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Cosmological Constant and the Vacuum Stability in the Standard Model

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Abstract: *We considered B.G. Sidharth's theory of cosmological constant based on the non-commutative geometry of the Planck scale space-time, what gives an extremely small Dark Energy density providing the accelerating expansion of the Universe. Theory of two degenerate vacua – the Planck scale phase and Electroweak (EW) phase – also is reviewed, topological defects in these vacua are investigated: black-hole solution with a "hedgehog" monopole in the Planck phase, and ANO magnetic vortices – in the EW phase, also the Compton wavelength phase, suggested by B.G. Sidharth, was discussed. A general theory of the phase transition recently developed by B.G. Sidharth and A. Das was applied to the phase transition between the Planck scale phase and Compton (EW) scale. We have reviewed a theory of cosmological constant and the problem of the vacuum stability in the Standard Model (SM) in this article.*

The Multiple Point Principle (MPP) also is reviewed here. It was demonstrated that the existence of two vacua into the SM was confirmed by calculations of the Higgs effective potential in the two-loop and three-loop approximations. The Froggatt-

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Nielsen's prediction of the top-quark and Higgs masses was given in the assumption that there exist two degenerate vacua in the SM. This prediction was improved by the next order calculations. Assuming that the recently discovered at the LHC new resonance with mass mS ‘ 750 GeV is a new scalar S bound state 6t + 6t, earlier predicted by C.D. Froggatt, H.B. Nielsen and L.V. Laperashvili, we try to provide the vacuum stability in the SM and exact accuracy of the MPP.

1. INTRODUCTION

The vast majority of the available experimental data is consistent with the Standard Model predictions. Until now no fully convincing sign of new physics has been detected, except for the resonances of masses 1.8 TeV, 750 GeV and maybe 300 GeV, perhaps seen at LHC.

The Standard Model (SM) is a theory with a group of symmetry:

$$G_{SM} = SU(3)_c \times SU(2)_L \times U(1)_Y, \tag{1}$$

which contains quarks (u, d, s, c, b, t), leptons (e, ν), the Higgs boson H and gauge fields: gluons G_μ, vector bosons W_μ and Z_μ, and electromagnetic field A_μ. All accelerator physics seems to fit well with the SM, except for neutrino oscillations.

These results caused a keen interest in possibility of emergence of new physics only at very high (Planck scale) energies. A largely explored scenario assumes that new physics interactions appear only at the Planck scale

$$M_{Pl} = 1{:}22 \times 10^{19}\,\text{GeV}. \tag{2}$$

According to this scenario, we need the knowledge of the Higgs effective potential $V_{eff}(\varphi)$ up to very high values of φ.

The loop corrections lead the $V_{eff}(\varphi)$ to values of φ, which are much larger than v (v is the location of the EW vacuum). The effective Higgs potential develops a new minimum at $v_2 >> v$. The position of the second minimum depends on the SM parameters, especially on the top and Higgs masses, M_t and M_H.

2. LHC: SEARCH FOR THE RESONANCES IN PP COLLISION DATA AT s 13 TeV

Recently the ATLAS and CMS collaborations [1–4] have presented the rst data obtained at the LHC Run 2 with pp collisions at energy s = 13 TeV. Fig. 1 (a) presents searches for a new physics in high mass diphoton events in proton-proton collisions at 13 TeV.

Fig. 1: (a) This figure presents searches for a new physics in high mass diphoton events in proton-proton collisions at 13 TeV. ATLAS and CMS Collaborations show a new resonance in the diphoton distribution at an invariant mass of 750-760 GeV.

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The ATLAS collaboration claims an excess in the distribution of events containing two photons, at the diphoton invariant mass $M \approx 750$ GeV with $3{:}9\sigma$ statistical significance. The ATLAS excess consists of about 14 events suggesting a best-fit width Γ of about 45 GeV with $\Gamma\ M \approx 0.06$.

See: Appendix A. Resonance 750 GeV.

ATLAS [1–4] collaboration presents searches for resonant and non-resonant Higgs boson pair production in proton-proton collision data at $s = 8$ TeV generated by the LHC and recorded by the ATLAS detector in 2012. In the search for a narrow resonance decaying to a pair of Higgs bosons, the expected exclusion on the production cross section falls from 1.7 pb for a resonance at

Fig. 1: (b) This figure presents searches for resonant and non-resonant Higgs boson pair production using 20:3 fb^{-1} proton-proton collision data at s = 8 TeV generated by the LHC and recorded by the ATLAS detector in 2012. The results show a resonance with mass ≈ 300 GeV

260 GeV to 0.7 pb at 500 GeV. It is not excluded that then results show: a resonance with mass ≈ 300–350 GeV.

3. MULTIPLE POINT PRINCIPLE

In general, a quantum field theory allows an existence of several minima of the effective potential, which is a function of a scalar field. If all vacua, corresponding to these minima, are degenerate, having zero cosmological constants, then we can speak about the existence of a multiple critical point (MCP) in the phase diagram of theory [5–7]).

In Ref. [5] Bennett and Nielsen postulated a Multiple Point Principle (MPP) for many degenerate vacua.

See: Appendix B: Literature for MPP.

This principle should solve the netuning problem by actually making a rule for netuning. The Multiple Point Model (MPM) of the Universe contains simply the SM itself up to the scale ~ 10^{18} GeV. If the MPP is very accurate, we may

have a new law of Nature, that can help us to restrict coupling constants from theoretical principles.

Assuming the existence of two degenerate vacua in the SM:

- the first Electroweak vacuum at v = 246 GeV, and
- the second Planck scale vacuum at v_2 10^{18} GeV,

Froggatt and Nielsen predicted in Ref. [7] the top-quark and Higgs boson masses, which gave:

$$M_t = 173 \pm \text{GeV}; M_H = 135 \pm \text{GeV}: \quad (3)$$

In Fig. 2 it is displayed the existence of the second (non-standard) minimum of the effective potential in the pure SM at the Planck scale.

The tree-level Higgs potential with the standard "Electroweak minimum" at $\varphi_{min1} = v$ is given by:

$$V_1 = V\,(\text{tree level}) = \lambda(\varphi^2 - v)^2 + C_1. \quad (4)$$

The new minimum at the Planck scale:

$$V_2 = V_{eff}(\text{at Pl scale}) = \lambda_{run}(\varphi^2 - v^2)^2 + C_2 \tag{5}$$

can be higher or lower than the EW one, showing a stable EW vacuum (in the rst case), or metastable one (in the second case).

Fig. 2: The second vacuum of the effective Higgs potential is degenerated with an usual Electroweak vacuum. The Standard Model is valid up to the Planck scale except $\varphi_{min2} M_{Pl}$.

In accord with cosmological measurements, Froggatt and Nielsen assumed that cosmological constants C_1 and C_2 for both vacua are equal to zero (or approximately zero): $C_{1,2} = 0$, or $C_{1,2} \approx 0$. This means that vacua $v = v_1$ and v_2 are degenerate.

The following requirements must be satised in order that the effective potential should have two degenerate minima:

$$V_{eff}(\varphi^2_{min1}) = V_{eff}(\varphi^2_{min2}) = 0, \tag{6}$$

and

$$V'_{eff}(\varphi^2_{min1}) = V'_{eff}(\varphi^2_{min2}) = 0, \tag{7}$$

where

$$V'(\varphi^2) = \frac{\partial V}{\partial \varphi^2} \tag{8}$$

Multiple Point Principle postulates: there are many vacua with the same energy density, or cosmological constant, and all cosmological constants are zero, or approximately zero.

If several vacua are degenerate, then the phase diagram of theory contains a special point the Multiple Critical Point (MCP), at which the corresponding phases meet together:

Here it is useful to remind you a triple point of water analogy.

It is well known in the thermal physics that in the range of fixed extensive quantities: volume, energy and a number of moles, the degenerate phases of water (namely, ice, water and vapour, presented in Fig. 3) exist on the phase diagram (P, T) of Fig. 4.

Fig. 3: If several vacua are degenerate, then the phase diagram contains a special point – the Multiple Critical Point (MCP), at which the corresponding phases assembly together.

Fig. 4: The degenerate phases of water (namely, ice, water and vapour) with xed extensive quantities: volume, energy and a number of moles.

At the netuned values of the variables–pressure P and temperature T–we have:

$$T_c \approx 0{:}01°\mathrm{C},\ P_c \approx 4{:}58\ \mathrm{mm\ Hg}, \tag{9}$$

giving the critical (triple) point *O* shown in Fig. 4. This is a triple point of water analogy.

The idea of the Multiple Point Principle has its origin from the lattice investigations of gauge theories. In particular, Monte Carlo simulations of $U(1)$-, $SU(2)$- and $SU(3)$-, gauge theories on lattice indicate the existence of the triple critical point.

4. COSMOLOGICAL CONSTANT

In the Einstein-Hilbert gravitational action:

$$S = \frac{1}{8\pi G_{Nm}} \int d x \left(\frac{R}{2} - \Lambda \right)$$

(here G_N is the Newton's gravitational constant), Dark Energy (*DE*) – vacuum energy density of our Universe – is related with a cosmological constant by the following way:

$$\rho_{DE} = \rho_{vac} = (M_{Pl}^{\mathrm{red}})^2 \Lambda \tag{11}$$

Here M_{Pl}^{red} is the reduced Planck mass:

$$M_{Pl}^{\mathrm{red}}\ 2.43 \times 10^{18}\ \mathrm{GeV}. \tag{12}$$

Cosmological measurements gives:

$$\rho_{DE}\quad (2 \times 10^{-3}\ \mathrm{eV})^4. \tag{13}$$

Fig. 5: The phase diagram (P, T) of water analogy. The triple point O with $T_c = 0.01_c$ and $P_c = 4{:}58$ mm Hg is shown in Fig. 4.

that means a tiny value of the cosmological constant:

$$\Lambda \; 10^{-84} \, \mathrm{GeV}^4. \tag{14}$$

By this reason, Bennett, Froggatt and Nielsen considered only zero, or almost zero, cosmological constants for all vacua, existing in our Universe.

4.1 Sidharth's Theory of Cosmological Constant (Dark Energy)

In 1997 year Sidharth was rst who suggested a model, in which the Universe would be accelerating, driven by the so called Dark Energy, corresponding to the extremely small cosmological constant [9, 10].

It was suggested before the discovery of *S*. Perlmutter, B. Schmidt and A. Riess (in 1998) [8], which were awarded by the Nobel Prize later for discovery of the Universe accelerating expansion.

We see that yet in 1997 year:

1. Sidharth predicted a tiny value of the cosmological constant:

$$\Lambda \sim H_0^{\;2}, \tag{15}$$

where H_0 is the Hubble rate in the early Universe;

Fig. 6: Stability phase diagram (M_H, M_t) is divided into three dierent sectors: (1) an absolute stability region – cyan region of figure, (2) a metastability (yellow) region, and (3) an instability (green) region. The black dot indicates current experimental values M_H 125.7 GeV and M_t 173.34 GeV. The ellipses take into account 1σ, 2σ and 3σ, according to the current experimental errors.

2. Sidharth predicted that a Dark Energy (*DE*) density is very small:

$$10^{-12}\,\mathrm{eV}^4 = 10^{-48}\,\mathrm{GeV}^4; \tag{16}$$

3. Sidharth first predicted that a very small *DE* density provides an accelerating expansion of our Universe after the Big Bang.

Sidharth proceeded from the following points of view [11]:

Modern Quantum Gravity (Loop Quantum Gravity, etc.,) deal with a non-dierentiable space-time manifold. In such an approach, there exists a minimal space-time cut *O*, which leads to the non-commutative geometry, a feature shared by the Fuzzy Space-Time also.

See: Appendix C. Non-commutativity, the main references.

Following the book [11], let us consider:

- R_{un} – the radius of the Universe ~ 10^{28} cm,
- (T_{un}) – the age of the Universe,
- N_{un} – the number of elementary particles in the Universe ($N_{un} \sim 10^{80}$),

- l – the Compton wavelength of the typical elementary particle with mass m, $(l = c/m)$ ($l \sim 10^{-10}$ cm for electron).

Then in a random walk, the average distance l between particles is

$$l R \approx N \tag{17}$$

and

$$T_{un} = N_{un} \tau, \tag{18}$$

where τ is a minimal time interval (chronon).

If we imagine that the Universe is a collection of the Planck mass oscillators, then the number of these oscillators is:

$$N_{unPl} \sim 10^{120} \tag{19}$$

If the space-time is fuzzy, non-dierentiable, then it has to be described by a non-commutative geometry with the coordinates obeying the following commutation relations:

$$[dx_\mu; dx_\nu] \approx \beta_{\mu\nu} l^2 \neq 0. \tag{20}$$

Fig. 7: The RG evolution of the Higgs self-coupling $\lambda(\mu)$ is given by blue lines, thick and dashed, for the current experimental values M_H 125.7 GeV and M_t 173.34 GeV for QCD constant s given by $\pm 3\sigma$. The thick blue line corresponds to the central value of $\alpha_s = 0{:}1184$ and dashed blue lines correspond to errors of α_s equal to 0.0007.

Eq. (20) is true for any minimal cut off l.

Previously the following commutation relation was considered by H.S. Snyder [12]:

$$[x, p] = \left[1 + \left(l\right)^2\right], \text{etc.,} \tag{21}$$

which shows that effective ly 4-momentum p is replaced by

$$p \to p\left(1 + \frac{l^2}{2} p^2\right)^{-1}. \tag{22}$$

Then the energy-momentum formula now becomes as:

$$E^2 = m^2 + p^2\left(1 + \frac{l^2}{2} p^2\right)^{-2} \tag{23}$$

or

$$E^2 \approx m^2 + p^2 - \gamma \frac{l^2}{2} p^4, \tag{24}$$

where $\gamma \sim 2$.

Fig. 8: (a) The Feynman diagram corresponding to the main contribution of the S bound state 6t + 6t to the running Higgs selfcoupling .

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Fig. 8: (b) Feynman diagrams of other contributions of NBS to the S, which are smaller within 20-25%.

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In such a theory the usual energy momentum dispersion relations are modied [13].

In the above equations l stands for a minimal (fundamental) length, which could be the Planck length, or for more generally - Compton wavelength. It is necessary to comment that if we neglect order of l^2 terms, then we return to the usual quantum theory.

Writing Eq. (24) as

$$E = E' - E'', \tag{25}$$

where E' is the usual (old) expression for energy, and E'' is the new additional term in modication. E'' can be easily veried as

$$E'' = mc^2. \tag{26}$$

In Eq. (26) the mass m is the mass of the field of bosons. Furthermore it was proved, that (25) is valid only for boson fields, whereas for fermions the extra term comes with a positive sign. In general, we can write:

$$E = E' + E'', \tag{27}$$

where $E'' = -m_b c^2 -$ for boson fields, and $E'' = +m_f c^2 -$ for fermion fields (with mass m_b, m_f, respectively). These formulas help to identify the *DE* density, what was first realized by B.G. Sidharth in Ref. [10].

DE density is the density of the quantum vacuum energy of the Universe. Quantum vacuum, described by Zero Point Fields (ZPF) contributions, is the lowest state of any Quantum Field Theory (QFT), and due to Heisenberg's principle has an infinite value, which is "renormalizable".

As it was pointed out in Refs. [14, 15] that quantum vacuum of the Universe can be a source of cosmic repulsion. However, a difficulty in this approach has been that the value of the cosmological constant turns out to be huge, far beyond what is observed by astrophysical measurements. This has been called "the cosmological constant problem" [16].

Using the non-commutative theory of the discrete space-time, B.G. Sidharth predicted the value of cosmological constant :

$$\mathrm{L}\ H_0{}^2, \tag{28}$$

where H_0 is the Hubble rate:

$$H_0\ 1.5 \times 10^{-42}\,\mathrm{GeV} \tag{29}$$

4.2 What is the Universe Vacuum?

It is well known that in the early Universe topological defects may be created in the vacuum during the vacuum phase transitions [18, 19].

It is thought that the early Universe underwent a series of phase transitions, each one spontaneously breaking some symmetry in particle physics and giving rise to topological defects of some kind, which in many cases can play an essential role throughout the subsequent evolution of the Universe.

In the context of the General Relativity, Barriola and Vilenkin [19] studied the gravitational eects of a global monopole as a spherically symmetric topological defect. It was found that the gravitational effect of global monopole is repulsive in nature. Thus, one may expect that the global monopole and cosmological constants are connected through their common manifestation as the origin of repulsive gravity. Moreover, both cosmological constant and vacuum expectation value are connected while the vacuum expectation value is connected to the topological defect. All these points lead us to a simple conjecture: There must be a common connection among them, namely, the cosmological constant, the global monopole (topological defect) and the vacuum expectation value.

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Remark

In the systematic phase of the early Universe, topological defects were absent.

During the expansion of the early Universe, after the Planck era, dierent phase transitions resulted in to the formation of the various kind of much discussed topological defects like monopoles (point defects), cosmic strings (line defects) and domain walls (sheet defects). The topology of the vacuum manifold dictates the nature of these topological defects. These topological defects appeared due to the breakdown of local or global gauge symmetries. In Ref. [20] it was studied the gravitational field, produced by a spherically symmetric "hedgehog" conguration in scalar field theories with a global $SO(3)$ symmetry.

For isovector scalar:

$$\Phi = (\Phi_1, \Phi_2, \Phi_3) \tag{30}$$

this solution is pointing radially, what means that is parallel to $\hat{r}$, the unit vector in the radial direction. The started Lagrangian of this theory is:

$$L = \frac{1}{2}\partial_\mu \Phi \cdot \partial_\nu \Phi\, g^{\mu\nu} + \lambda(\Phi \cdot \Phi - v^2), \tag{31}$$

If Φ is constraint as $\Phi \cdot \Phi = v^2$ (for example, at $|\Phi| \to \infty$), then the Lagrangian is:

$$L = \frac{1}{2}\partial_\mu \Phi \cdot \partial_\nu \Phi\, g^{\mu\nu}, \tag{32}$$

Topological structures in fields are as important as the fields themselves. In Ref. [21] the gauge-invariant hedgehog-like structures in the Wilson loops were investigated in the $SU(2)$ Yang-Mills theory. In this model the triplet Higgs field $\Phi \equiv \Phi^a \frac{1}{2}\sigma_a$ $(a = 1, 2, 3)$ vanishes at the center of the monopole $x = x_0$:

$$\Phi(x_0) = 0 \tag{33}$$

and has a generic hedgehog structure in the spatial vicinity of this monopole.

Recently in arXiv appeared the investigation [22]. In this connection, it is interesting to see Ref. [23].

In Refs. [22, 23] the authors obtained a solution for a black-hole in a region that contains a global monopole in the framework of the $f(R)$ gravity, where $f(R)$ is a function of the Ricci scalar R. Near the Planck scale they considered the following action:

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$$S = \frac{1}{\kappa^2}\int d^4x\, f\left(R\, () + \frac{1}{2} D^b_\mu (\varphi^b)^\dagger D^\mu_a \varphi^b - \frac{1}{4}(\varphi^{a\,2} - v^2)^2 + \ldots \right) \tag{34}$$

where $\kappa^2 = 8\pi G_N$, G_N is the Newton's gravitational constant, Φ_a is the Higgs triplet field ($a = 1, 2, 3$), is the Higgs self-interaction coupling, and v (which here is v_2) is the vacuum expectation value (VEV) of Φ at the Planck scale:

$$v = v_2 = \langle \Phi_{min2} \rangle \sim 10^{18}\,\text{GeV}. \tag{35}$$

Here D_μ is a covariant derivative:

$$D_{\mu a} = \partial_\mu + i\omega_{\mu\ a} + iW_{\mu\ a}, \tag{36}$$

where $\omega_{\mu\ a}$ is the gravitational spin-connection, and $W_{\mu\ a}$ is the $SU(2)$ gauge field.

Considering the time independent metric with spherical symmetry in (3+1) dimensions:

$$ds^2 = B(r)dt^2 - A(r)dr^2 - r^2(d\theta^2 + \sin(2\theta)d\phi^2; \tag{37}$$

the authors of Refs. [22, 23] obtained a monopole conguration, which is described as:

$$\varphi^a = {}_2(v) r \frac{x^a}{r}, \tag{38}$$

where $a = 1, 2, 3$ and $x_a x_a = r^2$. This is "a hedgehog" solution by Alexander Polyakov's terminology.

In the at space the hedgehog core has the size:

$$\delta \sim \frac{1}{\lambda_v}, \tag{39}$$

and the mass:

1

$$M^{core} \sim \lambda, \tag{40}$$

which is:

$$M_{BH} \sim M_{Pl} \sim 10^{-5}\,\text{gms}; \tag{41}$$

or

$$M_{BH} \sim 10^{18}\,\text{GeV}. \tag{42}$$

This is a black-hole solution, which corresponds to a global monopole that has been swallowed by a black-hole.

Now we see, that the Planck scale Universe is described by a non-dierentiable space-time: by a foam of black-holes, having lattice-like structure, in which sites are black-holes with the “hedgehog” monopoles inside them.

Global monopole is a heavy object formed as a result of gauge-symmetry breaking in the phase transition of an isoscalar triplet Φ_a system. The black-holes- monopoles-hedgehogs are similar to elementary particles, because a major part of their energy is concentrated in a small region near the monopole core. In the Guendelman-Rabinowitz theory [20], a gravitational effect similar to hedgehogs can be generated by a set of cosmic strings in a spherically symmetric conguration, which can be referred to as a “string hedgehog”. The authors investigated the evolution of bubbles separating two phases: one being the “false vacuum” (Planck scale vacuum) and the other the "true vacuum” (EW-scale vacuum). The presence of the hedgehogs, called "defects”, is responsible for the destabilization of a false vacuum. Decay of a false vacuum is accompanied by the growth of bubbles of a true vacuum. Guendelman and Rabinowitz also allowed a possibility to consider an arbitrary domain wall between two phases. During the ination domain wall annihilates, producing gravitational waves and a lot of SM particles, having masses.

The non-commutative contribution of the black-holes of the Planck scale vacuum compensates the contribution of the Zero Point Fields and the cosmological constant of the Planck scale phase is:

$$\Lambda(\text{at Pl: scale}) = \Lambda_{ZPF}(\text{at Pl: scale}) - \Lambda_{BH} = 0, \tag{43}$$

That is, the phase with the VEV $v = v_2$ has zero cosmological constant.

By cosmological theory, the Universe exists in the Planck scale phase for extremely short time. By this reason, the Planck scale phase was called “the false vacuum". After the next phase transition, the Universe begins its evolution toward the second, Electroweak (EW) phase. Here the Universe underwent the ination, which led to the phase having the VEV:

$$v = v_1 \approx 246 \text{ GeV}. \tag{44}$$

The Electroweak ("true") vacuum with the VEV $v \approx 246$ GeV is the vacuum, in which we live.

5. PHASE TRANSITION(S) IN THE UNIVERSE

Now it is useful to understand the eects of the nite temperature on the Higgs mechanism (see [24]).

At some nite temperature which is called the critical temperature T_c, a system exhibits a spontaneous symmetry breaking. A ferromagnet is an example of spontaneously broken symmetry. In this theory the equations of motion are rotatiofinally symmetric, but the ground state of a ferromagnet has a preferred direction.

In the Landau and Ginzburg theory [25], the free energy of an isotropic ferromagnet is

$$F = \frac{1}{2}\alpha M^2 + \frac{1}{4}\beta M^4, \tag{45}$$

where α is positive and M is the magnetization, α has a temperature dependence, and near the critical point it is given by $\alpha = \alpha_0(T - (T_c)$. Thus, for temperatures below the critical temperature, α is negative, and the vacuum value of $|M|$ is nonzero. For temperatures above the critical temperature, is positive, and the magnetization vanishes. This is what one intuitively expects: at high temperatures the kinetic energy of the atoms is much greater than the spin exchange interaction energy, thus the average magnetization should vanish. Therefore, at high temperatures the rotational $O(3)$ symmetry of a ferromagnet is restored.

The spontaneous symmetry breakdown of a gauge theory also vanishes at high temperature, and the gauge symmetry is restored. Kirzhnits [26] and Linde [27] were first who considered the analogy between the Higgs mechanism and superconductivity, and argued that the Higgs field condensate disappears at high temperatures, leading to symmetry restoration. As a result, in the

Higgs model at high temperatures, all fermions and vector bosons are massless. These conclusions were confirmed, and the critical temperature was estimated in Refs. [28–30].

See also the review article by A. Linde [31].

Let us consider now the phase transition from a false vacuum to a true vacuum. At the early stage the Universe was very hot, but then it began to cool down. Black-holes-monopoles (as bubbles of the vapor in the boiling water) began to disappear. The temperature dependent part of the energy density died away. In that case, only the vacuum energy will survive. Since this is a constant, the Universe expands exponentially, and an exponentially expanding Universe leads to the ination (see [32–34], etc.).

During the ination the triplet Higgs field, φ_a, $a = 1, 2, 3$, decays into the Higgs doublet fields of $SU(2)_L$, Φ. Here we follow to the Gravi-Weak Unication theory of Ref. [35], and finally we have the Standard Model Lagrangian with gravity:

$$\frac{1}{2} f(R) - \Lambda + \frac{1}{2} D_\mu \Phi^\dagger D^\mu \Phi - \frac{1}{4}\lambda (\Phi^2 - v^2)^2 + L_{\text{matter}} + L_{\text{gauge}} + L_{Yuk}, \tag{46}$$

where Λ is a cosmological constant, and

$$D_\mu = \partial_\mu + i\omega_\mu^{\ i} + iW_\mu^{\ i}\tau_i + iA_\mu \tag{47}$$

is a covariant derivative.

L_{matter}, L_{gauge} and L_{Yuk} are respectively the matter fields Lagrangian (including quarks with flavors f and leptons e, ν), the gauge fields Lagrangian (including gluons G_μ, vector bosons W_μ and the electromagnetic field A), and the Yukawa couplings Lagrangian of type $_f$ $Y_{f}^{\ j}$. Here;

$$sl(2; C)_{(grav)} : \{\rho_i\} = (\sigma_i \otimes 1_2), \tag{48}$$

and

$$su(2)_{(weak)} : \{\tau_i\} = \{1_2 \otimes \sigma_i\}, \tag{49}$$

The Electroweak vacuum has the Higgs field's VEV: $v \approx 246$ GeV.

While the Universe was being in the false vacuum and expanding exponentially, so it was cooling exponentially. This scenario was called supercooling in the false vacuum.

When the temperature reached the critical value T_c, the Higgs mechanism of the SM created a new condensate $\Phi_{\min 1}$, and the vacuum became similar to superconductor, in which the topological defects are the closed magnetic vortices. The energy of black-holes is released as particles, which were created during the radiation era of the Universe, and all these particles (quarks, leptons, vector bosons) acquired their masses through the Yukawa coupling mechanism

$Y_f \quad f \quad f$

The Electroweak spontaneous breakdown of symmetry $SU(2)_L \times U(1)_Y \rightarrow U(1)_{el.mag}$ leads to the creation of the topological defects in the EW vacuum. They are the Abrikosov-Nielsen-Olesen closed magnetic vortices of the Abelian Higgs model [36, 37]. Then the electroweak vacuum again presents the non-dierentiable manifold, and again we have to consider the non-commutative geometry, in accordance with the Sidharth's theory of the vacuum.

However, here we have fermions, which have a mass, therefore Compton wavelength, $\lambda = /mc$, and according to the Sidharth's theory of the cosmological constant, we have in the EW-vacuum lattice-like structure of bosons and fermions with lattice parameter "l" equal to the Compton wavelength: $l = /mc$.

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Taking into account the relation between the vacuum energy density, vac, and the cosmological constant, Λ:

$$\rho_{vac} = \rho_{DE} = M_{Pl} \quad {}^{red.2} \Lambda, \tag{50}$$

we easily see that in the Planck scale vacuum (with the VEV $v_2 \sim 10_{18}$ GeV) we have:

$$\rho_{vac}\,(\text{at Planck scale}) = \rho_{ZPF}\,(\text{at Planck scale}) - (\quad {}^{NC\ )}_{black\ holes} \quad 0, \tag{51}$$

and

$$\rho_{vac}\,(\text{at EW scale}) = \rho_{ZPF}\,(\text{at EW scale}) - (\quad {}^{NC\ )}_{vortex\ contr} \ . \ {}^{(NC\ )}_{boson\ fields} \quad {}^{(NC\ )}_{fermion\ fields} \quad 0, \tag{52}$$

In the above equations "*NC*" means the "non-commutativity" and "*ZPF*" means "zero point fields".

Here I want to comment that the correctness of an assessment of the non-commutative theory is well known in the paper Ref. [38]. It is necessary to emphasize that, due to the energy conservation law, the vacuum density before the phase transition at the critical temperature T_c is equal to the vacuum density after the phase transition, that is:

$$\rho_{vac}(\text{at Planck scale}) = \rho_{vac}(\text{at EW scale}). \quad (53)$$

The analogous link between the Planck scale phase and Electroweak phase was considered in the paper [39]. It was shown that the vacuum energy density (DE) is described by the dierent contributions to the Planck and EW scale phases. This dierence is a result of the phase transition. However, the vacuum energy densities (DE) of both vacua are equal, and we have a link between gravitation and electromagnetism *via* the Dark Energy (see Ref. [39]). According to the last equation (53), we see that if ρ_{vac}(at Planck scale) is almost zero, then vac(at EW scale) also is almost zero, and we have a triumph of the Multiple Point Principle!

A general theory of the phase transition from the one type lattice structure to the another type, in particular, from the Planck scale lattice with sites φ_P to the Compton scale lattice with sites φ_c, was developed in Refs. [40, 41]. Previously it has been proved that the phase transition from the Planck scale phase to the Compton scale (EW) phase is similar to the Landau-Ginzburg phase transition [42]. In these investigations it has been substantiated that the 2D universe undergoes a phase transition from the Planck phase to the Compton phase in analogy with the ferromagnetic case.

This result should also be hold in the case of a 3D universe.

Here I would like to specify the concept "Compton phase" entered by Sidharth. Taking into account Sidharth's previous works [42, 43], we have, in analogy with a coherence parameter ξ of the Ginzburg-Landau theory [25], the following coherence parameter:

$$hc \quad , \quad mc^2 \quad , \quad \frac{2}{mc} \quad 2 \; {}_c l \quad (54)$$

where ${}_c \; l \; mc$ is the Compton length of a particle having mass m.

If we consider the Higgs particle (with mass m_H), then we have it's Compton length:

$$l \quad ,$$

$$_{H} \quad m\ e \tag{55}$$

i.e. the coherence parameter of the phase under consideration is the Compton length of the Higgs boson. In general, we can say: The Compton length is the fundamental aspect of the Compton phase, which is synonymous to the Electroweak phase the current phase of the Universe.

Thus, B.G. Sidharth explains in his investigations, why the Compton scale plays such a rudimentary role in all phenomena of the quantum physics. The Compton scale gives the description of an accelerating Universe with a small positive cosmological constant [10].

In the paper [44] it was given that the Compton scale gives the correction to the electron anomalous gyromagnetic ratio $g = 2$, what also was considered by J. Schwinger from the quantum field theoretical point of view.

The papers [45] and [46] were devoted to the Lamb shift as a phenomenon that can be attributed only to the Compton scale and to the non-commutative nature of the space-time.

6. VACUUM STABILITY AND THE MULTIPLE POINT PRINCIPLE

Now let us concentrate our attention on the vacuum stability problem in the Standard Model, which has a long history:

See: Appendix D and references in [17].

If $\Lambda_{EW} > \Lambda_{Pl}$, what means:

$$\rho_{vac}(\text{at EW scale}) > \rho_{vac}(\text{at Planck scale}); \tag{56}$$

than our vacuum is not stable, it decays! And the MPP is not exact.

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For energies higher than EW scale the analysis of the vacuum stability is reduced to the study of the renormalization group evolution of the Higgs quartic coupling λ (see [24]).

The Froggatt-Nielsen's prediction for the mass of the Higgs boson $M_t =$ 173 ± 5 GeV; $M_H = 135 \pm 9$ GeV was improved in Ref. [47] by the calculation of the two-loop radiative corrections to the effective Higgs potential.

The prediction of Higgs mass 129:4 ± 1:8 GeV provided the possibility of the theoretical conrmation of the value M_H 125:7 GeV observed at the LHC. The authors of Ref. [48] have shown that the most interesting aspect of the measured value of M_H is its near-criticality. They extrapolated the SM parameters up to the high (Planck scale) energies with full three-loop NNLO RGE precision.

The main result of the investigation of Degrassi *et al*. is: The observed Higgs mass M_H = 125:66 ± 0:34 GeV at LHC leads to the negative value of the Higgs quartic coupling λ at some energy scale below the Planck scale, making the Higgs potential unstable or metastable. For the vacuum stability investigation a highly precise analysis is quite necessary.

With the inclusion of the three-loop RG equations (Buttazzo *et al*.) and two-loop matching conditions (Degrassi *et al*.), the instability scale occurs at 10^{11} GeV well below the Planck scale. This means that at that scale the effective potential starts to be negative, or that a new minimum can appear with negative cosmological constant. According to these investigations, the experimental value of the Higgs mass gives scenarios, which are at the borderline between the absolute stability and metastability. The measured value of M_H puts the Standard Model in the so-called near-critical position. Using the present experimental uncertainties on the SM parameters (mostly the top-quark mass) it is conclusively impossible to establish the fate of the EW vacuum, although metastability is preferred. Thus, the careful evaluation of the Higgs effective potential by Ref. [47], combined with the experimentally measured Higgs boson mass in the pure SM, leads to the energy density getting negative for high values of the Higgs field, what means that the minimum of the effective potential at 10^{18} GeV (if it exists) has a negative energy density. Therefore, formally the vacuum, in which we live, is unstable although it is in reality just metastable with an enormously long life-time. However, only this unstable vacuum corresponding to the experimental Higgs mass of 125:66 ± 0:34 GeV is indeed very close to the Higgs mass 129:4 ± 1:8 GeV obtained by Degrassi *et al*. [47]. The last value makes the 10^{18} GeV Higgs field vacuum be degenerate with the Electroweak one. In this sense, Nature has chosen parameters very close to ones predicted by the Multiple Point Principle.

6.1 Could the Multiple Point Principle be exact due to corrections from the new bound state 6*t* + 6anti-*t*?

See: Appendix E. Theory of the new bound state 6*t*+ 6anti-*t*, the main references.

The purpose of the articles of Refs. [17,49] is to estimate the correction from the NBS 6 *t* 6 *t* to the Higgs mass 129:4 ± 1:8 GeV obtained by Degrassi *et al*. in Ref. [47]. This is actually can be done by identifying a barely signicant peak obtained at the LHC Run2 with proton-proton collisions at energy

s 13 TeV in the LHC-experiments [50–52].

If the observed diphoton excess indeed corresponds to decay of a hitherto unknown particle then this will be the first conrmation of new physics beyond the SM. If the observed excess is due to a resonance it has to be a boson and it cannot be a spin-1 particle [53, 54]. This leaves the possibility of it being either a spin-0 or spin-2 particle [55].

If it is indeed a new particle, then one must wonder what kind of new physics incorporates it.

In previous Ref. [56] we have speculated that 6 t 6 t quarks should be so strongly bound that these bound states would eectively function at low energies as elementary particles and can be added into loop calculations as new elementary particles or resonances. The exceptional smallness of the mass mS of the new bound state particle S:

$$m_S << 12M_t \tag{57}$$

is in fact a consequence of the degeneracy of the vacua, and thus of the Multiple Point Principle.

Run 2 LHC data show hints of a new resonance in the diphoton distribution at an invariant mass of 750 GeV. We identify this peak with our NBS 6 t . 6 t
It means that taking into account the contribution of the LHC resonance with mass 750 GeV as an our bound state S during the calculations of the correction to the predicted Higgs mass, we must obtain a new result for the vacuum stability and MPP.

What is this result?

6.2 The Higgs effective potential

A theory of a single scalar field (see Ref. [24]) is given by the effective potential $V_{eff}(\varphi_c)$, which is a function of the classical field c. In the loop expansion this V_{eff} is given by:

$$V_{eff} = V^{(0)} + \sum_{n=1} V^{(\ )}{}_{,n} \tag{58}$$

where $V_{(0)}$ is the tree level potential of the SM.

The Higgs mechanism is the simplest mechanism leading to the spontaneous symmetry breaking of a gauge theory. In the SM the breaking

$$SU(2)_L \times U(1)_Y \to U(1)_{em}, \tag{59}$$

achieved by the Higgs mechanism, gives masses to the Higgs and gauge bosons, also to fermions with avor f.

With one Higgs doublet of $SU(2)_L$, we have the following tree level Higgs potential:

$$V_{(0)} = -m^2\Phi^+\Phi + \lambda(\Phi^+\Phi)^2. \tag{60}$$

The vacuum expectation value of Φ is:

$$\Phi = \frac{1}{\sqrt{2}}\begin{pmatrix} 0 \\ v \end{pmatrix}, \tag{61}$$

where

$$v = \sqrt{\frac{m^2}{\lambda}} \approx 246 \text{ GeV}, \tag{62}$$

Introducing a four-component real field φ by

$$\Phi^+\Phi = \frac{1}{2}\varphi^2, \tag{63}$$

where

$$\varphi^2 = \sum_{i=1}^{4}\varphi_i^2, \tag{64}$$

we have the following tree level potential:

$$V^{(0)} = -\frac{1}{2}m^2\varphi^2 + \frac{1}{4}\lambda\varphi^4. \tag{65}$$

As is well-known, this tree-level potential gives the masses of the gauge bosons W and Z, fermions with avor f and the physical Higgs boson H:

$$M_W^2 = \frac{1}{4}g^2v^2, \tag{66}$$

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$$M_Z^2 = \frac{1}{4}(g^2 + g'^2)v^2, \tag{67}$$

$$M_f = \frac{1}{2} g_f v, \tag{68}$$

$$M_H^2 = \lambda v^2, \tag{69}$$

where g_f is the Yukawa couplings of fermion with the avor f; g, g' are respectively $SU(2)_L$ and $U(1)_Y$ coupling constants.

7. Stability Phase Diagram

These results caused a keen interest in possibility of emergence of the new physics only at very high (Planck scale) energies. A largely explored scenario assumes that new physics interactions appear only at the Planck scale $M_{Pl} =$ 1:22 × 10^{19} GeV. According to this scenario, we need the knowledge of the Higgs effective potential $V_{eff}(\varphi)$ up to very large values of φ. The loop corrections lead the $V_{eff}(\varphi)$ to the very large (Planck scale) values of φ, much larger than v the location of the EW vacuum. The effective Higgs potential develops a new minimum at $v_2 >> v$. The position of the second minimum depends on the SM parameters, especially on the top and Higgs masses, M_t and M_H. It can be higher or lower than the EW minimum, showing a stable EW vacuum (in the first case), or metastable one (in the second case).

Considering the lifetime τ of the false vacuum (see Ref. [57]) and comparing it with the age of the Universe T_U, we see that, if τ is larger than T_U, then our Universe will be sitting in the metastable vacuum, and we deal with the scenario of metastability. The stability analysis is presented by the stability diagram in the plane (M_H, M_t).

The stability line separates the stability and the metastability regions, and corresponds to M_t and M_H obeying the condition $V_{eff}(v) = V_{eff}(v_2)$. The instability line separates the metastability and instability regions. It corresponds to M_t and M_H for $\tau = T_U$. In the stability gure the black dot indicates current experimental values M_H 125.7 GeV and M_t 173.34 GeV: see Particle Data Group.

It lies inside the metastability region. The ellipses take into account 1σ; 2σ and 3σ, according to the current experimental errors.

When the black dot sits on the stability line, then this case is named "critical", according to the MPP concept: then the running quartic coupling λ and the corresponding beta-function vanish at the Planck scale v_2:

$$\lambda(M_{Pl}) \sim 0 \text{ and } \beta(\lambda(M_{Pl})) \sim 0. \tag{70}$$

Stability phase diagram shows that the black dot, existing in the metastability region, is close to the stability line, and this "near-criticality" can be considered as the most important information obtained for the Higgs boson.

7.1 Two-loop corrections to the Higgs mass from the effective potential

Still neglecting the new physics interactions at the Planck scale, we can consider the Higgs effective potential $V_{eff}(\varphi)$ for large values of :

$$V_{eff}(\varphi) \quad \frac{1}{4}\lambda_{eff}(\varphi)\varphi^4 . \tag{71}$$

Here $V_{eff}(\varphi)$ is the renormalization group improved (RGE) Higgs potential (see [24]), and $\lambda_{eff}(\varphi)$ depends on as the running quartic coupling $\lambda(\mu)$ depends on the running scale μ. Then we have the one-loop, two-loops or three-loops expressions for V_{eff}. The corresponding up to date Next-to-Next-to-Leading-Order (NNLO) results were published by Degrassi *et al*. [47] and Buttazzo *et al*. [48].

The relation between λ and the Higgs mass is:

$$\lambda(\mu) = \frac{G_F}{2} M_H^2 + \Delta\lambda(\mu), \tag{72}$$

where G_F is the Fermi coupling. Here $\Delta\lambda(\mu)$ denotes corrections arising beyond the tree level potential. Computing $\Delta\lambda(\mu)$ at the one-loop level, using the two-loop beta functions for all the Standard Model couplings, Degrassi *et al*. [47] obtained the first complete NNLO evaluation of $\Delta\lambda(\mu)$. In the RGE gure blue lines (thick and dashed) present the *RG* evolution of $\lambda(\mu)$ for current experimental values M_H 125.7 GeV and M_t 173.34 GeV, and for α_s given by $\pm 3\sigma$.

The thick blue line corresponds to the central value of $\alpha_s = 0.1184$ and dashed blue lines correspond to errors of α_s equal to ± 0.0007. Absolute stability of the Higgs potential is excluded by the investigation [47] at 98% C.L. for $M_H < 126$ GeV. In gure we see that asymptotically $\lambda(\mu)$ does not reach zero, but approaches to the negative value, indicating the metastability of the Electroweak vacuum:

$$\lambda \to -(0{:}01 \pm 0{:}002), \tag{73}$$

According to Degrassi *et al*. [47], the stability line is the red thick line in the figure, and corresponds to: $M_H = 129.4 \pm 1{:}8$ GeV. Our aim is to show that the stability line could correspond to the current experimental values of the SM parameters, with $M_H = 125.7$ GeV, given by LHC, provided we include a correction caused by the newly found at LHC resonance, which is identied as the bound state of our 6 $t + 6t$.

7.2 The effect from the new bound states 6*t* + 6anti-*t* on the measured Higgs mass

In Ref. [56] was first assumed that:

1. there exists 1*S*-bound state 6 t + 6 t – scalar particle and color singlet,
2. that the forces responsible for the formation of these bound states originate from the virtual exchanges of the Higgs bosons between top(anti-top)-quarks,
3. that these forces are so strong that they almost compensate the mass of 12 top(antitop)-quarks contained in these bound states.

The explanation of the stability of the bound state 6 t + 6 t is given by the Pauli principle: top-quark has two spin and three color degrees of freedom (total 6). By this reason, 6 quarks have the maximal binding energy, and 6 pairs of 6*tt* in 1*S*-wave state create a long lived (almost stable) colorless scalar bound state S. One could even suspect that not only this most strongly bound state *S* of 6 t + 6 t, but also some excited states exist, and a new bound state 6 t + 5 t which is a fermion similar to the quark of the 4th generation.

These bound states are held together by exchange of the Higgs and gluons between the top-quarks and anti-top-quarks as well as between top and top and between anti-top and anti-top. The Higgs field causes attraction between quark and quark as well as between quark and anti-quark and between anti-quark and anti-quark, so the more particles and/or anti-particles are being put together the stronger they are bound. But now for fermions as top-quarks, the Pauli principle prevents too many constituents being possible in the lowest state of a Bohr atom constructed from dierent top-quarks or anti-top-quarks surrounding (as electrons in the atom) the "whole system" analogous to the nucleus in the Bohr atom.

Because the quark has three color states and two spin states meaning 6 internal states there is in fact a shell (as in the nuclear physics) with 6 top-quarks and similarly one for 6 anti-top-quarks. Then we imagine that in the most strongly bound state just this shell is lled and closed for both top and anti-top. Like in nuclear physics where the closed shell nuclei are the strongest bound, we consider this NBS 6 t + 6 t as our favorite candidate for the most strongly bound and thus the lightest bound state *S*. Then we expect that our bound state *S* is appreciably lighter than its natural scale of 12 times the top mass, which is about 2 TeV. So the mass of our NBS *S* should be small compared to 2 TeV. Estimating dierent contributions of the bound state S, we have considered the main Feynman diagrams correcting the effective Higgs self-interaction coupling constant $\lambda(\mu)$. They are diagrams containing the bound state *S* in the loops.

7.3 The Effect from the New Bound States 6 *t* 6 *t* on the Measured Higgs Mass. The Main Diagrams Correcting the effective Higgs Self-interaction Coupling Constant

Now we have the following running $\lambda(\mu)$:

$$\lambda(\mu) = \frac{G_F}{2} M_H^2 + \delta\lambda(\mu) + \Delta\lambda(\mu), \tag{74}$$

where the term $\delta\lambda(\mu)$ denotes the loop corrections to the Higgs mass arising from our NBS, and the main contribution to $\delta\lambda(\mu)$ is the term S, which corresponds to the contribution of the first Feynman diagram:

$$\delta\lambda(\mu) = \lambda_S + \ldots \tag{75}$$

The rest contributions are shown in the second figure of the Feynman diagrams.

You can see the result of the corrections to the running from the bound state S in the recent papers [17, 49].

The result is:

$$\lambda_S \approx \frac{1}{\pi^2} \left(\frac{6 g_t}{b} \times \frac{m_t}{m_S} \right)^4, \tag{76}$$

where g_t is the experimentally found Yukawa coupling of top-quark with the Higgs boson, m_t and m_S are masses of the top-quark and S-bound state, respectively, and b is a parameter, which determines the radius r_0 of the bound state S:

$$r_0 = \frac{b}{m_t}, \tag{77}$$

As we see, the figure given by Degrassi *et al*. [47] showed that asymptotically $\lambda(\mu)$ does not reach zero, but approaches to the negative value:

$$\lambda \to -(0{:}01 \pm 0.002), \tag{78}$$

indicating the metastability of the Electroweak vacuum.

If any resonance gives the contribution:

$$\lambda \to +0.01, \tag{79}$$

then this contribution transforms the metastable (blue) curve of the stability diagram into the red curve, which is the borderline of the stability.

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Using the results obtained earlier in Ref. [58], we have calculated in Ref. [17] the value of the S-bound state's radius:

$$r_0 \approx \frac{2.34}{m_t} \tag{80}$$

Such radius of S gives:

$$\lambda_S 0.009 \tag{81}$$

or taking into account that the uncertainty coming from the contributions of the rest Feynman diagrams can reach 25%, we have finally:

$$\lambda_S 0.009 \pm 0.002 \tag{82}$$

Just this result for radius provides the vacuum stability in the Standard Model conrming the accuracy of the Multiple Point Principle.

8. SUMMARY AND CONCLUSIONS

1. Here we have reviewed the Sidharth's theory of the cosmological constant theory of the vacuum energy density of our Universe, or Dark Energy. B.G. Sidharth was to show (in 1997) that the cosmological constant is extremely small: $\Lambda \sim H_0^2$, where H_0 is the Hubble rate, and the Dark Energy density is very small ($\sim 10^{-48}$ GeV^4), what provided the accelerating expansion of our Universe after the Big Bang.

2. We considered the theory of the vacua of the Universe Planck scale phase and Electroweak phase. Considering the topological defects in these vacua, we have discussed that topological defects of the Planck scale phase are black-holes solutions, which correspond to the "hedgehog" monopole that has been "swallowed" by a black-hole. It was suggested to consider the topological defects in the Electroweak phase as Abrikosov-Nielsen-Olesen magnetic vortices.

   The Compton wavelength phase also was discussed. We have used the Sidharth's predictions of the non-commutativity for these non-dierentiable manifolds with aim to prove that cosmological constants are zero, or almost zero.

3. We considered a general theory recently developed by B.G. Sidharth and A. Das of the phase transition between the two dierent lattice structures. This theory was applied to the phase transition between

the Planck scale phase and Compton scale phase.

The link between the gravitation and electromagnetism *via*Dark Energy also was established by Sidharth in his recent paper.

4. We reviewed the Multiple Point Model (MPM) by D.L. Bennett and H.B. Nielsen. We showed that the existence of two vacua into the Standard Model: the first one at the Electroweak scale ($v = v_1 \approx 246$ GeV), and the second one at the Planck scale ($v_2 \sim 10^{18}$ GeV), was conrmed by calculations of the Higgs effective potential in the two-loop and three-loop approximations. The Froggatt-Nielsen's prediction of the top-quark and Higgs masses was given in the assumption that there exist two degenerate vacua in the Standard Model. It was calculated that this prediction was improved by the next order calculations.

5. We showed that for energies higher than Electroweak scale, the analysis of the vacuum stability is reduced to the study of the renormalization group evolution of the Higgs quartic coupling . The prediction for the mass of the Higgs boson was improved by the calculation of the two-loop radiative corrections to the effective Higgs potential. The prediction of Higgs mass 129.4 ± 1:8 GeV by Degrassi *et al*. provided the theoretical explanation of the value M_H 125.7 GeV observed at the LHC.

   Buttazzo *et al*. extrapolated the Standard Model parameters up to the high (Planck scale) energies with full three-loop NNLO RGE precision.

6. It was shown that the observed Higgs mass $M_H = 125.66 \pm 0{:}34$ GeV leads to a negative value of the Higgs quartic coupling λ at some energy scale below the Planck scale, making the Higgs potential unstable or metastable. With the inclusion of the three-loop RG equations, the instability scale occurs at 10^{11} GeV (well below the Planck scale) meaning that at that scale the effective potential starts to be negative, or that a new minimum with negative cosmological constant can appear.

   It was shown that the experimental value of the Higgs mass leads to a scenario which gives a borderline between the absolute stability and metastability.

7. We assumed that the recently discovered at the LHC new resonances with masses m_S 750 GeV are a new scalar S bound state 6 t + 6$\bar{t}$ earlier predicted by C.D. Froggatt, H.B. Nielsen and L.V. Laperashvili. It was shown that this bound state, 6 top and 6 anti-top, which we identify

with the 750 GeV new boson, can provide the vacuum stability and exact accuracy of the Multiple Point Principle, according to which the two vacua existing at the Electroweak and Planck scales are degenerate.

8. We calculated the main contribution of the S-resonance to the effective Higgs quartic coupling λ, and showed that the resonance with mass m_S 750 GeV, having the radius $r_0 = b/m_t$ with $b \approx 2.:34$, gives the positive contribution to λ, equal to the ≈ = +0.01. This contribution compensates

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the negative value of the λ = –0.01, which was earlier obtained by Degrassi *et al*., and therefore transforms the metastability of the Electroweak vacuum into the stability.

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A. Appendix: Resonance 750 GeV

Recently both the ATLAS and CMS collaborations observed an excess in diphoton events with an invariant mass in the region of 750 GeV. Although more data is needed to conrm or exclude the excess, a large number of works have already appeared on this possible new physics signal:

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B Appendix: Multiple Point Principle, literature

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