

CENTRE VORTICES AS THE ORIGIN OF QUARK CONFINEMENT

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Quantum chromodynamics (QCD) manifests two key features; the confinement of quarks inside hadrons, and dynamical chiral symmetry breaking, associated with the dynamical generation of mass. The nature of the underlying mechanisms responsible for these phenomena, and whether they share a common origin, have remained open questions. It is generally accepted that these features originate from the topological structure of the QCD vacuum.

Using Lattice QCD, we reveal a fundamental connection between centre vortices and several key features associated with dynamical chiral symmetry breaking and quark confinement. Calculations are performed in pure SU(3) gauge theory using the chiral overlap fermion action. Starting from the original gauge field, a vortex identification procedure yields vortex-removed and vortex-only backgrounds. By studying the quark mass function, we demonstrate the removal of dynamical mass generation via the removal of the centre-vortex degrees of freedom from the gauge fields. The low-lying hadron mass spectrum is also calculated, with results that are consistent with the restoration of chiral symmetry on vortex-removed backgrounds at light quark masses.

Remarkably, we observe that the vortex-only degrees of freedom are able to encapsulate the qualitative features of the original gauge fields. Through visualisations of the topological charge density, we find evidence of a link between centre vortices and the instanton structure of the vacuum, specifically vortex-only backgrounds provide gauge-field degrees of freedom sufficient to create instantons upon cooling. Furthermore, after some smoothing, we observe dynamical mass generation on the vortex-only backgrounds consistent with that of the original gauge-field ensemble.