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Small Instantons and the Strong CP Problem

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We describe new solutions to the strong CP problem obtained by embedding the Standard Model QCD in a strongly coupled $SU(3) \times SU(3)$ or $SU(3) \times SU(3) \times SU(3)$ product gauge group at high energies, without requiring any discrete symmetries or mirror partners of the SM matter in the extra $SU(3)$ sectors. In one family of solutions, the strong CP problem is solved by axions obtaining masses parametrically larger than the mass generated near the QCD scale, with potentially observable cosmological, collider, and astrophysical signatures. In a second family of solutions, some of the Yukawa couplings are generated only by non-perturbative effects, solving the strong CP problem in the same way as the well-known (but unviable) massless up-quark solution, with no axion-like states present. In this case, a non-zero theta parameter is generated at loop level near current bounds.

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