4. Research Reports in 2009 Fiscal Year

4.1. GCOE Program Members

The GCOE has been organized by the program members of 30 professors of Tohoku University. Their research fields are in Physics, Astronomy, Mathematics and Philosophy. The list of members and their research titles is as follows. Then, their research reports are the following.

- **Kunio Inoue (Physics, Professor, Program Leader)**
  1. Precise measurement of neutrino oscillation parameters,
  2. Observation of geologically produced neutrinos,
  3. Observation of low energy solar neutrinos,
  4. Search for neutrino-less double beta decay in the ultra-low background environment,
  5. Development for directional measurement of anti-neutrinos

- **Ken-ichi Hikasa (Physics, Professor)**
  Theoretical High Energy Physics

- **Osamu Hashimoto (Physics, Professor)**
  Strangeness nuclear physics

- **Yoshio Kuramoto (Physics, Professor)**
  Theory of strongly correlated electrons and topological insulators

- **Yoshiro Hirayama (Physics, Professor)**
  1. Transport characteristics of semiconductor quantum systems,
  2. Hyperfine interactions and novel NMR (NER),
  3. NMR (NER) studies of semiconductor quantum systems,
  4. Nanoprobing of semiconductor quantum systems
  5. Transport characteristics of nano-materials

- **Hirokazu Tamura (Physics, Professor)**
  Study of hypernuclei via high precision gamma-ray spectroscopy
• Masahiro Yamaguchi (Physics, Professor)
  Particle Theory

• Riichiro Saito (Physics, Professor)
  Optical properties of graphene and carbon nanotubes

• Hitoshi Yamamoto (Physics, Professor)
  Electron-positron colliders

• Toshihiro Kawakatsu (Physics, Professor)
  Study on Structure and Dynamics of Soft Matter

• Teruya Ishihara (Physics, Professor)
  Light-Matter interaction in metallic photonic crystals and metamaterials

• Toshio Kobayashia (Physics, Professor)
  Study on Unstable Nuclides

• Hajime Shimizu (Physics, Professor)
  Research of Quark Nuclear Physics with a Photon Beam

• Yasuhiro Sakemi (Physics, Professor)
  Study of the violation of time reversal invariance with the search for electron electric dipole moment measurements

• Taka-hisa Arima (Physics, Professor)
  Study of Interplay between Magnetism and Ferroelectricity in Transition-metal Oxide Compounds

• Kazuyoshi Yamada (Physics, Professor)
  Neutron scattering studies on Cuprate Superconductors

• Takashi Takahashi (Physics, Professor)
  High-resolution ARPES study of novel functional materials
• **Katsumi Tanigaki (Physics, Professor)**
  1. Materials with regulated nanospaces: light-element strategy
  2. Nano carbon materials,
  3. New Superconductors: synthesis and physical properties
  4. Molecular semiconductors: Fundamentals in device physics

• **Hideo Kozono (Mathematics, Professor)**
  Nonlinear Analysis

• **Motoko Kotani (Mathematics, Professor)**
  Discrete Geometric Analysis

• **Reiko Miyaoka (Mathematics, Professor)**
  Geometry

• **Eiji Yanagida (Mathematics, Professor)**
  Reaction-Diffusion Systems and Nonlinear PDEs

• **Takashi Shioya (Mathematics, Professor)**
  Geometry

• **Takyoshi Ogawa (Mathematics, Professor)**
  Real and Harmonic Analysis on Nonlinear PDE

• **Toshifumi Futamase (Astronomy, Professor)**
  General Relativity and Cosmology

• **Takashi Ichikawa (Astronomy, Professor)**
  Study of galaxy evolution at high redshift universe and new instruments for infrared astronomy in Antarctica

• **Toru Yamada (Astronomy, Professor)**
  Galaxy Formation and Evolution
• **Makoto Hattori (Astronomy, Professor)**
  Development of high accuracy component separation scheme between Cosmic Microwave Background and Foreground emission from mm-wave polarization emission maps

• **Keiichi Noe (Philosophy, Professor)**
  Philosophy of Science in West and East

• **Kiyotaka Naoe (Philosophy, Associate Professor)**
  Study of Philosophy and Ethics of Technology
### Name
Kunio Inoue

### Department
Research Center for Neutrino Science

### Position
Professor

### Research Title
1. Precise measurement of neutrino oscillation parameters,
2. Observation of geologically produced neutrinos,
3. Observation of low energy solar neutrinos,
4. Search for neutrino-less double beta decay in ultra low background environment
5. Development for directional measurement of anti-neutrinos

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**I. Summary of Research in 2009 fiscal year**

1. We’ve accumulated about 500 days of data after the previous publication in 2008. In the updated data period, reactor operation was about half of the maximum capacity due to a serious earthquake happened in 2007. On the other hand, new reactor core located at about the first oscillation minimum, Shika-2, has been started. The added data is appropriate to investigate the correlation between reactor signal and reactor power, and to improve oscillation parameters.

2. We’ve performed liquid scintillator purification using distillation and gas purge methods. After the purification, $^{210}$Po (the background source of $^{13}$C(alpha, n)$^{16}$O) has been decreased by factor 16 and neutrino background from nuclear power reactor was also about half. We are accumulating good data for geo-neutrino observation. And preliminary analysis is providing very high significance of geo-neutrino signal and improved precision of geo-neutrino flux.

3. The liquid scintillator purification was also effective in the low energy solar neutrino range. $^{85}$Kr and $^{210}$Bi have been decrease by factor 65000 and 2000, respectively. It made low energy $^7$Be solar neutrino observation feasible. Preliminary analysis is providing high significance of the signal excess. We are going to accumulate $^7$Be solar neutrino data until we start the search for neutrino-less double beta decay in 2011.

4. The key issues for performing the world most sensitive neutrino-less double beta decay search at KamLAND are massive production of enriched Xenon gas, clean and thin balloon for Xenon-loaded liquid scintillator and methods for Xenon-loading to and Xenon-extraction from liquid scintillator. We’ve prepared 140 kg of enriched Xenon out of planned 400 kg before 2011. We also performed various R&D for the balloon film. So far, we have two choices, Nylon and EVOH and two more candidates Kynar and Saran. Full-size balloon has been produced and tests for installation and inflation of it are going on.
We are going to start neutrino-less double beta decay search with 400 kg of enriched Xenon in 2011, aiming at the world best sensitivity at 60 meV.

5. We’ve succeeded to develop Li-loaded liquid scintillator with good light yield and acceptable transparency using LiBr solution and POE surfactant, and produced enough amount of enriched $^6\text{LiBr}$ for a cubic meter size detector. Neutron tagging for fission neutrons and spallation neutrons was also confirmed with the scintillator successfully.

II. Publications
1. Production of radioactive isotopes through cosmic muon spallation in KamLAND
2. The KamLAND full-volume calibration system
   B.E.Berger et al. (KamLAND collaboration), Journal of Instrumentation 4:P04017, 2009
3. Direction of Neutrino Research (in Japanese)

III. Presentations
1. “Geo-neutrino observation”,
2. “Neutrino Physics (overview)”,
   K.Inoue, 2nd France Asia Particle Physics School (FAPPS), (November 5-18, 2009, Fujiyoshida, Japan).
3. “The universe seen from underground”,
   K.Inoue, Science lecture for elementary and junior high school students (March 26, 2010, Sendai, Japan). (in Japanese)
4. “Neutrino Science @ Tohoku Universityiy”,
   Kunio Inoue, Tohoku University Day in Shanghai Jiao Tong University (December 18, 2009, Shanghai, China).
5. “The universe and earth with neutrinos”,
   Kunio Inoue, 1st enjoyable school on quantum (October 30, 2009, Okayama, Japan). (in Japanese)
6. “Double beta decay experiment with KamLAND 3”,
   Kunio Inoue, JPS meeting (September 10-13, 2009, Kobe, Japan). (in Japanese)
7. “Status and prospects of neutrino-less double beta decay”,
   Kunio Inoue, KEK seminar (June 12, 2009, Tsukuba, Japan). (in Japanese)
I. Summary of Research in 2009 fiscal year
1. We have developed a formalism to evaluate helicity amplitudes including particles with spin 0, 1/2, 1, 3/2, and 2 in a unified manner which makes explicit the angular dependence of the amplitude in a clear way in terms of Wigner d functions utilizing the conservation of angular momentum.
2. We have evaluated recent publications in particles physics concerning searches for Higgs bosons and dark matter WIMPs for their inclusion in the forthcoming edition of the Review of Particle Physics, which is scheduled to be published in summer 2010.

II. Publications
1. “Weak Interaction”,
2. “LHC opens a new world of elementary particles” (in Japanese),

III. Presentations
1. “Symmetries in the world of elementary particles: Nobel prize and remaining mystery”
   K. Hikasa, Tohoku University Science Café No. 46 (April 24, Sendai Mediatheque, Sendai, Japan).
Name: Osamu Hashimoto
Department: Physics Department, School of Science
Position: Professor
Research Title: Strangeness nuclear physics

I. Summary of Research in 2009 fiscal year

1. Precision spectroscopy of L hypernuclei by the (e,e’K+) reaction

In 2009, we made significant progress in (e,e’K+) spectroscopy experiments at Thomas Jefferson National Accelerator Facility (JLab) in Virginia, USA. The first, the analysis of the 2nd generation experiments at JLab Hall C with $^7$Li, $^{12}$C and $^{28}$Si revealed precision structure of the $^7_{\Lambda}$He, $^{12}_{\Lambda}$B and $^{28}_{\Lambda}$Al. In particular, the systematic errors of absolute binding energies of these hypernuclei are thoroughly examined. For $^7_{\Lambda}$He the binding energy was for the first time determined and the result is under discussion in terms of Charge Symmetry Breaking (CSB) of the LN interaction. Fig. 1 summarizes the binding energies of A=7 iso-triplet hypernuclei, $^7_{\Lambda}$He, $^7_{\Lambda}$Li and $^7_{\Lambda}$Be. As seen in the figure, a recent advanced cluster model calculation predicts deeper (shallower) binding energies for $^7_{\Lambda}$He and $^7_{\Lambda}$Be if we assume un accounted binding energy shift of the T=1/2 is-doublet hypernuclei, $^4_{\Lambda}$He, $^4_{\Lambda}$H, while the experimental results seems to show the opposite shift. Intensive investigation is under way and it will be further tested in the A=10 T=1 iso-doublet hypernuclei, $^{10}_{\Lambda}$Be and $^{10}_{\Lambda}$B.

The 3rd generation hypernuclear spectroscopy experiments was also carried out at JLab Hall C, and successfully concluded in the fall. The 3rd generation experiment newly introduced high-resolution electron spectrometer (HES) in addition to the high-resolution kaon spectrometer (HKS) which was used in the 2nd generation experiments. The setup is shown in Fig. 2. The HKS-HES spectrometer system becomes the ideal one for (e,e’K+) hypernuclear spectroscopy. Data for $^7_{\Lambda}$He, $^{10}_{\Lambda}$B, $^{12}_{\Lambda}$B and $^{52}_{\Lambda}$V were accumulated and the analysis is underway.
2. Elementary strangeness photo-production at LNS, Tohoku University
The data taken with the neutral kaon spectrometer (NKS2) utilizing the energy tagged photons from the LNS 1.2 GeV booster ring were analyzed. Neutral kaon events in the

$$\gamma + n \rightarrow \Lambda^+ K_s^0 (K_s^0 \rightarrow \pi^+ \pi^-, \Lambda \rightarrow p + \pi^-)$$

reaction on the liquid deuterium target were identified through the charged-particle decay channels with the NKS2. Not only the singles $K_s^0$ or L events were analyzed, but also the four track events in the above reaction channel were observed as shown in Fig. 3, which helps us to analyze the data with less ambiguity of Fermi momentum distributions of a neutron in the target deuteron.

3. Establishing strangeness nuclear physics network under the JSPS core-to-core program
In addition to the on-going experiments described in item 1 and 2, the member also started forming an international network for “hypernuclear physics with electron beams” under the JSPS core to core program (Category B), which aims building and expanding a cooperative international framework in leading-edge fields of science among universities and research institutions granted for JFY 2009 and 2010. Two core-to-core seminars were organized, the 1st one at JLab, Virginia and the 2nd one at INFN Rome having participants from US, Germany and Chec and other physicists together with Japanese experimentalists, theorists and graduate students. In the seminars, it was agreed to strengthen the cooperation and collaboration further utilizing accelerator facilities at CEBAF at JLab, MAMI-C at MIANZ and 1.2 GeV Internal tagging facility at LNS, Tohoku University.

II. Publications
1. “Three-Body Nonmesonic Weak Decay of the $^{12}\Lambda C$ Hypernucleus”,
2. “Study Of Double Pion Photoproduction On The Deuteron”,

III. Presentations
1. “Experimental overview with an emphasis on $\Lambda$ hypernuclear spectroscopy”,

O. Hashimoto, International conference “MAMI and Beyond”, March 30 - April 3, 2009, Schloss Waldhausen, Mainz, Germany

2. “Opening address and overview of strangeness nuclear physics by the (e,e’K+) reaction”, O. Hashimoto, “The 1st JSPS Core-to-core Seminar on “Strangeness Nuclear Physics by Electron Beams”, March 10-11, 2009, Thomas Jefferson Laboratory ( JLab ), Virginia, USA

3. “Opening address – Future collaboration on hypernuclear spectroscopy by electron beams”

4. “(e,e’K+) Hypernuclear Spectroscopy and Examination of charge symmetry breaking in the \( A=7 \ T=1 \ \Lambda \) hypernuclei”, International Conference on spin-isospin response, February 17-21, 2010, Koshiba Hall, Hongo Campus, University of Tokyo, Tokyo, Japan

5. “Test of charge symmetry breaking in the \( A=7 \ \Xi \) hypernuclei”
Osamu Hashimoto, March 15, 2010, Seminar given at Department of Physics, University of Rochester, NY, USA
Name: Yoshio Kuramoto  
Department: Physics  
Position: Professor  
Research Title: Theory of strongly correlated electrons and topological insulators

I. Summary of Research in 2009 fiscal year

1. New kinds of electronic order are investigated theoretically. We argue that octupole and even higher multipoles can order in skutterudites and other systems with high symmetry sites. Our model explains naturally magnetic, elastic, and thermodynamic anomalies in the phase transition where the order parameter has not been identified.

2. Electronic ordering phenomena in Kondo lattice models has been studied by the continuous-time quantum Monte Carlo method. It has been found that the antiferromagnetism (AF) in the Kondo lattice involves itinerant states of f electrons by the Kondo effect. The prevailing claim that the AF accompanies the localization transition has been disproved.

3. Numerical study using the continuous-time quantum Monte Carlo method has been extended to systems without the Kramers degeneracy such as Pr and U compounds. A new staggered order of CEF and Kondo singlets is found, which is a candidate of the strange order in systems such as PrFe4P12 and URu2Si2.

4. A new class of insulators with gapless edge excitations has been studied theoretically. For a model of doped graphene, we propose that the electric field perpendicular to the system causes the transition from Anderson insulator to a metal characterized by the symplectic symmetry. Furthermore it is shown that pn junctions involving these systems should show unique characteristics such as complete transmission as well as reflection depending on the gate voltage.

II. Publications

1. "Ordering and Crossover in a Pseudo-Sextet Localized Electron Model -Possible Scenario for SmRu4P12 Skutterudite-"  

2. "Spin-Orbit Effects in a Graphene Bipolar pn Junction"  
4. Research Reports in 2009 Fiscal Year

4.1. GCOE Program Members

Tohoku University GCOE program
"Weaving Science Web beyond Particle-Matter Hierarchy"

3. "Weak Localization Properties of the Doped $Z_2$ Topological Insulator"

4. "Continuous-Time Quantum Monte Carlo Approach to Singlet-Triplet Kondo Systems"

5. "Multipole Orders and Fluctuations in Strongly Correlated Electron Systems"

6. "Temperature Dependent Phonon Spectra in Anharmonic Lattice with Cage-Like Structure"

7. "Weak Localization Properties of Graphene with Intrinsic and Rashba Spin-Orbit Couplings"

8. "Klein Tunneling in Graphene under Substrate Electric Field"

9. "Anti-Localization of Graphene under Substrate Electric Field"

10. "Quantum Many-Body Physics"
Yoshio Kuramoto (Asakura Publishing. 2010)

11. "Dynamics of One-Dimensional Quantum Systems - Inverse-Square Interaction Models"
Yoshio Kuramoto and Yusuke Kato (Cambridge University Press, 2009)

III. Presentations


2. "Edge States of $Z_2$ Insulators and Its Robustness",
K. Imura and Y. Kuramoto, Divisional Meeting of the Physical Society of Japan, (25-28 September 2009, Kumamoto, Japan)

3. “Charge and Spin Transport in pn Junctions of $Z_2$ Insulators”

Y. Kuramoto, Annual Meeting of the Physical Society of Japan, (20-23 March 2010, Okayama, Japan)

5. "Staggered Order of Kondo and Crystalline-Electric Field Singlets in f2 Systems",

6. "Disorder Effects in Junctions of Topological Insulators",
A. Yamakage, K. Imura, K. Nomura and Y. Kuramoto, Annual Meeting of the Physical Society of Japan, (20-23 March 2010, Okayama, Japan)

7. "Bulk-Edge Correspondence in Quantum Spin Hall Systems",
Name: Yoshiro Hirayama  
Department: Department of Physics, Graduate School of Science  
Position: Professor  
Research Titles:  
1. Transport characteristics of semiconductor quantum systems,  
2. Hyperfine interactions and novel NMR (NER),  
3. NMR (NER) studies of semiconductor quantum systems,  
4. Nanoprobing of semiconductor quantum systems  
5. Transport characteristics of nano-materials

I. Summary of Research in 2009 fiscal year  
1. We have studied resistively-detected NMR based on \( \nu = 2/3 \) electron spin transition. Especially, we have put emphasis how the \( \nu = 2/3 \) transition peak shifts by nuclear spin polarization. We found that the transition peak spectroscopy gives us rich microscopic information about local nuclear spin polarization.  
2. We have demonstrated nuclear electric resonance (NER) mediated by radio frequency (RF) electric field instead of magnetic field in 2008 and continued studies on detailed characteristics of this NER. Reflecting a key role of the domain wall motion, we found NER signals not only at Larmor frequency but also at 1/2, 1/3 and 1/4 of the Larmor frequency. Dependence of NER signals on oscillating voltage amplitude gives us insight into the interplay between locally-polarized nuclear spins and the oscillating domain walls.  
3. Using scanning tunneling spectroscopy at low temperature (about 0.3 K) and high magnetic fields (up to \( B = 12 \) T), we have directly probed electronic wave functions across an integer quantum Hall transition. We clarified a relation between real space observation and \( k \)-space characteristics. We also started a setup of a nanoprobe system operating at dilution temperatures.  
4. We have studied transport characteristics of InSb two-dimensional systems. Because of very large g-factor of InSb, we found many Landau-level crossings in a tilted magnetic field experiment. The resistance spike typical to quantum Hall ferromagneto was clearly observed at the crossing points. We have also studied \( \text{SiO}_2/\text{Si}/\text{SiO}_2 \) quantum well putting emphasis on how mobility is affected by valley degree of freedom. Characterization has been extended to \( \text{SiO}_2/\text{Si}/\text{SiGe} \) strained Si systems, too.  
5. As a fundamental study of nanostructure, we have studied quantum point contact, i.e., one-dimensional ballistic channel. Both n-type and p-type channels were studied. We found clear quantization and so-called 0.7 structures in n-type channel. More interestingly, for
p-type channel, we observed an extreme anisotropy of the Zeeman spin splitting of one-dimensional energy levels depending on the relative orientation of the in-plane magnetic field, quantum channel, and the host crystal. We have also continued experiments about bilayer systems with total filling factor 1.

6. We are collaborating with many outside organizations. We work together with researchers coming from ERATO Nuclear Spin Electronics Project (ERATO-NSEP). In this frame, we are collaborating with NTT, Oklahoma Univ., Univ. of Tokyo, and Niigata Univ. In the framework of Japan-Germany international program, we are collaborating with NTT and Paul-Drude-Institute (PDI) at Berlin. Especially, we should emphasize that high quality heterostructures are provided by NTT, PDI, and Oklahoma University. We are collaborating with University of New South Wales (Australia) in p-type quantum-point-contact experiment and with Chiba Univ. and Tsukuba Univ. in the optical characterization of semiconductor quantum wells.

II. Publications
6. “Spectroscopic study of nuclear magnetic resonance induced by oscillating electron spin
domain walls”,
7. “Strains in heterostructures detected by standard NMR”,

III. Presentations
1. “Strains in heterostructures detected by standard NMR”,
2. “Circular polarization reversal of split photoluminescence peaks at $\nu$ of slightly less than 1”,
3. “High sensitive measurement of Kerr rotation spectra of quantum Hall states”,
4. “Electron-hole transport in a 40 nm thick silicon slab”,
5. “Spectroscopic study of nuclear magnetic resonance mediated by oscillating electron spin domain walls”,
6. “Spin relaxation mechanism in a quantum Hall ferromagnet”,
7. “The interplay between the confinement and crystallographic anisotropy in ballistic hole quantum wires”,
8. “Imaging of local filling factor in current flowing $v = 1$ quantum Hall state by scanning Kerr microscope”,

9. “Nuclear spin polarization and relaxation probed by spin phase transition peak”,

10. “Nuclear magnetic resonance in semiconductor quantum structures”,
Yoshiro Hirayama, Canada-Poland-Japan Int. Symp. on Semiconductor, magnetic and photonic nanostructures (October 4-7, 2009, Wroclaw, Poland) (invited).

11. “Exchange enhancement of effective $g$ factors in a symmetrically doped InSb quantum well”,

Yoshiro Hirayama, The 9th Sweden-Japan Workshop on Quantum Nanophysics and Nanoelectronics (QNANO) (Nov. 13-14, 2009, Tokyo, Japan) (invited).

13. "NMR and NER in GaAs quantum Structures”,

14. “Advanced functionality with three-dimensionally controlled nanostructures”,
Klaus-Juergen Friedland and Yoshiro Hirayama, JST-DFG Workshop on Nanoelectronics (January 18-20, 2010, Bad Honnef, Germany)

15. “Quantum Hall effect: Present and future”,
Name: Hirokazu Tamura
Department: Physics
Position: Professor
Research Title: Study of hypernuclei via high precision gamma-ray spectroscopy

I. Summary of Research in 2009 fiscal year
1. The final results on the $\gamma$-ray spectroscopy experiment for $^{11}\Lambda B$ and $^{12}\Lambda C$ hypernuclei performed at KEK (E556) in 2005 with the Ge detector array, Hyperball2, have been obtained. From data analysis in 2009, we successfully observed the $1^2\rightarrow2^-$ and $2^\rightarrow1^1$ transitions in $^{12}\Lambda C$ and the ground-state doublet $(2^-,1^1)$ spacing of $^{12}\Lambda C$ was found to be $161.4\pm0.7$ keV. The ground-state doublet spacings measured for $^{12}\Lambda C$ and $^{11}\Lambda B$ confirmed the strength of the $\Lambda N$ spin-spin interaction to be $\Delta=0.33$ MeV.

2. In order to run the hypernuclear $\gamma$-ray spectroscopy experiment at J-PARC (E13) in 2010, we have been constructing the new Ge detector array, Hyperball-J. Ge detectors were connected to mechanical refrigerators and their performance was found to be excellent. Detailed tests were carried out for newly-developed PWO counters for background suppression. The support frame for the whole array was fabricated and the remote control system for all the detectors was developed.

3. The magnetic spectrometer system for hypernuclear experiments at J-PARC was constructed at the Hadron Hall K1.8 beam line. In particular, we fabricated and installed large drift chambers and a plastic scintillation counter wall at the exit of the SKS spectrometer magnet, as well as aerogel Cherenkov counters for K/\pi separation in the beam. Using the first beam delivered to the K1.8 beam line, the energy resolution, the performance for particle identification and the efficiency of the whole system were confirmed to be good enough for physics runs in 2010.

II. Publications
1. “Revised spin-parity assignment and a new interpretation of the high-spin isomer in $^{151}$Er”

2. “Strangeness at J-PARC”,
3. “Present Status and Future Prospects of Hypernuclear Physics”

4. “Strangeness Nuclear Physics”

5. “Mechanisms of the nonmesonic weak decay of Λ hypernuclei and the three-body process”

6. “Three-body nonmesonic weak decay of $^{12}_Λ$C hypernuclei”

7. “Gamma-Ray Spectroscopy of Λ Hypernuclei”,

III. Presentations

1. “Hypernuclear physics: Present status and perspectives” (invited talk),
   H. Tamura, 5th Int. Conf. on Quarks and Nuclear Physics, (September 21--26, 2009, Institute of High Energy Physics, Beijing, China).

2. “Gamma-ray spectroscopy of hypernuclei – a Decade of Hyperball Project and Future Prospects at J-PARC” (invited talk),
   H. Tamura, 10th Int. Conf. on Hypernuclear and Strange Particle Physics (Hyp-X), (September 14--18, Tokai, Japan).

3. “Hypernuclear Physics at J-PARC” (invited talk),
   H. Tamura, Int. Conf. on Nuclear Fragmentation--from Basic Research to Applications--(NUFRA2009), (September 27 -- October 4, 2009, Kemer, Turkey).

4. “Spectroscopy of S= -1 Hypernuclei at KEK, BNL and J-PARC” (invited talk),
   H. Tamura, Third Joint Meeting of the Nuclear Physics Divisions of the APS and JPS (HAW09), (October 13--17, 2009, Waikoloa, Hawaii, United States).

5. “Overview of hypernuclear spectroscopy by the hadronic beams and gamma-ray
spectroscopy”,
H. Tamura, JSPS Core-to-Core Program Seminar, (December 14--15, 2009, Rome University, Rome, Italy).
6. “Nuclear and Hadron Physic Program at J-PARC” (invited talk),
I. Summary of Research in 2009 fiscal year
1. We discuss the sparticle mass patterns that can be realized in deflected mirage mediation scenario of supersymmetry breaking, in which the moduli, anomaly, and gauge mediations all contribute to the MSSM soft parameters. Analytic expression of low energy soft parameters and also the sfermion mass sum rules are derived, which can be used to interpret the experimentally measured sparticle masses within the framework of the most general mixed moduli-gauge-anomaly mediation. Phenomenological aspects of some specific examples are also discussed.

II. Publications
1. “Sparticle masses in deflected mirage mediation”,

III. Presentations
1. “Axion/Saxion Cosmology Revisited ”,
Name Riichiro Saito
Department Physics
Position Professor
Research Title Optical properties of graphene and carbon nanotubes

I. Summary of Research in 2009 fiscal year
1. Exciton energies of single wall carbon nanotube are calculated as a function of chiral index \((n,m)\) and the dielectric constant of the surrounding materials. The calculated results are compared with the experimental results of resonance Raman spectroscopy in Brazil.
2. Edge phonons and Raman spectra of graphene nano-ribbons are calculated and predicted the edge specific Raman spectra. The calculated results are compared with the experimental results of Raman spectra in China.
3. The bolon-nitride nano-ribbon is calculated as a function of doping levels. An interesting behavior on superconductivity can be predicted from the first principles calculations.

II. Publications
6. Diameter Dependence of the Dielectric Constant for the Excitonic Transition Energy of Single-Wall Carbon Nanotubes,

7. Fermi energy dependence of the G-band resonance Raman spectra of single-wall carbon nanotubes,


9. Edge States of Zigzag Boron Nitride Nanoribbons,

10. Spin-Orbit Interaction in Single Wall Carbon Nanotubes: Symmetry Adapted Tight-Binding Calculation and Effective Model Analysis,

11. Surface and Interference Coenhanced Raman Scattering of Graphene,

12. Resonant coherent phonon spectroscopy of single-walled carbon nanotubes,

13. Softening of the Radial Breathing Mode in Metallic Carbon Nanotubes,

III. Presentations

1. Exciton effect and phonon softening effect in the Raman spectroscopy of single wall carbon nanotubes,
   (Invited), R. Saito, 3rd workshop on nanotube optics and nanospectroscopy, WONTON09, (6. 7-10, 2009, Matsushima, Japan).

2. Optical properties of ultra-thin single-walled carbon nanotubes aligned in the nano channels of zeolite AEL single crystals,

3. Fermi energy dependence of radial breathing mode in metallic single wall carbon nanotubes,
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Tohoku University GCOE program
"Weaving Science Web beyond Particle-Matter Hierarchy"


4. Exciton energy Kataura plot and excitonic effect of single wall carbon nanotubes,

5. The exciton effect of the optical transition energies of single wall carbon nanotubes

6. Spin-Orbit Interaction in Single Wall Carbon Nanotubes: Symmetry Adapted Tight-Binding Calculation and Effective Model Analysis,
W. Izumida, K. Sato, R. Saito, The 10th International Conference on Sciences and Application of Carbon Nanotubes, NT09, (6. 21-26, 2009, Tsinghua University, Beijing, China).

7. Chirality Dependent Phonon Frequency Shift in Metallic Single Wall Carbon Nanotubes,

8. Fermi energy dependence of the G band resonance Raman spectra of metallic single-wall carbon nanotubes,

9. Bright and dark exciton energy and excitonic effect of single wall carbon nanotubes,

10. Diameter dependence of dielectric constant for the excitonic transition energy of single-wall carbon nanotubes,

11. Exciton environmental effect for optical transition energies of single-wall carbon nanotubes,
12. Excitonic effects and chirality dependence of photoluminescence intensity of single-wall carbon nanotubes,

13. Fermi energy dependence of radial breathing mode and G band in metallic single-wall carbon nanotubes,

14. Exciton environmental effect on Raman spectroscopy of single wall carbon nanotubes,

15. Phonon softening phenomena in graphene and carbon nanotubes (invited),
R. Saito, 2009 RIEC Cooperative Research Project on Control and Elucidation of growth Mechanism of Graphene for device applications in the next generation (invited) (10. 6, 2009, Research Institute of Electron Communications, Tohoku University, Japan).

16. Phonon softening effect and exciton environmental effect in Raman spectroscopy of single wall carbon nanotubes (invited),

17. Kohn anomaly effect in Raman spectroscopy of graphene and metallic single wall carbon nanotubes (invited),

18. Carbon Nanotubes; Physical properties and its applications,

19. Optical properties of graphene and single wall carbon nanotubes (invited),
R. Saito, The Hong Kong University of Science and Technology, William Mong Nano Seminar Series, (2. 8-10, 2009, The Hong Kong University of Science and Technology, Hong Kong).
<table>
<thead>
<tr>
<th>Name</th>
<th>Hitoshi Yamamoto</th>
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<tr>
<td>Department</td>
<td>Physics</td>
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<tr>
<td>Position</td>
<td>Professor</td>
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<tr>
<td>Research Title</td>
<td>Electron-positron colliders</td>
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**I. Summary of Research in 2009 fiscal year**

1. Measurement of the CP violating angle $\phi_3$ by the Belle detector using DK modes of $B$ mesons decays.
2. Study of the IR region for the Super B-factory. In particular, oversaw a student to estimate the beam backgrounds of the IR region.
3. Research and development of the vertex detector for the ILD detector for ILC and the SOIC-based beam profile monitor, as well as the SOIC-based vertex detector for Belle-II.
4. Managing the ILD detector as a joint steering board member. Oversaw the process of producing the LOI. The ILD detector subsequently passed a review by the ILC research directorate.
5. Managing the ILC experimental program as the Asian representative for the research directorate of ILC.
6. Managing the JSPS creative scientific research program for the ILC detector R&D as its PI.

**II. Publications**

6. “Measurement of Inclusive Radiative $B$-meson Decays with a Photon Energy Threshold of

III. Presentations
3. “Workshop Charge”,
   H. Yamamoto, Joint ACFA Physics and Detector Workshop and GDE meeting on
   International Linear Collider 2009, 2009.4.17, Tsukuba, Japan.
4. “Advanced Detector Technologies”,
5. “Recent Belle Results”,
6. “Prospects of ILC”,
7. “Summary of Physics and Detectors Working Group”,
   H. Yamamoto, CLIC09 Workshop, 2009.10.16, CERN Switzerland.
8. “ILC and CLIC detector R&Ds”,
   H. Yamamoto, Muon Collider Physics Workshop 2009, 2009.11.12, Fermilab, USA.
Name: Toshihiro Kawakatsu  
Department: Physics  
Position: Professor  
Research Title: Study on Structure and Dynamics of Soft Matter

I. Summary of Research in 2009 fiscal year

1. Development of Hybrid Particle-Field Simulation Method for Polymeric Systems; 
   In order to simulate static and dynamic properties of mesoscopic domains in polymer blends and block copolymer systems, we develop a hybrid particle-field simulation technique, where polymer chains interact only through self-consistent field. Using this technique, we simulate microphase separation of block copolymer melt. The result of this simulation shows a good agreement with those of the full atomistic molecular dynamics simulation but with a considerably reduced computational cost [Ref.1 and 3]. We applied this method to simulate an amphiphilic bilayer membrane which is a model of biological cell membrane [unpublished].

2. Electric Field-Induced Phase Transition between Perforated Lamellar Phase and Cylindrical Phase of an ABA Triblock Copolymer Thin Layer; 
   We studied the dynamics of phase transition from perforated lamellar phase to cylindrical phase of an ABA triblock copolymer thin film induced by external electric field. Depending on the direction and the strength of the imposed electric field, we observe different kinetic pathways. We also observe critical-like behavior of the transition when we change the strength of the electric field [Ref.2].

3. Coarse-Grained Dynamical Model for Shear Banding Phenomena; 
   Starting from a phenomenological dynamical model of viscoelastic fluid, i.e. diffusive Johnson-Segalman model, we derived a time-dependent Ginzburg-Landau type coarse-grained model for the shear-banding phenomena. We demonstrated that this coarse-grained model has an evaluation function which is similar to thermodynamic potential, with which one can determine the stability of the shear-banded state [Ref.4].

II. Publications


3. “Hybrid Particle-Field Molecular Dynamics Simulations for Dense Polymer Systems”,
   G. Milano and T. Kawakatsu, Virtual J. Biological Physics Research, 17 (No.12).
4. "Why does shear banding behave like first-order phase transitions?: Derivation of a
   potential from a mechanical constitutive model",

III. Presentations
   T. Kawakatsu,
   The 3rd Discussion Meeting on Glass Transition, (March 15-16, 2009, IFS and World
   Center of Education and Research for Trans-disciplinary Flow Dynamics, Sendai, Japan).
Name: Teruya Ishihara  
Department: Physics  
Position: Professor  
Research Title: Light-Matter interaction in metallic photonic crystals and metamaterials

I. Summary of Research in 2009 fiscal year

1. Transverse photo-induced voltage was investigated in metallic photonic crystal slabs. The transverse photo-induced voltage is generated not only from circularly polarized light but also from obliquely incident linear polarization. The origin was identified due to the mixing of two polarization components. Based on a collaboration with a group in Kyoto University, the wavelength dependence of photo-induced voltage was readily reproduced.

2. Longitudinal photo-induced voltage in asymmetric metallic grating structure was investigated. We investigated photo-induced voltage generation in a case where no diffraction is involved. The voltage was attributed to non-equivalent intensity of surface Plasmon polariton scattering. The numerical code to calculate optical spectra, photo-induced voltage as well as field distribution was developed for one-dimensional grating structure.

3. Magnetic response of stratified metal dielectric multi-layers was investigated. Especially large magnetic response is found to be ascribed to the inhomogenous distribution of magnetic field in a photonic unit cell. The origin of pseudo-resonance due to thickness fluctuation was identified.

II. Publications


III. Presentations


2. “Photo induced voltage due to circularly polarized light in 2D metallic photonic cry
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Tohoku University GCOE program
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stal slabs”,

3. “Magnetic resonance in stratified metal-dielectric metamaterials”,

4. “Novel optical properties of metal-dielectric artificial structures”,

5. “Circularly polarized light induces transverse voltage in metallic photonic crystal slabs”,

T. Hatano, T. Ishihara, Y. Kurami and N. Nishimura, (Feb. 22-25, Mariott Hotel, Cairo, Egypt).
Name                     Hajime Shimizu
Department               Research Center for Electron Photon Science
Position                 Professor
Research Title           Research on Quark Nuclear Physics with a Photon Beam

I. Summary of Research in 2009 fiscal year
1. Employing FOREST, a 4p electro-magnetic (EM) calorimeter, we have been conducting neutral meson photoproduction experiments with a 1 GeV photon beam. A newly developed liquid hydrogen/deuterium target is utilized. About $2 \times 10^9$ events were obtained for each target in the experiments in this fiscal year. Data analyses are now underway.
2. A design work has been completed for another 4p EM calorimeter, “BGO Egg”, to be used in the 2nd phase of our research project.
3. We started construction of a mechanical support system for BGO Egg which is an assembly of 1260 BGO crystals being about 2 tons in weight. We have now just half of the total number of BGO crystals in hand.

II. Publications
1. “Near-threshold photoproduction of $\Lambda(1520)$ from protons and deuterons”,
2. “Measurement of the incoherent $\gamma d \rightarrow \phi p n$ photoproduction near threshold”,

III. Presentations
1. “Photoproduction of $\eta/\pi0$ on the Deuteron at 1 GeV”,
   H. Shimizu, International Workshop on Narrow Nucleon Resonance, (June 8-10, University of Edinburgh, Scotland, UK).
2. “Experimental Arrangements for Quark Nuclear Physics at Sendai”,
   H. Shimizu, YITP Molecule Workshop "Algebraic aspect of chiral symmetry for the study of excited baryons", (Nov. 4-5, Yukawa Institute, Kyoto, Japan).
3. “University-based Accelerator Facilities for Quark Nuclear Physics at Sendai”,
   H. Shimizu, The first ANPhA Symposium, (Jan. 18-19, J-PARC, Tokai, Japan).
Name: Yasuhiro Sakemi
Department: Physics (Cyclotron and Radioisotope Center)
Position: Professor
Research Title: Study of the violation of time reversal invariance with the search for electron electric dipole moment measurements.

I. Summary of Research in 2009 fiscal year

1. The developments of the experimental apparatus to search for the permanent electric dipole moment of the electron using the laser cooled unstable nuclei such as the $^{210}$Fr were performed and in progress.
2. The thermal ionizer to produce and extract the Fr ions was upgraded to get a higher Fr intensity by changing the material of the oven which is stable chemically, and performed the experiment to measure the extraction efficiency.
3. The new beam transport line for the Fr ions was designed and developed. The quadrupole electrostatic lens to focus the Fr beam was developed which had a unique structure consisting of the quartz cylinder installed inside the electrodes to realize the high vacuum. The beam test was done to check the focusing the extracted Fr beam.

II. Publications


III. Presentations
1. “Search for the permanent electric dipole moment of the electron with Francium atom”,
   Y. Sakemi, Workshop on “Fundamental physics using atoms”, (Aug. 4-5, Tokyo Institute of Technology, Tokyo, Japan).

2. “A permanent electric dipole moment of the electron with laser cooled radioactive atom”,
   Y. Sakemi, KEK seminar, (Feb. 19, KEK, Tsukuba, Japan).
Name: Taka-hisa Arima
Department: Physics
Position: Professor
Research Title: Study of Interplay between Magnetism and Ferroelectricity in Transition-metal Oxide Compounds

I. Summary of Research in 2009 fiscal year
1. We have found that the magnetization of a canted magnet CuB2O4 can be controlled by the application of an electric field along the c-axis. The magnetization direction is rotated in the tetragonal (001) plane by 30 degrees at most in an electric field. This phenomenon is reproducible and repeatable.

2. Magnetic structures of a magnetoelectric multiferroic hexaferrite Ba2Mg2Fe12O22 has been investigated as a function of temperature and magnetic field by a neutron diffraction measurement. The periodicity of the magnetic modulation successively changes. A low-temperature high-field ferroelectric phase corresponds to the twofold magnetic modulation.

3. Recent intensive researches showed that the cycloidal magnetic alignment should induce ferroelectric polarization. If the cycloidal spin plane rotates by the application of a magnetic field, the electric polarization also rotates. We investigated the direction of the polarization rotation with the application of a magnetic field in TbMnO3 and MnWO4. The results clearly show that the direction of ferroelectric polarization rotation in such magnetic-field-induced electric polarization rotation is dominated by the canting direction of an external magnetic field. The phenomenon is explained by Zeeman energy of a composite 90-degree-type domain-wall in helimagnetic ferroelectrics.

II. Publications


### III. Presentations


Arima, M. Kawasaki, Y. Tokura, 2009 RIKEN Workshop Emergent Phenomena of Correlated Materials, (Dec. 2-4, 2009, Wako, Japan)

6. “Domain-wall structures in cycloidal magnetoelectric multiferroics”,

7. “Multiferroic Perovskite Manganites with Symmetric and Antisymmetric Exchange Strictions”,

8. “Gigantic terahertz magneto-chromism of electromagnons in conical spin magnets”,

9. “Interplay among magnetism, electricity, and light in CuB_2O_4”,
   T. Arima, The 2nd RIEC-CNSI Workshop on Nanoelectronics, Spintronics and Photonics, (Oct. 22, 2009, Sendai, Japan)

10. “X-ray study of magnetism in Sr_2IrO_4”,

11. “Observation of Spin Chirality using Circularly-Polarized Synchrotron Radiation X-rays”,

12. “Polarized neutron and synchrotron X-ray studies of helimagnetic ferroelectrics”,

13. “Control of the electric polarization flop direction by a conted magnetic field in a magnetoelectric multiferroic material MnWO_4”,

14. “Control of the polarization flop direction in multiferroic RMnO_3 by a tilted magnetic field”,
15. “Neutron Studies on Magnetoelectric Multiferroics”,
   T. Arima, Workshop on Possible Scientific View from New Neutron Spectroscopy
   Opportunities in J-PARC, (Jul. 9, 2009, Tokai, Japan)
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Tohoku University GCOE program
"Weaving Science Web beyond Particle-Matter Hierarchy"

Name: Kazuyoshi Yamada
Department: Physics, WPI
Position: Professor
Research Title: Neutron scattering studies on Cuprate Superconductors

I. Summary of Research in 2009 fiscal year

Magnetic excitation signal of single layered Bi-cuprate was observed by neutron scattering for the first time. Similar to the previous study on single layered La-cuprate we observed incommensurate spin correlations. Therefore, we proposed that the incommensurate magnetic excitations commonly exist for both systems and play an important role for the superconducting properties.

Spin injection effect in this Bi-system has been systematically studied. We discovered that the missing incommensurate spin correlations in the overdoped region are induced by doped Fe spins.

More detailed neutron scattering study supported by the GCOE will be performed in March this year at the pulsed neutron source in Oak Ridge National Laboratory.

II. Publications


5. Tunneling Spectroscopy on an Electron-Doped Pr$_{1-x}$LaCe$_x$CuO$_4$ with $x=0.11$,

6. Tunneling Spectroscopy on an Electron-Doped Pr$_{1-x}$LaCe$_x$CuO$_4$ with $x=0.11$,

7. Tunneling Spectroscopy on an Electron-Doped Pr$_{1-x}$LaCe$_x$CuO$_4$ with $x=0.11$,

8. Crossover from Coherent Quasiparticles to Incoherent Hole Carriers in Underdoped Cuprates,

9. First Investigation of Pressure Effects on Transition from Superconductive to Metallic Phase in FeSe$_{0.5}$Te$_{0.5}$ ,

10. Relationship between Spin Gap and Crystal Structure in La-214 Cuprate Superconductor,

11. Neutron-Scattering Study of Impurity Effect on Stripe Correlations in La-Based 214 High-Tc Cuprate,

12. Enhancement of Electronic Anomalies in Iron-Substituted La$_2$Sr$_x$Cu$_{1-y}$Fe$_y$O$_4$ around $x=0.22$,

13. Enhancement of Electronic Anomalies in Iron-Substituted La$_2$Sr$_x$Cu$_{1-y}$Fe$_y$O$_4$ around $x=0.22$,

14. Enhancement of Electronic Anomalies in Iron-Substituted La$_2$Sr$_x$Cu$_{1-y}$Fe$_y$O$_4$ around $x=0.22$,
15. Enhancement of Electronic Anomalies in Iron-Substituted La$_{2.3}x$Sr$x$Cu$_{1.3}$Fe$_y$O$_4$ around $x=0.22$,
16. Uncharacteristic phase separation trends with the ionic size in cobaltites,
17. Charge and spin ordering in La$_{2.3}$Sr$_x$CoO$_{4}$ (0.4<$x<$0.6),
18. Unquenched geometric frustration effect on spiral spin correlation in magnetically ordered phase,

III. Presentations
1. “Role of neutron scattering for the elucidation of high temperature superconductivity”,
K. Yamada, A3 Hokkaido Summer School (Aug. 3-6, 2009, Rusutsu, Hokkaido)
2. “Static Spin Correlations hidden behind the superconductivity in La$_2$-xSr$_x$CuO4”,
M. Fujita, M. Enoki, S. Iikubo, K. Yamada, Gordon Research Conference “Superconductivity”, (June 7-12, Hong Kong University of Science and Technology, Hong Kong, China)
3. “Fe-doping effects on magnetism in hole-type superconductors of (Bi,Pb)2Sr2CuO6”,
4. “Hot pressing of Ge crystals toward a reflection-plane-selective neutron monochromator”,
Y. Miyake, H. Hiraka, K. Ohoyama, Y. Yamaguchi and K. Yamada, The International Conference on Magnetism (ICM) (July 26-31, Congress Center Karlsruhe, Karlsruhe, Germany)
I. Summary of Research in 2009 fiscal year

1. High-resolution ARPES study of high-Tc pnictide superconductors
2. High-resolution ARPES study of high-Tc cuprate superconductors
3. High-resolution ARPES study of cobaltate superconductors
4. High-resolution ARPES study of graphite-intercalation superconductors
5. High-resolution ARPES study of tungsten bronze
6. High-resolution ARPES study of surface Rashba effect
7. Development of high-resolution spin-resolved ARPES system

II. Publications

1. “Fermi-surface-dependent superconducting gap in C₆Ca”,
2. “Angle-Resolved Photoemission Spectroscopy of the Fe-Based Ba₀.₆K₀.₄Fe₂As₂ High Temperature Superconductor: Evidence for an Orbital Selective Electron-Mode Coupling”,
3. “Electronic structure of heavily electron-doped BaFe₁.₅Co₀.₃As₂ studied by angle-resolved photoemission”,
4. “High-resolution photoemission study of NaV₂O₄”,
5. “Superconducting-gap symmetry of Ba₀.₆K₀.₄Fe₂As₂ studied by angle-resolved photoemission spectroscopy”,

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Name: Takashi Takahashi
Department: Physics
Position: Professor
Research Title: High-resolution ARPES study of novel functional materials

7. “Doping dependence of superconducting-gap anisotropy in YBa$_2$Cu$_3$O$_{7-d}$”,

8. “Fermi surface nesting induced strong pairing in iron-based superconductors”,

9. “Evolution of pairing-induced pseudogap from superconducting gap in (Bi,Pb)$_2$Sr$_2$CuO$_6$”,

10. “Magnetic Phase Transition of CeSb Studied by Low-Energy Angle-Resolved Photoemission Spectroscopy”,

11. “Band structure and Fermi surface of an extremely overdoped iron-based superconductor KFe$_2$As$_2$”,

12. “Reconstruction of Fermi surface and anisotropic excitation gap of Na$_{0.5}$CoO$_2$”,

13. “Metal-insulator transition of Na$_3$WO$_3$ studied by angle-resolved photoemission spectroscopy”,

14. “Peculiar Rashba Splitting Originating from the Two-Dimensional Symmetry of the Surface”,

III. Presentations
1. “ARPES of CaC$_6$ (invited talk)”,

Tohoku University GCOE program
“Weaving Science Web beyond Particle-Matter Hierarchy”
T. Takahashi, 9th International Conference on Materials and Mechanisms of Superconductivity, (Sept. 7-12, 2009, Keio Plaza Hotel, Tokyo, Japan).
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Name: Katsumi Tanigaki
Department: Physics, WPI
Position: Professor
Research Titles:
1. Materials with regulated nanospaces: light-element strategy
2. Nano carbon materials
3. New Superconductors: synthesis and physical properties
4. Molecular semiconductors: Fundamentals in device physics

I. Short Summary of Researches in 2009 fiscal year

1. Materials with regulated nanospaces: light-element strategy

   Phonons play a very important role for controlling physical properties. Lattice phonons have been the main issues for electron-phonon interactions as well as for phonon scattering in controlling physical properties for long years so far. Recently, intra-cluster phonons are also considered to play an important role and even more importantly the latter phonons can provide possible phonon engineering. Thanks to the inner nano spaces in polyhedral network compounds that can accommodate atoms, the atomic anharmonic motions showing large freedom can be generated and these are recently drawing much attention as a new collective mode of phonons. Clathrate compounds have the nano cage structure consisting of IVth group elements with shared faces arranged. Therefore, these materials can accommodate atomic elements to be confined. The endohedral atoms move under the potentials made by the cages and give rise to such rattling phonons featured by anharmonic oscillations. These phonons are greatly different from the conventional lattice phonons and may produce unique electron-phonon interactions. We have studied how the low-temperature physical parameters can be influenced by these anharmonic phonons using single crystal clathrates with various carrier concentrations.

2. Nano carbon materials

   Molecular hydrogen (H\(_2\)), the simplest system among all molecules, has been studied extensively to date, and its electronic spectra have been fundamental in establishing the fundamentals of quantum mechanics. An H\(_2\) molecule is not expected to be completely localized at lattice sites even in the solid state at 0 K due to its large zero point motion, and therefore H\(_2\) retains translational and orientational quantum solids, and this is from the consequence of the triply-degenerate rotational levels in the of para-H\(_2\) (J=0, 2, 4…) and ortho-H\(_2\) (J = 1, 3, 5…) nuclear spin isomers. We have confirmed this unique the quantum
free-rotor description by observing the specific heat in H$_2$@C$_{60}$, where H$_2$ is endohedrally confined in a nano space, over a broad temperature range, and obtained the smallest yet observed splitting of rotational energy sublevels of encapsulated single H$_2$ molecules, 0.1–0.2 meV, in the nearly spherical potential of highly isotropic C$_{60}$ cages. The minuscule splitting provides unprecedented opportunities to study free-molecule quantum dynamic properties.

3. Exotic superconductors: synthesis and physical properties

FeAs superconductors have recently resulted in a surge of interest in exotic superconductors. As a hole superconductor in this family, we have made structural details in Pr$_{1-x}$Sr$_x$FeAsO, using data obtained from synchrotron x-ray diffraction. The structural parameters are carefully studied as the system moves from non-superconducting to hole-doped superconducting with an increase of the Sr concentration. The linear increase in the lattice parameters proves that Sr is successfully introduced into the system, and the Sr concentration can be accurately determined by electron density analyses. The evolution of structural parameters with Sr concentration in Pr$_{1-x}$Sr$_x$FeAsO and the comparison of them to other similar structural parameters of the related Fe-based superconductors suggest that the interlayer space between the conducting As–Fe–As layer and the insulating Pr–O–Pr layer is important for improving $T_c$ in hole-doped superconductors. This seems to be a different trend from that encountered in the electron-doped systems.

4. Molecular semiconductors: Fundamentals in device physics

Ambipolar carrier injection is observed in organic field-effect transistors FETs based on 2,5-bis-(4-biphenyl) bithiophene single crystals. The device shows carrier mobilities of 0.04 and 0.02 cm$^2$ V$^{-1}$ s$^{-1}$ for holes and electrons, respectively. Strong edge emission is observed, and the emission zone shifts upon the applied gate voltage. The electron mobility is significantly more sensitive to the transport direction than the hole mobility, suggesting that tuning the transport direction is very important to realize amplified spontaneous emission in organic FETs.

II. Publications


2. $^{73}$Ge and $^{135/137}$Ba--NMR Studies of Clathrate Superconductor Ba$_2$Ge$_{100}$, 
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Tohoku University GCOE program  
“Weaving Science Web beyond Particle-Matter Hierarchy”


3. Influence of interface modifications on carrier mobilities in rubrene single crystal ambipolar field-effect transistor,  

4. Rotational Sub-level of Ortho-Hydrogen Molecule Encapsulated in Isotropic C_{60} Fullerene Cages,  

5. p- and n-Type Ba_{8}Ga_{16}Ge_{30} studied by X-ray photoelectron spectroscopy,  

6. Soft x-ray photoelectron spectroscopy study of type-I clathrates,  

7. A structural study of the hole-doped superconductors Pr1−xSrFeO,  

III. Presentations

1. Role of phonons searching for good thermoelectricity and high Tc superconductivity,  

2. “Phonons and electronic states in compounds with regulated nanospaces”,  

3. Physical Properties in Nano-Assembled Materials: Endohedral Atoms and Molecules in Confined Nanospaces,  
Katsumi Tanigaki, International Symposium ISIM- 2009 (International Symposium on Interdisciplinary Science), (March 9-10, 2009, Tsukuba International Conference Center,
4. Interplay between electrons and phonons searching for good thermoelectricity and high Tc superconductivity, 

5. Nanomaterials and Their Applications to Field Effect Transistors with Two Dimensional Electronic States, 

6. Superconductivity in Silicon and Germanium Polyhedra, 
Katsumi Tanigaki, Kazumi Sato, Jing Ju, Zhaofei Li, Jun Tang, Takeshi Rachi and Alfonso San Miguel, 9th International Conference on Materials and Mechanisms of Superconductivity, (Sep. 7-12, 2009, Tokyo, Japan).

7. Fermi-level pinning/depinning at metal-graphene interfaces, 
Ryo Nouchi, Tatsuya Saito, and Katsumi Tanigaki, 10th Anniversary of the European Conference on Molecular Electronics, ECME2009, (Sep. 9-12, 2009, Copenhagen, Denmark).

8. Modification of interfaces in organic light-emitting field-effect transistors, 
Yan Wang, Ryotaro Kumashiro, and Katsumi Tanigaki, 10th Anniversary of the European Conference on Molecular Electronics, ECME2009, (Sep. 9-12, 2009, Copenhagen, Denmark).

9. Conducting layer at organic single crystals heterointerfaces, 
Hiroki Watanabe, Ryo Nouchi, and Katsumi Tanigaki, 10th Anniversary of the European Conference on Molecular Electronics, ECME2009, (Sep. 9-12, 2009, Copenhagen, Denmark).

10. Metal-contact induced anomaly in transfer characteristics of graphene Field-effect Transistors, 

11. Transport Properties of Graphene Field-effect Transistors with Different Metal Electrodes, 

12. Modification of Semiconductor-Dielectric Interface in Organic Light-emitting Field-effect Transistor, 
Yan Wang, Ryotaro Kumashiro, Naoya Komatsu, and Katsumi Tanigaki, Materials
Research Society Spring Meeting (April 14-17, 2009, San Francisco, U.S.A)

13. FET characteristic of Chemically-Modified CNT,
   Ryotaro Kumashiro, Yan Wang, Naoya Komatsu, and Katsumi Tanigaki, Materials

14. Comparison of electron- and hole-doped 1111 phase in Fe-based oxypnictides,
   Jing Ju, Zhaofei Li, Masanori Watahiki, Kazumi Sato, Gang Mu, Jun Tang, Huynh Khuong,
   Hidenori Terasaki, Eiji Ohtani, Hirotsugu Takizawa, Takahiko Sasaki and Katsumi Tanigaki,
   International Conference on Intercalation Compounds, ISIC15, (May 10-15, 2009, Beijing,
   China)

15. Magnetic Properties of a Series of New Transition Metal Borates with Porous Frameworks,
   Jing Ju, Zhaofei Li, Jun Tang, and Katsumi Tanigaki, International Conference on

16. Superconductivity in FeSe\textsubscript{x} series,
   Zhaofei Li, Jing Ju, Jun Tang, Kazumi Sato, Masanori Watahiki, Katsumi Tanigaki,
   International Conference on Intercalation Compounds, ISIC15, (May 10-15, 2009, Beijing,
   China)

17. Real Structure of FeSe\textsubscript{x} Series Superconductors,
   Zhaofei Li, Jing Ju, Jun Tang, Kazumi Sato, Masanori Watahiki, Matsuoka Eiichi, Katsumi
   Tanigaki, 9\textsuperscript{th} International Conference on Materials and Mechanisms of Superconductivity,
   (September 7-12, 2009, Tokyo, Japan),

18. Exploration of Hole-Doped Fe based (1111) Oxypnictides,
   Jing Ju, Zhaofei Li, Jun Tang, Kazumi Sato, Masanori Watahiki, Hidenori Terasaki, Eiji
   Ohtani, Hirotsugu Takizawa and Katsumi Tanigaki, 9\textsuperscript{th} International Conference on
   Materials and Mechanisms of Superconductivity, (September 7-12, 2009, Tokyo, Japan)
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Tohoku University GCOE program
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<thead>
<tr>
<th>Name</th>
<th>Hideo Kozono</th>
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<tr>
<td>Department</td>
<td>Mathematics</td>
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<tr>
<td>Position</td>
<td>Professor</td>
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<tr>
<td>Research Title</td>
<td>Nonlinear Analysis</td>
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I. Summary of Research in 2009 fiscal year

1. **Leray’s problem in multi-connected domains**: Consider the stationary Navier-Stokes equations in a bounded domain \( \Omega \subset \mathbb{R}^3 \) with the smooth boundary \( \partial \Omega \). We investigate the solvability under the general flux condition which implies that the total sum of the flux of the given data on each component of the boundary is equal to zero. Based on our Helmholtz-Weyl decomposition, we prove existence of solutions if the harmonic part of the solenoidal extension of the given boundary data is sufficiently small in \( L^3 \) compared with the viscosity constant.

2. **Global Div-Curl Lemma**: We consider a global version of the Div-Curl lemma for vector fields in a bounded domain \( \Omega \subset \mathbb{R}^3 \) with the smooth boundary \( \partial \Omega \). Suppose that \( \{u_j\}_{j=1}^\infty \) and \( \{v_j\}_{j=1}^\infty \) converge to \( u \) and \( v \) weakly in \( L^r(\Omega) \) and \( L^{r'}(\Omega) \), respectively, where \( 1 < r < \infty \) with \( 1/r + 1/r' = 1 \). Assume also that \( \{\text{div } u_j\}_{j=1}^\infty \) is bounded in \( L^q(\Omega) \) for \( q > \max\{1,3r/(3+r)\} \) and that \( \{\text{rot } v_j\}_{j=1}^\infty \) is bounded in \( L^s(\Omega) \) for \( s > \max\{1,3r'/3(3+r')\} \), respectively. If either \( \{u_j \cdot v_j [\partial \Omega]\}_{j=1}^\infty \) is bounded in \( W^{1-1/q,q}(\partial \Omega) \), or \( \{v_j \cdot v_j [\partial \Omega]\}_{j=1}^\infty \) is bounded in \( W^{1-1/q,\infty}(\partial \Omega) \) (\( \nu \): unit outward normal to \( \partial \Omega \)), then it holds that \( \int_\Omega u_j \cdot v_j dx \rightarrow \int_\Omega u \cdot v dx \). In particular, if either \( u_j \cdot \nu = 0 \) or \( v_j \cdot \nu = 0 \) on \( \partial \Omega \) for all \( j = 1,2,\ldots \) is satisfied, then we have that \( \int_\Omega u_j \cdot v_j dx \rightarrow \int_\Omega u \cdot v dx \). As an immediate consequence, we prove the well-known Div-Curl lemma for any open set in \( \mathbb{R}^3 \). The Helmholtz-Weyl decomposition for \( L^r(\Omega) \) plays an essential role for the proof.

3. **Keller-Segel system**: We show existence of **global strong solution** to the semilinear Keller-Segel system in \( \mathbb{R}^n \), \( n \geq 3 \) of **parabolic-parabolic type** with small initial data \( u_0 \in H^{\infty-2m}(\mathbb{R}^n) \) and \( v_0 \in H^{\infty-m}(\mathbb{R}^n) \) for \( \max\{1, n/4\} < r < n/2 \). Our method is based on the perturbation of linearization together with the \( L^p-L^q \)-estimates of the heat semigroup and the fractional powers of the Laplace operator. As a by product of our method, we prove the decay property of solutions as the time goes to infinity.

4. **Stokes operator in general domains**: It is known that the Stokes operator is not well-defined in \( L^q \)-spaces for certain unbounded smooth domains unless \( q = 2 \). We generalize a new approach to the Stokes resolvent problem and to maximal regularity in general unbounded smooth domains from the three-dimensional case, to the \( n \)-dimensional one, \( n \geq 2 \), replacing the space \( L^q, 1 < q < \infty \), by \( \mathcal{L}^q \) where \( \mathcal{L}^q = L^q \cap L^2 \) for \( q \geq 2 \) and \( \mathcal{L}^q = L^q + L^2 \) for \( 1 < q < 2 \). In particular, we show that the Stokes operator is well-defined in \( \mathcal{L}^q \) for every unbounded domain of uniform \( C^{1,1} \)-type in \( \mathbb{R}^n \), \( n \geq 2 \), satisfies the classical resolvent estimate, generates an analytic semigroup and has maximal regularity.
5. **New regularity criterion on the Navier-Stokes equations:** Consider a weak solution $u$ of the nonstationary Navier-Stokes system in a bounded domain of $\mathbb{R}^3$ satisfying the strong energy inequality. We prove among other things that $u$ is regular if either the kinetic energy $\frac{1}{2}\|u(t)\|^2_{L^2}$ or the dissipation energy $\int_0^t \|\nabla u(\tau)\|^2_{L^2} d\tau$ is (left-side) Hölder continuous as a function of time $t$ with its Hölder exponent greater than $1/2$. In the critical exponent $1/2$, we need smallness of the norm.

6. **Stability of the plane Couette flow:** We consider a plane Couette flow $v_0 = (x_n, 0, \ldots, 0)$ in an infinite layer domain $\Omega = \mathbb{R}^{n-1} \times (-1, 1)$, where $n \geq 2$ is an integer. The exponential stability of $v_0$ is shown under the condition that the initial perturbation is periodic in $(x_1, \ldots, x_{n-1})$ and sufficiently small in the $L^3$-norm. This stability result holds for any value of the Reynolds number.

7. **Helmholtz-Weyl decomposition in $L^p$:** We show that every $L^p$-vector field on $\Omega$ can be uniquely decomposed into two spaces with scalar and vector potentials, and the harmonic vector space via operators $\text{rot}$ and $\text{div}$, where $\Omega$ is a bounded domain in $\mathbb{R}^3$ with the smooth boundary $\partial \Omega$. Our decomposition consists of two kinds of boundary conditions such as $u \cdot \nu|_{\partial \Omega} = 0$ and $u \times \nu|_{\partial \Omega} = 0$, where $\nu$ denotes the unit outward normal to $\partial \Omega$. Our results may be regarded as an extension of the well-known de Rham-Hodge-Kodaira decomposition of $\mathcal{C}^\infty$-forms on compact Riemannian manifolds into $L^p$-vector fields on $\Omega$. As an application, the generalized Biot-Savart law for the incompressible fluids in $\Omega$ is obtained. Furthermore, various bounds of $u$ in $L^p$ for higher derivatives are given by means of $\text{rot} u$ and $\text{div} u$.

8. **Inhomogeneous boundary value problem for the stationary Navier-Stokes equations:** We consider the stationary Navier-Stokes equations on a multiply connected bounded domain $\Omega$ in $\mathbb{R}^n$, $n = 2, 3$, under the inhomogeneous boundary condition. We prove a criterion on a new sufficient condition for the existence of the weak solutions. This sufficient condition is described as a variational estimate in terms of the harmonic part of solenoidal extensions of the given boundary data. To show this criterion, we essentially use the Helmholtz-Weyl decomposition theorem of vector fields over $\Omega$ satisfying adequate boundary conditions. We further put forward a systematic study on the validity of Leray’s inequality under some assumptions on symmetry of $\Omega$.

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**II. Publications**


III. Presentations


Tohoku University GCOE program  
“Weaving Science Web beyond Particle-Matter Hierarchy”

Name: Motoko Kotani  
Department: Mathematics  
Position: Professor  
Research Title: Discrete Geometric Analysis

I. Summary of Research in 2009 fiscal year
2. Collaborated with Physicist to set up a mathematical model for nano tube by using a convergence theorem, which concerns curvature effects.

II. Publications
   “Noncommutativity and Singularities”  
   Proceedings of French--Japanese symposia held at IHÉS in 2006  
   J.-P. Bourguignon, M. Kotani, Y. Maeda and N. Tose
   “Probabilistic approach to geometry”  
   Proceedings of the 1st MSJ-SI in 2008  
   M. Kotani, M. Hino and T. Kumagai

III. Presentations
1. “Mathematical challenge to a new phase of material sciences”,  
2. “Geometry of crystal lattices”  
   Motoko Kotani, Series of Lectures, Nov.2- Nov.5th, 2009, Hokkaido University, Japan.
3. “Mathematical challenge to a new phase of material sciences”,  
Name: Reiko Miyaoka
Department: Mathematics
Position: Professor
Research Title: Geometry

I. Summary of Research in 2009 fiscal year
1. I gave a new proof of the Dorfmeister-Neher’s theorem on the classification of isoparametric hypersurfaces with six single principal curvatures, (see II-1).
2. I classified isoparametric hypersurfaces with six double principal curvatures, and have submitted the paper “Isoparametric hypersurfaces with (g,m)=(6,2)”, (66 pages).
3. I investigated the G2 orbits from the view point of Kaehler and symplectic structures and submitted the paper “Geometry of G2 orbits and isoparametric hypersurfaces”, (13 pages).

II. Publications
1. “The Dorfmeister-Neher’s theorem on isoparametric hypersurfaces”,
2. “Classification of isoparametric hypersurfaces”,
3. Riemann Surfaces, Harmonic Maps and Visualization

III. Presentations
1. “Hypersurface geometry and special geometry”, R. Miyaoka,
   Colloquium talk at Hiroshima U., (May 26, Hiroshima Univ., Japan).
2. “Problem on exceptional values of the Gauss map”, R. Miyaoka
   Geometry seminar at Tohoku U., (July 7, Tohoku Univ., Japan)
3. “A proof of homogeneity of isoparametric hypersurfaces with (g,m)=(6,2) ”,
   R. Miyaoka, Hiroshima Geometry Meeting (Oct. 7-9, Hiroshima Univ., Japan).
4. “Isoparametric hypersurfaces with (g,m)=(6,2) ”
   R. Miyaoka, Colloquium talk at Peking U., (Oct.23, Peking Univ., China)
5. “Kaehler and symplectic geometry of G2 orbits”
   R. Miyaoka, Colloquium talk at Tsinghua U., (Oct.22, Tsinghua Univ., China)
6. “Hypersurface geometry and related topics”,
   R. Miyaoka, Colloquium talk at Sun Yat-Sen U., (Dec.8, Sun Yat-Sen Univ., China)

7. “Hypersurface geometry”,
   R. Miyaoka, UK-Japan Winter school, (Jan.7-10, Manchester Univ., England)

8. Introduction to Harmonic maps and integrable systems,
   R. Miyaoka, GCOE Spring school at Tohoku U., (Mar.9-11, Tohoku Univ. Japan)
I. Summary of Research in 2009 fiscal year

1. I have investigated the dynamics of nonlinear diffusive systems from a mathematical viewpoint. More specifically, with Marek Fila, I studied the existence of entire solutions of a semilinear parabolic equation with a supercritical power nonlinearity. With Shota Sato, I considered the global existence of solutions with moving singularities.

2. With Shin-ichiro Ei and Kota Ikeda, I studied the stability of multi-spot solutions in a shadow system of reaction-diffusion systems. This result is applied to the FitzHugh-Nagumo equation and the Gierer-Meinhard system.

3. With Chun-Kong Law, I have studied an inverse problem for the Sturm-Liouville operator on graphs. We gave a complete answer to the so-called Ambarzumyan problem.

II. Publications

1. “Solutions with moving singularities for a semilinear parabolic equation”,

2. “Convergence of anisotropically decaying solutions for a supercritical semilinear heat equation”,

III. Presentations

1. “Solutions with moving singularities in a semilinear parabolic equation”,
   E. Yanagida, Topological and variational methods for partial differential equations, (May. 18-22, Oberwolfach, Germany).

2. “Speed of traveling waves for some nonlocal equations”,
   E. Yanagida, ReaDiLab Conference on Reaction-Diffusion Systems”, (June. 2-5, Universite Paris-Sud, France).

3. “Stabilization to equilibria in a supercritical parabolic equation”,
   E. Yanagida, Italy-Japan Workshop on Geometric Properties for elliptic and Parabolic PDE’s, (June. 15-19, Tohoku University, Japan).

4. “Global and non-global solutions with moving singularities for a semilinear parabolic equation”,

E. Yanagida, East-Asia Conference on PDEs, (December 14-18, Chinese University of HongKong, HongKong).
Name: Takashi Shioya  
Department: Mathematics  
Position: Professor  
Research Title: Geometry

I. Summary of Research in 2009 fiscal year
1. As a continuation of my research before, I studied together with K. Kuwae a splitting theorem for weighted Alexandrov spaces of Cheeger-Gromoll type. In this year, we generalize the weight measure to be a general Radon measure, though the measure in the previous research is only the Hausdorff measure with a continuous weight function. This progress has been achieved by proving the new version of the maximum principle for subharmonic functions.
2. I and K. Funano studied the concentration phenomenon of the Riemannian volume measure and the eigenvalues of the Laplacian on closed Riemannian manifolds of nonnegative Ricci curvature.

II. Publications
1. “Geometric Analysis on Alexandrov spaces”,  
   Takashi Shioya, Sugaku 61 (2009), no. 1, 1-20.

III. Presentations
1. “Geometric aspect of measure concentration”,  
2. “Geometry of measure concentration”,  
3. “A splitting theorem for weighted Alexandrov spaces”,  
I. Summary of Research in 2009 fiscal year

1. Classical mechanics generated by the fundamental partial differential equations describes various models in the different physical scales. The equation of the continuity and the Poisson equation as the field equation with the moment balance gives a typical model for the dissipative system of conservation laws and the model generates various reductions by choosing the parameter in a various way. In particular, under the 0 limiting model of the relaxation time $\tau \to 0$, the model is reduced so called the drift-diffusion system. This model has a simple scaling invariant form and classified in the degenerate parabolic-elliptic system. The system contains the natural physical parameter stems from the adiabatic constant $\alpha \geq 1$. The system can be reduced as the semi-linear non-local non-linear heat equation when $\alpha = 1$. We consider the initial value problem of this model in both $\alpha = 1$ and $\alpha > 1$ cases and find out a new critical exponent. This critical exponent $\alpha = 2 - 2/(n+2)$ where $n$ is the space variable dimension is corresponding to the Sobolev critical exponent and many of the mathematical analysis break down at this particular exponent. Here we show that at this exponent, the solution of the Cauchy problem is completely classified either globally stable and decaying solution or blows-up in a finite time under the solution has the limited entropy-energy functional. The threshold value is exactly given by the exact solution of the nonlinear elliptic equation with the Sobolev critical exponent.

2. With M.Mizuno (PhD course student), we show the regularity of the degenerate parabolic system of the drift-diffusion type and show the large time behavior of the weak solution of the Keller-Segel system when the exponent is critical case $\alpha = 2 - 2/n$. This result completely improves the known result for the system and the proof relies on the uniform H"older continuity of the solution. The proof is applied for the equation derived from the forward self-similar transformed type and method of Di Benedetto is reconsidered and re-constructed by the resale alternative iteration.

3. With H.Takeda (PhD course student), we consider the global existence of the non-linear damped waves system and show the critical exponent for the global existence of the solution. The system is generalized for the product of the each components and the critical exponent for the global existence is given by the matrix form of the set of the exponents. Beside, the global solution decays at $t \to \infty$ and the limiting profile of the solution is converging to the...
heat kernel.

II. Publications
1. Multiple global existence of solutions for nonlinearly perturbed elliptic parabolic system in $\mathbb{R}^2$,
2. Non-existence of weak solutions to nonlinear damped wave equations in exterior domains,
3. Asymptotic behavior of solutions to drift-diffusion system with generalized dissipation,
4. Global existence of solutions for a nonlinearly perturbed elliptic parabolic System in $\mathbb{R}^2$,
5. End-point maximal regularity and wellposedness of the two dimensional Keller-Segel system in a critical Besov space,
6. Interpolation inequality of logarithmic type in the abstract Besov spaces and application to semilinear evolution equations,
7. Proceedings of International Conference of “Mathematical Analysis for Self-organization
   and Self-similarity”
   T. Ogawa, T. Nakaki, T. Senba, M. Kawashita, M. Kurokiba eds, RIMS Kôkyûroku Bessatsu
   15, p 204. 2009.

III. Presentations
1. International conference: 1st Italian-Japanese workshop for Geometric Properties of
   Parabolic and Elliptic PDE’s “Drift-diffusion system in the critical case” (June 15-18, 2009,
   Tohoku Univ. Sendai, Japan).
Name: Toshifumi Futamase
Department: Astronomy
Position: Professor
Research Title: General Relativity and Cosmology

I. Summary of Research in 2009 fiscal year
1. We have calculated quasi-normal modes of Kerr Black hole in an asymptotically anti-De Sitter spacetime and found new type of instability. This study will be relevant for AdS/CFT correspondence.
2. We have investigated an effect of local inhomogeneities on the distance-redshift relation and found a systematic deviation from the standard distance up to 10%. This effect must be taken into account for future high redshift supernovae observation to determine the nature of dark energy.
3. We have developed a new method to measure gravitational shear signal using higher-order moments of gravitational lensed images. This method provides a partially independent measure of weak lensing signal and thus improve an accuracy of reconstructed mass map as well as the determination of the nature of dark energy in cosmic shear analysis.

II. Publications
1. “Scalar Perturbations of Kerr-AdS black holes”, 
2. “Distance-Redshift Relation in a Realistic Inhomogeneous Universe”,
   T. Okamura and T. Futamase, Progress of Theoretical Physics, 122, No2. 511-520, (2009)
3. “A method to measure a relative transverse velocity of source-lens-observer system using gravitational lensing of gravitational waves,
4. “Appearance of classical Mixmaster Universe from the No-boundary Quantum State”,
5. “A New method for measuring Weak Lensing Gravitational Lensing Shear using Higher Order Spin-2 HOLICs”,
6. “Non-Gaussianity generated in the inflationary scenario with non-minimally coupled inflation field”,
III. Presentations

1. “Gravitational Lensing with Subaru HSC(Hyper Suprime Camera)
   T. Futamase, The Compact Star 10, (March 16-17, Okinawa, Japan).
Name: Takashi Ichikawa  
Department: Astronomy  
Position: Professor  
Research Title: Study of galaxy evolution at high redshift universe and new instruments for infrared astronomy in Antarctica

I. Summary of Research in 2009 fiscal year

1. A comprehensive framework for comparing spectral data from different planets has yet to be established. This framework is needed for the study of extrasolar planets and objects within the solar system. We completed observations to compile a library of planet spectra for all planets, some moons, and some dwarf planets in the solar system to study their general spectroscopic and photometric natures. During May and November of 2008, we acquired spectra for the planets using TRISPEC, which is capable of simultaneous three-band spectroscopy across a wide wavelength range of 0.45–2.5 μm with low resolving power (λ/∆λ 140–360). Patterns emerge when comparing the spectra. By analyzing their general spectroscopic and photometric natures, we show that it is possible to distinguish between gas planets, soil planets, and ice planets. These methods can be applied to extrasolar observations acquired using low resolution spectrography or broad-band filters.

Conclusions. The present planet spectral library is the first library to contain observational spectra for all of the solar system planets, based on simultaneous observations at visible and near infrared wavelengths. This library will be a useful reference for analyzing extrasolar planet spectra and calibrating planetary data sets.

2. We use very deep near-infrared (NIR) imaging data obtained in MOIRCS Deep Survey (MODS) to investigate the evolution of the galaxy stellar mass function back to $z \sim 3$. The MODS data reach $J = 24.2$, $H = 23.1$, and $K = 23.1$ (5σ, Vega magnitude) over 103 arcmin$^2$ (wide) and $J = 25.1$, $H = 23.7$, and $K = 24.1$ over 28 arcmin$^2$ (deep) in the GOODS-North region. The wide and very deep NIR data allow us to measure the number density of galaxies down to low stellar mass ($10^9$–$10^{10}$ $M_{\odot}$) even at high redshift with high statistical accuracy. The normalization of the mass function decreases with redshift, and the integrated stellar mass density becomes ~8%–18% of the local value at $z \sim 2$ and ~4%–9% at $z \sim 3$, which are consistent with results of previous studies in general fields. Furthermore, we found that the low-mass slope becomes steeper with redshift from $\alpha = -1.3$ at $z \sim 1$ to $\alpha = -1.6$ at $z \sim 3$ and that the evolution of the number density of low-mass ($10^9$–$10^{10}$ $M_{\odot}$) galaxies is weaker than that of $M^*$ ($\sim 10^{11}$ $M_{\odot}$) galaxies. This indicates that the
contribution of low-mass galaxies to the total stellar mass density has been significant at high redshift. The steepening of the low-mass slope with redshift is an opposite trend expected from the stellar mass dependence of the specific star formation rate reported in previous studies. The present result suggests that the hierarchical merging process overwhelmed the effect of the stellar mass growth by star formation and was very important for the stellar mass assembly of these galaxies at 1<z<3.

II. Publications
1. "Tohoku-Hiroshima-Nagoya planetary spectra library: A method for characterizing planets in the visible to near infrared"
2. "MOIRCS Deep Survey. IV: Evolution of Galaxy Stellar Mass Function back to z~3"
3. "The Seventh Data Release of the Sloan Digital Sky Survey"
4. "MOIRCS Deep Survey III: Active Galactic Nuclei in Massive Galaxies at z = 2-4"

III. Presentations
1. "Future plans for astronomy at Dome Fuji”
Ichikawa, T. (Invited) XXVIIth IAU General Assembly, (August 2009, Rio de Janeiro, Brazil)
2. “SCIENTIFIC GOALS OF SPICA FOR GALAXY FORMATION AND EVOLUTION IN EARLY UNIVERSE”
Ichikawa, T. in the SPICA Joint European Japanese Workshop, (6–8 July 2009, Oxford, United Kingdom)
I. Summary of Research in 2009 Fiscal Year

1. We investigated the distribution and properties of the high-redshift emission line galaxies. In the field of a proto-cluster at z=3, or 11.5 billion years ago, we detected more than 2000 hydrogen Lyman Alpha emission-line galaxies. Among them, we newly detected about 100 large extended Ly Alpha nebulae, or so-called Ly Alpha Blobs, which are considered to be the present-day massive galaxies.

2. We investigated the relation between active galactic nuclei, which are the super massive black holes in the center of galaxies activated by the accretion of the surrounding material. We, for the first time, show the fraction of the AGN among the massive galaxies at high redshift, z~3. We found that the bright AGN appear only in the massive galaxies and the fraction of the galaxies with AGN is very high, more than 40% among the massive galaxies at the time.

II. Publications


III. Presentations
1. “Relation between Lyman alpha Blobs and their connection with sub-mm sources and AGNs”
   Yamada, T. in “Ly Alpha Universe”, (Jul. 6-10, 2009, Paris, France)
2. “WISH: Wide-field Imaging Surveyor for High redshift”
Name           Makoto Hattori
Department     Astronomy
Position       Associate Professor
Research Title Development of high accuracy component separation scheme between Cosmic Microwave Background and Foreground emission from mm-wave polarization emission maps

I. Summary of Research in 2009 fiscal year
1. For realization of one of key issues, that is multi wave band polarization observation in mm-wave bands, for improvement of accuracy of components separation between Cosmic Microwave Background radiation and Foreground emissions, we have proposed new polarization modulator based on refractive Fourier Transform Spectrometer. Preparation for testbed laboratory experiment system of this instrument has completed.
2. Application of interference phenomena of gravitational waves to astronomy was considered and new idea was proposed.
3. We have constructed part of data reduction schemes and tools of far-infrared all sky survey data obtained by Japanese infrared observations satellite AKARI as one of members of international collaboration team.
4. Development of multi aperture Fizeau Type bolometric interferometer which is able to measure complex visibility. Further, we have developed new nulling interferometer which is able to perform spectrally resolved imaging observation. These provides new window to exo-earth habitable planets search.

II. Publications

III. Presentations
1. “Application of refractive polarizing Fourier Transform Spectrometer to broad band
4. Research Reports in 2009 Fiscal Year: 4.1. GCOE Program Members

Tohoku University GCOE program
"Weaving Science Web beyond Particle-Matter Hierarchy"

millimeter-submillimeter wave polarimetry”,

2. “Bolometric interferometer”,
M.Hattori, The 10th Workshop on Submillimeter-Wave Receiver Technologies in Eastern Asia, (Nov. 15-18, Lakeview Park Resort, WuXi, China)

3. “Application of refractive polarizing Fourier Transform Spectrometer to broad band millimeter-submillimeter wave polarimetry”,

4. “AKARI Far-Infrared all sky survey”,

5. “The AKARI Diffuse Maps”,

6. “Multiple Aperture Imaging and its Application to Exo-Earth Imager”,
T.Matsuo, W.A.Traub, M.Tamura, and M.Hattori, Pathways toward Habitable Planets, (September 14-18, Barcelona, Spain)

7. “Spectral Imaging with Nulling Interferometer”,
T.Matsuo, W.A.Traub, M.Tamura, and M.Hattori, Pathways toward Habitable Planets, (September 14-18, Barcelona, Spain)
Name: Keiichi Noe
Department: Philosophy
Position: Professor
Research Title: Philosophy of Science in West and East

I. Summary of Research in 2009 fiscal year
1. Kitaro Nishida, a representative philosopher in modern Japan, devoted his later years to studying philosophy of science. I analyze his unique position from the viewpoint of relationship with Brouwer’s intuitionism in mathematics, Bridgman’s operationalism in physics and Haldane’s organism in biology.
2. Comparing Husserl’s philosophy of science with Bergson’s, I try to elucidate the difference between exact science and rigorous science.
3. Reexamining Husserl’s criticism of Galileo’s scientific method, I develop the meaning of the “mathematization of nature” by Galileo.

II. Publications
1. “Nishida Kitaro as Philosopher of Science”,
2. “The Actual Significance of Husserl’s Philosophy of Science by Contrast with Bergson’s” (in Japanese),

III. Presentations
1. “Philosophical Approach to the Integration of Knowledge”,
K. Noe, The 3rd Conference of Transdisciplinary Federation of Science and Technology, (Dec. 3-5, Tohoku University, Sendai, Japan).
2. "Rehabilitation of Cosmology”,
K. Noe, The 20th Cosmos Forum, (Dec. 13, Bellesalle Iidabashi, Tokyo, Japan.).
3. “Between Science and Philosophy”
K.Noé, Kyoto Philosophy Foundation Symposium, (Dec. 24-26, Kyoto Garden Palace, Kyoto, Japan)
I. Summary of Research in 2009 fiscal year

1. I investigate Japanese philosophy of technology from a contemporary perspective. Theories of technological mediation developed by some pre- and postwar Japanese philosophers (ex. K.Miki, H.Saegusa) gave a comprehensive understanding to the technological process as a whole. Through a critical examination, I argue that these theories can contribute to mediate subdivisions of this field (philosophy of design, philosophy of engineering science, ontology of artifacts etc.) and thus to reconstruct an integrated view of technology.

2. Brain-machine interface is a direct communication pathway between a neural system and an external device (computer system etc.). This technology can be used, for example, for neuroprosthesis that aims to restore human functions, but there are debates about its ethical implications, especially about human enhancement. Based on philosophical considerations about this new technology, I evaluate the main arguments against the human enhancement and propose a common platform for further ethical discussions.

II. Publications

1. “Value of Life and Brain-Machine- Interface”

2. "Creation and Reception”,
   Kiyotaka Naoe, Shisaku(Medetations),42, 1-19 ( 2009)

III. Presentations

1. "Dialectics of Totality(ho-bensho) inTakahashi Satomi ",
   Kiyotaka Naoe, Japanese Hegel-Association, June 13-14, 2009, Tohoku University, Sendai, Japan

2. “Critical Reappraisal of pre- and postwar Japanese Philosophy of Technology”,
   Kiyotaka Naoe, 8th Annual Meeting of the Japanese Society for Science and Technology Studies, November 14-15, 2009, Waseda University, Tokyo, Japan

3. “Philosophy of Technological Mediations”,
   Kiyotaka Naoe, UTCP Seminar on Philosophy of Technology, December 19, 2009, The University of Tokyo, Tokyo, Japan