A New Hypothetical Solution to Gravitational Singularities

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Abstract

An expected behaviour of space-time and matter within a black hole is postulated regarding a model based on the mathematical indications of other well-known and empirically confirmed theories, without invalidating such theories when applied where they correspond, and solving the mathematical problems such as the gravitational singularity and the information paradox.

What happens inside the event horizon of a black hole is unknown. General theory of relativity[1] describes with enormous precision almost all space-time regions we know, but when applied to the inside of a black hole, a gravitational singularity is suggested to appear, that is, a location where the gravitational field is predicted to become infinite, as well as the density of matter.

This kind of incoherences are usually considered wrong predictions, just like the forces of gravity between two particles that should increase exponentially to infinity when approaching at very small distances by the Newton's equation

$$\vec{F}_{12} = -G\frac{m_1 m_2}{r_{21}^2}\hat{r}_{21}$$

This equation, which does not give us wrong predictions when applied to the correct cases, certainly presents many indications of how does matter behaves in the general relativity. We will study the indications of Newtons equation for a special case: two equal but negative masses.

Following the equation, both negative signs in the masses are cancelled and we obtain the traditional forces of the same value, equal direction and different sense (attractive) for every particle. The Newtons acceleration equation

$$\vec{a} = \frac{\vec{F}}{m}$$

results in equal accelerations, in the same direction, but different (repulsive) sense, taking into account the negative of the inertial mass for each particle. This indicates that both particles would experience a repulsive effect, equivalent to antigravity, in a way that the conjecture of the weak principle of equivalence holds (a negative mass would have the same gravitational and inertial mass).[2]

Problem arises when applying this development to two particles of different mass signs. The results are two accelerations in the same direction, which implies that both particles would accelerate, one chasing each other, infinitely or at least up to the speed of light, together with paradoxes like perpetual motion machines or infinite energy sources.

To adequate the Newton's law to this case, we should take a more universal approach about what negative mass should look like in our universe. If a negative mass is predicted to cause an antigravitational effect, general relativity would interpret it as a deformation of space-time in the opposite sense that a positive mass does. Unlike the cases of two equal masses with equal sign, which would deform space in the same sense and have equal time coordinates, this case involves two different time intervals or time distances for each particle (one in the past and one in the future respectively). In the common and not physically precise example of extrinsic space-time curvature, a negative mass would be visualized as a curvature towards the other side of usual deformations, and even though the deformations should extend to infinite space, there would always be a zero-curvature line between the particles. We should consider then the difference in full space-time coordinates by using the space-time interval

$$(\Delta s)^2 = (\Delta ct)^2 - (\Delta x)^2 - (\Delta y)^2 - (\Delta z)^2$$

and for only one difference in space dimensions between the particles

$$(\Delta s)^2 = (\Delta ct)^2 - (\Delta x)^2$$

that can be zero for some cases, such as trajectories for light, which applied to our case (Figure 1.)

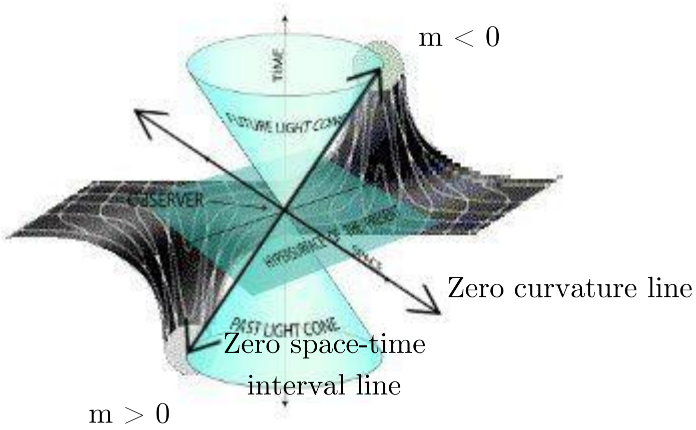

Fig.1. Coinciding light trajectories with relative particle-antiparticle positions, with a line of zero curvature in between (notice particles should be considered objects of greater mass and volume to avoid quantum theory problems of uncertainty)

it would lead to a result without the mathematical singularity that arises when considering only distances with the absolute time that Newton supposed when applied to the equation for the force of gravity, resulting in

$$F_{12} = -G\frac{m_1 m_2}{(\Delta s)^2} \quad *$$

which gives us a zero value of force, and consequently zero acceleration, that is, no interaction between the particles. A deeper inside on this clue would make us imagine that the gravitational force between these two particles would be equal to the force generated by the difference of mass, been repulsive or attractive depending on the sign of the net mass It is suggested that this antigravitational effect would be consistent with the model if the negative mass particle inside a curved space-time by ordinary matter would be following the traditional paths, even though there would be a very small counter curvature effect due to the small mass of the negative mass particle.

The existence of negative masses is not prohibited by general relativity[3], and it is consistent with the theory and its proven application since it was discovered (if the space-time we know is vastly surrounded by ordinary particles). It is suggested that antimatter's negative energy solution from Dirac's equation

$$\psi = u(E,\vec{p})e^{i(\vec{p}.\vec{r}-Et)}$$

taking into consideration the time dependence with p=0

$$\psi = u(E,0)e^{-iEt}$$

with solution for negative energy

$$E = -mc^2 \text{; with } c=1\text{; } E = -m$$

(notice the negative inertial mass or rest mass,), gives us two spinor states

$$\psi_3 = \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} e^{+imt}; \text{ and } \psi_4 = \begin{pmatrix} 0 \\ 0 \\ 0 \\ 1 \end{pmatrix} e^{+imt}$$

that can be interpreted as a negative energy solution with negative time (particles moving backwards in time), following the Feynman-Stueckelberg interpretation[4] with p≠0

$$\begin{aligned} v_1(E,p)e^{-i(Et-\mathbf{x}\cdot\mathbf{p})} &= u_4(-E,-p)e^{i(Et-\mathbf{x}\cdot\mathbf{p})} \\ v_2(E,p)e^{-i(Et-\mathbf{x}\cdot\mathbf{p})} &= u_3(-E,-p)e^{i(Et-\mathbf{x}\cdot\mathbf{p})} \end{aligned}$$

$$Et - \boldsymbol{p}\cdot\boldsymbol{x}$$

$$\begin{aligned} -E &\rightarrow E \\ t &\rightarrow -t \\ \boldsymbol{p} &\rightarrow -\boldsymbol{p} \end{aligned}$$

(antimatter would have positive energy and positive mass in a positive time universe and negative energy and negative mass in a negative time universe, due to the non-symmetrical time transformation, consistent with positive energy results of antiparticle-particle annihilation) could be a real physical solution.[5] The change in the sign of time is the key point for relating this case to black holes, and the change in the sign of momentum will also be discussed for this particular case.

It is said that moving in space becomes partially moving in time inside a black hole. A better explanation is given by the solution to the Einstein's field equations by the Schwarzschild metric[6]

$$ds^2 = -c^2 d\tau^2 = -\left(1-\frac{r_s}{r}\right)c^2dt^2 + \frac{dr^2}{1-\frac{r_s}{r}} + r^2\left(d\theta^2 + \sin^2\theta\, d\varphi^2\right) \quad r_s = \frac{2GM}{c^2}$$

in a way in which substituting and simplifying we obtain

$$ds^2 = -\left(1-\frac{2GM}{c^2r}\right)(\mathrm{c}dt)^2 + \left(1-\frac{2GM}{c^2r}\right)^{-1}\mathrm{d}r^2 + r^2d\Omega^2$$

so that, for $r < r_s$ (Schwarzschild radius), the terms $\left(1-\frac{2Gm}{c^2r}\right)$ turn to be negative, and by that change, dt changes its sign to positive. The sign of space is changed as well, but only its radial component, not its angular or orbital, and so, partially.

This change in the sign for the time coordinates (not the classical time evolution)[7] will indicate that particles inside the black hole would behave as if they were antiparticles, and matter as antimatter, with antigravitational interactions. Supposing matter inside a black hole behaves as antigravitational antimatter does not imply any other problems, because both sides of this divided space time would never be in contact (no annihilation would occur), and changing all the particles charge would result in no change for a neutrally charged black hole (the common assumption for real black holes), and if not, its flipped charge in contrast to what surrounds it and was created by, could be measured and taken as a possible evidence for the model. With a mostly antigravitational space-time, no infinite density volumes could form because of the repulsive force growing exponentially when trying to create very big density volumes of mass, so we would be looking at a solution for gravitational singularities, and also a solution without the disappearance of physical information (information paradox).[8] Also, the common need of changes in coordinates for the event horizon would indicate the parity transformation, required for the inside of the black hole to be rotating in the same direction as the outside when reversing time,[9] (pt transformation equivalent to the inversion of the Kruskal-Szekeres coordinates)[10] and Eddington-Finkelstein coordinates from (t, r, θ, ϕ) to (v, r, θ, ϕ)

$$ds^2 = -\left(1 - \frac{2M}{r}\right) dv^2 + 2dvdr + r^2 d\Omega_2^2$$

$$ds^2 = \left(1 - \frac{2M}{r}\right) du^2 - 2dudr + r^2 d\Omega_2^2$$

(time independent) are ignored because of their prediction of a singularity and their assumption of radial null coordinates until $r = 0$ which contradicts the hypothesis of the non-existence singularity by not considering the antigravitational behaviour of matter within the black hole (notice that the Schwarzschild metric is also not applied at $r < 2M$ but just used as an indicator). The theoretical questions of why does the stellar mass of the original star that formed the black hole becomes the mass of the black hole, or where does the mass of the black hole come from, with the problem that arises when considering that mass the one compacted in the singularity, are also easily answered with this model (its mass would be the mass inside the space-time within the event horizon, understood as positive mass from outside it). For obtaining the same gravitational results outside the event horizon, the mass-energy distribution within the black hole should follow Saint-Venant's principle: the difference between the effects of two different but statically equivalent loads becomes very small at sufficiently large distances from load.[11] (Figure 2.)

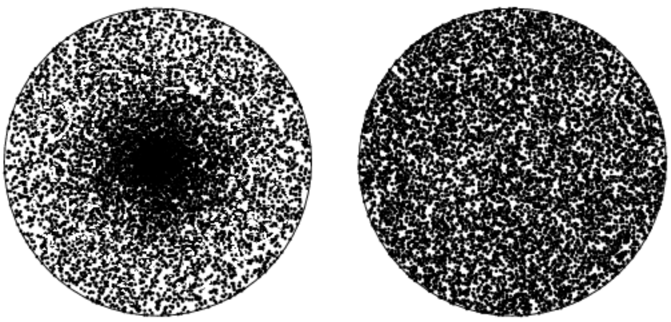

Fig. 2. Singularity and antigravitation 2D models of mass-energy distribution for Saint-Venant's principle to hold (if not, it would be possible to measure such difference)

Another consequence of the solution is that space in the inside of a black hole should be changing in size, just like ordinary space does. We have a clue about what causes a black hole to change in size, not only the mass absorbed that makes it grow, but also the quantum fluctuations in empty space by the Hawking radiation that makes it shrink or even evaporate. If so, it would be the energy of space the one closely related to the evolution of space-time inside the black hole, and so outside it, just like the dark energy hypothesis points at the fluctuations of empty space as the reason for the accelerated expansion of the universe. The existence of a white hole at the other side of the black hole is an assumption of the model, plausible according to the mathematics of general relativity regarding white holes (i.e. their existence is not prohibited in the universe, and their no-observational evidence would be explained if they would only exist at the other side of black holes), and consistent with the accepted idea of a white hole been a “time-reversed” black hole, with entropy related problems (second law of thermodynamics) of this entity solved when considering the reversed time in which exists.

Even though common sense is the least indication for a model of this nature to be grounded, the author makes an invitation to think that if the “flow of time” is approaching zero when getting close to the event horizon for an external observer, and “the flow of time” stopping at the right edge, then in the other side we should not think of the “flow of time” as a continuation of been stopped, but to begin reversing in the opposite sense (time transformation) (Figure 3). This thought experiment helps to understand the real phenomena of the hypothesis. The change in parity might as well help the inflation or bounce of space within the event horizon, considering an initial high kinetical energy star or full momentum space of the matter within. Thus, the event horizon would not be more than the place in space in which time begins to move backwards, and the asymmetry of that transformation within the laws of physics should be taken into account when describing the inside of a black hole.

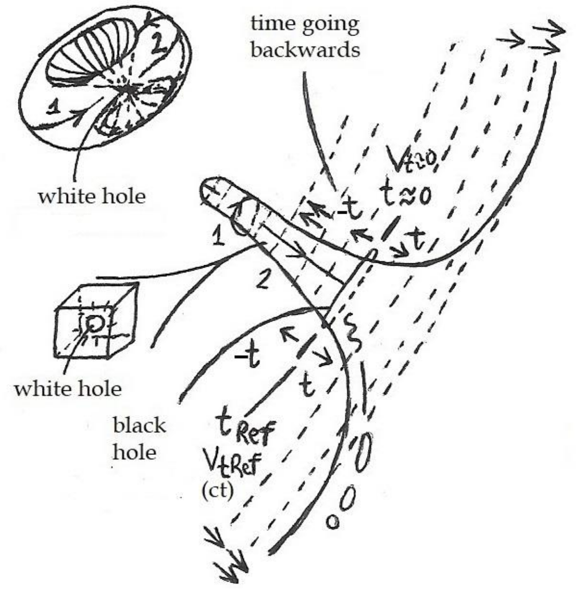

Fig. 3. A visualization of the hypothesis by the approximated model of extrinsic curvature representation with space dimensions reduced to 2D surfaces and a space-time shape is proposed following what a region like that, with a white hole and antigravitational matter inside, would be shaping the space-time according to what its been explained together with the rest of physical phenomena, such as expansion or contraction, developing like in the well-known outer space-time.

Conclusions:

This paper shows multiple mathematical hints which suggest that a parity-time (pt) transformation takes place when crossing the event horizon of a black hole, equivalent to a charge transformation, and that matter inside might behave as antimatter with negative energy corresponding to negative mass, which would interact antigravitationally, solving all questions, paradoxes and mathematical singularities that arise from the study of these astrophysical entities.

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