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Topological Phases and Surface States with Strong Interactions

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Previous work on topological insulators and superconductors has been largely based on free fermions with topological "band" structures. We will discuss qualitatively new phenomena that arise with strong interactions, where one cannot invoke a band structure. First, we point out examples of new topological phases with protected edge modes that only appear in the presence of interactions. Next, in contrast to conventional wisdom which held that 3D Topological Insulators and superconductors must be associated with gapless, metallic surface states if the symmetries are preserved, we argue that the 2D surface *can* in fact acquire a gap while remaining fully symmetric if it develops topological order. That is, if the surface state contains excitations with fractional statistics, like in a fractional Quantum Hall state. Interestingly, in some cases the surface states must contain particles with non-Abelian statistics. Finally, we discuss how interactions can modify the classification of free fermion topological phases in 3D. In particular, using surface topological order as a tool, we show that the integer classification of topological superconductors in 3D (class DIII, with time reversal symmetry) is actually reduced to a Z_{16} classification.