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Color Confinement, Hadron Dynamics, and Hadron Spectroscopy from Light-Front Holography and Superconformal Algebra

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QCD is not supersymmetrical in the traditional sense – the QCD Lagrangian is based on quark and gluonic fields, not squarks nor gluinos. However, its hadronic eigensolutions conform to a representation of superconformal algebra, reflecting the underlying conformal symmetry of chiral QCD and its Pauli matrix representation. The eigensolutions of superconformal algebra provide a unified Regge spectroscopy of meson, baryon, and tetraquarks of the same parity and twist as equal-mass members of the same 4-plet representation with a universal Regge slope. The pion $q\bar{q}$ eigenstate has zero mass for $m_q = 0$. The superconformal relations also can be extended to heavy-light quark mesons and baryons. The combined approach of light-front holography and superconformal algebra also provides insight into the origin of the QCD mass scale and color confinement. A key observation is the remarkable dAFF principle which shows how a mass scale can appear in the Hamiltonian and the equations of motion while retaining the conformal symmetry of the action. When one applies the dAFF procedure to chiral QCD, a mass scale κ appears which determines universal Regge slopes, hadron masses in the absence of the Higgs coupling, and the mass parameter underlying the Gaussian functional form of the nonperturbative QCD running coupling: $\alpha_s(Q^2) \propto \exp -Q^2/4\kappa^2$, in agreement with the effective charge determined from measurements of the Bjorken sum rule. The mass scale κ underlying hadron masses can be connected to the parameter $\Lambda_{\overline{MS}}$ in the QCD running coupling by matching its predicted nonperturbative form to the perturbative QCD regime. The result is an effective coupling $\alpha_s(Q^2)$ defined at all momenta. One also obtains empirically viable predictions for spacelike and timelike hadronic form factors, structure functions, distribution amplitudes, and transverse momentum distributions. I will also discuss properties of the QCD and electroweak light-front vacuum.

Primary author: Prof. BRODSKY, Stanley J. (SLAC National Accelerator Laboratory, Stanford University)

Presenter: Prof. BRODSKY, Stanley J. (SLAC National Accelerator Laboratory, Stanford University)

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