

Title	Quantum field theory in curved space : general relativity : numerical methods : machine learning
Sub Title	Quantum polarization effects in curved space
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Abstract	The main goal of this project has been to discuss some ideas connecting the physics of the quantum vacuum, the Casimir effect, and the mechanism of symmetry breaking in different backgrounds. The underlying idea is that when interactions are present in a system, its quantum vacuum structure changes in a nontrivial way. The implications of these changes are the appearance of a tiny but measurable force that, on one side is a proxy of quantum phenomena, so it can be used to understand better the quantum field theory at hand, on the other this quantum-fluctuation induced force can be practically used in applications to nano-scale electro-mechanical devises. On a technical level the research focus of this project has been centered around vacuum polarization effects in curved space and in flat space with boundaries. The topics addressed were the computation of the vacuum polarization on a certain spherically symmetric deformed geometries (with "non-relativistic scaling"), the study of the Casimir effect in theories with interactions and symmetry breaking, and on the quantum vacuum structure in non-linear quantum field theories and rotation. The results have appeared in two papers already published in international refereed journals and one paper currently in preparation. Further related research is also in progress. One of the problems discussed in this work has to do with the quantum vacuum structure of a nonlinear quantum field theory in 1 spatial + 1 time dimensions when the spatial dimension is compact (i.e., ring-like) and it rotates. This can be achieved in cold atomic systems and thus experiments can be performed. To the best of our knowledge, it has been the first time that such problem has been considered and it has opened a window onto new application of quantum vacuum phenomena. Our study has revealed that the way rotation under certain conditions amplifies the intensity of the interaction strength. Interestingly, we have also observe a departure from the typical massless behavior where the quantum vacuum energy is proportional to the inverse size of the ring. Within this work we have developed a new numerical implementation to a mathematical technique called zeta function regularization. We are currently extending this approach to more general situations. In further work, we have discussed how the mechanism of symmetry breaking alters the Casimir force and how certain type of transitions can be triggered. Finally, in another work we have developed a method to compute the vacuum polarization in geometries with "non-relativistic" scaling (and we have developed an application to black hole physics).
Notes	
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研究課題 (日本語)						
Quantum field theory in curved space; General Relativity; Numerical methods; Machine learning						
研究課題 (英訳)						
Quantum polarization effects in curved space						
1. 研究成果実績の概要						
The main goal of this project has been to discuss some ideas connecting the physics of the quantum vacuum, the Casimir effect, and the mechanism of symmetry breaking in different backgrounds. The underlying idea is that when interactions are present in a system, its quantum vacuum structure changes in a nontrivial way. The implications of these changes are the appearance of a tiny but measurable force that, on one side is a proxy of quantum phenomena, so it can be used to understand better the quantum field theory at hand, on the other this quantum-fluctuation induced force can be practically used in applications to nano-scale electro-mechanical devices. On a technical level the research focus of this project has been centered around vacuum polarization effects in curved space and in flat space with boundaries. The topics addressed were the computation of the vacuum polarization on a certain spherically symmetric deformed geometries (with “non-relativistic scaling”), the study of the Casimir effect in theories with interactions and symmetry breaking, and on the quantum vacuum structure in non-linear quantum field theories and rotation. The results have appeared in two papers already published in international refereed journals and one paper currently in preparation. Further related research is also in progress.						
2. 研究成果実績の概要 (英訳)						
One of the problems discussed in this work has to do with the quantum vacuum structure of a nonlinear quantum field theory in 1 spatial + 1 time dimensions when the spatial dimension is compact (i.e., ring-like) and it rotates. This can be achieved in cold atomic systems and thus experiments can be performed. To the best of our knowledge, it has been the first time that such problem has been considered and it has opened a window onto new application of quantum vacuum phenomena. Our study has revealed that the way rotation under certain conditions amplifies the intensity of the interaction strength. Interestingly, we have also observe a departure from the typical massless behavior where the quantum vacuum energy is proportional to the inverse size of the ring. Within this work we have developed a new numerical implementation to a mathematical technique called zeta function regularization. We are currently extending this approach to more general situations. In further work, we have discussed how the mechanism of symmetry breaking alters the Casimir force and how certain type of transitions can be triggered. Finally, in another work we have developed a method to compute the vacuum polarization in geometries with “non-relativistic” scaling (and we have developed an application to black hole physics).						
3. 本研究課題に関する発表						
発表者氏名 (著者・講演者)	発表課題名 (著書名・演題)	発表学術誌名 (著書発行所・講演学会)	学術誌発行年月 (著書発行年月・講演年月)			
Antonino Flachi	Quantum vacuum phenomena in various backgrounds (paper)	International Journal of Modern Physics (World Scientific)	Vol. A 37, No. 19, 2241008 (10 July 2022))			
Antonino Flachi (with M. Edmonds)	Quantum vacuum, rotation, and nonlinear fields (paper)	Physical Review	Vol. D 107, 025008 – Published 18 January 2023			
Antonino Flachi (with M. Pasini)	Vacuum polarization effects in quantum corrected black holes (paper)	Physical Review	to be submitted (2023)			
Antonino Flachi	Reflections on symmetry breaking and the quantum vacuum (presentation)	Avenues of quantum field theory in curved space (International Conference)	Sept 14–16, 2022 University of Genova			