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Quantum distillation and resurgent semi-classics in QFT

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The dimension of the Hilbert space of QFT scales as exponential of the volume of the space that the theory lives, yet one can define a graded dimension (such as Witten index in supersymmetric theories) which is a pure number. Can we make this observation useful in non-supersymmetric quantum field theories in four dimensions? In this talk, we constructs a graded state sum in non-supersymmetric theories including a theory remarkably close to QCD: Yang-Mills theory with $N_f = N_c$ fundamental Dirac and one adjoint Weyl fermion, and study its dynamics using graded partition functions. We describe both in Hilbert space operator formalism and path integral formalism. Despite the existence of fundamental fermions, the theory possess an exact 0-form color-flavor center symmetry. At one-loop order, the potential for holonomy of $SU(N_c)$ theory has a an exponentially growing number of degenerate minima and allows for all possible realization of center-symmetry. At two-loop order, the degeneracy is lifted and center-symmetry remains unbroken at small L. Relatedly, quantum distillation in Hilbert space, H is due to powerful Bose-Bose, Fermi-Fermi and Bose-Fermi cancellations. (not only as Bose-Fermi as in supersymmetric theories.) We prove spontaneous chiral symmetry breaking within the domain of validity of semi-classics, and show that except for Nambu-Goldstone modes, the spectrum is gapped, and with the inclusion of soft quark mass, the theory is gapped. This construction provides a solution of QCD(F) (plus one heavy adjoint fermion) on $\mathbb{R}^3 \times S^1$. The vacuum structures of the theory on $\mathbb{R}^4$ and $\mathbb{R}^3 \times S^1$ are controlled by the same mixed 't Hooft anomalies.

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