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Electric-magnetic duality of topological insulators

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Recently, we have seen unexpected connections emerge between three seemingly unrelated problems: i) Strongly correlated surface states of 3d topological insulators, ii) Quantum spin-liquids with emergent photon excitations, iii) Quantum Hall (QH) fluid at filling factor$\nu = 1/2$. These connections have lead to a dual description of the single Dirac cone on the topological insulator surface, given by quantum electrodynamics (QED3) with a single Dirac cone coupled to a fluctuating gauge field. The dual Dirac fermion has the interpretation of a double vortex in the electronic fluid, and the duality is akin to the celebrated particle-vortex duality of bosons. A striking consequence of the duality is a novel theory of the composite fermion liquid state of the QH-fluid at$\nu = 1/2$, where the composite fermion is a Dirac fermion. This theory resolves a 20 year old puzzle regarding the fate of particle-hole symmetry at$\nu = 1/2$and is strongly supported by recent DMRG simulations.