

Deconstructing the Extra-Dimensional Axion

We present a four-dimensional deconstruction of the extra-dimensional axion arising from a $U(1)$ gauge theory in a five-dimensional orbifold, where the axion is identified with the Wilson line of the $U(1)$ gauge field and its coupling to QCD is generated by a 5D Chern-Simons (CS) term. We construct the corresponding 4D moose (quiver) gauge theory with link scalar fields, in which the axion emerges as a collective pseudo-Nambu-Goldstone boson. The axion-gluon coupling is described by a gauged Wess-Zumino-Witten term, providing the 4D counterpart of the 5D CS term. We further analyze non-perturbative effects from zero-mode and “fractional” instanton configurations. While the latter is exponentially suppressed in the regime corresponding to the 5D description, ensuring consistency with the higher-dimensional picture, we point out that this suppression can break down for smaller instantons whose inverse size exceeds the 5D cutoff scale, leading to a potentially significant effect. We also study axion potentials induced by bulk matter fields and boundary-localized symmetry-breaking operators, reproducing the characteristic nonlocal suppression associated with propagation in the extra dimension. Our construction provides a renormalizable 4D framework with a transparent understanding of the axion shift symmetry and its quality.

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