtain a repulsive resultant gravitation at this scale for a pair of particles with masses m_1 and m_2, the repulsive force due to the gravitic dipole must be greater than the attractive Newtonian force:

$$\frac{G}{c^2}\frac{k_{\mu 1}k_{\mu 2}}{r^4} > G\frac{m_1 m_2}{r^2} \tag{8}$$

In a particle-antiparticle pair, we have $m_1 = m_2 = m$ and $k_{\mu 1} = k_{\mu 2} = k_\mu$ and r represents the distance between the particle and its antiparticle. The parameter r therefore also represents the characteristic size of the pair. We then have:

$$\frac{G}{c^2}\frac{k_\mu^2}{r^4} > G\frac{m^2}{r^2} \Rightarrow k_\mu > rmc \tag{9}$$

It is interesting to note that the smaller the size of the pair, the stronger the repulsive force. For a quark, we have $m \sim 10^{-30}\ \text{kg}$ and for a Planck distance, we have $r \sim 10^{-35}\ \text{m}$. With these values, repulsive gravitation dominates as soon as the gravitic dipole is greater than:

$$k_\mu > 10^{-57}\ \text{J}\cdot\text{s} \tag{10}$$

For example, if we assume a gravitic moment on the order of $k_\mu \sim 10^{-55}\ \text{J}\cdot\text{s}$, the two components of gravitation ($F_{m_1 m_2}$ for the Newtonian and $F_{k_{\mu 1}k_{\mu 2}}$ for the "gravitic" magnetization) are then on the order of:

$$\begin{aligned} F_{m_1 m_2} &\sim G\frac{m_1 m_2}{r^2} \sim 6\times 10^{-11}\frac{10^{-30}\times 10^{-30}}{10^{-70}} \sim 0.6N \\ F_{k_{\mu 1}k_{\mu 2}} &\sim \frac{G}{c^2}\frac{k_{\mu 1}k_{\mu 2}}{r^4} \sim 6\times 10^{-28}\frac{10^{-55}\times 10^{-55}}{10^{-140}} \sim 6\times 10^{2} N \sim 10^{3} F_{m_1 m_2} \end{aligned} \tag{11}$$

At this scale (the early Universe), the repulsive force is then largely dominant within all pairs. Given the approximations made, these values are certainly very approximate, but the possibility of highly repulsive gravitation is confirmed.

It should be noted that in this model, although antimatter does not possess negative gravitational mass (as erroneously assumed in the various articles where we have discussed DE), our solution generates, at this scale, a repulsive gravitation that resembles negative gravitational mass. Indeed, by interpreting the forces of the GRL as a single Newtonian component (where the gravitic field would be assumed to be negligible), we can improperly rewrite:

$$F \sim -G\frac{m^2}{r^2} + \frac{G}{c^2}\frac{k_\mu^2}{r^4} \sim -\frac{G}{r^2}\left(m^2 - \frac{k_\mu^2}{c^2 r^2}\right) \sim -\frac{G}{r^2}m\left(m - \frac{k_\mu^2}{mc^2 r^2}\right) = \frac{Gm}{r^2}m_{appa} \tag{12}$$

The apparent mass of the antiparticle at this Planck scale is then:

$$m_{appa} \sim m - \frac{k_\mu^2}{mc^2 r^2} \sim 10^{-30} - \frac{10^{-55}\times 10^{-55}}{10^{-30}\times 10^{17}\times 10^{-70}} \sim -10^{-27}\ \text{kg} \tag{13}$$

This mass can therefore be misinterpreted as a negative gravitational mass. This is why the solution presented in this article allows us to revisit much of the work proposed in our previous articles [1]-[5] explaining DE. This relation (13) is somewhat equivalent to that in DM (relationship (3) of [7]) which demonstrates that a gravitic field can be interpreted as a gravitational mass.

Note that the weak-field GR approximation (Einstein-Maxwell equations) is verified (metric of GRL $|h_{00}| \ll 1$) for the antiparticle field. However, these approximate results remain primarily indicative for explaining our approach:

$$\begin{aligned} &|\varphi_m| = \frac{Gm}{r} \sim 6\times10^{-11}\frac{10^{-30}}{10^{-35}} \sim 6\times10^{-6}\,N \Rightarrow |h_{00}| = 2\varphi_m \sim 10^{-5}\,N \ll 1 \\ &\left|\varphi_{m_{appa}}\right| = \frac{Gm_{appa}}{r} \sim 6\times10^{-11}\frac{10^{-27}}{10^{-35}} \sim 6\times10^{-3}\,N \Rightarrow |h_{00}| = 2\varphi_{m_{appa}} \sim 10^{-2}\,N \ll 1 \end{aligned} \tag{14}$$

3. Big Bang Scenario in Our Hypothesis

3.1. Gravitational Repulsion and Attraction => Primordial Inflation, Reheating

As already explained in our articles [1]-[5], with our theoretical approach of repulsive gravitation, we can propose a scenario for the birth of the Universe. In this account, at the origin of the Universe, a primordial cloud condenses into particle-antiparticle pairs (due to a phase change). Within this primordial cloud, each pair then experiences this primordial gravitic repulsion, which is much greater than the attractive gravitational component, as seen qualitatively and approximately quantitatively in the previous chapter. Our scenario thus generates primordial inflation.

We will discuss later the distinction between particle and antiparticle, as well as the orientation of their gravitic moments, which can be either repulsive or attractive. At this stage, the gravitic moments between a particle and an antiparticle will be considered to have opposite orientations, the gravitic moments between particles will be considered to have similar orientations, and the same applies to antiparticles. However, we will see that the situation will require a bit more precision in the orientation of the various gravitic components (intrinsic gravitic moment and gravitic moment of the pair). At this early stage, countless collisions occur while maintaining the maximum physically permissible velocity (as we will see later), which could correspond to a period of large-scale transfer of kinetic energy into thermal energy and vice versa, similar to a reheating process.

3.2. Gravitational Repulsion and Attraction => Segregation of Masses/Moments and Slow Rolling

This inflation very rapidly separates particles with opposite gravitic moments (repulsive force). Simultaneously, particles with similar elementary gravitic moments begin to aggregate around each particle, attracting each other (attractive force). A segregation of masses takes place, which is in our new scenario a segregation of gravitic moments. The primordial cloud thus becomes increasingly granular, with grains growing in size and number. This segregation phase can last for a long time because, although the repulsion pushes the grains apart (which would reduce collisions and therefore temperature and pressure), neighboring grains fill the empty spaces and maintain a high level of collision, which ultimately preserves the pressure and temperature conditions. Furthermore, primordial inflation likely imparted a maximum velocity to each component of this cloud, slowing the aggregation of grains, which are regularly broken apart. And, even as these grains grow, their distance remains small (due to the filling of empty spaces). Gravitational attraction therefore remains weak because the grains and anti-grains are so close that the attractive effect of gravitation is masked, always in favor of the repulsive component. Within the cloud, the slowing of its expansion remains small, and the physical parameters evolve little, except perhaps for the size of the grains. The slowing will become significant once the grains in this cloud have reached sufficient sizes and the spaces between grains no longer fill. This phase (where the gaps are filled) can be corresponded to "slow-rolling." Subsequently, these grains will become so immense that they will then form primordial universes. It should also be noted that the sustained filling of gaps is associated with a sufficient extent of the primordial cloud because the gaps are initially filled by close neighbors, but over time, neighbors that were initially distant come to fill these spaces. Emerging from this inflation, this cloud became a network of universe grains, more precisely a succession of universe grains and anti-universe grains. Within each universe grain (and anti-universe grains), there are attractive neighborhoods with gravitic fields of similar direction, thanks to the work of slow rolling and the homogeneous sorting of gravitic moment directions (the segregation of masses, which in this new framework would be more accurately described as a segregation of gravitic moments). Between each neighboring universe grain, there is repulsion because the neighborhoods at the edges of these nearby universes have opposite, repulsive resultant gravitic moments.

The slow rolling in our scenario is explained by the filling of voids. This can theoretically occur in two ways: either the temperature and pressure conditions of the phase transition are maintained, allowing condensation—*i.e.*, the creation of pairs—to continue, but we can question the ability to continuously generate pairs at a given location. As mentioned earlier, we favor the second conceivable way: that this phase transition takes place over an extended area. This is, in fact, one of the reasons why we refer to it as a cloud. With a sufficiently large primordial cloud, the voids at any given internal point can be filled by particles coming from increasingly farther away from the cloud. In our narrative, the Big Bang is therefore not a point singularity but an extended primordial cloud undergoing a phase transition.

The primordial inflation in our scenario certainly implies that two phases occur simultaneously. At the edges, inflation causes the cloud to expand and rapidly dilute because the voids quickly become unfilled (due to a lack of neighboring particles). Conversely, at the core of the primordial cloud, the slow-rolling phase will last until the "edge dilution wave", propagating inward, reaches the core. The primordial inflation in this scenario is therefore quite unique, causing expansion (because two initially close particles move further apart on average) with a constant density (because the extent of the primordial cloud means that initially distant neighboring particles fill the voids within the cloud for a certain period).

3.3. Gravitational Repulsion and Attraction => DE and DM

The primordial cloud, and subsequently the granular cloud, are characterized, among other things, by two characteristic distances: the average distance between two neighboring particles and the average distance between a particle and an antiparticle. In our scenario, during the condensation of the primordial cloud, these two characteristic distances are similar and have values on the order of a pair, since particle-antiparticle pairs appear. But over time, with the growth of the universe-grains (through particle aggregation and expansion), these two characteristic distances will become significantly divergent. The distance between particles will roughly characterize the "density" within the universes, and the distance between particles and antiparticles will roughly characterize the size of the universes. The universe-anti-universe distance then becomes much larger than the distance between particles, the former tending towards the infinitely large while the latter remains in the infinitely small. The distance between particles influences the intensity of the attractive gravitational force within universes. The homogeneous sorting resulting from segregation has indeed favored the clustering of attractive gravitic moments, which accentuates the Newtonian attractive gravitational component. The distance between particles and antiparticles influences the intensity of the repulsive gravitational force between neighboring universes through their opposing resultant gravitic moments. On the scale of universes, the distance between universes and anti-universes weakens the Newtonian component more strongly than the second component of gravitation (the gravitic field) because it is partially compensated by the coherence of elementary gravitic moments (which then add up within universes). This is what gives rise to DE, where universes are, in a way, compressed, caught between anti-universes and vice versa. Within a universe, the distance between particles will cause the first Newtonian term to dominate, and the coherence of gravitic moments (locally within a universe) will lead to the emergence of a gravitic component that will support the gravitational attraction at the origin of DM. In our scenario, a link is then established between DE and DM through this gravitic field. DE thus develops on a large scale, between universes (through the dominance of the second component of GR over the Newtonian term, like a repulsion between neighboring universes with opposing gravitic moments), while DM develops on a "small" scale, within a universe (like an attraction within the large internal structures of a universe of homogeneous local gravitic moments where the second component of GR supports the dominant Newtonian term).

This scenario does not imply anisotropy of the universes. Indeed, somewhat symbolically, this succession of universes should be imagined as a succession of spheres in which the gravitic moments are arranged perpendicularly to the surface of the spheres. For anti-universes, these gravitic fields would, for example, be directed outwards, and for universes then inwards. Ultimately, for a universe (or anti-universe), the sum over the entire circumference of the sphere results in a zero-net field, and therefore isotropy on the global scale of the universe. And around a universe (or anti-universe), the influence of neighboring anti-universes (or universes) would be due to their nearest half (their other half influencing the neighboring universes on their other side). This influence would be the DE.

Remind that we propose a scenario for DM [7]-[9] which assumes the existence of a gravitic field $\boldsymbol{k}_0$ along large areas of our Universe, relatively uniform at the scale of galaxy clusters, and which accentuates gravitational attraction. Such a gravitic field would originate from the accumulation of coherent gravitic fields from neighboring clusters (similar to the accumulation of coherent spins in ferromagnetic materials to explain magnetization). However, this DM scenario lacks an essential ingredient: an intrinsic gravitic spin to explain a gravitic field much stronger than that of mass currents in GR. The existence of a primordial cloud condensing into a universe that locally favors the establishment of coherent gravitic moments could help generate such fields. We will briefly address this topic later.

3.4. Gravitational Repulsion and Attraction => Redshift

We previously discussed two characteristic distances. There is another interesting distance parameter, the mean free path (distance between two successive collisions), which characterizes heat exchange and pressure (the number of collisions). In this initial phase of the universe, it seems reasonable to assume that the mean free path is roughly of the same order of magnitude as the distance between particles. These two parameters (mean free path distance ~ distance between particles and grain size ~ distance between grain and anti-grain) largely control both the mass of the grains (density related to the distance between particles), the attraction (mass of the grains and distance between particles), the gravitational repulsion (mass of the grains, distance between grain and anti-grain, and number of particles for the sum of gravitic moments), and the velocity of the particles (collision related to density and gravitational interaction). In this initial phase of the universe, these two parameters will evolve in an extremely homogeneous manner (in the same way in space and at the same rate in time) within the cloud (except certainly at the cloud's edge, which we will assume is sufficiently distant to ensure this homogeneity for a long time).

During slow-rolling, as the voids fill regularly, the mean free path distance between particles increases very slightly and is almost constant. The mass of the grains (through the aggregation of particles with homogeneous gravitic moments, subsequently of "homogeneous" grains, and finally of increasingly larger grains) also increases very slightly (because collisions re-dissociate the grains). Gravitational attraction therefore increases, but very slightly, and is almost constant.

Consequently, the slowing of the expansion is very small, and the expansion rate remains relatively constant. The speed of the particles remains at its maximum (the speed of light) due to the enormous impulse of inflation. Collisions under these extreme conditions do not actually slow the particles down but only change their direction of travel.

Gradually, the voids will fill less and less, and expansion will then play its role of dilution by increasing the average distance between particles, leading to a decrease in collisions, an increase in homogeneous masses, and thus an increase in gravitational attraction. The increasing distance between particles (due to expansion) and the increasing size of the grains (due to segregation) simultaneously lead to a faster increase in the grain-anti-grain distance than the distance between particles, and therefore a decrease in local repulsion in favor of the attractive Newtonian component, which will slow the expansion. This trend will continue steadily, with, as is relevant to our study of redshift, a decrease in the expansion rate. Thus, at any given moment, we have a cloud characterized by an expansion rate (relatively constant across the entire cloud) that gradually decreases over time (still relatively constant across the entire cloud). In other words, regardless of the observation point, we observe the same curve of decreasing expansion rate over time.

This spatial homogeneity and temporal decrease associated with cloud expansion explain the redshift phenomenon. While particles constantly collided at maximum speeds during inflation, at the end of inflation, when expansion causes dilation and dilution across the entire cloud, the collisions (and therefore changes in direction) decrease. The consequence of maintaining homogeneous directions and intensities in the neighborhood for the expansion velocity is that two neighborhoods with different velocities will inevitably separate because the expansion velocity follows a decreasing curve (and therefore cannot catch up with their neighbors). Only areas with parallel velocities will remain close. Thus, very soon after inflation, the velocities of these areas become homogeneous, not only in magnitude but also in direction. This evolution is shared across the entire cloud. From any observation point, locally, similar velocities will be consistently observed, and the further away one looks (*i.e.*, further back in time), the higher the measured velocities will be (because the cloud's velocity in the past was higher due to the expansion rate that has slowed down since then). This demonstrates the phenomenon of redshift.

3.5. Towards a Quantum Mechanics of Gravitation

We have seen that this explanation of the DE (through the repulsion of gravitic moments) could create a link with the solution of DM because the source of the DE could also be the source of the gravitic fields of DM. Remind that our explanation of DM assumes the existence of a uniform gravitic field $\boldsymbol{k}_0$ [9] whose intensity, required to explain DM without exotic matter, needs to be much greater than that which can be deduced from the mass currents alone calculated by GR. However, thanks to the proximity of GRL and EM, we can go further and propose a hypothesis that leads us into the field of quantum mechanics of gravitation. Generally speaking, in EM, an angular momentum $\boldsymbol{L}$ corresponds to a magnetic moment $\boldsymbol{\mu}$. In quantum mechanics (QM), the notion of spin $\boldsymbol{S}$ (a kind of intrinsic fundamental angular momentum of elementary particles) gives rise to a spin magnetic moment which adds to $\boldsymbol{\mu}$ to obtain a total magnetic moment of greater intensity than that deduced from the charge currents alone in EM, thus explaining the intense magnetic moments $\boldsymbol{m}$ of magnets. Like EM, GRL implies the existence of a gravitic moment $\boldsymbol{k}_\mu$ proportional to the classical angular momentum. And like QM, we can venture to hypothesize the existence of an intrinsic gravitic spin $\boldsymbol{S}_k$ whose gravitic moment would add to $\boldsymbol{k}_\mu$ to obtain a total gravitic moment of greater intensity than that deduced from the mass currents alone in GR. The idea would then be that this primordial field, during segregation, favored the homogenization of gravitic moments in neighboring structures. As these clusters grew, they could have given rise to gravitic fields far greater than those achievable by mass currents alone in GR for structures such as galaxy clusters. These clusters would then have themselves given rise to the uniform gravitic field term $\boldsymbol{k}_0$ necessary to explain DM. And this gravitic moment $\boldsymbol{k}_\mu$ at the origin of inflation would also (following the homogenization of $\boldsymbol{k}_\mu$ by segregation) be responsible for a weak resulting gravitic field which, on the scale of the universes, would cause DE (just as the $\boldsymbol{k}_0$ field explaining DM is extremely weak and whose influence is only felt on the scale of large-scale structures in the universe).

We can add a remarkable fact (though it doesn't constitute proof). In EM, the intensity of the magnetic fields of the magnets can only be explained by the concept of spin from QM. There is a ratio between the magnetic field of a magnet and the "classical" field that would permeate the material, called magnetic susceptibility. The value of this ratio can reach 10^5. In our solution of DM, we have a factor of 10^6 between the gravitic field resulting from the mass currents of GR (which are too weak) and the gravitic field $\boldsymbol{k}_0$. This difference may seem enormous, but surprisingly, it is of the same order of magnitude as the magnetic susceptibility in EM, which also characterizes a kind of ratio between a "classical" magnetic field and the magnetic field of a magnet. Even if these ratios are not exactly equivalent, they demonstrate similar extraordinary intensities that are inexplicable within a "classical" approach (EM or GRL).

To continue on this quantum aspect of gravitation, our approach could allow a first linearized approximation of this quantum theory in weak gravitational fields since quantum gravity should tend towards the linearized equations of the GRL (in the same way that QM allows us to find EM as a limiting case).

3.6. A New Explanation for the Absence of Antiparticles in Our Universe

Up to now, we have discussed particles and antiparticles somewhat elusively. In our articles [1]-[5], where repulsive gravitation was explained by negative mass (a hypothesis refuted by experiment), mass segregation occurred naturally according to its sign. It was deduced that particles (with positive gravitational mass) and antiparticles (with negative gravitational mass) necessarily separated during this phase of universe and anti-universe segregation. This naturally explained the absence of antiparticles in our particle universe.

This natural segregation occurred because antiparticles possessed a specific intrinsic characteristic: negative gravitational mass. In our new hypothesis of repulsive gravitation due to gravitic moments, if we want to maintain this explanation for the absence of antiparticles in our particle universe, these gravitic moments must allow us to define an intrinsic parameter that separates particles from antiparticles. However, it is not easy to establish that the segregation of gravitic moments can also be a "particle-antiparticle" segregation. Indeed, when we relied on the sign of the mass, we had a truly absolute (intrinsic) parameter that differentiated particles from antiparticles. With the orientation of the gravitic moment, it seems that simply flipping the particle would give it a spin oriented like an antiparticle, which makes this parameter relative to the context and not exclusively dependent on the particle. But we can imagine a way to make this parameter intrinsic to the particle. It was assumed that upon the appearance of a particle-antiparticle pair, one was rotating in the opposite direction to the other. If we assume now that an elementary gravitic spin moment (that of a hypothetical gravitic spin in QM of gravitation) is added to the "classical" gravitic moment of GR (associated with the angular momentum), the gravitational configuration of the particles and antiparticles could be intrinsically distinct, one having its intrinsic gravitic spin moment oriented in the same direction as its rotation (its gravitic moment), and the other having its intrinsic gravitic spin oriented in the opposite direction to its rotation. In this case, an antiparticle would, for example, be the one with the opposite orientation between its gravitic spin and its proper rotation, while the particle would be the one with the same orientation. This hypothesis then implies a new and interesting consequence. Within a particle-antiparticle pair, the total gravitic spin would no longer be zero, which would contradict the conservation of angular momentum between before and after the appearance of the pair. We are thus led to propose that this appearance is concomitant with the appearance of a second pair with opposite spins and gravitic moments. In such a scenario, it is no longer particle-antiparticle pairs that appear, but rather quadruplets, particle pairs, and antiparticle pairs. This hypothesis is interesting because we could then ask whether, in general, a primordial quartet of particles could be the origin of the nonlinearity of an interaction (as is the case with GR) and a primordial pair of particles the origin of the linearity of an interaction (as is the case with EM). This reflection aligns with our study on nonlinear structures [13]. Indeed, it appears that, for linear structures, a "+" characteristic (in physical terms, this could be the charge of a particle) is associated with an opposite "-" characteristic (in physical terms, this could be the charge of its antiparticle). For nonlinear relationships, a characteristic "(+,+)" is associated with an opposite characteristic "(-,-)" but also with two complementary characteristics "(-,+)" and "(+,-)" which are themselves opposite to each other. This leads to the notion of a quadruplet, which defines four couple that, in our case, would be translated as the couple "(signs of intrinsic gravitic spins, signs of gravitic moments)". These four configurations then form two families: one of universes and the other of anti-universes, *i.e.*, one of opposite moments (the two couples of opposite signs) and the other of moments of the same direction (the two couples of the same sign).

We note that proposing a particle-antiparticle distinction from the appearance of gravitational interaction, before the appearance of EM interaction, whereas this distinction to date is made exclusively in EM (change of sign of the charge between a particle and its antiparticle) certainly implies that there is in this context a link between the sign of the EM charge and gravitational interaction (via gravitic moments and intrinsic gravitic spins).

4. Conclusions

This work helps to give meaning to the notion of repulsive gravitation by relying on the possible repulsion of gravitic moments. Equation (13), even if very approximate, is a kind of proof of concept, showing that such gravitic fields can be erroneously interpreted as a negative gravitational mass. This relation then provides a correspondence that allows us to recover much of the work proposed in the articles on negative masses [1]-[5]. In particular, it allows us to recover primordial inflation with its slow rolling and a segregation of particles and antiparticles, explaining the absence of antimatter in our Universe. We have also seen that this new hypothesis of repulsive gravitation based on gravitic moments allows us to explain the phenomenon of redshift and could potentially also explain the non-linearity of the gravitational interaction. It should also be noted that in this scenario, the Big Bang is not a point singularity but a phase transition of an extended primordial cloud. Such an approach has also led us to a potential QM of gravitation which would contain an intrinsic gravitic spin and of which GRL would be a limiting case as EM can be for QM.

This gravitic spin would be a link between DE and DM. The segregation of masses, which in this new scenario translates into an aggregation of homogeneous gravitic moments, ultimately generates a network of universes and anti-universes. Universes are caught between anti-universes and vice versa, generating pressure on the universes that gives rise to DE. And within a universe, these aggregates of homogeneous gravitic spin could provide the gravitic field of greater intensity than the mass currents of GR necessary to explain the DM of the large-scale structures of the universe. While our explanation of DM is a way of rejecting exotic matter, it is ironic to note that in our previous explanation of DE, when we proposed a negative gravitational mass, we were ultimately proposing exotic matter. The explanation of repulsive gravitation by gravitic moments thus restores coherence between these two explanations of DE and DM. In this narrative, we therefore manage to find common causes for the DE and the DM, while explaining that, in the context of the DE, the gravitic field will have a repulsive effect both on a very small scale (between particles in the very first moments of the universe) and on a very large scale (between the grains of the universe, the rest of the time) and that, in the context of the DM, the gravitic field accentuates the attractive effect of gravity on a "medium" scale (within our Universe, also the rest of the time).

Particles and antiparticles would differ in the direction of rotation of their "classical" gravitic moment (derived from the mass currents of general relativity) relative to their gravitic spin moment (derived from an elementary gravitic spin of a hypothetical QM of GR). Depending on whether it is the universe or the anti-universe, there would be a tendency to rotate in one direction rather than the other at the elementary level. This solution could explain the chirality of our world, which would tend to favor a "local" elementary rotation direction due to segregation that would have concentrated masses possessing coherent elementary gravitic fields. However, this locally coherent direction would evolve step by step, meaning that the further apart two masses are, the less parallel their directions will be. This reflects the mixture of isotropy and anisotropy depending on the scale considered, as proposed in the explanation of the DM [7].

In GR, based on relation (4), we observe that from a theoretical point of view, there are only two ways to make gravitation repulsive: either a negative gravitational mass (for the Newtonian term) or repulsive gravitic dipoles (for the non-Newtonian component). Our previous articles [1]-[5] attempted the path of repulsive gravitation using the first solution (negative gravitational mass), which has been experimentally proven impossible. It is therefore important to note that this second path, presented in this article, is the only other way to obtain repulsive gravitation within the framework of GR. There will thus be no other way to "save" our explanation of DE.

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] Le Corre, S. (2022) Negative Gravitational Mass: A Perfect Solution for Primordial Inflation and Dark Energy in the Early Universe. *Open Access Library Journal*, **9**, e9473. https://doi.org/10.4236/oalib.1109473

[2] Le Corre, S. (2021) Recent Cosmological Anisotropy Explained by Dark Energy as Universes of Negative Gravitational Mass. *Open Access Library Journal*, **8**, e7585. https://doi.org/10.4236/oalib.1107587

[3] Le Corre, S. (2020) Negative Gravitational Mass: An Ideal Solution for Cosmology. *Open Access Library Journal*, **7**, e6070. https://doi.org/10.4236/oalib.1106070

[4] Le Corre, S. (2018) About the Negative Gravitational Mass. *Open Access Library Journal*, **5**, e4312. https://doi.org/10.4236/oalib.1104312

[5] Le Corre, S. (2015) Dark Energy, A New Proof of the Predictive Power of General Relativity. https://hal-ens-lyon.archives-ouvertes.fr/ensl-01122689

[6] Anderson, E.K., Baker, C.J., Bertsche, W., Bhatt, N.M., Bonomi, G., Capra, A., *et al.*

(2023) Observation of the Effect of Gravity on the Motion of Antimatter. *Nature*, **621**, 716-722. https://doi.org/10.1038/s41586-023-06527-1

[7] Le Corre, S. (2026) Exotic Matter and MOND as Special Cases of a More General Solution in Pure General Relativity. *Frontiers in Astronomy and Space Sciences*, **12**, Article ID: 1664364. https://doi.org/10.3389/fspas.2025.1664364

[8] Le Corre, S. (2015) Dark Matter, a New Proof of the Predictive Power of General Relativity. arXiv: 1503.07440.

[9] Le Corre, S. (2024) Milky Way Could Invalidate the Hypothesis of Exotic Matter and Favor a Gravitomagnetic Solution to Explain Dark Matter. *Scientific Reports*, **14**, Article No. 27526. https://doi.org/10.1038/s41598-024-79201-9

[10] Adler, R.J. (2015) The Three-Fold Theoretical Basis of the Gravity Probe B Gyro Precession Calculation. *Classical and Quantum Gravity*, **32**, Article ID: 224002. https://doi.org/10.1088/0264-9381/32/22/224002

[11] Everitt, C.W.F., *et al.* (2015) The Gravity Probe B Test of General Relativity. *Classical and Quantum Gravity*, **32**, Article ID: 224001.

[12] Vokoun, D., Beleggia, M., Heller, L. and Šittner, P. (2009) Magnetostatic Interactions and Forces between Cylindrical Permanent Magnets. *Journal of Magnetism and Magnetic Materials*, **321**, 3758-3763. https://doi.org/10.1016/j.jmmm.2009.07.030

[13] Le Corre, S. (2020) Study about Non-Linear Structures. *Open Access Library Journal*, **7**, e6726. https://doi.org/10.4236/oalib.1106726