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Spontaneous CP breaking in 4D SU(N) gauge theory at $\theta = \pi$ and its restoration at finite temperature

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Recent studies on the ‘t Hooft anomaly matching condition for 4D SU(N) gauge theory have suggested that the phase structure at $\theta = \pi$ should be nontrivial. Namely, some symmetry will be spontaneously broken, or gapless modes will appear. In the large-N limit, it is known that CP symmetry at $\theta = \pi$ is broken in the confined phase, while it restores in the deconfined phase, which is indeed one of the consequence of the anomaly matching. However, at small N, one may find a qualitatively different phase structure, which will be another possible scenario consistent with the anomaly matching. Here we investigate this issue for $N = 2$ by direct lattice calculations. The crucial point of our method is that the restoration of CP symmetry can be probed by the sudden change of the topological charge distribution at $\theta = 0$, which can be seen by simulating the theory at imaginary θ without the sign problem. Our results suggest that the CP symmetry at $\theta = \pi$ is restored at higher temperature than the deconfining temperature unlike the situation in the large-N limit.

Primary author: Dr MATSUMOTO, Akira (RIKEN iTHEMS)

Presenter: Dr MATSUMOTO, Akira (RIKEN iTHEMS)

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