Mikhail Shaposhnikov – Lecture 1 Questions

Questions marked in green were answered during the Q&A session. Original questions listed without correction for grammar/spelling. Where a slide number was given it is shown.

Q1 (slide 8) This must be a dumb question but what is Landau pole?

Take, for example, the equation for the U(1) gauge coupling g' and solve it. The solution is:

g'^2(\mu) = 48\pi^2/(41 log(\Lambda/\mu)),

where \Lambda is some mass parameter. For the SM it is very large and far above the Planck scale. When \mu=\Lambda, the expression above has a pole, which is called Landau pole. The theories with Landau poles are believed to be inconsistent.

For the asymptotic freedom, take, for example, the equation for the SU(3) gauge coupling. The solution is

g_3^2(\mu) = 8\pi^2/(7 log(\mu/\Lambda)).

For large \mu the coupling constant goes to zero (asymptotic freedom). At the infrared scale \mu\sim \Lambda the theory is in the strong coupling regime.

Q2: Are there simple modifications to the SM to prevent the Higgs self-coupling going negative?

According to the computation made in https://arxiv.org/abs/1507.08833 the Higgs self-coupling is always positive if the pole mass of the top quark is smaller than 171.6 GeV (for error-bars please look in this paper).

For possible modifications of the SM valid up to the Planck scale and positive scalar self-couplings see https://arxiv.org/pdf/1603.03603.pdf and references therein.

Q3 (slide 12) It says here that top quark Yukawa is known with lowest accuracy. Aren't light quarks less well known? E.g. Plots of kappa vs mass always have a point for top but no points for light.

Indeed, my statement was not correct, the relative accuracy for Yukawa couplings of light quarks is worse than that for the top quark. My point was that for the extrapolation of the Standard Model to very high energies the relevant couplings are g, g’, g_3, y_t, and \lambda. The Yukawa couplings of lighter quarks are much smaller numerically and thus they do not contribute to the RG evolution of the relevant couplings. And we look at the accuracy of experimental determination of g, g’, g_3, y_t, and \lambda, then indeed the uncertainties in y_t matter the most.

Q4 (slide 34) What is "S" and "NV"? They appear in the exponentials.

Slide 34: once you compute the path integral or tunneling amplitudes by semiclassical methods (WKB approximation), the answer is typically represented in the form that contains an exponent, \exp(-S). S here is the classical action computed with the solution of the Euclidean equations of motion with appropriate boundary conditions. For an introduction to these methods see the book by Coleman “Aspects of symmetry”, Chapter 7.

The formula with NV is associated with another mechanism of producing exponentially small numbers, appearing in Bardeen-Cooper-Schrieffer superconductors. It comes from a solution of self-consistency equations for propagators. N in it is the electronic density at the Fermi level, V is the electron-phonon potential and E_D is the Debye screening energy.

Q5: How does your claim that SM is effective all the way up to M_P gel with baryogenesis?

The SM alone cannot explain baryogenesis. There are no phase transitions in it which could lead to substantial deviations from thermal equilibrium. Also, Kobayashi-Maskawa CP violation is too small to produce a sizable effect. A modification of the SM described in slide 3 leads to baryogenesis, provides a candidate for Dark Matter particles and explains neutrino masses. This modification does not change the discussion presented later in the Lecture since the Yukawa couplings of Majorana leptons are small and can be neglected.

Q6: Does your model imply that mH=125 gev for the SM Higgs is a derived solution (not just a measured value) when requiring the SM+Gravity an asymptotically safe theory? Wow, it is amazing. However, does it mean that no other Higgs scalars are predicted below TeV or few TeV scale? If this is true, how can we explain the BAU puzzle as FOPT is not achievable in the SM+Gravity model setup. New Physics is needed to address several cosmological issues, do you agree with this?

Indeed, the value of the Higgs mass is a derived solution for a_\lambda >0 (slide 23), provided the top quark mass is fixed, see https://arxiv.org/abs/0912.0208. In general, if new particles are introduced with masses at the TeV scale with substantial coupling to the particles of the Standard Model, the prediction will be spoiled. Indeed, this is an argument against new physics above the Fermi scale.

There is very little new physics which is needed to address cosmological issues. Adding to the SM three Majorana fermions with masses below the Fermi scale is enough, see slide 3. This new physics does not spoil any discussion given in the lecture, since the Yukawa couplings of Majorana leptons are small and can be neglected.

Q7: If we introduce new particles below TeV to address other problems (i.e. Baryogenesis), then require this new model plus gravity as an asymptotically safe, will we still mH=125 solution?

Please see the answer to Q6.