False vacuum decay: how magnetism meets cosmology in ultracold atoms

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Abstract: We exploit the ferromagnetic phase transition of an ultracold sodium mixture to observe False Vacuum Decay, a process predicted in the '70 but never observed due to the extremely challenging theoretical and experimental obstacles.

Ultracold atoms are an extraordinary tool to investigate the quantum physics of microscopic and low energy scales. However the strong similarity between low and high energy hamiltonians recently allows to unfold processes usually associated with particle physics and cosmology, with focus on phase transition and critical phenomena

For example, in our experiment, we exploit the ferromagnetic phase transition of a coherently coupled ultracold sodium mixture to investigate False Vacuum Decay (FVD). This process was predicted in the '70 [1-3] and triggered an intense research in quantum field theory due to the extremely challenging theoretical obstacles and the untestable character on cosmological scales.

Interestingly, FVD is sometimes referred to as the most dramatic way to destroy the universe, due to the speculations on the stability of the Higgs field within the Standard model of particles.

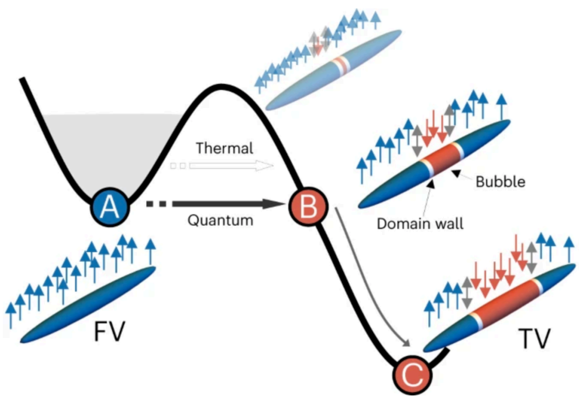

Fig. 1 The decay of False Vacuum (FV) in cold atoms manifests with the appearance of a bubble of spin down atoms in the bulk of up ones, which relaxes down to the True Vacuum (TV).

Thanks to the large tunability of the atomic system and the extreme control of the experimental environment we are able to observe for the first time False Vacuum Decay [4] and its distinctive bubbles and we find good agreement with numerical simulations and the "instanton" solution.

Example References

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[4] A. Zenesini, A. Berti, R. Cominotti, C. Rogora, I. G. Moss, T. P. Billam, I. Carusotto, G. Lamporesi, A. Recati, and G. Ferrari, False vacuum decay via bubble formation in ferromagnetic superfluids, Nature Physics 20, 558 (2024).