The Quantum Space Phase Transitions for Particles and Force Fields

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We introduce a phenomenological formalism in which the space structure is treated in terms of attachment space and detachment space. Attachment space attaches to an object, while detachment space detaches from the object. The combination of these spaces results in three quantum space phases: binary partition space, miscible space and binary lattice space. Binary lattice space consists of repetitive units of alternative attachment space and detachment space. In miscible space, attachment space is miscible to detachment space, and there is no separation between attachment space and detachment spaces. In binary partition space, detachment space and attachment space are in two separate continuous regions. The transition from wavefunction to the collapse of wavefuction under interference becomes the quantum space phase transition from binary lattice space to miscible space. At extremely conditions, the gauge boson force field undergoes a quantum space phase transition to a "hedge boson force field", consisting of a "vacuum" core surrounded by a hedge boson shell, like a bubble with boundary.

1 The origin of the space structure

The conventional explanation of the hidden extra space dimensions is the compactization of the extra space dimensions. For example, six space dimensions become hidden by the compactization, so space-time appears to be four dimensional. Papers [1, 2] propose the other explanation of the reduction of >4D space-time into 4D space-time by slicing >4D space-time into infinitely many 4D slices surrounding the 4D core particle. Such slicing of >4D space-time is like slicing 3-space D object into 2-space D object in the way stated by Michel Bounias as follows: "You cannot put a pot into a sheet without changing the shape of the 2-D sheet into a 3-D dimensional packet. Only a 2-D slice of the pot could be a part of sheet".

This paper proposes that the space structure for such reduction of >4D space-time can also be derived from the cosmic digital code [3, 4], which one can consider as "the law of all laws". The cosmic digital code consists of mutually exclusive attachment space and detachment space. Attachment space attaches to an object, while detachment space detaches from the object. The cosmic digital code is analogous to two-value digital code for computer with two mutually exclusive values: 1 and 0, representing *on* and *off*. In terms of the cosmic digital code, attachment space and detachment space are represented as 1 and 0, respectively. The object with >4D space-time attaches to >4D attachment space, which can be represented by

$(i\ 1_{3+k})_m$ as $>$ 4D attachment space with m repetitive units of time (i) and $3+k$ space dimension.

The slicing of >4D attachment space is through 4D detachment space, represented by

$(i\ 0_3)_n$ as detachment space with n repetitive units of time (i) and three space dimension.

The slicing of >4D attachment space by 4D detachment space is the space-time dimension number reduction equation as follows

$$\underbrace{(i\ 1_{3+k})_m}_{\text{4D attachment space}} \xrightarrow{slicing} \underbrace{(i\ 1_3)_m}_{\text{4D core attachment space}} + \underbrace{\sum_{k=1}^{k} ((i\ 0_3)\ (i\ 1_3))_{n,k}}_{k \text{ types 4D slices}} \tag{1}$$

The two products of the slicing are the 4D-core attachment space and 4D slices represented by n repetitive units of alternative 4D attachment space and 4D detachment space. They are k types of 4D slices, representing the total number of space dimensions greater than three-dimensional space. For example, the slicing of 10D attachment space produces 4D core attachment space and six types of 4D slices. The value of n approaches to infinity for infinitely many 4D slices.

The core attachment space surrounded by infinitely many 4D slices corresponds to the core particle surrounded by infinitely many small 4D particles. Gauge force fields are made of such small 4D particles surrounding the core particle. The space with repetitive units (of alternative attachment space and detachment space) is binary lattice space.

The combination of attachment space (1) and detachment space (0) results in three quantum space phases: miscible space, binary partition space, or binary lattice space for four-dimensional space-time.

$$\begin{aligned} &(1_4)_n \text{ attachment space} + (0_4)_n \text{ detachment space} \\ &\xrightarrow{combination} \text{ three quantum space phases:} \\ &(1_4\ 0_4)_n \text{ binary lattice space, miscible space, or} \\ &(1_4)_n\,(0_4)_n \text{ binary partition space.} \end{aligned} \tag{2}$$

Binary lattice space consists of repetitive units of alternative attachment space and detachment space. In miscible space, attachment space is miscible to detachment space, and there is no separation of attachment space and detachment space. In binary partition space, detachment space and attachment space are in two separate continuous regions.

2 The quantum space phase transition for particles

Binary lattice space, $(1_4 0_4)_n$, consists of repetitive units of alternative attachment space and detachment space. Thus, binary lattice space consists of multiple quantized units of attachment space separated from one another by detachment space. Binary lattice space is the space for wavefunction, which thus appears as not an abstract entity but a real one filled with a substance, that is in line with works [5, 6]. In wavefunction

$$|\psi\rangle = \sum_{i=1}^{n} c_i |\,\phi_i\rangle \tag{3}$$

each individual basis element $|\phi_i\rangle$ attaches to attachment space, and separates from the adjacent basis element by detachment space. Detachment space detaches from object. Binary lattice space with n units of four-dimensional, $(1_4 0_4)_n$, contains n units of basis elements.

Detachment space contains no object that carries information. Without information, detachment space is outside of the realm of causality. Without causality, distance (space) and time do not matter to detachment space, resulting in non-localizable and non-countable space-time. The requirement for the system (binary lattice space) containing non-localizable and non-countable detachment space is the absence of net information by any change in the space-time of detachment space. All changes have to be coordinated to result in zero net information. This coordinated non-localized binary lattice space corresponds to nilpotent space. All changes in energy, momentum, mass, time, space have to result in zero as defined by the generalized nilpotent Dirac equation [7, 8]

$$\begin{aligned} &\big(\mp \mathbf{k}\partial/\partial t \pm \mathbf{i}\nabla + \mathbf{j}m\big)\big(\pm i\mathbf{k}E \pm \mathbf{ip} + \mathbf{j}m\big)\times \\ &\qquad\times \exp\big(i(-Et + \mathbf{pr})\big) = 0\,, \end{aligned} \tag{4}$$

where E, $\mathbf{p}$, m, t and $\mathbf{r}$ are respectively energy, momentum, mass, time, space and the symbols ± 1, $\pm i$, $\pm \boldsymbol{i}$, $\pm \boldsymbol{j}$, $\pm \boldsymbol{k}$, $\pm \mathbf{i}$, $\pm \mathbf{j}$, $\pm \mathbf{k}$ are used to represent the respective units required by the scalar, pseudoscalar, quaternion and multivariate vector groups. The changes involve the sequential iterative path from nothing (nilpotent) through conjugation, complexification, and dimensionalization. The non-local property of binary lattice space for wavefunction provides the violation of Bell inequalities [9] in quantum mechanics in terms of faster-than-light influence and indefinite property before measurement. The non-locality in Bell inequalities does not result in net new information.

In binary lattice space, for every attachment space, there is its corresponding adjacent detachment space. Thus, a basis element attached to attachment space can never be at rest with complete localization even at the absolute zero degree. The adjacent detachment space forces the basis element to delocalize.

In binary lattice space, for every detachment space, there is its corresponding adjacent attachment space. Thus, no part of the object can be irreversibly separated from binary lattice space, and no part of a different object can be incorporated in binary lattice space. Binary lattice space represents coherence as wavefunction. Binary lattice space is for coherent system.

Any destruction of the coherence by the addition of a different object to the object causes the collapse of binary lattice space into miscible space. The collapse is a quantum space phase transition from binary lattice space to miscible space.

$$\begin{aligned} &\underbrace{\big((0_4)\ (1_4)\big)_n}_{\text{binary lattice space}} \\ &\xrightarrow{quantum\ space\ phase\ transition} \text{ miscible space.} \end{aligned} \tag{5}$$

In miscible space, attachment space is miscible to detachment space, and there is no separation of attachment space and detachment space. In miscible space, attachment space contributes zero speed, while detachment space contributes the speed of light. A massless particle is on detachment space continuously, and detaches from its own space continuously. For a moving massive particle, the massive part with rest mass m_0 belongs to attachment space and the other part of the particle mass, which appears due to the motion, induces an additional energy, namely the kinetic energy K, that changes properties of attachment space and leads to the propagation speed v lesser than the speed of light c.

To maintain the speed of light constant for a moving particle, the time (t) in a moving particle has to be dilated, and the length (L) has to be contracted relative to the rest frame

$$\begin{aligned} &t = \frac{t_0}{\sqrt{1 - v^2/c^2}} = t_0\gamma\,, \\ &L = L_0/\gamma\,, \\ &E = K + m_0c^2 = \gamma m_0 c^2, \end{aligned} \tag{6}$$

where $\gamma = 1/\sqrt{1 - v^2/c^2}$ is the Lorentz factor for time dilation and length contraction, E is the total energy and K is the kinetic energy.

The information in such miscible space is contributed by the combination of both attachment space and detachment space, so detachment space with information can no longer be non-localize. Any value in miscible space is definite. All observations in terms of measurements bring about the collapse of wavefunction, resulting in miscible space that leads to eigenvalue as definite quantized value. Such collapse corresponds to the appearance of eigenvalue E by a measurement operator H on a wavefunction ψ, i. e.

$$H\psi = E\psi . \tag{7}$$

Another way for the quantum space phase transition from binary lattice space to miscible space is gravity. Penrose [10] pointed out that the gravity of a small object is not strong enough to pull different states into one location. On the other hand, the gravity of large object pulls different quantum states into one location to become binary partition space. Therefore, a small object without outside interference is always in binary lattice space, while a large object is never in binary latticespace.

3 The quantum space phase transitions for force fields

At zero temperature or extremely high pressure, binary lattice space for a gauge force field undergoes a quantum space phase transition to become binary partition space. In binary partition space, detachment space and attachment space are in two separate continuous regions as follows

$$\begin{gathered}\underbrace{(1_4)_m + \sum_{k=1}^{k}\big((0_4)\ (1_4)\big)_{n,k}}_{\text{particle gauge boson field in binary lattice space}} \longrightarrow \\ \underbrace{(1_4)_m}_{\text{hedge particle}} + \underbrace{\sum_{k=1}^{k}(0_4)_{n,k}\ (1_4)_{n,k}}_{\text{hedge boson field in binary partition space}}\end{gathered} \tag{8}$$

The force field in binary lattice space is a gauge boson force field, the force field in binary partition space is denoted as a *hedge boson force field*. The detachment space in hedge boson field is a "vacuum" core, while hedge bosons attached to attachment space form the hedge boson shell. Gauge boson force field has no boundary, while the attachment space in the binary partition space acts as the boundary for hedge boson force field. Hedge boson field is like a bubble with core vacuum surrounded by membrane where hedge bosons locate.

Hedge boson force is incompatible to gauge boson force field. The incompatibility of hedge boson force field and gauge boson force field manifests in the Meissner effect, where superconductor repels external magnetism. The energy (stiffness) of hedge boson force field can be determined by the penetration of boson force field into hedge boson force field as expressed by the London equation for the Meissner effect

$$\nabla^2 H = -\lambda^{-2} H , \tag{9}$$

where H is an external boson field and λ is the depth of the penetration of magnetism into hedge boson shell. Eq. (9) indicates that the external boson field decays exponentially as it penetrate into hedge boson force field.

The Meissner effect is the base for superconductivity. It is also the base for gravastar, an alternative to black hole [11–13]. Gravastar is a spherical void as Bose-Einstein condensate surrounded by an extremely durable form of matter. This paper proposes gravastar based on hedge boson field.

Before the gravitational collapse of large or supermassive star, the fusion process in the core of the star to create the outward pressure counters the inward gravitational pull of the star's great mass. When the core contains heavy elements, mostly iron, the fusion stops. Instantly, the gravitational collapse starts. The great pressure of the gravity collapses atoms into neutrons. Further pressure collapses neutrons to quark matter and heavy quark matter.

Eventually, the high gravitational pressure transforms the gauge gluon force field into the hedge gluon force field, consisting of a vacuum core surrounded by a hedge gluon shell, like a bubble. The exclusion of gravity by the hedge gluon force field as in the Meissner effect prevents the gravitational collapse into singularity. To keep the hedge gluon force field from collapsing, the vacuum core in the hedge gluon force field acquires a non-zero vacuum energy whose density (ρ) is equal to negative pressure (P). The space for the vacuum core becomes de Sitter space. The vacuum energy of the vacuum core comes from the gravitons in the exterior region surrounding the hedge gluon force field as in the Chapline's dark energy star. The external region surrounding the hedge gluon force field becomes the vacuum exterior region. Thus, the core of gravastar can be divided into three regions: the vacuum core, the hedge gluon shell, and the vacuum exterior region

$$\begin{array}{ll}\text{vacuum core region:} & \rho = -P \\ \text{hedge gluon shell region:} & \rho = +P \\ \text{vacuum exterior region:} & \rho = P = 0\end{array} \tag{10}$$

Quarks without the strong force field are transformed into the decayed products as electron-positron and neutrino-antineutrino denoted as the "lepton composite"

$$\text{quarks} \xrightarrow{\textit{quark decay}} \underbrace{e^- + e^+ + \bar{\nu} + \nu}_{\text{the lepton composite}} \tag{11}$$

The result is that the core of the collapsed star consists of the lepton composite surrounded by the hedge gluon field. This lepton composite-hedge gluon force field core constitutes the core for gravastar. The star consisting of the lepton composite-hedge gluon field core (LHC) and the matter shell is "gravastar". The matter shell consists of different layers of matters: heavy quark matter layer, quark matter layer, neutron layer, and heavy element layer one after the other:

LHC (lepton composite
— hedge gluon force field core):

lepton composite region:	$\rho = +P$
vacuum core region:	$\rho = -P$
hedge gluon shell region:	$\rho = +P$
vacuum exterior region:	$\rho = P = 0$ (12)

MATTER SHELL
(heavy quark layer
quark layer
neutron layer
heavy element layer): $\rho = +P$

4 Summary

Thus our formal phenomenological approach allows us to conclude that the quantum space phase transition is the quantum phase transition for space. The approach that is developed derives the space structure from attachment space and detachment space. Attachment space attaches to an object, while detachment space detaches from the object. The combination of attachment space and detachment space results in three quantum space phases: binary partition space, miscible space, or binary lattice space. Binary lattice space consists of repetitive units of alternative attachment space and detachment space. In miscible space, attachment space is miscible to detachment space, and there is no separation of attachment space and detachment space. In binary partition space, detachment space and attachment space are in two separate continuous regions. For a particle, the transition from wavefunction to the collapse of wavefuction under interference is the quantum space phase transition from binary lattice space to miscible space.

At zero temperature or extremely high pressure, gauge boson force field undergoes a quantum space phase transition to "hedge boson force field", consisting of a vacuum core surrounded by a hedge boson shell, like a bubble with boundary. In terms of the quantum space phase, gauge boson force field is in binary lattice space, while hedge boson force field is in binary partition space. The hedge boson force fields include superconductivity and gravastar.

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