# Abstract

This thesis is concerned with the detailed analysis of the statistical properties of complex systems with chiral symmetry, using random matrix approach. First, an ensemble of random matrices is considered with a combination of fixed 'matrix' constraints, e.g., Hermiticity and chiral symmetry along with (or without) time-reversal symmetry, and the effect of 'ensemble' constraints on spectral statistics is studied by changing the strength of disorder. Later, keeping the 'ensemble' constraints, e.g., disorder, same, the response of 'matrix' constraints, e.g., conservation laws, on eigenfunction localization and spectral statistics is studied by changing the structure of the single matrix. In wide range of complex systems, e.g., charge transport in bipartite systems like graphene, conductance fluctuations in mesoscopic systems, topological systems etc., complexity appears with chirality and thus being the motivation of my thesis. The effects of different constraints on the statistical properties of chiral ensemble are the main focus of this thesis.

In the first part of my thesis, chiral ensembles with uncorrelated but multivariate Gaussian distributed elements are considered. Theoretically it is analyzed there exist a single parameter, referred as complexity parameter which basically is a function of all ensemble parameters, governs the dynamics of spectral statistics. My analysis demolished the intuition that the spectral statistics of a multi-parametric chiral Gaussian ensembles depends on many parameters. Numerical study of four different ensembles with different strength of disorder (but same 'matrix' constraint class) confirms the validity of complexity parameter and proves our claim that if the spectral complexity parameters of two systems, with different 'ensemble' conditions, are equal, their spectral statistics must be same. It reveals an underlying connection not only between chiral complex systems with seemingly different system conditions but also to other complex systems, e.g., multi-parametric Wishart ensembles as well as generalized Calogero-Sutherland Hamiltonian.

In the next part of the thesis, five different ensembles are considered with specific conservation laws and symmetry conditions leading to various constraints and hence the structures in their matrix representation. An exact theoretical analysis of eigenfunction localization and eigenvalue statistics of column constrained chiral ensembles with circulant off-diagonal blocks pulled down the popular wisdom that Poisson statistics must be associated with the localized eigenfunctions and Wigner-Dyson statistics with delocalized ones. The numerical analysis also confirms our theoretical result which reveals the coexistence of extended wave-dynamics with Poisson spectral statistics.

In the last part of the thesis, the statistical properties of the above mentioned five ensembles are studied in detail, and it is found that the relationship between eigenfunction dynamics and eigenvalue statistics is way more complicated than believed so far. An important trend is revealed that the spectral statistics is strongly dependent on the number of independent matrix elements whereas the eigenfunction statistics seems to be mainly influenced by their relative strengths. As the number of constraints increases, the eigenvalue statistics varies from Wigner-Dyson to Poisson limits but the eigenfunction statistics remains weakly-multifractal in the bulk. The spectral statistics for some constraints is also found to be independent of matrix size, thus indicating a critical point. An existence of new universality classes depending on the 'matrix' constraints is also indicated; those classes are different from already known symmetry based ten universality classes.