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Exploring the QCD Phase Transitions with Imaginary Rotation

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In this talk, I will report our recent achievements based on refs. [1,2]. Below are highlights from our results.

Confinement under Imaginary Rotation
STAR Collaboration found nuclear matter rotating at $\omega \sim 10^{22}\ s^{-1}$ in heavy ion collisions. Neutron stars can also spin at $\omega \sim 10^{3}\ s^{-1}$. It is interesting but difficult to unravel mysteries in understanding how quarks and gluons behave in rapidly rotating matter. In our study, we considered the Polyakov loop potential at high T with "imaginary"angular velocity. Imaginary rotation provides a well-defined formulation for investigating the QCD phase transition.

Perturbative Realization of Confinement
In ref. [1], we perturbatively calculated the Polyakov loop potential for the imaginary rotating Yang-Mills system. With increasing angular velocity, we found a phase transition to confinement around $\omega/T \simeq i\pi/2$. Furthermore, we argued that this perturbative confined phase can be smoothly connected to the hadronic phase, i.e., the adiabatic continuity can be realized.

Chiral Symmetry Breaking
In ref. [2], we introduce fermions at finite chemical potential and investigated the chiral phase transition. Our results show the spontaneous breaking of chiral symmetry in our previously found confined phase with imaginary angular velocity for any high T.

Toward Real Rotation
The physics goal is to analytically continue the results to real rotation, for which the system size must be finite due to the causality condition. In ref. [2], we discuss the boundary condition for the finite size system.

[1] S. Chen, K. Fukushima, and Y. Shimada, *Perturbative Confinement in Thermal Yang-Mills Theories Induced by Imaginary Angular Velocity*, Phys.Rev.Lett. 129 (2022) 24, 242002.
[2] S. Chen, K. Fukushima, and Y. Shimada, *Chiral Symmetry Breaking with Perturbative Confinement at Finite Imaginary Angular Velocity*, in completion.

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