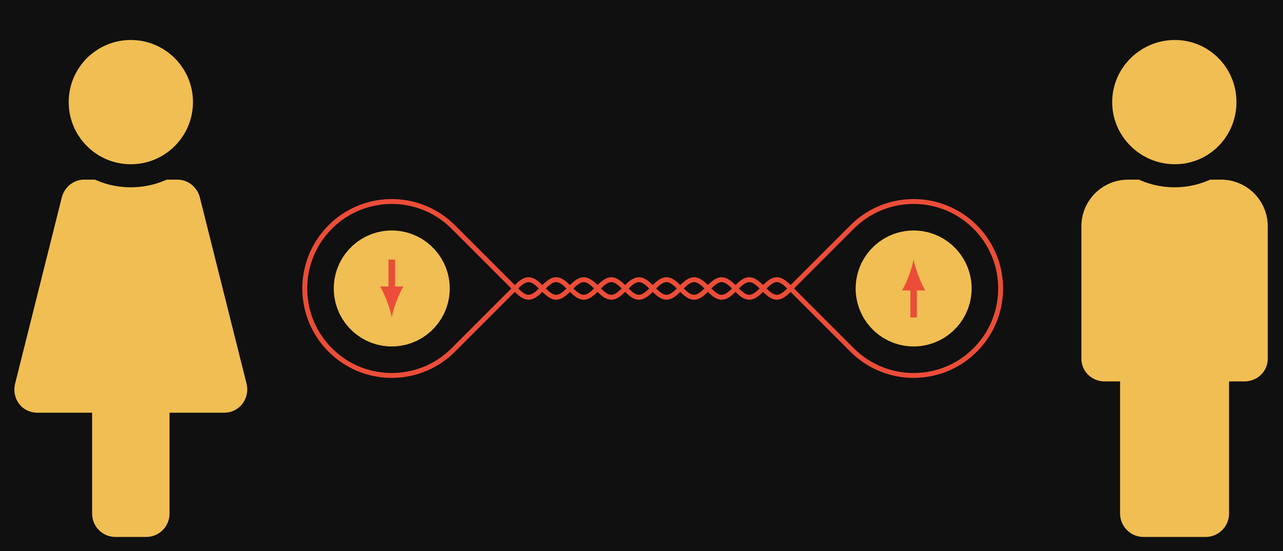
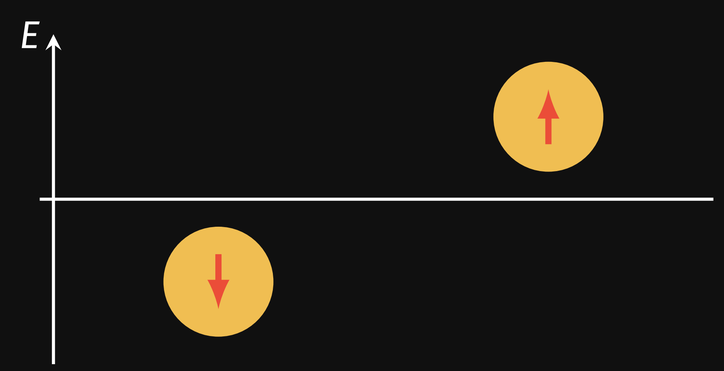
Nonperturbative Aspects of Quantum Field Theory in Curved Spacetime

Níckolas de Aguiar Alves, André G. S. Landulfo
arXiv: 2305.17453 [gr-qc]

Introduction

Landulfo (2016) showed how two observers in a very general spacetime can communicate using degenerate two-level systems interacting with a quantum field. This model has a number of advantages, including being exactly solvable. Nevertheless, the fact the two-level systems are degenerate implies, among other things, that quantum communication is only possible with the aid of extra entanglement between the pairs and that the two-level systems cannot be used as particle detectors.



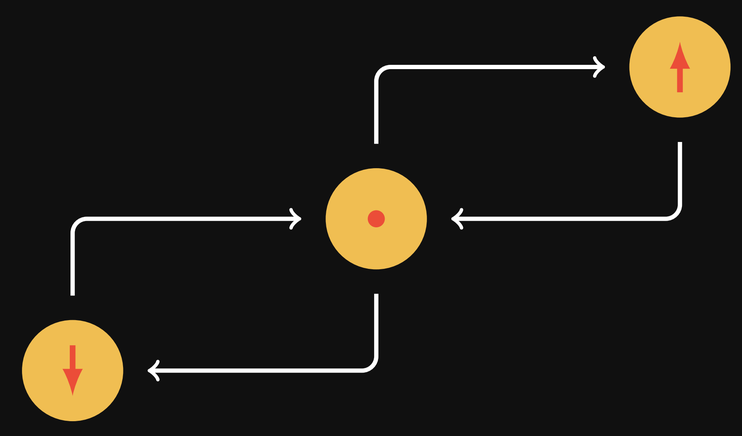


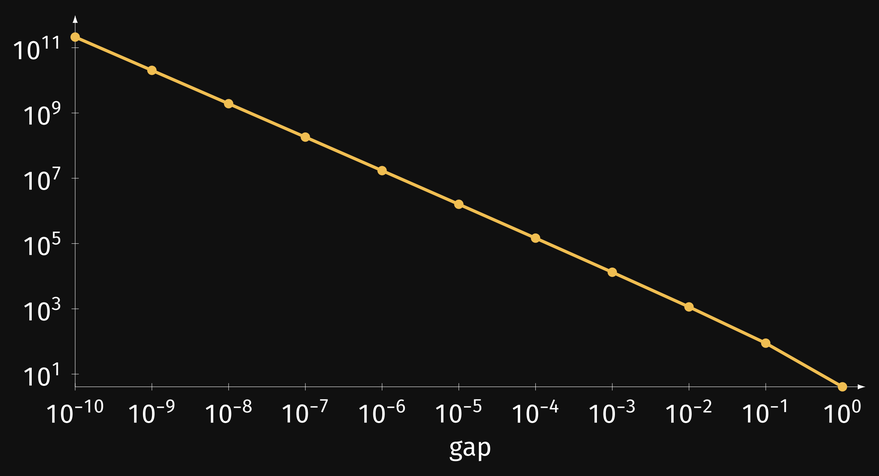
Model

To refine these aspects, we can consider a nondegenerate two-level system. While this solves the issues we previously found, it also spoils the exact solution. To bypass this limitation, we can solve the system using perturbation theory in the energy gap between the two levels of the system. However, a more sofisticated approach is to also employ a nonperturbative realization of the renormalization group—called the functional renormalization group (FRG)—to improve the perturbative calculation. Notice there is no need to assume a weak coupling between the quantum field and the two-level systems.

Methods

The FRG requires prescribing an ansatz for the system's action and another for a cutoff, that selects the renormalization scale of interest. The action for a two-level system coupled to a quantum field was adapted from the one given by Burbano, Perche, and Torres (2021). This ansatz involves adding an intermediate "true-vacuum" state in the two-level system and then quantizing the ladder operators among the two levels and this true vacuum. The chosen cutoff ansatz was an extra artificial gap. This is due to most of the FRG literature typically using an artificial mass term, and the gap term is the closest analogue to a mass term in a two-level system.





Results

The FRG calculations are tricky, but manageable. Nevertheless, after performing them we obtain problematic results. Namely, some of the beta functions have divergent coefficients in the degenerate limit. To the left one sees a numerical solution for one of the coefficients in the beta function for the coupling between field and two-level system. As the gap vanishes, the coefficient grows. This is believed to be due to the difficulty in finding an appropriate cutoff ansatz for the innovative case of a two-level system, and further research is necessary to completely understand this behavior.

References

Landulfo 2016. Phys. Rev. D **93**, 104019. arXiv: 1603.06641 [gr-qc].

Burbano, Perche, and Torres 2021. J. High Energ. Phys. **2021**, 76. arXiv: 2012.14912 [hep-th].

Acknowledgments

We thank Antônio D. Pereira Junior and Alex G. Dias for helpful discussions.

Contact

alves.nickolas@ufabc.edu.br

CAPES UFABC FAPESP