WEINBERG
COLLEGE OF
ARTS & SCIENCES

Department of Physics and Astronomy
2145 Sheridan Road
Evanston, Illinois 60208-3112

www.physics.northwestern.edu

Judd A. and Marjorie Weinberg College of Arts and Sciences
Northwestern University

Phone 847-491-3685
Fax 847-491-9982

NORTHWESTERN
UNIVERSITY

Phone: (847) 467 2618
Email: ilow@northwestern.edu

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Dear Colleague,

I am delighted to write a most enthusiastic letter of support for Mr. Qiaofeng Liu's application to QUANTUM COMPUTING BOOT CAMP at the Thomas Jefferson National Accelerator Facility. Even though Qiaofeng is only a first year Ph.D. student in the Department of Physics and Astronomy at Northwestern University, he already has one super-interesting publication and is functioning like a junior postdoc, research-wise, as I will explain below.

Prior to Northwestern, Qiaofeng was an undergraduate at Duke University working with my collaborator Professor Thomas Mehen, who very strongly recommended Qiaofeng. Based on that, I recruited Qiaofeng first to the Master program at Northwestern in the fall of 2021 and then to the Ph.D. program in the fall of 2022. He took quantum field theory from Prof. Mehen as an undergraduate at Duke and then again as a graduate student at Northwestern. So by now he has completed (or will have completed by the time of the summer school) the required coursework for a theory student at Northwestern.

As soon as his arrival at Northwestern in the Fall of 2021, Qiaofeng began working with me and Prof. Mehen on quantum entanglement and emergent symmetries in effective field theories in the context of Pionless EFT, which is a low-energy EFT of QCD below the pion production threshold. Low-energy QCD has several emergent symmetries that are not symmetries of the fundamental QCD Lagrangian. Examples include the SU($2N_f$) quark spin-flavor symmetry (N_f is the number of light quark flavors), Wigner's SU(4) neutron-proton spin-flavor symmetry, non-relativistic conformal symmetry (also known as the Schrodinger symmetry) in the neutron-proton scattering and a large SU(16) spin-flavor symmetry acting on the spin-1/2 octet baryons. Among these the SU($2N_f$) and Wigner's SU(4) can be derived in the large N_c limit of QCD, but there is no explanation of the NR conformal invariance and SU(16) symmetry.

In an article in 1812.03138, Beane et. al. observed an intriguing correlation between the emergence of the NR conformal invariance , as well as SU(16) spin-flavor symmetry, and the entanglement suppression in neutron-proton scatterings in the very low-energy, which is described by the Pionless EFT. Inspired by this observation, in 2104.10835 Prof. Mehen and I considered the S-matrix in the two-to-two scattering of fermions as a quantum logic gate acting on the two qubit system and gave an entirely quantum information-theoretic derivation of the the correlation between emergent symmetries and entanglement suppression. We discovered that the spin-flavor symmetry is associated with the Identity gate and

the NR conformal symmetry is associated with the SWAP gate.

Qiaofeng and I, together with Prof. Mehen, generalized the treatment in 2104.10835 to scattering of spin-1/2 octet baryons. This is a highly non-trivial task as we need to figure out how to incorporate scattering processes where the flavors of initial state baryons could in general be different from those of the final state baryons. (This never occurs in neutron-proton scattering.) Moreover, the Pionless EFT describing the baryon-baryon scattering contains six operators at the LO, while there are only two for the neutron-proton case. Within a year, Qiaofeng made tremendous progresses and obtained many interesting results. Along the way, he not only demonstrated familiarity with the intricate EFT calculations, as well as the information-theoretic concepts, but also acquired in-depth knowledge on the group theory of $SU(N)$. What impresses me the most is Qiaofeng's ability to get things done and make steady progress week after week. When we run into road blocks, he always finds a way to get things done. As I mentioned, he is already functioning like a junior postdoc, despite being a first year Ph.D. student.

Our findings were published in 2210.12085, in which we showed that successive entanglement minimization in SU(3)-symmetric scattering channels are correlated with increasingly large emergent symmetries in the Pionless EFT. In particular, we identified scattering channels whose entanglement suppression are indicative of emergent SU(6), SO(8), SU(8) and SU(16) symmetries and also observe the appearance of non-relativistic conformal invariance in channels with unnaturally large scattering lengths. I think these are super-interesting results and hint at a new paradigm to understand the origin of symmetry from the quantum information viewpoint.

There are two follow-up projects we are pursuing simultaneously and Qiaofeng's growth curve seems to be accelerating. One of the projects has to do with simulating real-time NN dynamics on the IBM quantum computer, which is directly related to the scope of the school. I believe Qiaofeng will benefit tremendously from attending the summer school. Conversely, the Summer School will definitely benefit from having an exceptional young talent like Qiaofeng. I support his application wholeheartedly!

Sincerely,

Ian Low
Professor of Physics