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Gravito-Maxwell formalism for unconventional gravity-superconductors interplay

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Abstract. We discuss the possible coupling between a superfluid and the local gravitational field. After introducing a quantum-gravity theoretical framework to characterize the possible supercondensate-graviton coupling, we exploit an effective theory for generalized Maxwell-type fields to analyze some predicted effects originating from the proposed interplay.

Keywords: gravito-Maxwell theory, superconductivity, time-dependent Ginzburg-Landau theory, local affection of gravitational field

Introduction. It is known that linearization of the Einstein equations for a nearly-flat spacetime metric (weak gravitational field) leads to a set of equations that resembles Maxwell's formalism [1, 2].

From an experimental point of view, it has been shown that generalized electric-type fields can be induced in (super)conductors by the presence of the Earth's weak gravitational field. These observations led to the formal introduction of a modified electric-type field, characterized by an electrical component and a gravitational one, determining detectable corrections to the free fall of charged particles [3].

Methods, materials, results. The above remarkable experimental results can be now combined to the theoretical weak-field gravity formulation, leading to a more general definition of new generalized electromagnetic fields. The latter feature a component defined in terms of the weak gravitational perturbations and satisfy a specific set of equations that can be put in a form closely analogous to Maxwell's equations [4]. The described framework can be exploited to analyze an interplay between gravity and supercondensates [5], the new generalized fields being involved in quantum effects originating from the interaction with the weak gravitational background, in analogy to what happens for gravity-induced fields in superconductors [6].

A straightforward application of the weak-field expansion is to consider detectable effects in simple systems like Josephson junctions and SQUID devices. The generalized fields and potentials, featuring a Maxwell component and a gravitational contribution, can give rise to local effects in the superconducting materials due to the presence of the surrounding gravitational field, under suitable experimental conditions [7].

The emerging formal symmetry between the Maxwell and weak gravity equations also allows the use of the Ginzburg — Landau model for the description of the physics, resulting in a mean-field theory for the system's thermodynamics, including the effects of thermal fluctuations [6]. The resulting differential equations can be used to obtain solutions explicitly describing the backreaction effects of the supercondensate on the local gravitational field [8-10].

Conclusions. These studies provide a theoretical framework to explore a possible, unconventional gravity-superconductors interplay. For short time intervals, the model predicts a slight local gravitational alteration, highlighting the backreaction of the supercondensate on the surrounding gravitational field. It is possible to show that sample dimensions and chemical composition are crucial to give larger effects, while it is fundamental to be very close to the critical temperature in order to increase the time range in which the effect takes place.

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