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Peeking into the theta vacuum of 4d Yang-Mills theory

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We propose a subvolume method to study the θ dependence of the free energy density of the four-dimensional SU(N) Yang-Mills theory on the lattice. As an attempt, the method is first applied to SU(2) Yang-Mills theory at $T = 1.2\,T_c$ to understand the systematics of the method. We then proceed to the calculation of the vacuum energy density and obtain the θ dependence, at least, to $\theta \sim \pi$. The numerical results combined with the theoretical requirements provide the evidence for the spontaneous CP violation at $\theta = \pi$, which is in accordance with the large N prediction and in contrast to the CP^1 model in two dimensions.

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