1. Semester report №2

by Bayarsaikhan BILGUUN (bilguun@student.elte.hu)
PhD program: Particle physics
Supervisor: Zoltán Trócsányi

Ph.D. Thesis title: Searching for signs of new physics beyond the standard model

Introduction: I am a first-year international student at ELTE-Doctoral School of Physics from the 2020/2021 Autumn semester. In first semester, because of some difference between the Mongolian and Hungarian educational systems, I had to catch up on more advanced topics first to participate in group research work and did not started my research work. However, 2nd semester I started my research work which is based on cosmological aspect of super-weak U(1) extension of the standard model. Moreover, I am interested in late-time accelerated expansion of the universe.

I am a member of ELTE – Particle Phenomenology Group, which has 7 members and supervised by professor Zoltán Trócsányi. Currently, there are many ongoing research topics, for instance: Cosmological constraints on the U(1) extension of Standard Model, Neutrino mass model, and Vacuum stability. My current research interest is a connection between cosmology, inflation and particle physics.

Research work carried out in the current semester: My current research work mostly concerns with the cosmological aspect of super-weak U(1) extension of Standard Model. The super-weak U(1) extension of standard model has many phenomenological applications such as: inflation, neutrino mass and late-time accelerated expansion of the universe. The super-weak U(1) model has two scalar fields, which might be responsible for inflation and late-time accelerated expansion of the universe. In order to study late-time accelerated expansion of the universe in super-weak U(1) model I used the dynamical system analysis approach. The dynamical system analysis is based on developing autonomous system equations from given Lagrangian density and studying the critical points of that system. Moreover, in the dynamical system analysis studying the stability of the critical points of the system one can use different methods: linear stability theory, center manifold method and Lyapunov function method. However, in this semester I studied the case of only one scalar field case to prepare for the multiple scalar field case, and cross check my result with review paper arXiv: 1712.03107v3. It is important that the form of the potential of the scalar field can be either exponential or power law. When the scalar field potential has an exponential form, I found 4 critical of points in that system.

Point	x	y	Existence
O	0	0	any
$A_\pm$	± 1	0	any
C	$\frac{\alpha}{\sqrt{6}}$	$\sqrt{1-\frac{\alpha^2}{6}}$	$\alpha^2 < 6$

Table 1: Critical points of system: Exponential scalar case.

Point	Eigenvalues	Stability
O	$\{-3, 0\}$	Different method needed*
A_+	$\{6, 3-\sqrt{\frac{3}{2}}\alpha\}$	Unstable if $\alpha^2 < 6$, saddle if $\alpha^2 > 6$.
A_-	$\{6, 3+\sqrt{\frac{3}{2}}\alpha\}$	Unstable if $\alpha^2 > -6$, saddle if $\alpha^2 < -6$.
C	$\{\alpha^2, \frac{1}{2}\left(-6+\alpha^2\right)\}$	Stable if $\alpha^2 < 0$, saddle if $0 > \alpha^2 > 6$.

Table 2: Stability and eigenvalues

In addition, there is 5th critical point in this system which mentioned in review paper: arXiv: 1712.03107v3 and it is necessary to understand why that point has not appeared in my result.

Conferences: I participated at the ELTE-Winter School Physics Beyond Standard Model: Modern Approaches, which took place between 1-5 February 2021,

see http://hector.elte.hu/iskola20/

Studies in current semester: I attended the graduate course on Beyond the Standard Model. The content of the course was presented at the aforementioned ELTE-Winter School, followed by four sets of homework assignments.