Topological Quantum States, Entanglement and the dream of topologically-protected quantum-information processing

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Classification of robust states of matter into topologically distinct classes has been one of the most surprising developments in condensed matter: incompressible (gapped) electronic states in different topological classes cannot change their topology without passing through a phase transition where the gap collapses. Starting with the integer quantum Hall effect in filled Landau levels, passing through topological insulators with or without broken time-reversal symmetry, this idea has transformed our our understanding of incompressible filled-band Slater-determinant states. However, when the extra ingredient of interaction-dominated "flat-band" physics is included, a more remarkable non-Slater-determinant physics emerges, first seen in the fractional quantum Hall effect in partially-filled Landau levels, but now extended to Bloch systems with partially-filled bands, where fractionally-charged excitations in some cases generate non-local entanglement patterns that, at least theoretically, can be used to "protect" non-locally-stored quantum information, and process it while shielding it from the local environment.