On the Origin of Mass

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Abstract

Mass is caused by fields of elementary particles that are able of creating cavities at their center. Another cause is the presence of a different geometric anomaly such as a black hole.

The origin of mass

Geo-cavities

Geo-cavities are geometrical abnormalities in the form of holes in the local geometry of a (pseudo)-Riemannian manifold.

A Riemannian manifold [1]is a real differentiable manifold in which each tangent space is equipped with an inner product, a Riemannian metric, which varies smoothly from point to point. On a pseudo-Riemannian manifold[2] the metric tensor need not be positive-definite. Instead a weaker condition of non-degeneracy is imposed.

The environment of a geo-cavity is described by a metric. The value of the metric depends on a selected coordinate system. Spherical geo-cavities require that the local geometry is specified using spherical coordinates.

Inside the hole no coordinates exist. Thus, the coordinates must circumvent the geo-cavity.

As a consequence, geo-cavities are surrounded by a very strong local curvature that follows the skin of the geo-curvature.

Nothing is present inside a geo-cavity. A quaternionic probability amplitude distribution[3] (QPAD) can be interpreted as the combination of a charge density distribution and a current density distribution. The squared modulus of this QPAD is a distribution of the presence of

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[1] http://en.wikipedia.org/wiki/Riemannian_manifold
[2] http://en.wikipedia.org/wiki/Lorentzian_manifold
[3] http://www.crypts-of-physics.eu/OriginOfPhysicalFields.pdf

the load of properties that the QPAD transports. Thus QPAD that is defined in the neighborhood of the geo-cavity goes to zero when its parameter approaches the geo-cavity.

Information can neither enter nor leave the geo-cavity.

Geo-cavities have a skin and that skin has an area.

All geo-cavities have a virtual mass. This mass relates to the area of its skin.
The curvature in the surround of the geo-cavity corresponds to a gravitational potential that depends on the mass of the geo-cavity.

When the area of the skin is large enough, then a geo-cavity has entropy. In that case the entropy is proportional to the area of its skin. Entropy has an integer value. The unit of entropy is set by Boltzmann's constant.

Geo-cavities may have electrical charge. This charge corresponds to an electrostatic potential. Electric charge has an integer value. The unit of electrical charge is fixed. Some elementary particles (quarks) have a charge which is ⅓ or ⅔ of that unit value.

The metric is a function of the properties of the geo-cavity.

Geo-cavities generate a gravitation field and when appropriate a Coulomb field. Both fields are administrators. The gravitation field administers the curvature that corresponds with the metric. The Coulomb field administers the scalar and vector potential that is caused by the electric charge.

Reference coordinates

The situation can be described by two coordinate systems. One is a flat reference system the other is mostly flat, but it can locally be strongly curved. The reference system can be used to locate the center of the geo-cavities. The values of the curved coordinate system are used as positioning parameters.

Categories of fields

Two categories of fields exist.

Primary fields

The first category consists of quaternionic probability amplitude distributions (QPAD's). The QPAD's may overlap and through this superposition they may form covering fields. The QPAD's exist in four sign flavors. The same holds for the covering fields. The QPAD's may interact. When different sign flavors interact the strength of the local interaction is characterized by a coupling factor. The members of this category will be called primary fields.

Secondary fields

The second category consists of administrator fields. These fields administer the effect of interactions on the local curvature of the positioning coordinate system. For all properties that characterize a coupling of sign flavors of primary fields an administrator field exist that registers the influence of that property during interactions on the local curvature.

One of these administrator fields is the gravitation field. It administers the influence of the strength of the coupling between sign flavors of primary fields on the local curvature. The electromagnetic fields administer the influence of the electric charge on the local curvature.

The angular momentum including the spin also influences the local curvature. Also this effect is administered

The members of this category will be called secondary fields or administrator fields.

Classes of geo-cavities

Several classes of geo-cavities exist.

One class of geo-cavities is generated and supported by a set of shearing fields. These fields are quaternionic probability amplitude distributions (QPAD's). Their squared modules are probabilities density distributions that describe the probability of the presence of a load of properties that characterize the set of coupled fields. We indicate the density distribution of the probability of presence with the shorthand DDPP. Inside the skin of the geo-cavity the DDPP does not exist and on approach of the skin the DDPP goes to zero.
The elementary particle geo-cavities share their properties with the fields that generate and support them. However, the geo-cavities generate the gravitation field and the Coulomb field. Both fields are administrators.

Another class of geo-cavities is formed by the black holes. The event horizon of the black hole forms the skin of the geo-cavity.

As an alternative to the Big Bang, the start of the universe can also be thought to be implemented by a start-cavity.

Elementary particles

The equation of motion of an elementary particle is a continuity equation. It means that describing the motion of elementary particles is in fact a streaming problem. The general form of the equation of free motion of a massive elementary particle is[4]:

$$\nabla\psi^{\mathrm{x}} = m\,\psi^{\mathrm{y}} \tag{1}$$

Here the quaternionic nabla operator is the transporter. ψ^{x} is the transported quaternionic field sign flavor[5]. ψ^{y} is the coupled quaternionic field sign flavor and m is the coupling factor. The ordered pair $\{\psi^{\mathrm{x}}, \psi^{\mathrm{y}}\}$ identifies the quantum type. The field configuration determines the coupling factor.
The coupling factor m follows from:

(2)

[4] http://www.crypts-of-physics.eu/EssentialsOfQuantumMovement.pdf
[5] Quaternionic fields have sign flavor. Elementary particles have flavor. http://en.wikipedia.org/wiki/Flavour_(particle_physics)

$$\int_V (\psi^{y*} \nabla\, \psi^x)\, dV \;=\; m \int_V (\psi^{y*}\, \psi^y)\, dV \;=\; m \int_V |\psi^y|^2\, dV = m\, g$$

The two fields shear. At the location of the sign switch the fields produce a geo-cavity. The size of this geo-cavity is determined by the strength of the coupling factor m.
This geo-cavity is surrounded by a curvature of the geometry that is so strong that information cannot pass the skin of the geo-cavity. Outside of the geo-cavity the curvature follows a pattern that corresponds to the rest mass of the particle.
The gravitation field administrates this curvature[6].
The surround of the geo-cavity is described by a metric, which is a function of the properties of the ordered pair $\{\psi^x, \psi^y\}$. Many of these properties are combined in the "charge" that is transported by the field ψ^x. These properties are:

- The coupling factor m
- The electric charge.
- The color charge.
- The spin.

The coupling factor and the electric charge are isotropic properties.
The color charge and the spin are anisotropic properties.
The coupling factor and the spin are integral properties.

The geo-cavity that is produced by an electron does not have the Kerr–Newman metric that characterizes black holes. Already the structure of the pair of field sign flavors that surround the geo-cavity differs from the structure of the EM field that is supposed to surround a charged black hole.

The heaviest top quark has a mass of 177 $\mathrm{GeV/c^2}$
In physics, the Planck mass (m_P) is the unit of mass in the system of natural units known as Planck units[7]. It is defined as

$$\mathrm{m_P} = \sqrt{\frac{\mathrm{h\,c}}{\mathrm{G}}} = 1.2209 \times 10^{19}\ \mathrm{GeV/c^2} \;=\; 2.17651(13) \times 10^{-8}\ \mathrm{kg} \tag{3}$$

The Planck mass is approximately the mass of the Planck particle[8], a hypothetical minuscule black hole who's Schwarzschild radius equals the Planck length.

$$\mathrm{l_{Pl}} = \sqrt{\hbar G/c^3} \;=\; 1.6 \cdot 10^{-35}\ \mathrm{m}. \tag{4}$$

The Planck mass is the smallest possible mass for an observable black hole.
This also leads to the conclusion that the elementary particle geo-cavity differs from the black hole geo-cavity.

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6 http://www.crypts-of-physics.eu/TheCauseOfGravitation.pdf
7 http://en.wikipedia.org/wiki/Planck_units
8 http://en.wikipedia.org/wiki/Planck_particle

The elementary particle geo-cavity cannot be limited by the Plank mass. At a significant distance from its skin it must still deliver the proper curvature and the corresponding gravitation field. This means that the elementary particle geo-cavity is a pure classical geo-cavity. On radii below the Planck scale the curvature k is specified by the strictly geometric formula:

$$k = 1/r^2 \tag{5}$$

The elementary particle geo-cavity is considered to have a radius defined by:

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

The radius is far below the Planck length.

Black holes

When considered as an observed item, a black hole fulfills the specification of a geo-cavity[9.]
The main difference with the usual notion of a black hole is that a geo-cavity is per definition empty. Within its skin nothing is present. A black hole is surrounded by a very strong curvature field such that information can no longer pass the skin of the hole. Therefore the hole can as well be completely empty. What happens to the material that is sucked up by the black hole? Well, that will be ripped apart into its smallest possible parts. Part of the debris is used to widen the skin of the hole. The other part escapes from the absorption process and is reflected back. The hole gets bigger, but that only becomes visible via the enlargement of the skin. The surface of the skin gives an indication of the mass, which the hole represents. The curvature around the black hole is in correspondence with this mass. However, the hole itself is empty.

The black hole fulfills the definition of a geo-cavity. However, it is a rather large one.

The skin of the black hole can be seen as a collection of ground states of absorbed particles. Each of these ground states occupies a very small part of the surface and each represents a minimum amount of information. In this way is the entropy of a black hole relates to the surface of the skin.

Black holes fulfill the no-hair theorem[10].

The surround of a black hole is described by a Kerr-Newman metric[11.]

The start cavity

At its start the universe may have consisted of space that was empty except for a large geometric abnormality. It was a geo-cavity with nothing outside its skin and nothing inside its skin.

The skin consisted of ground states of particles. This cavity appeared to be instable and imploded[12]. The debris spread through the space that came available. The ground state obtained energy and their fields unfolded.

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[9] Usually a black hole is not considered to be empty. However, it is impossible to check this fact.

[10] http://en.wikipedia.org/wiki/No-hair_theorem

[11] http://en.wikipedia.org/wiki/Kerr%E2%80%93Newman_metric

[12] This differs from the picture that corresponds to the Big Bang.

The size of the start cavity was huge and so was the mass that it represented. This mass was converted to energy, which became attached to the ground states.
The start cavity fits in the definition of a geo-cavity.

Appendix

Kerr-Newman metric

The Kerr–Newman metric describes the geometry of spacetime in the vicinity of a rotating mass M with charge Q. The formula for this metric depends upon what coordinates or coordinate conditions are selected. See:

Spherical coordinates

The line element $d\tau$ in spherical coordinates is given by:

$$c^2\, d\tau^2 = -\left(\frac{dr^2}{\Delta} + d\theta^2\right)\rho^2 + (c\, dt - \alpha\ sin^2(\theta)\ d\phi)^2 \frac{\Delta}{\rho^2} \qquad (1)$$

$$-\left((r^2 + \alpha^2)\, d\phi - \alpha\, c\, dt\right)^2 \frac{sin^2(\theta)}{\rho^2}$$

where the coordinates r, θ and ϕ are the parameters of the standard spherical coordinate system. The length-scales α, ρ and Δ have been introduced for brevity.

$$\alpha = \frac{J}{M\, c} \qquad (2)$$

$$\rho^2 = r^2 + \alpha^2\, cos^2(\theta) \qquad (3$$

$$\Delta = r^2 - r_s\, r + \alpha^2 + r_Q^2 \qquad (4)$$

r_s is the Schwarzschild radius[13] (in meters) of the massive body, which is related to its mass M by

$$r_s = \frac{2GM}{c^2} \qquad (5)$$

where G is the gravitational constant[14].

Compare this with the Planck length, $l_{Pl} = \sqrt{\hbar G/c^3}$
The Schwarzschild radius is radius of a spherical geo-cavity with mass M. The escape speed from the surface of this geo-cavity equals the speed of light. Once a stellar remnant collapses within this radius, light cannot escape and the object is no longer visible. It is a characteristic radius associated with every quantity of mass.

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[13] http://en.wikipedia.org/wiki/Schwarzschild_radius
[14] http://en.wikipedia.org/wiki/Gravitational_constant

r_Q is a length-scale corresponding to the electric charge Q of the mass

$$r_Q^2 = \frac{Q^2 G}{4\pi\varepsilon_0 c^4} \tag{6}$$

where $\frac{1}{4\pi\varepsilon_0}$ is Coulomb's force constant[15].

Cartesian coordinates

The Kerr–Newman metric can be expressed in "Kerr–Schild" form, using a particular set of Cartesian coordinates

$$g_{\mu\nu} = \eta_{\mu\nu} + f\, k_\mu\, k_\nu \tag{1}$$

$$f = \frac{G\, r^2}{r^4 + a^2\, z^2}[2\, M\, r - Q^2] \tag{2}$$

$$k_x = \frac{r\, x + a\, y}{r^2 + a^2} \tag{3}$$

$$k_y = \frac{r\, y - a\, x}{r^2 + a^2} \tag{4}$$

$$k_0 = 1 \tag{5}$$

Notice that $\boldsymbol{k}$ is a unit vector. Here M is the constant mass of the spinning object, Q is the constant charge of the spinning object, η is the Minkowski tensor, and a is a constant rotational parameter of the spinning object. It is understood that the vector $\boldsymbol{a}$ is directed along the positive z-axis. The quantity r is not the radius, but rather is implicitly defined like this:

$$1 = \frac{x^2 + y^2}{r^2 + a^2} + \frac{z^2}{r^2} \tag{6}$$

Notice that the quantity r becomes the usual radius $R = \sqrt{x^2 + y^2 + z^2}$ when the rotational parameter a approaches zero. In this form of solution, units are selected so that the speed of light is unity ($c = 1$).

In order to provide a complete solution of the Einstein–Maxwell Equations, the Kerr–Newman solution not only includes a formula for the metric tensor, but also a formula for the electromagnetic potential:

$$A_\mu = \frac{Q\, r^3}{r^4 + a^2\, z^2} k_\mu \tag{7}$$

At large distances from the source (R>>a), these equations reduce to the Reissner-Nordstrom metric[16] with:

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[15] http://en.wikipedia.org/wiki/Coulomb%27s_law

$$A_\mu = \left(-\phi, A_x, A_y, A_z\right) \tag{8}$$

The static electric and magnetic fields are derived from the vector potential and the scalar potential like this:

$$\boldsymbol{E} = -\boldsymbol{\nabla}\phi \tag{9}$$

$$\boldsymbol{B} = \boldsymbol{\nabla} \times \boldsymbol{A} \tag{10}$$

Schwarzschild metric

Schwarzschild coordinates

Specifying a metric tensor[17] is part of the definition of any Lorentzian manifold[18]. The simplest way to define this tensor is to define it in compatible local coordinate charts and verify that the same tensor is defined on the overlaps of the domains of the charts. In this article, we will only attempt to define the metric tensor in the domain of a single chart.
In a Schwarzschild chart[19] (on a static spherically symmetric spacetime), the line element ds takes the form

$$ds^2 = -\left(f(r)\right)^2 dt + \left(g(r)\right)^2 dr + r^2(d\theta^2 + \sin^2(\theta)\, d\phi^2) \tag{1}$$

$$-\infty < t < \infty,\ r_0 < r < r_1, 0 < \theta < \pi, -\pi < \phi < \pi$$

In the Schwarzschild chart, the surfaces $t = t_0, r = r_0$ appear as round spheres (when we plot loci in polar spherical fashion), and from the form of the line element, we see that the metric restricted to any of these surfaces is

$$d\sigma = r_0^2(d\theta^2 + \sin^2(\theta)\, d\phi^2), \qquad 0 < \theta < \pi, -\pi < \phi < \pi \tag{2}$$

That is, these nested coordinate spheres do in fact represent geometric spheres with surface area

$$A = 4\pi r_0^2 \tag{3}$$

And Gaussian curvature

$$K = 1/r_0^2$$

That is, they are geometric round spheres. Moreover, the angular coordinates θ, ϕ are exactly the usual polar spherical angular coordinates: θ is sometimes called the colatitude and ϕ is usually called the longitude. This is essentially the defining geometric feature of the Schwarzschild chart.

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16 http://en.wikipedia.org/wiki/Reissner%E2%80%93Nordstr%C3%B6m_metric
17 http://en.wikipedia.org/wiki/Metric_tensor
18 http://en.wikipedia.org/wiki/Lorentzian_manifold
19 http://casa.colorado.edu/~ajsh/schwp.html

With respect to the Schwarzschild chart, the Lie algebra of Killing vector fields is generated by the time-like irrotational Killing vector field $\boldsymbol{\partial_t}$ and three space-like Killing vector fields $\boldsymbol{\partial_\phi}, \sin(\phi)\ \boldsymbol{\partial_\theta} + \cot(\theta)\cos(\phi)\ \boldsymbol{\partial_\phi}, \cos(\phi)\ \boldsymbol{\partial_\theta} - \cot(\theta)\sin(\phi)\ \boldsymbol{\partial_\phi}$

Here, saying that $\boldsymbol{\partial_t}$ is irrotational means that the vorticity tensor of the corresponding time-like congruence vanishes; thus, this Killing vector field is hyper-surface orthogonal. The fact that our spacetime admits an irrotational time-like Killing vector field is in fact the defining characteristic of a static spacetime. One immediate consequence is that the constant time coordinate surfaces $t = t_0$ form a family of (isometric) spatial hyper-slices. (This is not true for example in the Boyer-Lindquist chart for the exterior region of the Kerr vacuum, where the time-like coordinate vector is not hyper-surface orthogonal.)

It may help to add that the four Killing fields given above, considered as abstract vector fields on our Lorentzian manifold, give the truest expression of both the symmetries of a static spherically symmetric spacetime, while the particular trigonometric form which they take in our chart is the truest expression of the meaning of the term Schwarzschild chart. In particular, the three spatial Killing vector fields have exactly the same form as the three non-translational Killing vector fields in a spherically symmetric chart on E3; that is, they exhibit the notion of arbitrary Euclidean rotation about the origin or spherical symmetry.

However, note well: in general, the Schwarzschild radial coordinate does not accurately represent radial distances, i.e. distances taken along the space-like geodesic congruence which arise as the integral curves of ∂r. Rather, to find a suitable notion of 'spatial distance' between two of our nested spheres, we should integrate $g(r)dr$ along some coordinate ray from the origin:

$$\Delta\rho = \int_{r_1}^{r_2} g(r)dr \tag{4}$$

Similarly, we can regard each sphere as the locus of a spherical cloud of idealized observers, who must (in general) use rocket engines to accelerate radially outward in order to maintain their position. These are static observers, and they have world lines of form $r = r_0, \theta = \theta_0, \phi = \phi_0$, which of course have the form of vertical coordinate lines in the Schwarzschild chart.

In order to compute the proper time interval between two events on the world line of one of these observers, we must integrate $f(r)dt$ along the appropriate coordinate line:

$$\Delta\tau = \int_{t_1}^{t_2} f(r)dt \tag{5}$$

Schwarzschild metric

In Schwarzschild coordinates[20], the Schwarzschild metric has the form:

$$\mathrm{c}^2\,\mathrm{d\tau}^2 = \left(1 - \frac{r_s}{r}\right)\mathrm{c}^2\,\mathrm{dt}^2 - \left(1 - \frac{r_s}{r}\right)^{-1}\mathrm{dr}^2 - r^2(d\theta^2 + \sin^2(\theta)\,d\phi^2) \tag{6}$$

where:

[20] http://en.wikipedia.org/wiki/Schwarzschild_coordinates

- τ is the proper time (time measured by a clock moving with the particle) in seconds,
- c is the speed of light in meters per second,
- t is the time coordinate (measured by a stationary clock at infinity) in seconds,
- r is the radial coordinate (circumference of a circle centered on the star divided by 2π) in meters,
- θ is the colatitude (angle from North) in radians,
- φ is the longitude in radians, and
- r_s is the Schwarzschild radius (in meters) of the massive body.

Lemaître coordinates

In Schwarzschild coordinates the Schwarzschild metric has a singularity. Georges Lemaître was the first to show that this is not a real physical singularity but simply a manifestation of the fact that the static Schwarzschild coordinates cannot be realized with material bodies inside the gravitational radius[21]. Indeed inside the gravitational radius everything falls towards the center and it is impossible for a physical body to keep a constant radius.
A transformation of the Schwarzschild coordinate system from $\{t, r\}$ to the new coordinates $\{\tau, \rho\}$,

$$d\tau = dt + \frac{\sqrt{r_s/r}}{\left(1 - \frac{r_s}{r}\right)}\, dr \tag{1}$$

$$d\rho = dt + \frac{\sqrt{r/r_s}}{\left(1 - \frac{r_s}{r}\right)}\, dr \tag{2}$$

leads to the Lemaître coordinate expression of the metric,

$$ds^2 = d\tau^2 - \frac{r_s}{r} d\rho^2 - r^2(d\theta^2 + \sin^2(\theta)\, d\phi^2) \tag{3}$$

Where

$$r = r_s^{1/3} \left[\frac{3\,(\rho - \tau)}{2}\right]^{2/3} \tag{4}$$

In Lemaître coordinates there is no singularity at the gravitational radius, which instead corresponds to the point $\frac{3\,(\rho-\tau)}{2} = r_s$. However, there remains a genuine gravitational singularity at the centrum, where $\rho - \tau = 0$, which cannot be removed by a coordinate change.
The Lemaître coordinate system is synchronous, that is, the global time coordinate of the metric defines the proper time of co-moving observers. The radially falling bodies reach the gravitational radius and the center within finite proper time.
Along the trajectory of a radial light ray,

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[21] http://en.wikipedia.org/wiki/Lemaitre_coordinates

$$dr = \left(\pm 1 - \sqrt{r_s/r}\right) d\tau \tag{5}$$

therefore no signal can escape from inside the Schwarzschild radius, where always $dr < 0$ and the light rays emitted radially inwards and outwards both end up at the origin.