UNIVERSITY OF CALIFORNIA, LOS ANGELES UCLA

BERKELEY • DAVIS • IRVINE • LOS ANGELES • MERCED • RIVERSIDE • SAN DIEGO • SAN FRANCISCO SANTA BARBARA • SANTA CRUZ

Department of Physics and Astronomy
Mani L. Bhaumik Institute for Theoretical Physics
University of California Los Angeles
Los Angeles, CA 90095, USA
Cell: (515) 231-9190
Email: zkang@ucla.edu

May 1, 2023

Reference Letter for Fanyi Zhao

Dear colleagues:

It is a great pleasure for me to write this letter in support of Fanyi Zhao, who has applied for Quantum Computing Boot Camp - QCBC23, to be held at Jefferson Lab during June 20, 2023 to June 30, 2023. I give Fanyi my strongest recommendation for attending this summer school. Fanyi is an extraordinarily talented scientist in the field of theoretical high energy nuclear and particle physics, in particular the area of Quantum Chromodynamics (QCD) and strong interactions, and has done some interesting work on the application of quantum simulations to strong interactions.

Fanyi is currently a graduate student in Department of Physics and Astronomy at University of California Los Angeles (UCLA), and currently working with me in the field of theoretical nuclear and particle physics, as well as quantum computing for QCD problems. She will graduate in the summer of 2023 and will then join the MIT Center for Theoretical Physics as a postdoc in September 2023.

Fanyi has done important work in QCD theory and phenomenology. QCD is the theory of strong interactions, which describes how elementary particles like quarks and gluons interact with each other and is responsible for how quarks and gluons make up hadrons. The fundamental laws of QCD are elegantly concise. However, understanding the structural complexity of protons and neutrons in terms of quarks and gluons governed by those laws is one of the most important challenges facing physics today, a challenge that motivates the newest generation of experimental facilities, e.g. the future Electron-Ion Collider (EIC) to be built at Brookhaven National Laboratory at around 2030.

The EIC will collide electrons into protons and heavier nuclei pushing the frontiers of our understanding of nuclear and particle physics. EIC can have both electron and nucleon beam polarized and also is able to measure the polarization of final-state particles. With the EIC at hand, we will be able to answer the questions such as, what are the quantum correlations between the motion of partons, their spin and the spin of the nucleon? Precisely along this direction, Fanyi made important contributions. She is particularly interested in studying the internal structure of QCD jets (which are streams of particles emerging from particle collisions) and recently developed a framework, referred to as “polarized jet fragmentation functions”, which utilizes jet substructure for probing spin dynamics of hadrons.

Another research direction Fanyi has made important progress is on Quantum simulation to QCD and strong interactions.

In our first paper [A. M. Czajka, Z. B. Kang, H. Ma and F. Zhao, JHEP **08**, 209 (2022)], we performed quantum simulation of chiral phase transitions. The Nambu-Jona-Lasinio (NJL) model has been widely studied for investigating the chiral phase structure of strongly interacting matter. The study of the thermodynamics of field theories within the framework of Lattice Field Theory is limited by the sign problem, which prevents Monte Carlo evaluation of the functional integral at a finite chemical potential. Using the quantum imaginary time evolution (QITE) algorithm, we construct a quantum simulation for the $(1+1)$ dimensional NJL model at finite temperature and finite chemical potential. We observe consistency among digital quantum simulation, exact diagonalization and analytical solution, indicating further applications of quantum computing in simulating QCD thermodynamics.

In our second paper [A. M. Czajka, Z. B. Kang, Y. Tee and F. Zhao, arXiv:2210.03062 [hep-ph]], we study chirality imbalance with quantum algorithms. To describe the chiral magnetic effect, the chiral chemical potential μ_5 is introduced to imitate the impact of topological charge changing transitions in the quark-gluon plasma under the influence of an external magnetic field. We employ the $(1+1)$ dimensional NJL model to study the chiral phase structure and chirality charge density of strongly interacting matter with finite chiral chemical potential μ_5 in a quantum simulator. By performing the `QITE` algorithm, we simulate the $(1+1)$ dimensional NJL model on the lattice at various temperature T and chemical potentials μ, μ_5 and find that the quantum simulations are in good agreement with analytical calculations as well as exact diagonalization of the lattice Hamiltonian.

To summarize, Fanyi has the background in QCD and strong interactions, as well as the basic knowledge on quantum computing. I thus feel that she can benefit mostly from your summer school, which is precisely targeting along this direction. To conclude, I give her my strongest possible recommendation. Please feel free to email or call if you have any questions.

Sincerely yours,

Zhongbo Kang

Zhong-Bo Kang
Associate Professor
High-Energy Nuclear Theory
UCLA