北京大学量子材料科学中心

International Center for Quantum Materials, PKU

Seminar

The RPA+DMFT approach for unconventional superconductivity: application to nickelate superconductors

Hanghui Chen

NYU-ECNU Institute of Physics, NYU Shanghai
Department of Physics, New York University

Time: 10:00 am, May 29, 2026 (Friday)

时间：2026年5月29日（周五）上午10:00

Venue: Room w563, Physics building, Peking University

地点：北京大学物理楼，西563会议室

Abstract

Spin fluctuations are widely believed to mediate electron pairing in unconventional superconductors. In gap-equation calculations, the random phase approximation (RPA) has been widely used to construct the spin-fluctuation pairing potential. However, RPA is formally valid only in the weak-coupling regime and tends to predict spin-density-wave (SDW) instabilities at unrealistically small interaction strengths. In this work [1], we extend RPA to intermediate and strong coupling by combining it with dynamical mean-field theory (DMFT), forming an approach we term RPA+DMFT. Within this framework, the bare susceptibility in RPA is replaced by a renormalized susceptibility that incorporates quasiparticle dispersion and spectral weight obtained from DMFT. This renormalized susceptibility is then used to construct the pairing interaction for the gap equation.

We apply the RPA+DMFT method to infinite-layer nickelates [2-4] and Ruddlesden-Popper nickelates [5]. For infinite-layer nickelates [1], we find that the orbital hybridization in infinite-layer nickelates leads to van Hove singularities (VHS) that are pinned to the Fermi surface. Those VHS bring the system closer to magnetic instability, which amplifies antiferromagnetic spin fluctuations. This naturally explains why infinite-layer nickelates such as $La_{0.8}Sr_{0.2}NiO_2$ exhibit robust superconductivity with a sizable T_c, though the self-doping effect “overdopes” its Ni-d_{x2-y2} orbital relative to the phase diagram of cuprates [6]. For Ruddlesden-Popper nickelate $La_{3-x}Sr_xNi_2O_7$[7], we find that hole doping induces a Ni-d_{3z2-r2} derived γ pocket on the Fermi surface. As x approaches 0.4, the γ pocket evolves from circular to diamond-shaped and expands to span half of the Brillouin zone, resulting in nearly perfect Fermi surface nesting with the optimal nesting vector Q=(π,π). This, in turn, strongly enhances antiferromagnetic spin fluctuations and substantially increases the leading superconducting eigenvalue to a level at which superconductivity becomes experimentally observable.

Reference:

[1]Chengliang Xia, Shengjie Zhou, **Hanghui Chen***, arXiv:2504.18778.
[2]Yuhao Gu, Sichen Zhu, Xiaoxuan Wang, Jiangping Hu, **Hanghui Chen*,** Commun. Phys. 3, 84 (2020).
[3]Hanghui Chen*, Yi-feng Yang*, Guang-Ming Zhang* and Hongquan Liu, Nat. Commun. 14, 5477 (2023).
[4]Yanbing Zhou, Dan Zhao, Boyun Zeng, Chengliang Xia, Yu Wang, **Hanghui Chen*,** Tao Wu*, Xianhui Chen*, arXiv:2505.09476 (2025).
[5]Hongquan Liu, Chengliang Xia, Shengjie Zhou, **Hanghui Chen*,** Nat. Commun. 16, 1054 (2025).
[6]Wenjie Sun, Zhicheng Jiang, Chengliang Xia, Bo Hao, Yueying Li, Shengjun Yan, Maosen Wang, Hongquan Liu, Jianyang Ding, Jiayu Liu, Zhengtai Liu, Jishan Liu, **Hanghui Chen*,** Dawei Shen*, Yuefeng Nie*, Sci. Adv. 11, eadr5116 (2025).
[7]Chengliang Xia, Jiale Chen, Hongquan Liu, **Hanghui Chen*,** arXiv:2605.19297 (2026).

About the speaker

Hanghui Chen is an Associate Professor of Physics at NYU Shanghai and a Global Network Associate Professor in the Department of Physics at NYU. Prior to joining NYU Shanghai, he was a post-doctoral fellow at Columbia University. He holds a PhD in physics from Yale University and a BS in physics from Peking University. Professor Chen’s research interests lie at the intersection of condensed matter physics and materials science. He combines state-of-the-art first-principles and many-body model calculations to study strongly correlated properties of quantum materials, with a recent emphasis on unconventional superconductivity.