IPMU Focus Week

Condensed Matter Physics Meets High Energy Physics

Program & Abstracts

Monday, 8th – Friday, 12th February, 2010

IPMU, University of Tokyo

hosted by the Institute for the Physics and Mathematics of the Universe (IPMU),
in cooperation with the Institute for Solid State Physics (ISSP)

Preface

Let us welcome you to the IPMU Focus Week *"Condensed Matter Physics Meets High Energy Physics"*. The interdisciplinary workshop has been organized with the following concept. Beautiful ideas developed by theorists in one area of physics often have unexpected applications in others. Quantum field theory is an outstanding example. As the basic language of both condensed matter physics and high energy physics, it has provided fertile ground for interactions of the two areas of physics, and common techniques using renormalization, symmetry, topology and integrability have been developed. Recently, the AdS/CFT correspondence has opened a new interface between condensed matter physics and quantum gravity. Hence the present workshop brings together the two communities to share ideas, identify common problems and develop new techniques to solve them. We are planning various arrangements to enhance interactions of condensed matter physicists and high energy physicists, including tutorial lectures and ample time for informal exchanges. Topics will include quantum criticality, quantum liquid, topological order, integrable systems, graphene, relativistic and non-relativistic conformal field theories and their holographic descriptions.

The workshop is hosted by the Institute for the Physics and Mathematics of the Universe (IPMU) of the University of Tokyo, in cooperation with the Institute for Solid State Physics (ISSP) of the University of Tokyo. The workshop is the first international conference held at the new IPMU building on the Kashiwa campus of the University of Tokyo.

This booklet contains the program, the abstracts and the questions that will be raised in the panel discussion.

Hideo Aoki*, *Department of Physics, University of Tokyo*,
Hirosi Ooguri*, *Caltech & IPMU, University of Tokyo*,
Masaki Oshikawa, *ISSP, University of Tokyo*,
Shinsei Ryu, *University of California at Berkeley*,
Tadashi Takayanagi, *IPMU, University of Tokyo.*
[Organizers (*: co-chairs)]

Program

Monday, 8th February ============================

Registration 8:45—

Opening

9:15–9:30	Welcome Address: Hirosi Ooguri Opening Remarks: Yasuhiro Iye (Director, ISSP)

Morning Session (chair: Hirosi Ooguri)

Mon-0 **Son, Dam**
9:30–10:30 (Pedagogical Lecture)

10:30–11:00 Coffee Break

Mon-1 **Aoki, Hideo**
11:00–12:00 How can condensed-matter problems interact with field theoretic ideas — an overview

Lunch Break 12:00–14:00

Afternoon Session (chair: Sumit Das)

Mon-2 **Kachru, Shamit**
14:00–15:00 New Horizons in AdS/CFT

15:00–15:30 Coffee Break

Mon-3 **Avishai, Yshai**
15:30–16:00 Electron in the Field of Magnetic Monopole: Tight-Binding Solution

Mon-4 **Yarom, Amos**
16:00–16:30 Large N superfluids

16:30–17:00 Coffee Break

Mon-5 **Read, Nick**
17:00–18:00

Tuesday, 9th February ==============================

Morning Session (chair: Mikio Nakahara)

Tue-0 9:00–10:00	**Wen, Xiao-Gang** Collective modes and topologcal defects in a topological phase – A unification of gauge interaction and Fermi statistics (Pedagogical Lecture)
10:00–10:30	Coffee Break
Tue-1 10:30–11:30	**Fujimoto, Satoshi** Topological Phases of Noncentrosymmetric Superconductors and Superfluids
Tue-2 11:30–12:00	**Nishimura, Jun** Precision test of the gauge/gravity duality from first principles

Lunch Break 12:00–14:00

Afternoon Session (chair: Tadashi Takayanagi)

Tue-3 14:00–15:00	**Hartnoll, Sean**
15:00–15:30	Coffee Break
Tue-4 15:30–16:00	**Nakamura, Shin** Gravity Dual of Spatially Modulated Phase
Tue-5 16:00–16:30	**Hatsugai, Yasuhiro** Correspondence between the bulk quantum states and boundary states in topological phases in condensed matter
16:30–17:00	Coffee Break
Tue-6 17:00–18:00	**Liu, Hong**

Banquet 18:00–

Wednesday, 10th February ==============================

Morning Session (chair: Hideo Aoki)

Wed-1 9:00–10:00	**Zhang, Shoucheng**
10:00–10:30	Coffee Break
10:30–10:35	**Hitoshi fMurayama** (Director, IPMU), Welcome address
10:35–10:45	**George Smoot**, TBA
10:45–11:45	**Panel Discussion** Fradkin, Fujimoto, Hartnoll, Kachru, Kitaev, Liu, Minwalla, Zhang Moderators: Aoki, Ooguri

Lunch Break (11:45–14:00)

Afternoon Session (chair: Akira Furusaki)

Wed-2 14:00–15:00	**Wen, Xiao-Gang** Emergence of gravitons from qbit models
15:00–15:30	Coffee Break
Wed-3 15:30–16:00	**Hashimoto, Koji** Holography and Nuclear Physics
Wed-4 16:00–16:30	**Nomura, Kentaro** Topological delocalization of two-dimensional massless Dirac fermions
16:30–17:00	Coffee Break
Wed-5 17:00–18:00	**Son, Dam** Quantum anomalies in hydrodynamics

Thursday, 11th February ================================

Morning Session (chair: Shinobu Hikami)

Thu-0	**Schomerus, Volker**
9:00–10:00	Superspace Sigma Models (Pedagogical Lecture)
10:00–10:30	Coffee Break
Thu-1	**Minwalla, Shiraz**
10:30–11:30	
Thu-2	**Kiritsis, Elias**
11:30–12:00	On Universality classes in Strongly coupled doped systems

Lunch Break (12:00–14:00)

Afternoon Session (chair: Shinsei Ryu)

Thu-3	**Kitaev, Alexei**
14:00–15:00	Classification of topological insulators and superconductors
15:00–15:30	Coffee Break
Thu-4	**Sato, Masatoshi**
15:30–16:00	Fractionalization and Hidden Symmetry in Topological Orders
Thu-5	**Oka, Takashi**
16:00–16:30	Many-body Schwinger-Landau-Zener Mechanism in Nonequilibrium Strongly Correlated Electron Systems
16:30–18:30	**Poster Session** (with Coffee)

Friday, 12th February =============================

Morning Session (chair: Kenzo Ishikawa)

Fri-0	**Read, Nick**
9:00–10:00	(Pedagogical Lecture)
10:00–10:30	Coffee Break
Fri-1	**Schomerus, Volker**
10:30–11:30	The Supersphere
Fri-2	**Natsuume, Makoto**
11:30–12:00	Critical phenomena in AdS/CFT duality

Lunch Break (12:00–14:00)

Afternoon Session (chair: Masaki Oshikawa)

Fri-3	**Takayanagi, Tadashi**
14:00–15:00	Entanglement Entropy and Topological Insulators from String Theory
15:00–15:30	Coffee Break
Fri-4	**Tanaka, Akihiro**
15:30–16:00	Gauge and gravitational anomalies in graphene-related systems
Fri-5	**Nakayama, Yu**
16:00–16:30	Universal time-dependent deformations of Schrodinger geometry
16:30–17:00	Coffee Break
Fri-5	**Fradkin, Eduardo**
17:00–18:00	Quantum Entanglement and Quantum Criticality
18:00–	**Closing**

Poster Presentations

P01 **Ahmad, Mohammad Ayaz**
Study of short-range correlations in relativistic heavy ion collisions

P02 **Ahn, Hyo Chul**
The quark mass dependence of the nucleon mass in AdS/QCD

P03 **Araki, Yasufumi**
Dynamical Theory of Graphene from Strong Coupling Expansion of U(1) Lattice Gauge Theory with Staggered Fermions

P04 **Bytsko, Andrei**
Non-Hermitian spin chains with real spectra

P05 **Chen, Chiang-Mei**
The RN/CFT correspondence

P06 **Chen, Jiunn-Wei**
Peak-Dip-Hump from Holographic Superconductivity

P07 **Fialkovsky, Ignat**
Quantum field theory as applied to graphene

P08 **Fukui, Takahiro**
Topological stability of Majorana zero-modes in superconductor-topological insulator systems

P09 **Garcia Garcia, Antonio M**
Holographic approach of phase transitions

P10 **Goryo, Jun**
Electromagnetic response in a quantum spin Hall system with electron correlation

P11 **Hasebe, Kazuki**
Supersymmetric Quantum Hall Effect and Quantum Spin Model

P12 **Hayashi, Mitsuo**
Matter production after Inflation in Modular Invariant Supergravity

P13 **Hikami, Shinobu**

On an Airy matrix model with a logarithmic potential

P14 **Hikida, Yasuaki**
The OSP(1|2) WZNW model with and without boundary

P15 **Hong, Deog-Ki**
Critical Phenomena of Holographic Planar Superconductor

P16 **Hotta, Kenji**
Creation of D9-brane–anti-D9-brane Pairs from Hagedorn Transition of Closed Strings

P17 **Ishikawa, Kenzo**
Macroscopic Interferences of Neutrino Waves

P18 **Ichinose, Shoichi**
Casimir Energy of the Universe and the 5D Warped Model

P19 **Kao, Hsien-chung**
Ballistic transport, chiral anomaly and emergence of the electron - hole plasma in graphene

P20 **Keeler, Cynthia**
Deformations of Lifshitz holography

P21 **Kim, Seok**
Supersymmetric vacua of mass-deformed N=6 Chern-Simons theory

P22 **Koroteev, Peter**
Holography and Lorentz Invatiance Violation

P23 **Nakata, Kouki**
Extended Quantum Dimer Model -Mapping by the $S = 1$ algebra

P24 **Lin, Feng-Li**
Holographic Anyons in the ABJM Theory

P25 **Maeda, Kengo**
Vortex lattice for a holographic superconductor

P26 **Maeda, Kenji**

Simulating dense QCD matter with ultracold atomic boson-fermion mixtures

P27 **Matsui, Chihiro**

Correlation functions for higher spin integrable systems

P28 **Meyer, Rene**

Adding Flavor to AdS(4)/CFT(3).

P29 **Morimoto, Takahiro**

Optical Hall conductivity in the graphene quantum Hall system — what happens to a topological number in ac response

P30 **Nishiyama, Seiya**

Supersymmetric sigma-Model Based on the SO(2N+1) Lie Algebra of the Fermion Operators - A way to proper solution -

P31 **Nitta, Muneto**

D-brane in Bose-Einstein Condensates

P32 **Panthi, Rajesh**

Interstellar Bubbles Candidates in the Far Infra-Red Sky

P33 **Reffert, Susanne**

The super Quantum Lifshitz Model from the Nicolai Map

P34 **Satoh, Yuji**

Entanglement through conformal interfaces

P35 **Schmidt-Colinet, Cornelius**

Bulk-boundary flows in the Virasoro minimal models

P36 **Suzuki, Junji**

Density matrix elements at finite temperatures

P37 **Wapler, Matthias**

2-Dimensional Holographic Quantum Liquids

P38 **Yasui, Shigehiro**

Fermion structure of non-Abelian vortex in color superconductivity

P39 **Yavartanoo, Hossein**

Schrodinger invariant solutions of M-theory with Enhanced Supersymmetry

P40 **Li, Wei**

On String Embedding of Lifshitz Fixed Point

Abstracts

Mon-0

(Pedagogical Lecture)

Son, Dam
University of Washington

Mon-1

How can condensed-matter problems interact with field theoretic ideas — an overview

Aoki, Hideo
Department of Physics, University of Tokyo

Various problems and phenomena in condensed-matter physics can accommodate diverse effective field theories on energy scales orders of magnitude smaller than those encountered in high-energy physics. Here I shall give an overview on the following.

(i) Phenomena: superconductivity, magnetism and quantum Hall effect, all of which realize some gauge symmetry breaking. Specifically, unconventional superconductivity (SC) in correlated electron systems accommodate electron mechanisms of SC. Even more exotic superconductors are now being discovered and discussed, among which are T-reversal broken SC, FFLO states, ferromagnetic SC, noncentrosymmetric SC, and multi-band (i.e., multi fermion species) SC (as in the most recent iron-based SC). Fractional quantum Hall system is described in terms of Chern-Simons gauge field in (2+1)D, which accommodates anyons, nonablelions, and also excited states. More generally, topological phases / insulators are an important avenue, with spin-off into, e.g., spin Hall effect.

(ii) Spatial dimensionality: realisable in condensed matter are 0D (quantum dots), 1D (quantum wires, nanotubes), 2D (QHE systems, layered cuprates, and recently atomically 2D graphene). These accommodate, respectively, Tomonaga-Luttinger physics, high-Tc SC, massless Dirac particles, etc.

(iii) Boundary states: bulk and edge states are intimately related (in fact the latter's existence "topologically protected" for topological states), and topological properties become visible through boundary states as in QHE edge states, which become peculiar in graphene.

(iv) Non-equilibrium phenomena accommodate wealth of physics, e.g., dielectric breakdown of a Mott insulator which turn out to be analogous to Schwinger's QED vacuum decay, or responses against T-broken perturbations in graphene.

Mon-2

New Horizons in AdS/CFT

Kachru, Shamit
KITP, University of California, Santa Barbara

The possible symmetry-breaking patterns of ground states in condensed matter systems are reflected in a rich and expanding array of new near-horizon geometries for black branes in AdS space-times. We discuss the physics that some of these horizons reflect in the dual field theory, and tie the genericity of their emergence to the attractor mechanism for black holes in string theory. As a concrete example we will mostly focus on branes with near-horizon Lifshitz symmetry (anisotropic scale invariance), but other examples will be briefly discussed.

Mon-3

Electron in the Field of Magnetic Monopole: Tight-Binding Solution

Avishai, Yshai
Ben Gurion University and University of Tokyo

The Dirac monopole is a central building block in high-energy physics. At the same time, it appears as an important conceptual tool in condensed matter physics (e.g in the study of the fractional quantum Hall effect, or spin ice). In the present work, the problem of an electron on a sphere subject to a central magnetic (monopole) field of strength $g = n(\hbar c)/(2e)$ ($n = 0, 1, 2 \ldots$) is solved within a tight binding model. For highly symmetric lattices, the energy spectrum (Landau levels) is calculated analytically as function of n and displays a beautiful pattern, distinct from the Hofstadter butterfly. The systematics of level degeneracy requires the inclusion of magnetic rotations within the theory of point symmetry groups. A remarkable relation between this problem and that of an electron subject to a central electric field with spin-orbit interaction is exposed. As a result, it is principally possible to study the physics of an experimentally inaccessible system (electron in the field of magnetic monopole) in terms of an experimentally accessible one (electron subject to spin-orbit force induced by central electric field).

Mon-4

Large N superfluids

Yarom, Amos
Princeton University

After reviewing the construction of a superfluid phase of gauge theories with a gravity dual, I will discuss some of its features: its speed of sound and its interaction with a heavy quark. I will argue that, as opposed to superfluid helium, these features indicate that the low lying excitations of the theory behave like massless quasi-particles.

Mon-5

Read, Nick
Yale University

Tue-0

Collective modes and topologcal defects in a topological phase – A unification of gauge interaction and Fermi statistics (Pedagogical Lecture)

Wen, Xiao-Gang
MIT

A topological phase is a phase with long range entanglement. We show that the collective modes in a topological phase can be a U(1) gauge modes. The ends of strings can fermions. The new topological order with long range entanglement can unify gauge interaction and Fermi statistics.

Tue-1

Topological Phases of Noncentrosymmetric Superconductors and Superfluids

Fujimoto, Satoshi
Kyoto University

In this talk, I review the recent studies on topological phases in noncentrosymmetric superconductors (SCs) and superfluids (SFs). Recently, many classes of SCs with broken inversion symmetry in their crystal structures have been experimentally discovered, and are called non-centrosymmetric SCs. In these systems, anti-symmetric spin-orbit interactions due to broken inversion symmetry give rise to various exotic superconducting properties including the realization of topological order.

In particular, the argument here is focused on the Z_2 topological order in the case with time-reversal symmetry, which is characterized by the existence of topologically protected gapless surface states, and the non-Abelian topological order in the case without time-reversal symmetry associated with the level-2 SU(2) Chern-Simons theory, for which the non-Abelian statistics of vortices described by the Ising conformal field theory is realized. The highlight of this subject is that the non-Abelian topological order is possible even for conventional s-wave superconducting states as long as an applied magnetic field is sufficiently large. It is pointed out that the s-wave SC with the anti-symmetric spin-orbit interactions and an applied magnetic field has the same topological order as that of a chiral p+ip-wave SC, which is a well-known system realizing the non-Abelian statistics.

Furthermore, I discuss the possibililty of realizing the non-Abelian topological order in s-wave superfluids of ultracold fermionic atoms with laser-generated fictitious "spin-orbit" interactions. These works have been done by the collaboration with Masatoshi Sato (ISSP, Tokyo) and Yoshiro Takahashi (Kyoto).

References

[1] M. Sato and S. Fujimoto, Phys. Rev. B79, 094504 (2009).

[2] M. Sato, Y. Takahashi, and S. Fujimoto, Phys. Rev. Lett. 103, 020401 (2009).

Tue-2

Precision test of the gauge/gravity duality from first principles

Nishimura, Jun

KEK

As the main theme of this workshop indicates, the concept of the gauge/gravity duality seems to be valid at least qualitatively in quite general systems including those relevant to condensed matter physics. On the other hand, it is poorly understood to what extent the duality actually holds at the quantitative level. I would like to summarize the status of such issues from the viewpoint of first principle calculations in strongly coupled gauge theories based by Monte Carlo methods.

Tue-3

Hartnoll, Sean
Harvard University

Tue-4

Gravity Dual of Spatially Modulated Phase

Nakamura, Shin
Kyoto University

We analyze the stability of the Reissner-Nordstrom black hole in the 5-dimensional Einstein+Maxwell+Chern-Simons theory with a negative cosmological constant. We show that the black hole is unstable if the Chern-Simons (CS) coupling is sufficiently large. The unstable mode is circularly polarized and always carries a non-zero momentum, suggesting a transition into a spatially modulated phase. In the possible CFT-dual picture, this suggests a spontaneous generation of a helical current. We find that the system is barely stable if we employ the CS coupling obtained from the type IIB supergravity. (Reference: arXiv:0911.0679 [hep-th].)

Tue-5

Correspondence between the bulk quantum states and boundary states in topological phases in condensed matter

Hatsugai, Yasuhiro
Institute of Physics, University of Tsukuba

It has been realized that many of important quantum effects are of topological origins in condensed matter physics, especially for quantum ground states with a finite excitation gap. While such gapped ground states can possess nontrivial geometrical phases as characterized by the Berry connection, they may look physically featureless as a bulk. However the topological features often appear as characteristic phenomena near the boundaries or impurities, which are caused by edge states. Thus the edge and the bulk are not independent, but intimately related with each other. We describe this bulk-edge correspondence with several examples that include quantum Hall systems, spin Hall systems, gapped quantum spin chains (ladders) and photonic crystals. Graphene as a condensed matter realization of chiral symmetric massless Dirac fermions in two dimensions are also described by this bulk-edge correspondence.

Tue-6

Liu, Hong
MIT

Wed-1

Zhang, Shoucheng
Stanford University

Wed-2

Emergence of gravitons from qbit models

Wen, Xiao-Gang
MIT

We discuss two qbit models, each support a topological phase with long range entanglement. We show that one phase has collective modes that correspond to gravitons with ommega   k3 dispersion. The other phase (with a less reliability) has collective modes that correspond to gravitons with ommega   k dispersion.

Wed-3

Holography and Nuclear Physics

Hashimoto, Koji
RIKEN

QCD describing quarks and gluons is notoriously known as a strongly coupled gauge theory. AdS/CFT correspondence suggests a way to compute various physical quantities of QCD. I'll report on our computations of nuclear force between nucleons (bound states of quarks). This would be a novel bridge between nuclear physics and particle physics.

Wed-4

Topological delocalization of two-dimensional massless Dirac fermions

Nomura, Kentaro
Tohoku University

It has recently been found that topological insulators exhibit gapless boundary modes which are described by massless Dirac fermions. We study the problem of Anderson localization in two dimensional massless Dirac fermion systems, which correspond to surface states of three dimensional topological insulators. The scaling function of a massless Dirac Hamiltonian subject to a random scalar potential is computed numerically. Although it belongs to, from a symmetry standpoint, the two-dimensional symplectic class, the scaling function of the Dirac model monotonically increases with decreasing conductance, in a sharp contrast to the conventional spin-orbit coupled systems. We also provide an argument based on the spectral flows under twisting boundary conditions, which shows that none of states of the massless Dirac Hamiltonian can be localized. It is also argued that the

half-integer quantized Hall phases survive even in the limit of strong disorder or weak magnetic fields.

[1] K. Nomura, M. Koshino, S. Ryu, Phys. Rev. Lett. 99, 146806 (2007)
[2] K. Nomura, S. Ryu, M. Koshino, C. Mudry, A. Furusaki, Phys. Rev. Lett.
100, 246806 (2008)

Wed-5

Quantum anomalies in hydrodynamics

Son, Dam
University of Washington

We show that when a volume of quark matter rotates, there is an axial current flowing along the rotation axis. This effect has been overlooked in all previous treatments of relativistic fluids until calculations using gauge/gravity duality indicate it existence. The effect is a manifestation of triangle anomalies, and may exhibit itself in heavy ion collisions with nonzero impact parameter.

Thu-0

Superspace Sigma Models (Pedagogical Lecture)

Schomerus, Volker
DESY

2D Sigma models on target superspaces have many applications ranging from disordered system to the AdS/CFT correspondence. For certain coset superspaces G/H, the associated sigma model may give rise to a family of conformal field theories with continuously varying exponents. The solution of such theories is a major challenge that requires developing entirely new methods. In my first lecture I will review some of the motivation for the study of sigma models on coset superspaces G/H before revisiting the theory of a compactified free bosonic field. In this case, the dependence on the compactification radius is well under control. The model is therefore ideally suited to illustrate some of the techniques and results we shall meet again when dealing with non-trivial target superspaces.

Thu-1

Minwalla, Shiraz
Tata Institute

Thu-2

On universality classes in strongly coupled doped systems

Kiritsis, Elias
University of Crete and APC, Paris

Thu-3

Classification of topological insulators and superconductors

Kitaev, Alexei
California Institute of Technology

Gapped free-fermion Hamiltonians have a topological character, witnessed by the robustness of gapless modes on a boundary between two phases. The hopping matrix of a general lattice system (possibly with disorder) can be transformed to a Dirac-type operator in the same universality class, which is characterized using Bott periodicity of Clifford algebras. The classification depends on the spatial dimension and the presence or absence of charge conservation and time-reversal symmetry. In some cases (e.g., integer quantum Hall systems) the difference between phases is stable to interactions, but counterexamples also known.

Thu-4

Fractionalization and Hidden Symmetry in Topological Orders

Sato, Masatoshi
The Institute for Solid State Physics, University of Tokyo

Fractionalization and hidden symmetry in topological orders are discussed. First, for 2+1 dimensional abelian topological orders, I show that flux insertions (or large gauge transformations) pertinent to the toroidal topology induce automorphisms of the braid group, giving rise to a unified algebraic structure that characterizes the ground-state subspace and fractionally charged, anyonic quasiparticles. I also argue topological properties by using this algebra. Then I generalize this argument to the non-abelian gauge theory in 3+1 dimensions, and discuss the relation between quark (de)confinement and topological orders.

Thu-5

Many-body Schwinger-Landau-Zener Mechanism in Nonequilibrium Strongly Correlated Electron Systems

Oka, Takashi
University of Tokyo

The dielectric breakdown may be regarded as a condensed matter realization of the Schwinger mechanism [1] - creation of electron-positron pairs by electric fields - in which the threshold for breakdown is considerably reduced due to a quantum leakage of the wave function. In Mott insulators, a many-body counterpart of this phenomena is shown to take place[2], which is here studied with the quantum tunneling formalism due to Dykhne-Davis-Pechukas as applied to the one-dimensional Hubbard model[3]. We implement this for the quantum tunneling rate with an analytic continuation of the Bethe-ansatz solution for excited states to a non-Hermitian case. This enables us to extend the many-body Landau-Zener picture to the thermodynamic limit, with a remarkable agreement with the time-dependent

density matrix renormalization group result.

[1] J. Schwinger, Phys. Rev. 82, 664 (1951).

[2] T. Oka and H. Aoki, Phys. Rev. Lett. 95, 137601 (2005); T. Oka and H. Aoki in Lecture Notes in Physics 762 (Springer, 2009), p.251.

[3] T. Oka and H. Aoki, arXiv:0903.2707 (Phys. Rev. B, to appear).

Fri-0

(Pedagogical Lecture)

Read, Nick
Yale University

Fri-1

The Supersphere

Schomerus, Volker
DESY

The second lecture is devoted to the study of sigma models whose target space is an odd dimensional supersphere. The main goal is to calculate the spectrum of the model as a function of the sphere's radius. The supersphere can be approached both through analytical techniques in the continuum formulation and through numerical studies of a discrete version. I discuss both approaches and show that their results nicely agree. As an application, I shall present strong evidence for a dual description of the supersphere sigma model. The dual model is a supersymmetric extension of the massless Thirring model. The talk will end with some speculative comments on possible extensions to strings in Anti-deSitter spaces and the duality with gauge theory.

Fri-2

Critical phenomena in AdS/CFT duality

Natsuume, Makoto
KEK

We study black holes with second-order phase transition in string theory (R-charged black

holes and holographic superconductors) and study their static and dynamic critical phenomena. Holographic superconductors have conventional mean-field values for static critical exponents, but R-charged black holes have unconventional ones. For dynamic universality class, holographic superconductors belong to model A and R-charged black holes belong to model B in the classification of Hohenberg and Halperin. Our analysis suggests that some black holes do obey the theory of critical phenomena in condensed matter physics.

Fri-3

Entanglement Entropy and Topological Insulators from String Theory

Takayanagi, Tadashi
IPMU, University of Tokyo

The entanglement entropy has recently been studied by many authors as a useful order parameter in various condensed matter systems, in addition to its importance in quantum information theory. In this talk, I will explain how we can calculate the entanglement entropy in strongly coupled quantum systems obtained by applying the AdS/CFT correspondence. This enables us to calculate this quantum mechanical quantity in terms of classical differential geometry.

In AdS/CFT, such quantum systems are typically obtained from D-branes in string theory. I will also show how the K-theory classification of D-branes is related to the recent ten-fold classification of topological insulators. This talk is mainly based on the collaborations with Shinsei Ryu.

Fri-4

Gauge and gravitational anomalies in graphene-related systems

Tanaka, Akihiro
National Institute for Materials Science

The peculiar chiral structure inherent to the low-energy physics of graphene and the 2+1d pi-flux state have lead to immense activity and a rich interdisciplinary cross-fertilization over the years. Here we explore their further implications, focusing on induced fermion numbers, quantum anomalies, and cross effects in

quantum transport. Among our findings are:

(1) a nontrivial duality among competing orders, each of which correspond to different ways

of breaking the chiral symmetry.

(2) emergent gravitational Chern-Simons/gravitational BF theories in several graphene-related insulators and spin liquids.

The former sheds some new light on the class of quantum critical phemenomena dubbed the deconfined criticality, while the latter bears direct implications to exotic quantum thermal Hall transport properties.

Fri-5

Universal time-dependent deformations of Schrodinger geometry

Nakayama, Yu
UC Berkeley

What is the field theory dual for the simplest Schrodinger invariant geometry? In order to attack the question, I study its exact time-dependent deformations. I present 1) scale invariant but non-conformal deformation, which sounds peculiar(?), 2) conformal invariant but non-scale invariant deformation, which sounds impossible(!), 3) both conformal and scale invariant deformation, which sounds...

All these deformations can be embedded in known supergravity solutions, so they are universal features of the gravity dual of Schrodinger invariant theories. In the course of the discussion, I also find that any time-dependent chemical potential can be exactly treated in the gravity dual approach.

Fri-5

Quantum Entanglement and Quantum Criticality

Fradkin, Eduardo
University of Illinois, Urbana-Champaign

The entanglement entropy of a pure quantum state of a bipartite system is defined as the von Neumann entropy of the reduced density matrix obtained by tracing over one of the two parts. Critical ground states of local Hamiltonians in one dimension have entanglement that diverges logarithmically in the subsystem size, with a universal coefficient that is is related to the central charge of the associated conformal field theory. In this talk I will discuss the extension of these ideas to two dimensional systems, either at a special quantum critical point or in a topological phase. We find the entanglement entropy for a standard class of $z = 2$ quantum critical points in two spatial dimensions with scale invariant ground state wave functions: in addition to a nonuniversal "area law" contribution proportional to the size of the boundary of the region under observation, there is generically a universal logarithmically divergent correction, and in its absence a universal finite piece is found. This logarithmic term is completely determined by the geometry of the partition into subsystems and the central charge of the field theory that describes the equal-time correlations of the critical wavefunction. On the other hand, in a topological phase there is no such logarithmic term but instead a universal constant term. We will discuss the connection between this universal entanglement entropy and the nature of the topological phase.

P01

Study of short-range correlations in relativistic heavy ion collisions

Ahmad, Mohammad Ayaz
The Aligarh Muslim University, Aligarh, India

Fluctuations depend on the properties of the system and may carry significant information about the intervening medium created in the collisions. Underlying dynamics of multiparticle production in relativistic nuclear collisions can be well understood by studying presence of fluctuations in these collisions.

Dynamical fluctuations may arise due to some physical processes taking place in the collisions. As an after effect of the formation of QGP, the multiplicity and pseudorapidity distributions of the secondary particles may show large non-statistical fluctuations in some events. An event-by-event analysis of fluctuations will surely help in separating dynamical and statistical fluctuations. Experimental and theoretical understandings and information are merging together to relate the fluctuations with phase transition of the confined hadronic matter to QGP. The power law behaviour of scaled factorial moments (SFMs) on bin size is known as *intermittency*, which can predict the existence of dynamical fluctuations. Evidence of power law behaviour in experimental data of e+e- annihilation, hadron-hadron, hadron-nucleus and nucleus-nucleus collisions have been found. Thus, intermittency seems to be a general property of multiparticle production. No single mechanism has been found to explain the intermittency.

P02

The quark mass dependence of the nucleon mass in AdS/QCD

Ahn, Hyo Chul
Pusan National University

We study the quark mass dependence of the baryon mass using Bottom- up approach of holographic QCD. We find that nucleon masses are linear to pion mass square and the slope of ground state, Roper state and N(1535) are 0.74 GeV, 0.47 GeV and 0.35 GeV respectively. And We compare our result with Lattice QCD and results of Top-down approach.

P03

Dynamical Theory of Graphene from Strong Coupling Expansion of U(1) Lattice Gauge Theory with Staggered Fermions

Araki, Yasufumi
Dept. of Physics, Univ. of Tokyo

The low-energy effective theory of graphene can be described by the (2+1)-dimensional massless Dirac particles with the fine structure constant enhanced by 300 times due to the small fermi velocity of electrons. We regularize this effective theory in terms of the strong coupling U(1) lattice gauge theory with staggerd fermions which have global chiral symmetry. We carry out analytic calculations of the theory by using the techinique of strong coupling expansion: We found that the mono-layer graphene at strong coupling shows exciton condensation due to similar mechanism as the dynamical breaking of chiral symmetry in gauge theories.

We derive the magnitude of the condensation together with the mass-gap of fermions and collective excitons up to the next-to-leading order of the strong coupling expansion. A new formula for the mass of pseudo Nambu-Goldstone exiton is derived, which is analogous to the Gell-Mann-Oakes-Renner relation in quantum choromodynamics (QCD).

P04

Non-Hermitian spin chains with real spectra

Bytsko, Andrei
Steklov Mathematics Institute, St.Petersburg

An open spin chain with quantum group symmetry is an example of a quantum mechanical system that has a non-Hermitian Hamiltonian but yet its spectrum can be real. A class of such models will be discussed from the point of view of the theory of quasi-Hermitian operators.

P05

The RN/CFT correspondence

Chen, Chiang-Mei
Department of Physics, National Central University, Taiwan

We considered the quantum gravity description of the near extremal extremal Reissner-Nordstrom (RN) black hole in the viewpoint of the AdS/CFT correspondence. We show that the absorption rate of a scalar filed in RN background matches the two-point function of CFT which supports the RN/CFT correspondence.

P06

Peak-Dip-Hump from Holographic Superconductivity

Chen, Jiunn-Wei
National Taiwan University

We study the fermionic spectral function in a holographic superconductor model. At zero temperature, the black hole has zero horizon and hence the entropy of the system is zero after the back reaction of the condensate is taken into account. We find the system exhibits the famous peak-dip-hump lineshape with a sharp low-energy peak followed by a dip then a hump at higher energies. This feature is widely observed in the spectrum of several high-T_c superconductors. We also find a linear relation between the gap in the fermionic spectrum and the condensate, indicating the condensate is formed by fermion pairing.

P07

Quantum field theory as applied to graphene

Fialkovsky, Ignat
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and Instituto de Fisica da Universidade de Sao Paulo

The low-energy quasi-particles in graphene are known to be described as Dirac fermions in 2+1 dimensions. This model possesses a rigorous quantum field theoretical treatment, and adopting this approach we investigate the interaction of quasi-particles in graphene with quantum and classical electromagnetic field.

We show that the presence of parity-odd terms in the polarization tensor of Dirac quasi-particles (i.e. in the conductivity tensor) leads to rotation of polarization of the electromagnetic waves passing through suspended graphene films. Parity-odd Chern-Simons type contributions appear in external magnetic field, giving rise to a quantum Faraday effect, though other sources of parity-odd effects may also be discussed. The estimated order of the effect is well above the sensitivity limits of modern optical instruments. The possible quantization of the effect is discussed.

We also present a calculation of the Casimir energy between a suspended graphene film and a parallel plane perfect conductor, using two different approaches. First, we use the QFT approach and evaluate the leading order diagram in a theory with 2+1 dimensional fermions interacting with 3+1 dimensional photons. Next, we consider an effective theory for the electromagnetic field with matching conditions induced by quantum quasi-particles in graphene. The two approaches turn out to be the complementary. The Casimir interaction itself appears to be rather weak but potentially measurable. It exhibits strong dependence on the mass of the graphene quasi-particles.

P08

Topological stability of Majorana zero-modes in superconductor-topological insulator systems

Fukui, Takahiro
Ibaraki University

We derive an index theorem for zero-energy Majorana fermion modes in a superconductor-topological insulator system in both two and three dimensions, which is valid for models with chiral symmetry as well as particle-hole symmetry. For more generic models without chiral symmetry, we suggest that Majorana zero-modes are classified by Z_2.

P09

Holographic approach of phase transitions

Garcia Garcia, Antonio M
University of Lisboa, Portugal

We provide a description of phase transitions at finite temperature in strongly coupled field theories using holography. For this purpose, we introduce a general class of gravity duals to superconducting theories that exhibit various types of phase transitions (first or second order with both mean and non-mean field behavior) as parameters in their Lagrangian are changed. Moreover the size and strength of the conductivity coherence peak can also be controlled. Our results suggest that certain parameters in the gravitational dual control the

interactions responsible for binding the condensate and the magnitude of its fluctuations close to the transition.

In collaboration with: Sebastian Franco (Santa Barbara), Diego Rodriguez-Gomez (Queen Mary, London)

Reference: arXiv:0911.1354

P10

Electromagnetic response in a quantum spin Hall system with electron correlation

Goryo, Jun
Institute for Industrial Science, the University of Tokyo

Kane-Mele model for Graphene shows the quantum spin Hall effect. We investigate this model with the electron correlation, i.e., on-site Coulomb coupling. This interaction can be expressed to introduce an auxiliary field coupled to the electron spin (s_x, s_y, s_z). Electromagnetic response of the system can be derived to integrate out Fermions and the auxiliary field.

We find that, in the strong coupling limit, the system becomes superconducting when s_z is conserved, and becomes insulating when s_z-conservation is broken by the Rashba term. In our discussions, BF-term plays an important role.

P11

Supersymmetric Quantum Hall Effect and Quantum Spin Model

Hasebe, Kazuki
Kagawa National College of Technology

We present a supersymmetric model of the quantum Hall effect and quantum spin model (AKLT model). We derive a supersymmetric Laughlin wavefunction and a supersymmetric valence bond state. The supersymmetric wavefunction realizes known quantum Hall states such as Laughlin, Moore-Read states in extremal limits. We discuss several properties peculiar to the supersymmetric states.

This work was in collaboration with Y. Kimura, D.P. Arovas, XL Qi, SC Zhang, and K. Totsuka.

P12

Matter production after Inflation in Modular Invariant Supergravity

Hayashi, Mitsuo
Dept. of Physics, Tokai University

P13

On an Airy matrix model with a logarithmic potential

Hikami, Shinobu
Dept. of Basic Sciences, University of Tokyo

The Airy matrix model with a logarithmic potential, the so called Kontsevich-Penner model, is derived from a Gaussian two-matrix model though a duality. Using the Virasoro constraints, we find that in addition to the parameter t_n, which appears in the KdV hierarchies, one needs to introduce half-integer indices $t_{n/2}$ to characterize the model.The free energy as a function of those parameters may be obtained from the Virasoro constraints. One finds the large N limit by solving an integral equation. The Kontsevich-Penner model, in its dual version, can be handled explicitly through the Fourier transform of n-point correlation function, from which one deduces values for topological invariants.

(In collaboration with E. Brezin, LPT, Ecole Normale Superieure.)

P14

The OSP($1|2$) WZNW model with and without boundary

Hikida, Yasuaki
Keio University

We study the WZNW model associated with a supergroup OSP(1|2). Correlation functions can be obtained by making use of a relation to $N = 1$ super Liouville field theory. Moreover, branes in the OSP(1|2) model are constructed by solving constraints coming from world-sheet duality.

P15

Critical Phenomena of Holographic Planar Superconductor

Hong, Deog-Ki
Pusan National University

We have studied the critical behavior of strongly interacting planar superconductors in the framework of gauge/string duality. We found the interesting relations among the critical exponents of soft modes of strongly interacting planar superconductors.

P16

Creation of D9-brane–anti-D9-brane Pairs from Hagedorn Transition of Closed Strings

Hotta, Kenji
Hokkaido University

It is well known that one-loop free energy of closed strings diverges above the Hagedorn temperature. One explanation for this divergence is that a ‘winding mode’ in the Euclidean time direction becomes tachyonic above the Hagedorn temperature. The Hagedorn transition of closed strings has been proposed as a phase transition via condensation of this winding tachyon. But we have not known the stable minimum of the potential of this winding tachyon so far. On the other hand, we have previously calculated the finite temperature effective potential of open strings on D-brane–anti-D-brane pairs, and shown that a phase transition occurs near the Hagedorn temperature and D9-brane–anti-D9-brane pairs become stable. In this paper, we present a conjecture that *D9-brane–anti-D9-brane pairs are created by the Hagedorn transition of closed strings*, and describe some circumstantial evidences.

We show that two types of the amplitude of open strings in the closed string vacuum limit at the Hagedorn temperature approaches to those of closed strings with winding tachyon insertion near the Hagedorn temperature. We also show that the potential energy at the open string vacuum decreases limitlessly as the temperature approaches to the Hagedorn temperature. It is natural to think that the open string vacuum becomes the global minimum near the Hagedorn temperature.

P17

Macroscopic Interferences of Neutrino Waves

Ishikawa, Kenzo
Hokkaido University

I report our work on neutrino coherence and new macroscopic interferences of neutrino waves. It is shown that interferences depend on the masses and coherence lengths of the neutrino. Implications for high energy baseline experiments and low energy flavour oscillation using reactor neutrino are considered.

P18

Casimir Energy of the Universe and the 5D Warped Model

Ichinose, Shoichi
University of Shizuoka

Casimir energy is obtained in the 5D warped model. The warp parameter is properly renormalized. Regarding Casimir energy as the main contribution of the cosmological constant, we show its renormalization behavior. This is a solution to the cosmological problem.

Related reference: ArXiv:1001.0222 [hep-th]

P19

Ballistic transport, chiral anomaly and emergence of the electron - hole plasma in graphene

Kao, Hsien-chung
National Taiwan Normal University

The process of coherent creation of particle - hole excitations by an electric field in graphene is quantitatively described using a dynamic "first quantized" approach. We calculate the evolution of current density, number of pairs and energy in ballistic regime using the tight binding model. The series in electric field strength E up to third order in both DC and AC are calculated. We show how the physics far from the two Dirac points enters various physical quantities in linear response and how it is related to the chiral anomaly. The third harmonic generation and the imaginary part of conductivity are obtained. It is shown that at certain time scale t_{nl} $E^{-1/2}$ the physical behaviour dramatically changes and the perturbation theory breaks down. Beyond the linear response physics is explored using an exact solution of the first quantized equations. While for small electric fields the I-V curve is linear characterized by the universal minimal resistivity, at $t > t_{nl}$ the conductivity grows fast. The copious pair creation (with rate $E^{3/2}$), analogous to Schwinger's electron - positron pair creation from vacuum in QED, leads to creation of the electron - hole plasma at ballistic times of order t_{nl}. This process is terminated by a relaxational recombination.

P20

Deformations of Lifshitz holography

Keeler, Cynthia
Harvard University

The simplest gravity duals for quantum critical theories with $z = 2$ 'Lifshitz' scale invariance admit a marginally relevant deformation. Generic black holes in the bulk describe the field theory with a dynamically generated momentum scale Λ as well as finite temperature T. We describe the thermodynamics of these black holes in the quantum critical regime where $T \gg \Lambda^2$. The deformation changes the asymptotics of the spacetime mildly and leads to intricate UV sensitivities of the theory which we control perturbatively in Λ^2/T.

P21

Supersymmetric vacua of mass-deformed N=6 Chern-Simons theory

Kim, Seok
Seoul National University

P22

Holography and Lorentz Invatiance Violation

Koroteev, Peter
University of Minnesota

Recently a family of solutions of Einstein equations in backgrounds with broken Lorentz invariance was found ArXiv:0712.1136. We show that the gravitational solution recently obtained by Kachru, Liu and Mulligan in ArXiv:0808.1725 is a part of the former solution which was derived earlier in the framework of extra dimensional theories. We show how the energy-momentum and Einstein tensors are related and establish a correspondence between parameters which govern Lorentz invariance violation. Then we demonstrate that scaling behavior of two point correlation functions of local operators in scalar field theory is reproduced correctly for two cases with critical values of scaling parameters. Therefore, we complete the dictionary of "tree-level" duality for all known solutions of the bulk theory. In the end we speculate on relations between RG flow of a boundary theory and asymptotic behavior of gravitational solutions in the bulk.

P23

Extended Quantum Dimer Model -Mapping by the $S = 1$ algebra

Nakata, Kouki
Kyoto University YITP(Yukawa Institute for Theoretical Physics)

Since P.W.Anderson's 1973 paper[1], the search for a resonating valence bond(RVB) states has been one of the recurrent theme in research on frustrated antiferromagnets. Quantum Dimer Model(QDM) proposed by Rokhsar and Kivelson in 1988 [2] exhibits crystalline order and confined spinons on the square lattice,except at RK-point. On the point,a short-ranged RVB state is realized.

Recently Moessner and Sondhi have revealed that there is a truly short-ranged RVB phase for a finite range of parameters on the triangular lattice[3]. What is more, they have noticed that Ising gauge physics is exactly the physics of the short-ranged RVB and have mapped the QDM to an Ising gauge theory[4].

Refering to these research,we propose Extended QDM(EQDM).This model is defined by the S=1 algebra and we have succeeded in deriving a S=1 spin Hamiltonian which is completely consistent with EQDM.Furthermore,this model exhibits the phase transitions(e.g.from columnar to herringbone) pointed out by Papanikolaou et al. [5] as well as the usual QDM transitions.

We now detecting a spin liquid region of EQDM.

[1]P.W.Anderson,Mater.Res.Bull.8,153(1973); Science235,1196(1987)
[2]D.S.Rokhsar and S.A.Kivelson,Phys.Rev.Lett.61,2376(1988)
[3]R.Moessner and S.L.Sondhi,Phys.Rev.Lett.86,1881(2001)
[4]R.Moessner and S.L.Sondhi,Phys.Rev.B.65,024504(2001)
[5]S.Papanikolaou,K.S.Raman,and E.Fradkin,Phys.Rev.B.75,094406(2007)

P24

Holographic Anyons in the ABJM Theory

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We consider the holographic anyons in the ABJM theory from three different aspects of AdS/CFT correspondence. First, we identify the holographic anyons by using the field equations of supergravity, including the Chern-Simons terms coupled to the probe branes. We find that the composite of Dp-branes wrapped over CP3 with the worldvolume magnetic fields can be the anyons. Next, we discuss the possible candidates of the dual anyonic operators on the CFT side, and find the agreement of their anyonic phases with the supergravity analysis. Finally, we try to construct the brane profile for the holographic anyons by solving the equations of motion and Killing spinor equations for the embedding profile of the wrapped branes. As a by product, we find a BPS spiky brane for the dual baryons in the ABJM theory.

P25

Vortex lattice for a holographic superconductor

Maeda, Kengo
Shibaura Institute of Technology

We investigate the vortex lattice solution in a (2+1)-dimensional holographic model of superconductors constructed from a charged scalar condensate. The solution is obtained perturbatively near the second-order phase transition and is a holographic realization of the Abrikosov lattice. Below a critical value of magnetic field, the solution has a lower free energy than the normal state. Both the free energy density and the superconducting current are expressed by nonlocal functions, but they reduce to the expressions in the Ginzburg-Landau (GL) theory at long wavelength. As a result, a triangular lattice becomes the most favorable solution thermodynamically as in the GL theory of type II superconductors.

P26

Simulating dense QCD matter with ultracold atomic boson-fermion mixtures

Maeda, Kenji
University of Tokyo

We delineate, as an analog of two-flavor dense quark matter, the phase structure of a many-body mixture of atomic bosons and fermions in two internal states with a tunable boson-fermion attraction. The bosons b correspond to diquarks, and the fermions f to unpaired quarks. For weak b-f attraction, the system is a mixture of a Bose-Einstein condensate and degenerate fermions, while for strong attraction composite b-f fermions N, analogs of the nucleon, are formed, which are superfluid due to the N-N attraction in the spin-singlet channel. We determine the symmetry breaking patterns at finite temperature as a function of the b-f coupling strength, and relate the phase diagram to that of dense QCD.

P27

Correlation functions for higher spin integrable systems

Matsui, Chihiro
Department of Physics, The University of Tokyo

Various integrable systems, which belong to Uq(sl2)-symmetry, such as the sine (sinh)-Gordon model and the XXZ model, have been studied. Calculation of correlation functions of them is one of the most interesting topics in study of integrable systems.

The biggest problem in computation of correlation functions via the Bethe ansatz is how to deal with sums which arise as a result of commutation relations among the monodromy matrix elements. The induction method in respect to the total spin of a system and change of basis are well-known methods to resolve this problem.

We derived multi-integral expressions of correlation functions for higher spin integrable systems. Furthermore, it was showed that the number of terms in sums appeared in correlation functions of higher spin integrable systems are reduced to that of spin 1/2 integrable systems by considering actions of the Uq(sl2) algebra on irreducible subspaces in multiple tensor products.

P28

Adding Flavor to AdS(4)/CFT(3)

Meyer, Rene
University of Crete, Heraklion, Crete, Greece

In this talk I present results of a recent attempt to introduce quenced fundamental (quark-like) degrees of freedom into the N=6 supersymmetric Chern-Simons-Matter theory put forward by Aharony, Bergman, Jafferis and Maldacena (ABJM). The additional fields are introduced by means of probe branes embedded in the dual AdS4xCP3 geometry. I discuss several intersections, space-filling and defect-like, which might also be of interest for holograpic descriptions of condensed matter systems.

P29

Optical Hall conductivity in the graphene quantum Hall system — what happens to a topological number in ac response

Morimoto, Takahiro

University of Tokyo

The quantum Hall effect represents a topological number, which is because the (dc) Hall conductivity, expressed as a current-current correlation function, coincides with a Berry's curvature so that the Hall conductivity becomes the Chern number of a U(1) bundle over the Brillouin zone spanned as a 2-dimensional torus.We can then pose an intriguing question: what will happen to the topological number if we go over to ac response, i.e., the optical Hall conductivity, $\sigma_{xy}(\omega)$.

Although one might at first expect the quantum Hall behavior be washed out in ac, we have revealed that the series of steps (plateaus) in the Hall conductivity against the Fermi energy is unexpectedly retained in the optical Hall conductivity even in the THz regime, for both the ordinary two-dimensional electron gas and the massless Dirac model of graphene in strong magnetic fields. While the plateau height in ac deviates from the quantized values, the effect is indeed robust against significant strengths of disorder, which we attribute to an effect of Anderson localization. Specifically, an important source of disorder in actual graphene (single atomic layer of carbon atoms in the form of a honeycomb lattice) is known to be ripples (corrugation of the atomic plane), which effectively acts as a random gauge field. Owing to Atiyah-Singer's theorem which ensures protected chiral zero modes, the Landau level that resides at the Dirac point (electron-hole symmetric point) remains delta-function like, because a random gauge field respects the chiral symmetry. We have shown that the protection is inherited by the ac response as an anomalously sharp step structure in the optical Hall conductivity.

P30

Supersymmetric sigma-Model Based on the SO(2N+1) Lie Algebra of the Fermion Operators - A way to proper solution -

Nishiyama, Seiya

Centro de Fisica Computacional, Departamento de Fisica, Universidade de Coimbra

The extended supersymmetric sigma-model is proposed on the bases of SO(2N+1) Lie algebra spanned by fermion annihilation-creation operators and pair operators. The canonical transformation, extension of an SO(2N) Bogoliubov transformation to an SO(2N+1) group, is introduced. To construct consistent anomaly-free supersymmetric coset models, we must embed an SO(2N+1) group into an SO(2N+2) group and use SO(2N+2)/U(N+1) coset variables on the Kaehler manifold. We adopt a coset coordinate in an anomaly-free spinor representation of SO(2N+2) group and give a corresponding Kaehler potential and a Killing potential for an anomaly-free SO(2N+2)/U(N+1) model based on each positive chiral spinor representation. Then we have a f-deformed reduced scalar potential. It is minimized with respect to the VEV of anomaly-free supersymmetric sigma-model fields. Thus we find an interesting f-deformed proper solution for an anomaly-free SO(12)/SU(6)XU(1) supersymmetric sigma-model.

P31

D-brane in Bose-Einstein Condensates

Nitta, Muneto
Keio University

We show that wall-vortex composite solitons, analogues of D-brane in string theory, can be realized in rotating phase-separated two-component Bose-Einstein condensates and they are experimentally observable. The structure is analyzed by the generalized nonlinear sigma model for the pseudospin of this system. The wall-vortex junction has a characteristic spin texture and a negative monopole charge density, which can be identified as a point defect at interface, called boojum.

P32

Interstellar Bubbles Candidates in the Far Infra-Red Sky

Panthi, Rajesh
Tribhuvan University

I present the results of numerical simulations for the first 104 years of the development of spherically symmetric interstellar bubble formed by the Asymptotic Giant Branch (AGB) wind. Assuming three phase interstellar medium (ISM) model we estimate the size of the interstellar bubbles. Our result will be based on 106 virtual stellar wind particles and discussed in the context of early and late AGB star. In addition to the numerical simulations, we systematically searched the bubble like structure in the IRASS (Infrared Astronomical Satellite Survey) and measured their sizes. A comparison between the results of the numerical simulations and the observations is discussed. It is found that the size of the interstellar bubble lie in the range 1.48 pc to 39.20 pc if the stellar wind speed is 15 km/s (early AGB wind). The size of the bubble ranges 2.82 pc to 74.64 pc if the stellar wind speed goes to 75 km/s (i.e., late AGB phase).

The cold ISM forms small-sized bubble whereas the hot ISM produces large-sized bubble. However the stability of cold interstellar bubble is higher than that of the hot interstellar medium. As a preliminarily investigation we propose 8 interstellar bubble candidates, probably shaped by the White Dwarf and the Pulsar. The first four candidates are relatively small-sized

(major diameter ¡ 0.88 pc) because of the low speed stellar wind emitted during the evolution of White Dwarfs. The last four bubble candidates are intermediate sized, probably shaped by the relativistic wind of the Pulsar. The emission feature of the outer shocked region should be studied in the future in order to justify the nature of the interstellar bubble.

P33

The super Quantum Lifshitz Model from the Nicolai Map

Reffert, Susanne
IPMU

In this talk, I will describe a method based on the Nicolai map of stochastic quantization to generate non-Lorentz invariant quantum field theories. This method gives rise to non-Lorentz invariant field theories such as the quantum Lifshitz model and Horava-Lifshitz gravity. This formalism is easy to use in concrete calculations. I will illustrate this by deriving the Feynman rules for an interacting version super quantum Lifshitz model.

P34

Entanglement through conformal interfaces

Satoh, Yuji
University of Tsukuba

We consider entanglement through permeable interfaces in the c=1 (1+1)-dimensional conformal field theory. We compute the partition functions with the interfaces inserted. By the replica trick, the entanglement entropy is obtained analytically. The entropy scales logarithmically with respect to the size of the system, similarly to the universal scaling of the ordinary entanglement entropy in (1+1)-dimensional conformal field theory. Its coefficient, however, is not constant but controlled by the permeability, the dependence on which is expressed through the dilogarithm function. The sub-leading term of the entropy counts the winding numbers, showing an analogy to the topological entanglement entropy which characterizes the topological order in (2+1)-dimensional systems.

P35

Bulk-boundary flows in the Virasoro minimal models

Schmidt-Colinet, Cornelius
IPMU

We consider the behaviour of boundary conditions under the least-relevant bulk perturbation for the Virasoro minimal models. Combining perturbative RG techniques, insights from defects, and results from non-perturbative boundary flows, we determine the boundary condition at the infrared fixed point.

P36

Density matrix elements at finite temperatures

Suzuki, Junji
Shizuoka University

Exact evaluation of density matrix elements of spin chains at finite temperature will be discussed in view of the quantum information.

P37

2-Dimensional Holographic Quantum Liquids

Wapler, Matthias
CQUeST, Sogang University

We study the low-temperature limit of holographic fundamental matter in a 2+1 dimensional defect setup at fixed mass and finite baryon number density. This defect case is special, as we find novel non-trivial temperature independent scaling solutions for the probe-brane embeddings as opposed to e.g. the usual "narrow funnel" low-temperature limit. By studying the thermodynamics, we observe a quantum liquid with density-dependent ground-state degeneracy and energy, and suppressed heat capacity.

P38

Fermion structure of non-Abelian vortex in color superconductivity

Yasui, Shigehiro
KEK

We study the internal fermionic structure of a non-Abelian vortex in color superconductivity

by using the Bogoliubov-de Gennes (B-dG) equation. The non-Abelian vortices appear in the Color-Flavor-Locked phase associated with the symmetry breaking pattern $\mathrm{SU}(3)_{c+L+R} \rightarrow \mathrm{SU}(2)_{c+L+R}\times\, \mathrm{U}(1)_{c+L+R}$. We analyze quark spectrum in the B-dG equation by treating the diquark gap having the vortex configuration as a background field. We find that there are zero energy states (zero modes) inside the vortex, and that triplet and singlet zero modes form a multiplet of the unbroken symmetry. We also discuss the low energy effective theory of fermion zero modes in 1+1 dimensions.

P39

Schrodinger invariant solutions of M-theory with Enhanced Supersymmetry

Yavartanoo, Hossein
Korea institute for advanced study

We find the most general solution of 11-dimensional supergravity compatible with $N = 2$ super-Schrodinger symmetry with six supercharges and $\mathrm{SU}(2) \times \mathrm{SU}(2) \times \mathrm{U}(1) \times \mathrm{Z}_2$ global symmetry. It can be viewed as a one-parameter extension of a recently constructed solution by Ooguri and Park. Our original motivation was to find the gravity dual of the non-relativistic ABJM theory. But, our analysis shows that no such solution exists within the reach of our assumptions. We discuss possible reasons for the non-existence of the desired solution. We also uplift a super-Schrodinger solution in IIB supergravity of Donos and Gauntlett to 11-dimension and comment on its properties.

P40

On String Embedding of Lifshitz Fixed Point

Li, Wei
IPMU, Tokyo University

The aim of this work is to find the string theory dual of the Lifshitz fixed point.

We construct a 5D gravitational Lifshitz solution, albeit with non-constant dilaton, in a D3-D7 system. To cure the problem of a diverging dilaton at the boundary, we further find a solution interpolating between the Lifshitz geometry in IR and AdS5 in UV. On the field theory side, this interpolating solution corresponds to an anisotropic RG flow between the N=4 SYM and the Lifshitz theory. We also present some no-go theorems against the embedding of 4D (constant-dilaton) Lifshitz solution in various string compactifications.

[1] arXiv: 0905.0688 (with T. Azeyanagi and T. Takayanagi).

[2] arXiv: 0908.0363 (with T. Nishioka and T. Takayanagi).

Panel discussion

■Panelists: E. Fradkin, S. Fujimoto, S. Hartnoll, S. Kachru, A. Kitaev, H. Liu, S. Minwalla, and S. C. Zhang

■Moderators: H. Aoki and H. Ooguri

■Proposed questions:

1. Can we perform a test of the AdS/CFT correspondence in condensed matter or atomic physics laboratories?
2. Can string theory give new insights on integrable lattice models or field theories, or can it give something beyond the Bethe ansatz solvability?
3. What is a (conformal) field theory describing the plateau transition of the 2d quantum Hall effect?
4. What are ground states of strongly correlated lattice models, such as the 2d Hubbard model, the $S = 1/2$ Heisenberg model on the Kagome lattice?
5. Is there a metal-insulator transition in (2+1)-dimensional electron systems in the presence of both interactions and disorder?
6. Can we describe strongly correlated systems out of equilibrium?
7. Can we solve the critical theory of the 3d Ising model?
8. Can we classify fixed point Hamiltonians including topological phases?
9. Can we find new classes of non-perturbative phenomena/treatments?
10. Will non-abelian statistics arise in condensed-matter physics beyond the fractional quantum Hall systems?
11. How can we expand the NG approach in systems with more than one gauge symmetries are spontaneously broken, where condensed matter examples are multiband superconductors/cold atoms, ferromagnetic superconductors, etc.
12. Are there the strong-coupling theories/treatments developed in the condensed-matter physics applicable to HEP?
13. Can you provide a useful definition of a "Mott insulator" in terms of continuum field theoretic calculables, as opposed to in terms of dynamics of an underlying lattice model (c.f. the Hubbard model with strong repulsive interactions at half-filling)? In particular, how would theorists working with gravity duals or with an abstract formalism that calculates correlation functions in a quantum field theory, be able to characterize a Mott insulator as opposed to a band-theoretic insulator? (Kachru)
14. What is a useful definition of a glass phase? Are there aspects of the glass transition (e.g. divergence in viscosity) that might be amenable to a gravity treatment, or that in any case remain mysterious from existing theoretical models? (Kachru)
15. Are there simple examples of quantum critical points where the scaling dimensions of a significant number of scaling operators are known from experiment? If so, which examples? (Kachru)

16. Are there places in condensed matter or atomic/molecular/optical physics where adjoint-like large N gauge theories may be reasonable models of underlying phenomena? If not, is there a serious possibility of (and interest in) engineering such systems using optical lattices? (Kachru)
17. What is known, within controlled computations, about disordered strongly interacting systems in 2+1 dimensions? Are there 'localisation' transitions? Can AdS/CFT help here? (Hartnoll)
18. To what extent is the 'strange metal' region of the heavy fermion compounds theoretically understood? Various non-controlled computations (Hertz-Millis etc.) seem to reproduce some scalings, but I have received conflicting statements from the cond-mat community about the extent to which comparing these computations with data is meaningful. Can AdS/CFT help here? (Hartnoll)
19. To what extent does the 'strange metal' region of the cuprates or of the heavy fermions have well-define quasiparticles excitations? (Hartnoll)
20. Some intersecting D-brane systems at finite density have a Fermi surface at weak coupling. Is there any trace of these Fermi surfaces in the strongly coupled gravitational dual? (Hartnoll)
21. Is the Z_k parafermion CFT (or Wess-Zumino-Witten CFT) a unique field theory which describes non-Abelian anyons? (Fujimoto)
22. Is there a deep theoretical structure associated with the minus sign problem with quantum Monte Carlo simulation? (Zhang)
23. Can we learn about axions, theta vacuum and strong CP problem from topological insulators? (Zhang)
24. What are the promising probes of Majorana fermions in cond mat and high energy? (Zhang)