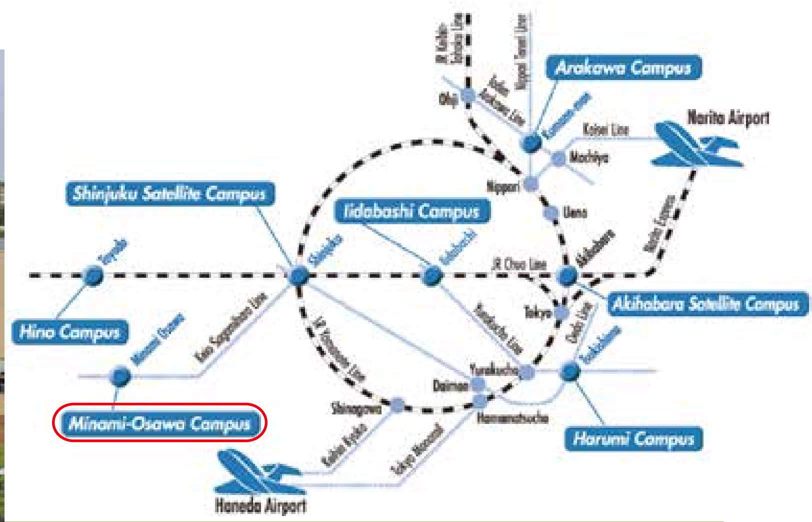
Tokyo Metropolitan University 2015

Department of Physics

TOKYO METROPOLITAN UNIVERSITY
首都大学東京

Graduate School of Science and Engineering,
Department of Physics



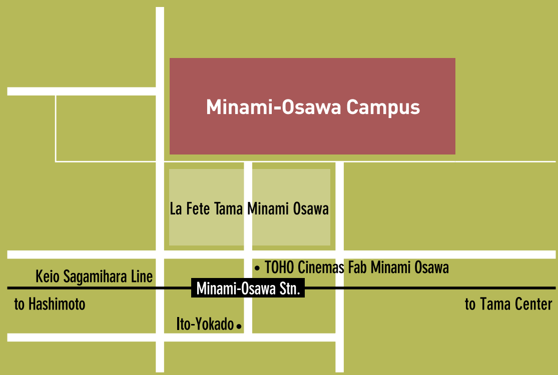
Campus Map

Minami-Osawa Campus

1-1 Minami-Osawa, Hachioji-shi, Tokyo 192-0397, Japan
Tel. +81-42-677-1111

- Faculty of Urban Liberal Arts
- Faculty of Urban Environmental Sciences
- Faculty of System Design (Freshman & Sophomore)
- Faculty of Health Sciences (Freshman)

International Affairs Office
International Student Support Section E-mail ryugawww@tmu.ac.jp
International Initiatives section E-mail kokusai-center@jmj.tmu.ac.jp
http://www.ic.tmu.ac.jp/english/



《Access》
[Keio Line] 5-minute walk from the ticket gate at the Minami Osawa Station, Keio Sagamihara Line.
*As you exit the ticket gate, on the right hand you will see the campus surrounded by greenery.

Tokyo Metropolitan University

http://www.tmu.ac.jp/english/

Department of Physics

http://www.phys.se.tmu.ac.jp/e/

What is the charm of physics ?

Takashi Hotta
Chair, Department of Physics
Tokyo Metropolitan University

"Nature is complex, but is never capricious." This phrase accurately explains the motivation of researchers and students in the field of physics, because one of the main attractions of physics is to find simple and beautiful principles hidden within complex natural phenomena. However, nature is immeasurably vast. How do we deal with such complexity?

To answer this question, it is necessary to recall that we live in a world with a hierarchical structure. For instance, in the universe, there exists a hierarchy of galactic clusters, the galaxy, and the solar system. The typical length scale is the light year, which is very large compared to a meter. We live on earth in the solar system, but the scale of our daily life is typically between 1 cm and 1 m. The infinitely variety of materials around us are composed of molecules and atoms, with a typical scale on the order of an angstrom (10^{-10} m). Further inside of atom, the world of the nucleus and elementary has a scale much shorter than 10^{-10} m.

It is difficult to understand from a unified viewpoint the natural phenomena across a length scale that varies by several orders of magnitude, but in the style of modern physics, we often treat an object in a certain hierarchy "A" as the aggregation of the elements of hierarchy "B" at the next smaller scale. By taking into account the interaction among the elements in hierarchy "B", we try to understand the physical rules in hierarchy "A". Then, using the chain of understanding in each hierarchy, we can cover all of nature from the elementary particle to the universe. On the basis of this hierarchical concept, the physics department of Tokyo Metropolitan University (TMU) covers the whole range of nature, from the extremely tiny scale in elementary particle physics to the gigantic scale in astrophysics, including atomic and nano scales in condensed matter physics and materials science. Every day, on each level of the hierarchy, we attempt to devote ourselves to the discovery of new phenomena and the understanding of new physics.

When we survey the history of physics, physicists first tried to interpret phenomena at a macroscopic level and then deepened their understanding to the microscopic level. The TMU Physics Department curriculum just traces the history of physics. Namely, undergraduate students first study classical mechanics, classical electromagnetism, and physical mathematics, then they move onto modern physics, such as statistical thermodynamics and quantum mechanics, which offer useful tools to handle the physics at a microscopic level. The TMU physics curriculum offers classes of exercise and experiment at each level of undergraduate study in addition to standard lectures. In the final undergraduate level, students take part in seminars with graduate students and complete a graduation study in the course of performing advanced laboratory research.

When the students enter graduate program, they begin their research activities in a laboratory corresponding to the hierarchy of physics. We hope that each student finds a new physics on their own, even if it is just a minor finding. At that moment, students can feel from the bottom of their hearts that "*Nature is complex, but is never capricious*."

Let us now join the physics world to be touched by the simplicity hidden in complexity!

Research Groups

Staff

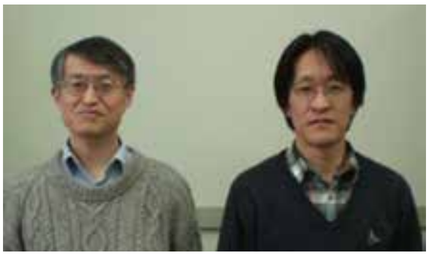
AOKI Yuji	*Professor*	Strongly Correlated Electron System, Low Temperature Physics, Superconductivity
HOTTA Takashi	*Professor*	Magnetism, Superconductivity, Theory
MANIWA Yutaka	*Professor*	Nanoscience, Condensed Matter Physic, Material Science
MASAI Kuniaki	*Professor*	High-Energy Astrophysics, Interstellar Medium, Clusters of Galaxies
MORI Hiroyuki	*Professor*	Low-Dimensional Systems, Cold Atoms, Quantum Phenomena
OHASHI Takaya	*Professor*	X-ray Astronomy, Observations and Instrumentation
SHUDO Akira	*Professor*	Nonlinear Dynamics, Classical and Quantum chaos
SUMIYOSHI Takayuki	*Professor*	High Energy Physics with e+e-collider. Reactor Neutrino Physics.
TANUMA Hajime	*Professor*	Atomic Collisions and Spectroscopy, Highly Charged Ions, Ion Mobility
YASUDA Osamu	*Professor*	Physics Beyond the Standard Model, Neutrino Physics
ARAHATA Emiko	*Associate Professor*	Quantum Gases, Superconductivity, Superfluidity
EZOE Yuichirou	*Associate Professor*	X-ray Astronomy, Observation and Instrumentation
HATTORI Kazumasa	*Associate Professor*	Condensed Matter Theory, Strongly Correlated Electron Systems, Quantum Critical Phenomena
ISHISAKI Yoshitaka	*Associate Professor*	X-ray Astronomy, Microcalorimeter
JIDO Daisuke	*Associate Professor*	Theoretical Subatomic Physics, Dynamics and Structure of Hadrons
KADOWAKI Hiroaki	*Associate Professor*	Quantum State of Matter, Neutron Scattering
KAKUNO Hidekazu	*Associate Professor*	Experimental High Energy Physics, Experimental Neutrino Physics
KETOV Serguei	*Associate Professor*	Quantum Field Theory, Theoretical High Energy Physics, Cosmology
KURITA Rei	*Associate Professor*	Soft Matter, Phase Transition, Non-Equilibrium
MATSUDA Tatsuma	*Associate Professor*	Strongly Correlated Electron Systems, New Materials Research
MIYATA Yasumitsu	*Associate Professor*	Synthesis of Nanoscale Materials, Electrical and Optical Properties
YANAGI Kazuhiro	*Associate Professor*	Condensed Matter Physics in Nano Materials, Material Science
FURUKAWA Takeshi	*Assistant Professor*	Atomic and Molecular Physics, Nuclear and Fundamental Physics using Atoms
HIGASHINAKA Ryuji	*Assistant Professor*	Strongly Correlated Electron System, Low Temperature Physics
KITAZAWA Noriaki	*Assistant Professor*	Theoretical High Energy Physics, Beyond the Standard Model, String Models
KUMITA Tetsuro	*Assistant Professor*	High Energy Physics, Beam Physics
NAKAI Yusuke	*Assistant Professor*	NMR, Low-Temperature Condensed Matter Physics
OIKAWA Noriko	*Assistant Professor*	Softmatter, Nonlinear Physics
OTSUKA Hiromi	*Assistant Professor*	Statistical Physics, Condensed Matter Theory, Numerical Simulations
SAKAMOTO Hirokazu	*Assistant Professor*	ESR, Condensed Matter Physics, Organic conductors
SASAKI Shin	*Assistant Professor*	Astrophysics, Cosmology, Intergalactic Medium
TAKATSU Hiroshi	*Assistant Professor*	Solid State Physics, X-ray and Neutron Diffraction
TANAKA Atsushi	*Assistant Professor*	Quantum Physics, Nonlinear Physics, Quantum Chaos
YAMADA Shinya	*Assistant Professor*	X-ray Astronomy & Astrophysics, Black Hole Observation, X-ray Micro Calorimeter

Particle Theory

The purpose of our group is to study the microscopic structure of matter beyond the standard model, and we are conducting research within international collaborations on neutrino physics and mechanisms of mass generation of elementary particles.
(Keyword: Beyond the Standard Model, Neutrino physics, Spontaneous broken electroweak symmetry)

1. Faculty Members and Web Page

Names and e-mail addresses:
Professor: Osamu Yasuda (yasuda@phys.se.tmu.ac.jp)
Assistant Professor: Noriaki Kitazawa (kitazawa@phys.se.tmu.ac.jp)
http://musashi.phys.se.tmu.ac.jp/English/



2. Recent Activities

2-1) Neutrino Physics, Astroparticle Physics

Neutrino mass was discovered by the Superkamiokande experiment, which opened the door to a new frontier. This was followed by the solar neutrino and the KamLAND reactor experiments, which elucidated the existence of the three-flavor mixing of leptons. Stimulated by these developments, efforts have been made to clarify the overall structure of the leptonic mixing matrix, i.e., to discover the leptonic CP phase and determine the neutrino mass pattern. These goals are expected to be achieved by long baseline experiments with intense beams from accelerators in the near future. Our group has been conducting basic theoretical research to contribute to the experiments. Long baseline experiments with intense beams will enable us to look for deviations from the standard framework of three-flavor massive neutrinos, and they may offer us a hint about physics beyond the Standard Model. Such scenarios include non-standard interactions of neutrinos, light sterile neutrinos, violation of unitarity due to heavy particles. Our group has been studying possible physics at long baseline experiments such as T2K (JPARC at Tokai to Superkamiokande) or the proposed neutrino factory (with neutrino source obtained from muon decays). The existence of neutrino masses and mixings have quite important implications for understanding the structure of the fundamental hierarchy of matter, and it is expected that they reflect physics at a much higher energy scale, such as Grand Unified Theories. The information obtained through neutrinos is complementary to that obtained by the LHC (Large Hadron Collider) which has been running since 2010, and we are trying to probe the deep structure of nature by combining the information on quarks and leptons.

2-2) Origin of elementary particle mass (Physics of spontaneous broken electroweak symmetry)

The origin of elementary particle mass is a mystery. While it was experimentally established that the gauge symmetry called the electroweak symmetry exists, this symmetry requires masses of elementary particles to vanish. Since we know that the electron mass does not vanish, this symmetry must be broken spontaneously. The mechanism of this spontaneous symmetry breaking is unknown, and various theories have been proposed. We are studying the possibility that this mechanism can be understood using string theory. The LHC experiment, started at CERN in 2010, is intended to elucidate physics of electroweak symmetry breaking. String theory is a framework which enables the unified treatment of matter and its interactions, including gravity. In the present framework of quantum field theory, we first assume matter particles and turn on the interactions; therefore, we cannot predict the interaction which mediates electroweak symmetry breaking, and this is the origin of the mystery. String theory has the potential to solve this problem. However, (super) string theory is still incomplete and exhibits many theoretical problems. We are conducting research on string theory related to the accelerator experiment mentioned above, research toward resolution of the theoretical problems of string theory, and, research about possible string theory implications for cosmology.

3. Collaborating Institutions

Pisa, Scuola Normale Superiore

4. Recent Papers

1) “On nonadiabatic contributions to the neutrino oscillation probability and the formalism by Kimura, Takamura and Yokomakura” O. Yasuda, in Phys. Rev. D89 (2014) 093023.
2) “Pre-inflationary clues from String Theory?” N. Kitazawa, A. Sagnotti, JCAP 1404 (2014) 017.
3) “Detectability of the second resonance of low-scale string models at the LHC” M. Hashi, N. Kitazawa, JHEP 1303 (2013) 127.
4) “Spontaneous Gauge Symmetry Breaking in a Non-Supersymmetric D-brane Model” N. Kitazawa, S. Kobayashi, Phys. Lett. B720 (2013) 373-378.
5) “CMB Imprints of a Pre-Inflationary Climbing Phase” E. Dudas, N. Kitazawa, S.P. Patil, A. Sagnotti, JCAP 1205 (2012) 012.
6) “Signatures of low-scale string models at the LHC” M. Hashi, N. Kitazawa, JHEP 1202 (2012) 050.
7) “Search for sterile neutrinos at reactors” O. Yasuda, JHEP 1109 (2011) 036.
8) “Sensitivity of the T2KK experiment to the non-standard interaction in propagation” H. Oki, O. Yasuda, Phys. Rev. D82 (2010) 073009.
9) “On Climbing Scalars in String Theory” E. Dudas, N. Kitazawa, A. Sagnotti, Phys. Lett. B694 (2010) 80-88.

High-Energy Theoretical Physics

We are conducting research in theoretical high-energy physics by constructing new models of particle physics that include gravitational interactions. Those models are based on supergravity theory and the theory of superstrings, and can also be used as a mathematical description of the early universe. Our Masters program serves as an introduction to theoretical particle physics and general relativity. In our Doctoral program, students are required to perform original research leading to new results to be published in leading international scientific journals (in English). Therefore, we have very stringent selection criteria for our doctoral candidates.

(Keywords: quantum field theory, supersymmetry, supergravity, superstrings, cosmological inflation)

1. Staff Members and HP:

Associate Professor: Dr. Rer. Nat. Habil. S.V. Ketov (ketov@tmu.ac.jp)
S. Ketov homepage: http//kiso.phys.se.tmu.ac.jp/~ketov/ketov.htm
Laboratory Homepage: http://www.kiso.phys.se.tmu.ac.jp

2. Recent Activities

2-1) Natural inflation and string theory:
A novel framework is proposed for embedding the natural inflation into type IIA superstrings compactified on a Calabi-Yau (CY) three-fold. Inflaton is identified with axion of the Universal Hypermultiplet (UH). The other UH scalars (including dilaton) are stabilized by the CY fluxes, whose impact can be described by gauging of the abelian isometry associated with the axion, when the NS5-brane instanton contributions are suppressed. Then the stabilizing scalar potential is controlled by the integrable three-dimensional Toda equation and leads to spontaneous N=2 SUSY breaking. The inflationary scalar potential of the UH axion is dynamically generated at a lower scale in the natural inflation via non-perturbative quantum field effects such as gaugino condensation. The natural inflation has two scales that allow any values of the CMB. See Ref. [4] for more.

2-2) Chaotic inflation in supergravity theory:
We propose a large class of supergravity models in terms of a single chiral matter superfield, leading to (almost) arbitrary single-field inflationary scalar potentials similar to the F-term in rigid supersymmetry. Those scalar potentials are positively semi-definite (in our approximation), and can preserve supersymmetry at the end of inflation. The only scalar superpartner of inflaton is stabilized by a higher-dimensional term in the Kaehler potential. We argue that couplings of the inflaton to other sectors of the particle spectrum do not affect the inflationary dynamics, and briefly discuss reheating of the universe by the inflaton decays. See Refs. [2,3,7] for more.

2-3) Dark energy in modified f(R) gravity models:
We calculate the f(R) gravity functions in the dual f(R) gravity description of the quintessence models with a power-law scalar potential and a positive cosmological constant. We find that in the large curvature regime relevant to chaotic inflation in early Universe, the dual f(R) gravity is well approximated by the (matter) loop-corrected Starobinsky inflationary model. In the small curvature regime relevant to dark energy in the present universe, the f(R) gravity function reduces to the Einstein-Hilbert one with a positive cosmological constant. See Refs. [1,6,10] for more.

3. Collaborating Institutions

Kavli IPMU at the University of Tokyo, Yukawa ITP at the Kyoto University, Waseda University, Tokyo Institute of Technology,
CERN, DESY, KEK,
Oxford University, University of Maryland, University of Montpellier, Max-Planck Institutes in Munich and Potsdam, University of Hannover, Tomsk Polytechnic University

4. Recent Papers

1) S.V. Ketov and N. Watanabe, Phys. Lett. B741 (2015) 242
2) S.V. Ketov and T. Terada, JHEP 1412 (2014) 062
3) S.V. Ketov and T. Terada, Phys. Lett. B736 (2014) 272
4) S.V. Ketov, TSPU Bulletin 12 (2014) 124
5) S.V. Ketov, Phys. Rev. D89 (2014) 085042
6) S.V. Ketov and N. Watanabe, Mod. Phys. Lett. A29 (2014) 1450117
7) S.V. Ketov and T. Terada, JHEP 1312 (2013) 040
8) S.V. Ketov, PTEP (2013) 123B04
9) S.V. Ketov and T. Terada, JHEP 1307 (2013) 127
10) S.V. Ketov and S. Tsujikawa, Phys. Rev. D86 (2012) 023529.

5. Awards

Inoue Foundation Research Award 2005,
CERN Theory Division Research Award 2010,
Australian Government Endeavour Executive Award 2012,
Norway Research Council Award 2013.

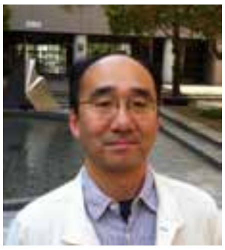
Nuclear Hadron Physics

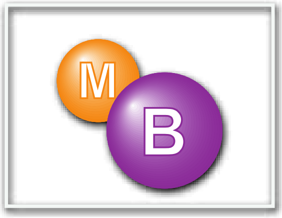
Hadrons interact with each other via the strong force, one of the fundamental forces in nature; for example, the nuclear force between protons and neutrons in the atomic nucleus is mediated by pions. Since quantum chromodynamics (QCD) has been established as the fundamental theory of the strong force, it is important that the structure and dynamics of hadrons be understood as a result of the dynamics of their subcomponents, quarks, and gluons. The Nuclear Hadron Physics group aims to solve important problems in nuclear hadron physics, such as why numerous hadrons exist in nature out of only a handful of quarks, how the hadronic mass is generated by the strong force, and what makes up the vacuum of QCD.

(Keyword: hadron physics, quantum chromodynamics, chiral symmetry, exotic hadron, hadrons in nuclei)

1. Staff Member:

Associate Professor: Daisuke JIDO
(jido@phys.se.tmu.ac.jp)
Home page:
http://www.comp.tmu.ac.jp/nuclth/index.html





2. Recent Activities

2-1) Hadrons in nuclei

The vacuum of the strong force is not trivial. In modern theoretical physics, the vacuum is defined as the ground state of the system, and it is not necessarily empty. The structure of the QCD vacuum is an important issue to be understood, because the nontrivial vacuum is considered to be responsible for quark confinement and mass generation. The strong force confines quarks to hadrons and gives rise to mass generation outside the Higgs mechanism, which explains only some percentage of the proton mass. Such fundamental phenomena can be studied by investigating hadronic properties in high temperature and/or density environments. Even inside the atomic nucleus, the vacuum is considered to change. Our group investigates the properties of hadrons in nuclear matter by considering nucleus-hadron bound systems to understand the QCD vacuum. We also propose possible experiments to demonstrate the change in the vacuum inside the atomic nucleus.

2-2) Exotic hadrons

There are two kinds of hadrons: mesons are composed of a quark and an antiquark, and baryons consist of three quarks. This is common knowledge in particle physics, but recently hadrons having more than three quarks/antiquarks have been observed, and we call these exotic hadrons. The fundamental theory of the strong force, QCD, does not forbid such multiquark particles, but only a few examples exist. This is one of the big mysteries of hadron physics, and it is an urgent issue to be solved both theoretically and experimentally. Another type of hadrons has also been proposed: a composite hadron itself composed of hadrons. One example is the Λ(1405) resonance, and it is considered to be a quasi-bound state of anti-kaon and nucleon. Because this group employs a wide study of hadrons, we understand the existence of possible forms of hadrons and propose new types of exotic hadrons. The study of the exotic hadron structure is an important foundation for understanding the dynamics of quark many-body systems.

3. Collaborating Institutions

Nara Women's University, Kyoto University, RIKEN, Tokyo Institute of Technology, University of Valencia, Yonsei University.

4. Recent Papers

1. *Pion properties at finite nuclear density based on in-medium chiral perturbation theory*, S. Goda, D. Jido, Prog. Theor. Exp. Phys. 2014, 033D03 (2014), DOI: 10.1093/ptep/ptu023.
2. *Lambda(1405) photoproduction based on chiral unitary model,* S.X. Nakamura, D. Jido, Prog. Theor. Exp. Phys. 2014, 023D01 (2014), DOI: 10.1093/ptep/ptt121
3. *In-medium eta' mass and eta' N interaction based on chiral effective theory*, S. Sakai, D. Jido, Phys. Rev. C 88, 064906 (2013), DOI: 10.1103/PhysRevC.88.064906.
4. *The nature of the Lambda(1405) resonance in chiral dynamics*, T. Hyodo, D. Jido, Prog. Part. Nucl. Phys. 67, 55-98 (2012). DOI: 10.1016/j.ppnp.2011.07.002
5. *Nuclear bound state of eta'(958) and partial restoration of chiral symmetry in the eta' mass*, D. Jido, H. Nagahiro, S. Hirenzaki, Phys. Rev. C 85, 032201(R) (2012), DOI: 10.1103/PhysRevC.85.032201
6. *Branching ratios of mesonic and nonmesonic antikaon absorptions in nuclear medium,* T. Sekihara, J. Yamagata-Sekihara, D. Jido, Y. Kanada-En'yo, Phys. Rev. C 86, 065205 (2012), DOI: 10.1103/PhysRevC.86.065205
7. *Compositeness of dynamically generated states in a chiral unitary approach*, T. Hyodo, D. Jido, A. Hosaka, Phys. Rev. C 85, 015201 (2012), DOI: 10.1103/PhysRevC.85.015201
8. *Diquarks: a QCD sum rule perspective,* K.I. Kim, D. Jido, S.H. Lee, Phys. Rev. C 84, 025204 (2011), DOI: 10.1103/PhysRevC.84.025204.
9. *Composite and elementary natures of a1(1260) meson,* H. Nagahiro, K. Nawa, S. Ozaki, D. Jido, A. Hosaka Phys. Rev. D 83, 111504(R) (2011), DOI: 10.1103/PhysRevD.83.111504.
10. *Multi-quark hadrons from Heavy Ion Collisions,* S. Cho *et al.* (ExHIC collaboration), Phys. Rev. Lett. 106, 212001 (2011), DOI: 10.1103/PhysRevLett.106.212001.

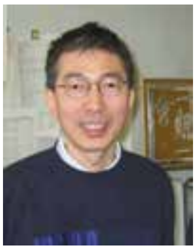
5. Awards

Jido, May 2000, Doctoral Thesis Award given by Tejima Seiichi Commemorative Foundation
Jido, May 2002, Rookie Paper Award given by Division of Nuclear Theory in the Physical Society of Japan.
Jido, 2004, Alexander von Humboldt Fellowship.

Theoretical Astrophysics

Astrophysics research at our group of Tokyo Metropolitan University (TMU) covers the fields of high-energy astrophysics and observational cosmology related to the structure formation of the universe. Astronomical systems of interest include supernova and supernova remnants, neutron stars, black holes, gamma-ray bursts, galaxies and clusters of galaxies, interstellar medium, and intracluster medium. For understanding the properties of such objects and their activities, particularly high-energy phenomena in the relativistic regime, we also study fundamental physical processes: particle acceleration and collisions, radiation and transport, etc.
(Keyword: high-energy astrophysics, observational cosmology)

1. Staff Members and HP




Professor: K. Masai (masai@phys.se.tmu.ac.jp)

Assistant Professor: S. Sasaki (sasaki@phys.se.tmu.ac.jp)

Home Page: http://www-astro.phys.se.tmu.ac.jp

2. Recent Activities

2-1) Supernova Remnants

Supernova remnant (SNR) is a shock-heated hot plasma formed by the interaction of supernova ejecta with ambient matter, following supernova explosion. Since the time scale for ionization equilibrium is longer than that required for electrons to be heated to a few keV, plasmas of X-ray emitting young SNRs are ionizing or under-ionized. However, it is found recently that some SNRs exhibit spectra of recombining plasmas. Those are categorized into mixed-morphology SNRs, which show shell-like radio and center-filled X-ray emission, and are characterized also by GeV/TeV gamma-ray emission.

We have investigated the origin of a recombining plasma and mixed radio/X-ray morphology. Considering a core-collapse supernova that exploded in its past stellar-wind matter, we investigated the evolution of the remnant (SNR) and successfully demonstrated that the reverse-shocked ejecta and stellar- wind matter rapidly cooled to be recombining by rarefaction, and the mixed morphology appeared when the blast-wave broke out of the stellar-wind matter into the rarefied interstellar medium. We also demonstrated that the intensities of GeV/TeV gamma- rays as well as synchrotron radio predicted by our SNR model were consistent with the observations.

2-2) Clusters of Galaxies

Cluster of galaxies is a self-gravity system which consists of 10 to 1000 galaxies, hot gas (called intracluster gas) and dark matter. In typical virialized clusters, the gas temperature is comparable with the gravitational potential, which is formed mainly by the dark matter; the mass ratios of dark matter and gas to galaxies are ~30 and ~5, respectively. The cluster mass can be estimated from X-ray observations by assuming that the intracluster gas is in a hydrostatic balance. We have investigated the validity of this manner by hydrodynamical simulations, and found that the mass thus estimated was smaller than the true mass because of the accelerated term in the Euler equation.

The intracluster gas radiatively cools with time, and the time scale is shorter in a cluster core than the Hubble time. Hence, outer hot gas could flow into the core to compensate lowering pressure. If such an inflow occurred drastically, a large amount of cold gas would be observed in the core center, but no evidence has been found. We consider a quasi-hydrostatic condition that the local inflow rate is controlled by the local cooling rate, and thus inflow is kept mild, while sound crossing time is enough shorter than cooling time. Based on this model, for a cool core we calculated the profiles of the electron temperature, density, gas pressure and entropy and compared the calculated profiles with observations. We found that the quasi-hydrostatic cooling model explains those profiles, and also two distinct peaks in the core-size distribution of clusters, fairly well.

2-3) Other ongoing research subjects

- Relativistic shock-breakout and gamma-ray bursts
- Extraction of the spin energy from a Kerr hole

3. Collaborating Institutions

Univ. of Tokyo, Kyoto Univ., Nara Women's Univ.

4. Recent Papers

1) Shimizu, Masai & Koyama, Evolution of Supernova Remnants Expanding out of the Dense Circumstellar Matter into the Rarefied Interstellar Medium, PASJ 64 (2012) 24

2) Ota, Onzuka & Masai, Density Profile of a Cool Core of Galaxy Clusters, PASJ 65 (2013) 47

3) Shimizu, Masai & Koyama, Non-Thermal Radio and Gamma-Ray Emission from a Supernova Remnant by the Blast Wave Breaking Out of the Circumstellar Matter, PASJ 65 (2013) 69

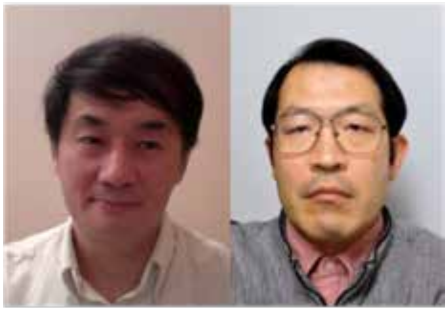
4) Suto et al., Validity of Hydrostatic Equilibrium in Galaxy Clusters from Cosmological Hydrodynamical Simulations, ApJ 767 (2013) 79

5) Mitsuishi et al., Exploring Hot Gas at Junctions of Galaxy Filaments with Suzaku, ApJ 783 (2014) 137

Nonlinear Physics

Classical and quantum mechanics in multi-dimensions are qualitatively different from those in one-dimension, because they are no more integrable in general, and chaos appears in the dynamics. This brings a great deal of complexity or even richness both to classical and quantum dynamics. We study chaos in classical and quantum mechanics in Hamiltonian systems, especially in generic systems that are neither completely integrable nor fully chaotic. Systems with mixed phase space are an inexhaustible source of nontrivial questions that are relevant for our understanding of the dynamics at microscopic levels.

(Keyword: Quantum chaos, Hamiltonian systems, Semiclassical analysis, Exotic quantum holonomy)



1. Staff Members and HP

Professor: Akira Shudo (shudo@tmu.ac.jp)
Assistant Professor: Atushi Tanaka (tanaka-atushi@tmu.ac.jp)

Home Page
http://www.comp.tmu.ac.jp/nonlinear/en/index.html

2. Recent Activities

2-1) Quantum chaos

Quantum chaos is a name of the research subject exploring the quantum manifestation of classical chaos. As is well known, chaos appears only in classical dynamics and does not exist in quantum mechanics in its strict sense. However, chaos in classical mechanics significantly affects the nature of quantum mechanics, and gives rise to various new phenomena absent in the system without chaos. Our group has been focused on purely quantum mechanical phenomena such as quantum tunneling or localization of wave functions. These have wave mechanical origins and have apparently no link to classical mechanics; nevertheless, classical chaos leaves clear fingerprints, even in such purely quantum phenomena. We take the semiclassical approach to understand how classical chaos enriches the corresponding quantum mechanics.

2-2) Classical Hamiltonian Dynamics

The phase space of generic Hamiltonian systems is composed of regular and chaotic regions, and various types of invariant structures coexist in a highly complicated manner. The orbits in chaotic components are strongly influenced by those in regular regions, and the nature of long-time correlation significantly differs from that expected in the uniformly hyperbolic system. Our motivation to study classical dynamics in Hamiltonian systems is to seek the origin of slow motions in nature from the microscopic dynamical levels. Our investigation targets systems with a few degrees of freedom to many dimensional systems. For the latter cases, there exist situations in which typical scenarios applied to systems with only a few degrees of freedom do not work.

2-3) Complex WKB analysis

The semiclassical method is a widely technique used to obtain asymptotic solutions of differential equations or to evaluate the integral with a small (or large) parameter. However, semiclassical expansions are asymptotic at best and divergent in general; therefore, ambiguities remain in its practical use. In particular, since controlling the exponentially small terms is usually beyond the treatment of asymptotic expansions, the so-called Stokes phenomenon has been handled only in a heuristic manner. We are applying recently developed mathematics, called the exact WKB method, to several physical problems such as quantum tunneling in the presence of chaos, multilevel nonadiabatic transition problems, and so on.

2-4) Exotic quantum holonomy

Adiabatic cycles may induce nontrivial changes in quantum systems. A famous example is Berry's phase, which is also called as a phase holonomy. Besides, (quasi-)eigenenergies and eigenspaces of stationary states exhibit nontrivial change, which is referred to as exotic quantum holonomy. We are investigating this phenomenon in various physical systems and seeking its topological structure.

3. Collaborating Institutions

Ritsumeikan University, Kyushu University, RIMS in Kyoto University, Technical University of Dresden, Universite Francois Rabelais de Tours, Lancaster University, Kochi University of Technology, Pusan National University.

4. Recent Papers

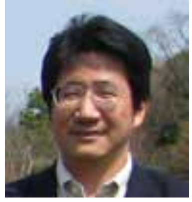
1) A. Shudo, Y. Ishii and K.S. Ikeda, J. Phys.A: Math. Theor., 42 (2009) 265101 (26pages).
2) A. Shudo, Y. Ishii and K.S. Ikeda, J. Phys.A: Math. Theor., 42 (2009) 265102 (34pages).
3) A. Ishikawa, A. Tanaka and A. Shudo, Phys. Rev. Lett., 104 (2010) 224102-1-4.
4) A. Shudo and K.S. Ikeda, in "Dynamical Tunneling" edited by S. Keshavamurthy and P. Schlagheck (CRC Press, 2011) Chapter 7, pp.139-176.
5) A. Akaishi, M. Hirata, K. Yamamoto and A. Shudo, J. Phys. A : Math. Theor. 44 (2011) 375101-1-12.
5) A. Shudo and K.S. Ikeda, Phys. Rev. Lett. 109 (2012) 154102-1-5.
7) A. Shudo, .Y Hanada, T. Okushima and K.S. Ikeda, Europhys. Lett., 108 (2014) 50004-1-5.
8) A. Tanaka, T. Cheon and S. W. Kim, J. Phys. A: Math. Theor. 45 (2012) 335305 (20pages).
9) A. Tanaka, N. Yonezawa and T. Cheon, J. Phys.: Math. Theor. 46 (2013) 315302 (17pages).
10) A. Tanaka, S. W. Kim and T. Cheon, Phys. Rev. E 89 (2014) 042904 (8pages).

Quantum Condensed Matter Theory

Every material around us is composed of numerous atomic nuclei and electrons. It sometimes exhibits various fascinating interaction-caused phenomena that cannot be expected from a single-particle viewpoint. Theoretical condensed matter physics aims to understand these phenomena and predict new properties based on thermodynamics, statistical mechanics, quantum mechanics, quantum field theory, etc. Our research includes studies of ultracold atoms, superconductivity, superfluidity, critical phenomena, spin systems, simulation techniques, and others. The Quantum Condensed Matter Theory Group actively works on a variety of topics, some of which are shown above, and leads graduate students to the frontier of physics research.

(Keyword: condensed matter, superconductivity, superfluidity, critical phenomena, statistical physics)





1. Staff Members and HP

Professor: H. Mori (mori@phys.se.tmu.ac.jp)
Associate Professor: E. Arahata (arahata@phys.se.tmu.ac.jp)
Assistant Professor: H. Otsuka (otsuka@phys.se.tmu.ac.jp)
http://www.comp.tmu.ac.jp/cmtg0/index_e.html

2. Recent Activities

2-1) Ultracold Bose-Fermi atoms

Recent developments in trapping and cooling neutral atoms enable us to build up a mixed system of ultracold Bose-Fermi atoms. Mixing different quantum statistics particles opens up new possibilities in quantum condensed matter physics. We can then focus on specific phenomena expected in the Bose-Fermi mixture systems.

Included in our study target are phase diagrams, the internal structure of a mixed Mott phase, the localization effect of random potentials, the effect of interactions between Bose-Fermi interactions, the fermion-induced Mott transition of bosons, etc.

To solve these problems we employ a variety of tools from analytical calculation to numerical calculation, including renormalization group technique, numerical computation of the Gross-Pitaevskii equation, quantum Monte Carlo calculation, and more.

The effect of a synthesized electromagnetic field applied to mixture systems is also of our recent interest. Unlike electrons in an electromagnetic field, a mixture of bosons and fermions is expected to have rich physical properties that we are trying to unveil.

2-2) Superfluid in ultracold atomic gases and unconventional superconductors

We study theoretically basic properties of superfluid in ultracold atomic gases. A superfluid behaves like a fluid with zero viscosity and is strongly connected with superconductors. One of the phenomena currently attracting attention is the dynamics of superfluid in ultracold atomic gases. We focus on the propagation of sounds and fluxes, which are specific properties of superfluid. We analyze these phenomena qualitatively and quantitatively by deriving general expression.

We also study basic properties of unconventional superconductors. Specifically, we focus on the noncentrosymmetric heavy Fermion superconductors, which show superconductivity together with magnetic order. We study theoretically further unusual properties that arise out of the interplay of magnetism and superconductivity.

One purpose of our studies is to find common properties of superfluidity and superconductivity in a variety of different systems.

2-3) New Monte-Carlo method

Frustration effects are of importance in condensed matter physics because they can result in unconventional phases and exotic excitations. Spin-ice materials such as $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ do not order down to low temperature and exhibit residual entropy as a hallmark of frustration.

Recently, we invented a cluster algorithm for Monte Carlo simulation of a spin-ice model in which ten types of graphs are introduced to decompose the system into a mixture of loops and strings.

This method, the loop-string algorithm, has some good points:

- It is free from the so-called spin-freezing problem.
- It is a simple enough implementation that it could provide a building block for simulations of more complicated systems with ice-type degeneracy.

Using the loop-string algorithm, we clarified that Debye screening works among magnetic monopole-like excitations, and that the deconfinement transition triggered by a fugacity of monopoles z is dictated by a singular part of the free-energy density proportional to z.

3. Collaborating Institutions

University of Tokyo, Tokyo University of Science, University of Hiroshima, Nara Medical University Institute for Solid State Physics, ETH Zurich, Princeton University.

4. Recent Papers

1) A. Masaki and H. Mori J. Phys. Soc. Jpn. 82, (2013) 074002.
2) N. Miyamoto and H. Mori, J. Phys. Soc. Jpn. 82, (2013) 105001.
3) E. Arahata and T. Nikuni, Phys. Rev. A 90 043601 (2014)
4) M. Achermann, T. Neupert, E. Arahata, and M. Sigrist J. Phys. Soc. Jpn 83, (2014) 044712.
5) E. Arahata and Y. Kato J. Low Temp. Phys. 175, (2014) 346.
6) E. Arahata and T. Nikuni, Phys. Rev. A 87, (2014) 033601.
7) H. Otsuka, Phys. Rev. B 90 (2014) 220406(R).
8) H. Otsuka, H. Takatsu, K. Goto, and H. Kadowaki, Phys. Rev. B 90, (2014) 144428.
9) H. Takatsu, K. Goto, H. Otsuka, R. Higashinaka, K. Matsubayashi, Y. Uwatoko, and H. Kadowaki, J. Phys. Soc. Jpn 82, (2013) 073707.
10) H. Otsuka, Phys. Rev. Lett. 106, (2011) 227204.

Strongly Correlated Electron Theory

Research on the properties of strongly correlated electron system is one of the central issues in condensed matter physics. Typical target materials are d-electron systems of transition metal compounds and f-electron systems such as actinide and rare earth compounds. Most theoretical studies of these systems have traditionally concentrated on simple models that ignore orbital and/or phonon degrees of freedom. However, to understand the magnetism and superconductivity that have been recently discovered in such systems, it is essential to consider multiple degrees of freedom, such as electron orbital and lattice vibration, in addition to spin and charge. By exploiting both analytical and numerical techniques, we develop theoretical research on magnetism and superconductivity in strongly correlated electron systems with new degrees of freedom and explore the novel quantum criticality emerging from the competition between the itinerant and localized nature of electrons.

(Keywords: electron correlation, magnetism, superconductivity, quantum criticality, orbital, phonon)

1. Staff Members and HP

Professor: T. Hotta (hotta@phys.se.tmu.ac.jp)
Associate Professor: K. Hattori (hattori@phys.se.tmu.ac.jp)
Home Page
http://www.comp.tmu.ac.jp/scet-lab/

2. Recent Activities

2-1) Chaos in Jahn-Teller rattling

We unveil chaotic behavior hidden in the energy spectrum of a Jahn-Teller ion vibrating in a cubic anharmonic potential as a typical model for rattling in cage-structure materials. When we evaluate the nearest-neighbor level-spacing distribution P(s) of eigenenergies of the present oscillator system, we observe the transition of P(s) from the Poisson to the Wigner distribution with the increase of cubic anharmonicity, showing the occurrence of chaos in the anharmonic Jahn-Teller vibration. The energy scale of the chaotic region is specified from the analysis of P(s), and we discuss a possible way to observe chaotic behavior in the specific heat experiment. It is an intriguing possibility that chaos in nonlinear physics could be detected by a standard experiment in condensed matter physics.

2-2) Two-channel Kondo effect emerging from a vibrating magnetic ion coupled with two-orbital conduction bands

When a magnetic ion vibrates in a metal, it inevitably introduces a new channel of hybridization with conduction electrons, and in general, the vibrating ion induces electric dipole moment. In such a situation, we find that magnetic and non-magnetic Kondo effects alternatively occur due to the screening of spin moment and electric dipole moment of vibrating ion. In particular, the electric dipolar two-channel Kondo effect is found to occur for a weak Coulomb interaction U. We also show that a magnetically robust heavy-electron state appears near the fixed point of the electric dipolar two-channel Kondo effect. We also analyze non-Fermi liquid properties along a line of critical points and find that the thermodynamic singularity for small U differs from that of the conventional two-channel Kondo problem.

2-3) Superconductivity near a transverse saturation field in Ising ferromagnetic metals.

We investigate re-entrant superconductivity in an Ising ferromagnetic superconductor URhGe under a transverse magnetic field h. The superconducting transition temperatures for p-wave order parameters T_{SC} are calculated and show two domes as a function of h. We find strong enhancement of T_{SC} in the high-field superconductivity near a saturation field h^*, where all the spins align in the transverse direction. Soft magnons emerging near h^* play an important role in realizing strong attractive interactions between conduction electrons.
We also discuss h dependence of superconducting d-vector and predict the direction of the d-vector near h^*, which corresponds to Cooper pairs with almost equal superposition of up-up and down-down spin electrons.

3. Collaborating Institutions

Faculty of Science, University of the Ryukyus
Institute for Solid State Physics, University of Tokyo
Advanced Science Research Center, Japan Atomic Energy Agency
Institute for Theoretical Physics, University of Cologne

4. Recent Papers

1) T. Hotta and A. Shudo, J. Phys. Soc. Jpn. **83**, 083705 (2014).
2) T. Hotta, J. Phys. Soc. Jpn. **83**, 104706 (2014).
3) K. Hattori and A. Rosch, Phys. Rev. B **90**, 115103 (2014).
4) Y. Hasegawa, T. Maehira, and T. Hotta, J. Mod. Phys. **4** 1574 (2013).
5) K. Hattori and H. Tsunetsugu, Phys. Rev. B **87**, 064501 (2013).
6) T. Hotta and K. Ueda, Phys. Rev. Lett. **108**, 247214 (2012).
7) K. Hattori, Phys. Rev. B **85**, 214411 (2012).
8) F. Niikura and T. Hotta, Phys. Rev. B **83**, 172402 (2011).
9) K. Hattori, J. Phys. Soc. Jpn. **79**, 114717 (2010).
10) T. Hotta, J. Phys. Soc. Jpn. **79**, 094705 (2010).

5. Awards

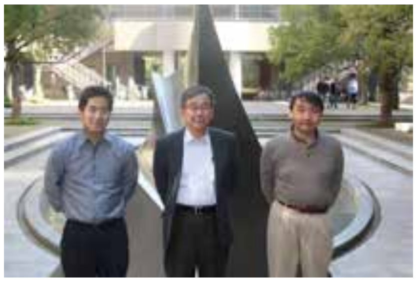
T. Hotta, President Prize for Most Valuable Research, Japan Atomic Energy Research Institute, 2004.
T. Hotta, The 8th Ryogo Kubo Memorial Prize, Inoue Foundation for Science, 2004.
T. Hotta, Award of JPSJ Papers of Editors' Choice, 2009.
K. Hattori, Award of JPSJ Papers of Editors' Choice, 2010.

Experimental High Energy Physics

Why we are made of matter, but not anti-matter? This question is quite simple to ask but very difficult to answer. We, as members of the experimental high energy physics group, research the fundamental physics of microscopic or high-energy states using experimental approaches to find answers to questions like this.
We participate in world-wide collaborative experiments, notably Belle II, Double Chooz, and T2K. Belle II is the next-generation B-factory experiment. Double Chooz and T2K are reactor-based and accelerator-based neutrino oscillation experiments, respectively. We also participate in relatively small experimental projects, DCBA, SND, and UNI. DCBA is a tracking-based double beta-decay experiment, SND is studying a new technique for detecting ultra-high energy neutrinos, and UNI is an experiment that searches for 5-gamma decay of positronium.
(Keywords: high energy physics, flavor physics, B physics, neutrino physics, double beta decay)

1. Staff Members and HP

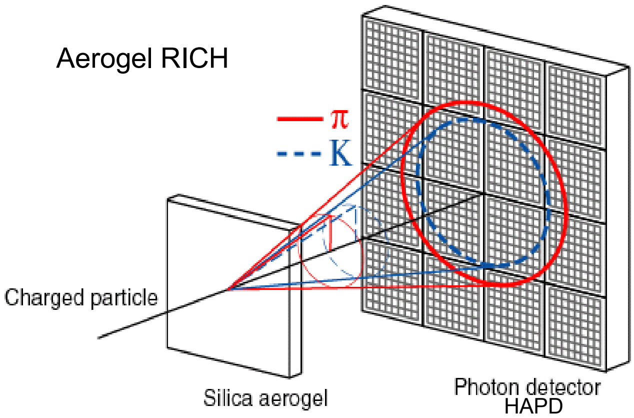
Names and e-mail addresses
Professor : T. Sumiyoshi (sumiyoshi@phys.se.tmu.ac.jp)
Associate Professor: H. Kakuno (kakuno@phys.se.tmu.ac.jp)
Assistant Professor: T. Kumita (kumita@phys.se.tmu.ac.jp)
Home Page
http://www-hep.phys.se.tmu.ac.jp



2. Recent Activities

2-1) Belle II experiment

The Kobayashi-Maskawa Mechanism, a part of the Standard Model, has been confirmed at the Belle experiment through studies of CP violations in B-meson decays. The Standard Model is successful in explaining almost all the experimental results of particle physics, but it may not be the ultimate theory of everything. The Belle II experiment searches for new physics beyond the Standard Model through precise measurements of B-meson decays. To find small signs that cannot be explained by the Standard Model, Belle II employs high- precision particle identification devices. The TMU-HEP group joins the development of the Aerogel RICH counter used as the endcap particle identification device of the Belle II detector. We developed a photo detector called HAPD and its readout ASICs.



2-2) Double Chooz experiment

Neutrino oscillation was first observed in 1998, which requires that neutrinos have non-zero mass. Neutrino oscillation parameters consist of two mass differences, three mixing angles, and a CP phase. Most of the oscillation parameters had been measured by many experiments in the world, but a mixing angle θ_{13} (and the CP phase δ) remained unknown. The Double Chooz experiment was created to measure θ_{13} via anti-electron neutrino disappearance of reactor neutrinos. Double Chooz claimed the first indication of anti-electron neutrino disappearance in 2011. Precise measurement of θ_{13} is important for the study of the last unknown and most important oscillation parameter, δ. In early 2015, the commissioning of the near detector is to be finished.

2-3) T2K experiment

The T2K experiment also aims to measure the neutrino mixing angle θ_{13} but the method is complimentary to that of Double Chooz. T2K uses a muon neutrino beam made by the J-PARC accelerator to observe electron neutrino appearance. In 2013, T2K discovered the neutrino appearance for the first time. T2K is planning to upgrade both its accelerator and far detector to measure the CP-violating phase, δ.

3. Collaborating Institutions

KEK, Niigata-U, TITech, Tohoku-U, IJS, and so on.

4. Recent Papers

1) "The physics of B factories", European Physics Journal C, 74:3026 (2013)
2) "Indication of Reactor $\bar{\nu}_e$ Disappearance in the Double Chooz Experiment", Phys. Rev. Lett. 108, 131801 (2012)
3) "Observation of Electron Neutrino Appearance in a Muon Neutrino Beam", Phys. Rev. Lett. 112, 061802 (2014)

5. Awards

T. Konno, 8th Young Scientist Award of the Physical Society of Japan

Atomic Physics

The Atomic Physics Laboratory is one of the oldest research groups in our department. Since 1949, this laboratory has been investigating the dynamics and spectroscopy in a variety of atomic/molecular collision systems using several self-developed apparatus. We cover a wide energy range from meV to GeV in the collisions of ionic projectiles, including highly charged ions and heavy molecular ions, with electron, atom, molecule, and crystal targets. We maintain a very strong collaboration with The Laboratory of Physical Chemistry of Molecular Structure and Reaction in our university and also The Atomic, Molecular and Optical Physics Laboratory in RIKEN.

(Keywords: Atomic, Molecular and Optical Physics; Atomic and Molecular Collisions; Atomic and Molecular Spectroscopy; Electrostatic Ion Storage Ring; Multiply Charged Ions; Ion Swarms; Atomic Data)

1. Staff Members and HP

Professor: H. Tanuma (tanuma-hajime@tmu.ac.jp)
Assistant Professor: T. Furukawa (takeshi@tmu.ac.jp)
Guest Professor: T. Azuma (toshiyuki-azuma@riken.jp)
Home Page
http://atom.phys.se.tmu.ac.jp

2. Recent Activities

2-1) Electrostatic Ion Storage Ring

An electrostatic ion storage ring is one of the most powerful tools used to investigate the dynamics and spectroscopy of ions. We developed a liquid-nitrogen-cooled apparatus, the TMU E-Ring, combined with a tunable optical parametric oscillator laser. Recently, we have become strongly interested in the cooling mechanism of highly vibrationally excited molecular ions produced with a laser ablation ion source and a Cs sputter negative ion source. A picture of the ring is shown in Figure 1.

Figure 1. TMU E-Ring, the third electrostatic ion storage ring in the world.

2-2) Multiply Charged Ion Collisions

We have a 14.25 GHz electronic cyclotron resonance ion source for the production of multiply charged ions. Using this ion source, we have performed measurements of charge transfer cross sections and charge exchange spectroscopy of multiply charged ions with neutral gases in the keV collision energy region to obtain atomic data for analysis of X-ray astrophysics, development of X-ray light sources, and diagnostic of fusion plasmas.

2-3) Low Temperature Ion Drift Tube

Ion swarm experiments have been performed using a very low temperature ion drift tube mass spectrometer cooled with liquid helium. Our main interest is the very low collision dynamics of atomic and small molecular ions with helium gas atoms at meV region. We are currently measuring the mobility of small molecular ions in helium gas to investigate the collision dynamics and the interaction potential energy between ions and neutral atoms.

2-4) Ion Mobility Spectrometry

Ion mobility measurements can be applied to micro-chemical analysis. We are collaborating in a national project to develop handy chemical warfare agent detectors. In our laboratory, we study fundamental phenomena such as production of ions by corona discharge and diffusion of ions in air.

2-5) Resonance Coherent Excitation

Fast ions passing through a solid crystal feel a periodic electronic potential in the crystal. When the period matches the transition frequency, the ion can be excited. Using this principle, we perform precise atomic spectroscopy of highly charged ions with relativistic energies in the GeV region at the Heavy Ion Medical Accelerator in Chiba.

2-6) Nuclear and Fundamental Physics using Atoms

One of our members (TF) works for the laser spectroscopic study of exotic nuclear structure in a superfluid helium environment, in collaboration with RIKEN, and also for the measurement of a permanent electric dipole moment in ^{129}Xe atoms, which indicates strong *CP*-violation in fundamental physics, in collaboration with Tokyo Institute of Technology.

3. Collaborating Institutions

Institute of Physical and Chemical Research (RIKEN), Kyoto University, University of Electro-Communications, Sophia University, Rikkyo University, Tokyo Institute of Technology, Osaka University, National Institute for Fusion Science, National Research Institute of Police Science, University of Gothenburg, University College Dublin, Institute for Applied Physics and Computational Mathematics

4. Recent Papers

1) N. Numadate *et al.*, Rev. Sci. Instrum. **85**, 103119 (2014).
2) G. Ito *et al.*, Phys. Rev. Lett. **112**, 183001 (2014).
3) M. Goto *et al.*, J. Chem. Phys. **139**, 054306 (2013).
4) M. Goto *et al.*, Phys. Rev. A **87**, 033406 (2013).
5) T. Furukawa *et al.*, Nucl. Instr. Meth. B **317**, 590 (2013).
6) Y. Ichikawa *et al.*, Nature Physics **8**, 918 (2012).
7) Y. Nakano *et al.*, Phys. Rev. A **85**, 020701 (2012).
8) H. Tanuma *et al.*, Phys. Rev. A **84**, 042713 (2011).
9) T. Sato *et al.*, Eur. Phys. J. D **63**, 189 (2011).
10) H. Ohashi *et al.* J. Phys. B **43**, 065204 (2010).

Experimental Astrophysics

The experimental astrophysics laboratory observes X-rays from the universe using X-ray satellites to clarify the nature of the universe and to solve astrophysical mysteries. We aim to develop X-ray detectors and new X-ray optics in-house. We perform astrophysical research (e.g., cluster of the galaxies, black holes, and planets) with X-ray missions in cooperation with researchers all over the world. We expand our research activity dynamically on a global scale.
(Keyword: astrophysics, X-ray satellites, superconducting detector, MEMS, X-ray mirrors)

1. Staff Members and HP

Professor: T. Ohashi (ohashi@phys.se.tmu.ac.jp)
Associate Professor: Y. Ishisaki (ishisaki@phys.se.tmu.ac.jp)
Associate Professor: Y. Ezoe (ezoe@phys.se.tmu.ac.jp)
Assistant Professor: S. Yamada (yamada@phys.se.tmu.ac.jp)
Home Page:
http://www-x.phys.se.tmu.ac.jp/home/wp/?lang=en

2. Recent Activities

2-1) Suzaku & ASTRO-H X-ray satellites

By using X-ray satellites, such as Suzaku (2005), we have conducted observational astrophysical research. X-ray microcalorimeters aboard the ASTRO-H satellite (expected 2015/2016) provide the world's highest energy resolution detector, the Soft X-Ray Spectrometer (SXS). This laboratory strongly contributes to the SXS system. Observation of high-energy cosmic phenomena, such as galaxies and clusters filled with high-temperature plasma and dark matter, black holes, and supernova remnants, allows us to explore the evolution and diversity of cosmic structures. The ASTRO-H satellite will play a key role in addressing intriguing questions.

2-2) Detector development

For future satellites, the laboratory also develops superconducting transition edge detectors (TES) and ultra-lightweight mirrors (MEMS mirrors). TES enables us to achieve better energy resolution than the ASTRO-H microcalorimeters. Based on cutting-edge technology, MEMS optics delivers the world's lightest X-ray mirrors.

2-3) Astrophysics

Our group aims to reveal the full picture of the evolution of the universe: how stars, galaxies, and clusters of galaxies, and large-scale structure that we observe, have evolved over cosmic time scales. In recent years, studies of the interactions between black holes, galaxies, and clusters of galaxies are becoming the center of interest of many astrophysicists. ASTRO-H, with its capability of observing dynamical and non-thermal processes simultaneously, will give us clear answers.

We carry out observational studies of wide categories of objects, from solar system to distant clusters and active galactic nuclei, in collaboration with outside groups.

3. Collaborating Institutions

JAXA/ISAS, NASA/GSFC, AIST, Univ. of Tokyo, Kyoto Univ. Kanazawa Univ., RIKEN, Rikkyo Univ., Tokyo Univ. of Science, Nagoya Univ., MIT, SRON, etc.

4. Recent Papers

1) “Radiation Tolerance Evaluation of the Ti/Au Bilayer TES Microcalorimeter”, Y. Ishisaki et al. (2014), JLTP, 176, 344
2) “Development of Multilayer Readout Wiring TES Calorimeter for Future X-ray Missions”, S. Yamada e al., (2014), JLTP, 176, 310
3) “Temperature and entropy profiles to the virial radius of the Abell 1246 cluster observed with Suzaku”, K. Sato, T. Ohashi et al. (2014), PASJ, 66, 85
4) “Tapered Edge Readout Wiring for Transition Edge Sensor Calorimeter Arras Using Ion Milling”, Y. Ezoe et al., IEEE TAS, (2015), DOI10.1109/TASC.2014.2374415

Correlated Electron Physics

During the last two decades, an enormous number of strongly interacting electrons in solid materials have been observed exhibiting various novel physical phenomena, such as unconventional superconductivity, quantum critical (non-Fermi liquid) behaviors, and exotic types of magnetism (multipolar orderings/fluctuations), that cannot be understood within the framework of conventional solid state physics. Our group aims to create and observe unprecedented and innovative electronic states in new materials, focusing on multiple-degrees of freedom involved in *d*- and *f*-electron, i.e., spin, orbital, charge, and ion vibration. For this purpose, we explore new compounds, grow world class high-quality single crystals by exploiting different types of furnaces, and perform systematic measurements of transport, magnetic, and thermodynamic properties to improve our fundamental understanding of novel phenomena, in collaboration with many institutions around the world. We are also interested in the application of our findings as novel functional materials.

(Keywords: strongly-correlated electrons, superconductivity, quantum critical phenomena, multipole)

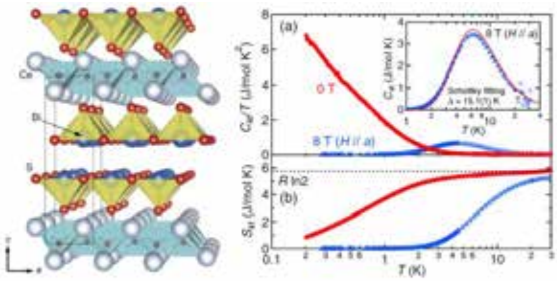
1. Staff Members and HP

Professor : Y. Aoki (aoki@tmu.ac.jp)
Associate Professor : T. Matsuda (tmatsuda@tmu.ac.jp)
Assistant Professor : R. Higashinaka (higashin@tmu.ac.jp)
Home Page
http://denshi-server.phys.se.tmu.ac.jp

2. Recent Activities

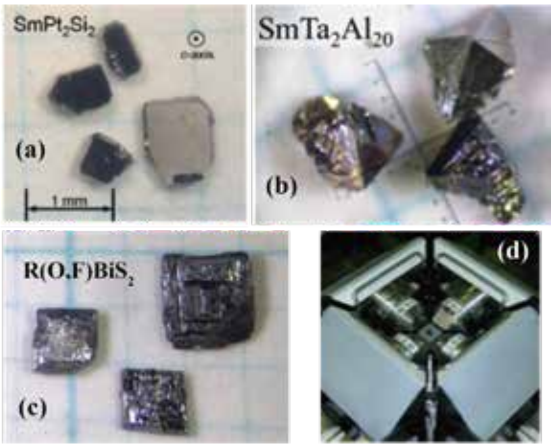
2-1) New class of unconventional superconductors and novel electronic states

Newly found layered superconductors *Ln*(O,F)BiS_2 (*Ln*: rare earth) are found to show not only anomalous superconducting properties but also exotic magnetism of *Ln* ions. In the mother compound, $CeOBiS_2$, we have observed a log*T* divergence of specific heat at low temperatures, indicating that this material is located in the vicinity of a quantum critical point (QCP), where quantum fluctuations of magnetic moments dominate. This is the first realization of *QCP in a nonmetallic system*; therefore, an unconventional mechanism is necessary to account for the QCP in $CeOBiS_2$ (note that all the QCPs reported so far appear in metallic materials and they are caused by the competition between the Kondo and RKKY interactions).



2-2) Extraordinary *f*-electron-based magnetism in Sm and Yb based materials

In Sm based caged materials, we have found remarkable *magnetic-field-insensitive* phenomena. Filled-skutterudite $SmOs_4Sb_{12}$ has a heavy-fermion ground state, in which the effective electron mass does not change in magnetic fields up to 30 T. $SmTa_2Al_{12}$ shows pronounced log*T*-dependent resistivity in the paramagnetic state and an antiferromagnetic ordering with quasiparticle mass enhancement, both of which are robust against applied magnetic fields. In an Ising magnet $SmPt_2Si_2$, we have observed magnetic anomalies that indicate the existence of *partially disordered Sm ions* in an antiferromagnetically ordered state. All of these exotic behaviors are considered to provide clues to clarify the mysterious *f*-electron nature of Sm ions.



Pictures of single crystals grown in our laboratory (a-c) and high pressure furnace (d).

3. Collaborating Institutions

University of Tokyo ISSP, Kobe University, Tokyo Institute of Technology, JASRI/SPring-8, JAEA, CNRS/Grenoble.

4. Recent Papers

1) R. Higashinaka *et al*., J. Phys. Soc. Jpn. **84**, 023702 (2015).
2) K. Fushiya *et al*., J. Phys. Soc. Jpn. **83**, 113708 (2014).
3) A. Yamada *et al*., J. Phys. Soc. Jpn. **82**, 123710 (2013).
4) Y. Aoki *et al*., J. Phys. Soc. Jpn., **80**, 054704 (2011).
5) S. Kambe *et al*., Nature Phys. **10**, 840 (2014).
6) T. Yamashita *et al*., Nature Phys. **11**, 17 (2014).
7) T. D. Matsuda *et al*., J. Phys. Soc. Jpn. **80**, 114710 (2011).
8) R. Okazaki *et al*., Science **331**, 439 (2011).

5. Awards

The 12th Excellent Paper Award of the Physical Society of Japan (2007).
The 15th Excellent Paper Award of the Physical Society of Japan (2010).
Award of JPSJ Papers of Editors' Choice (2005, 2006, 2011, 2014).

Neutron Scattering and Magnetism

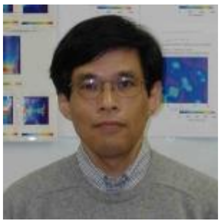
We are investigating the dynamical, magnetic, and structural properties of condensed matter using neutron and x-ray scattering techniques. These intriguing and unique scattering experiments utilize particle beams with wavelength of only a few angstroms which provide direct microscopic information about condensed matter. Our research interests center on quantum phase transitions and geometrically frustrated systems. Experiments are performed in collaboration with several research groups around the world.

(Keywords: neutron, x ray, quantum phase transition, geometrically frustrated system)

1. Staff Members and HP

Associate Professor: Hiroaki Kadowaki (kadowaki@tmu.ac.jp)
Assistant Professor: Hiroshi Takatsu (takatsu@tmu.ac.jp)

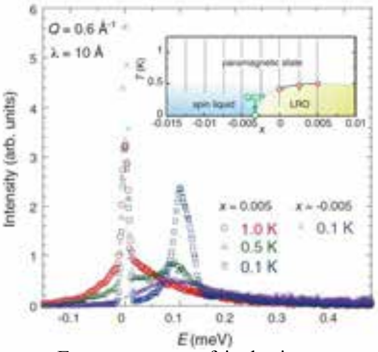
Home Page
http://bb.phys.se.tmu.ac.jp/~kado/



2. Recent Activities

2-1) Spin-liquid state and quantum phase transition in $Tb_{2+x}Ti_{2-x}O_{7+y}$

Geometrically frustrated systems provide us with a rich playground for studying new types of electronic and magnetic behaviors with unconventional order parameters. The dynamical spin liquid (SL) state with the emergence of the long-range order (LRO) in $Tb_2Ti_2O_7$ is a subject of hot debate in this research field. To understand these mysterious and entangled states, we are studying low temperature properties of $Tb_{2+x}Ti_{2-x}O_{7+y}$ using neutron diffraction and bulk measurements for high-quality single- and poly-crystalline samples. We found that the compound can be tuned by a minute change of x from the LRO ground state to the SL ground state, accompanied by a quantum phase transition at $x_c \sim 0.003$.

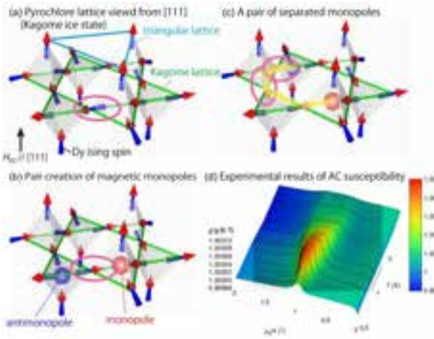


Energy spectra of inelastic neutron diffraction for $Tb_{2+x}Ti_{2-x}O_{7+y}$ (x = +0.005, -0.005).

2-2) Observation of magnetic monopole in spin ice $Dy_2Ti_2O_7$

The pyrochlore oxide $Dy_2Ti_2O_7$ bears resemblance to $Tb_2Ti_2O_7$, but is known as "spin ice", where the spin configurations are stabilized as the so-called 2-in 2-out structure in the same way as the ice rule of the proton configurations in water ice. The ground states of spin ice are macroscopically degenerate, giving rise to residual entropy. Interestingly, excitations from the ground state can be regarded as fractionalized magnetic point defects, i.e., monopoles.

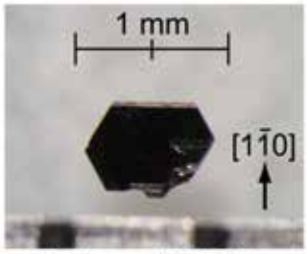
We are studying monopole dynamics in the spin ice $Dy_2Ti_2O_7$ by several approaches such as neutron diffraction, AC magnetic susceptibility, and Monte Carlo simulations.



2-3) Unconventional electronic properties in PdMO_2 (M = Cr, Co)

The materials PdMO_2 (M = Cr, Co) show remarkable electro-magnetic properties, originating from low-dimensional electron motion and the multiple spin order parameters, namely, spin chiralities.

We have grown single crystals of these materials and studied electrical transport properties. We discovered that the extremely large magnetoresistance arises in *nonmagnetic metal* $PdCoO_2$, which is comparable to the enhancement of giant magnetoresistance in magnetic multilayers. We also found that an unconventional anomalous Hall effect arises in $PdCrO_2$, accompanied by the formation of a noncoplanar spin structure leading to finite spin chirality.



Single crystal of $PdCoO_2$

3. Collaborating Institutions

ISSP, University of Tokyo, Kyoto University, Osaka University, Osaka City University, Hiroshima University, NIST, ILL, University of Waterloo, Stanford University,

4. Recent Papers

1) H. Takatsu et al., Phys. Rev. B **90**, 235110 (2014).
2) H. Takatsu *et al.*, Phys. Rev. B. **89**, 104408 (2014).
3) H. Takatsu *et al.*, Phys. Rev. Lett. **111** 056601 (2013).
4) T. Taniguchi *et al.*, Phys. Rev. B. **87**. 060408, (2013).
5) J.A.Sobota (third H. Takatsu), PRB **88** 125109 (2013).
6) H. Takatsu *et al.*, J. Phys. Soc. Jpn. **82** 104710 (2013).
7) H. Takatsu *et al.*, J. Phys. Soc. Jpn. **82** 073707(2013).
8) H. Takatsu *et al.*, JPCM **24** 052201(2012).
9) K. Goto *et al.*, J. Phys. Soc. Jpn. **81**, 015001 (2012).
10) H. Kadowaki et al., J. Phys. Soc. Jpn. **78**, 103706 (2009).

5. Awards

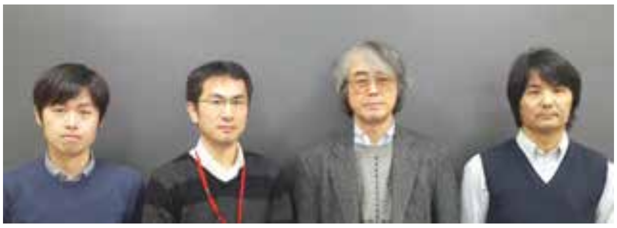
1) IOP Select, JPCM 2012 Highlights (J. Phys.: Cond. Matter **24**, 052201 (2012).)
2) Editors' Suggestion (Phys. Rev. Lett. **111**, 056601 (2013).)
3) Selection of "Synopses" in Physics (Phys. Rev. Lett. **111**, 056601 (2013).)

Nano-science Research

Our group is developing new materials with structures on a nanometer scale, such as atomic layers, single-wall carbon nanotubes (SWCNTs), fullerenes, and fullerene complexes. In addition, we continuously investigate and search for novel material properties using various techniques such as NMR, ESR, x-ray diffraction (XRD), transport, and optical measurements. Computer simulations are also employed to analyze experimental data and predict new novel properties in these materials. Potential applications are also being discussed.
(Keywords: material science, nanostructures, atomic layers, carbon nanotubes, NMR, computer simulations)

1. Staff Members and HP

Professor : Y. Maniwa (maniwa@phys.se.tmu.ac.jp)
Associate Professor: Y. Miyata (miyata-yasumitsu@tmu.ac.jp)
Assistant Professor : K. Sakamoto (sakamoto@phys.se.tmu.ac.jp)
Assistant Professor : Y. Nakai (nakai@tmu.ac.jp)
Home Page
http://www.comp.tmu.ac.jp/nanotube/



2. Recent Activities

2-1) Giant Seebeck coefficient in SWCNTs

We found a giant Seebeck effect in semiconducting SWCNT films, which exhibited a performance comparable to that of commercial Bi_2Te_3 alloys. Carrier doping of SWCNT films further improved the thermoelectric performance. These results were reproduced well by first-principles transport simulations based on a simple SWCNT junction model. The findings suggest strategies that pave the way for emerging printed, all-carbon, flexible thermoelectric devices.

2-2) Haldane state in carbon nanotubes

We investigated oxygen molecules with spin-1, encapsulated in SWCNTs with diameters of about 0.8 nm by XRD, magnetic susceptibility, and high-field magnetization measurements. The oxygen molecules formed a spin-1 one-dimensional Heisenberg antiferromagnet. Furthermore, it was shown that the Haldane state is realized in a nanospaced material for the first time. This provides an alternative to the conventional condensed matter approach to forming quantum spin systems.

2-3) Chirality fingerprinting of carbon nanotubes

While the detailed structures of SWCNTs, such as a carbon–carbon bond length, should be important, they have not been fully clarified yet. In this work, we examine the possibility of powder XRD method to characterize structures of SWCNTs. It is found that the XRD is a useful tool to “fingerprint” the chiral indices of bulk SWCNT samples. Besides, we find that information on the detailed structure within a SWCNT can be obtained from the XRD pattern.

2-4) Graphene/Hexagonal Boron Nitride Hybrid Sheets

The synthesis of graphene and hexagonal boron nitride (hBN) hybrid sheets has been achieved using a two-step chemical vapor deposition (CVD) process. Optical absorption and Raman measurements reveal that the hBN is formed on the bare surface of Cu foil and the graphene grains play a crucial role as an inactive protective layer of Cu foil for the ammonia borane CVD. Furthermore, the hBN growth is found to be initiated preferentially by the edge of graphene grains.

2-5) Phase diagram of confined water inside SWCNTs

Studies on confined water are important not only from the viewpoint of scientific interest but also for the development of new nanoscale devices. In this work, we aimed to clarify the properties of confined water in the cylindrical pores of SWCNTs that had diameters in the range of 1.1 to 2.40 nm. It was revealed that water inside SWCNTs with diameters between 1.68 and 2.40 nm undergoes a wet-dry type transition with the lowering of temperature; below the transition temperature T_{wd}=218-237 K, water was ejected from the SWCNTs. T_{wd} increased with increasing SWCNT diameter. On the other hand, water within thinner SWCNTs forms ice-nanotube on cooling. We also clarified an open end effect of the SWCNTs on the water structure.

2-6) Our discoveries

We discovered wet-dry transition, exchange transition, nano-valve mechanism, and room temperature ice-nanotubes in water-SWCNT systems. We also discovered a giant Seebeck effect in SWCNT films.

3. Collaborating Institutions

National Institute of Advanced Industrial Science and Technology, Tokyo University of Science, Nagoya University, and Osaka University.

4. Recent Papers

1) M. Hagiwara *et al*., J. Phys. Soc. Jpn. **83**,113706 (2014)
2) Y. Nakai *et al*., Appl. Phys. Express **7**, 025103 (2014)
3) T. Kumeta *et al*., J. Phys. Soc. Jpn. **83**, 084801 (2014)
4) K. Yanagi, *et al*., Nano Lett. **14**, 6437 (2014)
5) R. Mitsuyama *et al*., Carbon **75**, 299 (2014)
6) H. E. Lim *et al*., Nature Communications **4**, 1 (2013)
7) Y. Miyata *et al,* Appl. Phys. Express **5**, 085102 (2012)
8) K. Matsuda *et al*., J. Phys. Soc. Jpn. **82**, 015001(2012)
9) H. Kyakuno *et al*., J. Chem. Phys. **134**, 244501 (2011)
10) K. Hanami *et al*., J. Phys. Soc. Jpn. **79**, 023601 (2010)

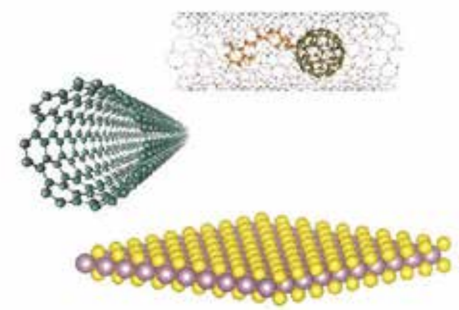
5. Awards

M. Hagiwara *et al*., Award of JPSJ Papers of Editors’ Choice, 2014.
Y. Nakai *et al*., Outstanding Paper Award of the Physical Society of Japan, 2013.
Y. Maniwa *et al*., Outstanding Paper Award of the Physical Society of Japan, 2009.

Surface and Interface Physics

The surface and interface of nano-sized materials significantly influence their electronic characteristics. Recently, atomically thin nano-materials such as single-wall carbon nanotubes, graphene, and two-dimensional chalcogenides, have generated a great deal of interest due to their extraordinary physical properties and their potential for device applications. These physical properties are strongly related to their surface structures, such as chirality, edge-structures, defects, broken inversion-symmetry, and so on. Precise control of their surface and interfaces is crucial for revealing their novel properties and is fundamental for their electric, opto-electric, thermo-electric, magnetic applications. In this group, we focus on understanding and controlling the physical properties of the surface of nano-materials.

(Keyword: surface, interface, optical, nano-materials, carbon nanotube, nanowires, two-dimensional chalcogenides)



1. Staff Members and HP

Associate Professor: Kazuhiro Yanagi
e-mail: yanagi-kazuhiro@tmu.ac.jp
Home Page
http://www.comp.tmu.ac.jp/nano2/

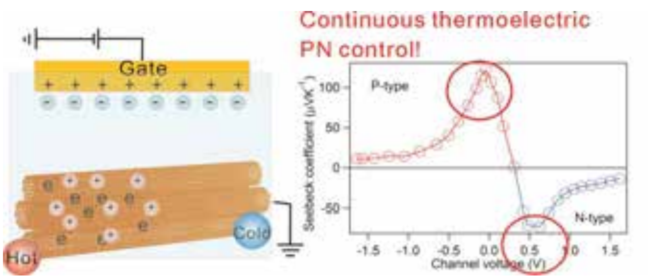
2. Recent Activities

2-1) Control of Optical properties of single-wall carbon nanotubes

Single-Wall Carbon Nanotubes (SWCNTs) are cylindrical graphitic tubes with a diameter of 1 nm, and their electronic properties strongly depend on how their graphene sheet is rolled (called chirality). They exhibit various colors depending on their chiralities, and we have revealed that metallic SWCNTs with diameter of 1.4, 1.0 and 0.8 nm show cyan, magenta, and yellow colors respectively. The colors are caused by the optical transitions between van-Hove singularities in density of states, reflecting the one-dimensional nature of SWCNTs. We tuned their colors using electron or hole injections through electric double layers formation using ionic liquids.

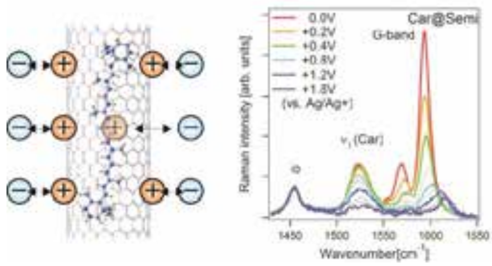
2-2) Control of Seebeck properties of one-dimensional nano-materials.

Thermoelectrics is a very important technology used to convert waste heat to electric power. The Seebeck coefficient is a parameter for characterizing the generation of electric voltage from a temperature difference. It is of great importance to prepare negative and positive Seebeck coefficient materials for high-performance thermoelectric devices. We achieved preparation of across-bandgap p-type and n-type control over the Seebeck coefficients of semiconducting SWCNTs through an electric double layer transistor setup using ionic liquids.



2-3) Manipulation of physical properties in molecules encapsulated inside nano-space

According to Gauss's law of electromagnetism, surface charges on conductive cylindrical tubes cannot influence materials located inside the cavity. However, in the nanoscale, the meaning of "surface" must be modified. We found that the charges in molecules encapsulated inside SWCNTs can be manipulated through carrier injections using electric double layers.



3. Collaborating Institutions

National Institute of Advanced Industrial Science and Technology (AIST), Waseda Univ., Univ. Vienna

4. Recent Papers

1) *Nano Lett*. **14**, 6437-6442 (2014)
2) *Appl. Phys. Lett.* **105**, 093102 (2014)
3) *ACS Nano* 8, 1375-1383 (2014)
4) *Phys. Rev. B* **87**, 195435 (2013)
5) *Appl. Phys. Lett.* **102**, 143107 (2013)
6) *Phys. Rev. Lett.* **110**, 86801 (2013)
7) *J. Am. Chem. Soc.* **134**, 9545-9548 (2012)
8) *Adv. Mater*. **23**, 2811-2814 (2011)
9) *Adv. Mater*. **22**, 3981-3986 (2010).
10) *ACS Nano* **4**, 4027-4032 (2010).

5. Awards (Yanagi)

1) The 9th Young Scientist Award of the Physical Society of Japan (The Physical Society of Japan)
2) The 4th Iijima Award (Fullerene-Nanotube Research Society, Japan)
3) The 21th Young Scientist Oral Presentation Award (The Japan Society of Applied Physics)

Soft Matter Physics

Soft matters are a group of materials that are easily deformed by weak stresses like thermal fluctuations. Typical examples of soft matters include liquid crystals, polymers, colloids, foams, gels, granular materials, and a number of biological materials. We see many soft matters in our daily life, such as liquid crystal displays, soaps, plastics, hair spray, ground coffee beans, and so on. You may think the physics governing these materials is already well understood, but it is not. Because dynamics of soft matters are too complicated to comprehend, almost all processes of making products like those described above rely on empirical rules alone. Our goals are to understand the principles of soft matters. We believe that the achievements will improve our daily lives.
(Keyword: Soft matters, non equilibrium, phase transition)

1. Staff Members and HP

Associate Professor: R. Kurita (Kurita@phys.se.tmu.ac.jp)
Assistant Professor: N. Oikawa （oikawa@tmu.ac.jp）
Home Page: http://www.comp.tmu.ac.jp/soft/index.html

2. Recent Researches

2-1) A discovery of a new type of solvation.

Imagine introducing a droplet of red liquid into a container of water. You may believe that the red droplet will expand, and its color will become diluted, and you would be correct, if the droplet is not an ionic liquid. Ionic liquids are composed of cation and anion and have very low melting temperatures. Recently, we discovered a new type of mixing process in an ionic liquid and water system. Dispersion of ionic liquids does not obey the usual diffusion equation. A droplet of ionic liquid has a sharp interface in water despite the miscibility of the droplet to water. This observation can not be explained by conventional theories (1).

2-2) Simple experiments for red blood cells.

We propose very simple methods for investigating interactions between red blood cells (RBCs). Two interactions have been proposed by many researchers about RBCs aggregate. One is a chemical bridging, the other is a depletion force (a physical interaction). It has been difficult to verify which is correct, because both interactions act as an attractive force between RBCs. We focus on interactions between RBCs and a glass substrate, instead of interactions between RBCs. Because only depletion forces are possible and bridging cannot occur for interactions between RBCs and glass substrate, we find that the interaction between RBCs is chemical bridging (2).

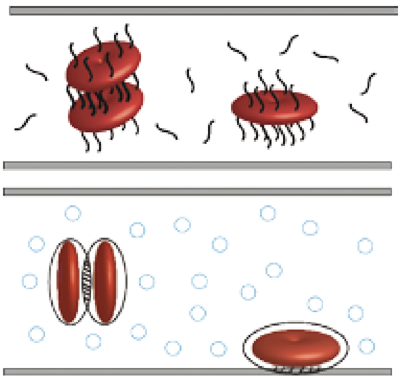


Fig. 1 Schemetic models for bridging and depleteon.

2-3) Modeling of aggregation in biosystems.

It is known that some kind of cells aggregate as a survival strategy when they are starved. You can see beautiful network patterns in their aggregation process. We proposed a very simple model for the aggregation dynamics and successfully reproduced the network patterns in numerical simulations (Fig.1). Because this model is constructed with a minimal number of factors, it is expected that the model can be applied to other systems that exhibit radial network patterns (3).

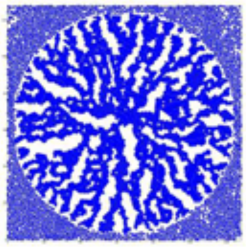


Fig.2 Network pattern created by the model.

2-4) Temperature gradient experiments for soft matters.

Soft matters are so sensitive to external stresses that even very weak stress like thermal fluctuations can deform them. Temperature gradients, therefore, strongly affect the dynamics of soft matters. We investigate the effect of temperature gradient on soft matter systems such as Rayleigh-Benard convections of gels (4) and membrane systems of surfactants (5, 6). Investigation of the effects of temperature gradients is important not only for basic research, but also for applications, as the temperature distribution is always heterogeneous in natural environments and practical situations.

3. Recent Papers

(1) N. Oikawa, D. Tahara and R. Kurita, submitted.
(2) D. Tahara, N.Oikawa and R. Kurita, in preparation.
(3) N. Oikawa and R. Kurita, in preparation.
(4) K. Kobayashi, N. Oikawa and R. Kurita, in preparation.
(5) R. Kurita, S. Mitsui and H. Tanaka, in preparation.
(6) S. Mitsui, N. Oikawa and R. Kurita, in preparation.

TOKYO METROPOLITAN UNIVERSITY

首都大学東京

古紙パルプ配合率100％再生紙を使用

VEGETABLE OIL INK