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Editorial: Interaction between macroscopic quantum systems and gravity

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Editorial on the Research Topic
Interaction between macroscopic quantum systems and gravity

The study of quantum macroscopic systems is an highly developed field in physics, with a huge potential for integration across different disciplines and research areas. One of the most intriguing potentiality is the analysis of the possible mutual interaction between macroscopic, coherent matter states (like superconductors and superfluids) and the local gravitational field. This fully interdisciplinary research field has witnessed a conspicuous progress in the last decades [1, 4, 8, 10, 11, 13, 15, 22, 25], and yet several questions are still completely open.

This Research Topic brings together contributions analysing the interaction between gravity and materials in the superconducting state, investigating possible observable effects not explained in terms of classical physics. A deeper understanding of this unconventional interplay would lead to a noteworthy development in theoretical physics, as well as opening remarkable perspectives for future direct applications.

In the research article *Measurement of Anomalous Forces from a Cooper-Pair Current in High-T_c Superconductors with Nano-Newton Precision*, Tajmar et al. report the results of precision measurements performed with a new custom-built double pendulum thrust balance, able to detect forces down to a level of 25–100 nN. Their aim is to test whether a superconductor carrying a supercurrent is subject to anomalous forces called "frame-dragging" forces or recoil forces, as observed in earlier experiments [20, 21]. The main virtue of the experimental setup, besides its precision, is that the entire apparatus (superconductor, cooling devices, power source) is mounted on a platform, whose motion is accurately monitored through laser interferometers. Special care has been devoted to the elimination of magnetic artifacts. The currents tested have intensity up to 15 A and are stationary, except for sharp gradients at switch-on/off. The obtained results rule out the occurrence of anomalous forces above a ratio of approximately $5 \cdot 10^{-9}$ N/A.

In the perspective article *On Gravitational Fields in Superconductors* Papini reviews DeWitt's seminal work [8] on the effects of the gravitational field on superconductors in the non-relativistic limit. The starting point is the Klein-Gordon equation for an ensemble of charged spinless bosons (Cooper pairs), flowing against a positively charged lattice background. The author then exploits the correspondent solutions to re-obtain the DeWitt results following the lines of [17], in a formalism where gravity is present in the wavefunction of a quantum system as a classical external field [5]. The proposed analysis gives some insights into the symmetry violations of the vacuum of the considered system. The latter violation, in particular, can lead to boson condensation phenomena, and can be used to describe some type-II superconductors in the presence of a weak gravitational field.

The research article *Effect of Medium on Fundamental Interactions in Gravity and Condensed Matter* exploits a mathematical analogy between the exponential cutoff in the gravitational potential at large cosmological scales (traced back to the interaction with the background matter [9]) and the behavior of the magnetic field induced by a thin solenoid placed in a superconductor [12]. The proposed background could be connected with the influence of the medium on fundamental interactions. As a result of the analogy, the authors find that the induced magnetic field in the supercondensate undergoes exponential screening at distances exceeding the magnetic field penetration length.

The review article *Interaction Between Macroscopic Quantum Systems and Gravity* collects experimental results about gravity-supercondensates unconventional interaction, as well as theoretical models to describe the proposed interplay. Starting from the pioneering Podkletnov setup [20], the authors describe different experimental evidences about interaction between quantum macrosystems and gravity, ranging from gravity-induced quantum interference [2, 7, 14] to the generation of generalized fields and potentials in (super)conductors [24, 27, 30, 31]. The authors also describe the use of superfluids as gravitational antennas [3, 16, 19], exploiting the effects of gravitational perturbations on supercondensates and supercurrents dynamics. Finally, they deal with the more subtle superfluid back-reaction acting on the surrounding gravitational field [11, 13, 25]; in particular, Ginzburg–Landau formalism is used to characterize the unconventional coupling between the local gravitational field and the macroscopic wavefunction describing Cooper pairs dynamics in superconductors [26, 28, 29].

In the research article *Superconductor Meissner effects for gravito-electromagnetic fields in harmonic coordinates due to non-relativistic gravitational sources*, Inan addresses some issues arising from DeWitt's approach to the gravito-magnetic Meissner effect [8] and draws physical consequences from these corrections. First, he modifies the general DeWitt Hamiltonian introducing a "space + time" Lagrangian, in order to obtain a canonical three-momentum and an Hamiltonian valid to all orders in the metric. Then, the author shows that the weak field, low velocity limit of the DeWitt Hamiltonian is missing some terms that are of comparable magnitude as those included. The missing terms have consequences for the associated London equations and therefore for assessing the penetration depths of the magnetic and the gravito-magnetic field. It turns out that the gravito-magnetic field is expelled if a magnetic field is also present, but otherwise the superconductor exhibits the analogue of a paramagnetic effect. Some of the conclusions obtained are compared to the existing results of other authors [6, 18, 23].

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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