Excursions in ill condensed matter: From Amorphous Topological Insulators to Fractional Spins

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Abstract

Condensed matter physics is a fascinating subject where collective properties of many particle systems show exotic emergent phenomena, practically unpredictable from the behavior of individual constituents. Many basic notions and thinking processes in this field are built on "clean" systems, where one idealizes the real system to be infinite and pristine. However, as has become clear eventually, disorder can induce and produce amazingly rich physics. The field, in recent years, is undergoing a makeover where concepts of topology, non-ordinary symmetries etc. are reshaping the subject fundamentally. But again, our understanding of these new ideas are limited to clean systems. This thesis, in its eight chapters, expands our understanding of these systems when they are no longer pristine or are therefore "*ill*". The thesis reports the various surprises encountered in these research pursuits. The introductory chapter (Chapter 1) introduces the idea of ill condensed matter and provides the motivations, the necessary background and the gist of forthcoming chapters. Chapter 2 discusses the various symmetries and derives the tenfold way of classifying all quadratic fermionic Hamiltonians. The canonical forms of symmetry operators are found and the generic structure of noninteracting Hamiltonians in all symmetry classes are obtained. Chapter 3 uses the formalism developed in Chapter 2 to construct topological Hamiltonians on amorphous systems. Robust edge states are shown to exist which can conduct precisely a unit quantum of conductance. Chapter 4 seeks to answer if topological phases can exist in systems with fractional dimensions -- such as a fractal. It is found that such systems cannot host a topologically insulating phase, but are instead metals which are chiral in nature. Chapter 5 discusses the effect of bond percolation on the Hofstadter butterfly, again a fractal pattern. It is found that the system transits from a topological phase to an Anderson insulator as more and more bonds are removed. Interestingly the transition occurs sooner for the bands closest to the band center. Chapter 6 discusses the physics when a clean spin-orbit coupled metal is rendered ill by an interacting impurity. It is found that this system can develop a fractional local moment and has a novel Kondo effect with a large Kondo temperature. In Chapter 7 the symmetry classification introduced in Chapter 1 is extended to arbitrarily interacting systems and structure of generic many body Hamiltonians are obtained in the ten classes. Chapter 8 serves as the epilogue which summarizes the various findings, describes its various implications and provides directions for future scope of research.