

The new bosonic mechanism (context description).

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1. Purpose

The main purpose of this paper is to introduce the new bosonic mechanism and new treatment of dark energy (<hal-01162606v4> (<https://hal.archives-ouvertes.fr/hal01162606v4/document>). 2015.). The bosonic mechanism focuses on obtaining masses by gauge bosons without assuming the existence of Higgs boson. The hypothesis on dark energy as the energy of a postulated dark field was made and a combined gravitational-dark field was introduced. This field is the key to a specified approach and allows addressing the fundamental starting points of the mechanism.

i. Complex scalar field is introduced in the description of the mechanism and is divided into two components: Goldstone-dark field and tensor-gravitational field; tensor-gravitational component outlines the physics of obtaining masses by gauge bosons and causes the existence of Goldstone-dark component, which defines physics behind the Goldstone theorem.

ii. The meaning of spontaneous symmetry breaking^{note} is understood in the context of changing between ‘mixed’ and ‘pure’ states of gauge field which appears in the framework of the outlined mechanism and can apply to global and local symmetry without violating the constraint denoted by Elitzur theorem (Phys. Rev. D 12, 3978-3982, 1975); thus the process of symmetry breaking is understood differently from the standard formulation (F. Mandl and G. Shaw, Quantum Field Theory, 2010) used in Higgs mechanism and assumes the existence of two paths (direct and restoring). The entanglement of these two paths is quantified by entropy as a parameter, based on which paths are chosen.

General theory Lagrangian (for interaction) in case of ‘pure’ state of gauge field is due to the existence of one dimensional cosmic string (‘Mexican hat’ potential); General theory Lagrangian (for non-interaction) in case of ‘mixed’ state of gauge field is due to dark energy as the restoring force to restore state of symmetry from local to global and thus flattening potential from ‘Mexican hat’-type to Goldstone-type. This means that physics of Lagrangian appearance in the proposed mechanism very different from Higgs approach.

iii. Noted mechanism incorporates Fierz-Pauli approach (Proc. Roy. Soc. London. A 173, 211-232, 1939) for particles of arbitrary spin and is further developed based on the outlined hypothesis, thus distinguishing between presented theory and other theories (i.e., Massive gravity) from the perspective of relevancy to the Fierz and Pauli thesis. It is shown that diffeomorphism invariance is preserved in the noted mechanism and interaction with matter is allowed. Higgs scalar is obtained within the scope of the presented approach and is included as a part of the mathematical expression, which describes obtaining mass by vector gauge boson. The noted scalar has properties consistent with the properties of Higgs scalar observed in the Standard Model.

iv. A possibility of formulating a consistent nonlinear interacting theory, which does not contradict de Wit (Phys. Rev. D 21, 358-367, 1980) and Deser's arguments (General Relativity and Gravitation 1, 9-18, 1970) was presented.

v. The cancellation mechanism leading to the absence of the observable Cherenkov radiation is also addressed in this article.

vi. AdS/CFT correspondence is incorporated into the framework of the outlined mechanism.

note

The meaning of the spontaneous symmetry breaking and its relevance to Elitzur theorem (S. Elitzur, 1975) is emphasized as follows:

1. As specified by the proposed approach there are two paths for spontaneous symmetry breaking, namely, direct and restoring.

a) In direct path:

symmetry breaking mechanism is analogous to the standard approach (F. Mandl and G. Shaw, 2010) with Elitzur constraint, i.e., spontaneously breaking global symmetry **a** explicitly breaking of local symmetry by a gauge fixing term. Thus, equations of the proposed theory formally coincide with standard theory equations although the physics are very different.

As outlined in the essence of the mechanism, the first stage of this process leads to mass appearance in dark sector and the second stage leads to mass appearance in gravitational (metric) sector. This process corresponds to moving gauge field from 'mixed' state at the first stage (coupled with gravitational-dark scalar mode) to 'pure' state at the second stage (decoupled from gravitational-dark tensor mode). This results in obtaining gauge bosons mass by means of application of a two-stage schema.

b) In restoring path:

There is a restoring force (due to dark sector in reference to dark energy), which restores the symmetry from local to global. In this context restoring means cancellation of gauge field, so there is no gauge fixing anymore, thus no spontaneous breaking of local symmetry can occur. State of symmetry is therefore restored to global.

This process corresponds to moving gauge field from 'pure' (-split) state (decoupled from gravitational-dark tensor mode) back to 'mixed' state (coupled with gravitational-dark scalar mode). This results in losing mass by gauge bosons and returning into massless form.

a, b f The process of coupling and decoupling of gauge field, i.e., moving between 'mixed' and 'pure' states is spontaneous and as such is used in this context throughout the paper. This spontaneous process is entropy directed and driven and plays a crucial role in obtaining masses in gravitational (metric) sector. Thus, entropy plays a role of a parameter to determine preference of a) –path over b) –path.

2. In the context of local symmetry, the spontaneous symmetry breaking means that the state of gauge field spontaneously changes from 'mixed' to 'pure', thus explicitly breaking local symmetry by gauge fixing term on a) –path; the state of gauge field can also spontaneously change from 'pure' to 'mixed', thus restoring the state of global symmetry by restoring force on b) –path).

2. Mechanism

Presented here is the developing theory on the subject of obtaining masses by bosons (in particular gauge vector bosons).

The scope of the suggested consideration is introducing a mechanism, which is an alternative to the Higgs mechanism; in addition, the proposed new mechanism incorporates dark energy. It was considered that work by (V. Fierz and W. Pauli, 1939) should foster another model for obtaining nonzero masses by fundamental particles.

While negative conclusions regarding construction of consistent interacting theories of higher spin in a form of the gauge theory of several coupled or self-coupled fields were outlined (B. de Wit and D. Freedman, 1980), it is noted that spontaneous breakdown of the unacceptable symmetries is a possibility in order to evade these difficulties.

The emphasized original hypothesis behind suggested alternative approach mainly constitutes:

a) Dark field.

P1. Postulate: Dark energy determines the existence of a dark field.

b) Curvature of spacetime (the pseudo-Riemannian metric).

P2. Postulate: Gravitational and dark fields compose a single gravitational – dark field.

The essence of the mechanism is:

i. massless gravitational-dark field acquires mass due to the spontaneous symmetry breaking and the contribution of matter;

ii. massless vector bosons acquire mass due to the interaction with a massive gravitational-dark field.

f Following are the differences of the underlying mechanism as compared to the Higgs mechanism:

i. there is not a scalar field associated with the Higgs boson, the existence of Higgs boson is not assumed;

ii. gravitational massless component of a gravitational –dark field acquires mass as a result of local symmetry breaking (ref. note above: The meaning of the spontaneous symmetry breaking and its relevance to Elitzur theorem); coupling to matter;

iii. dark massless component acquires mass as a result of global symmetry breaking; gravitational field determines the dark field appearance, as the source of the dark field is the stress-energy tensor; coupling to matter;

iv. gauge bosons acquire mass not as a result of symmetry breaking but due to the interaction with a gravitational-dark field;

v. there is no specific assumption, which is limited to the consideration by gauge vector bosons only.

f Following is the analysis of these mechanisms:

1. Higgs mechanism (ref. Fig. 1.1).

Higgs approach demonstrates physical and mathematical discrepancies.

a) physical discrepancy consists in formulated instability of vacuum.

(In the framework presented in the paper this discrepancy can be explained by referencing the second law of thermodynamics which states that entropy must increase so as to reach the state with maximum symmetry, ref. ‘the special symmetry evolution principle’, (J. Rosen, Comment: The symmetry principle, Entropy **7**, 308-313, 2005).

Higgs’ approach assumes that gauge bosons acquire mass as a result of symmetry breaking and, in this model, there is no driving force to restore the state of maximum symmetry, i.e., there is no mechanism of increasing entropy in this theory.

This leads to the instability of Higgs’ solution (ref. instability of vacuum, (M.S. Turner and F. Wilczek, 1982)).

b) mathematical discrepancy follows from the analysis outlined in Higgs model presentation in (F. Mandl and G. Shaw, 2010) where the main focus of the analysis is on the usage of unitary gauge, which assumes the elimination of ‘ghost field’; however, proving renormalizability of this model is provided in ‘tHooft gauge requiring reintroduction of the ‘ghost field’.

Presence of virtual particles (quantum fluctuations) associated with the ‘ghost field’ leads to instability of vacuum solution in Higgs model.

This two contradictory mathematical procedures which are required to prove Higgs model demonstrate build-in mathematical discrepancy and their existence points to the necessity of introducing the driving force to restore the state of maximum symmetry.

2. The new bosonic mechanism (ref. Fig. 1.2).

The new bosonic approach demonstrates physical consistency and, as result, does not include mathematical discrepancy.

The mechanism described in this paper represents a stable solution whereas Higgs mechanism represents an unstable solution. The scalar term obtained within the scope of the presented approach is consistent in action of assigning mass to vector gauge boson with the corresponding result obtained by means of Higgs scalar.

Physical consistency is determined by the following: the mechanism presented in this paper incorporates the driving force which restores the state of maximum symmetry from the state of symmetry breaking.

The dark energy, which is the driving force, increases the volume, which leads to the state with more entropy, i.e. symmetry. This driving force is determined by the requirement to cancel local vacuum fluctuations (i.e. maintain the thermodynamic equilibrium between baryonic sector and the thermal bath).

The thermal bath – micro black hole (b.h.) system increases entropy due to accretion of matter and uses Hawking’s radiation to make this entropy equal to the baryonic sector entropy in order to reach thermodynamic equilibrium and obtain stable solution.

f The description of new bosonic mechanism structure.

This paper introduces the mechanism based on two postulates: P1, P2.

This mechanism is constructed upon a model of spontaneous breaking of local symmetry (ref. note above: The meaning of the spontaneous symmetry breaking and its relevance to Elitzur theorem).

The model describes massive gravitational and dark fields and their interaction with the vector field based on the Fierz-Pauli approach.

Gauge bosons acquire masses as a result of the interaction with a massive combined gravitational- dark field.

a) in the ‘mixed’ state gravitational-dark field is reduced to case characterized by scalar mode. This corresponds to the Higgs model:

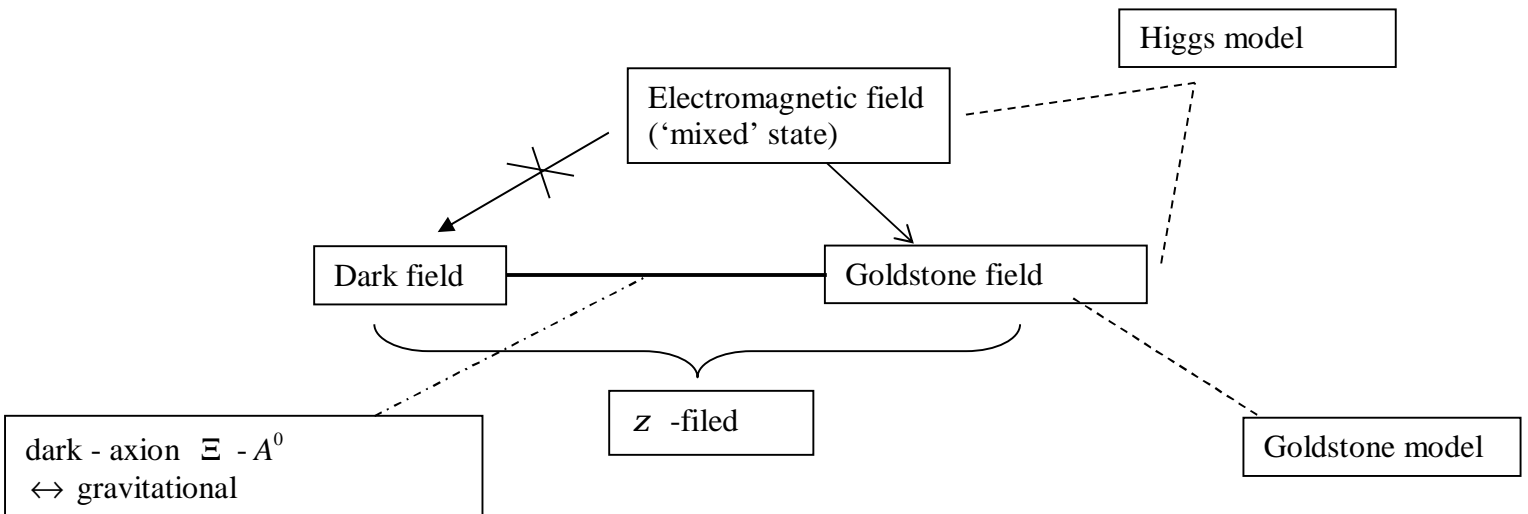


Fig. 1.1 Correspondence to Higgs mechanism (theory framework).

In this case the mass channel is driven by Goldstone boson.

Obtaining mass by vector gauge boson is due to coupling between vector gauge boson and scalar mode. Scalar mode mass range is characterized by dark-axion value.

P electromagnetic (gauge) field is massless due to non- interaction with scalar mode.

Viz. Ansatz: Lagrangian under small perturbations incorporates (Ivo van Vulpen, The Standard Model Higgs Boson, 2014):

p

1. the appearance of mass term for photon, which is associated with gauge field of the theory in ‘mixed’ state (case before symmetry breaking);
2. the additional term $-enA_i(\partial^i h)$, which is associated with the coupling limit of the presented theory, thus having specific meaning.

f the equations below are presented by notations which are specific to the new bosonic mechanism

- 1, 2. Unitary gauge is defined as follows:

$$A'_i(x) = A_i(x) + \partial_i f(x), f(x) = -\frac{eh(x)}{n}$$

where,

$h(x)$ tensor-gravitational::dark field $\{h::\Xi\}$;

the presented mechanism describes Goldstone-dark scalar beyond the decoupling limit.

pp Proving renormalizability of the presented theory.

f f ‘tHooft gauge is defined as follows:

$$\partial_i A^i(x) - k_h h(x) = 0$$

where,

$h(x)$ tensor-gravitational field $\left\{ \left(\equiv \langle g^{ik} \rangle h_{ik} \right), \langle \quad \rangle \text{ is the vacuum value} \right\}$ defines scalar;

k_h is gravitational field mass;

the presented mechanism describes gravitational scalar in decoupling limit.

This eqs. are relevant to the presented new mechanism and they mathematically formulate the process of spontaneous symmetry breaking on direct path (i.e. transition from the ‘mixed’ state to ‘pure’ state of the gauge field). While the former corresponds to tensor-gravitational::dark field coupling limit (i.e., ref. electromagnetic field in ‘mixed state’); the later corresponds to tensor-gravitational::dark field decoupling limit(i.e., ref. electromagnetic field in ‘pure’ state).

Since the dark mode can initiate vacuum instability in the theory (direct path), this process have to be augmented by the implementation of the mechanism of restoring symmetry (restoring path).

b) in the ‘pure state’ the gravitational-dark field is reduced to case characterized by tensor mode. This corresponds to ‘the new bosonic mechanism’ model:

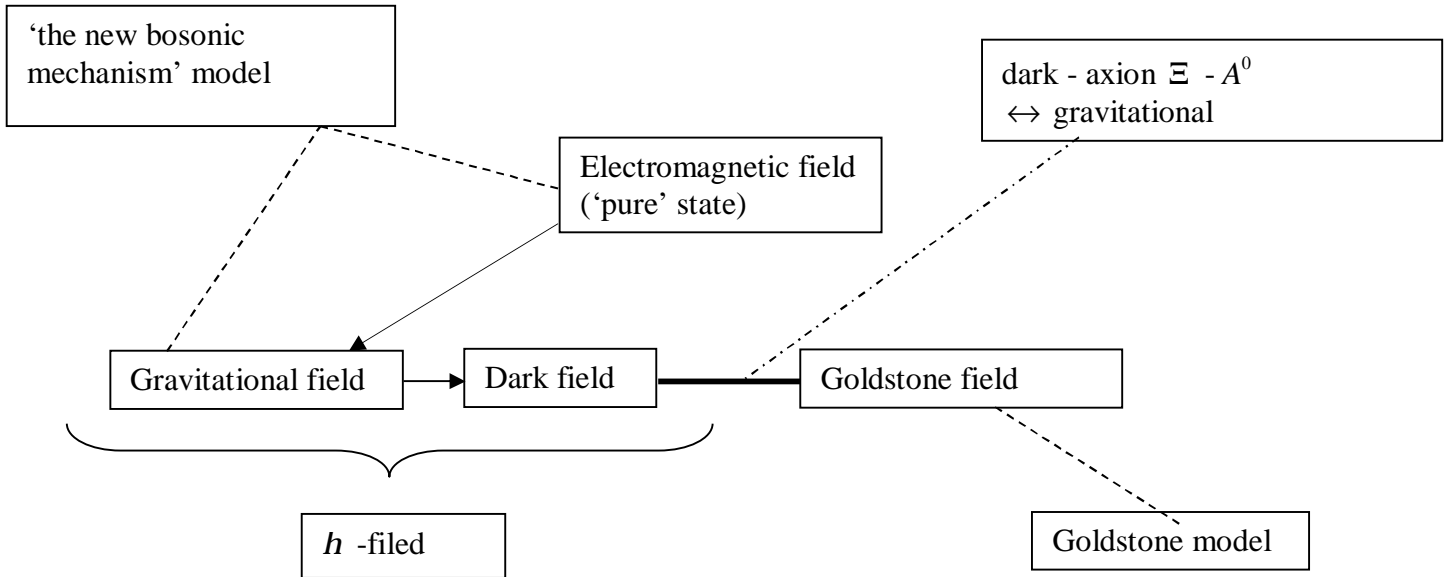


Fig. 1.2 Correspondence to ‘the new bosonic mechanism’ (theory framework).

In this case the mass channel is driven by gravitational field.

1-channel (gravitational): \exists coupling between vector gauge boson B_k and gravitational field h_{ik} .

2-channel (tensor-gravitational) : \exists coupling (due to gravitational instanton h) between vector gauge boson B_k and dark boson - axion $\Xi - A^0$.

P Obtaining mass by vector gauge boson is due to coupling between vector gauge boson and gravitational instanton (tensor mode, in this case, is reduced to tensor-gravitational scalar mode by coupling with inverse metric tensor).

In the outlined mechanism gravitational instanton represents connection bundle, which connects (\Leftrightarrow couples) dark boson – axion and vector boson.

This coupling results in the fact that the mass of vector gauge boson in scalar sector is identical to combined dark boson-axion mass.

f Thus, the corresponding mass term in the theory Lagrangian can denote either one.

Following diagram depicts two possible channels of gravitational coupling.

P gravitational coupling in the theory framework

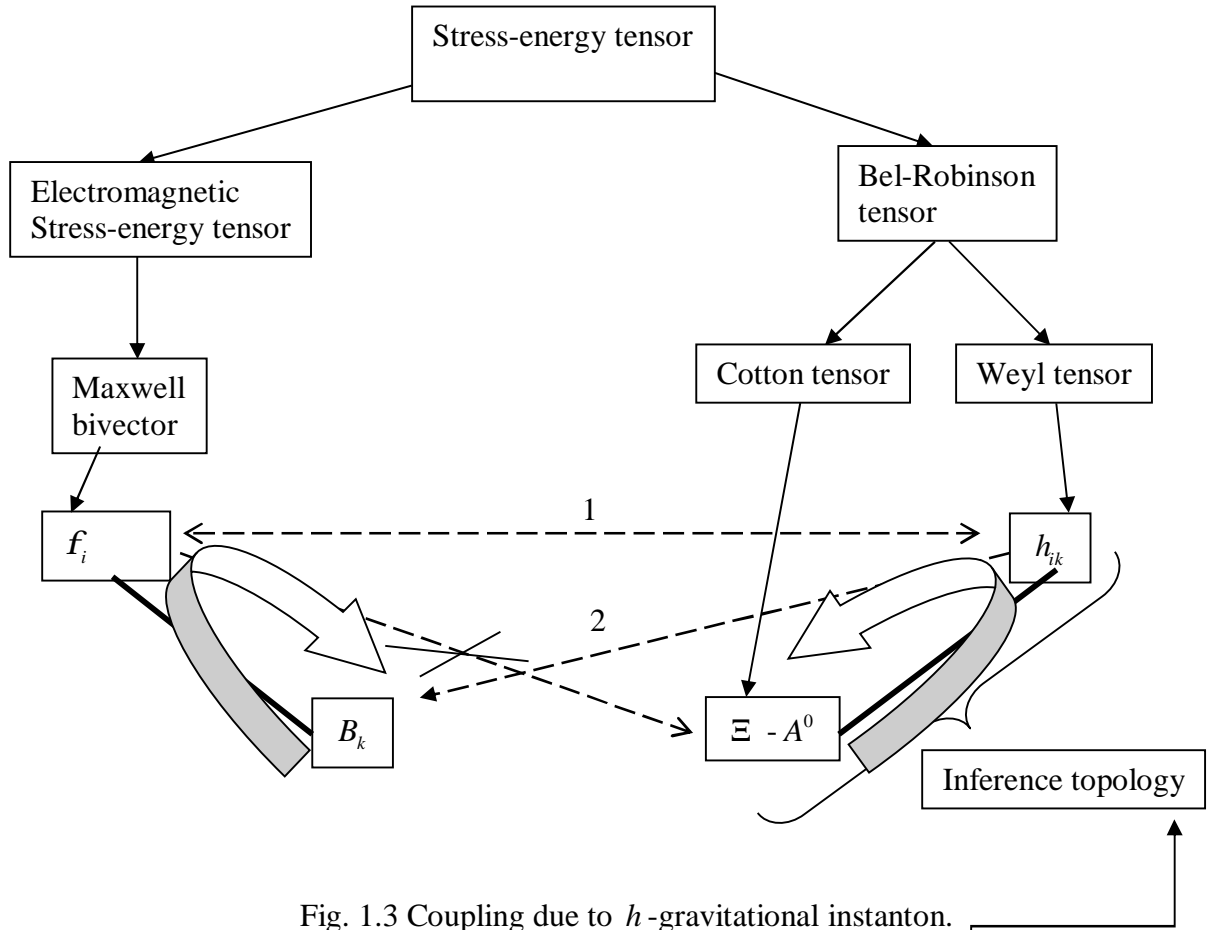
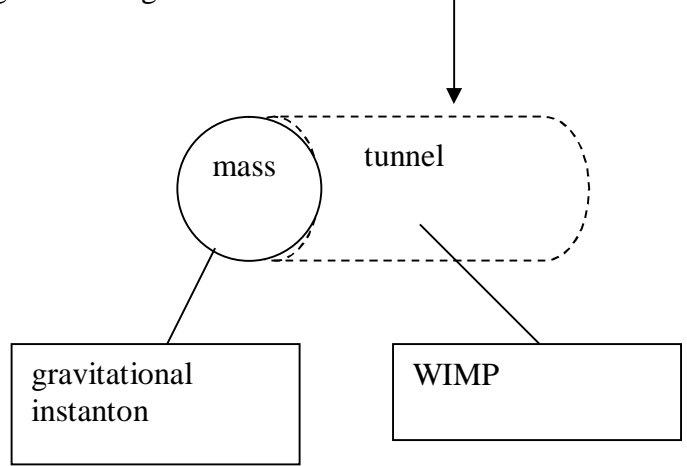


Fig. 1.3 Coupling due to h -gravitational instanton.



WIMP (dark part \Leftrightarrow tunnel) interacts with baryonic matter by means of gravitational instanton (gravitational part \Leftrightarrow mass).

ff 1-channel (gravitational): \exists coupling between photon with gravitational field h_{ik} , there is no interaction between photon f_i and dark sector $\Xi - A^0$.

P electromagnetic (gauge) field is massive due to non minimal interaction with tensor mode, thus corresponding to the Ginzburg -Landau model.

Sections identified below represent major segments in the structure of the paper. The structure is focused on the role which the electromagnetic field plays in the mechanism.

I.

Step 1 (Model of gravitational-dark field masses).

As Weyl's conjecture associates gauge with a local symmetry and the change of phase with $U(1)$ gauge symmetry, the electromagnetic field appears as a result of quantum mechanical consideration of the wave function of a charged particle.

The electromagnetic field, which appears as a result of the above-mentioned process, is presented in 'mixed' and 'pure' states, which accordingly correspond to the cases Before symmetry breaking (ref. 'Lagrangian for non-interaction') and After symmetry breaking (ref. 'Lagrangian for interaction')^{note}.

Step 2 (Case: before symmetry breaking).

The paper presented in this case the description of obtaining mass by dark (Goldstone-dark) field.

The consideration starts from the assumption that Goldstone and gravitational-dark fields interact. The composite system of electromagnetic field in 'mixed' state and a scalar gravitational-dark field interact with a vacuum state.

As result of this interaction the following is obtained:

a) in the domain of electromagnetic field - vacuum state, vacuum state coincides with the Goldstone field.

Expectation value of this field spontaneously breaks underlying global symmetry which leads to the appearance of massless Goldstone bosons.

b) in the domain of gravitational-dark - vacuum state, there appears a split of massless gravitational and dark components of a massless gravitational-dark field.

Mass term for the dark field appears from substitution vacuum state::tensor-gravitational::dark field -field in 'Lagrangian for non-interaction'.

note

a 'mixed' state is represented as the superposition state of composite system including electromagnetic field \mathbf{a} 'Lagrangian for non-interaction';
a 'pure' state assumes interaction between electromagnetic field and system \mathbf{a} 'Lagrangian for interaction';
the vacuum state represents redundant degrees of freedom, i.e., it is manifestly associated with 'mixed' state of electromagnetic field (gauge field) and Goldstone boson (axion A^0).
 n is the expected value of the vacuum state and appears as a result of gauge symmetry breaking, which, in this framework, means the following:

- a) gauge symmetry is the gauge structure represented by a set of three labels-components: vacuum state, tensor-gravitational, dark field;
- b) gauge symmetry breaking is the change of gauge structure (i.e., Landau phase transition with order parameter n), which results in change of the labeling schema from 'mixed' to 'pure'.

end_of_note

(Sub-case: no matter)

a) it is demonstrated by the results described above that matter directly contributes only to the mass of gravitational field;

- for massless spin - 0 (Goldstone) field Fierz-Pauli eq. refers to Goldstone mechanism and is inline with vacuum Einstein eq.;
- for massless gravitational field Fierz-Pauli eq. is reduced to 0;
- dark field is massive due to **the first channel - Step 2, item b**).

Step 3 (Case: after symmetry breaking).

The consideration includes different topics logically connected and combined under a specified title.

The paper presents in this chapter the description of obtaining mass by massless gravitational field and the appearance of Nambu-Goldstone boson.

It addresses the spontaneous breaking of a local symmetry which leads to obtaining mass by gravitational and Goldstone (appearance of Nambu-Goldstone bosons) components of gravitational-dark field.

As a result of substituting vacuum state::tensor-gravitational::dark field -field in 'Lagrangian for interaction' presented:

mass term for the Goldstone-dark field, i.e. Nambu-Goldstone boson (Goldstone boson remain massless in Step 2) provided that there is non - interaction between dark field and electromagnetic field;

b) massive gravitational field;

i. (Sub-case: force free eq.)

The appearance of the massive gravitational field determines **the second channel** (in addition to the first channel - Step 2, item b) of the source of mass for dark field, namely the coupling between massive dark field and vacuum metric tensor is described by Klein-Gordon eq. for gravitational interaction action; this coupling exists because the source of dark field is stress-energy tensor for scalar field.

This chapter continues the analysis taking into account the contribution of matter (baryonic).

ii. (Sub-case: matter)

this sub-case determines *the second channel* (in addition to *the first channel - Step 3*) of the source of mass for gravitational field, namely the appearance of mass for the gravitational – dark field is due to “stress – energy tensor factor” channel.

According to this mechanism, mass for the gravitational field appears directly as a result of \exists stress – energy tensor, while mass term for dark field appears as a result for the account of the second channel of source of mass for dark field.

In this case, DVZ discontinuity disappears in covariant limit thus reflecting the fact that massive gravitational-dark field in covariant form couples to matter.

II. (Model of boson masses).

This chapter of the paper outlines mechanism of assigning mass to the vector gauge bosons due to the interaction with a massive gravitational - dark field.

Resulted Lagrangian includes terms proportional to square of vector boson field (i.e., mass terms for vector bosons) as well as terms proportional to square of gravitational field and dark field parts of gravitational-dark field (i.e., mass terms corresponding to these parts).

III. (Quantization).

The approach in this chapter is focused on reducing the problem of quantization of gravitational field to the standard methodology of quantization scalar field. To address this issue, the gravitational field is defined through Weyl complex scalar, thus reducing mathematical formulation of quantization to the quantization of scalar field.

Two modes are specifically addressed:

- quantization of tensor-gravitational field (gravitational field in scalar mode) is represented as standard expression for quantized scalar field;
- quantization of gravitational field (tensor mode) is represented by the expression for the quantized form of spin $n(=2)$ field.

The validity of this form is due to the fact that the propagator for spin $n(=2)$ field is expressed through the propagator of scalar field, so that the tensor mode appears from a scalar mode and not from tensor rank - 2 mode.

The outline above means that quantization of tensor mode is provided by means of the extension result obtained for quantized scalar mode transferring to the case of spin $n(=2)$ field (on the basis of corresponding propagator identity) and not by direct quantization of tensor rank - 2 mode (M. Kachelrieß, Advanced Quantum Field Theory, 2010).

IV. (Logically connected and interlinked topics).

This chapter of the paper addresses different topics including, but not limited to, the following:

1. the definition of gauge theory (as the theory which is mathematically related to fiber bundle) application is introduced via ‘inference topology’ defined in the paper and addressing related aspects.

The subject of inference topology is directly related to the types of curvatures which exist in the reference to the space-like hypersurface. These types depend on the value of electromagnetic field and are represented by hypersphere or hypersadle.

The geometry of topological structure constitutes compound of dark (tunnel) and gravitational (mass) parts.

Geometry is characterized as AdS_3 for the dark part and Lorentzian CFT for the gravitational part, which defines the arrow of time.

In the context of gauge theory, the gravitational part is characterized by mass; while the dark part is represented by connected helicoids with two ends in separate points in spacetime. This corresponds to the Piceci-Quinn symmetry.

Breaking this symmetry results in \exists of axion.

‘Inference topology’ radiation dynamics corresponds to the solution of the Navier-Stokes eq. in blow-up regime.

2.

a) This theory incorporates the complete Lagrangian, EoM and canonically quantized gravitational field. It was checked for the asymptotic behavior and coincides with Einstein eq. within appropriate limits.

b) Obtained results have specific applications, for example:

1. Case of changing spacetime geometry;
2. It is shown how the theory naturally leads to AdS/CFT correspondence;
3. Obtained reformulation of quantum mechanical wavefunction, i.e. presented the way to treat wavefunction as a continuous function, which describes the object from inside and outside;
4. Based on the group theory, mathematically demonstrated the solution to the arrow of time problem;
5. Obtained a mathematical topological explanation to the entanglement problem and a mechanism of the existence of stable traversable and non-traversable wormholes.

c) In order to prove this theory it must be shown to satisfy precision experimental constraints on quantum corrections.

d) Appendixes of this paper present further itemization of the different topics relevant to the outlined framework.

This include:

i. the mathematical definition to prove different eqs. is referred to in the mechanism;

ii. consistent Lagrangian of the theory is presented in the paper;

iii. additional terms are presented which account for non-minimal coupling in ‘Lagrangian for interaction’;

iv. underlying statistical field theory is introduced in this paper, which is used to explain the quantum effects considered in the framework of the mechanism, namely

1. presented mathematical formulation of compact - 3 manifold to compact - 2 manifold correspondence. This framework points out \exists of singularity.

2. Presented entropic approach to the analysis of microstates characterizing singularity^{*}. Noted that the microstates of the system (black body + singularity) are described by quantum mechanics of non-observables developed in Extensions Chapter.

The paper also presents the formulation of wavefunction as probability to obtain specific shape at particular point and related to entropy at this point.

3. The following consideration addresses the structure of gravitational field and the context of the forming singularity.

This chapter of the paper presents the formula for vacuum metric which include mathematical reference to \exists of connected helicoids outlined in physical description of dark part of ‘inference topology’ geometry. This is followed by the analysis of the expression for the vacuum metric which is defined by means of ‘power law’ function, thus addressing the presence of renormalization group; and the b -function behavior, which is determined by

dint of the mechanism generation of entropy (ref. ^{*} in consideration of microstates characterizing singularity).

In the reference to phase transition, order phase and the behavior of a chaotic attractor of the system ('inference topology') relative to a system parameter are evaluated.

The appendix points to \exists of vortex solution in order phase. The paper also addresses the investigated regimes related to the different behavior of a chaotic attractor. It is also noted in the paper that the wormhole structure can form in tunnel area of system in 'intermitted switching' regime.

v. Connections between the following items are described in the paper as well:

1. instability point;
2. instanton solution;
3. soliton solution;
4. exciton model for the BE condensate (this includes the solution of the Navier-Stokes existence and smoothness problem);
5. absence of vacuum instability in gravitational coupling regime (Fig. 1.3), ref. Implication of quantum fluctuations paragraph.

vi. The appearance and the cancellation mechanism for Lorentz violation are discussed in Supplementary Chapter.