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Quantum structure of the minimal calculable unified model

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Despite of its tremendous success various theoretical and experimental issues seem to indicate the need to go beyond the Standard Model framework. One of the most promising ways to address the open questions is offered by the Grand Unification paradigm. Its main experimental signature is the prediction of proton decay and with the new generation of experiments under way (Hyper-K, DUNE, \ldots) an order of magnitude increase in the sensitivity of such searches is expected. To take advantage of these huge experimental efforts one would on the theory side need to improve the accuracy of proton lifetime predictions. That means going to the next-to-leading order calculation that has never been done in this context before. But first one needs to find a way to overcome some large uncertainties involved.

The unknown flavour structure of the theory (Yukawa sector) is only part of the reason for that - the other difficulty lies in determination of the scale of gauge coupling unification due to the Planck scale effects.
Proton lifetime depends strongly on the masses of the heavy fields which mediate its decay. In the non-supersymmetric case those mediators are predominantly the heavy gauge bosons, whose masses can be identified with M_{GUT}. But how accurately we are really able to determine it without the access to the high energy physics?
At next-to-leading order one should consider the 2-loop running
of all the couplings and use the 1-loop threshold effects to account for the splitting of particles' masses around the matching scales of different effective theories. However, at this level of accuracy one typically can not avoid the Planck suppressed operators, particularly dangerous being the gauge kinetic form terms $\kappa/M_P F^{\mu\nu}\langle\phi\rangle F_{\mu\nu}$ which through inhomogeneous and uncontrolled shifts in the matching condition inflict a theoretical uncertainty of a several orders of magnitude on our prediction of M_{GUT}.
With this operator present there is no point of ever trying to compute proton decay better than at the leading order.

One of the rare exceptions where this issue can be overcome is the minimal renormalizable non-supersymmetric SO(10) model with the 45 Higgs.
There such a term is exactly zero due to the antisymmetry of the adjoint representation.
The model consists of two irreducible representations in the Higgs sector - besides 45 needed to spontaneously break the unification group one needs either 16 or 126 to break the rank as well. Having neutrino masses in the right ball park discards the option with 16 that doesn't give us enough freedom in the Yukawa sector. But even the model with 126 has long been considered excluded due to tachyonicity of the tree-level masses or otherwise admitting only the phenomenologically not viable breaking to SU(5). But at the quantum level the masses receive substantial corrections and can become non-tachyonic. %They are especially interesting because they are exactly the particles which mediate proton decay.
That's the reason why the masses entering the 1-loop threshold corrections can not be the tree level masses as one would naively expect but must be computed at the 1-loop as well.
Our goal is then to use the effective potential approach to compute the spectrum, show that it's realistic, the vacuum state is long-lived and provide the first ever NLO computation of the corresponding proton lifetime.

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