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Mathematica and Fortran programs for various analytic QCD couplings

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Perturbative QCD in the usual mass independent schemes gives us running coupling $a(Q^2) \equiv \alpha_s(Q^2)/\pi$ which has unphysical (Landau) singularities at low squared momenta $|Q^2| < 1$ GeV^2 (where $Q^2 \equiv -q^2$). Such singularities do not reflect correctly the analytic (holomorphic) properties of spacelike observables $calD(Q^2)$ such as current correlators or structure function sum rules, the properties dictated by the general principles of (local) quantum field theory. Therefore, evaluating $calD(Q^2)$ in perturbative QCD in terms of the coupling $a(\kappa Q^2)$ (where $\kappa \sim 1$ is the renormalization scale parameter) cannot give us correct results at low $|Q^2|$. As an alternative, analytic (holomorphic) models of QCD have been constructed in the literature, where $A_1(Q^2)$ [the holomorphic analog of the underlying perturbative $a(Q^2)$] has the desired properties. We present our programs, written in Mathematica and in Fortran, for the evaluation of the $A_\nu(Q^2)$ coupling, a holomorphic analog of the powers $a(Q^2)^\nu$ where ν is a real power index, for various versions of analytic QCD:
(A) (Fractional) Analytic Perturbation Theory ((F)APT) model of Shirkov, Solovtsov et al. (extended by Bakulev, Mikhailov and Stefanis to noninteger ν); in this model, the discontinuity function $\rho_\nu(\sigma) \equiv \mathrm{Im}A_\nu(-\sigma - i\epsilon)$, defined at $\sigma > 0$, is set equal to its perturbative counterpart: $\rho_\nu(\sigma) = \mathrm{Im}a(-\sigma - i\epsilon)^\nu$ for $\sigma > 0$, and zero for $\sigma < 0$.
(B) Two-delta analytic QCD model (2δanQCD) of Ayala, Contreras and Cvetic; in this model, the discontinuity function $\rho_1(\sigma) \equiv \mathrm{Im}A_1(-\sigma - i\epsilon)$ is set equal to its perturbative counterpart for high $\sigma > M_0^2$ (where $M_0 \sim 1$ GeV), and at low postive σ the otherwise unknown behavior of $\rho_1(\sigma)$ is parametrized as a linear combination of two delta functions.
(C) The massive QCD of Shirkov, where $A_1(Q^2) = a(Q^2 + M^2)$ with $M \sim 1$ GeV.

Summary

We present programs, in Mathematica and in Fortran, for calculation of the general power analogs of the coupling in three different analytic (holomorphic) models of QCD.

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