Zhengqian Cheng

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Quantum many-body theories, especially strongly correlated fermion models. With strong background on mathematics and computer science.

Education

- **Columbia University** — **New York, NY**
  The Department of Applied Physics and Applied Math (APAM) — *2013–2020*
  PhD in Applied Physics (2020); MPhil in Applied Physics (2017); MS in Applied Physics (2015)
  - *Advisor: Chris Marianetti*
- **Peking University** — **Beijing, China**
  The Department of Physics — *2009–2013*
  BS in Physics

Research and Teaching Experience

- **Columbia University, Columbia Center for Computational Electrochemistry (CCCE)** — **New York, NY**
  Postdoctoral Research Scientist — *Oct. 2020 – present*

  Variational discrete action theory
  - Applied variational discrete action theory to multi-band Hubbard models and strongly correlated systems.
  - Generalized variational discrete action theory to finite temperature, real time, and non-equilibrium cases.
  - Developed quantum-classical algorithm for solving multi-orbital Hubbard model
- **Columbia University, APAM** — **New York, NY**
  Research Assistant — *Sept. 2014 – Sept. 2020*

  Variational discrete action theory
  - Developed a novel variational theory based on sequential product density matrix and discrete action theory.
  - Applied the theory to single band Hubbard model and Anderson model.

  Off-shell effective energy theory
  - Developed an efficient and robust method for quantum system based on an exact variational ansatz.
  - Bench-marked the theory to single and two band Hubbard model for zero temperature and finite temperature.

  Minimal cell for phonon interaction
  - Used group theory and number theory to find the minimum cell to compute a given order of phonon interaction.
- **Columbia University, APAM** — **New York, NY**
  Teaching Assistance — *2014–2015*
  - Graded and provided solutions to the course: Electronic and Magnetic Properties of Materials.
  - Graded the homework and exams: Numerical Methods.
- **Peking University, International Center for Quantum Materials** — **Beijing, China**
  Undergraduate Research Project — *2011–2013*

  Thermodynamic approach to the orbital magnetization
  - Derived a set of formulae of orbital magnetization for crystalline material using the linear response theory and Kubo correlation function

  Heat superconductivity
  - Using the general idea of that a spontaneous symmetry associated with a superconductive current, we proposed that the time crystal, which breaking the time translation symmetry, should exhibit the heat (energy) superconductivity.

Publication

- Zhang, Junyi, and Zhengqian Cheng. "Density-Matrix Mean-Field Theory." arXiv preprint arXiv:2401.06236 (2024).
- Tscheppe, Patrick, Jiawei Zang, Marcel Klett, Seher Karakuzu, Armelle Celarier, Zhengqian Cheng, Chris A. Marianetti

et al. "Magnetism and metallicity in moiré transition metal dichalcogenides." Proceedings of the National Academy of Sciences 121, no. 3 (2024): e2311486121.
- Cheng, Zhengqian, and Chris A. Marianetti. "Gauge constrained algorithm of variational discrete action theory at N= 3 for the multiorbital Hubbard model." Physical Review B 108, no. 3 (2023): 035127.
- Cheng, Zhengqian, and Chris A. Marianetti. "Precise ground state of multiorbital Mott systems via the variational discrete action theory." Physical Review B 106, no. 20 (2022): 205129.
- Cheng, Zhengqian, and Chris A. Marianetti. "Variational Discrete Action Theory." Physical Review Letters 126, no. 20 (2021): 206402.
- Cheng, Zhengqian, and Chris A. Marianetti. "Foundations of variational discrete action theory." Physical Review B 103, no. 19 (2021): 195138.
- Cheng, Zhengqian. "Variational Discrete Action Theory". Doctorial thesis for Columbia University 2020.
- Cheng, Zhengqian, and Chris A. Marianetti. "Off-shell effective energy theory: A unified treatment of the Hubbard model from d= 1 to $d = \infty$." Physical Review B 101.8 (2020): 081105.
- Fu, Lyuwen, Mordechai Kornbluth, Zhengqian Cheng, and Chris A. Marianetti. "Group theoretical approach to computing phonons and their interactions." Physical Review B 100, no. 1 (2019): 014303.
- Shi, Junren, and Zhengqian Cheng. "Heat Superconductivity." arXiv preprint arXiv:1211.3633 (2012).

Awards

- **Mercedes-Benz Award** Award for undergraduate in Peking University based on academic performance. 2 recipients for 200 in physics department.
- **Gold Medal for 10th Asian Physics Olympiad (APHO)** Total score ranked 5 of 23 gold medals

Contributed Talks

- Mapping the Hubbard model to self-consistent spin models: a quantum-embedded Jordan-Wigner transformation, APS March Meeting 2024
- A precise single-particle density matrix functional for multi-orbital Mott physics via VDAT, APS March Meeting 2023
- Precise ground state of multi-orbital Mott systems via the variational discrete action theory, APS March Meeting 2022
- A multi-projective variational approach to the quantum lattice problem, APS March Meeting 2019
- Entropy functional approach for Fermionic lattice models, APS March Meeting 2018
- Single-particle plus local reduced density matrix functional theory for Fermionic lattice models, APS March Meeting 2017
- Hubbard operator density functional theory for Fermionic lattice models, APS March Meeting 2016
- Local density fluctuation approach to Fermionic lattice models, APS March Meeting 2015
- Single-site density matrix embedding theory: from one to infinite dimensions, APS March Meeting 2014

Software Development

- **VDATN3multi.jl**: An efficient implement of variational discrete action theory for multi-orbital Hubbard model with general interaction. `https://github.com/chengzhengqian/VDATN3multi.jl`
- **Wick.jl**:A JIT compiler to evaluate Wick's theorem, i.e, Feynman diagrams. `https://github.com/chengzhengqian/Wick.jl`
- **VecDiff.jl** A backward-forward mixed mode automatic differentiation library in Julia, for efficient evaluation of Hessian matrix. `https://github.com/chengzhengqian/VecDiff.jl`

Skills

- **Physics**: many-body theory, dynamical mean field theory, density matrix renormalization group, Green's function techniques, renormalization group, quantum Monte Carlo, composite operator theory
- **Mathematics**:differential geometry, algebraic topology, category theory
- **Programming language**: python, Julia, Mathematica, C, C++, java, kotlin, lisp, Haskell