Antigravity as the basis for a New Interpretation of the Planck Length

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It is shown how the gravitational repulsion between matter and antimatter (called antigravity) naturally leads to the emergence of the Planck Length

In spite of the immense and long lasting efforts to unify gravity with the other fundamental interactions, it has remained the greatest unsolved problem of physics in 20th Century. As well known, the root of difficulties lies in the fact that General Relativity is basically a non-quantum theory while other interactions are described by quantum field theories. None of the many attempts to reconcile gravity with quantum physics were considering the possibility of antigravity (gravitational repulsion between matter and antimatter).

Despite the fact that the scientific community is reluctant to the idea of antigravity, in my opinion there are big potentials hidden behind it. Already at classical level, with assumption of antigravity, there is a higher level of similarity between Newton's Gravitational Law and Coulomb's Law. It may serve as the basis to describe gravitation with a kind of modified Maxwell's electrodynamics (the key modification being that attraction exists between charges of the same sign and repulsion between charges of the opposite sign). Of course, the use of modified Maxwell's equations will describe not only gravitation but will also introduce a gravitational equivalent of a magnetic field (if such a phenomenon doesn't exist in the case of gravitation, we may consider the theory in the limit when appropriate terms go to zero). So, in principle, under the assumption of antigravity, classical description of electromagnetism and gravitation may have very similar mathematical structures. As well known, classical electrodynamics was successfully quantized and we may hope to do the same with gravitation if it has a similar mathematical structure as electrodynamics. Let's mention, that Gravitoelectromagnetism (for a brief review see Reference [1]), may eventually serve as a starting point, if carefully reconsidered, without neglecting possibility of gravitational repulsion between matter and antimatter. But, in the present short paper our goal is much less ambitious. We will limit to demonstrate how assumption of antigravity applied to the case of a black hole naturally leads to the Planck length i.e. to the Planck Scale in general. In fact, nearly a century ago, Max Planck had noticed that there is a length

$$L_P = \sqrt{\frac{\hbar G}{c^3}} \tag{1}$$

made up from the fundamental constants of nature and so, he suspected that it plays the role of a fundamental length, what is largely accepted today.

The creation of particles from the vacuum is one of the most important phenomena in the quantum field theory. An illuminating example is the case of a sufficiently strong external (classical i.e. unquantized) constant and homogenous electric field ***E***. In such a field, the (Dirac) vacuum becomes unstable and decays leading to a spontaneous production of electron-positron pairs, with an exactly known probability [2, 3] for pair production per unit time and volume:

$$w = \frac{1}{\pi^3}\left(\frac{E}{E_{cr}}\right)^2 \frac{mc^2}{\hbar}\left(\frac{mc}{\hbar}\right)^3 \sum_{n=1}^{\infty}\frac{1}{n^2}\exp\left(-\frac{n\pi}{2}\frac{E_{cr}}{E}\right) \tag{2}$$

In fact a significant pair creation occurs only for fields *E*, greater than a critical value, E_{cr}:

$$E \geq E_{cr} = \frac{2m^2c^3}{e\hbar} \tag{3}$$

In a recent publication [4] it was pointed out that under the assumption of gravitational repulsion between matter and antimatter (antigravity), a sufficiently strong gravitational field may lead to a spontaneous production of particle-antiparticle pairs in the same way as a classical external electric field creates electron-positron pairs. In fact, in a vacuum, short-living "virtual" particle-antiparticle pairs are continuously created and annihilated again by quantum fluctuations. These pairs can be separated spatially by the external gravitational field (*if there is antigravity, particle and antiparticle from a virtual pair, are pushed in opposite directions!*) and so converted into real particles by the expenditure of the field energy. For this to become possible, the potential energy has to vary by an amount $\Delta V = ma\Delta l > 2mc^2$ in the range of about one Compton wavelength $\Delta l \approx \hbar / mc$. Therefore the pair creation (of a pair with mass *m*) occurs for gravitational fields i.e. accelerations greater than a critical value:

$$a \geq a_{cr} = \frac{2mc^3}{\hbar} = \frac{2c^2}{\lambdabar_m} \tag{4}$$

where $\lambdabar_m = \hbar / mc$ is the Compton wavelength (divided by 2π) for a particle with mass *m*. The exact result (1) remains valid in the case of a constant gravitational field, if electric field *E* is replaced by acceleration *a*, while charge *e* must be replaced by mass *m.* Let us point out that gravitation as universal interaction may do more than an electric field; it may create both particle-antiparticle pairs of charged and neutral fermions (a formula slightly different from (1) is valid for creation of boson-antiboson pairs [5]).

It is immediately clear that only a black hole may be the source of such a strong gravitational field as demanded by Equation (3). Now, as in Reference [3], let's consider a sphere, S_{Cm}, with a radius R_{Cm} and let's suppose that there is a spherically symmetric distribution of mass M inside this sphere. The question is for which value R_{Cm} acceleration on the surface of the sphere is equal to the critical acceleration a_{cr} determined by Equation (3). Combining Equation (3) with Newton's universal law of gravitation leads to:

$$R_{Cm}^2 = \frac{\lambdabar_m R_S}{4} \tag{5}$$

where R_S is the Schwarzschild radius of a black hole with mass *M*.

$$R_S = \frac{2GM}{c^2} \tag{6}$$

It is obvious that to every kind of particles corresponds a "critical" sphere S_{Cm} (defined by the corresponding "critical" radius R_{Cm}). So, there is a series of decreasing critical radiuses:

$$R_{C\nu_e}, R_{C\nu_\mu}, R_{Ce}, R_{C\nu_\tau}, R_{C\mu}, R_{C\pi^0}, ..., R_{Cp}, ... \tag{7}$$

corresponding respectively to electron-neutrino (ν_e), muon-neutrino (ν_μ), electron (e), tau-neutrino (ν_τ), muon (μ), π^0 meson … proton (p), and so on. When the radius R of the collapsing body is smaller than a critical radius R_{Cm}, significant creation of the appropriate particle-antiparticle pairs may occur in the volume enclosed by the surface of the body and the critical sphere S_{Cm}.

Let's limit our considerations to the case of a Star. At the end, the fusion in the Star must stop, after which the Star cools and contracts under the influence of its own gravitational field. If the mass M of the Star is greater than a critical value, General Relativity teaches us that the collapse can't be stopped. Having reached the Schwarzschild radius the body will continue to collapse, with all of its particles arriving at the centre within a finite time (which is very short compared with the lifetime of a black hole).

If there is antigravity, a radically different qualitative picture of the collapse inside the horizon may be expected. During the collapse, the surface of the contracting body passes through a succession of the critical surfaces defined by their critical radiuses (7). The production of $\nu_e \overline{\nu_e}$ pairs starts when the first critical surface ($R_{C\nu_e}$) is reached. If, for instance, the black hole is made from ordinary matter, produced neutrinos must stay confined inside the Schwarzschild sphere, while antineutrinos will be violently ejected because of gravitational repulsion. When the second critical surface is reached it is time for the beginning of the creation of $\nu_\mu \overline{\nu_\mu}$ pairs and so on following the series (7). In general, a black hole made of matter ejects antiparticles and just opposite to it, a black hole made of antimatter ejects particles.

By the way, let us note that an initially neutral black hole must inevitably become charged if the radius of the collapsing body is less than R_{Ce}, when (if made from ordinary matter) the black hole emits positrons and absorbs electrons from created pairs. So, at R= R_{Ce} a transition from the Schwarzschild metrics to Reissner- Nordstrom metrics may be expected. Of course the charge of the black hole changes in a complex way because, not only electrons, but other charged particles like protons should be absorbed (and antiprotons emitted). In principle a charged black hole is not expected to collapse to singularity. So, the electric charge of a black hole caused by gravitational repulsion between matter and antimatter is a possible mechanism to prevent the collapse predicted as inevitable by General Relativity

In principle, if the radius of the collapsing body (i.e. the black hole) is very small, pairs of very large mass may be produced. It is evident that the ultimate mass of the created pair equals the mass of the black hole. The question is at which critical radius, R_{Cm}, it may happen. After substitution $\lambda\!\!\!^{-}_m = \hbar / mc$ and $R_S = 2GM / c^2$ Equation (4) immediately gives

$$R_{Cm} = \sqrt{\frac{\hbar G}{c^3} \frac{M}{2m}} = L_P \sqrt{\frac{M}{2m}} \tag{8}$$

where L_P is the well known Planck length. So, in general the critical radius is proportional to the Planck length and in the ultimate limit $M=2m$ the critical radius is equal to the Planck length. If the collapse is not stopped earlier by other mechanisms, at $R_{Cm}=L_P$, the black hole will abruptly end its life emitting the same quantities of matter and antimatter (just as in a small copy of the big bang).

So, the Planck length appears in a simple and amusing way, as a universal length (independent of initial mass of the black hole) at which (if not stopped before by other mechanism), further gravitational collapse is prevented by a mini big bang. As, if the black holes prefer death to the prison called singularity.

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