Quantum Particles From Quantum Information

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Abstract. Many problems in modern physics demonstrate that for a fundamental entity a more
general conception than quantum particles or quantum fields are necessary. These concepts cannot
explain the phenomena of dark energy or the mind-body-interaction. Instead of any kind of "small
elementary building bricks", the Protyposis, an abstract and absolute quantum information, free of
special denotation and open for some purport, gives the solution in the search for a fundamental
substance. However, as long as at least relativistic particles are not constructed from the Protyposis,
such an idea would remain in the range of natural philosophy. Therefore, the construction of
relativistic particles without and with rest mass from quantum information is shown.

1. Introduction
Modern physics has to deal with problems which refer to a principal understanding of nature. On the one
end of the line of the actual problems, we find the so-called dark energy. It seems to be responsible for an
essential portion of the cosmic expansion and it is often declared as an unknown entity. At the other end,
science is confronted with the mind-body-interaction.

At first view, it seems to be odd that these problems may have something in common, but it is not. The
material objects from visible and dark matter seem to constitute only a small part of reality. For the dark
energy it seems to be evident that a particle-like basis does not exist. Then again thoughts and feelings are
real but the elementary objects with or without a rest mass – the photons or atoms – cannot explain the
reality of the human psyche.

The solution of both issues and for some others is related to a new and fundamental understanding of
matter because quantum particles and even quantum fields, which can be reduced to quantum particles, are
not enough to explain the phenomena.

Therefore it can be often read in the last years that there is a need for a more general idea. The
millennium-old idea must be transcended that matter ultimately consists of some types of small building
bricks. Such "elementary bricks" were envisaged primarily as the atoms, later on as the hadrons, then as
the leptons and quarks and in the last years as the strings. However, such an imagination of small
elementary objects prevents a solution of the problems and it can also be defeated by modern quantum
theory. Quantum theory knows already structures which do not appear as free particles in space. Structural
quanta like phonons, quarks, and so on, cannot appear as free relativistic particles, nevertheless, they can achieve effects.

The key for a solution is abstract and absolute quantum information. It must be introduced as having primarily no special denotation, but it has to be open for some purport. To avoid the obvious identification of information with destination or meaning, a new term is introduced: Protyposis. In the 1950s C. F. v. Weizsäcker had started to think about quantum information as the basis for all of the physical objects. However, the conceptions of particles and fields are too successful to abandon them. Not only chemistry is incomprehensible without the particle conception. Therefore, to connect such an idea with the established parts of physics, it is inevitable to show in which way particles can be constructed from qubits. Wigner gave the mathematical construction for the description of relativistic particles. The group of motions in Minkowski-space consists of the Lorentz-group and the translations. Therefore, Wigner spoke about the "inhomogeneous Lorentz-group". Today, the name Poincaré-group became popular for it.

If the protyposis should be connected with the established parts of physics, then, beside other requirements, the construction of relativistic particles from qubits has to be given. This means that irreducible representations of the Poincaré-group must be constructed. Today the related physics can be found in many textbooks. So, let us first describe the qubits.

The states of the qubits are normalized vectors in a complex two-dimensional space $\mathbb{C}^2$:

$$e^{i\phi} (x+iy, z+iw)$$

with $x^2 + y^2 + z^2 + w^2 = 1$

The invariance group for the expectation values consists of the complex conjugation, a U(1) for the phase, and a SU(2). The SU(2) is locally isomorphic to O(3), the rotational group in three dimensions. Therefore v. Weizsäcker's conjecture was that the three-dimensional cosmic position space is a consequence of quantum information and he had the hope that the real existing quantum particles can be constructed from quantum bits.

In these early times, one of the problems was that the models were in conflict with general relativity and that the intended numbers for the qubits of a particle seems to be too large for the imagination of the physicists. In this time the idea seemed to be unacceptable for most of them that a proton is $10^{40}$ qubits. In the 1980s, Görnitz had shown that such numbers can be connected to the existing parts of physics by using the Bekenstein-Hawking-entropy and a rational cosmology.

The states of a qubit can be understood as forming a two-dimensional sub-representation of the regular representation of SU(2). These states are represented by functions having only one knot surface on the SU(2), a three-dimensional sphere $S^3$ which will be identified with the cosmic position space. Such functions will divide the $S^3$ into only two parts. Many qubits are represented by the tensor product of the two-dimensional representations of the SU(2). These product representations can be reduced to irreducible representations. In such a reduction scheme, more localized functions appear. Therefore, something bounded can be localized by many qubits on the $S^3$. We will illustrate this by a trivial example.

$$f(x) = \sin(2\pi x)$$

*Fig. 1: The sinus divides the interval $[0,1]$ into two parts.*
If $N$ qubits are present in the cosmic position space, the tensor product of the two-dimensional representations $^{2}D_{1\over 2}$ can be reduced to irreducible representations. The resulting Clebsch-Gordan-series results as

$$(^{2}D_{1\over 2})^\otimes N = \bigoplus_{j=0}^{\lfloor N/2 \rfloor} \frac{N!/ (N + 1 - j)!}{(N + 1 - j)!} D_{j}$$

with the factor of multiplicity

$$f(j) = \frac{N! (N + 1 - 2 j)}{(N + 1 - j)! j!}$$

Set $k=\lfloor N/2 \rfloor - j$. The representations $^{2k+1}D_{k}$ with $0 \leq k \leq N/2$ have the factors for the multiplicity

$$f(k) = \frac{N! (2k+1)}{(N/2 + 1 + k)! (N/2 - k)!}$$

has its maximum for $^{2k+1}D_{k}$ at the value $k = \frac{1}{2} \sqrt{N}$. Then an exponential decrease follows and functions with shorter wavelengths disappear more and more quickly. As an illustration, a plot of $f(k)$ for $N=900$ is given.

**Fig. 3:** $f(k)$ for $N=900$, $\sqrt{N} = 30$, $k_{\text{maximum}} = 14.514$,

$$(0) = 4.98 \times 10^{266}, f(14.514) = 9.082 \times 10^{267}, f(30) = 3.86 \times 10^{267}, f(60) = 1.76 \times 10^{265}$$
Let $R$ be the radius of the $S^3$. With respect to the exponential decrease, it seems rational to introduce a smallest physically accessible length between $R/(1/2)\sqrt{N}$ and $R/2\sqrt{N}$ and to ignore the states with a shorter wavelength.

For a relation between the number of qubits and the evolution of cosmic space, this means for a cosmological model, the basic assumptions of the three fundamental theories of physics, i.e. special relativity, quantum theory, and thermodynamics, were demanded.

1. There exists a universal and distinguished velocity.

This assumption introduces $c$, the velocity of light. Recently, Riess et. al. [5] published the most accurate determination of $H_0$. With an uncertainty of only 3%, they found the following value: $H_0 = 73.8 \pm 2.4 \text{ km s}^{-1} \text{ Mpc}^{-1}$. Assuming the age of the universe as $1.325 \times 10^{10}$ yr, then $H_0 t_0 = 1$. A value $H_0 t_0 = 1$ means that the universe is expanding with velocity $c$. This supports the earlier work of Tonry et al [6] which, among other results, has shown that for the value of the Hubble parameter $H_0$ and the age of the universe $t_0$, the relation $H_0 t_0 = 0.96 \pm 0.04$ holds true. Set $c = 1$ then the age of the universe $t_{\text{cosmos}}$ and the curvature Radius $R$ become equal and the number of qubits $N$ increases with $t_{\text{cosmos}}^2$.

2. The energy of a quantum system is inversely proportional to its characteristic wavelength.

This second assumption is the familiar Planck relation, $E = h\nu = hc/\lambda$. A qubit has a wavelength of order $2R$. Set $h = 1$. Then a qubit has an amount of energy of order $1/2R$.

3. The first law of thermodynamics is valid.

This allows to define a cosmological pressure $p$ according to $dU + pdV = 0$. By the second assumption $U$ increases proportional to $R$ and therefore the energy density decreases with $1/R^2$. According to the first law of thermodynamics, the state equation for the cosmic substrate, the protyposis, follows as $\mu = -\rho/3$.

If the Planck-length is introduced as $l_{\text{Planck}} = R/(\sqrt{3/2N}) = R/1.225 \sqrt{N}$, then Einstein's Equations follow as the description for the local disturbances of a homogeneous and isotropic universe. [7]

This cosmological model has no horizon problem, needs no unphysical ad-hoc-inflation or ghost dimensions. It has no problem with a cosmological constant or with flatness and has also no problem of empiricism. It does not violate the strong energy condition: $\mu + 3\rho \geq 0$ and induces a photon-to-baryon-ratio of $10^{-9}$.[8]

In Planck's units, the age of the universe is $10^{61} t_{\text{Planck}}$ and the number of qubits is of order $10^{122}$. A proton has the mass of $7.68 \times 10^{-20} m_{\text{Planck}}$. This corresponds to $10^{41}$ qubits and is of the order of $v$. Weizsäcker's conjecture long time ago.[9]

2. From cosmos to particles

The meaning-open absolute quantum information, the protyposis, is primarily a cosmological entity. It is not localized in time and space, but it is acting on the expansion of the universe.

Nevertheless, special forms of it can appear as either energetic or material objects. Energetic objects can be localized in time, material objects also in space. Both types of objects can act as carrier of localized and meaningful information. For instance, mind is quantum information with a living brain as its carrier. Therefore an interaction of mind – being quantum information that is able to know itself – and matter – being quantum information in the special form that has rest mass – will no longer be counted among the outside of scientific descriptions.

Such a philosophical idea will only become part of science if one can show in which way the particles can be reconstructed from quantum information. It is well known in physics from the effects of the Hawking radiation that fields of acceleration are able to produce particles. Therefore, the idea of the vacuum as an area without any particle becomes questionable outside Minkowski space. For a lucid definition of a relativistic particle, we have to leave the real cosmic space with its inhomogenities and accelerations and have to work in the idealization of the cotangential space, i.e. in the Minkowski space. Here an "elementary object" is clearly defined as an entity that can be moved in space and time, thereby
changing only its state but not the object itself. Mathematics shows that any such object can be represented by an irreducible representation of the Poincaré group. The parameters that characterize such an irreducible representation are mass and spin.

By the transition from the physical space to the flat Minkowski space, we lose the naturally given measure that can be introduced by the relation between curvature radius of cosmic space and Planck's length. Therefore, the connection between qubits and space, respectively between qubits and energy is lost and the mass of a particle is a parameter which must be prescribed from the outset.

3. Second quantization of qubits

To construct a particle from quantum bits, the process of “second quantization” can give hints. Einstein's idea that an object with a very large or infinite number of degrees of freedom, for instance the electromagnetic field, can sometimes be better described by a very large or infinite number of objects with few degrees of freedom, like photons. In an analogous way, the formation of a relativistic particle can be achieved from an indefinite number of qubits. If all quantum bits of the Protyposis are supposed to be different, such a condition of a "Boltzmann quantization" appears as being too strong because no commutation relations are possible and no group representation can be constructed. If all bits are supposed to be equal, then particles can be constructed with such Bose commutation relations, but under this condition only massless objects. Para-Bose-statistic appeared as a fruitful conjecture.

The ParaBose commutation relations are three-linear.

\[
\frac{1}{2} \{a_r, a^\dagger_s\}, a_t, a_s = -\delta_{st} a_r
\]

\[
\{a_r, a^\dagger_s, a_t\} = \{a^\dagger_r, a_s, a^\dagger_t\} = \{a^\dagger_r, a^\dagger_s, a_t\} = 0
\]

In the consequence we get also

\[
\frac{1}{2} [a_r, \{a^\dagger_s, a^\dagger_t\}] = -\delta_{st} a^\dagger_r - \delta_{rs} a^\dagger_t
\]

\[
\frac{1}{2} [a^\dagger_r, \{a_s, a_t\}] = -\delta_{st} a^\dagger_s - \delta_{sr} a^\dagger_t
\]

\[
\frac{1}{2} [a^\dagger_r, \{a^\dagger_s, a_t\}] = -\delta_{st} a^\dagger_s
\]

By the Green decomposition\[10\] it becomes evident that Para-Bose statistics can be interpreted as bosons which are anticommuting in case they are of different types.

\[
a_r = \sum_{a=1}^p b^a_r \quad a^\dagger_s = \sum_{a=1}^p b^{\dagger a}_s
\]

with

\[
[b^a_r, b^{\dagger a}_s] = \delta_{rs}
\]

\[
[b^a_r, b^b_s] = [b^{\dagger a}_r, b^{\dagger b}_s] = 0
\]

\[
\{b^a_r, b^b_s\} = \{b^{\dagger a}_r, b^{\dagger b}_s\} = \{b^a_r, b^{\dagger b}_s\} = 0 \quad \text{for} \quad \alpha \neq \beta
\]

Finally

\[
a_r a^\dagger_s |\Omega\rangle = \delta_{rs} p |\Omega\rangle
\]

|\Omega\rangle is the vacuum of the Protyposis, \(p\) is the Para-Bose-order, \(p=1\) restores Bose statistics. The vacuum in Minkowski space, the Lorentz vacuum |0\rangle, is an eigenstate of the Poincaré-group with mass, energy and spin zero. It can be constructed over the vacuum of qubits |\Omega\rangle as
It shows that the statement "at every point in Minkowski-space there is no particle" corresponds to a potentially infinite amount of information. Besides the qubits (index 1 and 2), also anti-qubits (index 3 and 4) are introduced. This is a possibility to linearly represent the complex conjugation which is a subgroup of the symmetry of the qubits. For the vacuum of the Minkowski-space, the annihilation of a qubit is equivalent to the creation of its anti-qubit:

\[ a_i |0\rangle = -a_i^\dagger |0\rangle \quad a_i |0\rangle = -a_i^\dagger |0\rangle \quad a_i |0\rangle = -a_i^\dagger |0\rangle \quad a_i |0\rangle = -a_i^\dagger |0\rangle \]

4. The Poincaré group

The Poincaré group is the ten-parameter group of motions in the Minkowski space \( \mathbb{R}(3,1) \). It is a semidirect product of the Lorentz group \( \text{SO}(3,1) \) with the four translations. The \( \text{SO}(3,1) \) is locally equivalent with \( \text{SL}(2,\mathbb{C}) \). This special linear group in two dimensions would be a general symmetry group for the qubits if the preservation of the norm was no longer stipulated. It was an early conjecture of v. Weizsäcker that this could be the deeper reason for the role of this group in special relativity.

The calculations of particle states and of the Casimir-operators quickly become very complicated. Therefore, the aid of the computer is very useful. For the calculations with \textit{mathematica®}, we use a form for the creation- and destruction-operators that is more valuable at the computer. We set

\[
|0\rangle = \sum_{n_1=0}^{\infty} \sum_{n_2=0}^{\infty} \frac{(-1)^{n_1+n_2}}{n_1!n_2!} \left( \frac{a_i^\dagger a_i^\dagger + a_i a_i}{2} \right)^{n_1} \left( \frac{a_i^\dagger a_i^\dagger + a_i a_i}{2} \right)^{n_2} |\Omega\rangle
\]

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\[
a_i^\dagger \Rightarrow e[r] \quad \text{(Erreger)}
\]
\[
a_i \Rightarrow v[r] \quad \text{(Vernichter)}
\]
\[
\{a_i^\dagger, a_j\} \Rightarrow 2f[r,s] \quad \{a_i, a_j\} \Rightarrow 2w[r,s]
\]
\[
\{a_i^\dagger, a_j\} \Rightarrow 2d[r,s] \quad |0\rangle \Rightarrow \text{vac}
\]

Then the generators of the Poincaré group get the following form:

**Translations:**

\[
P_1 = (-w[2,3]-f[3,2]-w[1,4]-f[4,1] -d[1,2]-d[2,1]-d[4,3]-d[3,4])/2
\]
\[
P_2 = I^*(w[2,3] +f[3,2] +w[1,4]-f[4,1] -d[1,2]-d[2,1]-d[4,3] +d[3,4])/2
\]
\[
P_3 = (-w[1,3]-f[3,1] +w[2,4] +f[4,2] -d[1,1] +d[2,2]-d[3,3] +d[4,4])/2
\]
\[
P_0 = (-w[1,3]-f[3,1]-w[2,4]-f[4,2] -d[1,1]-d[2,2]-d[3,3]-d[4,4])/2
\]

**Boosts:**

\[
M_{10} = I^*(w[1,4]-f[4,1] +w[2,3]-f[3,2])/2
\]
\[
M_{20} = (w[1,4] +f[4,1]-w[2,3] +f[3,2])/2
\]
\[
M_{30} = I^*(w[1,3]-f[3,1]-w[2,4]+f[4,2])/2
\]

**Rotations:**

\[
M_{32} = (d[2,1]+d[1,2]-d[3,4]-d[4,3])/2
\]
\[
M_{21} = (d[1,1]-d[2,2]-d[3,3] +d[4,4])/2
\]
\[
M_{31} = I^*(d[2,1]-d[1,2]-d[3,4] +d[4,3])/2
\]

By ** non-commutative multiplication is denoted and the non-commutative product of \( n \) times \( f[r,s] \), i.e. \( f[r,s]**f[r,s]**...**f[r,s] \) is abbreviated by \( f[r,s,n] \).

The two Casimir-Operators of the Poincaré group are the square of the mass

\[ \Omega
\]
\[ m^2 = P_0^2 - P_1^2 - P_2^2 - P_3^2 = \]
\[-d[1,1] + d[3,3] + f[3,1] + f[4,2] - d[1,1]^2 - d[2,2]^2 - d[3,3]^2 - d[4,4]^2 - d[1,2]^2 - d[1,3]^2 - d[2,4]^2 - d[3,1]^2 - d[1,1]^2 w[2,4] + d[1,2]^2 w[1,4] + d[2,1]^2 w[2,3] - d[2,2]^2 w[1,3] - d[3,3]^2 w[2,4] + d[3,4]^2 w[1,3] - f[4,1]^2 w[2,3] + f[4,1]^2 w[1,3] - f[3,1]^2 w[2,4] - f[3,1]^2 w[1,4] - f[3,3]^2 w[2,4] = 0. \]

and the Pauli-Lubanski-operator \( W^2 = W_d W^a \) with \( W_d = (1/2) \varepsilon_{abcd} M^{ab} P^c \).

In the appendix we give the explicit form of \( W^2 \). Its ugly expression shows that it appears evident that without computer-aid, such expressions seem to be hardly manageable.

5. Relativistic particles

Now examples of states for massless particles with different helicities and for massive particles at rest with spin 0 and 1/2 will be presented.

We denote the Para-Bose-order by \( p[0] \). Let the momentum be \( P_0 = P_3 = m \), \( P_1 = P_2 = 0 \) and the spin equal to zero, then the state has the form

\[ \sum_{p[1]=0}^\infty \frac{(p[0]-1)!}{p[1]! (p[0]-1+p[1])!} f[3,1, p[1]]**lvac \]

It is also possible to define states with helicity \( p[2]=1,2,3,\ldots \), which get the structure

\[ \sum_{p[1]=0}^\infty \frac{(2 p[2]+p[0]-1)!}{p[1]! (p[0]-1+p[1]+2 p[2])!} f[3,1, p[1]]**f[1,1, p[2]]**lvac \]

For the state of a massless fermion with helicity \( p[2]=(1/2) \) we find

\[ \sum_{p[1]=0}^\infty \frac{(2 p[2]+1+p[0]-1)!}{p[1]! (p[0]-1+p[1]+2 p[2]+1)!} c[1]**f[3,1, p[1]]**f[1,1, p[2]]**lvac \]

The state of a massive spinless boson at rest is more complicated. Here the Para-Bose-order has to be greater than one: \( p[0] > 1 \). The momentum at rest is \( P_0 = m, P_1 = P_2 = P_3 = 0 \) and the spin is 0.

\[ \sum_{p[1]=0}^\infty \sum_{p[2]=0}^\infty \sum_{p[3]=0}^\infty \frac{(-1)^{p[1]+p[2]+p[3]}}{(m)^2 (p[1]+p[2]+p[3])! (p[1]+p[2]+p[3]+p[0]-2)!} \]
\[ \frac{(2 p[1]+p[2]+p[3]+p[0]-1)! (p[3]-1+p[0]-1+p[1])! (p[2]-1+p[0]-1+p[1])! (p[1]+1)! (p[2]+1)! (p[3]+1)!}{f[4,2] p[3]**f[4,1, p[1]]**f[3,2, p[1]]**f[3,1, p[2]]**lvac} \]

The state of a massive fermion at rest is still more complicated. Again the Para-Bose-order has to be greater than one: \( p[0] > 1 \). The momentum at rest is \( P_0 = m, P_1 = P_2 = P_3 = 0 \), and the spin in z-direction is \( s_z = 1/2 \). The expression has two parts:
There is a possibility for another state of a massive fermion at rest with the same mass, momentum, spin and spin direction. It is not far to seek this second state as the state of the antiparticle of the former one.

With the Para-Bose-operators beside the Casimir-operators, also other operators can be constructed that do commutate with all the generators of the Poincaré group. Among them, two operators are interesting which can be interpreted as operators transforming a charge.

In consequence of the calculation process, these two operators are denoted as $P_{832}$ and $P_{906}$.

\[
\sum_{p_{[3]}=0}^{\infty} \sum_{p_{[2]}=0}^{\infty} \sum_{p_{[1]}=0}^{\infty} \frac{(-1)^{\mu(p_{[1]}+p_{[2]}+p_{[3]})}}{(p_{[1]}+p_{[2]}+p_{[3]}+p_{[0]}-1)!} \frac{(m)^{2(p_{[1]}+p_{[2]}+p_{[3]})}}{(p_{[1]}+p_{[2]}+p_{[3]}+p_{[0]}-1)!} \ * \ * \ * \ *
\]

There is a possibility for another state of a massive fermion at rest with the same mass, momentum, spin and spin direction. It is not far to seek this second state as the state of the antiparticle of the former one.

\[
\sum_{p_{[3]}=0}^{\infty} \sum_{p_{[2]}=0}^{\infty} \sum_{p_{[1]}=0}^{\infty} \frac{(-1)^{\mu(p_{[1]}+p_{[2]}+p_{[3]})}}{(p_{[1]}+p_{[2]}+p_{[3]}+p_{[0]}-1)!} \frac{(m)^{2(p_{[1]}+p_{[2]}+p_{[3]})}}{(p_{[1]}+p_{[2]}+p_{[3]}+p_{[0]}-1)!} \ * \ * \ * \ *
\]

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In consequence of the calculation process, these two operators are denoted as $P_{832}$ and $P_{906}$.
P906 = - 3d[3,2] + 4d[4,1] - d[1,1]**w[1,2] + d[1,2]**w[1,1] - d[2,2]**w[2,2] + d[2,2]**w[1,2] + d[3,1]**d[1,2] - d[3,1]**w[2,3] + d[3,2]**d[2,2] + d[3,3]**d[3,3] + d[3,3]**w[1,3] - d[4,1]**d[1,1] - d[4,1]**w[2,4] - d[4,1]**d[2,1] - d[4,2]**d[3,4] + d[2,2]**w[2,2] + d[2,2]**w[1,4] - d[1,2]**w[2,3] - d[3,2]**d[2,2] - d[2,2]**w[2,4] - d[3,3]**d[3,3] - d[3,3]**w[1,3] - d[3,3]**w[2,4] + f[4,1]**d[4,1] + f[4,1]**w[4,1] + f[4,2]**d[3,2] + f[4,2]**w[2,1] + f[4,3]**w[3,3] - f[3,3]**d[4,4] + f[4,3]**w[1,3] - f[4,3]**w[2,4] + f[4,4]**d[4,4] + f[4,4]**w[1,4]

For any generator M of the Poincaré group it holds [M, P832] = [M, P906] = 0.

Further on, P832 as well as P906 annihilates massless particle states and massive spinless states. However, (1/m)*P906 transforms the massive spin-(1/2)-particle state into the corresponding antiparticle state, and (-1/m)*P832 transforms the massive spin-(1/2)-antiparticle state into the corresponding particle state.

6. Conclusions

By the construction of states of relativistic particles, a necessary step is done for a connection of the conception of abstract and absolute quantum information, protyposis, with the existing areas of physics. This has some crucial consequences. There is no longer a need for looking into smaller and smaller areas in space to find "the last objects" for an explanation of nature. For a quantum description of the universe, it seems no longer necessary to quantize Einstein's equations. Also a scientific treatment of consciousness becomes possible with this new model for matter. As long as only the cells and atoms in the brain are grasped as real, consciousness cannot be seen as an acting reality. However, with matter as a special form of quantum information that is able to gather and to emit not only energy but also information, an interaction of matter, energy and information came into the realm of physics. Consciousness is quantum information with the living brain as its carrier, so an interaction between mind and matter can be scientifically described. [12]

7. Appendix

The explicit form of the Pauli-Lubanski-operator $W^a = W_a W^a$ with $W_d = (1/2)\epsilon_{abcd} M^{ab} P_c$.

For any generator M of the Poincaré group it holds [M, P832] = [M, P906] = 0.
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