Gravitation, quantum computing and quantised vortices

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The connection forged by Witten between 2+1 dimensional gravity and Chern–Simons topological quantum field theory [1] is an example of a growing number of dualities that are establishing a unified perspective to quantum theory and general relativity. The fractional quantum Hall effect (FQHE) of two-dimensional electron gas is known to be described by a Chern–Simons theory and the quasiparticles at filling factor $\nu = 5/2$ may serve for realizations of non-abelian Fibonacci anyons that could be used as building blocks of a universal topological quantum computer. More recently, gravitational description of the FQHE has been progressing [2]. In combination such developments are suggestive that fractional quantum Hall liquids could potentially provide a platform for laboratory studies of low-dimensional quantum gravity and topological quantum information processing.

The mapping between the Hamiltonians of rapidly rotating neutral superfluids, including atomic Bose–Einstein condensates, and electronic quantum-Hall systems is well known [3]. Recently it has been shown that quantised vortices in certain spinor Bose–Einstein condensates may also offer a pathway for realizations of non-abelian vortex anyons [5, 6], and that the dynamics of the vortices is affected by an effective gravity endowed by an acoustic metric [4]. Here we present our ongoing work aiming to further elucidate to what extent the physics of low-dimensional gravitation and topological quantum information processing could be modeled using quantised vortices in atomic superfluids.

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