HKU-UCAS Young Physicists Symposium 2024

Topic: Non-Fermi liquids and anomalous transport in two dimensions

Introduction:

The symposium named "HKU-UCAS Young Physicists Symposium 2024" is a special event in the “HKU-UCAS Young Physicists Forum” (https://www.physics.hku.hk/~youngforum/) series of lectures hosted by the HKU-UCAS Joint Institute of Theoretical and Computational Physics at Hong Kong and Beijing. The aim is to enhance communication between young researchers in the field of strongly correlated matters with a particular focus on the quantum critical phenomenon in metals and promote collaborations in the early states of career. The invited speakers are primarily young scholars actively engaged in the forefront of relevant scientific research.

Program:

	Aug 19th (Mon)	Aug 20th (Tue)	Aug 21th (Wed)	Aug 22th (Thu)	Aug 23th (Fri)
20:00 - 21:00	Songci Li (Tianjin University)	Hao Song (ITP)	Xiao-Tian Zhang (KITS)	Thomas Sheerin (University of St Andrews)	Yin Zhong (Lanzhou University)
21:05 - 22:00	Haoyu Guo (Cornell)	Zhengyan Darius Shi (MIT)	Xingyu Ma (IOP)	Nikolai Peshcherenko (MPI-CPS)	Meng Zeng (MPI-PKS)

The time zone is based on China Standard Time (GMT+8);
Talks are given in English.

Venue:

Kavli Institute for Theoretical Sciences (KITS) is inviting you to a scheduled Zoom meeting.

Topic: HKU-UCAS Young Physicists Symposium 2024

Time: Aug 19, 2024 07:45 PM Beijing, Shanghai
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Aug 20, 2024 07:45 PM
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Talk Informations:

Speaker: Haoyu Guo (Cornell)

Title: Fluctuation Spectrum of Critical Fermi Surfaces

Abstract:
We investigate the low-energy effective theory of a Fermi surface coupled to an Ising-nematic quantum critical point in (2+1) spacetime dimensions with translation symmetry. We formulate the system using the large N Yukawa-SYK model, whose saddle point is described by the Migdal-Eliashberg equations. The low-energy physics can be revealed by studying the Gaussian

fluctuation spectrum around the saddle point, which is generated by the Bethe-Salpeter kernel K_BS. Based on the Ward identities, we propose an inner product on the space of two point functions, which reveals a large number of soft modes of K_BS. These soft modes parameterize deformation of the Fermi surface, and their fluctuation eigenvalues describe their decay rates. We analytically compute these eigenvalues for a circular Fermi surface, and we discover the odd-parity modes to be parametrically longer-lived than the even-parity modes, due to the kinematic constraint of fermions scattering on a convex FS. The sign of the eigenvalues signals an instability of the Ising-nematic quantum critical point at zero temperature for a convex Fermi surface. At finite temperature, the system can be stabilized by thermal fluctuations of the critical boson. We derive an effective action that describes the soft-mode dynamics, and it leads to a linearized Boltzmann equation, where the real part of the soft-mode eigenvalues can be interpreted as the collision rates. The structure of the effective action is similar to the theory of linear bosonization of a Fermi surface. As an application of the formalism, we investigate the hydrodynamic transport of non-Fermi liquid. Analyzing the Boltzmann equation, we obtain a conventional hydrodynamic transport regime and a tomographic transport regime. In both regimes, the conductance of the system in finite geometry can be a sharp indicator for the soft-mode dynamics and non-Fermi liquid physics.

About the speaker:
Haoyu Guo(郭浩宇) is a Bethe postdoctoral fellow at Cornell University. He received his PhD from Harvard University in 2023 under Prof. Subir Sachdev and BS from MIT in 2018 under Prof. Leonid Levitov. He is interested in various novel transport phenomena in strongly correlated systems, such as strange metallicity, thermal Hall effect and electron hydrodynamics.

Speaker: Zhengyan Darius Shi

Title: Non-perturbative methods for clean non-Fermi liquids

Abstract:
Conventional approaches to non-Fermi liquids focus on diagrammatic calculations within controlled perturbative expansions. While useful at leading order, several of these perturbative expansions suffer from instabilities/IR divergences at higher order that render them uncontrolled. This quandary invites the development of complementary non-perturbative methods. In this talk, we review a non-perturbative framework based on the infinite-dimensional emergent symmetries and 't Hooft anomalies associated with a Fermi surface. After deriving some basic kinematic consequences of the symmetry and anomaly structure such as Luttinger's theorem, we specialize to non-Fermi liquids of the Hertz-Millis type and discuss several dynamical implications corroborated by state-of-the-art perturbative calculations: a) sharp criterion

for the presence/absence of Drude weight. (b) vanishing critical incoherent optical conductivity. The invisibility of critical fluctuations in the transport behavior of clean Hertz-Millis models motivates us to consider several extensions that can evade the non-perturbative constraints. We comment on the general model-building strategies suggested by these extensions, which can potentially bring us closer to the phenomenology of real strange metals in the future.

About the speaker:
Mr. Zhengyan Shi is a PhD student at MIT in Senthil's group. Though primarily interested in strongly interacting metals, I sometimes dabble in quantum dynamics and quantum information to make more friends. When procrastinating, I like to boulder and memorize lines from bojack horseman, occasionally at the same time.

Speaker: Songci Li (Tianjin University)

Title: Optical conductivity of a metal near Ising-nematic quantum criticality

Abstract:
We study the optical conductivity of a clean electron system near an Ising-nematic quantum critical point. We discuss the relation between the frequency scaling of the optical conductivity of a single band system and the shape of the Fermi surface namely, whether it is isotropic, convex, or concave. We confirm the cancellation of the leading order terms in the optical conductivity for the cases of isotropic and convex Fermi surfaces and show that the remaining contribution scales as $|\omega|$^2/3 at T = 0. On the contrary, the leading term, ~$|\omega|$^−2/3, survives for a concave FS. We then consider a two- valley system near an Ising-nematic quantum critical point and show that intervalley drag leads to a $|\omega|$^−2/3 scaling of the optical conductivity in 2D near Ising-nematic quantum criticality.

About the speaker:
Songci Li received his PhD from University of Washington in 2017. He then held postdoctoral positions at National High Magentic Field Laboratory/University of Florida from 2017-2019 and at University of Wisconsin-Madison from 2019-2023. He joined Department of Physics, Tianjin University as an assistant professor since 2023. His research focuses on electron transport in correlated and quantum critical electron systems and superconducting hybrid systems.

Speaker: Xiao-Tian Zhang (KITS)

Title: Strange metal and exotic non-Fermi liquids at two-dimensional van Hove singularity

Abstract:
Non-Fermi liquids, particularly the universal strange metal, are ubiquitously observed in strongly correlated materials, that includes the high-Tc cuprates, ruthenate oxides and twisted bilayer graphenes. The unprecedent tunablity of these two-dimensional (2D) systems provides access towards the Lifshitz transition where the Fermi surface exhibits van Hove singularity (VHS) saddle points. Despite extensive investigation on the ordering instabilities, the critical phenomenon induced by the VHS are rarely explored. Here, we investigate the NFL behaviors at Lifshitz transition in the 2D magnetic heterostructure interface, where the Fermi surface undergoes a convex-to-concave topological transition. We uncover an exotic NFL phase at the VHS with the quasiparticle lifetime scaling as ~ ω^1/2. This exotic NFL feature dominates over the rest of the Fermi surface points in the low-energy limit. At finite energies, it crossovers to the marginal Fermi liquid. Importantly, we demonstrate the strange metal behaviors, that includes the linear-in-T resistivity and the Tln(1/T) specific heat, can emerge solely from the inclusion of spatially uniform interactions owing to the Galilean invariance breaking at VHS. Furthermore, we propose that the non-magnetic ARPES can directly probe the exotic NFL features at heterostructure interface. Our findings explore the interplay of VHS in lower dimension, disorder and strong interactions, which paves a novel path to study the high-Tc superconductivity, 2D magnetism and spintronics.

About the speaker:
Xiao-Tian Zhang earned his bachelor's degree from the College for Gifted Youngs at the University of Science and Technology of China in 2013. He then pursued his PhD at the International Center for Quantum Materials, Peking University, under the supervision of Prof. Ryuichi Shindou, graduating in 2019. From 2019 to 2022, he worked as a postdoc in Prof. Gang Chen's group at the University of Hong Kong. In 2022, he joined the Kavli Institute for Theoretical Sciences at UCAS, as a Director's Postdoctoral Fellow and Special Research Assistant.

Speaker: Hao Song (ITP)

Title: Anomalous quasiparticle lifetime in geometric quantum critical metals

Abstract:
Metals can undergo geometric quantum phase transitions where the local curvature of the Fermi surface changes sign without a change in symmetry or topology. At the inflection points on the Fermi surface, the local curvature vanishes, leading to an anomalous dynamics of quasiparticles. In this talk, we study geometric quantum critical metals that support inflection points in two dimensions, and show that the decay rate of quasiparticles goes as E^α with 1 < α < 2 as a function of quasiparticle energy E at the inflection points.

About the speaker:
Hao Song is an Associate Professor at the Institute of Theoretical Physics, CAS. He obtained his B.S. in Physics from Nanjing University in 2009, followed by an M.S. and Ph.D. in Physics from the University of Colorado Boulder in 2012 and 2015, respectively. Dr. Song furthered his research as a Postdoctoral Researcher at the Complutense University of Madrid and later as a Postdoctoral Fellow at McMaster University, where he also served as a Visiting Scholar. His research focuses on Quantum Many-body Physics, Topological Phases and Quantum Error Correction, and Fracton Models.

Speaker: Thomas Sheerin (University of St Andrews)

Title: Non-Fermi Liquids Induced by U(1) Gauge Field Interactions: A Functional Renormalization Group Analysis

Abstract:
Developing internally consistent theories of non-Fermi liquids (NFLs) in two spatial dimensions remains a significant challenge to the condensed matter community. One major hindrance to progress has been the fact that NFLs in 2-D usually occur at O(1) couplings and feature strong correlations, so that little is known about the form of the low energy theory, and predictive power is lost. A remedy is to utilize exact identities and constraints on the low energy theory, such as those provided by symmetries, to make modelling procedures more robust. We begin by discussing the advantages of the functional renormalization group as applied to NFLs, and outline a regularization scheme (first proposed by Maier and Strack [1]) that allows Landau damping to develop gradually during the renormalization group flow, while maintaining an analytic effective action at intermediate scales. We then move to the model considered in this work, namely that of a circular Fermi surface coupled to a dynamic U(1) gauge field. We delineate how the above regularization scheme interplays with the gauge symmetry, resulting in a set of constraints ("modified Ward identities") that must be obeyed at all stages in the flow. We then demonstrate how incorporation of these constraints affects the properties of the NFL renormalization group fixed point, compared to the unconstrained case – in particular, how gauge-symmetry forbids a conventional ordering transition. We finish with some commentary on the implications our results have for robust modelling of NFLs.
References: [1] S. A. Maier and P. Strack, Phys. Rev. B 93, 165114 (2016)

About the speaker: Mr. Thomas Sheerin is a Phd student in University of St Andrews supervised by Dr. Chris Hooley at Max Planck Institute for the Physics of Complex Systems in Dresden, Germany.

Speaker: NIkolai Peshcherenko (MPI-CPS)

Title: Sublinear transport in Kagome metals: Interplay of Dirac cones and Van Hove singularities

Abstract:
Kagome metals are known to host Dirac fermions and saddle point Van Hove singularities near Fermi level. With the minimal two-pocket model (Dirac cone + Van Hove singularity), we propose a semiclassical theory to explain the experimentally observed sublinear resistivity in Ni$_3$In and other Kagome metals. We derive the full semiclassical description of kinetic phenomena using Boltzmann equation, and demonstrate that internode electron-electron interaction leads to sublinear in T scaling for both electrical and thermal transport at low temperatures. At higher temperatures above the Dirac node chemical potential, thermal and electric currents dissipate through distinct scattering channels, making a ground for Wiedemann-Franz law violation.

About the speaker:
Mr. NIkolai Peshcherenko is is a Phd student at Max Planck Institute for Chemical Physics of Solids (Dresden, Germany)
supervised by Prof. Yang Zhang from University of Tennessee (US).

Speaker: Yan Zhong (Lanzhou University)

Title: What can solvable Hatsugai-Kohmoto model teach us about Non-Fermi Liquid

Abstract:
Recently, a solvable many-body system called Hatsugai-Kohmoto (HK) model has been intensively studied since it provides exact examples on non-Fermi liquid (NFL) and Mott insulator. In this lecture, we will introduce the general ideas of NFL and its experimental implications. Then, we turn to HK model and discuss its NFL properties, such as thermodynamics, spectrum, response to impurity and external magnetic field. The latter two ones are relevant to Friedel oscillation (FO) and quantum oscillation (QO), which have inspired interesting ideas of fractionalization and Kondo breakdown in cuprate high-Tc superconductor and topological Kondo insulator SmB6. It is found that FO is dominated by the inter-band transition, which is in contrast to the 2kF singularity in Landau’s Fermi liquid (FL). Furthermore, we find QO exists in NFL

of HK model just like the case in FL although its frequency relates to the pseudo-Fermi surface of non-Landau's quasiparticles. These findings highlight the essential role of NFL on physical observables and it may help us to understand generic NFL in strongly correlated electron systems.

About the Speaker:
Yin Zhong is an Associate Professor in Lanzhou University. He graduated in 2016 with a degree in Theoretical Physics from Lanzhou University, under the supervision of Professor Honggang Luo. His primary research interests lie in strongly correlated electron systems and gauge field theory. He utilizes quantum many-body theory methods, particularly field theory, and numerical simulation techniques, such as quantum Monte Carlo, to study theoretical models and novel physical effects related to heavy fermion systems, high-temperature superconductivity, Mott transitions, and quantum critical phenomena. To date, he has published over 30 SCI papers in journals such as Physical Review Letters, Physical Review B, New Journal of Physics, and European Journal of Physics C. In recent years, he has focused on theoretical work related to topological Kondo insulators and the origin of non-Fermi liquid behavior in correlated electron systems. He also has a keen interest in quantum simulations of strongly correlated electron physics and the application of AdS/CFT correspondence in condensed matter physics.

Speaker: Zeng Meng (MPI-PKS)

Tile: Green's function zeros in symmetric mass generation

Abstract:
In recent years, it has been realized that, under certain conditions, critical points and critical phases can be trivially gapped out through symmetry-preserving interactions, a mechanism now called symmetric mass generation (SMG). One interesting feature of SMG is the emergence of Green's function zeros at the fermi level after the original quasiparticles (Green's function poles) are gapped out. In the case of fermi liquid, the fermi surface would be replaced by a Luttinger surface (the surface of zeros) enclosing the same momentum space volume, which implies a generalized Luttinger theorem. A natural question to ask is whether these zeros have any low-energy physical consequences. In this talk, I will partially answer this question in the context of SMG. For systems with onsite interactions, the answer is no, but subtleties could arise for some of the other systems with non-onsite interactions.

About the speaker:
Meng Zeng is a Postdoctoral Fellow at the Max Planck Institute for the Physics of Complex Systems (MPI PKS) in Germany, beginning in 2024. He earned his Ph.D. in Physics from the University of California, San Diego, following a B.S. in Physics (1st Class Honors) with a second major in Pure Mathematics from

Nanyang Technological University (NTU) in Singapore. Meng's research focuses on the non-perturbative aspects of quantum many-body physics, particularly the roles of topology and quantum anomalies. His interests also include unconventional superconductivity, quantum dynamics, and non-equilibrium statistical physics.

Speaker: Xingyu Ma (IOP)

Title: T-linear resistivity and superconductivity in cuprate

Abstract:
The transport property has been the focus of the cuprate superconductors. And recently, an intimate link between the nature of the strange metallic normal-state and superconductivity in the overdoped electron-doped cuprate superconductors is observed and calling for an explanation. Here the intrinsic correlation between the strength of the low-temperature linear in-temperature normal-state resistivity and superconducting transition temperature Tc in the overdoped electron-doped cuprate superconductors is studied within the framework of the kinetic-energydriven superconductivity. On the one hand, the main ingredient is identified into a electron pairing mechanism involving the spin excitation, and then Tc has a dome-like shape doping dependence with the maximal Tc that occurs at around the optimal electron doping. On the other hand, in the normal-state above Tc, the low-temperature linear-in-temperature normal-state resistivity in the overdoped regime arises from the momentum relaxation due to the electron umklapp scattering mediated by the same spin excitation. This same spin excitation that governs both the electron umklapp scattering responsible for the low-temperature linear-in-temperature normal-state resistivity and electron pairing responsible for superconductivity naturally generates a correlation between the strength of the low-temperature linear-in-temperature normal-state resistivity and Tc in the overdoped regime.

About the speaker:
Xingyu Ma received his Ph.D. in 2024 from the School of Physics and Astronomy at Beijing Normal University. He is currently conducting postdoctoral research at the Institute of Physics, Chinese Academy of Sciences. His primary research focuses on the various anomalous transport properties of high-temperature superconductors and the study of various physical properties of electronic states in strongly correlated electron systems.