A New Hypothetical Solution to Gravitational Singularities

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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.

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 in 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 incoherencies are usually considered as 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 Newtons 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 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 Newtons 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 make an antigravitation 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. We should consider then the difference in full space-time coordinates by using the space-time interval:

$$\Delta s^2 = -c^2 \Delta t^2 + \Delta x^2 + \Delta y^2 + \Delta z^2$$

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, 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:

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

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. This physical phenomenon has not been detected due to the difficulties of measuring such small gravitation effect of the small mass of the created matter in experiments. The author suggests that this antigravity effect would be consistent with the model if this 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 because of the small mass of the particle.

Now we may wonder where does this negative mass come from. 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;

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

with solution for negative energy with p=0;

$$E_0 = -mc^2$$

(notice the negative 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 positive energy with negative time (particles moving backwards in time), following the Feynman-Stueckelberg interpretation[3]:

$$\begin{aligned} v_1(E,p)e^{-i(Et-\mathbf{x}\cdot\mathbf{p})} &= u_4(-E,-p)e^{i(Et-\mathbf{x}\cdot\mathbf{p})} \\ v_2(E,p)e^{-i(Et-\mathbf{x}\cdot\mathbf{p})} &= u_3(-E,-p)e^{i(Et-\mathbf{x}\cdot\mathbf{p})} \end{aligned}$$ with p≠0;

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

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

The change in the sign of time will be the key point for relating this case to black holes.

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[4]:

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

in a way in which substituting and simplifying we obtain;

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

so that, for $r < r_s$ (Schwarzschild radius), the terms $\left(1 - \frac{2Gm}{c^2 r}\right)$ turn to be negative, and by that change, dt^2 changes its sign to positive (space also, but only its radial component, not its angular or orbital, and so, partially). This change in the sign for the time coordinates will indicate that particles inside the black hole would behave as if they were antiparticles, and matter as antimatter, with antigravitational interactions. Changing time and changing the nature of the matter to antimatter would result in the same behavior as the case with no changes, so notice there is only one change, so the particles would interact antigravitationally between them. Supposing matter inside a black hole behaves as 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 (if needed to fit the model) would result in no change for a neutral charged black hole (the common assumption of 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 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.

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 around us. But 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 disappear. [5] 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 point 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, perfectly possible with the mathematics regarding white holes (its existence is not prohibited in the universe).

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" stops 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. Thus, the event horizon, would not be more than the place in space in which time begins to move backwards.

A visualization of the hypothesis by the approximated model of extrinsic curvature representation with space dimensions reduced to 2D surfaces would look like Figure 1., and a space-time shape is proposed (Figure 1.11) 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.

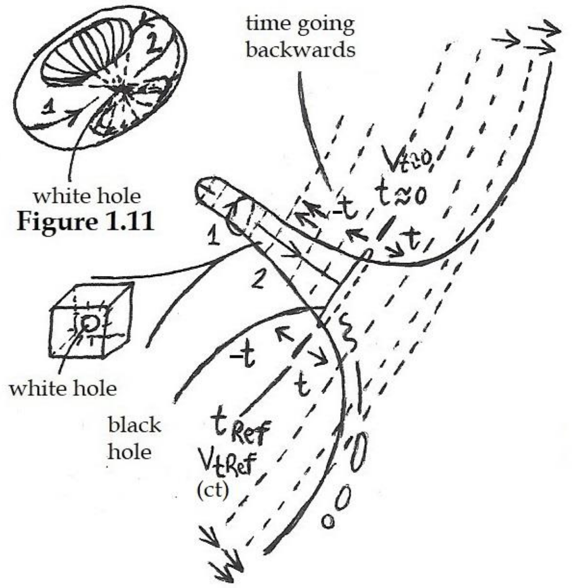

Figure 1.

References:

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[2] J. S. Farnes, *A Unifying Theory of Dark Energy and Dark Matter: Negative Masses and Matter Creation within a Modified ΛCDM Framework,* (2018)

[3] Lancaster, Tom; Blundell, Stephen J.; Blundell, Stephen*, Quantum Field Theory for the Gifted Amateur,* (2014)

[4] K. Schwarzschild, *Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie*, Sitzungsber. Preuss. Akad. Wiss. Berlin, pp.189-196, (1916)

[5] S. W. Hawking, *A Brief History of Time,* Bantam Dell, (1998)