Black-holes-hedgehogs in the false vacuum and a new physics beyond the Standard Model

C.R. Das, L.V. Laperashvili, H.B. Nielsen
and B.G. Sidharth

The 3rd international conference on
particle physics and astrophysics

Gravitation and Cosmology - 1 Parallel Session
10:30 - 10:45, 3rd October, 2017

arXiv:1703.05594[hep-ph]

- During the expansion after the Planck era, the early Universe underwent a series of phase transitions as a result of which there were arisen such vacuum topological defects as monopoles or hedgehogs (point defects), strings (line defects), bubbles and domain walls (sheet defects).

- These topological defects appeared due to the breakdown of local or global gauge symmetries.

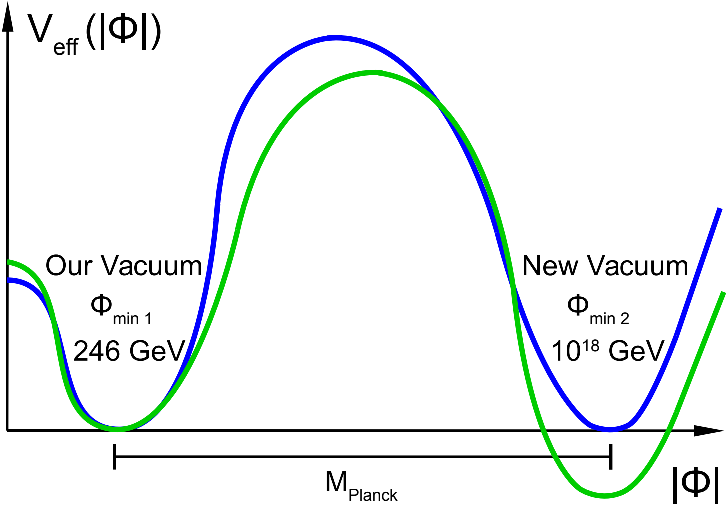
In this investigation, we were based on the discovery that a cosmological constant of our Universe is extremely small, almost zero, and assumed a new law of Nature which was named as a Multiple Point Principle (MPP).

The MPP postulates:

There are two vacua in the SM with the same energy density, or cosmological constant, and both cosmological constants are zero, or approximately zero.

We considered the existence of the following two degenerate vacua in the SM:

1. the first Electroweak vacuum at $v_1 = 246$ GeV, which is a "true" vacuum, and
2. the second "false" vacuum at the Planck scale with VEV $v_2 \sim 10^{18}$ GeV.



Minima of the effective Higgs potential in the pure Standard Model, which correspond to the first Electroweak "true vacuum", and to the second Planck scale "false vacuum".

- The bubble, which we refer to as “the false vacuum”, is a de Sitter space with its constant expansion rate H_F.
- The initial radius of this bubble is close to the de Sitter horizon, which corresponds to the Universe radius.
- The space-time inside the bubble, which we refer to as “the true vacuum”, has the geometry of an open The Friedmann–Lemaître–Robertson–Walker (FLRW) universe.

- We investigated the topological structure of the universal vacua. Different phase transitions, which were resulted during the expansion of the early Universe after the Planck era, produced the formation of the various kind of topological defects.

  The aim of this investigation is the consideration of the hedgehog configurations as defects in the false vacuum. We have obtained a solution for a black-hole in the region which contains a global monopole in the framework of the $f(R)$ gravity, where $f(R)$ is a function of the Ricci scalar R.

- Here we have used the results of the Gravi-Weak unification (GWU) model. The gravitational field, isovector scalar Φ^a with $a = 1, 2, 3$, produced by a spherically symmetric configuration in the scalar field theory, is pointing radially: Φ^a is parallel to $\hat{r}$ – the unit vector in the radial direction.

  In this GWU approach, we obtained a "hedgehog" solution (in Alexander Polyakov's terminology). We also showed that this is a black-hole solution, corresponding to a global monopole that has been "swallowed" by a black-hole.

- We estimated all parameters of the Gravi-Weak unification model, which gave the prediction of the Planck scale false vacuum VEV equal to $v = 2\sqrt{2}M_{Pl}^{red} \approx 6.28 \times 10^{18}$ GeV.

- We have shown, that the Planck scale Universe vacuum is described by a non-differentiable space-time: by a foam of black-holes, or by lattice-like structure, where sites are black-holes with the "hedgehog" monopoles inside them.

  This manifold is described by a non-commutative geometry, leading to a tiny value of cosmological constant $\Lambda \approx 0$.

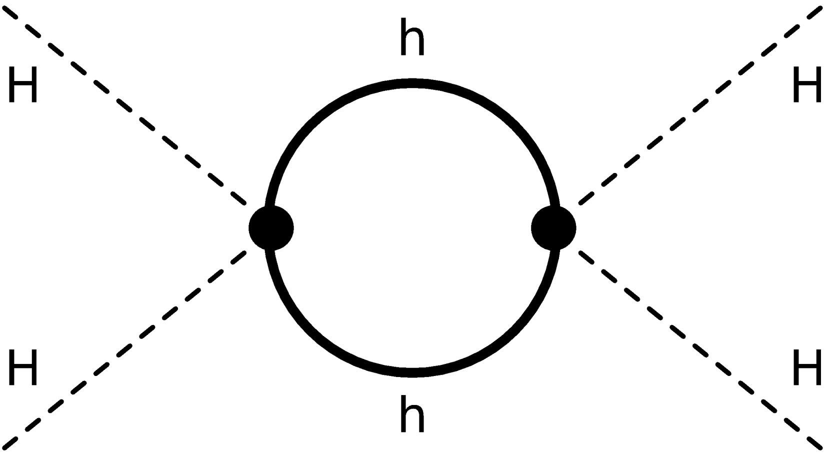
- Taking into account that the phase transition from the "false vacuum" to the "true vacuum" is a consequence of the electroweak spontaneous breakdown of symmetry $SU(2)_L \times U(1)_Y \to U(1)_{el.mag}$, we considered topological defects of EW-vacuum: the Abrikosov-Nielsen-Olesen closed magnetic vortices ("ANO strings") of the Abelian Higgs model and Sidharth's Compton phase objects. We showed that the "true vacuum" (EW-vacuum) again is presented by the non-differentiable manifold with non-commutative geometry leading to an almost zero cosmological constant.

- By solving the gravitational field equations we estimated the black-hole-hedgehog's mass, radius and horizon radius are $M_h \approx 3.65 \times 10^{18}$ GeV, $R_h \sim 10^{-21}$ GeV^{-1} and $r_h \approx 2.29 R_h$ respectively.

- We considered that due to the energy conservation law, the vacuum energy density before the phase transition is equal to the vacuum energy density after the phase transition: $\rho_{vac}(\text{at Planck scale}) = \rho_{vac}(\text{at EW scale})$. This result confirms the Multiple Point Principle: we have two degenerate vacua v_1 and v_2 with an almost zero vacuum energy density (cosmological constants). By these considerations we confirmed the vacuum stability of the EW-vacuum, in which we live. The Planck scale vacuum cannot be negative because of the exact equality $V_{eff}(min_1) = V_{eff}(min_2)$.

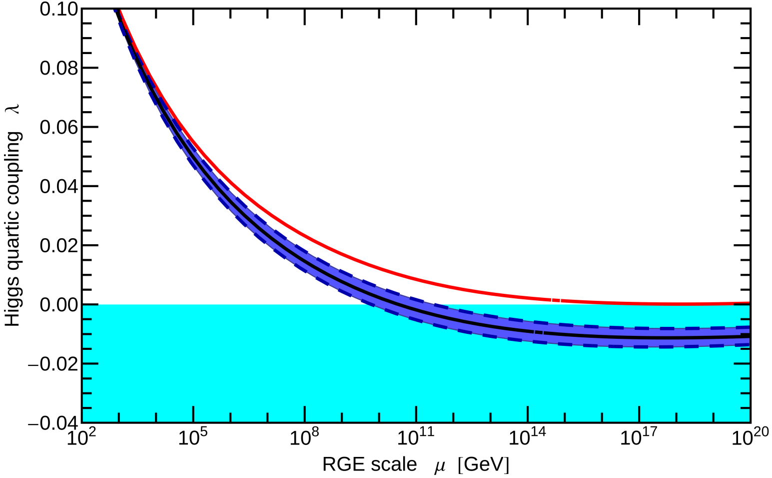
- Hedgehogs in the Wilson loops of the $SU(2)$ Yang-Mills theory, and phase transitions in this theory were investigated revising the results. Using their lattice result for the critical value of the temperature of hedgehog's confinement phase: $\beta_{crit} \approx 2.5$, we predicted the production of the $SU(2)$-triplet Higgs bosons at LHC at energy scale $\mu \sim 10$ TeV, providing a new physics in the SM.

- We considered an additional confirmation of the vacuum stability and accuracy of the MPP taking into account that hedgehog fields Φ^a produce a new physics at the scale ~ 10 TeV, and calculating at high energies the contribution of the black-hole-hedgehog corrections to the effective Higgs potential. This result essentially depends on the hedgehog field parameters: mass, radius and mixing coupling constant λ_{hH} of the interaction of hedgehogs with the SM doublet Higgs fields H.



The main Feynman diagram containing hedgehogs in the loop, which corrects the effective Higgs mass.

- The loop corrections give the V_{eff} with values of ϕ, which are much larger than $v_1 \approx 246$ GeV. The effective Higgs potential develops a new minimum at $v_2 \gg v_1$. The position of the second minimum depends on the SM parameters, especially on the top and Higgs masses, M_t and M_H. This $V_{eff}(min2)$ can be higher or lower than the $V_{eff}(min1)$ showing a stable EW vacuum (in the first case), or metastable one (in the second case).



The RG evolution of the Higgs selfcoupling λ for $M_t \simeq 173.34$ GeV and $\alpha_s = 0.1184$ given by $\pm 3\sigma$. Blue lines present metastability for current experimental data, red (thick) line corresponds to the stability of the EW vacuum.

- The red solid line of the figure shows the running of the $\lambda_{H,eff}(\phi)$ for $M_H \simeq 125.7$ GeV and $M_t \simeq 171.43$ GeV, which just corresponds to the stability line, that is, to the stable EW-vacuum. In this case the minimum of the $V_{eff}(H)$ exists at the $\phi = \phi_0 \sim 10^{18}$ GeV, where according to MPP:

$$\lambda_{H,eff}(\phi_0) = \beta(\lambda_{H,eff}(\phi_0)) = 0.$$

Unfortunately, this case does not correspond to the current experimental values.

- In previous figure blue lines (thick and dashed) present the RG evolution of $\lambda_H(\mu)$ for current experimental values $M_H \simeq 125.7$ GeV and $M_t \simeq 173.34$ GeV. The thick blue line corresponds to the central value of $\alpha_s = 0.1184$ and dashed blue lines correspond to its errors equal to ± 0.0007. We see that absolute stability of the Higgs potential is excluded by at 98% C.L. for $M_H < 126$ GeV. It shows that asymptotically $\lambda_H(\mu)$ does not reach zero but approaches to the negative value:

$$\lambda_H \to -0.01 \pm 0.002,$$

indicating the metastability of the EW vacuum.

Multiple Point Principle (MPP) is not exact.

We see that the current experimental values of M_H and M_t show the metastability of the present EW-vacuum of the Universe, and this result means that the MPP law is not exact.