Anderson Localization transition in QCD spectrum

Abstract

Lattice QCD is currently our best numerical approach to the non-perturbative regime of strong interaction. Asymptotic freedom guarantees that at high energy scales, the theory is weakly interacting and a perturbative treatment is possible.

Through Monte Carlo simulations of the Path Integral, it's possible to investigate numerous non-perturbative effects arising from low energy scales. One such effect is Anderson localization, initially described in the context of disordered electronic systems. It seems to be related to the behavior of low-energy fermionic states when we couple Dirac fermions to the QCD non-Abelian $SU(3)$ gauge field.

In the following work, we use Rational Hybrid Monte Carlo sampling techniques to generate gauge configurations to couple with the staggered Dirac fermion operator and analyze the statistical properties of the spectrum. The aim is to visualize a transition in the distribution of the Unfolded Level Spacings (ULSD) of the Dirac modes, from a Poissonian to a Wigner-Dyson distribution proceeding towards higher eigenvalues. The Poissonian behavior of the spectrum indicates the presence of localized modes, while a GUE distribution is expected for the eigenvalues up to a mobility edge. By computing the integral of the ULSD, I_{s_0}, we can identify the mobility edge as the critical value of I_{s_0}, at which the spacings switch distribution and localization/delocalization appears. We will investigate the behavior of the Participation Ratio (PR), a measure of the fraction of the system occupied by a certain mode, looking for evidence of localization.

Moreover, localization should be linked to topological excitations (instantons and anti-instantons) of the gauge field and the associated fermionic zero modes. We will investigate the potential relation between topological charges and chiral symmetry restoration, providing a possible connection scenario between localization and chirality phenomena.

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