ON THE CONNECTION BETWEEN MASS AND SPACE

By E. VAN BRUMMELEN

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Abstract

In this paper we look at the connection between mass and space. We start with postulating that there is only space. Then we derive what mass stands for. It appears that what we call mass is equal to the surface area of a black hole. The unit kg transforms into m^2. We find equation $R = c^2 / G$ describing the size of the universe. Constant G transforms into a 'universal acceleration' with units m s^{-2}. Rewriting the equation as $G = c^2 / R$ tells us that the universe has an inherent 'rotational' aspect and therefore gives rise to a coriolis force. The latter force might be the reason for galaxies having spiral arms. We show that the universe has an associated time scale $T = c / G$ and that its mass is defined by equation $M = c^4 / G^2$. Furthermore we show that the 'planck length' and Heisenberg's uncertainty principle are connected to the size of the universe and we argue that energy is quantized with levels defined by equation $E(n) = n\, h\, G / c$ where $E(1) = h\, G / c$ is the zero-point energy. We show that the photon might have a defined volume. And finally we derive a value for the total amount of energy packets in the universe and show that the vacuum energy density is given by the equation $\rho(E) = G$.

Introduction

General relativity is a theory describing the relation between spacetime, matter and radiation. It assumes that matter is something separate from space. What if matter is not separate from space but is made of space itself?

The reason for asking this question is unification. If we want to unify we have to take apparently different things and bring them together, discover them as fundamentally being the same thing. The approach will be top down. Start with only one thing, and derive everything else from it. This process has the advantage of implicit unification. We will use space as our fundamental starting point and then explore how we can derive mass from space. The top down path should, at some point, connect with real world physics, in this case general relativity. The paper is written in a compact 'computer code' style, with only sparse comments. At a certain point in this paper I decide to leave out numerical factors like 2, 4, π, etc. This is for readability. The reader should be aware of this. The reader is invited to follow the train of thought, with focus on the general picture rather than the last digit. Specifically the reader is asked to thoroughly contemplate the step where mass is redefined. That is the key point of this paper.

Main

To start we postulate

1. There is only space[1]

Now we have to derive everything else from space. After pondering over this we take the next step by declaring that space can have different 'configurations'. At this point there are no units. Later on, any unit we know and use in real world physics, like seconds, meters or kilograms should be an expression of space. In this paper we focus on deriving mass from space, and what the unit kilogram means in terms of space. We will accept meters and seconds as units without further explanation[2]. The only thing we can postulate at this point is

2. Mass is a specific configuration of space

What configuration does space have when it is denoted as mass? Here we look at general relativity and the predicted existence of black holes. Black holes might hold a key.

A black hole will be formed after a neutron star collapses. The collapsed neutron star had a certain size and a certain mass. The black hole retains the mass, but in a much smaller size, as if all unnecessary space has been ejected. If we heuristically assume that black hole space is completely configured as mass[3], nothing else, then we can postulate

[1] It implies that things like mass, time, charge, spin have to be derived from space
[2] These will be treated in separate papers
[3] This might have a relation with the no-hair theorem [1]

3. A black hole is a region of space purely configured as mass

A region of space has a volume. And a volume has a surface. This surface encloses the volume and it defines the volume. Therefore in the case of a black hole which consists of space purely configured as mass, its surface, which defines its volume, should also define the mass. We postulate

4. The surface area of a black hole defines its mass

A black hole has an associated radius called the Schwarzschild radius from within this radius no light can escape, hence 'black hole'. This radius depends on mass m of the black hole as follows [2]

$$r_s = 2\,G\,m\,/\,c^2 \quad (1)$$

We are looking for a way to express mass in terms of space. Here we arrive at that point. Using postulate 4 we attach *the label mass* to the surface area of the black hole to see what happens, to see if it 'connects' with real world physics, to see if it makes sense. We associate the mass of the black hole with its surface area as follows

$$m = 4\,\pi\,r_s^2 \quad (2)$$

The consequence of this choice is that the <u>unit kg transforms into m^2</u>. Inserting (2) into (1) we get

$$r_s = 2\,G\,4\,\pi\,r_s^2\,/\,c^2 \quad (3)$$

Rearranging (3) we find the following equation

$$r_s = c^2\,/\,(8\,\pi\,G) \quad (4)$$

With $c = 3 \times 10^8$ m s^{-1} and $G = 6.7 \times 10^{-11}$ m^3 kg^{-1} s^{-2} (m s^{-2}) we find

$$r_s = 5.4 \times 10^{25} \text{ meters}$$

This number has the same order of magnitude as the size of our observable universe[4]. The result 'connects' to the real world in the way that it coincides with the value for the size of the universe. It is not easy to explain why the local Schwarzschild equation (1) 'flipped' to a universal scale. But we see that by expressing mass in terms of space, equation (1) transforms into (4) which seems to reveal something about the universe as a whole, pointing to *a universal relation between G, R and c*. Interestingly G has transformed into a 'universal acceleration' as its new units are m s^{-2}.

From this point on <u>I will leave out numerical factors like 2, 4, π, etc</u>. This is to have more clarity regarding the relations between G, R, c, etc. The reader should be aware that calculated values are therefore not exact but are for illustrative purposes, with the focus being the order of magnitude rather than the last digit.

Equation (4) with R in place of r_s becomes elegant as follows

$$R = c^2 / G \quad (5)$$

$$R = 1.3 \times 10^{27} \text{ meters}$$

Equation (5) is static. Would it be dynamic, as in e.g. a 'big bang' scenario where R is variable, then it would imply that G and/or c also vary over time[5].

Another observation arises when we rearrange (5) as follows

$$G = c^2 / R \quad (6)$$

Equation (6) seems to indicate the universe having *an inherent 'rotational' aspect*, as it has the exact same form as the equation for centrifugal force.

In a closed universe, a photon, flying through the universe, eventually would end up at its starting position, and thus would have flown a circle. Equation (6) suggests G being an inherent universal centrifugal force felt by all photons.

Furthermore when there is a rotating system, there is not only a centrifugal force but also a coriolis force. The coriolis force, inherent to the universe, scales with c / R. This inherent universal coriolis force might be the reason why galaxies like Andromeda and the Milky Way have spiral arms. It is no coincidence that hurricanes and galaxies look the same because both result from a coriolis force.

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[4] Which is currently estimated at 4.4x10^26 meter

[5] It should be noted that time itself is an expression of space as per postulate 1

Extra

With constants c and G we can construct a time scale for the universe as follows

$$T = c / G \quad (7)$$

$$T = 4.5 \times 10^{18} \text{ seconds (around 142 billion years)}$$

From (5) we can extract an equation for the smallest possible packet of energy in the universe. We start with defining the longest wavelength of a photon possible in the universe

$$\lambda = R \quad (8)$$ [6]

The associated energy is

$$E = h\,c / \lambda \quad (9)$$

Substituting (8) in (9)

$$E = h\,c / R \quad (10)$$

Substituting (5) in (10)

$$E = h\,G / c \quad (11)$$

With $h = 6.6 \times 10^{-34}$ kg m^2 s^{-1} (m^4 s^{-1}) we find the smallest possible packet of energy to be

$$E = 1.5 \times 10^{-52} \text{ Joule}$$

This energy is the zero-point energy[7]. This energy represents an amount of mass by the famous Einstein relation

[6] As a reminder, we have left out 2π, like any numerical constant, as mentioned before
[7] Nullpunktsenergie

$$E = mc^2 \quad (12)$$

Equating (11) and (12)

$$hG/c = mc^2 \quad (13)$$

Rearranging (13)

$$m = hG/c^3 \quad (14)$$

We find the smallest possible mass to be

$$m = 1.6 \times 10^{-69} \text{ kilogram}$$

When we regard this mass as being a black hole as per postulate 3 and 4, we can transform m into r by substituting (2) into (14)

$$r_s^2 = hG/c^3 \quad (15)$$

Rearranging (15)

$$r_s = \sqrt{hG/c^3} \quad (16)$$

The radius of this black hole turns out to be equal to the planck length [3]. The derivation provides the planck length with a real world meaning. *The planck length is directly related to the longest wavelength possible in the universe*. No lower energy packet is possible because its associated wavelength doesn't 'fit' in the universe. Therefore no lower associated mass is possible and therefore no smaller associated black hole is possible.

Although this black hole can't get smaller because it can't radiate longer wavelengths, it might evaporate by becoming a photon with a wavelength which exactly fits the universe. This poses an interesting question. How does the black hole 'know' what the maximum wavelength is? If the black hole can't radiate energy below a certain limit this implies it has to 'know' how big the universe is. This implies 'instantaneous knowledge' of the universe. In other words, information faster than lightspeed.

If we regard the universe itself as being a black hole[8] with mass M and insert its 'radius' R into equation (1) we get

$$R = G M / c^2 \quad (17)$$

Substituting (5) in (17)

$$c^2 / G = G M / c^2 \quad (18)$$

Rearranging (18)

$$M = c^4 / G^2 \quad (19)$$

We find the mass of the universe to be

$$M = 1.8 \times 10^{54} \text{ kilogram}$$

Alternatively we could use (2) to arrive at the same result

$$M = R^2 \quad (20)$$

Substituting (5) in (20)

$$M = c^4 / G^2 \quad (21)$$

Let us go back to the idea of the longest wavelength possible in the universe as written in equation (5). We can generalize this to the following quantized version

$$n \lambda_n = R \text{ with } n = \{ 1 , 2 , 3 , \ldots \} \quad (22)$$

The relation between wavelength λ and frequency ν is given by

$$c = \lambda \nu \quad (23)$$

Substituting (23) into (22) and rearranging give the possible frequencies ν_n as

[8] No radiation can escape from our universe

$$\nu_n = n\, c \,/\, R \quad \text{with} \quad n = \{ 1 , 2 , 3 , \ldots \} \qquad (24)$$

Substituting (5) into (24) gives

$$\nu_n = n\, G \,/\, c \quad \text{with} \quad n = \{ 1 , 2 , 3 , \ldots \} \qquad (25)$$

The difference between a certain frequency and the next one is given by

$$\Delta\nu = \nu_{n+1} - \nu_n = G \,/\, c = c \,/\, R \qquad (26)$$

This is *a fixed value*

$$\Delta\nu = 2.2 \times 10^{-19} \text{ hertz}$$

The energy of a photon is given by $E = h\,\nu$ which together with (24), (25) and (26) implies that energy comes in discrete levels, i.e. *energy is quantized*. The smallest separation is given by $\Delta E = h\,\Delta\nu$ which is associated with the longest wavelength possible in the universe. Energy levels are given by

$$E_n = n\, h\, G \,/\, c \quad \text{with} \quad n = \{ 1 , 2 , 3 , \ldots \} \qquad (27)$$

$E_{n=1}$ is the zero-point energy as we saw before in equation (11).

The energy of a photon can be expressed in two ways. Using frequency as in $E = h\,\nu$ and using momentum as in $E = p\,c$ which combined give

$$p = h\,\nu \,/\, c \qquad (28)$$

Introducing delta 'step' Δ into (28) gives

$$\Delta p = h\,\Delta\nu \,/\, c \qquad (29)$$

Substituting (26) into (29) gives

$$\Delta p = h \,/\, R \qquad (30)$$

Location x of a photon can be anywhere in the universe

$$\Delta x = R \quad (31)$$

Substituting (31) into (30) gives

$$\Delta p = h / \Delta x \quad (31)$$

Rearranging (31) gives the equation for Heisenberg's uncertainty principle [4]

$$\Delta p \, \Delta x = h \quad (32)$$

Finally we examine the planck constant h

$$h = 6.6 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}$$

As we have seen earlier, the unit kg transforms into m^2. So h has units $m^4 \, s^{-1}$. We can rewrite this as $m^3 \, m \, s^{-1}$ which is volume × speed. If we take c to represent the speed then we can find an associated volume and, in case the volume is a sphere, a radius are as follows

$$h = V c = r^3 c \quad (33)$$

Rearranging (33)

$$V = h / c \quad (34) \qquad\qquad r = \sqrt[3]{h / c} \quad (35)$$

$$r = 1.3 \times 10^{-14} \text{ meter}$$

What is the real world interpretation of this volume and the radius? Is this a 'sphere of influence' of a photon? After all, the photon is often regarded as a wave-packet with a finite size as if it were a particle. Yet, the volume might not be a sphere. It might depend on the frequency. It could be stretched in one direction to accommodate for the wavelength, and therefore shrink in the other directions so that the total volume remains constant according to (34).

Now let us consider the universe being only one photon. Then (34) would apply for this one photon

$$V_1 = h_1 / c_1 \quad \text{with} \quad V_1 = h_1 = c_1 = 1$$

If the universe would consist of two photons, each photon would have a volume V_2 given by

$$V_2 = h_2 / c_2$$

And the universe would have a volume V_U given by

$$V_U = 2\, V_2$$

If the universe would consist of N photons we get

$$V_N = h_N / c_N \quad (36) \quad \text{and} \quad V_U = N\, V_N \quad (37)$$

In our 'N universe' with radius R we have values for constants G, c, h, etc. These constants however are not constant in the absolute sense. They depend on the size of the universe, thus on the value of N. We can associate a value N with these constants using (36) and (37) as follows

$$V_U = R^3 = N\, h / c \qquad (38)$$

Substituting (5) in (38) gives

$$(c^2 / G)^3 = N\, h / c \qquad (39)$$

Rearranging (39) gives

$$N = c^7 / (h\, G^3) \quad (40)$$

$$N = 1.1 \times 10^{123}$$

This is the total number of energy packets in the universe if all packets would break up into the smallest energy packet possible. The packet density ρ_N is

$$\rho_N = N / V_U = c / h \quad (41)$$

With energy E of one packet given by (11), the energy density ρ_E becomes

$$\rho_E = E\,\rho_N = h\,G / c \cdot c / h \quad (42)$$

Rearranging (42) gives

$$\rho_E = G \quad (43)$$

As per postulate 1 this energy density is not something in space but space itself waving. It is the basic configuration of space. A vacuum energy in the form of a 'sea of waves' with wavelengths defined by equation (22) and an energy density defined by equation (43). G is everywhere.

Closing remarks

I will pose the following thought experiment to the reader. Imagine the universe only containing one matter particle. What happens to that one particle if we remove space? … (after pondering over this for a while, the reader is invited to go back to postulate 1)

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Contact: evertvanbrummelen@gmail.com

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