Renormalizing Spacetime

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Abstract

Three of the four fundamental forces have been successfully renormalized, yielding theoretical predictions that agree with experiment to an unprecedented level of accuracy. However, gravity is not renormalizable [1]. Why does renormalization work so well for the other three forces, but not for gravity? Firstly, consider how renormalization is applied in the case of quantum electrodynamics (QED). The QED Lagrangian is a function of bare charge and mass, as well as bare fields. Renormalizing only the bare parameters of charge and mass will not yield a finite theory. It is crucial that the bare fields are also renormalized. The same is true in perturbative quantum chromodynamics (QCD), where one must renormalize the quark and gluon fields, in addition to the coupling constant and quark mass, in order to obtain a finite theory. In fact, in all quantum field theories, field fluctuations modify bare fields such that they become a function of scale. A bare field ϕ, for example, is converted into a renormalized field $\tilde{\phi}$ via so-called wavefunction renormalization $\tilde{\phi} = \phi Z^{-1/2}(p)$, where $Z(p)$ is a renormalization factor encoding how ϕ depends on the momentum scale p. However, up until now the renormalization of the gravitational field (the spacetime metric tensor $g_{\mu\nu}$) has been largely neglected [2]. The aim of this talk is to determine a unique expression for the wavefunction renormalization of gravity, and to explore how this procedure may help to make quantum gravity renormalizable.

References

[1] Marc H. Goroff and Augusto Sagnotti. The Ultraviolet Behavior of Einstein Gravity. *Nucl.Phys.*, B266:709, 1986.

[2] T. Padmanabhan. Distribution function of the Atoms of Spacetime and the Nature of Gravity. *Entropy*, 17:7420–7452, 2015.