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The Hong Kong University of Science and Technology

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Contents

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Program Schedule

Venue: Padma and Hari Harilela Lecture Theater (LT - C), HKUST *[except where indicated]*

14 December 2012 (Friday)		
Time	*Event*	*Presenter*
8:30 – 9:00	Registration	
9:00 – 9:10	Welcome Remarks	
9:10 – 9:45	Talk #1: "Magnetic Response in the Underdoped Cuprates"	Maurice Rice *[ETH Zürich]*
9:45 – 10:20	Talk #2: "Topological Insulator, Quantum Spin Hall and Quantum Anomalous Hall Effects"	Shoucheng Zhang *[Stanford University]*
10:20 – 10:55	Talk #3: "Interface Induced High Temperature Superconductivity in Single Unit-cell FeSe Films"	Qikun Xue *[Tsinghua University]*
10:55 – 11:15	Refreshments/Group Photo	
11:15 – 11:50	Talk #4: "A Symmetry Protected Topological Insulator of Bosons in 3d via Dyon Condensation and the 'Statistical Witten Effect'"	Matthew Fisher *[University of California, Santa Barbara]*
11:50 – 12:25	Talk #5: "Realizing the Pfaffian Quantum Hall State with Cold Atom Magic"	Tin-Lun (Jason) Ho *[Ohio State University and HKUST Institute for Advanced Study]*
12:25 – 14:00	Lunch at China Garden Restaurant (for registered participants only)	
14:00 – 14:35	Talk #6: "Spin Seebeck Effect in a Variety of Magnetic Systems"	Sadamichi Maekawa *[Japan Atomic Energy Agency]*
14:35 – 15:10	Talk #7: "Topological Insulators of Bosons"	Senthil Todadri *[Massachusetts Institute of Technology]*
15:10 – 15:45	Talk #8: "ARPES on Electronic Structure and Superconducting Gap of $A_xFe_{2-y}Se_2$ (A=K, Tl, Rb) and Single-layer FeSe/$SrTiO_3$ Superconductors"	Xingjiang Zhou *[Institute of Physics, Chinese Academy of Sciences]*
15:45 – 16:05	Refreshments	
16:05 – 16:40	Talk #9: "Orbital Chirality in Non-magnetic and Magnetic Bands and Its Implications"	Jung Hoon Han *[Sungkyunkwan University]*
16:40 – 17:15	Talk #10: "Spintronics using Topological Insulators and Triplet Superconductors"	Takehito Yokoyama *[Tokyo Institute of Technology]*

15 December 2012 (Saturday)		
Time	*Event*	*Presenter*
9:00 – 9:35	Talk #11: "Highly Entangled Quantum Matter: A New Chapter in Condensed Matter Physics"	Xiao-Gang Wen *[Massachusetts Institute of Technology]*
9:35 – 10:10	Talk #12: "Excitation Spectra of 2D Massless Dirac Fermion Systems: Graphene and Topological Insulators"	Steven G. Louie *[Lawrence Berkeley National Laboratory, University of California, Berkeley and HKUST Institute for Advanced Study]*
10:10 – 10:45	Talk #13: "Recent Advancement in β–$FeSe_{1-x}$ and Related Superconductors"	Maw-Kuen Wu *[Academia Sinica]*
10:45 – 11:15	Refreshments	
11:15 – 11:50	Talk #14: "Topological Protection of Bound States against the Hybridization"	Naoto Nagaosa *[The University of Tokyo]*
11:50 – 12:25	Talk #15: "Bi(111) Thin Film with Insulating Interior but Metallic Surfaces"	Xiaofeng Jin *[Fudan University]*
12:25 – 14:00	Lunch at China Garden Restaurant (for registered participants only)	
14:00 – 14:35	Talk #16: "Dynamical Generation of Spin Currents"	Eiji Saitoh *[Tohoku University]*
14:35 – 15:10	Talk #17: "Impurity-induced Bound States in Topological Insulators and Superconductors"	Shun-Qing Shen *[The University of Hong Kong]*
15:10 – 15:45	Talk #18: "Symmetry Protected Topological Phases and Quantum Critical Phases in One-dimensional Quantum Spin Chains"	Guang-Ming Zhang *[Tsinghua University]*
15:45 – 16:05	Refreshments	
16:05 – 16:40	Talk #19: "Anomalous Properties of Dirac Particles in Graphene and its Multilayers"	Mikito Koshino *[Tohoku University]*
16:40 – 17:15	Talk #20: "Black Holes and Optical Conductivity"	David Tong *[University of Cambridge]*

16 December 2012 (Sunday)		
Time	*Event*	*Presenter*
9:00 – 9:35	Talk #21: "Beyond Graphene: Two-dimensional Crystals"	Antonio H. Castro Neto *[National University of Singapore]*
9:35 – 10:10	Talk #22: "Spin-orbit Induced-spin Torques in Single Ferromagnets"	Aurelien C. Manchon *[King Abdullah University of Science and Technology]*
10:10 – 10:45	Talk #23: "Indication for Macroscopic Quantum Tunneling up to 10 K in Nanostructures of $SrRuO_3$"	Lior Klein *[Bar-Ilan University]*
10:45 – 11:15	Refreshments	
11:15 – 11:50	Talk #24: "Coexistence of Superconductivity and Magnetism of LaAlO3/SrTiO3 Heterostructure Interface"	Lu Li *[University of Michigan]*
11:50 – 12:25	Talk #25: "Symmetry Protected Topological Order in Superfluid ^{3}He-B"	Takeshi Mizushima *[Okayama University]*
12:25 – 14:00	Lunch Break	
14:00 – 14:35	Talk #26: "Topological and Quantum Magnetic Phases in 5d Ir-oxides with Strong Spin-Orbit Coupling"	Jaejun Yu *[Seoul National University]*
14:35 – 15:10	Talk #27: "Majorana Fermions in Gapped and Nodal Topological Superconductors"	Kam Tuen Law *[The Hong Kong University of Science and Technology]*
15:10 – 15:45	Talk #28: "Exotic Quantum Phases Driven by Correlations in Low-dimensional Electron Systems"	Jianxin Li *[Nanjing University]*
15:45 – 16:05	Refreshments	
16:05 – 16:40	Talk #29: "Theory of Spin-current Generation from Rigid and Elastic Motions"	Mamoru Matsuo *[Japan Atomic Energy Agency]*
16:40 – 17:15	Talk #30: "The Fate of Bose-Einstein Condensate in the Presence of Spin-orbit Coupling"	Qi Zhou *[The Chinese University of Hong Kong]*
17:15 – 17:25	Closing Remarks	
18:00 – 21:00	Banquet at Po Toi O (for registered participants only)	

Abstracts

Beyond Graphene: Two-dimensional Crystals

(Talk #21)

Antonio H. Castro Neto*

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Graphene is possibly one of the largest and fastest growing fields in condensed matter research. However, graphene is only one example in a large class of two-dimensional crystals with unusual properties. In this talk I will briefly review the properties of graphene and look at the exciting possibilities that lie ahead.

A Symmetry Protected Topological Insulator of Bosons in 3d via Dyon Condensation and the 'Statistical Witten Effect'

(Talk #4)

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Electron topological insulators discovered theoretically by C. Kane are members of a broad class of "symmetry protected topological" (SPT) phases of fermions *and* bosons which possess distinctive surface behavior protected by bulk symmetries. For 1d and 2d SPT's the surfaces are either gapless or symmetry broken, while in 3d, gapped symmetry-respecting surfaces with (intrinsic) 2d topological order are also possible. The electromagnetic response of (some) SPT's can provide an important characterization, as illustrated by the Witten effect in 3d electron topological insulators – an external magnetic monopole acquires a quantized half-odd integer polarization charge – as shown by Zhang et.al.. A classification of free fermions SPT's is possible, and a group cohomology classification has been proposed for bosonic SPT's by XG Wen et.al.. Moreover, 2d bosonic SPT's can be accessed dynamically using quantum Hall (K-matrix) technology, but 3d bosonic SPT's are less well understood. In an important advance, Vishwanath and Senthil (VS) obtained the 2d surface properties of some 3d bosonic SPT's using a "dimensionality-bootstrap" approach, but the bulk 3d field theory is less clear (to me). Together with M. Metlitski and C. Kane, we have recently developed a new approach to access novel 3d boson phases. Within a U(1) parton-gauge-theory representation the bosonic partons and magnetic monopoles can be combined to form dyons, and a subsequent *dyon condensation* can lead to exotic new phases including some 3d bosonic SPT's. We thereby can obtain a 3d field theory for a bosonic SPT with both time-reveral and charge conservation symmetries, a theory which supports a gapped, symmetry-unbroken 2d surface with topological order – a toric code with charge one-half anyons – consistent with the VS bootstrap construction. The 3d electromagnetic response of this bosonic SPT phase is quite remarkable – an external magnetic monopole can remain charge neutral, but is *statistically transmuted becoming a fermion* – a 'statistical Witten effect' that characterizes the phase.

Orbital Chirality in Non-magnetic and Magnetic Bands and Its Implications

(Talk #9)

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We present a simple argument [1] showing that the natural consequence of inversion symmetry breaking (ISB) in degenerate-orbital band structure is the emergence of orbital chirality, or chiral orbital angular momentum. This is the analogue of spin angular momentum chirality familiar from the Rashba effect but occurs in the orbital sector, even in the absence of spin-orbit interaction. Recent experimental demonstration by circularly polarized ARPES experiment confirms our claim [2]. We explore the minimal model Hamiltonian following from our multi-band picture with ISB both in the case of non-magnetic [1] and magnetic [3] band structures. In the latter case we show that the band-specific orbital chirality is manifested in the form of band-dependent Rashba parameter.

This work is done in collaboration with Jin-Hong Park, Choong H. Kim, Jun-Won Rhim, Hyun-Wook Lee, and Changyoung Kim.

References:

[1] Seung Ryong Park, Choong H. Kim, Jaejun Yu, Jung Hoon Han, and Changyoung Kim, Phys. Rev. Lett. 107, 15803 (2011); Jin-Hong Park, Choong H. Kim, Jun-Won Rhim, and Jung Hoon Han, Phys. Rev. B 85, 195401 (2012).

[2] Beomgyoung Kim et al. Phys. Rev. B 85, 195402 (2012).

[3] Jin-Hong Park, Choong H. Kim, Hyun-Woo Lee, and Jung Hoon Han, arXiv:1207.0089.

Realizing the Pfaffian Quantum Hall State with Cold Atom Magic

(Talk #5)

Tin-Lun (Jason) Ho*

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Institute for Advanced Study, The Hong Kong University of Science and Technology, Hong Kong

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The Pfaffian quantum Hall state is a p-wave BCS state of composite fermions, and is known to have Majorana fermion excitations. It has a bosonic analog in fast rotating Bose gas. The achievement of bosonic Quantum Hall State is difficult because of the strong competition of Bose-condensation. Here, we show that a natural and practical way to generate the bosonsic Laughlin state, Pfaffian state, and various non-abelian quantum Hall states using is a novel version of "BEC-BCS crossover" captured by some remarkable algebraic identifies.

Bi(111) Thin Film with Insulating Interior but Metallic Surfaces

(Talk #15)

Xiaofeng Jin*

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The electrical conductance of epitaxial Bi thin films grown on BaF_2(111) by molecular beam epitaxy has been systematically investigated as a function of both film thickness (4 - 540nm) and temperature (5-300K). Unlike bulk Bi as a prototypical semimetal, the Bi thin films up to 90nm are found to be insulating in the interior but metallic on the surface. This finding not only has unambiguously resolved the longstanding controversy about the existence of the semimetal-semiconductor transition in Bi thin films but also provided a straightforward interpretation for the perplexing temperature dependence of the resistivity of Bi thin films, which in turn might have some potential applications in spintronics.

Indication for Macroscopic Quantum Tunneling up to 10 K in Nanostructures of $SrRuO_3$

(Talk #23)

Lior Klein[1]*, James W. Reiner[2], Omer Sinwani[1]

**[1]Department of Physics, Nano-magnetism Research Center,
Institute of Nanotechnology and Advanced Materials, Bar-Ilan University, Israel**

[2]Hitachi Global Storage Technologies, California, USA

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One of the most remarkable consequences of quantum physics is the finite probability of a particle tunneling through a barrier that according to classical physics is insurmountable. Quantum tunneling of microscopic particles is quite ubiquitous and is generally well understood. However, the extension of quantum tunneling to macroscopic objects remains an intriguing theoretical and experimental challenge. A promising route to macroscopic quantum tunneling is the use of magnetic nanoparticles with two stable states of reversed magnetization separated by an energy barrier. Classically, the energy required for hopping above the barrier is supplied by temperature; hence, the probability for reversal is strongly temperature dependent. On the other hand, quantum tunneling is temperature independent. In previous studies temperatures below 1 K were required to reliably identify magnetization reversal of magnetic nanoparticles dominated by macroscopic quantum tunneling, which complicated and limited considerably the study of this phenomenon. Now, we show [1] clear evidence for macroscopic quantum tunneling up to 10 K by monitoring the magnetization reversal of individual strontium ruthenate ($SrRuO_3$) nanoparticles consisting of millions of atoms. We show that above 10 K the reversal is strongly temperature dependent and well described by classical models whereas below 10 K the reversal rate is practically temperature independent. This cross-over to macroscopic quantum tunneling at a temperature an order of magnitude higher than previously seen in individual magnetic nanoparticles provides exciting opportunities for the study of this phenomenon at new and larger length and temperature scales.

Reference:

[1] Omer Sinwani, James W. Reiner, and Lior Klein, Phys. Rev. B 86 100403(R) 2012.

Anomalous Properties of Dirac Particles in Graphene and its Multilayers

(Talk #19)

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Graphene is characterized with Dirac quasiparticles in the low-energy spectrum, which give rise to anomalous physical properties due to the linear dispersion and non-trivial Berry phase. One of the manifestations of the unusual band structure is anomalous orbital diamagnetism, where the susceptibility has a singularity expressed as a delta function in Fermi energy, which diverges at Dirac point and vanishes otherwise [1-5]. The singular diamagnetism is closely related to the scale-less property of the electronic structure, and we can show that the delta-function susceptibility is always concluded in any systems as long as the Hamiltonian is linear to the wave number [1]. The scale-less electronic structure also manifests itself in response to non-uniform magnetic fields, where graphene works as a magnetic mirror, i.e., the counter magnetic field induced by graphene perfectly copies the external field distribution [2].

There are growing interests in multilayer variants of graphene such as bilayer and trilayer, which also support chiral quasiparticles. We study the electronic structures of Bernal(AB) stacked multilayer graphenes in the presence of uniform perpendicular electric field, and show that the interplay of the trigonal warping and the external electric field gives rise to a number of additional Dirac cones nearly touching at zero energy. In Bernal trilayer graphene, in particular, we find that non-trivial valley Hall state is realized by applying the electric field, where the energy gap is filled by the chiral edge channels counter-propagating between two valleys. We show that the non-trivial valley Hall state generally occurs in odd layer graphenes with electric field, and this is closely related to a hidden approximate chiral symmetry which exists only in odd layer graphene.

References:

[1] M. Koshino and T. Ando, Phys. Rev. B 76, 085425 (2007).

[2] M. Koshino, Y. Arimura and T. Ando, Phys. Rev. Lett. 102, 177203 (2009).

[3] M. Koshino and T. Ando, Phys. Rev. B 81, 195431 (2010).

[4] M. Koshino, Phys. Rev. B 84, 125427 (2011).

[5] Y. Ominato and M. Koshino, Phys. Rev. B 85, 165454 (2012).

[6] T. Morimoto and M. Koshino, in preparation.

Majorana Fermions in Gapped and Nodal Topological Superconductors

(Talk #27)

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In the first part of the talk, we will show that a quasi-one-dimensional $d_{x^2-y^2}$-wave superconductor with Rashba spin-orbit coupling is a DIII class, time-reversal invariant, topological superconductor (TS) which supports a Majorana Kramers Doublet (MKD) at each end of the TS. A MKD is a pair of Majorana end states (MESs) protected by time-reversal symmetry (TRS). An external magnetic field breaks TRS and drives the system from DIII to D class in which case a single MES appears at each end of the TS. We show that a MKD induces resonant Andreev reflection with zero bias conductance peak of $4e^2/h$. Experimental realizations of the proposed model using non-centrosymmetric superconductors are discussed.

In the second part of the talk, we will show that an in-plane magnetic field can drive a fully gapped p ± ip topological superconductor into a gapless phase which supports symmetry protected Majorana Flat Bands (MFBs). We show that the MFBs in the gapless regime are protected by a chiral symmetry and are associated with MESs.

References:

[1] Chen et al., Nature 487, 77 (2012); Fei et al., Nature 487, 82 (2012).

[2] Manjavacas et al., ACS Nano 6, 1724 (2012).

[3] Thongrattanasiri et al., Phys. Phys. Lett. 108, 047401 (2012).

Exotic Quantum Phases Driven by Correlations in Low-dimensional Electron Systems

(Talk #28)

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Nanjing University, China**

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The search for the exotic quantum phases (orders) constitutes one of the most important and hot issues in modern condensed matter physics. Here, we present our recent theoretical investigations on the possible quantum phases and the quantum phase transitions realized in the Kane-Mele-Hubbard model, anisotropic Hubbard model and a 1/6 hole-doped Hubbard model on the kagome lattice via the variational cluster approach.

Collaborators: S. L. Yu and J. Kang (Nanjing University), X. C. Xie (Peking University), T. Xiang (IOP, CAS)

References:

[1] S. L. Yu, X. C. Xie and J. X. Li, Phys.Rev.Lett. 107, 010401 (2011).

[2] J. Kang, S. L. Yu, T. Xiang and J. X. Li, Phys. Rev. B 84, 064520 (2011).

[3] S. L. Yu and J. X. Li, Phys. Rev. B. 85, 144402 (2012).

Coexistence of Superconductivity and Magnetism of $LaAlO_3/SrTiO_3$ Heterostructure Interface

(Talk #24)

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The $LaAlO_3/SrTiO_3$ heterostructure is a potential candidate for a high mobility two-dimensional electron system with novel electronic and magnetic properties. Magnetic ordering has been proposed to arise from the d-electrons transferred by polarization discontinuity. However the magnetization of this system has not previously been studied, due to the small volume of the interface. Using torque magnetometry, we detect the magnetic moment of the interface system directly [1]. Our results indicate the existence of a magnetic ordering at the two-dimensional conductive interface. The ferromagnetic-like ordering state persists up to 200 K. Moreover, the same magnetic behavior persists even when the sample is superconducting, which suggests an unconventional two-dimensional superconducting phase.

Reference:

[1] Lu Li, C. Richter, J. Mannhart, and R. C. Ashoori. Nature Physics 7, 762 (2011).

Excitation Spectra of 2D Massless Dirac Fermion Systems:
Graphene and Topological Insulators

(Talk #12)

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We present results of some recent theoretical studies on the electronic excitation spectra associated with the 2D massless Dirac fermions in graphene and topological insulators. These systems present a new opportunity for study of unusual manifestation of concepts/phenomena that may not be so prominent or have not been seen in bulk materials. For doped graphene, angle-resolved photoemission experiments reveal that there is an intriguing satellite peak in the measured spectra, in addition to the expected quasiparticle peak. The question remains whether this satellite peak is, as suggested previously, due to a new elementary excitation – the plasmaron. By combining the *ab initio* GW method with cumulant expansion (thus including significant vertex corrections), our first-principles results explain the observed satellite properties in terms of coupling to the carrier plasmons, but do not find existence of plasmarons (defined as excitations that are solutions to the Dyson's equation). For topological insulators, we show that the degree of spin polarization of photoelectrons from the topologically protected surface states is 100% if fully polarized light is used as in typical photoemission measurements, and, hence, can be significantly higher than that of the initial state. Moreover, we find that the spin orientation of these photoelectrons in general can be very different from that of the initial surface state and is controlled by the photon polarization.

Spin Seebeck Effect in a Variety of Magnetic Systems

(Talk #6)

Sadamichi Maekawa*

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When metals and semiconductors are placed in a temperature gradient, the electric voltage is generated. This mechanism to convert heat into electricity, the so-called Seebeck effect, has attracted much attention as the mechanism for utilizing wasted heat energy [1].

Ferromagnetic insulators are good conductors of spin current, i.e., the flow of electron spins [2]. When they are placed in a temperature gradient, generated are spin current and the spin voltage [3], i.e., spin accumulation. Once the spin voltage is converted into the electric voltage by the inverse spin Hall effect in attached metal films, the electric voltage is obtained from heat energy [4-5]. This is called the spin Seebeck effect (SSE).

Here, we present the linear-response theory of SSE based on the fluctuation-dissipation theorem [6-9] and discuss about SSE in a variety of the magnetic devices.

References:

[1] S. Maekawa et al., *Physics of Transition Metal Oxides* (Springer, 2004).

[2] S. Maekawa et al., *Spin Current* (Oxford University Press, 2012).

[3] *Concept in Spin Electronics*, eds. S. Maekawa (Oxford University Press, 2006).

[4] K. Uchida et al., Nature 455, 778 (2008).

[5] K. Uchida et al., Nature Materials 9, 894 (2010).

[6] H. Adachi et al., APL 97, 252506 (2010) and Phys. Rev. B 83, 094410 (2011).

[7] J. Ohe et al., Phys. Rev. B (2011).

[8] K. Uchida et al., Appl. Phys. Lett. 97, 104419 (2010).

[9] Y. Ohnuma et al., to be published.

Spin-orbit Induced-spin Torques in Single Ferromagnets

(Talk #22)

Aurelien Manchon*

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Manipulating the magnetization of a ferromagnet using spin-polarized current has been made possible via the theoretical and experimental demonstration of spin transfer torque in ferromagnetic spin-valves [1]. Alternatively, it has been recently demonstrated that appropriately designed spin-orbit coupling (SOC) can be used to generate spin torque (coined SOC-torque) in a single ferromagnet, without the need of an external polarizer [2]. This effect has been observed experimentally in both metallic [3,4] and semiconducting systems [5]. Interestingly, due to the complex structure of metallic systems, the microscopic origin of the current-driven magnetization dynamics is still under debate.

In this presentation, I will examine the different origins of the SOC-torque and discuss experimental implications. In the first part, I will introduce the concept of Rashba spin-orbit coupling in 2 dimensional electron gases and show that it can be extended to sharp interfaces. In the second part, I will discuss the spin-dependent transport in the presence of strong spin-orbit coupling through drift-diffusion model and its implication in terms of SOC-torque. Rashba torque and spin Hall effect torques will be addressed. Finally, the experimental issues related to the extraction of these torques will be discussed.

References:

[1] J. C. Slonczewski, J. Magn. Magn. Mater. 159, L1 (1996); J. A. Katine et al., Phys. Rev. Lett. 84, 3149 (2000).

[2] A. Manchon and S. Zhang, Phys. Rev. B 78, 212405 (2008); X. Wang and A. Manchon, Phys. Rev. Lett 108, 117201 (2011).

[3] I. M. Miron et al., Nature Mater. 9, 230 (2010); Nature Mater. 10, 419 (2011); Nature (London) 476, 189 (2011).

[4] L. Liu, et al., Phys. Rev. Lett. 106, 036601 (2011); Science 336, 555 (2012).

[5] A. Chernyshov, M. Overby, X. Liu, J. K. Furdyna, Y. Lyanda-Geller, and L. P. Rokhinson, Nature Physics 5, 656 (2009); Fang et al. Nature Nanotechnology 6, 413 (2011).

Theory of Spin-current Generation from Rigid and Elastic Motions

(Talk #29)

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[1]Advanced Science Research Center, Japan Atomic Energy Agency, Japan

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In this talk, we would like to discuss our recent work on spin-current generation from rotational motions of rigid and elastic bodies. In the rigidly rotating body with an external magnetic field, the spin-orbit interaction (SOI) is modulated by the mechanical motion [1]. The augmented SOI is responsible for the spin-current generation from the mechanical rotation [Fig. 1]. In the presence of the surface acoustic wave (SAW), the elastically driven rotational motion couples to electron spins and the spin current is created parallel to the gradient of the mechanical rotation [Fig. 2]. Dependence of the spin diffusion length, amplitude and frequency of the SAW on the spin current will be discussed [2].

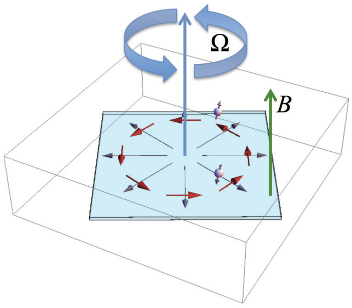

Figure 1. Spin current created in Pt film by rigid rotation with an external magnetic field parallel to the rotation axis.

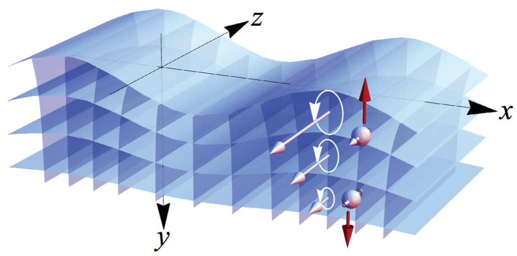

Figure 2. Spin current generation in a non-magnetic metal/semiconductor by the SAW.

References:

[1] M. Matsuo, J. Ieda, E. Saitoh, and S. Maekawa, Phys. Rev. Lett. 106, 076601 (2011); Appl. Phys. Lett. 98, 242501 (2011); Phys. Rev. B 84, 104410 (2011).

[2] M. Matsuo, J. Ieda, K. Harii, E. Saitoh, and S. Maekawa, in preparation.

Symmetry Protected Topological Order in Superfluid ^{3}He-B

(Talk #25)

Takeshi Mizushima[1,2]*, Masatoshi Sato[3], Kazushige Machida[1]

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The superfluid ^{3}He-B has been recognized as a concrete example of topological superconductors, where the time-reversal symmetry ensures a nontrivial topological number and the existence of helical Majorana fermions. This may indicate that any time-reversal breaking disturbance wipes out the topological nature. However, we demonstrate here that the B phase under a magnetic field in a particular direction stays topological due to a discrete symmetry, that is, in a symmetry protected topological order [1]. Due to the symmetry protected topological order, helical surface Majorana fermions in the B phase remain gapless and their Ising spin character persists. We unveil that the competition between the Zeeman magnetic field and dipole interaction involves anomalous quantum phase transition where topological phase transition takes place together with spontaneous breaking of symmetry. Based on the quasiclassical theory, we illustrate that the phase transition is accompanied by anisotropic quantum criticality of spin susceptibilities on the surface, which is detectable in NMR experiments [1,2].

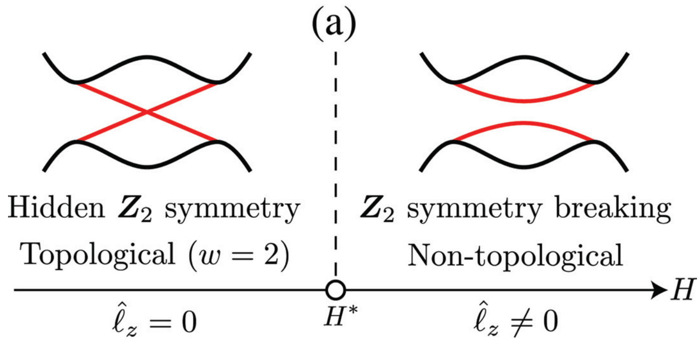

Figure 1. Schematic phase diagram of ^{3}He-B under a parallel magnetic field, where H^* involves the topological phase transition with spontaneous symmetry breaking.

References:

[1] T. Mizushima, M. Sato, and K. Machida, Phys. Rev. Lett. 109, 165301 (2012).

[2] T. Mizushima, Phys. Rev. B 86, 094518 (2012).

Topological Protection of Bound States against the Hybridization

(Talk #14)

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Localization of electronic wave functions is governed by their topological nature as well as the symmetry and dimensionality of the system. An example is the surface states of three dimensional topological insulators, which are extended as long as the gap in the bulk remains. In this talk, I will discuss the opposite case, i.e., the topology protects the "localized states". More explicitly, when the two-dimensional quantum Hall system is put on the three dimensional trivial insulator, the two dimensional states remain localized along the normal direction to the surface in spite of the hybridization with the continuum of extended states. The behavior of the edge channels is also discussed.

This work has been done in collaboration with B. J. Yang and M. S. Bahramy.

Magnetic Response in the Underdoped Cuprates

(Talk #1)

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The dynamical magnetic response of underdoped cuprates is calculated [1] by employing a phenomenological theory of a doped resonant valence bond state with a Fermi surface truncated into four pockets. This theory predicts a resonant spin response, which with increasing energy (0 to 100 meV), appears as an hourglass. A very low energy spin response is found at (π,π ± δ) and (π ± δ,π) and is determined by scattering from the pockets' front side to the tips of opposite pockets where a van Hove singularity resides. At energies beyond 100 meV, strong scattering is seen from (π,0) to (π,π). This theory thus provides a semi-quantitative description of the spin response seen in both inelastic neutron scattering and resonant inelastic x-ray scattering experiments at all relevant energy scales.

Reference:

[1] A. J. A. James, R. M. Konik and T. M. Rice, Phys. Rev. B 86, 100508(R) (2012).

Dynamical Generation of Spin Currents

(Talk #16)

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Spin current, a flow of electrons' spins in a solid, is the key concept in spintronics that will allow the achievement of efficient magnetic memories, computing devices, and energy converters. I here review phenomena which allow us to use spin currents in insulators [1]: inverse spin-Hall effect [2,4], spin pumping, and spin Seebeck effect [4-6]. We found that spin pumping and spin torque effects appear at an interface between an insulator YIG and Pt. Using this effect, we can connect a spin current carried by conduction electrons and a spin-wave spin current flowing in insulators. We demonstrate electric signal transmission by using these effects and interconversion of the spin currents [1]. Seebeck effect (SSE) is the thermal spin pumping [5]. The SSE allows us to generate spin voltage, potential for driving non-equilibrium spin currents, by placing a ferromagnet in a temperature gradient. Using the inverse spin-Hall effect in Pt films, we measured the spin voltage generated from a temperature gradient in various ferromagnetic insulators.

This research is collaboration with K. Ando, K. Uchida, Y. Kajiwara, S. Maekawa, G. E. W. Bauer, S. Takahashi, and J. Ieda.

References:

[1] Y. Kajiwara & E. Saitoh et al., Nature 464 (2010) 262.

[2] E. Saitoh et al., Appl. Phys. Lett. 88 (2006) 182509.

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[4] K. Uchida & E. Saitoh et al., Nature 455 (2008) 778.

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[6] K. Uchida & E. Saitoh et al., Nature Materials 10 (2011) 737-741.

Impurity-induced Bound States in Topological Insulators and Superconductors

(Talk #17)

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Topological insulators are narrow-band semiconductors with band inversion generated by strong spin-orbit coupling. They are distinguished from the ordinary band insulators according to the Z2 invariant classification of the band insulators that respect time-reversal symmetry. The variation of the Z2 invariant at their boundaries will lead to the topologically protected edge or surface states with the gapless Dirac energy spectrum. Imperfections, such as impurity, vacancy, and disorder, are inevitably present in topological insulators. Owing to the time-reversal symmetry, an exciting feature of topological insulator is that its boundary states are expected to be topologically protected against weak nonmagnetic impurities or disorders. This provoked much interest on the single impurity problem in topological insulators and superconductors. In this talk, the speaker will introduce a series of solutions of the bound states induced by impurities in topological insulators and superconductors. The impurities can be classified as the topological and non-topological ones. Conventional defects and impurities can induce a series of in-gap bound states while topological defects such as domain walls, vortex lines and magnetic monopoles may produce the bound states of zero energy which are robust against geometry deformation and disorders in the materials. In topological superconductors, these zero energy bound states are Majorana fermions.

References:

[1] S. Q. Shen, Topological Insulators – Dirac equations in condensed matters, (Springer Series in Solid State Sciences 174, 2013).

[2] S. Q. Shen, W. Y. Shan, and H. Z. Lu, SPIN 1, 33 (2011).

[3] W. Y. Shan, J. Lu, H. Z. Lu, and S. Q. Shen, Phys. Rev. 84, 035307 (2011).

[4] J. Lu, W. Y. Shan, H. Z. Lu, and S. Q. Shen, New J. Phys. 13, 103016 (2011).

[5] R. L. Chu, J. Lu, and S. Q. Shen, EPL 100, 17013 (2012).

Topological Insulators of Bosons

(Talk #7)

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***Email of Presenting Author: senthil@mit.edu**

I describe physical properties and realizations of examples of Symmetry Protected Topological insulating phases of bosons. These phases generalize the concept of topological insulators to interacting bosons or fermions. I will first discuss the possibility of an Integer Quantum Hall Effect for a system of interacting bosons as a very useful example of this kind of phase. I will then describe the properties of three dimensional time reversal symmetric topological insulators of bosons. Different characterizations of these 3d bosonic topological insulators will be discussed, for instance, their quantized magnetoelectric effect and protected surface states. I point out interesting connections of the theory of these surface states with deconfined quantum criticality and other phenomena familiar from 2d quantum magnetism. The surface may also be in a gapped symmetry preserving phase but must then have surface topological order. Symmetries are realized in this surface topological ordered phase in a manner not possible in a strictly two dimensional system with a local realization of symmetry.

Black Holes and Optical Conductivity

(Talk #20)

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Holography is a duality that maps problems in certain strongly interacting quantum field theories to questions about the dynamics of black holes in general relativity. I will review this correspondence and then describe recent work, in collaboration with Gary Horowitz and Jorge Santos, in which we compute the optical conductivity in a large class of such theories. The results are striking similar to the behavior seen in a class of strange metals.

Highly Entangled Quantum Matter: A New Chapter in Condensed Matter Physics

(Talk #11)

Xiao-Gang Wen*

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Department of Physics, Massachusetts Institute of Technology, USA and
Institute for Advanced Study, Tsinghua University, China

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I review the progress in last 20 - 30 years, during which we discovered that there are new states of matter that are beyond Landau symmetry breaking theory. We discuss new "topological" phenomena, such as topological degeneracy, that reveal the existence of those new phases – topologically ordered phases. Just like zero-viscosity defines the superfluid order, the new "topological" phenomena define the topological order at macroscopic level. More recently, we found that, at the microscopical level, topological order is due to long-range quantum entanglements, just like fermion superfluid is due to fermion-pair condensation. Long-range quantum entanglements lead to many amazing emergent phenomena, such as fractional quantum numbers, fractional/non-Abelian statistics, and perfect conducting boundary channels.

Reference:

[1] Xiao-Gang Wen, Topological order: from long-range entangled quantum matter to an unification of light and electrons, arXiv:1210.1281

Recent Advancement in β–$FeSe_{1-x}$ and Related Superconductors

(Talk #13)

M.-K. Wu[1,2]*, C.-C. Chang[2], Y.-C. Wen[2], T. K. Chen[2] and M. J. Wang[3]

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It has been more than 4 years since the discovery of β–$FeSe_{1-x}$ superconductor. Through the efforts of many outstanding research groups unprecedented advancement in the field has been achieved. High quality single crystals of β–$FeSe_{1-x}$ and related compounds have been successfully prepared by various techniques, thus allowing us to explore in details the physical properties of this class of materials. Detailed structure and properties characterizations of these crystals have provided critical information for better understanding the origin of superconductivity in β–$FeSe_{1-x}$. Recently, our high-resolution Transmission Electron Microscopy (HRTEM) study demonstrates the presence and ordering of iron vacancies in high-pressure synthesized tetragonal β–FeSe. Combining analytical electron microscopy and multi-slice simulation, we show that the new phase, called β'–FeSe, exhibits an iron-vacancy ordering of 2x2 d_{110} with ½ d_{100} shift every other (001) plane (the Fe-Se layer). Preliminary measurement of this new phase indicates the existence of a magnetic order at low temperature. It is believed that this new phase is more likely the parent compound of the superconducting phase.

On the other hand, it has also been clearly demonstrated [1] that the occurrence of superconductivity is directly associated with a low temperature structure distortion. Several anomalous behaviors are also found to accompany the structural distortion. Recent measurements [2] on quasiparticle and acoustic phonon dynamics with respect to the orbital modification in β–$FeSe_{1-x}$ suggested the opening of an energy gap below 130 - 140 K, accompanying with a coincident transfer of the optical spectral weight in the visible range and alterations in the transport properties. These observations provide convincing evidence that the modification of the electronic structure is prior to the lattice distortion. These results further suggest that the high-T gap and the lattice symmetry breaking are driven by short-range orbital and/or charge orders. Implication of these results to the occurrence of superconductivity in β–FeSe will be discussed.

References:

[1] M. K. Wu, *et al*., *Physica C*, 469, 340 (2009); M. J. Wang *et al.*, Phys. Rev. Lett. 103 (2009) 117002.

[2] Y. C. Wen, K. J. Wang, H. H. Chang, J. Y. Luo, C. C. Shen, H.L. Liu, C. K. Sun, M. J. Wang, and M. K. Wu, *Phys. Rev. Lett*., 108, 267002 (2012).

Interface Induced High Temperature Superconductivity in Single Unit-cell FeSe Films

(Talk #3)

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We report high transition temperature superconductivity in single unit-cell (UC) thick FeSe films grown on the Se-etched $SrTiO_3$(001) substrate by molecular beam epitaxy (MBE). A superconductive gap as large as 20 meV and the magnetic field induced vortex state revealed by *in situ* scanning tunneling microscopy (STM) suggest that the superconductivity of the 1 UC FeSe films could possibly occur around 77 K. The control transport measurement shows that the onset superconductivity temperature is well above 50 K. Our work not only demonstrates a powerful way for finding new superconductors and for raising T_C, but also provides a well-defined platform for systematic study of the mechanism of unconventional superconductivity by using different superconducting materials and substrates.

The work was carried out in collaboration with Xucun Ma, Lili Wang, Xi Chen, Ke He, Shuaihua Ji, Yayu Wang, Jian Wang, Xingjiang Zhou and Jinfeng Jia.

Spintronics using Topological Insulators and Triplet Superconductors

(Talk #10)

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***Email of Presenting Author: yokoyama@stat.phys.titech.ac.jp**

In this talk, I would like to present our recent works on spintronics using topological insulators and triplet superconductors. First, I will focus on topological insulators coupled to ferromagnets and discuss magneto transport in ferromagnet junctions, magnetization dynamics, current-induced magnetization reversal and rectification effect. The predicted effects are direct manifestation of Dirac fermions on the surface of a topological insulator [1]. Next, I will talk about charge pumping in ferromagnet/triplet superconductor junctions where the magnetization of the ferromagnet is inhomogeneous and dynamical. It is shown that charge current is pumped due to the coupling of the localized spins with triplet vector chirality, vector chirality formed by the triplet vector of Cooper pairing. Physical mechanism of the charge pumping is also discussed [2].

References:

[1] T. Yokoyama, Y. Tanaka, and N. Nagaosa, Phys. Rev. B 81, 121401(R) (2010); T. Yokoyama, J. Zang, and N. Nagaosa, Phys. Rev. B 81, 241410(R) (2010); T. Yokoyama, Phys. Rev. B 84, 113407 (2011); T. Yokoyama and S. Murakami, Phys. Rev. B 83, 161407(R) (2011) ; H. T. Ueda, A. Takeuchi, G. Tatara, and T. Yokoyama, Phys. Rev. B 85, 115110 (2012).

[2] T. Yokoyama, Phys. Rev. B 84, 132504 (2011).

Topological and Quantum Magnetic Phases in 5d Ir-oxides with Strong Spin-Orbit Coupling

(Talk #26)

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A novel j_{eff} =1/2 state in Sr_2IrO_4 was reported as a unique manifestation of the spin-orbit coupling (SOC) and on-site Coulomb (U) interaction effect in 5d transition metal oxides [1]. The electron correlation combined with strong SOC under a large crystal field present is responsible for the observed peculiar electronic and magnetic properties. We carried out LDA+SO+U calculations including both on-site U and SOC for 5d Ir oxide compounds including Sr_2IrO_4, Na_2IrO_3, and Li_2IrO_3. The results show that there is an interesting competition between local lattice distortion and spin-orbit coupling, which controls the degree of j_{eff} =1/2 components in the state near E_F. We predict a topological quantum phase transition from normal to topological insulator in Na_2IrO_3, driven by the control of long-range hopping and trigonal crystal field [2]. By fine-tuning the structural parameters in Ir-oxides, one can explore more interesting characteristics of transition metal oxides with competing strong SOC and Coulomb correlation. In addition, we observe that intriguing effective magnetic interactions arise from the strong spin-orbit coupling with on-site Coulomb interaction. Possible topological insulator and exotic magnetic phases suggest that Ir-oxide and related systems can be an "interesting" playground for the study of the interplay between spin-orbit coupling and on-site Coulomb interaction.

Work was done in collaboration with Heungsik Kim, Choong H. Kim, Hogyun Jeong, and Hosub Jin.

References:

[1] B. J. Kim et al., Phys. Rev. Lett. 101, 076402 (2008).

[2] C. H. Kim et al., Phys. Rev. Lett. 108, 106401 (2012).

Symmetry Protected Topological Phases and Quantum Critical Phases in One-dimensional Quantum Spin Chains

(Talk #18)

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Many years ago, from the theory of nonlinear sigma model with theta term, Haldane predicted that antiferromagnetic Heisenberg spin chains are classified into two universality classes: half-odd integer spins with gapless excitations and integer spins with gapped excitations. The Haldane gap phases can be regarded as an example of a symmetry protected topological (SPT) phase in 1D. For a quantum Heisenberg antiferromagnetic spin-1 chain, nonlocal string order parameters are proposed to describe the hidden antiferromagnetic correlations, and a unitary nonlocal transformation was established to convert the nonlocal string order parameters to the local ones and to reveal the hidden discrete Z2 x Z2 symmetry. Recently, we have developed a similar description scheme for the higher integer spin chains, where the required higher symmetry SO(2S+1) in the ground state is essential.

Moreover, recent studies have indicated that the Haldane gapped phase with an odd integer spin is a SPT phase and the fractionalized edge spins are symmetry protected, while the even integer spin phase is not. In order to consider the question as whether the differences between the odd and even integer Haldane gapped phases can be understood from their effective field theories, we carefully examine the effective field theory of the Bethe ansatz integrable spin-S Heisenberg antiferromagnetic chains. It shows that the quantum critical theories for the integer spin chains should be characterized by the SO(3) level-S Wess-Zumino-Witten model. There exist two distinct universality classes determined by the parity of the integer spin number, and associated with two completely different conformal field theories. We further show that these two classes of critical states describe the boundary theory of a two-dimensional doubled Chern-Simons topological field theory on an SO(3) group manifold with spin structure.

References:

[1] H. H. Tu, G. M. Zhang, and T. Xiang, Phys. Rev. B 78, 094404 (2008).

[2] H. H. Tu, G. M. Zhang, T. Xiang, Z. X. Liu, and T. K. Ng, Phys. Rev. B 80, 014401 (2009).

[3] Z. X. Liu and G. M. Zhang, to be published.

Topological Insulator, Quantum Spin Hall and Quantum Anomalous Hall Effects

(Talk #2)

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I shall give a brief review on topological insulators, and then discuss recent developments in interacting topological insulators, quantum spin Hall and quantum anomalous Hall effects.

The Fate of Bose-Einstein Condensate in the Presence of Spin-orbit Coupling

(Talk #30)

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The recent realization of synthetic gauge fields for ultra cold atoms provides physicists exciting opportunities to investigate the interplay between two fundamental phenomena in nature, Bose-Einstein condensation and spin-orbit coupling. In this talk, I will discuss a novel effect of spin-orbit coupling in bosonic systems, namely, it can destroy a high-dimensional condensate even at sufficiently low temperatures. This effect will be first demonstrated using simple examples of non-interacting bosons, which highlight the underlying physics that spin-orbit coupling qualitatively changes the single-particle Density of States at low energies. I will then turn to interacting systems, where a condensate is stabilized by interaction at zero temperature. On the other hand, condensate depletion is significantly enhanced by spin-orbit coupling. Particularly, thermal depletion becomes divergent when spin-orbit coupling becomes isotropic and interaction is spin-independent. This leads to the disappearance of a three-dimensional condensate at any finite temperature, and suggests an interesting routine to suppress the long-range order in weakly interacting atomic systems via spin-orbit coupling.

ARPES on Electronic Structure and Superconducting Gap of $A_xFe_{2-y}Se_2$ (A=K, Tl, Rb) and Single-layer $FeSe/SrTiO_3$ Superconductors

(Talk #8)

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High resolution angle-resolved photoemission measurements have been carried out to study the electronic structure and superconducting gap of the newly discovered $A_xFe_{2-y}Se_2$ [A=K, (Tl,K) and (Tl,Rb)] superconductors [1,2,3] and single-layer FeSe superconductor grown on $SrTiO_3$ substrate [4,5]. Distinct Fermi surface topology and nearly isotropic superconducting gap without nodes are observed in these systems. Phase diagram is established and high temperature superconductivity at ~65K is realized in tuning the carrier concentration of the single-layer FeSe film by an annealing process [5]. Implications of these results on the superconductivity mechanism of the iron-based superconductors will be discussed.

References:

[1] D. X. Mou, X. J. Zhou et. al, Phys. Rev. Lett. 106, 107001 (2011).

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Restaurants	Types of Food	Location
China Garden Restaurant	Chinese dim sum, and Peking & Cantonese dishes	G/F (near Lifts 13-15)
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LG1 Canteens	Fast food, sandwiches, snacks and desserts	LG1 (via Lifts 10-12 / 13-15)
LG7 Canteens	Hong Kong and Asian style fast food	LG7 (via Lifts 10-12)
McDonald’s	Burgers, fast food	LG5 (via Lifts 10-12)
UC Bistro	Western menu, lunch, dinner and snacks	Lo Ka Chung University Center

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UC Bistro (Reservations)	2335-1875
Campus Security	2358-6565
Emergency / Ambulance	999 / 2358-8999
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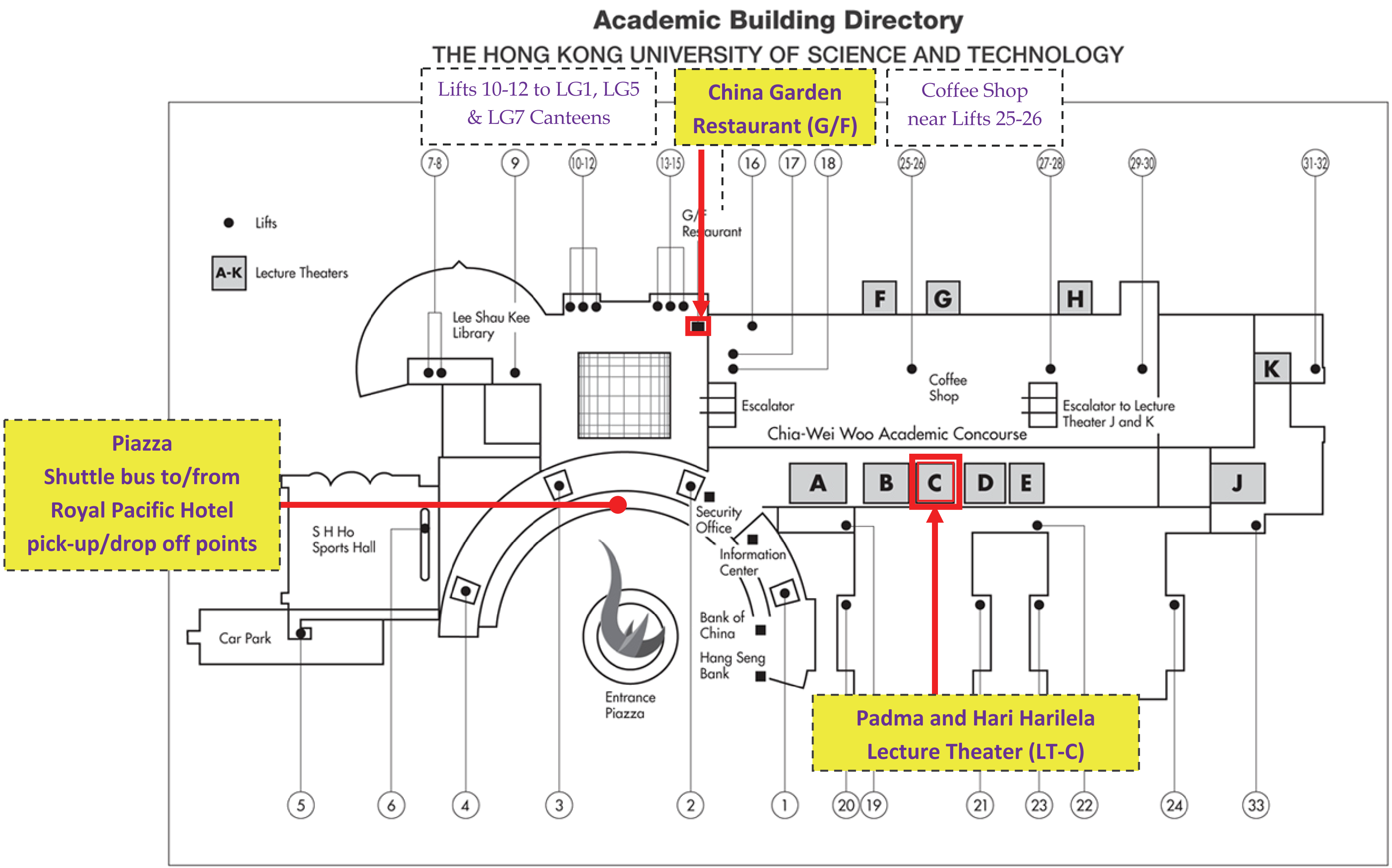
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LOCATION MAP

THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

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Choi Hung 彩虹：	91, 91M	11, 11S
Ngau Tau Kok 牛頭角：		104
Tiu Keng Leng 調景嶺：	792M	
Hang Hau 坑口：		11, 11M, 11S
Po Lam 寶琳：	91M	11S, 12

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For passengers with bulky luggage, taking a taxi to HKUST direct is recommended.
Those with simple luggage may take Airport Bus A22 to Lam Tin, and change for taxi to HKUST.

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Green Minibus Routes 綠色專線小巴路線

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