Comment on
`http://www-com.physik.hu-berlin.de/~fjeger/WienVCES17Talk.pdf`:

I would like to clarify the main points of my Higgs inflation scenario. I assume a SM regularized by the Planck cutoff and what we see at laboratory energies is emergent as a low energy effective structure, the renormalizable SM. The renormalized low energy effective theory is devoid of any cut-off effects. The latter get hidden by reparametrization of the low energy effective theory in terms of renormalized parameters tuned to appropriate measured observables. Cut-off effects are still there in the relation between the bare and the renormalized parameters. Cutoff effects are meant to be physical when approaching short distances. The simplest implementation would be the SM on a lattice, with lattice spacing the Planck length. The cutoff system is considered to mimic real physics behind what we see at long distances (in the universality class of the SM). There is a plethora of cutoff theories with identical low energy behavior. The lattice supplemented SM is a non-perturbative implementation of the SM[1]. Then in principle I can calculate the effective low energy parameters from the bare Lagrangian. Since we do not know the bare parameters a priori, we calculate them from the known renormalized low energy parameters instead bottom-up. The bare theory is the one physical at short distances, where we would see the Planck medium. Of course we cannot know the true Planck system, however, what we know for sure is that it has a physical cutoff which allows us to perform a low energy expansion in that cutoff. The seen low energy tail does not depend on the details of the Planck system. In the cutoff supplemented SM the relation between the low energy Higgs mass and the bare one is subject to big corrections (usually claimed to be a problem for the SM: the hierarchy problem). This correction at LO has been calculated by Veltman 1980 as the "The Infrared - Ultraviolet Connection" and is a main element of the scenario I advocate. Similarly, the vacuum energy, which at low energy likely may be identified by the observationally established dark energy (DE) (CMB and SN counts), is calculable in the cutoff bare theory and the relation between bare and renormalized DE is subject to huge radiative corrections (large but finite in the cutoff theory) and gives rise to what we know as the cosmo-

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[1] A key point is that the Planck cutoff is very far away from our low energy world which includes energy ranges accessible by any high energy collider. This is in vast contrast to the situation in lattice QCD where the cutoff usually is not very far above the strong interaction scale Λ_{QCD}.

logical constant problem of the SM. If low energy parameters are such that the Higgs vacuum remains stable up to the Planck scale (except for the top Yukawa coupling, evaluated from the top quark mass, different groups agree on the other relevant parameters) surprisingly the radiative corrections to both the Higgs mass as, well as to the vacuum energy vanish at some high energy scale well below the Planck scale, so that these zeros attain a physical meaning: matching points between the renormalized SM parameters and the bare theory. For the Higgs boson to be a bona-fide inflaton candidate the power enhanced corrections which lead to a heavy Higgs in the symmetric high energy phase and to a huge cosmological constant in the early universe are crucial in order to provide the necessary amount of inflation (CMB causal horizon problem). Since these zeros are well below the Planck scale, these enhancements are effective in any case irrespective of the fact that the low energy expansion breaks down close to the Planck scale itself, i.e. on power counting grounds it is not expected that the enhancements get substantially reduced by non-universal cut-off effects. This is a scenario based on straight forward SM calculations (which however quite elaborate and are very sensitive to the implementation of the matching conditions needed to calculate $\overline{\mathrm{MS}}$ renormalization group parameters form measured SM particle masses and form higher order (3–loop) RG equation coefficients). I consider this scenario to be far less speculative than most others, since it is based on well known mechanisms known from condensed matter physics (emergent long range physics) in particular it can be scrutinized by Wilson's RG approach to critical phenomena (relating quantitatively short distance to long distance physics).

The key observation supporting this picture is the fact that known ingredients (symmetry patterns) for the renormalizable SM are emergent! i.e. they are the result of the low energy expansion and the fact that many details of the cutoff system get unobservable. All ingredients necessary to get a renormalizable low energy effective theory like gauge symmetry, chiral symmetry, anomaly cancellation the existence of a Higgs boson and even the dimensionality of space-time are self-organized (emergent).

The crucial point is that the system before inflation starts is in the symmetric phase, with lots of relativistic degrees of freedom which make the primordial universe hot (Stefan-Boltzmann law) and with only the four Higgses of the complex doublet (all physical in this phase) are very heavy, because the Higgs fields are the only ones not protected by a symmetry. This makes the big difference to standard considerations. The decaying heavy Higgs bosons are naturally reheating the universe which otherwise would cool down dramatically during inflation.

One could argue that the UV extension/completion of the SM is “a big unknown” and will not allow any half-way reliable prediction e.g. for what concerns what happens in the early universe. This is not a killing argument however: first, we know from knowing the SM what are the UV divergences to be cured, the quadratic and quartic enhancements are real. UV divergences are simply the result of an over idealization and there is no doubt that they must have a physical meaning. Second, taking a kind of minimal UV completion the SM predicts dark energy and inflation, which are established phenomena, and thus support this scenario. Details in such a scenario require far from trivial higher order SM calculations and presently we are not able to settle the details (missing precision of input parameters, higher order effects) e.g. for what concerns the spectral indices. But already now we can see that the gross pattern matches established facts, and there are surprising coincidences not taken into account in the usual approaches by attaching an inflaton sector of primarily unknown properties by hand.

The possibility that such a scenario works, in my view is very attractive and should be seriously investigated in much more detail. In particular the inflation era and the phase transition era when the system gets out of equilibrium requires a more detailed analysis as the running couplings also are expected to follow the out of equilibrium and reheating pattern and certainly affects the thermal history. Another point which requires to be investigated is the fact that QED is a residual $U(1)_{\mathrm{em}}$ sector after the Higgs mechanism has taken place, i.e. there is no QED in the symmetric phase. Instead we have a physics of an unbroken $SU(2)_L \otimes U(1)_Y$ with 4 massless gauge bosons in the electroweak sector.

One crucial impact of the LEESM scenario is that future experimental projects should be focusing on high precision (Higgs and top quark physics in particular) in the ILC, FCCee range, while an increase in energy by one or two orders of magnitude is not expected to provide much progress in the “The Infrared - Ultraviolet Connection” to the Planck scale. This also is challenging a more accurate understanding of the SM and those missing parts we know must be there like dark matter, axions, singlet neutrinos (Majorana?). These missing pieces likely are more a matter of precision investigations in the region below 1 TeV, rather than at the high energy frontier of possible future hadron colliders.

Behind the prose above there are non-trivial SM calculations, see my Durham and Krakow Lectures for more on the context:
http://www-com.physik.hu-berlin.de/~fjeger/SMcosmology.html
For detailed calculations see:

M. J. G. Veltman, *The Infrared - Ultraviolet Connection*, Acta Phys. Polon. B 12 (1981) 437.
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