Xu-Cheng Wang

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EDUCATION

Fudan University, Department of Physics   Shanghai, China

PhD in Theoretical Physics (Condensed Matter Theory)   *Sept. 2021 – Present*

- *Elite PhD program (10/125), GPA: 3.82/4.0*
- *Supervised by Prof. Yang Qi*
- *Thesis title: Phase fluctuations and novel phenomena in two-dimensional superconductors*

Fudan University, Department of Physics   Shanghai, China

BSc in Physics, GPA: 3.65/4.0 (top 15%)   *Sept. 2017 – Jun. 2021*

- *Relative courses: Linear Algebra, Probability and Statistics, C/C++ and Python Programming,*
  Computational Physics, Embodied Intelligence, etc.

ACADEMIC EXPERIENCE

Phase fluctuations, pseudogap, and Fermi arcs in 2D superconductors

- Developed a phenomenological theory of phase-disordered superconductor, combining pertubative expansion and disorder-average technique, which revealed the universal connection among phase fluctuations, pseudogap and Fermi arcs in 2D superconductors.

- Validated the predicted phase-fluctuation-driven pseudogap and Fermi arcs with exact determinant quantum Monte Carlo (DQMC) simulations; Extracted the real-frequency electronic spectra by approximately solving the ill-conditioned inverse of integral transformation using the stochastic analytic continuation (SAC) algorithm.

- Developed high-performance DQMC and SAC code in modern C++, incorporating Markov chain Monte Carlo and simulated annealing at the algorithmic level; Addressed essential technical aspects including numerical instability when inversing matrices with high condition numbers, serialization in MPI programming, and implementing Eigen-MKL wrapper; Certain variants of the code are open-sourced at *dqmc-framework.git* and *sac.git* respectively.

- **Related papers:**
  1. **X.-C. Wang** and Yang Qi, *Phase fluctuations in two-dimensional superconductors and pseudogap phenomenon*, Phys. Rev. B, **107**, 224502 (2023).
  2. **X.-C. Wang**, Xiao Yan Xu, and Yang Qi, *The interplay of phase fluctuations and nodal quasiparticles: ubiquitous Fermi arcs in two-dimensional d-wave superconductors*, arXiv:2310.05376 (2023).

Emergent magnetic pseudogap from phase fluctuations and the coherent enhancement

- Investigated the spin-lattice relaxation rate $1/T_1T$ of phase-disordered superconductors up to bubble graph and leading-order vertex correction; Identified magnetic pseudogap, emerging entirely from normal-state phase fluctuations, and the coherent enhancement of $1/T_1T$ signals in the normal state of s-wave superconductors.

- Leveraged adaptive high-dimensional Monte Carlo integration to compute spin susceptibility; Accelerated the hotspot code with Numba JIT compilation.

- **Related paper: X.-C. Wang** and Yang Qi, in preparation (2025).

Geometric localization length and criticality of disordered, ideally flat Chern band

- Explored the localization transition of ideally flat Chern band and innovatively proposed that its localization length and criticality have a quantum geometric origin; Extended the transfer matrix algorithm novelly to the optimally localized hybrid Wannier basis.

- Developed efficient Python code for the transfer matrix calculation of localization length, specifically computing the Lyapunov spectra associated with a product of random matrices; Overcame the numerical instability of consecutive transfer matrix multiplications through periodic QR factorization; Optimized the CPU and memory usage by leveraging the sparse structure of Wannier basis.

- **Related paper: X.-C. Wang** and Yang Qi, in preparation (2025).

LANGUAGES & TECHNICAL SKILLS

Languages: Mandarin, English

Computer Science: C/C++, Python, Linux Server/Shell, Git

王 勘 成

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教育经历

复旦大学 物理学系 | 理论物理博士 (凝聚态理论)　　　　　　　　　　　　2021 年 9 月 – 至今，上海
- 入选首届卓博计划（*10/125*），*GPA: 3.82/4.0*
- 指导老师：戚扬研究员
- 博士论文题目：二维超导体中的超导相位涨落和新奇物态

复旦大学 物理学系 | 理学学士　　　　　　　　　　　　　　　　　　2017 年 9 月 – 2021 年 6 月，上海
- *GPA: 3.65/4.0 (Top 15%)*
- 相关课程：线性代数，概率统计，*C/C++*程序设计，*Python* 程序设计，计算物理，具身智能等

学术经历

二维超导体中的相位涨落，赝能隙，和费米弧现象
- 建立了关于二维相位涨落超导体的唯象模型；结合微扰展开和无序平均技术，揭示了二维超导体中超导相位涨落、赝能隙和费米弧之间的普遍联系
- 利用精确的行列式量子蒙特卡洛计算 (Determinant Quantum Monte Carlo, DQMC)，在强关联量子模型中观察并证实了超导相位涨落导致的赝能隙和费米弧现象；通过随机解析延拓法 (Stochastic Analytic Continuation, SAC) 近似求解一系列病态逆积分变换，以计算实频率电子谱函数
- 编写高性能 C++代码，实现行列式量子蒙特卡洛模拟和随机解析延拓计算，涵盖了马尔可夫链蒙特卡洛、模拟退火等算法；解决一系列关键技术困难，包括大条件数矩阵逆运算中的数值不稳定、MPI 并行编程及序列化、MKL 数学库中关键函数的 Eigen 封装等；相关项目代码分别在 *dqmc-framework.git* 和 *sac.git* 开源
- **相关文章：**
    1. **X.-C. Wang** and Yang Qi, *Phase fluctuations in two-dimensional superconductors and pseudogap phenomenon*, Phys. Rev. B, **107**, 224502 (2023).
    2. **X.-C. Wang**, Xiao Yan Xu, and Yang Qi, *The interplay of phase fluctuations and nodal quasiparticles: ubiquitous Fermi arcs in two-dimensional d-wave superconductors*, arXiv:2310.05376 (2023).

二维超导体中相位涨落演生的磁赝能隙和相位相干增强
- 研究了相位涨落超导体理论的自旋晶格弛豫率 $1/T_1T$，并从理论上预言了由超导正常态相位涨落演生的磁赝能隙和二维 s 波超导体中超导相位相干导致的 $1/T_1T$ 增强；计算了电子自旋磁化率的气泡图贡献和领头阶顶角修正
- 利用自适应高维蒙特卡洛积分，计算电子自旋磁化率；结合 Numba 即时编译技术加速热点代码
- **相关文章：** **X.-C. Wang** and Yang Qi, in preparation (2025).

无序理想拓扑平带中的几何局域化长度和量子相变
- 系统研究了理想拓扑平带中的局域化相变，创新性地提出其局域化长度源于布洛赫波函数的量子几何性质；在最优局域化的混合瓦尼尔波函数 (optimally localized hybrid Wannier wavefunction) 表象下，推广了传统转移矩阵算法
- 开发高性能 Python 代码，通过转移矩阵算法计算体系的局域化特征长度，具体包括对随机矩阵乘积的李亚普诺夫谱 (Lyapunov spectra) 的精确求解；通过周期性 QR 分解克服了连续转移矩阵乘法中的数值不稳定问题；结合瓦尼尔波函数的稀疏性质，优化 CPU 和内存利用
- **相关文章：** **X.-C. Wang** and Yang Qi, in preparation (2025).

语言和个人技能

语言： 中文，英文

计算机技能： C/C++, Python, Linux Server/Shell, Git